Lewis River Fish Passage Program
2021 Annual Report (*Final*)

Monitoring and Evaluation (M&E) Plan Metrics

FERC Project Nos. 935, 2071, 2111 and 2213

Adult spring Chinook staging prior to spawning just downstream of Lower Lewis River Falls in the Gifford Pinchot National Forest.
Photo by Malcolm Karchesky

PacifiCorp
&
Public Utility District No.1 of Cowlitz County

June 10, 2022

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ACRONYMS AND ABBREVIATIONS

ACC	Aquatics Coordinating Committee
ATE	Adult Trap Efficiency
ATS	Aquatic Technical Subgroup (formally the H&S Subgroup[1])
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
CS	Combined Survival Rate
CWT	Coded Wire Tag
DIT	Double Index Tag
EA	Electro-Anesthesia
ESA	Endangered Species Act
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
HOR	Hatchery-origin recruit
LCFEG	Lower Columbia Fish Enhancement Group
LRBTRT	Lewis River Bull Trout Recovery Team
LWS	Ladder Water Supply
mm	millimeter
M&E	Monitoring and Evaluation
NF	North Fork
NMFS	National Marine Fisheries Service
NOR	Natural-origin recruit
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
ROV	Remotely Operated Vehicle
R/S	Recruits per Spawner
SA	Settlement Agreement
SAR	Smolt-to-adult ratio

[1] In December 2018, the H&S subgroup voted to change the group's name to the Aquatic and Technical Subgroup (ATS) to reflect the expanded technical role of the group, which included Monitoring and Evaluation related topics.

Services	National Marine Fisheries Service and U.S. Fish and Wildlife Service
SIA	Stable Isotope Analysis
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. Smolts are silvery in color and shed scales readily. Smolts can range from 120 to 300 mm depending on fish species.
USFS	U.S. Forest Service
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[2] (M&E Plan) during 2021. 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 were further implemented in 2021. The following is a brief summary of relevant performance metrics documented in this report:

Description	Ref. to Page	M&E Obj.	Performance Goal	2021 Estimate	Summary
Number of Juveniles Passing Eagle Cliff During Screw Trap Operations	Page 14	Obj. 7 Task 7.1	Monitoring	97,761 Coho 1,451 Chinook 19,520 Steelhead 3,455 Cutthroat	Estimates of the total number of juvenile Coho, Chinook, Steelhead, and Cutthroat were made over a 19-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	Page 14	Obj. 7 Task 7.2	Monitoring	241,397 Coho 13,057 Chinook 31,914 Steelhead 17,453 Cutthroat	Estimates of the total number of juvenile Coho, Chinook, Steelhead, and Cutthroat that entered Swift Reservoir during 2020.
Number of Fish Collected at the Swift Floating Surface Collector (FSC)	Page 23	Obj. 6	Monitoring	71,710 Coho 3,204 Chinook 5,873 Steelhead 760 Cutthroat 6 Bull Trout 4,140 hatchery Rainbow Trout	A total 85,693 salmonids were captured by the FSC in 2020. Of these fish, 81,295 were transported and released downstream of Merwin Dam.
Juvenile Migration Timing	Page 27	Obj. 8	Monitoring	Various	Overall, the run timing in 2021 followed a normal frequency distribution in the spring, with peak migration occurring in late-May to early-June. The late-fall migration component was substantially higher in 2021 than in previous years, which was largely attributed to increased coho parr passage following extreme high in-flow conditions of Swift Reservoir in November.

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

Description	Ref. to Page	M&E Obj.	Performance Goal	2021 Estimate	Summary
FSC Collection Efficiency (CE)	Page 41	Obj. 2	Juvenile Collection Efficiency ≥ 95%	Coho 40% Chinook 52% Steelhead 48%	In 2021, CE was evaluated with acoustic transmitters. The 2021 effort continued to demonstrate that the vast majority of out-migrants entering the Swift Dam forebay are finding the entrance to the FSC, but are not successfully captured.
Swift FSC Injury	Page 43	Obj. 5	Smolt and Fry ≤ 2%	COMBINED: Fry (0.0%) Smolt (1.6%)	Annual injury rates for Chinook smolts were higher than the performance standard of 2.0% overall, but all other fish were lower. This was largely attributed to heavy debris accumulation that occurred at the facility during early spring 2021. Parr were combined with smolt to derive estimates of injury for smolt.
Swift FSC Survival	Page 43	Obj. 4	Fry ≥ 98.0% Smolt ≥ 99.5% Bull trout = 99.5%	COMBINED: Fry (100.0%) Smolt (93.3%) Bull trout (100.0%)	The survival rate for salmonid fry (S_{COL}) met the 98% performance standard in 2021. However, the survival rate (CS) for smolts did not. Heavy debris accumulation that occurred at the facility during early spring largely contributed to lower survival rates in 2021. This was particularly due to lower than average survival rates for juvenile spring Chinook. Parr were combined with smolt to derive estimates of CS for smolt.
Overall Downstream Survival (ODS)	Page 50	Obj. 1	≥ 80%	Coho 28.2% Chinook 22.1% Steelhead 17.4% Cutthroat 5.3%	During 2021, 1,627 Coho, 58 Chinook, 813 Steelhead, and 93 Cutthroat were tagged and released for the ODS study. Of these fish, 468 Coho, 15 Chinook, 147 Steelhead, and 5 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	Page 53	Obj. 11	Monitoring	Various	A total 29,560 fish were captured at the Merwin Trap in 2021. A total of 322 winter Steelhead, 1,184 spring Chinook, 6,174 early Coho, 3,239 late Coho, and 168 Cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2021.

Description	Ref. to Page	M&E Obj.	Performance Goal	2021 Estimate	Summary
Adult Upstream Passage Survival (UPS)	Page 58	Obj. 9	≥ 99.50%	Coho (S) 99.6% Coho (N) 99.7% Chinook 99.7% Steelhead 99.7% Cutthroat 98.2%	Twenty-six early (S) Coho, 10 late (N) Coho, 3 spring Chinook, 1 winter Steelhead, and 3 Cutthroat mortalities were observed during the trap and haul process.
Adult Trap Efficiency (ATE)	Page 59	Obj. 10	≥ 98%	Not completed	The ATE evaluation was not completed in 2021 as modifications are underway for redesigning the facility's lift and conveyance system. It is anticipated that this work will be completed by 2023 and that ATE studies will resume at that time.
Determine Spawner Abundance, Timing, and Distribution of Transported Adult Anadromous Fish	Page 60	Obj. 15	Monitoring	Total Chinook redd count = 240, total Coho redd count = 419; Winter Steelhead redds counted = 19	Chinook estimates suggest that most (if not all) adult female Chinook transported upstream during 2021 spawned. Early Coho spawning peaked in mid-October; late Coho spawned from November onward. Spawning of both species was well distributed throughout the available accessible habitat. Due to flooding in November and inaccessible conditions during December, the portion of transported Coho that spawned could not be reliably determined. Winter Steelhead redds were observed throughout several surveyed reservoir tributaries in 2021 from mid-April through mid-June. While most tributaries surveyed did have some observed spawning, Swift Creek accounted for the majority (78 percent) of the observed winter Steelhead redds.

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.

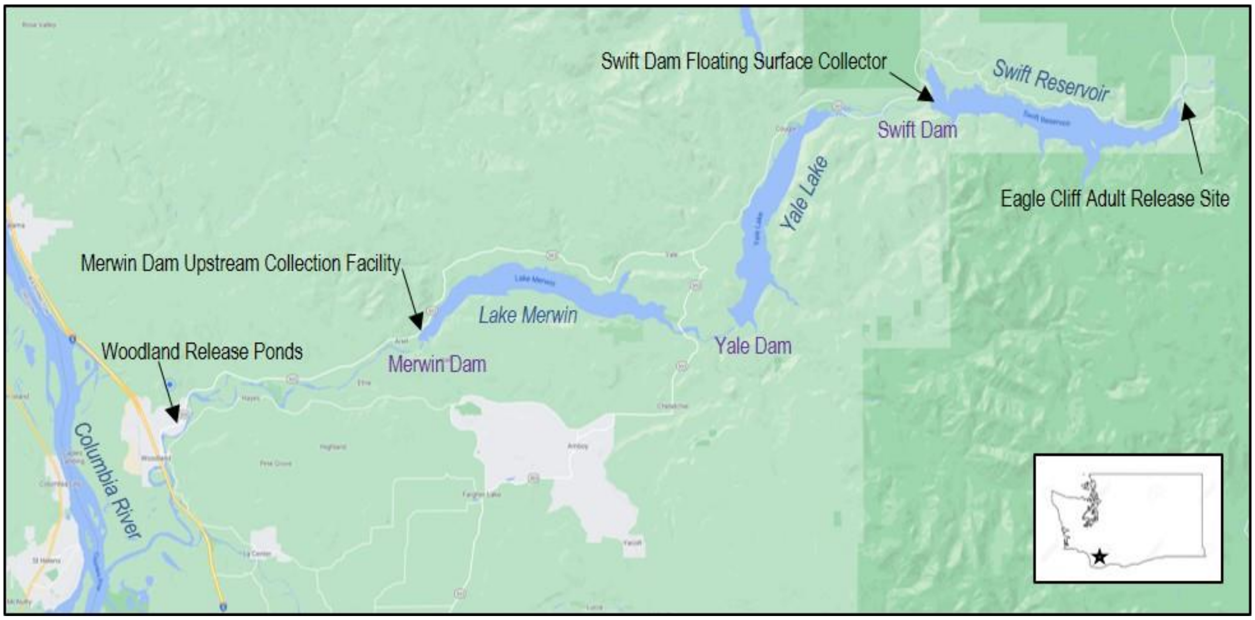

Figure 1.0-1. An overview of key features of the North Fork Lewis River Hydroelectric Project and key fish passage facilities and other infrastructure located in southwest Washington.

On June 26, 2008, FERC issued Orders approving the Settlement Agreement and granting new licenses for the North Fork Lewis River Hydroelectric Projects to PacifiCorp and Cowlitz PUD. Among the conditions contained within the Settlement Agreement 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 Settlement Agreement for reintroduction are spring Chinook salmon (*Oncorhynchus tshawytscha)*, early-run (S-type) Coho salmon (*O. kisutch)*, and winter Steelhead (*O. mykiss*).

The Settlement Agreement called for a phased approach for reintroduction that occurs over a seventeen-year period following issuance of the new Licenses. The phased approach provides a carefully devised plan to protect the Endangered Species Act (ESA) listed species and to verify the effectiveness of passage facilities as the reintroduction program takes effect. Among the tasks identified for Phase I of the reintroduction plan were establishing a downstream passage facility in the forebay of Swift No.1 Dam, and making upgrades to the existing adult fish capture facility at Merwin Dam. Subsequent phases may establish facilities for both upstream and downstream passage at Merwin, Yale, and Swift No.1 Dams. On October 27, 2021 the National Marine Fisheries Service (NMFS) filed with the FERC a notice that the agency along with the US Fish and Wildlife Service (USFWS) (collectively the Services) had completed their final determination regarding fish passage into Yale Reservoir, and that fish passage remains appropriate in this reservoir. On December 23, 2021 the Services notified the Utilities that the Services had completed their final determination regarding fish passage into Merwin Reservoir and that fish passage into this reservoir remains appropriate. Additional 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 Settlement Agreement 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 Settlement Agreement, 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 Settlement Agreement)[3]. 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 (2017) during 2021. It is worth noting that work began in spring 2021 to develop the second revision to the M&E Plan, and is still in development at the time of this annual submittal.

Some noteworthy environmental conditions and procedural changes occurred, or continued to be implemented, in 2021. These are summarized below:

- *Minimum Flow Requirement Below Merwin Dam:* Inflows during 2021 allowed for minimum flow levels stipulated in the June 26, 2008 FERC licenses to be met. In general, annual flows below Merwin Dam were lower than the 10-year average (Figure 1.0-2). River flow as recorded at the Lewis River above Muddy River (Figure 1.0-3) generally tracked below the 10-year average through most of the year November when flows remained above the 10-year average the majority of the month, peaking at 17,600 cfs in mid-November.

- *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. 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. 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 continued to be followed in 2021. A detailed description of these changes can be found in the Lewis River Fish Passage Program Annual Report for 2015 (PacifiCorp 2015).

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[3] The current M&E Plan (2017) was reviewed and updated in 2021 by the Lewis River Aquatics Technically Committee and approved by ACC in April 2022. It is anticipated that the revised M&E Plan (2022) will implemented during the 2022 field season.

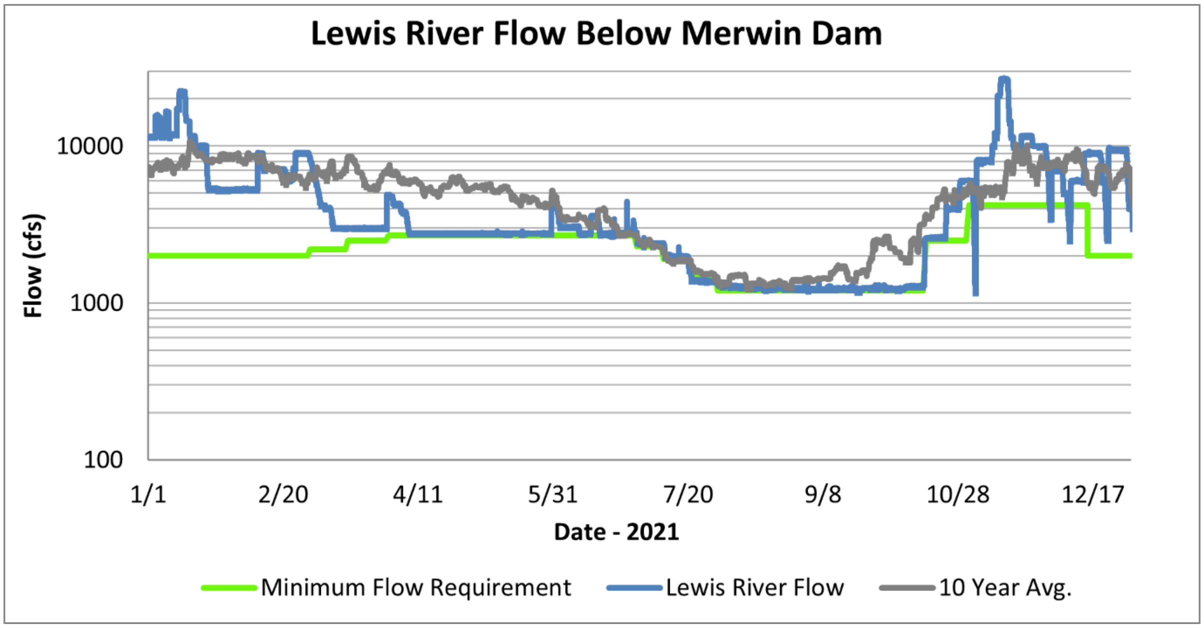


Figure 1.0-2. Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA), in 2021 and compared with the 10-year average.[4] Minimum flow requirements are also shown.

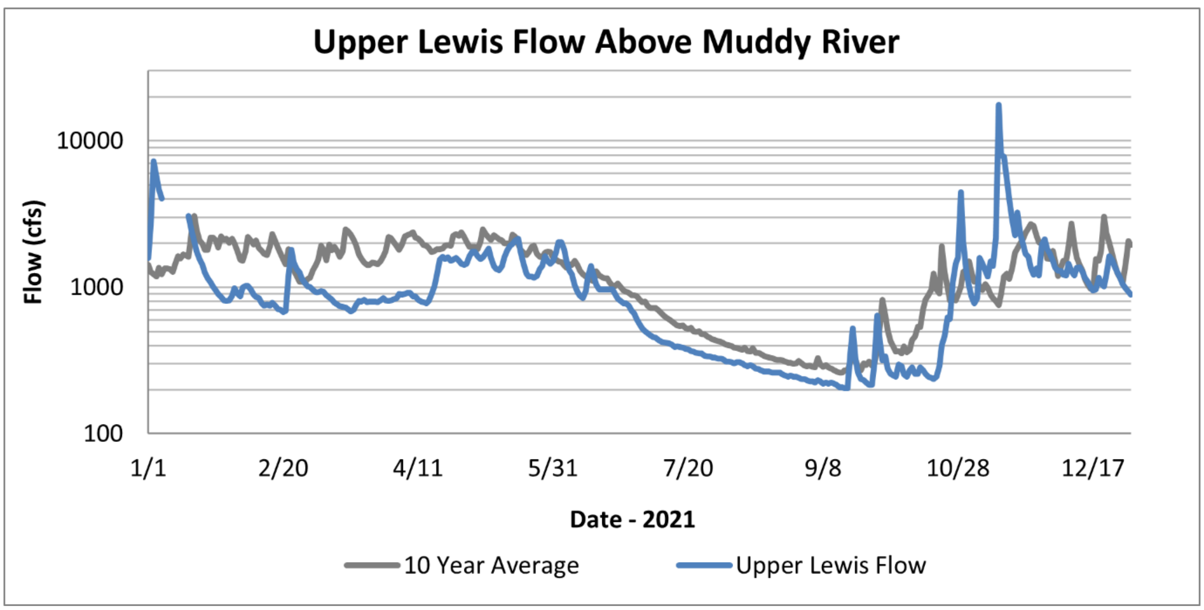


Figure 1.0-3. Lewis River flow above Muddy River as recorded by USGS Gauge (14216000 Lewis River Above Muddy River Near Cougar, WA) in 2021 compared to the 10 Year average flow.

[4] The sharp 'dips' in flow during November and December are scheduled drawdowns associated with WDFW fall Chinook carcass surveys. (Note: lines above may not be exact due to calibration anomalies.)

- *Modification of the Supplementation Protocols for Adult Coho Transported Upstream of Swift Dam:* In July 2015, the Lewis River Aquatic Technical Subgroup (ATS) 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 protocol changes 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; and

    - 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 in 2021.[5]

- *Releases of Acclimation Fish Changed from Upstream Releases to Downstream Releases:* On May 31, 2018, the Lewis River ATS met to discuss the spring Chinook Acclimation Program[6] 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 North Fork Lewis River and Muddy River watersheds[7]), 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 (PacifiCorp 2019). The ATS 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

[5] The current Hatchery and Supplementation Plan (2020) calls for a target of 6,800 adult coho upstream of Swift Dam based on EDT model estimates, however the supplementation target of 9,000 adults as modified and approved by the ACC remained in place in 2021.
[6] No acclimation programs ever occurred for Coho and Steelhead upstream of Merwin Dam, and therefore all juveniles of these species out-migrating from the upper basin are NOR.
[7] Spawning surveys of spring Chinook in 2021 presented in this report (see Section 4.4.2) further demonstrate Chinook distribute well throughout the available habitat upstream of Swift Dam.

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 ATS release strategy evaluation. This action was discussed and approved at the June 14, 2018 Lewis River ACC Meeting. These recommendations by the ATS were adopted beginning in 2019 and continued in 2020. Details of adult returns from this program are discussed in Section 4.1 below.

- *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 can be found in the Lewis River Fish Passage Program 2019 Annual Report; PacifiCorp 2020).

- *Nutrient Enhancement Above Swift Dam:* The possibility of using surplus hatchery-reared adult Coho carcasses for nutrient enhancement upstream of Swift Dam was originally discussed at the June 27, 2019 Lewis River 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 on an annual basis. The use of adult Coho carcasses for nutrient enhancement above Swift Dam in fall 2019 was approved by the Lewis River ACC at the July 11, 2019 meeting. This initial effort was considered a pilot year with the support of Lower Columbia Fish Enhancement Group (LCFEG), Washington Department of Fish and Wildlife (WDFW), United States Forest Service (USFS), and the Utilities. This initial year's effort is summarized in the Lewis River Fish Passage Program 2019 Annual Report; PacifiCorp 2020). Based on the success of the 2019 effort, nutrient enhancement continued in 2020 (PacifiCorp 2021).

  On November 22, 2020, the LCFEG submitted a full proposal for funding of a nutrient enhancement project in the North Fork Lewis River through the Lewis River Aquatic Fund Process (December 10, 2020 ACC Meeting Notes). This project was later approved with conditions on ACC and/or ATS approval regarding allocation, location and timing of carcasses (March 11, 2021 ACC Meeting Notes). Following subsequent discussions regarding allocation sites and timing of carcass dispersion in fall of 2021, the ACC was notified by the LCFEG that it was short staffed and would not be able to adequately complete the carcass enhancement work in 2021. The ACC approved a one-year extension to the contract (out to December 31, 2026) and a delay of the initial year of allocation until fall of 2022 (September 9, 2021 ACC Meeting Notes). Therefore, no carcasses were distributed into the upper basin of the Lewis River in 2021.

- *Adjustments to Annual Rainbow Trout Stocking into Swift Reservoir*: At the October 8, 2020 meeting, the ACC approved a reduction in the number of resident Rainbow Trout being stocked annually into Swift Reservoir from 20,000 pounds to 14,400 pounds beginning in spring 2021. This reduction was made over concern of possible direct and/or indirect effects of these fish on juvenile salmon and Steelhead in both Swift Reservoir and below Merwin Dam when they are transported downstream incidentally with juvenile out-migrants. To offset this reduction, an additional 5,600 pounds are now stocked in the Swift No.2 power canal located just below Swift Dam for recreational fishing opportunity in the area. This decision was intended to be temporary and serves as a placeholder action until a more long-term solution can be determined. The Utilities are required to stock 20,000 pounds of resident Rainbow Trout into Swift Reservoir annually in the spring for recreational fishing per the Lewis River Settlement Agreement (Section 8.6). A more detail description of this decision can be found in the October 8, 2020 meeting notes of Lewis River ACC. A detailed summary of the stocking events of resident Rainbow Trout into Swift Reservoir and in the Swift No.2 power canal in 2021 can be provided by WDFW upon request.

- *Temporary Operational Changes due to COVID-19*: Temporary changes to daily fish passage operations due to the COVID-19 pandemic were continued in 2021 to reduce the risk of COVID-19 transmission. PacifiCorp continued to implement modified fish transport and staffing schedules at both the Merwin Trap and Swift FSC when necessary to comply with statewide mandates and work site restrictions. While these changes did reduce exposure risk of employees to COVID-19, they did not restrict daily fish passage requirements for both upstream and downstream transport in 2021.

- *Upper Swift Reservoir Fish Surveys* – Beginning in the summer of 2020, surveys were conducted at the head of Swift Reservoir to document the presence of fish in isolated pools created in the drawdown zone. Additional surveys were also conducted in the summer of 2021 and summarized in a technical memorandum provided to the ACC in November 2021 (Appendix A). Additional information regarding this topic can be found in the June through August meeting notes of the ACC.

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 for transport downstream of the Lewis River Hydroelectric Projects. 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, parr/smolt, and adult) and then routes them to holding tanks for biological sampling and transport downstream[8]. The artificial stream channel is

[8] Following transport downstream, out-migrants are released into the Woodland Releases Ponds located near Woodland, Washington. Fish are held in these ponds before being allowed to volitionally enter the lower Lewis River.

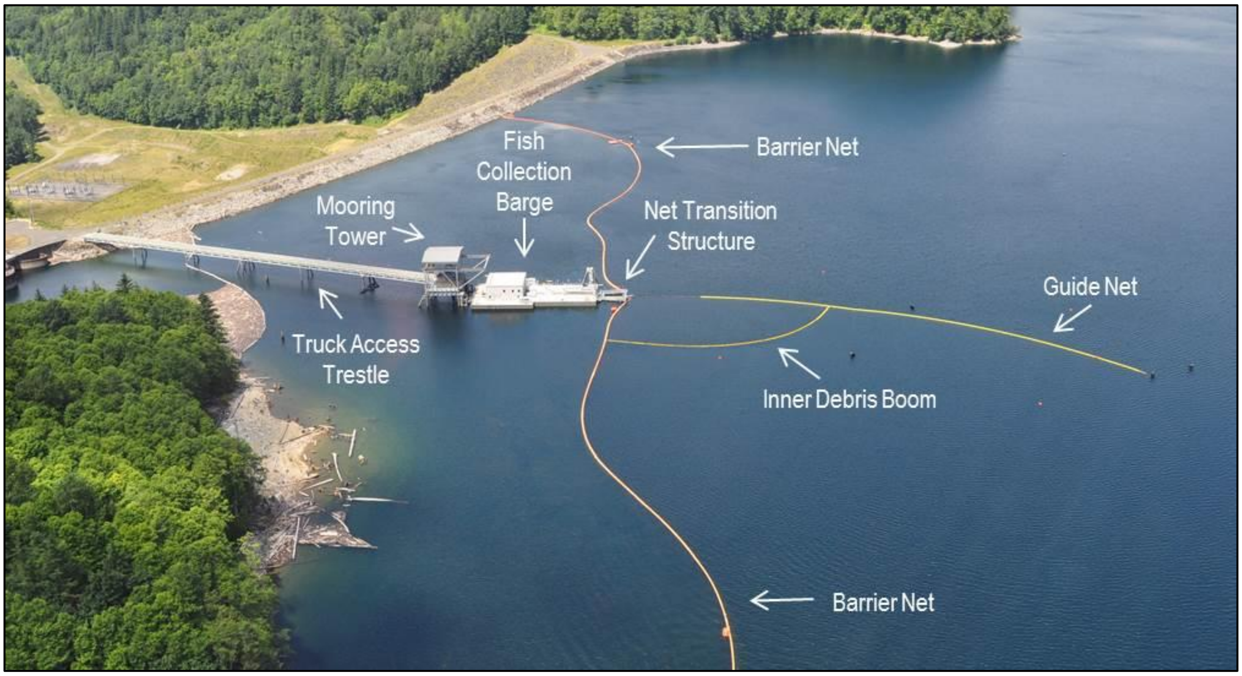


Figure 2.1-1. Aerial photo of the Swift Reservoir Floating Surface Collector layout.

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).

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[9].

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.

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

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 originally extended approximately 30 feet inside the entrance of the existing NTS to prevent fish from easily swimming back out the opposite side of the FSC. However, it was found that this configuration was conducive for the net to block portions of the NTS's outer entrance, and would create areas of abrupt and elevated hydraulic velocity or "hot spots" that would prevent fish from entering the FSC. In 2018, the lead net was removed from the inside of the NTS as to prevent this from occurring. In the modified configuration, the lead net now terminates approximately 20 feet from the outer entrance of the NTS.

The original entrance of the NTS measured 30 feet wide by 37 feet deep (1,110 square feet). The floor of the NTS then sloped up to a depth of 12 feet at the connection with the FSC fish channel. In February 2019, the NTS was modified to increase water velocity at the entrance. 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 to approximately 1.3 fps.

There have been a number of adjustments made to the FSC's fish sorting area since the facility was commissioned in order to improve passage and transport conditions for fish during periods of high debris entrainment. Accumulation of woody debris and other material within the facility's fish conveyance flumes and holding tanks was initially problematic following high inflow events and periods when the reservoir was being filled. Elevated rates of injury and mortality were identified during these conditions and required around the clock staffing to maintain safe passage. These adjustments have included: 1) the incorporation of traveling screens into fish holding tanks to allow for continuous filtration and debris removal; 2) widening of conveyance flumes and transport pipes to prevent blockage, and to allow woody debris and other material to more readily pass through the system; and 3) redesigning the fish sorting system and incorporating additional spray bars and other equipment to reduce debris accumulation. In addition to the infrastructural changes to the facility's sorting area, PacifiCorp has also implemented several debris management measures in Swift Reservoir to minimize debris entrainment into the FSC. These have included installation of several debris booms located at the head of the reservoir as well as in and around the forebay near the FSC. PacifiCorp also actively manages debris on the reservoir by using containment and removal procedures. While these additional measures have largely improved passage and transport conditions for fish during periods of debris entrainment, there are still certain reservoir conditions related rapid filling and high winds that the facility can sporadically be overwhelmed by debris, which can cause unscheduled shutdowns and fish mortality.

The FSC operated 24-hours a day through 2021 except during periods when it was necessary to shut the facility down due to inclement weather conditions, power outages, debris removal, facility adjustments, and/or scheduled or unscheduled maintenance (Table 2.1-1).

Table 2.1-1. List of FSC outages that occurred in 2021.

Date	Reason For Outage
1/01/21 -1/02/21	Debris removal in fish channel
01/08/21 - 01/09/21	Electric Repairs to Sorting Areas Flow Pumps
02/11/21 - 02/16/21	Inclement weather conditions and snow removal (Figure 2.1-2)
04/28/21	Debris removal from fish channel and repairs to adult tank
6/17/21	Loss of station service - power outage
7/13/21 – 11/08/21	Summer outage and maintenance period
11/06-21 – 11/09/21	Outage to install static debris weir
12/24/21 12/31/21	Inclement weather conditions and snow removal

Figure 2.1-2. Ice formation on the NTS and leading edge of the Swift FSC during the February 11, 2021 inclement weather conditions.

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 (per the Lewis River SA, Section 4.1.4).

The new facility was 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 and as outlined in Section 4.3 below), 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

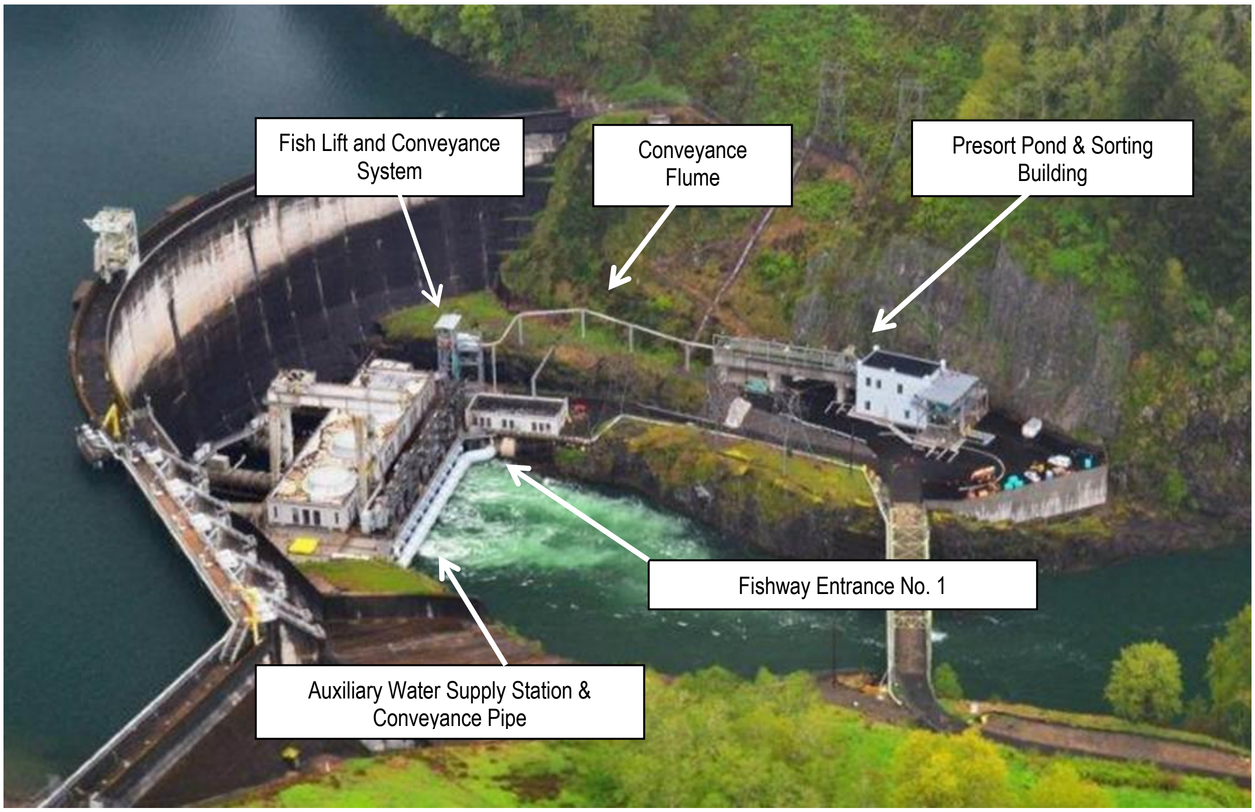


Figure 2.2-1. Merwin Dam Upstream Collection Facility.

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 pool (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 from Merwin Fish Hatchery (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 feet.

To prevent fish from returning to the tailrace once they have entered the lower fish ladder, a vertical weir was installed on the upstream side of the Pool 1-2 weir in November 2016. The "V" style weir 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 Dam Upstream Fish Collection Facility operated 24-hours a day through 2021 except during periods when it was necessary to shut the facility down due to tailrace water elevation exceeding the facility's operational limits, facility modifications, scheduled maintenance, or emergency repairs (Table 2.2-1).

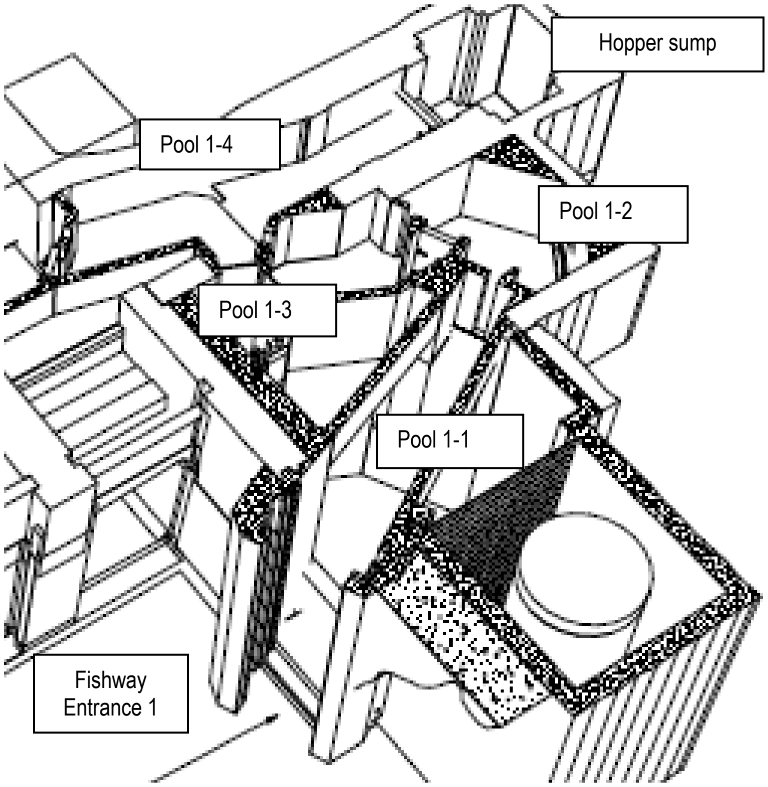


Figure 2.2-2. Merwin Dam fish ladder entrance and pool configuration.

Table 2.2-1. List of scheduled and unscheduled outages at the Merwin Fish Sorting Facility in 2021.

Outage Duration	Purpose for Outage
1/08/21	Tailwater elevation exceedance (high water spill event)
1/13/21 - 1/18/21	Tailwater elevation exceedance (high water spill event)
2/10/21 – 2/15/21	Inclement weather and unsafe operating conditions for lift and conveyance system
2/28/21	Repairs to lift and conveyance system – limit switch
3/02/21	Quarterly maintenance outage
6/08/21 – 6/11/21	Quarterly maintenance outage
6/27/21[a]	Repairs to presort pond crowder
11/13/21 -11/15/21	Tailwater elevation exceedance (high water spill event)
11/27/21 – 11/29/21	Repairs to lift and conveyance system – lift controller
12/24/21 – 12/31/21	Inclement weather and unsafe operating conditions for lift and conveyance system

[a] The fish ladder, lift and conveyance system remained operational – only fish were not sorted and transported at the facility.

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 approximately 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 operation, and no unscheduled outages were necessary in 2021. When circumstances required an alternate release location (i.e., unscheduled outages of the facility's supply pumps), out-migrants transported from the Swift FSC were released directly into the lower Lewis River at the WDFW boat ramp on Pekin Ferry Rd. at approximately river mile 3.0. This secondary release location is also used for adult fish being transported downstream of Swift Reservoir (e.g., steelhead kelts).

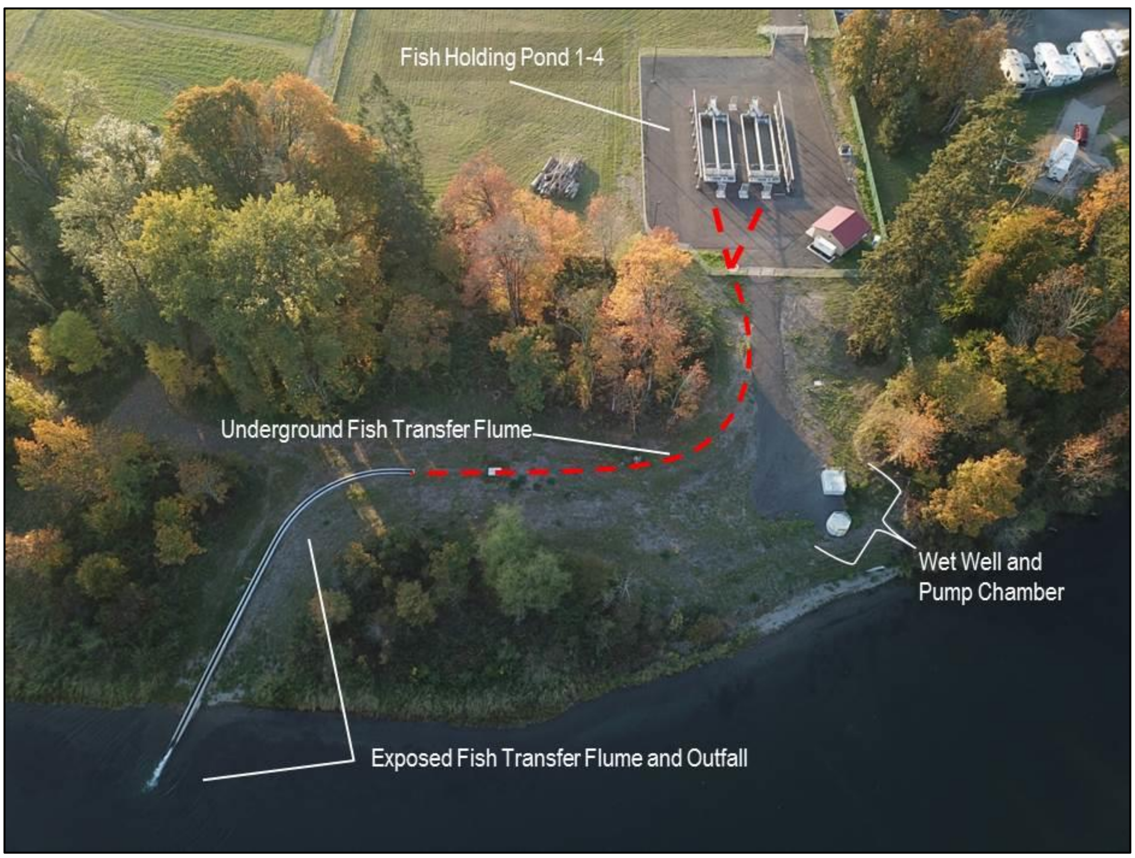


Figure 2.3-1. Aerial photo of the Woodland Release Ponds and associated infrastructure near Woodland, WA.

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 Settlement Agreement 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 juvenile anadromous fishes likely migrate into Swift Reservoir outside of the March-June screw trap operation period. 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 sub-basin 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 is 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, weekly estimates of the total juvenile out-migration by species during the trapping season were calculated using the 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:

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

Weekly estimates of juvenile migration were combined to calculate the total number of juveniles migrating downstream during the monitoring period (season) using the following formula:

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

Entire monitoring period variance:

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

95 percent Confidence Interval:

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

In addition, total estimates of fish passing the trap and their associated 95 percent confidence intervals were generated using the Bootstrap Method (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 that focal fishes 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 and PIT 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; PacifiCorp 2019, 2020, 2021). 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 2021, parsing was done based on brood-year and separated (for all species) by 0+, 1+, and 2+ year old fish.

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; and

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 was calculated using Equation 3.1-5 above.

3.1.2 Results/Discussion

Objective 7 Task 7.1

A detailed technical memorandum describing the methods and results of the 2021 effort can be found in Appendix B. A summary of this report is provided below.

Field crews operated the Eagle Cliff 8-foot-diameter rotary screw trap (trap) from March 23, 2021 to July 30, 2021, and checked the trap on a daily basis. A total of 2,008 Coho, 28 Chinook salmon, 517 Rainbow/Steelhead and 94 Cutthroat Trout were marked and released upstream of the trap to estimate trap efficiency via mark-recapture (Table 3.1-1). Marked juvenile Coho, Chinook, Steelhead/Rainbow, and Cutthroat were released upstream of the trap daily (as fish were available from trap captures) to estimate trap efficiency via mark-recapture methods. Naturally produced salmonids ≥60 mm fork length (FL) were PIT-tagged; naturally produced salmonids ≥50mm FL, but <60 mm FL were marked with an Alcian Blue tattoo or Bismark Brown dye; and salmonid fry <50mm FL were marked with Bismark Brown dye. Total fish passing the trap was calculated by using adjusted trap efficiencies on a weekly basis (Table 3.1-2). That is, on a weekly basis all species recapture data was pooled and used as one applied efficiency. If not enough recapture data was available efficiencies were set based on river flow and cone RPM. Chinook of 1+ age out-migrating in 2021 were progeny of adults transported above Swift Dam in 2019. In 2019 only 24 adult Chinook (12 male, 12 female) were transported above Swift Dam, hence the low capture numbers of 1+ Chinook. No hatchery-raised spring Chinook juveniles that were formally stocked as acclimation juveniles have been planted above Swift Dam since August 11, 2017.

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 (Figures 3.1-1 and 3.1-2). The majority of juvenile Coho (74 percent) and Chinook (76 percent) were less than 80 mm FL. For Steelhead/Rainbow, 60 percent were less than 100 mm FL. Length size intervals to determine brood-year (i.e., 0+, 1+, 2+ years old) were unique per species and were staggered throughout the trapping season based on length frequency distribution breaks over time to account for fish growth; details on this are provided in Appendix B.

These data suggest that during the 2021 monitoring period, most juvenile Coho (age 1 and 2+) passed the trap in May, while most subyearling Coho (age 0+) passed the trap in June and July as did subyearling Chinook. Steelhead/Rainbow, Cutthroat, and Bull Trout passed the trap over a more protracted period, but mostly in April and May, though Steelhead/Rainbow fry were captured in July after emergence began (Figures 3.1-3 and 3.1-4).

In total, 97,761 Coho, 1,451 naturally produced Chinook, 19,520 Rainbow/Steelhead, and 3,455 Cutthroat were estimated to pass the trap during trapping operations using the Bootstrap Method (March 23 to July 30, 2021; Table 3.1-3). The majority of Coho (76 percent) and Chinook (91 percent) estimated to pass the trap were of the subyearling 0+ age class. The majority of Steelhead/Rainbow (53 percent) and Cutthroat (49 percent) passing the trap were of the 1+ year age class. The difference between the total outmigration estimates by species generated by the Bootstrap and Volkhardt methods is not statistically significant. These estimates should only be viewed as an index of the total fish that passed the trap during the trapping period (~late-March through July) and not total species out-migration abundance for the year.

Table 3.1-1. Summary of Eagle Cliff screw trap total captures, 2021.

Species	Naturally Produced Subyearling 0+	Naturally Produced 1+ Year Old	Naturally Produced 2+ Year Old	Grand Total	Marked/ Released Upstream ≥50 mm FL	Total Recaptured
Coho Salmon	2,549	661	38	**3,248**	2,008	72
Chinook Salmon	45	2	2	**49**	28	2
Steelhead/ Rainbow Trout	144	406	124	**674**	517	16
Cutthroat Trout	7	58	43	**108**	94	2
Bull Trout	2	27	20	**49**	0	0
Total	**2,747**	**1,154**	**227**	**4,128**	**2,647**	**92**

Species	Total
Hatchery Rainbow Trout	11
Longnose Dace	10
Sculpin	80
Sucker	78

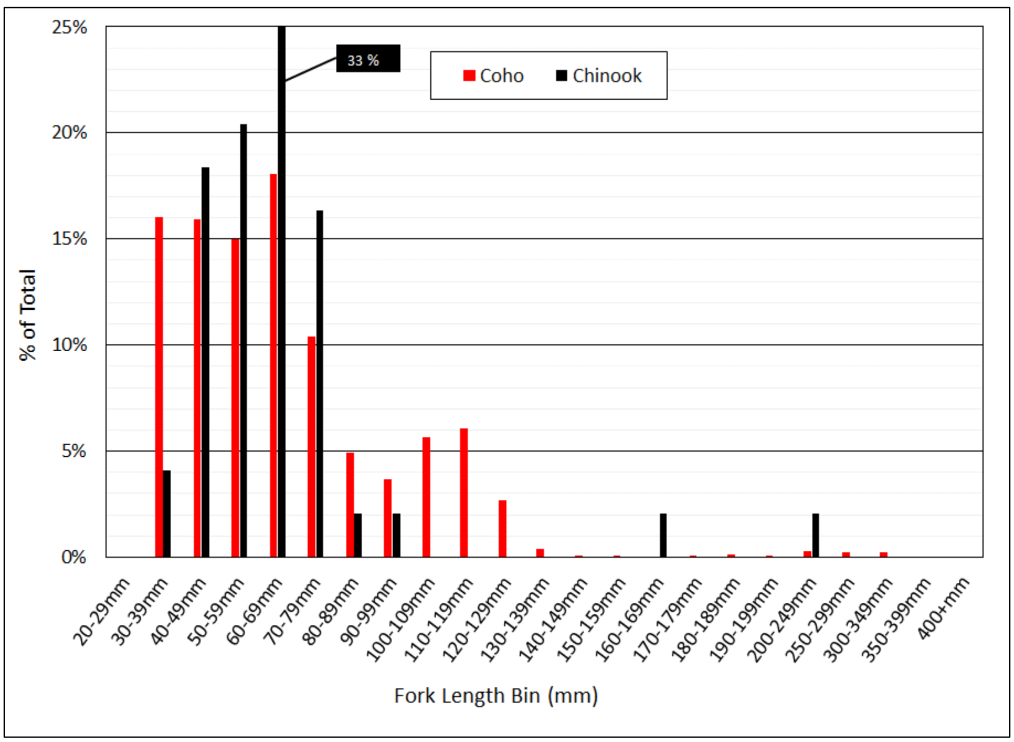


Figure 3.1-1. Length frequency distribution of juvenile salmon, 2021.

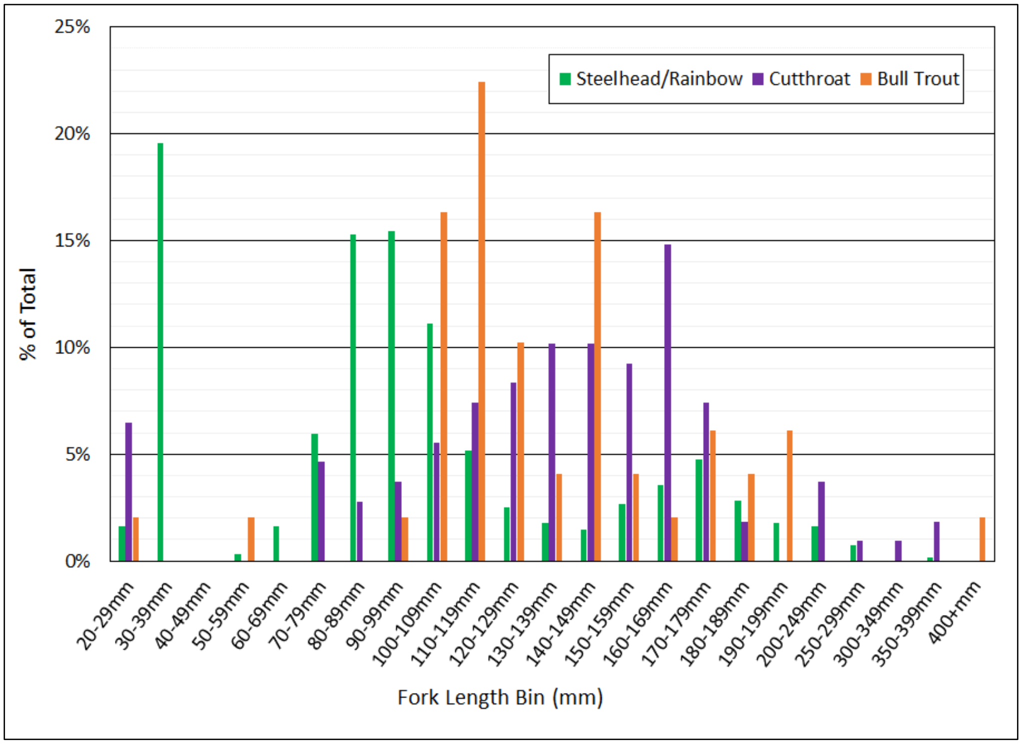


Figure 3.1-2. Length frequency distribution of naturally produced trout/char, 2021.

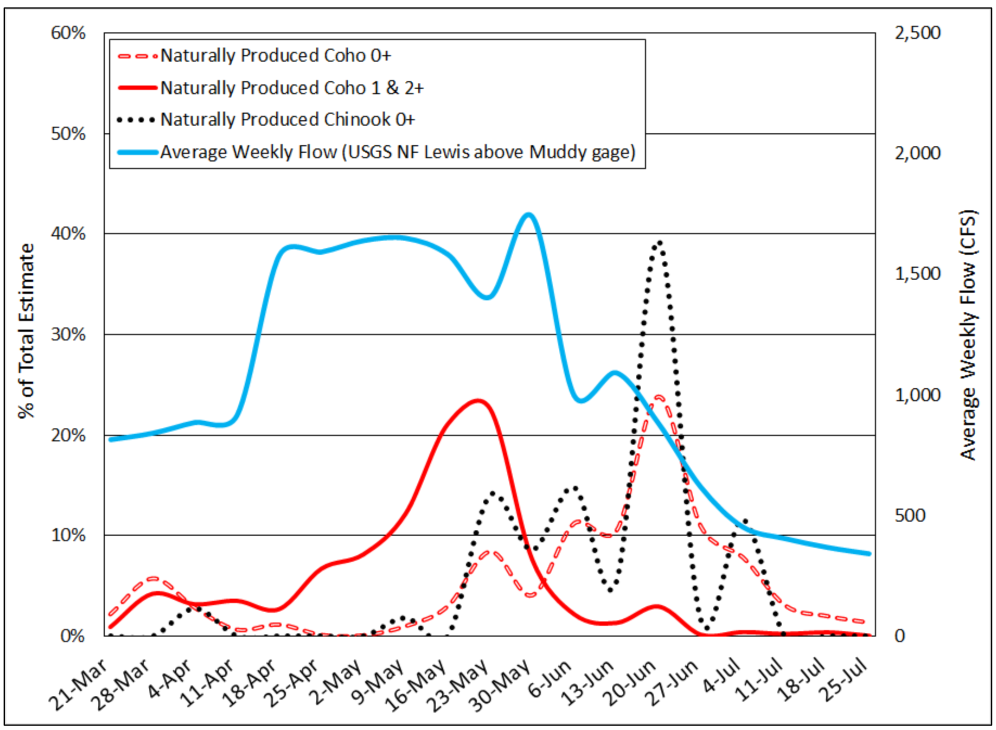


Figure 3.1-3. Naturally produced salmon migration timing, 2021.

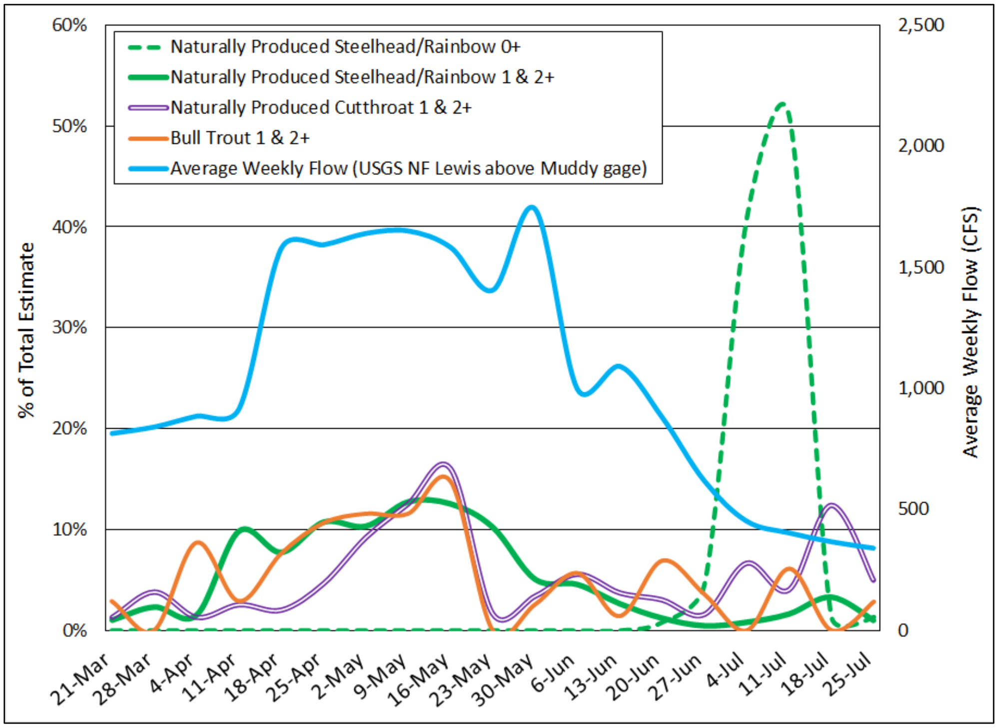


Figure 3.1-4. Naturally produced trout/char migration timing, 2021.

Table 3.1-2. Summary of mark-recapture tests of trap efficiency for the Eagle Cliff screw trap, 2021.

Week (first day)	Total Caught[a]	Total Marked & Released Upstream[a]	Total Recaptured[a]	Trap Efficiency	Average Weekly Flow (cfs)[b]	Average Weekly Cone RPMs	Adjusted Weekly Efficiency Based on Flow/RPMs
22-Mar	10	10	1	0.100	814	4.8	0.0234[c]
29-Mar	36	35	0	0.000	841	4.9	0.0234[c]
5-Apr	26	23	2	0.087	886	4.7	0.0234[c]
12-Apr	61	60	0	0.000	916	4.2	0.0234[c]
19-Apr	93	86	2	0.023	1,579	6.1	0.0447[d]
26-Apr	164	160	9	0.056	1,593	6.0	0.0447[d]
3-May	144	144	6	0.042	1,640	5.9	0.0353[e]
10-May	202	196	6	0.031	1,650	6.2	0.0353[e]
17-May	175	145	3	0.021	1,583	6.4	0.0184[f]
24-May	185	181	3	0.017	1,406	5.8	0.0184[f]
31-May	188	171	9	0.053	1,740	6.3	0.0526
7-Jun	265	261	6	0.023	997	4.3	0.0479[g]
14-Jun	366	365	24	0.066	1,092	4.6	0.0479[g]
21-Jun	380	305	6	0.020	882	3.3	0.0197
28-Jun	287	236	9	0.038	619	2.4	0.0381
5-Jul	137	129	1	0.008	452	2.0	0.0222[h]
12-Jul	60	51	3	0.059	404	1.7	0.0222[h]
19-Jul	64	56	2	0.036	367	1.1	0.0238[i]
26-Jul	36	28	0	0.000	341	0.5	0.0238[i]
Total	**2,879**	**2,642**	**92**	**0.035**			

[a]Total naturally produced Coho, Chinook, Steelhead/Rainbow, and Cutthroat.
[b]USGS Gage No. 14216000 – Lewis River Above Muddy River Near Cougar, WA.
[c]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 22-March and 12-April).
[d]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 19-April and 26-April).
[e]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 3-May and 10-May).
[f]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 17-May and 24-May).
[g]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 7-June and 14-June).
[h]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 5-July and 12-July).
[i]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 19-July and 26-July).

Table 3.1-3. Estimates of total naturally produced salmonids passing the Eagle Cliff trap (2021) by species and age class.

Species (Age Class)	Cohort/ Brood-Year	Bootstrap Method Mean Estimate (95% CI) (CV%)	Volkhardt Method Estimate (95% CI) (CV%)
Coho (subyearling 0+)	Sep 20-Jan 21	74,617 (+/- 17796) (12%)	71,871 (+/- 17625) (13%)
Coho (1+ year old)	Sep 19-Jan 20	22,200 (+/- 7927) (18%)	19,745 (+/- 7302) (19%)
Coho (2+ year old)	Sep 18-Jan 19	944 (+/- 365) (20%)	1,016 (+/- 467) (23%)
Total Coho Estimate		**97,761 (+/- 19485) (10%)**	**92,632 (+/- 19083) (11%)**
Chinook (subyearling 0+)	2020	1,326 (+/- 509) (20%)	1,338 (+/- 567) (22%)
Chinook (1+ year old)	2019	97 (+/- 123) (65%)	89 (+/- 107) (61%)
Chinook (2+ year old)	2018	28 (+/- 53) (97%)	32 (+/- 61) (98%)
Total Chinook Estimate		**1,451 (+/- 526) (19%)**	**1,459 (+/- 580) (20%)**
Steelhead/Rainbow (subyearling 0+)	2021	6,015 (+/- 3100) (26%)	4,772 (+/- 3438) (37%)
Steelhead/Rainbow (1+ year old)	2020	10,373 (+/- 2715) (13%)	10,141 (+/- 2874) (14%)
Steelhead/Rainbow (2+ year old)	2019	3,132 (+/- 922) (15%)	3,387 (+/- 1177) (18%)
Total Steelhead Estimate		**19,520 (+/- 4222) (11%)**	**18,301 (+/- 4633) (13%)**
Cutthroat (subyearling 0+)	2021	285 (+/- 255) (46%)	392 (+/- 576) (75%)
Cutthroat (1+ year old)	2020	1,695 (+/- 677) (20%)	1,486 (+/- 612) (21%)
Cutthroat (2+ year old)	2019	1,475 (+/- 564) (19%)	1,191 (+/- 485) (21%)
Total Cutthroat Estimate		**3,455 (+/- 918) (14%)**	**3,069 (+/- 970) (16%)**
Bull Trout (subyearling 0+)	2020	59 (+/- 86) (75%)	50 (+/- 69) (70%)
Bull Trout (1+ year old)	2019	874 (+/- 446) (26%)	705 (+/- 327) (24%)
Bull Trout (2+ year old)	2018	538 (+/- 256) (24%)	532 (+/- 259) (25%)
Total Bull Trout Estimate		**1,471 (+/- 521) (18%)**	**1,287 (+/- 423) (17%)**

Shown below in Table 3.1-4 is a comparison of migration estimates for fish (greater than or equal to 60 mm FL) passing Eagle Cliff based on seasonal screw trapping (similar to that described above) from 2016-2021. Comparing to the past six years, estimates derived for juvenile Coho, Rainbow/Steelhead, and Cutthroat in 2021 were considerably greater than estimates derived in previous years, with each species seeing their largest estimates to date. Among the species evaluated, estimates for juvenile Chinook have been the most varied during the sampling period, likely because adult spring Chinook transport upstream of Swift Dam is highly variable each year due to variability in returns to the Lewis River basin. Overall, estimates for juvenile Chinook have remained low (20-1,500 fish annually) over the years except in 2019 when 4,120 fish were estimated passing the screw trap during the sampling period, which followed the largest number of spring Chinook adults transported upstream the prior year in 2018. It is important to note that the same field crew, field sampling methods, and data analysis methods were the same over the 2016 to 2021 sampling periods.

Table 3.1-4: A summary of screw trap Bootstrap Method estimates for each species from 2016-2021. Estimates are for fish greater than or equal to 60 mm fork length.

Year	Trap Operation Period	Coho		Chinook		Steelhead		Cutthroat	
		Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
2016	3/24 to 6/30	7,164	4,485	77	100	3,832	1,976	1,104	623
2017	4/20 to 5/30	33,385	10,212	20	38	2,366	615	1,057	355
2018	3/13 to 6/30	22,974	4,509	588	218	3,195	767	1,365	385
2019	3/5 to 7/19	31,071	6,258	4,120	1,170	4,855	1,168	1,050	348
2020	3/9 to 7/15	37,225	9,087	334	174	4,745	1,142	1,047	357
2021	3/21 to 7/27	97,716	19,485	1,451	526	19,520	4,222	3,455	918

Objective 7 Task 7.2:

All PIT tags used in the screw trap operations at Eagle Cliff (Task 7.1 above) were also used in Task 7.2. In addition to these tags, PacifiCorp also PIT tagged juvenile salmonids captured at the FSC and released them at the head of Swift Reservoir. This was done to bolster sample size of ODS estimates. Combining these data, a total of 1,627 Coho, 58 Chinook, 813 Steelhead, and 93 Cutthroat juveniles were PIT tagged and released at the head of Swift Reservoir for analysis. It is important to note that within each species pooled group exists different cohorts of fish that were tagged either from the Eagle Cliff screw trap or Swift FSC. The bootstrapping methodology was applied to estimate both the mean and variances of the total number of fish per species entering Swift Reservoir during 2021. From this analysis, it was estimated that 241,397 Coho, 13,057 Chinook, 31,914 Steelhead, and 17,453 Cutthroat juveniles entered Swift Reservoir during 2021 (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 parr and smolt (1+ and 2+ age classes) estimated to pass Eagle Cliff during screw trapping operations in 2021 suggests that the majority of parr and smolt enter Swift Reservoir during times when the screw trap was not in operation and/or from other independent Swift Reservoir tributaries outside the upper NF Lewis River watershed.

Table 3.1-5. Estimates of total naturally produced fish (adipose fin intact and ≥60 mm FL) entering Swift Reservoir during 2021 by species (bootstrap method).

Species	Tags Released	Tags Recaptured at FSC	Recapture Rate, S_1 (S_{RES}*P_{COL}) Applied	Total untagged fish captured at FSC[A]	Bootstrap Mean Total Estimate	95% CI +/-
Coho	1,627	468	0.29	68,839	***241,397***	**18,227**
Chinook	58	15	0.26	3,177	***13,057***	**5,908**
Steelhead	813	147	0.18	5,755	***31,914***	**4,856**
Cutthroat	93	5	0.05	751	***17,453***	**22,477**

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

Included in Task 7.2 is a comparison of size of fish captured at the screw trap to those at the FSC, in addition to a longer-term assessment of mark-recapture data from PIT tags to parse yearly estimates of total of focal fish in the reservoir by size/year class. This additional analysis was not completed in 2021 as revisions to the M&E Plan that will be implemented beginning in 2022 that address the short comings of current methodology used to address this objective. For now, Task 7.2 should be interpreted as *'the number of fish in the reservoir in 2021'* as in previous years, rather than *'the number of fish that entered the reservoir in 2021*.

3.2 Fish Numbers Collected at the FSC

3.2.1 Overview/Methods

Section 9.2.1(j) of the Settlement Agreement requires PacifiCorp to enumerate the number of salmonids collected at the 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 was 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 – historically April through June), only a portion of fish are sampled and the rest are diverted to the general population tanks (which are not enumerated or biosampled). 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):

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

With associated variance estimator:

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

And 95 percent Confidence Interval:

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

Where,

T = total number of fish during the subsampling period
O = total number of fish during 100 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 α/2

The Swift FSC was operational for the entirety of 2021, with the exception of the outages as shown in Table 2.1-1. Sample rates were set to 100 percent from January 1 through May 3 due to moderate fish collection totals. The subsample rate was adjusted to 25% from May 4 through June 30, and again from November 17 through December 8. For the period in which fish were subsampled, the equations described above were used to derive the total number of fish collected on a given day, as well as the associated variance and error.

3.2.2 Results/Discussion

A total of 85,693 (95% CI range: 70,621 – 100,765) salmonids were captured by the Swift FSC in 2021 (Table 3.2-1). Of these fish, approximately 81,295 were transported and released downstream of Merwin Dam (Table 3.2-2). Any transport species that were not transported downstream, were either used for various M&E evaluations in which fish were released back upstream or were recorded as a mortality associated with collection as described below in Section 3.5.2. Juvenile Coho accounted for the highest percentage of the overall estimated catch (82.5 percent), followed by Steelhead (6.8 percent), spring Chinook (3.7 percent), and Cutthroat Trout (0.9). A total of 2,262 hatchery Rainbow Trout and six (6) Bull Trout were also collected in 2021 and returned to the reservoir. An additional estimated 1,878 hatchery Rainbow Trout were collected and passed downstream of Merwin Dam during the timeframe that fish were being subsampled. 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.

Based on the total number of fish transported downstream, 2021 was the second largest out-migration year (81,295 juvenile and adult fish transported downstream) since the FSC began operation in 2013, only being surpassed in 2019, when 111,702 fish were transported (Table 3.2-3). As with all previous years, Coho were the most abundant species transported downstream in 2021.

Table 3.2-1. Estimated monthly and annual totals of all salmonids collected at the FSC in 2021.

Month	Coho				Chinook			Steelhead					Cutthroat			Bull Trout	Golden-dales	Total Trapped
	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Fry	Parr	Smolt	Adult	Kelt	Fry	< 13 Inches	> 13 Inches			
Jan	185	2065	265	26	0	4	219	4	9	47	0	0	1	77	1	0	16	**2,919**
Feb	32	644	252	1	9	12	158	3	11	21	1	1	1	48	0	0	57	**1,251**
Mar	49	903	357	0	1	19	418	1	7	23	1	0	1	24	2	1	143	**1,950**
Apr	8	115	1,148	0	0	3	875	0	55	606	22	8	0	56	3	4	529	**3,432**
May	16	246	18,018	0	1	27	160	0	40	4,331	23	18	0	360	10	1	1,682	**24,933**
Jun	95	205	18,978	0	14	388	101	2	24	357	3	7	0	75	0	0	1,695	**21,944**
Jul	15	23	718	0	2	59	5	13	0	5	0	0	0	5	1	0	8	**854**
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Nov	1,154	16,020	5,405	339	0	13	217	10	26	132	0	1	0	55	9	0	7	**23,388**
Dec	279	2,563	914	672	0	8	491	0	21	40	0	0	0	31	0	0	3	**5,022**
Annual Total	**1,833**	**22,784**	**46,055**	**1,038**	**27**	**533**	**2,644**	**33**	**193**	**5,562**	**50**	**35**	**3**	**731**	**26**	**6**	**4,140**	**85,693**
95% CI	***±360***	***±3,691***	***±8,031***	***±0***	***±0***	***±121***	***±351***	***±0***	***±58***	***±1,323***	***±0***	***±0***	***±0***	***±171***	***±17***	***±0***	***±948***	***±15,072***

Table 3.2-2. Estimated annual totals of salmonids transported downstream in 2021.

Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Goldendales	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	
1,828	22,431	45,691	0	27	533	2,464	0	33	184	5,442	0	33	3	722	26	0	1,878	81,295

[A] The total number of target species downstream does not include hatchery origin Rainbow Trout (i.e., Goldendales) stocked for recreational fishing in Swift Reservoir.

Table 3.2-3. Estimated annual totals of salmonids transported downstream for years 2013 through 2021.

Year	Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Golden-dale	Target Species Downstream
	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Kelt	Fry	<13 in.	>13 in.			
2013	*na*	*na*	15,074	0	*na*	*na*	1,431	0	*na*	*na*	166	0	9	*na*	550	6	1	453	17,690
2014	*na*	*na*	7,588	0	*na*	*na*	2,164	0	*na*	*na*	539	0	7	*na*	854	3	0	0	11,155
2015	*na*	6,478	25,441	0	*na*	227	5,174	0	*na*	47	1,277	0	28	*na*	763	48	0	290	39,483
2016	836	11,307	48,833	0	6	673	3,114	0	32	74	2,095	0	66	32	1,036	33	0	1,713	68,175
2017	3,598	9,576	14,924	0	0	278	5,523	0	19	73	1,724	0	9	14	744	46	0	444	36,972
2018	998	4,843	35,880	0	31	462	4,187	0	13	18	7,863	0	19	4	854	18	0	146	55,336
2019	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
2020	88	4,925	25,940	0	3	2,927	12,447	0	67	53	4,063	0	180	1	474	28	0	1,041	51,196
2021	1,828	22,431	45,691	0	27	533	2,464	0	33	184	5,442	0	33	3	722	26	0	1,878	81,295

[A] The total number of target species downstream does not include hatchery origin Rainbow Trout (i.e., Goldendales) stocked for recreational fishing in Swift Reservoir.

3.3 Juvenile Migration Timing

3.3.1 Overview/Methods

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

Following the 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 estimated 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 estimating migration timing, PacifiCorp also measured juvenile fish length to describe, temporally, the size (or life-stage) of fish entering the FSC. Size distributions for Coho, Chinook, Steelhead and Cutthroat were calculated on a monthly basis. Length frequencies in 2021 were calculated on a monthly basis, rather than a seasonal basis, in order to more precisely track the lengths of each cohort through time. Size distributions were not calculated for the time period from mid-July through mid-November as the FSC was off for annual summer maintenance and construction activities.

3.3.2 Results/Discussion

The run timing in 2021 was consistent with previous years with two general out-migration periods occurring; one occurring during the spring and the other occurring during late-fall. Species composition and life-stages represented did vary slightly however among periods. Overall, the run timing for spring Chinook and Coho followed a double peak frequency distribution, with the first peak occurring in late May, and the second peak occurring during mid-November. A similar pattern, although less pronounced, was observed for Cutthroat Trout with passage occurring in both in the spring and fall. Peak out-migration of juvenile Steelhead, however, occurred almost exclusively over a two-month period in the spring between April 15 and June 15. Within this time frame, 90 percent of the Steelhead were collected, relative to the total annual catch for this species.

Coho Size Distributions

Length frequency data for Coho during 2021 demonstrated three general cohorts moved through the system and were passaged downstream (Figures 3.3-11 to 3.3-13). During the months of January-March, the majority of the catch was composed of smaller fish less than 120mm (parr), which were produced by adults transported upstream in 2019 (i.e., brood year 2019). A smaller proportion of larger out-migrants (> 250 mm) were also seen earlier in the year. These large fish were likely holdovers from the previous outmigration year (2020) and represented juveniles produced by adults transported in 2018. From April through May, the median lengths of both cohorts increased, and over 85 percent of juvenile Coho that were captures at the FSC had lengths greater than 121 mm (Figure 3.3-12). By June, nearly all smolts collected at the FSC were from brood year 2019, and had a median length of 175 mm. Beginning in July, smaller Coho (fry) produced from adults transported in 2020 began appearing at the FSC. These smaller fish along with holdovers from the 2019 brood year comprised the catch late in the year in 2021 (i.e., November and December).

Chinook Size Distributions

All juvenile Chinook collected in 2021 represented fish naturally produced in the upper basin from adult spring Chinook transported upstream; the remaining juveniles released as part of the previous acclimation program in the upper basin were released in August 2017 and are no longer in the system. (No acclimation programs ever occurred for Coho and Steelhead upstream of Merwin Dam, and therefore all juveniles out-migrating from the upper basin are NOR.). Juvenile Chinook lengths observed early in the year (prior to April 2021) indicated a wide distribution of sizes ranging from less than 120mm up to 310 mm (Figures 3.3-14 through 3.3-16). The smaller fish were the progeny of adults transported upstream in 2019, while the larger fish from adult transported in 2018.

A similar broad size distribution for Chinook was also observed into the early spring with fish ranging in size from 110 mm to 310 mm being collected. As has been typical for Chinook out migrating from Swift Reservoir, very few fish were captured during the month of May, only to have a surge of smaller fish (<130mm) beginning to arrive in late June and into July. Numbers of these smaller fish arriving at the FSC begin to drop as water temperature rises in the summer, but continue their out-migration in the fall when temperatures drop. During November and December the median length of juvenile Chinook collected at the FSC was 185 mm and 183 mm, respectively.

Steelhead Size Distributions

Juvenile Steelhead size distributions observed in 2021 (Figure 3.3-17) were similar to those seen in previous years, and appeared to be comprised of two distinct cohorts of fish. These cohorts would represent juveniles produced from adults transported upstream in 2019 and 2020. Because the vast majority (>93.5 percent) out-migrate during the month of April through June, length frequency distributions were only generated during these months. The mean FL for Steelhead captured during these months ranged from 190 mm to 235 mm with a combined median length of 202 mm. Juvenile Steelhead less than 130mm FL accounted for less than 18 percent of the combined catch.

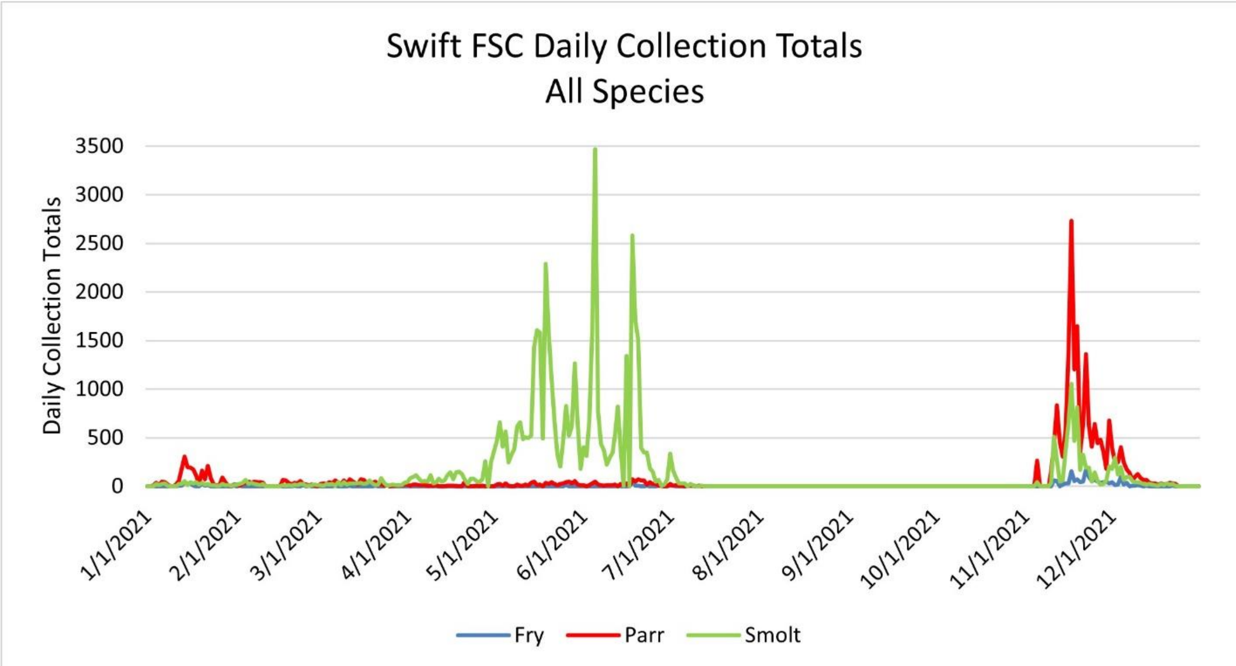


Figure 3.3-1. Estimated daily collection totals for all species at Swift FSC, 2021[10]

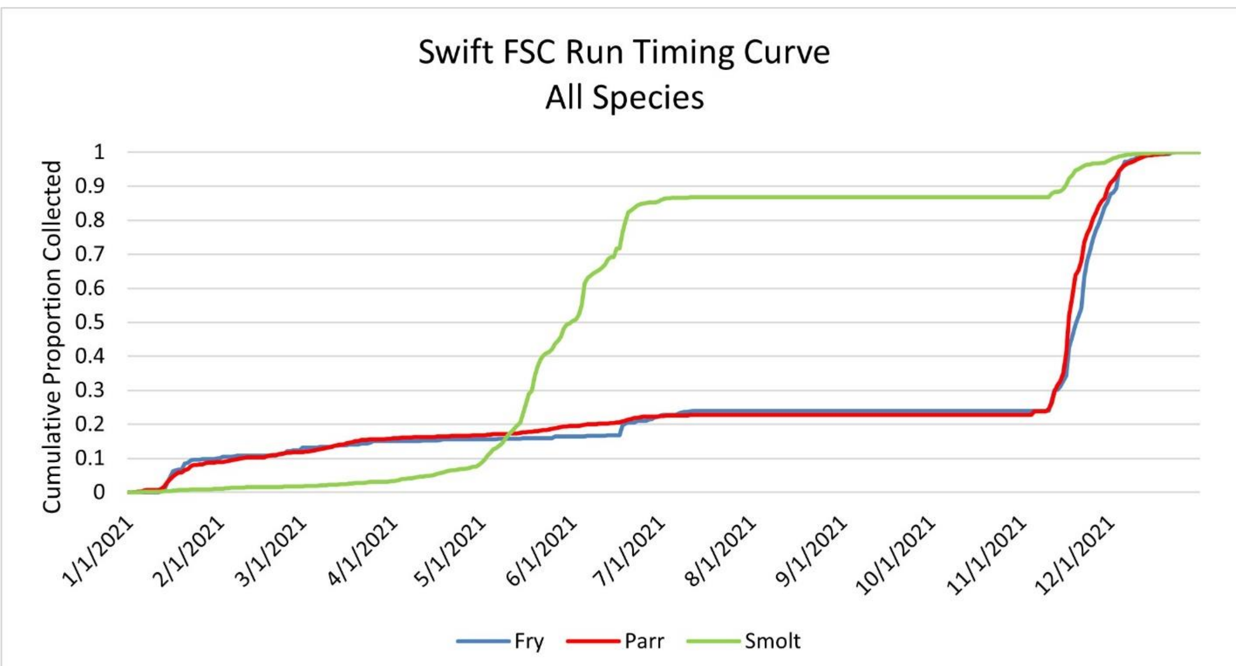


Figure 3.3-2. Cumulative migration timing among all species at Swift FSC, 2021

[10] The Swift FSC was not operational from July 13 through November 4, 2021 due to schedule outages.

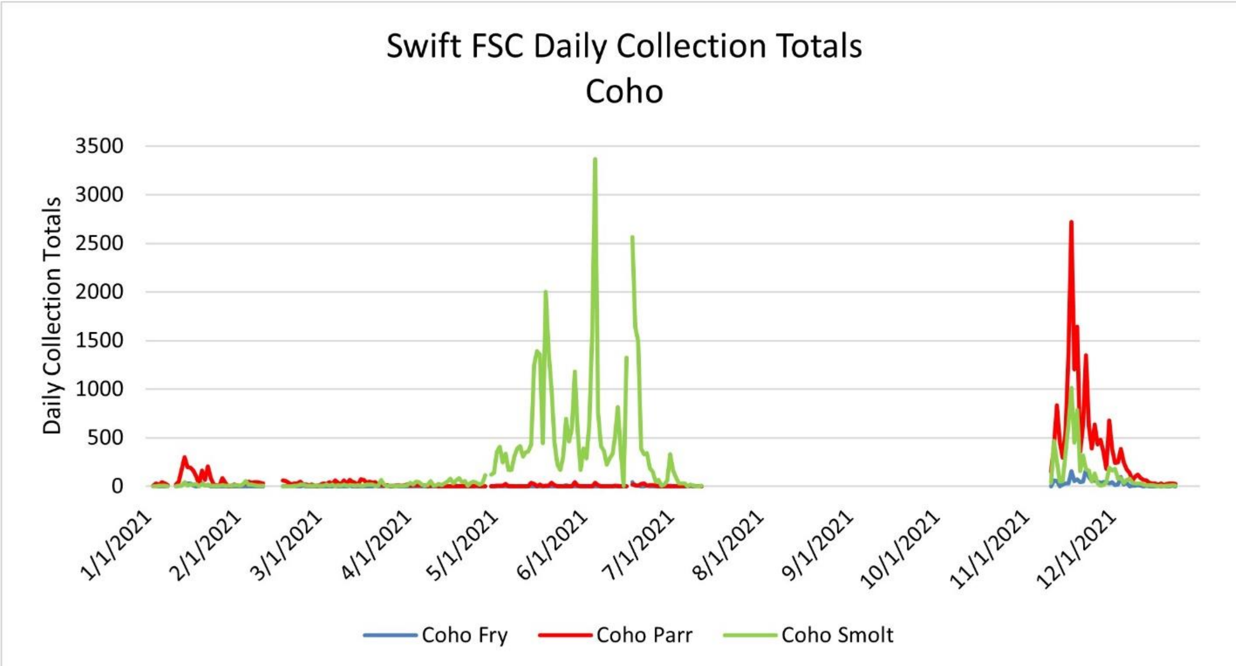


Figure 3.3-3. Estimated daily collection totals of juvenile Coho at Swift FSC, 2021[11]

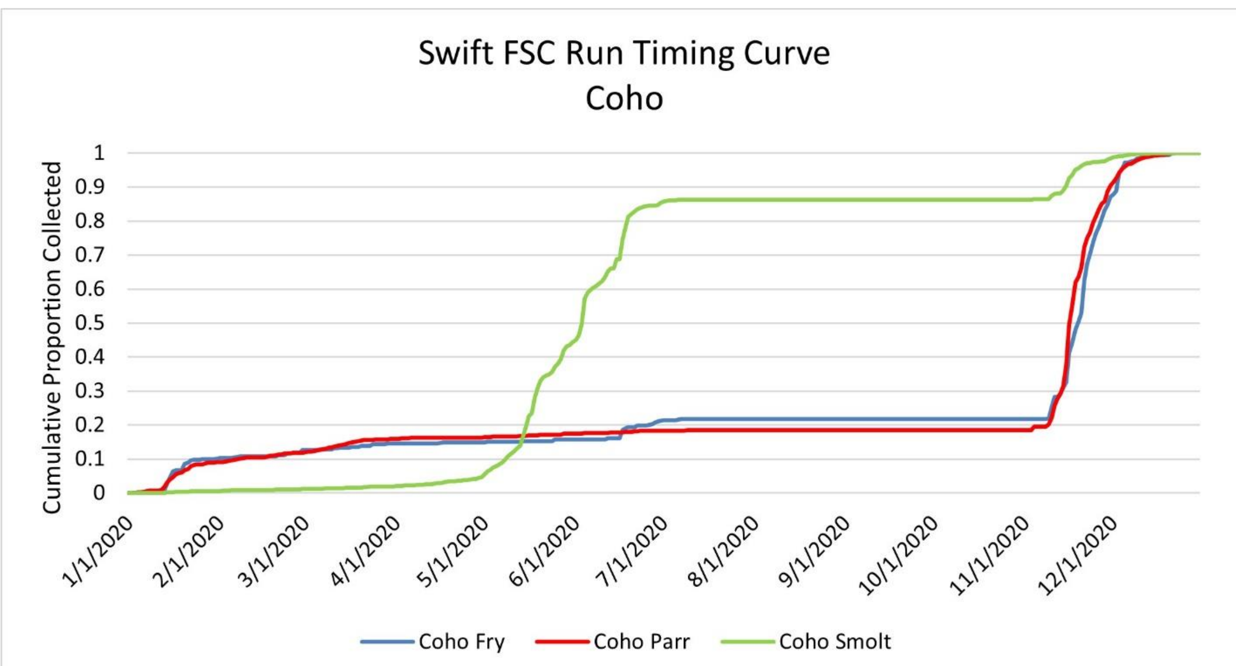


Figure 3.3-4. Cumulative migration timing of juvenile Coho at Swift FSC, 2021.

[11] The Swift FSC was not operational from July 13 through November 4, 2021 due to schedule outages.

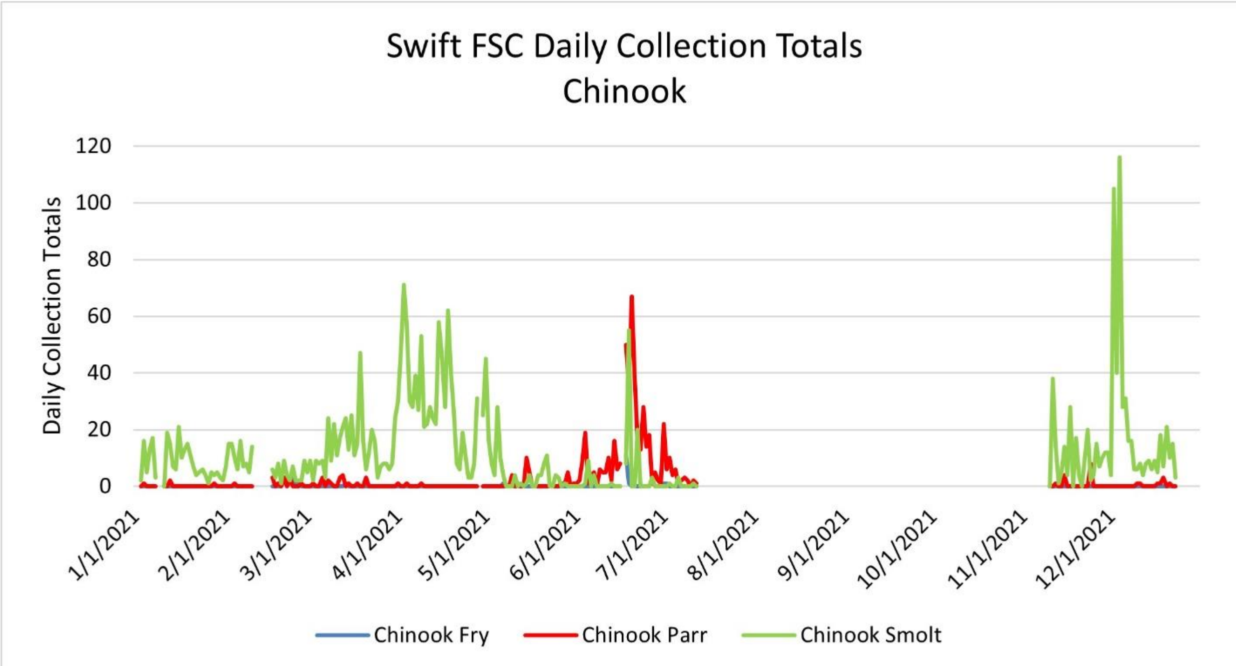


Figure 3.3-5. Estimated daily collection totals of juvenile Chinook at Swift FSC, 2021.[12]

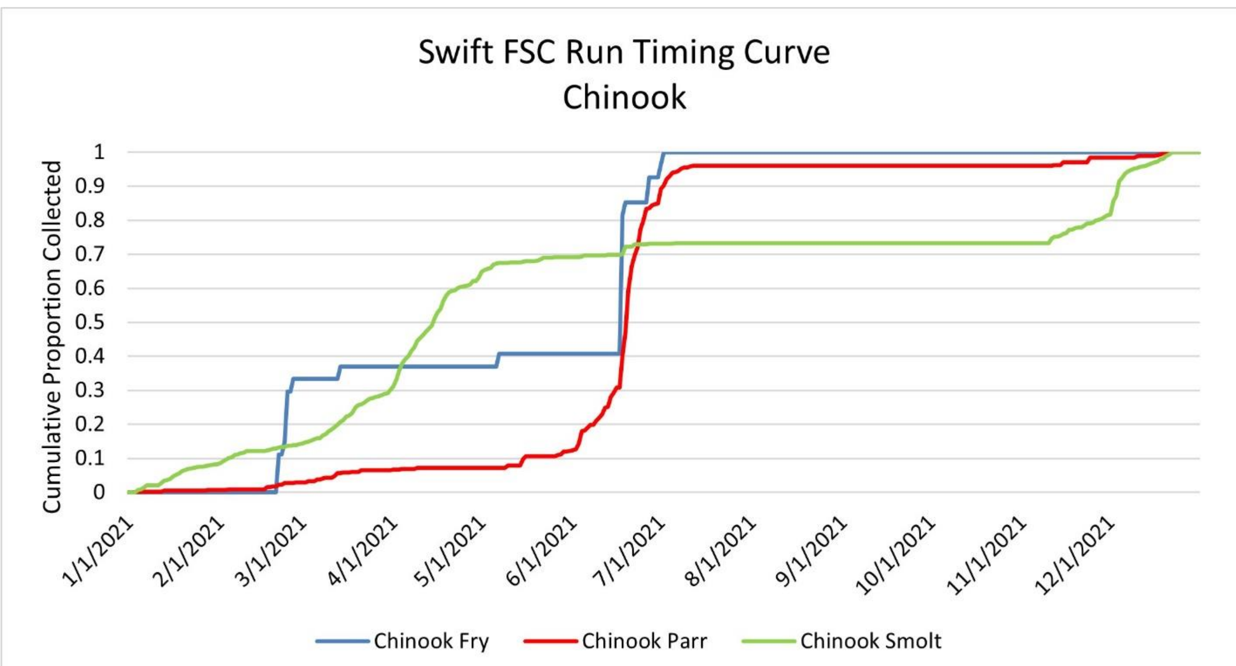


Figure 3.3-6. Cumulative migration timing of juvenile Chinook at Swift FSC, 2021.

[12] The Swift FSC was not operational from July 13 through November 4, 2021 due to schedule outages.

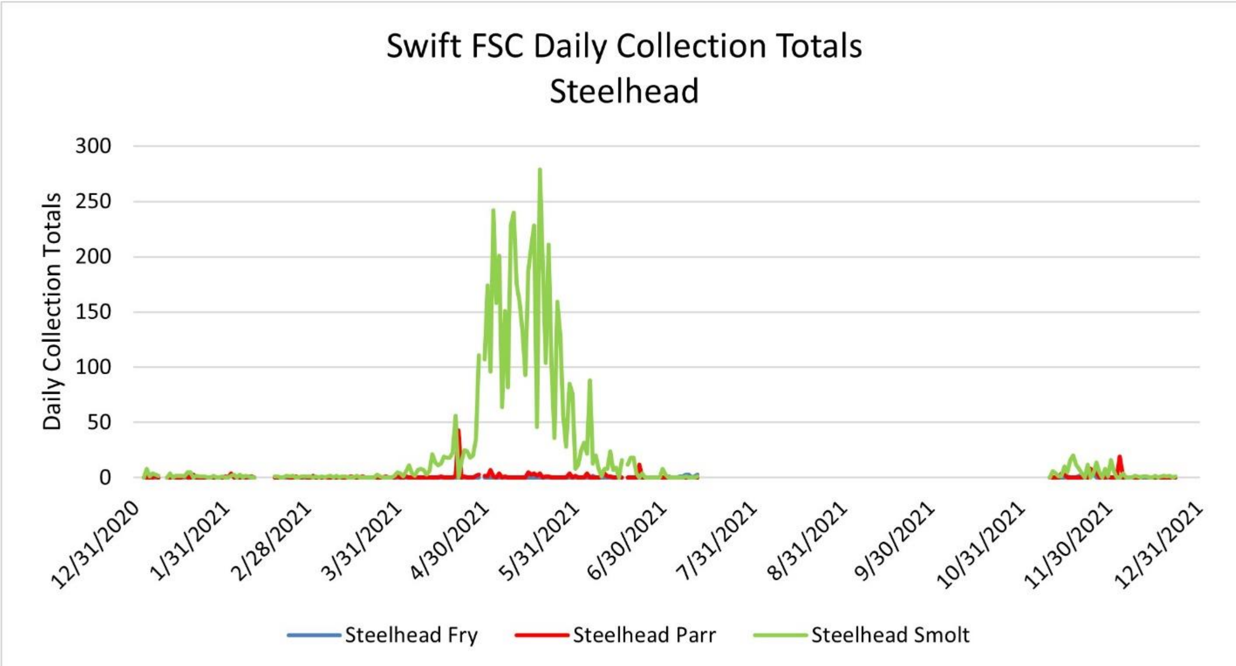


Figure 3.3-7. Estimated daily collection totals of juvenile Steelhead at Swift FSC, 2021.[13]

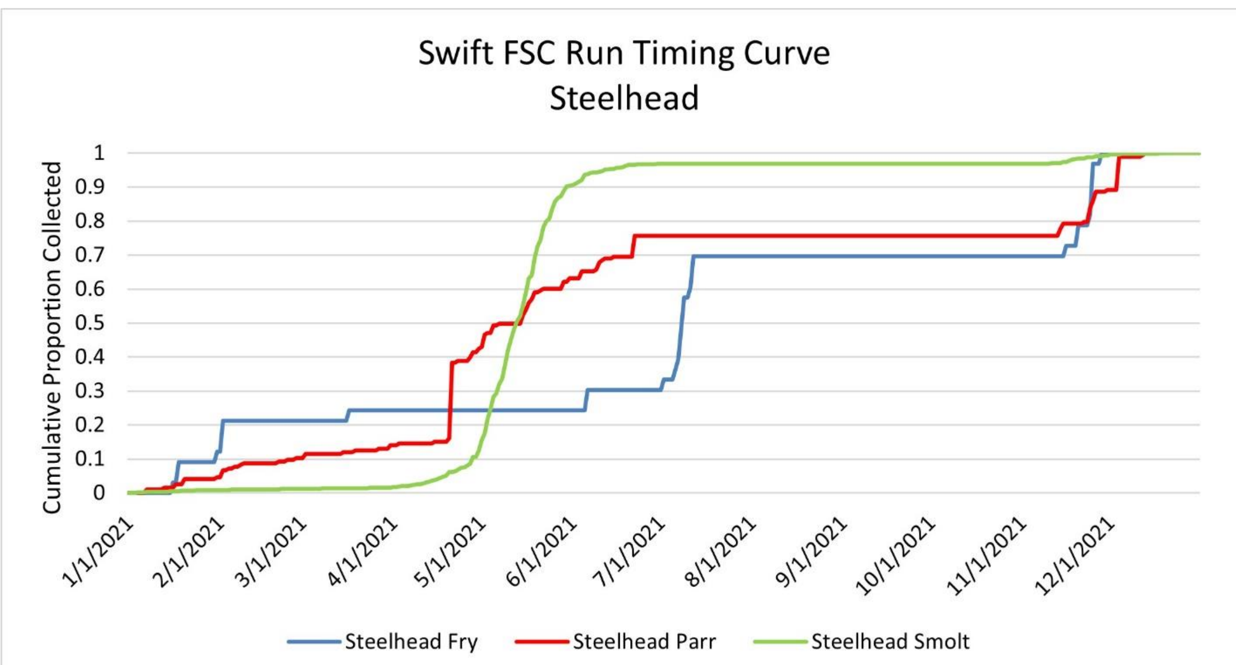


Figure 3.3-8. Cumulative run timing of juvenile Steelhead at Swift FSC, 2021.

[13] The Swift FSC was not operational from July 13 through November 4, 2021 due to schedule outages.

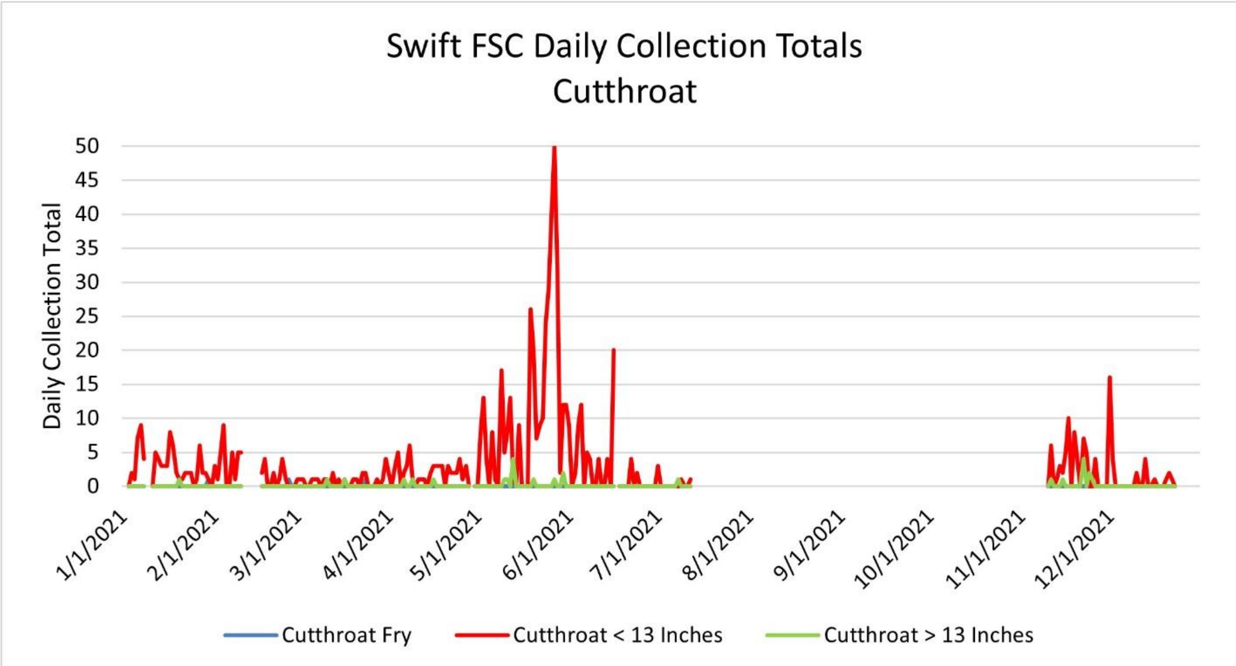


Figure 3.3-9. Estimated daily collection totals of juvenile Cutthroat Trout at Swift FSC, 2021. [14]

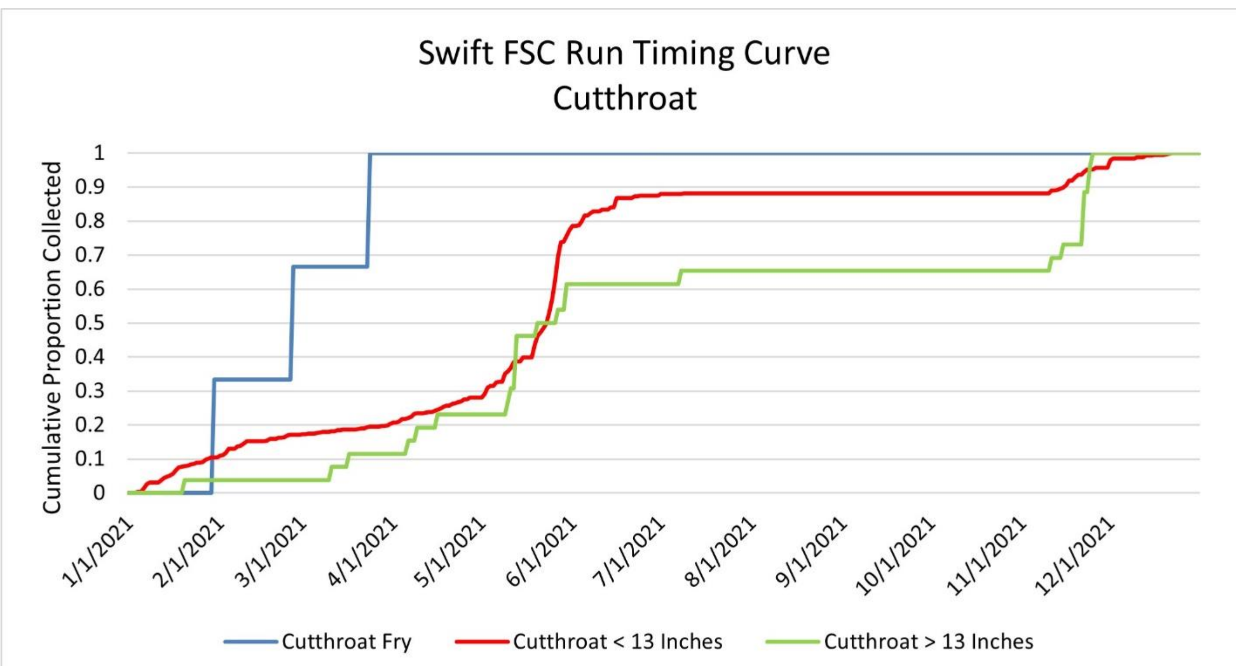


Figure 3.3-10. Cumulative run timing of juvenile Cutthroat Trout at Swift FSC, 2021.

[14] The Swift FSC was not operational from July 13 through November 4, 2021 due to schedule outages.

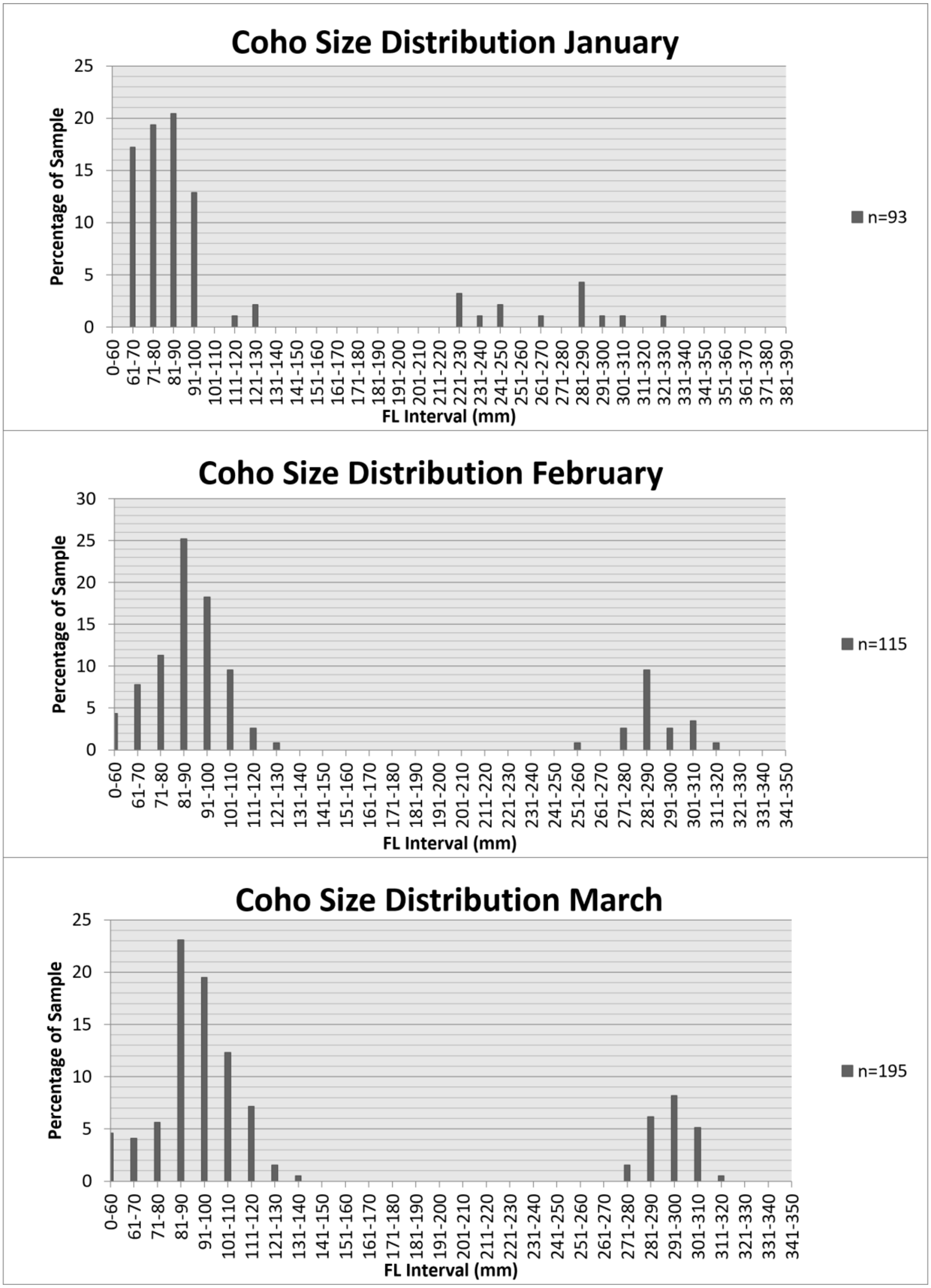


Figure 3.3-11. Size distribution of Coho migrants collected at the Swift FSC in 2021 (Jan-Mar).

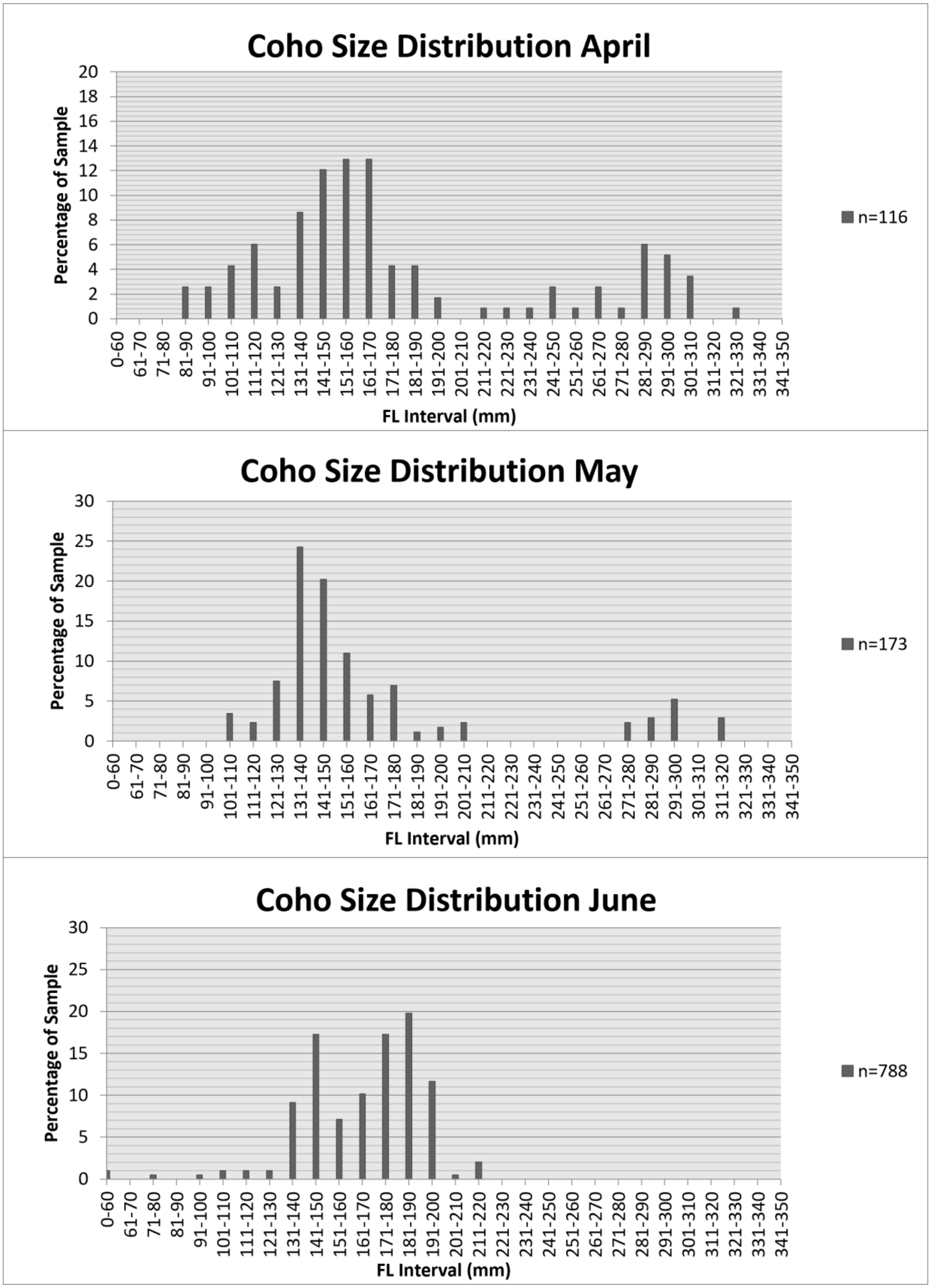


Figure 3.3-12. Size distribution of Coho migrants collected at the Swift FSC in 2021 (Apr-Jun).

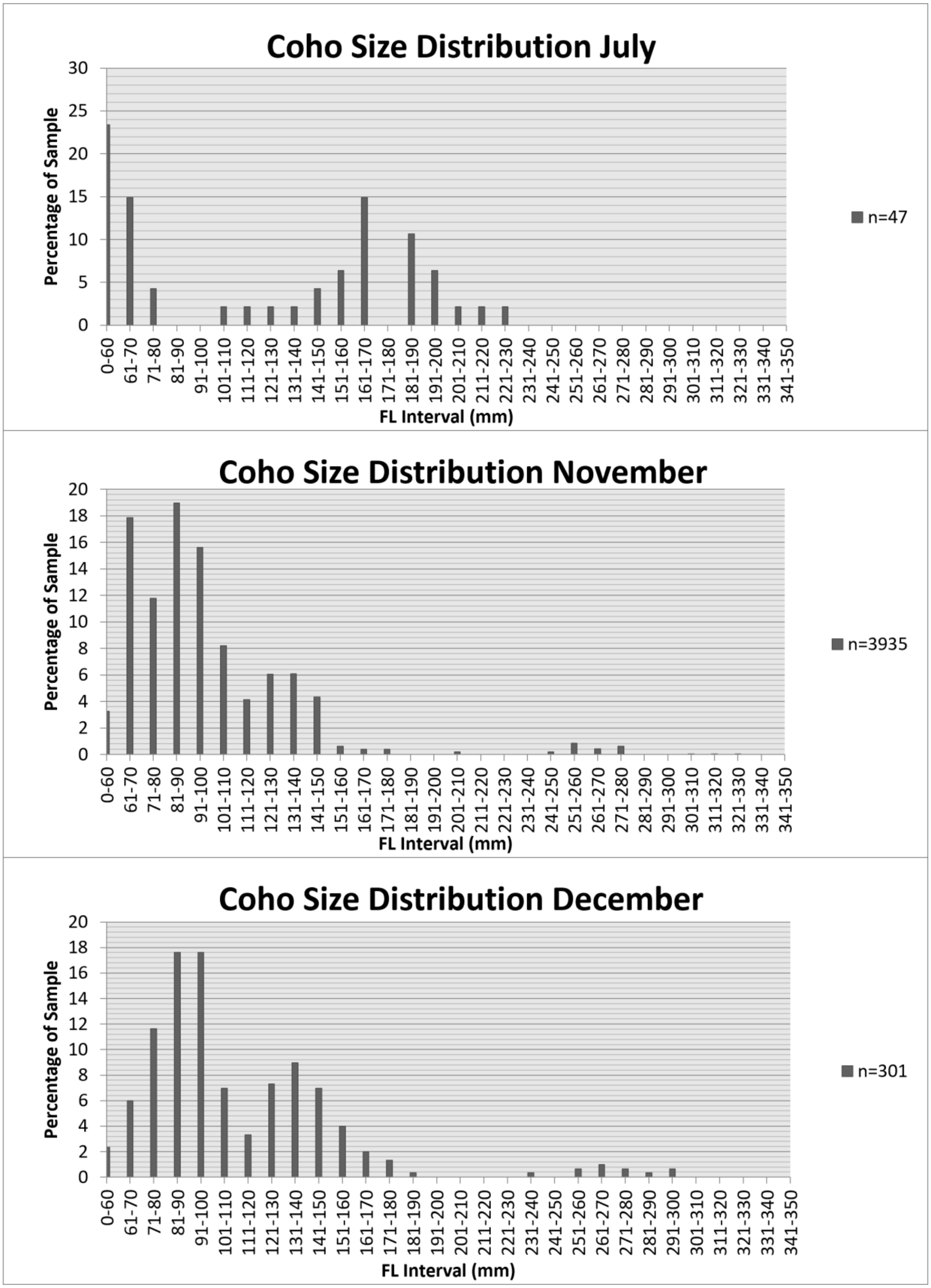


Figure 3.3-13. Size distribution of Coho migrants collected at the Swift FSC in 2021 (Jul-Dec).

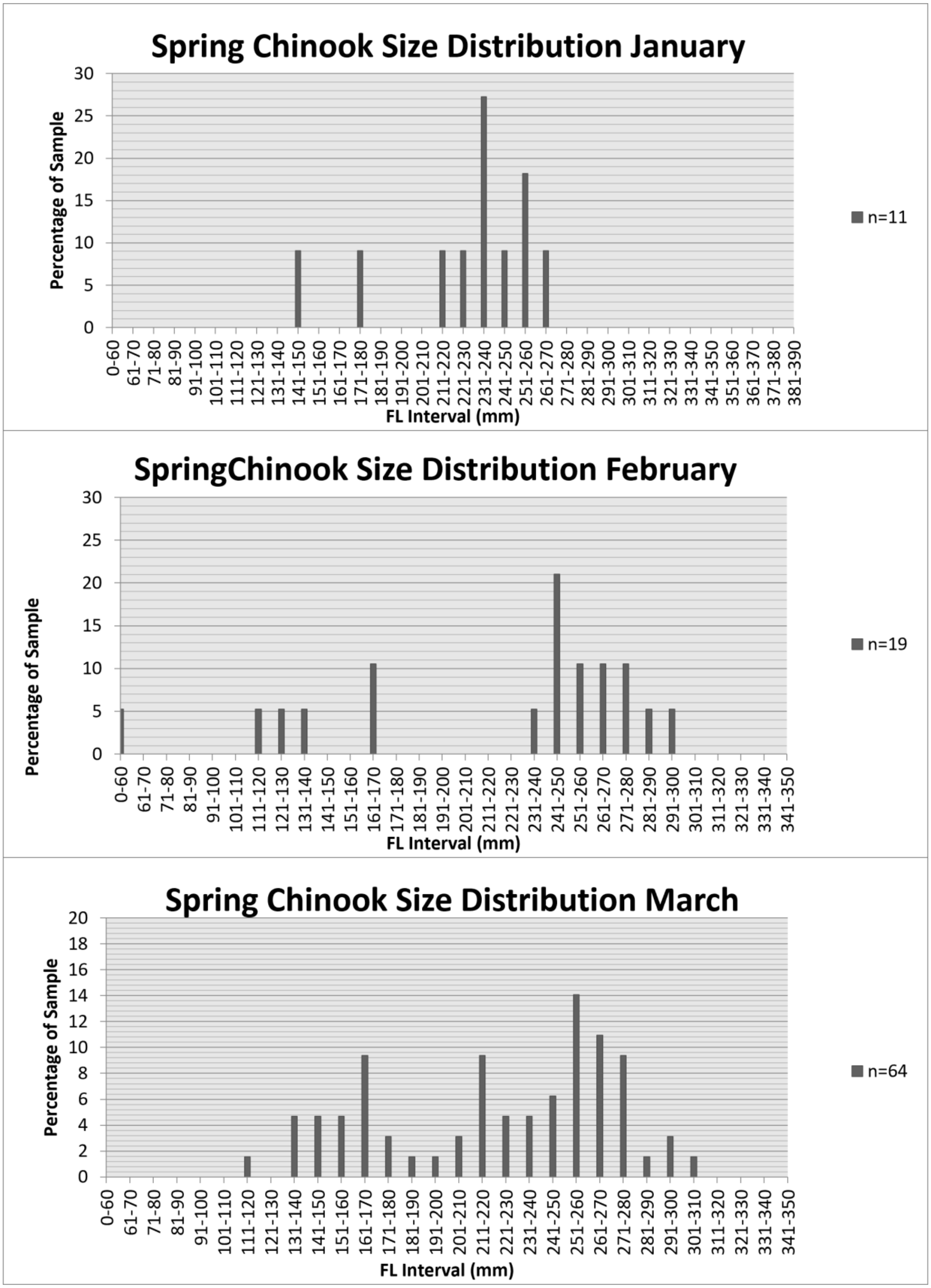


Figure 3.3-14. Size distribution of spring Chinook migrants collected at the Swift FSC in 2021 (Jan-Mar).

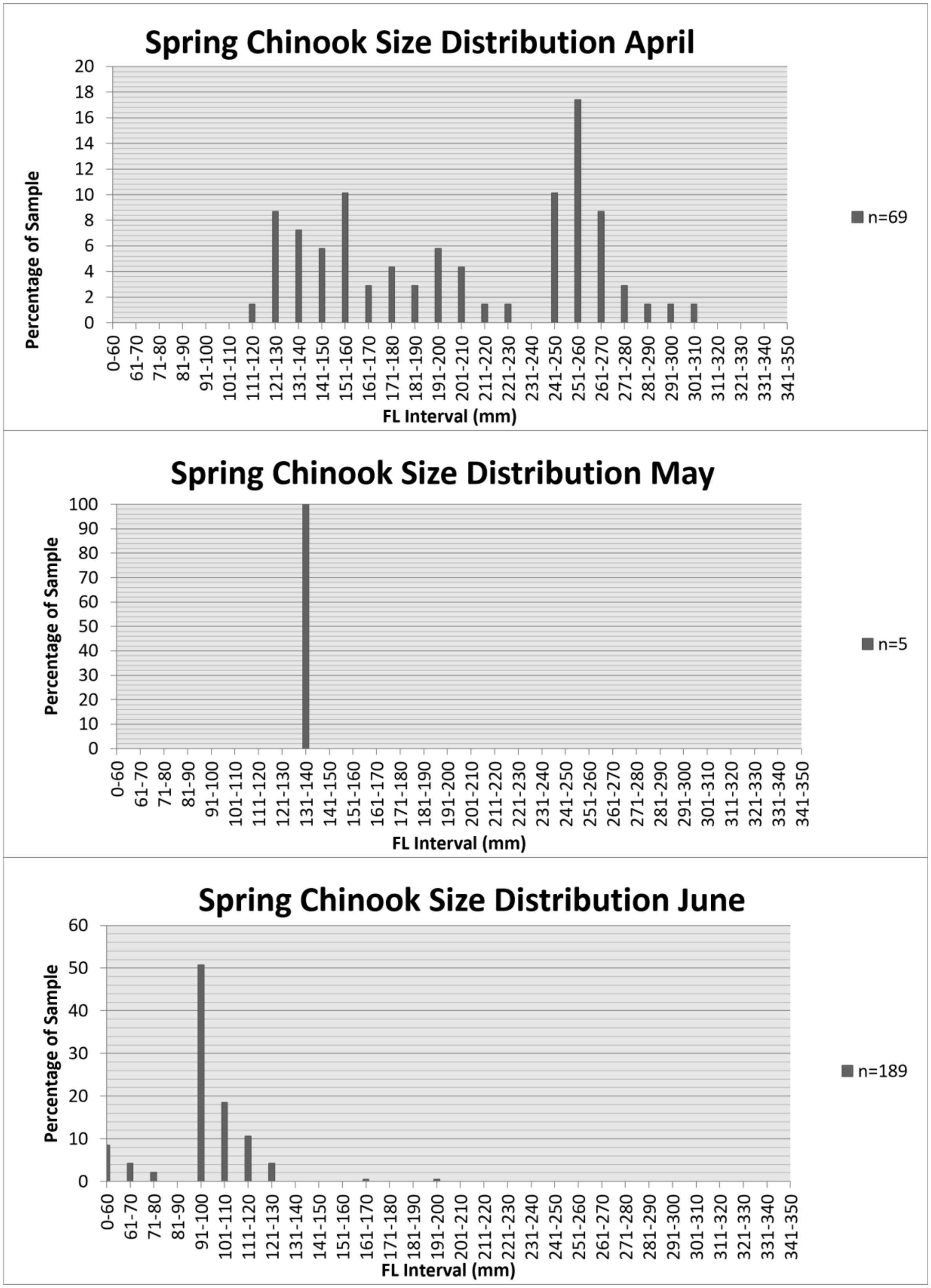


Figure 3.3-15. Size distribution of spring Chinook migrants collected at the Swift FSC in 2021 (Apr-Jun).

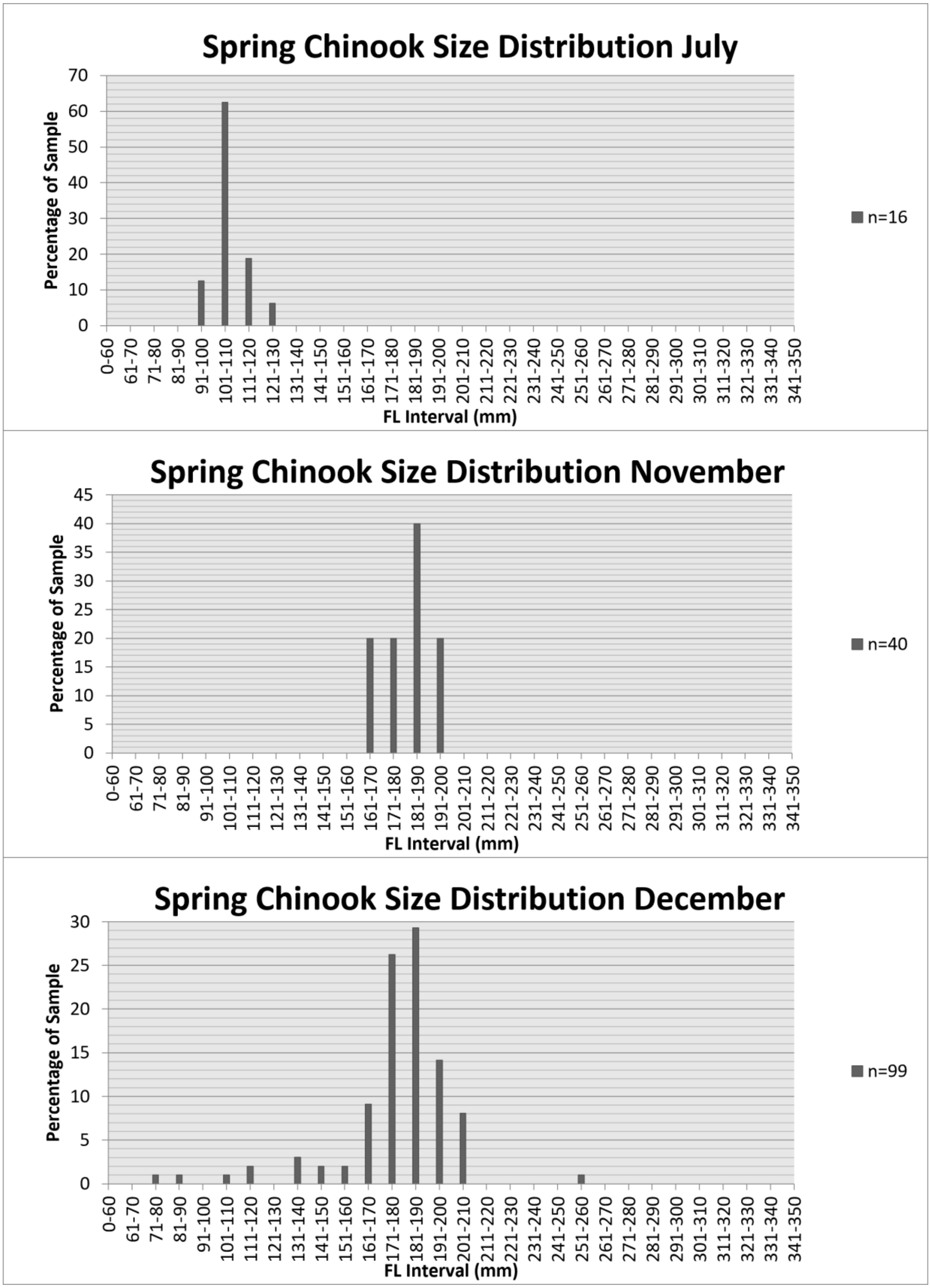


Figure 3.3-16. Size distribution of spring Chinook migrants collected at the Swift FSC in 2021 (Jul-Dec).

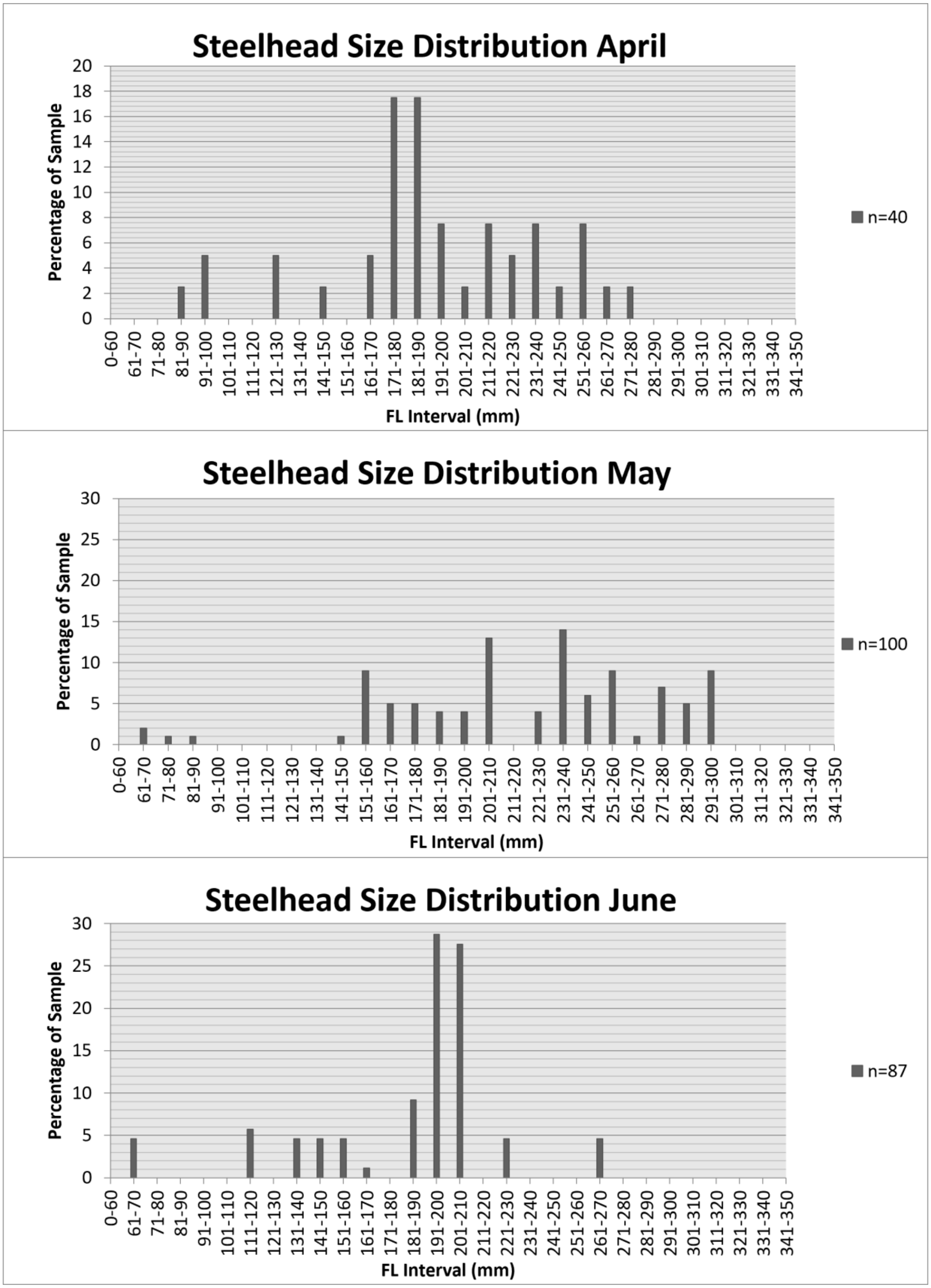


Figure 3.3-17. Size distribution of Steelhead migrants collected at the Swift FSC in 2021 (Apr-Jun).

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 2021. This evaluation was in accordance with Section 9.2.1(c) of the Settlement Agreement and based on findings and recommendations from the 2013 pilot study (Courter et al. 2013), 2014 evaluation (Stroud et. al 2014), 2015 evaluation (Reynolds et.al 2015), 2016 evaluation (Caldwell et. al 2017), 2017 evaluation (Anchor QEA 2018), 2018 evaluation (PacifiCorp 2019), and 2019 and 2020 evaluations (Four Peaks Environmental 2020, 2021). Objective 2 of the current M&E Plan (2017) defines P_{CE} as the percentage of juvenile salmonids emigrating from Swift Reservoir that are available for collection and that are actually collected. A juvenile that is available for collection is one that is enters 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[15] was agreed upon for P_{CE}.

The primary goals of the 2021 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) examine fine-scale fish behavior and movement within the collection channel to identify locations within the extent of the structure where fish reject and turn back upstream.

The specific study objectives of the 2021 FSC collection efficiency evaluation were to:

1. Estimate reservoir passage (P_{PASS}), the proportion of released study fish that are detected entering the Swift Reservoir forebay as defined by the Devil's Backbone acoustic hydrophone array;

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

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

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

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

6. Describe the behavior of downstream migrants once they enter the fish channel, specifically in relation to the number of passage attempts, progress through the fish channel and any holding behavior, and last location prior to returning to the reservoir for fish that are not successfully captured. This was characterized as channel-collector transition rate, or probability of capture (P_{CAP}).

[15] 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 2021 effort can be found in Appendix C. A brief summary of this report is provided below.

A total of 443 fish were dual PIT and acoustic tagged and released upstream of FSC between April 1 and June 3, 2021, to measure system performance and monitor fish behavior. At total of 39 Chinook, 212 Coho, and 192 Steelhead juveniles were tagged and released (Table 3.4-1). All study fish were released near Swift Forest Camp Boat launch at the head of Swift Reservoir. The proportion of fish successfully transiting the reservoir during the study period was quantified in 2021 using the P_{PASS} metric. P_{PASS} summarizes the proportion of all dual-tagged study fish that were detected at the Devil's Backbone before the conclusion of the 2021 Study. In 2021, P_{PASS} was 74 percent for Chinook Salmon, 89 percent for Coho Salmon, and 73 percent for Steelhead.

Collection efficiency ($\mathrm{P_{CE}}$) is a key performance metric that represents the proportion of dual-tagged study fish reaching the ZOI that were subsequently collected. In 2021, $\mathrm{P_{CE}}$ was 52 percent for Chinook Salmon, 40 percent for Coho Salmon, and 48 percent for Steelhead. Compared to 2020 results, these proportions represent an 18 percent (8 percentage point) increase for Chinook, a 3 percent (1 percentage point) decrease for Coho, and a 14 percent (6 percentage point) increase for Steelhead. Entrance efficiency ($\mathrm{P_{ENT}}$), quantifies the proportion of fish in the ZOI that were then detected within the NTS at the entrance of the FSC. $\mathrm{P_{ENT}}$ was near 100 percent for all three species; 95 percent for Steelhead to 100 percent for Chinook Salmon. Together, these results suggest that, although 11 percent to 26 percent of study fish (by species) did not reach the forebay during the study period (either due to mortality, premature tag failure, or delayed migration), once study fish reached the ZOI, most entered the NTS.

Over three quarters (79 percent) of the fish that entered the NTS were subsequently detected within the collection channel ($\mathrm{P_{CHAN}}$) of the FSC. $\mathrm{P_{CHAN}}$ ranged from 57 percent for Chinook to 84 percent for Steelhead. Among these fish that entered the NTS; however, less than half (45 percent overall) were retained within the FSC and ultimately collected ($\mathrm{P_{RET}}$). $\mathrm{P_{RET}}$ was 52 percent for Chinook salmon, 41 percent for Coho salmon, and 50 percent for Steelhead. Once in the collection channel, 57 percent of all study fish were collected ($\mathrm{P_{CAP}}$); with 92 percent of Chinook Salmon (noting very low sample size for Chinook in 2021), 52 percent of Coho salmon, and 60 percent of Steelhead being captured. Thus, the relatively low observed ($\mathrm{P_{CE}}$) appear to be largely the product of low retention, rather than attraction to the FSC. These relatively low retention rates reflect apparent "turnaround" points for all three species that were located (1) between the downstream NTS and the primary channel, (2) between the primary channel and the upstream secondary channel, and (3) between the downstream secondary channel and the sorting building entrance (i.e., collection). Among these three turnaround points, it appears that the largest bottleneck for successful passage occurs within the downstream portion of the secondary channel. This is an area where flow velocity within the fish channel decelerates just upstream of the weir that fish pass over before entering the sorting building. Increasing the retention of fish that have transited to this area appears to be the single action that would result in the biggest increase in collection efficiency.

Acoustic telemetry data collected during the 2021 study demonstrated that the lead net installed in 2016 continues to successfully attract out-migrating juvenile anadromous salmonids to the entrance of the Swift FSC once they enter the forebay of Swift Reservoir. Data also indicate that retention of study fish that have entered the NTS and collection channel remains low and appears to be the bottleneck for successful passage. After evaluating many environmental and operational factors hypothesized to affect collection efficiency, it appears that poor retention is driven primarily by patterns of flow within the channel, including areas where flow accelerates and decelerates and areas of relatively low velocity. The single greatest bottleneck to passage occurs within the low velocity deceleration region just before the entrance of the sorting building. It is thought that fish can rest in this area before attempting to exit the fish channel. Given the higher resolution of acoustic receivers deployed within the fish collection channel during the 2021 Study, it now appears that increasing retention of fish that have reached the downstream portion of the secondary collection channel is the most critical area for improvement and offers potential for a considerable net increase of collection efficiency at the Swift FSC. PacifiCorp plans to retest collection efficiency through an acoustic tag study in the spring of 2022.

Table 3.4-1. Summary of seasonal corrected passage metrics for tagged fish released at the head of Swift Reservior by species in 2021.

Species	No. Rel.	DET_{ZOI}	DET_{NTS}	DET_{CHA}	DET_{COL}	$\hat{P}_{PASS}$ (90% CI)	$\hat{P}_{ENC}$ (90% CI)	$\hat{P}_{ENT}$ (90% CI)	$\hat{P}_{CHAN}$ (90% CI)	$\hat{P}_{CAP}$ (90% CI)	$\hat{P}_{CE}$ (90% CI)	$\hat{P}_{RET}$ (90% CI)
Chinook Salmon	39	25	25	12	13	74% *(63%, 86%)*	86% *(76%, 97%)*	100% (--)[3]	57% *(40%, 73%)*	92% *(79%, 100%)*	52% *(36%, 68%)*	52% *(36%, 68%)*
Coho Salmon	212	179	175	137	71	89% *(86%, 93%)*	95% *(92%, 97%)*	98% *(96%, 100%)*	78% *(73%, 83%)*	52% *(45%, 59%)*	40% *(34%, 46%)*	41% *(34%, 47%)*
Steelhead	192	132	124	105	63	73% *(68%, 78%)*	94% *(91%, 98%)*	95% *(92%, 98%)*	84% *(78%, 89%)*	60% *(52%, 68%)*	48% *(41%, 55%)*	50% *(43%, 58%)*
All	443	336	324	254	147	81% *(78%, 84%)*	94% *(92%, 96%)*	97% *(95%, 98%)*	79% *(75%, 83%)*	57% *(52%, 62%)*	44% *(39%, 48%)*	45% *(41%, 50%)*

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 at the FSC during 2020 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 current M&E Plan (2017), 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 is 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	Minor Scrap or Open Wound w/ fungus
Gill Damage	Bruising > 0.5 cm diameter	Bruising < 0.5 cm diameter
Loss Of Equilibrium	Descaling > 20%	Descaling < 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*. Any trap related mortality was recorded as S_{COL}.

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

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

Where:

R_{Inj} = Observed daily injury rate per species;

SS_{inj} = Number of injured fish per species in subsample, mortalities are not included; and

SS_{Total} = Total number of fish per species in subsample, mortalities are not included.

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

Where:

CS[16] = 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;

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; and

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. *Note: A detailed description of how S_{TRAN} is calculated is provided in Section 3.7 below.*

[16] CS was calculated for smolts (combined with parr), whereas only S_{COL} was recorded for fry. Fry were transported downstream in 2020; 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 7.72 percent (Table 3.5-3). Juvenile Chinook had the highest overall injury rate (7.2 percent), followed by juvenile Steelhead (1.22 percent) , and Coho (1.15 percent). No injuries were observed for any salmonid fry, Cutthroat Trout, adult Steelhead, or Bull Trout. As in previous years, descaling accounted for the greatest proportion of the injuries observed (98.4 percent) in all species, followed by bruising (1.0 percent), loss of equilibrium (0.5 percent), and hemorrhaging (0.1 percent) (Figure 3.5-2).

Annual injury rates for all species and life-stages of salmonid met the required performance standard maximum of 2.0 percent, with the exception of juvenile (parr and smolt) Chinook. The elevated injury rate for Chinook is largely attributed to heavy debris loading in the early Spring, which coincides with the peak of the Spring Chinook outmigration.

PacifiCorp has continued to address sources of injury at the FSC. Debris accumulation in both the smolt transport flume and adult fish holding tank have been a significant source of injury and mortality to date. In an effort to reduce injury and mortality caused by debris loading, PacifiCorp has made a number of modifications to both of these areas including:) the incorporation of traveling screens into fish holding tanks to allow for continuous filtration and debris removal; 2) widening of conveyance flumes and transport pipes to prevent blockage, and allow woody debris and other material to more readily pass through the system; 3) redesigning the fish sorting system and incorporating additional spray bars and other equipment to reduce debris accumulation and allow for safe passage. In addition to the infrastructural changes to the facility’s sorting area, PacifiCorp has also implemented several debris management measures in Swift Reservoir to minimize debris entrainment at the FSC. These have included installation of several debris booms located at the head of the reservoir as well as in and around the forebay near the FSC (Figure 3.5-2). PacifiCorp also actively manages debris on the reservoir by using containment and removal procedures. In 2022, PacifiCorp will be purchasing a debris-skimmer boat that will be operated during periods of high debris loading in the Swift Reservoir forebay, thereby further reducing the amount of debris being entrained inside the FSC. Delivery of the skimmer boat is scheduled for July of 2022. PacifiCorp will continue to monitor the efficacy of these debris management measures 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.

Species and Life Stage	No. Injured [A]	No. Sampled [B]	Injury Rate (%)
Coho (Fry)	0	1,389	0
Chinook (Fry)	0	21	0
Steelhead (Fry)	0	30	0
Cutthroat (Fry)	0	3	0
Combined (Fry)	*0*	*1,443*	*0*
Coho (Parr & Smolt)	402	34,912	1.15 ± 0.11
Chinook (Parr & Smolt)	196	2,538	7.72 ± 1.04
Steelhead (Parr & Smolt)	33	2,695	1.22 ± 0.42
Cutthroat (Parr & Smolt)	0	439	0
Combined (Parr & Smolt)	*631*	*40,584*	*1.55 ± 0.12*

Species and Life Stage	No. Injured [A]	No. Sampled [B]	Injury Rate (%)
Steelhead Adults	1	50	0
Steelhead Kelts	0	35	0
Bull Trout	0	6	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.

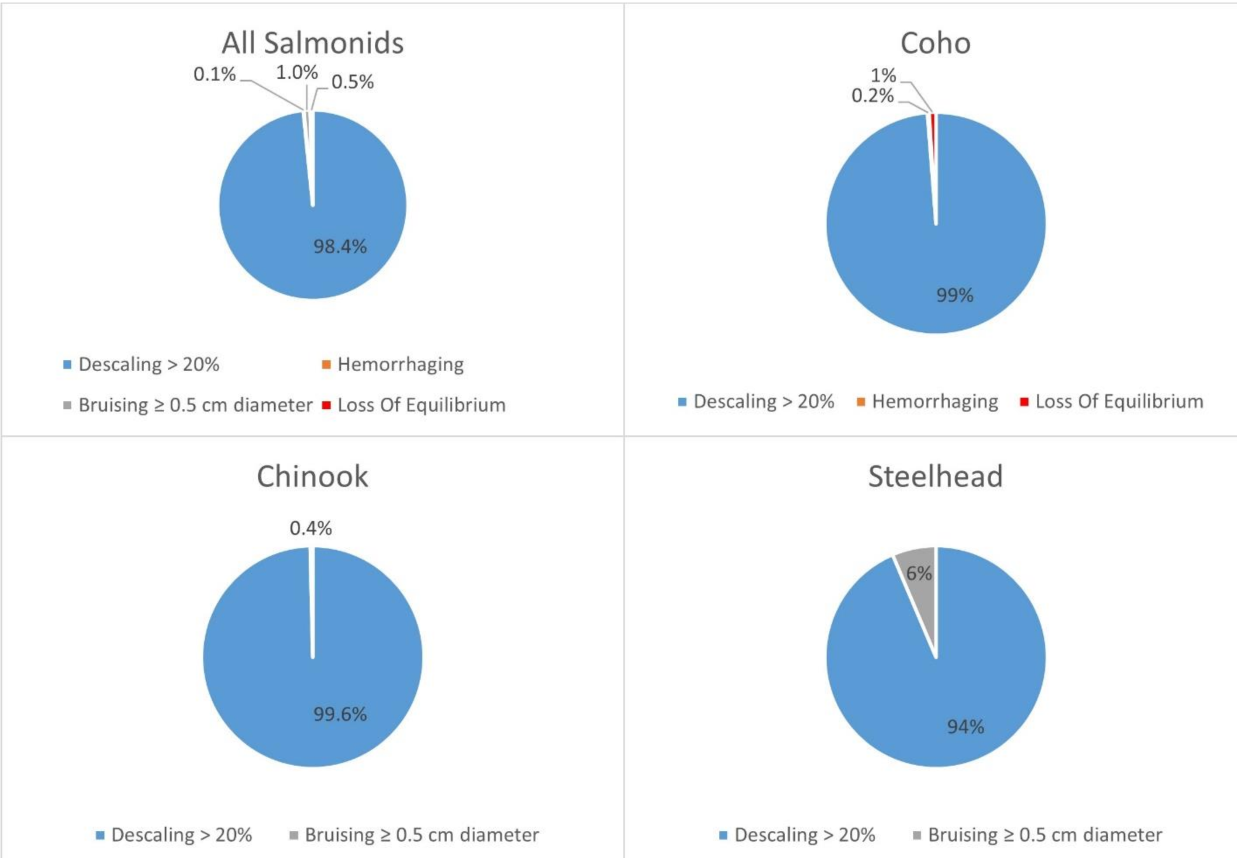


Figure 3.5-1. Composition of injury type occurrences by species in 2021. Percentages reflect the proportion of injury type observed of the total number of fish injured, not the total number of fish evaluated. Percentages reflect parr and smolts numbers sampled that are referenced in Table 3.5-3.[17]

[17] Note: Zero Cutthroat sampled were injured in 2021.

Figure 3.5-2. Woody debris accumulated behind the upper debris boom located near the head of Swift Reservoir.

Survival Rate

Combined survival rates (*CS*) among all larger outmigrants (parr and smolt) ranged from 88.9 to 98.0 percent (Table 3.5-4), demonstrating a general increase in survival rates in 2021, relative to 2020. Nearly all mortality observed onboard the FSC and during the transport process was associated with debris accumulation on the fish sorting bars and in sample tanks (Figure 3.5-3; Table 3.5-5). As mentioned above with regard to fish injury, PacifiCorp has continued to make operational and structural changes to the FSC in order to decrease debris-related mortality. Modifications to the adult tank were completed in the winter of 2021, and are intended to improve debris management and removal. Summaries of data used to calculate S_{COL} and S_{TRAN} are provided in Tables 3.5-5 through 3.5-7.

Survival rates (S_{COL}) of salmonid fry were generally higher than those of larger outmigrants (Table 3.5-6). Only five mortalities were observed among the 1,443 salmonid fry that were sampled, all of which were Coho. The debris management improvements to the fry holding tank, which were completed in 2018, have been largely responsible for the higher fry survival rates observed over the last three years.

Table 3.5-4. Combined annual survival rates for juvenile salmonids (parr and smolt) collected and transported from the Swift FSC (CS).

Species	Combined S_{COL} Survival% (from Table 3.5-5)	S_{TRAN} Survival% (from Table 3.5-6)	Combined Survival % (CS) with 95%CI
Coho	98.1	99.9	98.0 ± 0.12
Chinook	93.1	95.5	88.9 ± 0.95
Steelhead	96.8	99.4	96.2 ± 0.63
Cutthroat	97.9	100.0	97.9± 1.31
Overall	**97.6**	**99.4**	**97.0 ± 0.14**

Table 3.5-5. 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%	Combined Survival% with 95%CI
Coho Parr	347	16,952	98.0%	98.1 ± 0.14
Coho Smolts	298	17,960	98.3%	
Chinook Parr	0	350	100.0%	93.1 ± 0.99
Chinook Smolts	176	2,188	92.0%	
Steelhead Parr	1	142	99.3%	96.8 ± 0.66
Steelhead Smolts	84	2,553	96.7%	
Cutthroat(< 13 inches)	9	419	97.9%	97.9 ± 1.32
Cutthroat (> 13 inches)	0	20	100.0%	
Total	915	40,584	**Overall**	**97.9 ± 1.32**
Steelhead Adults	2	50	96.0%	96.5 ± 3.92
Steelhead Kelts	1	35	97.1%	
Bull Trout	0	6	100.0%	100

Table 3.5-6. Annual transport survival rates (S_{TRAN}) for salmonid parr and smolt.

Species	Tagged and Transported	No. Dead	Survival% (S_{TRAN}) with 95%CI
Coho (Parr/Smolt)	3,428	4	99.9 ± 0.11
Chinook (Parr/Smolt)	343	21	95.5 ± 2.53
Steelhead (Parr/Smolt)	467	2	99.4 ± 0.59
Cutthroat (Parr/Smolt)	88	0	100.0
Overall	**4,326**	**27**	**99.4 ± 0.23**

Table 3.5-7. Annual survival rates (S_{COL}) for salmonid fry.

Species	No. of Mortalities [A]	No. Sampled	Survival% (CS)
Coho Fry	5	1,389	99.6 ± 0.35
Chinook Fry	0	21	100.0
Steelhead Fry	0	30	100.0
Cutthroat Fry	0	3	100.0
		Overall:	**99.6 ± 0.30**

[A] Fry were transported downstream in 2021; 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 2021.

Figure 3.5-3. Example of woody debris accumulated within the fish passage channel (A), and on the sorting bars (B) within the Swift FSC.

3.6 Swift Powerhouse Entrainment Evaluation

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

3.7 Overall Downstream Survival

3.7.1 Overview/Methods

The Settlement Agreement requires that the Utilities achieve an overall downstream survival (ODS) rate of greater than (or equal) to 80 percent[18]. 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.*

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). Estimates of ODS were developed 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 are entered into the Pacific Northwest Region PIT tag database (PTAGIS[19]).

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 as outlined in the current M&E Plan are as follows:

- Test fish were obtained from the screw trap operated at the head of Swift Reservoir (i.e., located at Eagle Cliff), or at the FSC. Fish collected at the FSC were only used if enough fish could not be collected at the screw trap. Using fish collected from two different locations is not preferred as this may introduce bias associated with previous expose to the reservoir environment, difference in size/age class, and life-stage.

- Fish captured at the traps were identified to species, measured for length and tagged with PIT tags. Only fish greater than, or equal to, 60 mm in length were tagged in 2021.

- Fish were released at the head of Swift Reservoir weekly throughout the spring out-migration period (late-March through July). To reach the desired statistical power (assuming a precision of

[18] 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 Settlement Agreement acknowledge that ODS rates of 80 percent or 75 percent are aggressive standards and will take some time to achieve.

[19] The Columbia Basin PIT Tag Information System (PTAGIS) is the centralized database for PIT-tagged fish in the Columbia River Basin. PTAGIS provides custom software for contributors to collect tagging and interrogation data, manages the database, and coordinates with fishery agencies and organizations. In addition, PTAGIS collects automated detection data and designs, installs, and maintains the equipment that records those detections. All data contributed to and collected by PTAGIS are freely available online (www.ptagis.org).

0.025 with 80 percent recapture rate and 95 percent detection efficiency), a total of 996 fish of each species is the sample size goal needed for each species for each 6-week spring test period. PIT tag releases were to continue into the summer and fall as long as a persistent juvenile migration exists.

- Sample size goals 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. Test fish captured and tagged at the FSC were held for 24 hours prior to release to quantify any potential handling mortality. Fish PIT tagged at the screw were released immediately after tagging.

- PIT-tag detectors located on the FSC and at the exit of the Woodland Release Ponds were used to confirm passage downstream and to generate the tag detection histories to estimate ODS.

- Throughout the out-migration period, the FSC, transport trucks, and release ponds were inspected daily for fish mortality occurring during the handling and transport processes. All dead fish were identified to species, measure for length, and inspected for source of injury and PIT tags. All dead fish found in the FSC and release ponds were assigned to collection loss (S_{COL}) and transport loss (S_{TRAN}), respectively. All PIT tag detections were recorded and reviewed for tagging date and location.

The seasonal ODS estimate were 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 (determined by PIT tags) were retrospectively added to the ODS estimate for their release year. The ODS calculation is shown in Equation 3.7-1.

$$\boldsymbol{ODS = S_1 * S_{COL} * S_{TRAN}} \qquad \textbf{Equation 3.7-1}$$

Where:

S_1 = Survival probability through reservoir and to capture at the FSC; 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

Estimates of ODS were derived in 2021 using 1,627 Coho, 58 Chinook, 813 Steelhead, and 93 Cutthroat (Table 3.7-1). Only PIT tag interrogations at the FSC and Woodland Release Ponds recorded on or before December 31, 2021 were included in the analysis. Due to low numbers of fish captured at the Eagle Cliff screw trap that could be PIT tagged (see Section 3.1, Task 7.1 above for details), additional releases of smolts collected/tagged at the FSC and released at the head of Swift Reservoir were used. Of the total number of fish used to derive ODS in 2021, 35.2 percent (n=573) of the Coho, 79.3 percent (n=46) of the Chinook, and 38.5 percent (n=313) of the Steelhead released were fish captured by the FSC, tagged, and transported upstream to the head of Swift Reservoir. All Cutthroat Trout were tagged and release from the screw trap. It is important to note that because of inadequate numbers of fish to tag, no species received the required 996 tags (during a six-week period) from the screw trap alone. Once additional fish from the FSC were supplemented to the study, only Coho met the required 996 tags released within a six-week period; 1,060 PIT tagged Coho were released near the head of Swift Reservoir between May 1, 2021 and June 1, 2021

Using PIT tag detections at the FSC and Woodland Release Ponds across the year, a total of 468 Coho, 15 Chinook, 147 Steelhead, and 5 Cutthroat were recaptured. This resulted in an annual S_{RES} estimate of 28.8 percent for Coho, 25.9 percent for Chinook, 18.1 percent for Steelhead, and 5.4 percent for Cutthroat.

Pooling data annually for 2021, S_{COL} was 98.1 percent for Coho, 93.1 percent for Chinook, 96.8 percent for Steelhead, and 97.9 percent for Cutthroat (Table 3.7-1). Estimates for S_{TRAN} during the same time period were 99.9 for Coho, 91.6 percent for Chinook, and 99.4 percent for Steelhead. S_{TRAN} for Cutthroat was 100 percent.

Overall, estimates of ODS were less than 30 percent for all species in 2021 (Table 3.7-1). While these estimates are low, they are generally consistent with estimates of ODS from previous years. The highest ODS recorded for Coho since the FSC was brought online in 2013 was 50.8 percent in 2019 (see Table 3.7-2 below), and 45.0 percent for Steelhead in 2018. ODS estimates for juvenile Chinook have remained around 20-30 percent since 2019 once the upper basin acclimation program had been discontinued and when only NOR fish were in the system (see Section 1.0-1 above). It is anticipated that estimates derived in 2021 will increase once tagged fish holding-over in the reservoir are collected in 2022. The ODS estimate for Cutthroat should also 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), 2021.

Species	Tagged and Released in 2021	FSC Recaptured in 2021	S_1 (%)	S_{COL} (%)[A]	S_{TRAN} (%)[B]	2021 ODS (%) with ±95% CI
Coho	1,627	468	28.8	98.1	99.9	28.2 ± 2.2
Chinook	58	15	25.9	93.1	91.6	22.1 ± 11.3
Steelhead	813	147	18.1	96.8	99.4	17.4 ± 2.6
Cutthroat	93	5	5.4	97.9	100.0	5.3 ± 4.6

[A] S_{COL} derived as part of combined survival (CS) outlined in Section 3.5 above and provided in Table 3.5-5.
[B] S_{TRAN} derived as part of combined survival (CS) outlined in Section 3.5 above and provided in Table 3.5-6.

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 2019 ODS estimates are summarized below in Table 3.7-2. An additional 59 tagged Coho, 19 Steelhead, 14 Chinook, and 2 Cutthroat from the 2019 ODS study were captured by the FSC during 2020. No additional tags from the 2018 ODS study were captured in 2019.

Table 3.7-2. 2020 adjusted annual ODS estimate for each species is shown (performance standard for all species is ≥ 80 percent).

Species	Tagged and Released in 2020	FSC Recaptured 2020	2020 ODS (%) with ±95%CI	FSC Recaptured 2021	Total Recaptured (Combined Years)	2020 Combined ODS (%) with ±95%CI
Coho	1,452	300	19.6 ± 2.1	145	445	29.1 ± 2.4
Chinook	194	36	16.6 ± 5.5	16	52	24.1 ± 6.2
Steelhead	343	38	10.3 ± 3.3	19	57	15.5 ± 3.9
Cutthroat	59	4	6.7 ± 6.4	2	6	10.0 ± 7.7

4.0 UPSTREAM COLLECTION AND PASSAGE METRICS

4.1 Summary

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

All adult salmonids collected were identified to species, sex, and sorted by origin (i.e., hatchery or wild), broodstock (i.e., hatchery or supplementation), and sorted based on program and broodstock needs.

A total 29,560 fish were captured at the Merwin Trap in 2021 (Table 4.1-1). Among the species collected, early Coho accounted for the largest proportion of fish captured (n=18,054), followed by late Coho (n= 5,439), spring Chinook (n=2,359), winter Steelhead (n=1,631), summer Steelhead (n=1,056), fall Chinook (n=843), Cutthroat (n=173), chum salmon (n=2), pink salmon (n=2), and sockeye salmon (n=1).

Of the 1,056 summer Steelhead collected at Merwin trap in 2021, 834 were naïve (had not previously encountered the Merwin Trap), while 222 were recaptured as part of WDFW's Recreational Angler Recycle Program. A total of 822 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 to re-ascend the river back to Merwin Dam and provide angling opportunities to recreational anglers. Once those fish previously recycled are recaptured at Merwin Dam, they are sent to Merwin Dam Fish Hatchery to be given to food banks or used as nutrient enhancement.

Spring Chinook that were part of the integrated acclimation releases in 2018 returned as four-year-old adults in 2021. Of the 2,359 spring Chinook collected in 2021, 74 (3.1 percent) were from the integrated release group. These fish are distinguished via the left ventral fin clip while having an intact adipose fin. It is anticipated that additional fish from the 2018 release group will return to the Merwin Trap as five-year-old adults in 2022.

A total of 248 PIT tagged adult salmonids returned to the Merwin Trap in 2021 (197 Coho, 19 Steelhead, 11 Chinook, 6 Cutthroat, 1 northern pikeminnow, and 14 tags with no origin, or "orphan tags"), the second highest number recorded since the facility was completed. All PIT tag interrogation records collected at Merwin Trap wee uploaded to the PTAGIS database.

A total of 6,174 early Coho, 3,239 late Coho, 1,182 spring chinook, 322 wild winter Steelhead (blank wire tag and NOR combined), and 168 Cutthroat were transported upstream and released above Swift

Dam as part of the reintroduction program in 2021 (Table 4.1-2). Lewis River Hatchery provided 547 early Coho, 277 spring Chinook, and 83 late Coho for upstream transport. The remaining fish were collected at the Merwin Trap. Of the wild winter Steelhead transported upstream, 210 were blank wire tag fish while 112 were of natural origin. NOR late Coho were transported upstream only after meeting brood integration 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 2021. 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]	763	688	257	157	147	60	153	115	19									**2,359**	8.0
Fall Chinook	223	179	21	29	14	3	128	184	62									**843**	2.9
Early Coho	5,159	4,769	3,512	1,190	1,109	752	723	575	265									**18,054**	61.1
Late Coho	1,169	1,717	479	407	520	99	496	464	88									**5,439**	18.4
Summer Steelhead	269	553					2	10							46	176		**1,056**	3.6
Winter Steelhead	746	499					73	102					87	124				**1,631**	5.5
Sockeye Salmon								1										**1**	0.0
Chum Salmon							1	1										**2**	0.0
Pink Salmon							1	1										**2**	0.0
Cutthroat (>13 inches)																	173	**173**	0.6
Cutthroat (< 13 inches)																		**0**	0.0
Rainbow (< 20 inches)																		**0**	0.0
Bull Trout (> 13 inches)																		**0**	0.0
Bull Trout (< 13 inches)																		**0**	
															Total			**29,560**	100

[a] Counts of male and female spring Chinook may vary slightly from those reported by WDFW broodstock counts.
CWT = Coded Wire Tag; BWT = Blank Wire Tag.

Table 4.1-2. Total salmonids transported alive above Swift Dam in 2021 (totals include Merwin Trap and Lewis River Hatchery Trap captures).

Species	Male	Female	Jack[20]	Not sexed	Female:Male Ratio	Jack:Adult Ratio	Total
Spring Chinook	663	230	289	-	0.24	0.32	***1,182***
Early Coho	2,722	3,183	269	-	1.06	0.05	***6,174***
Late Coho	1,341	1,810	88	-	1.27	0.03	***3,239***
Winter Steelhead	127	195	-	-	1.53	-	***322***
Cutthroat >13"	-	-	-	168	-	-	***168***
Bull Trout >13"	-	-	-	-	-	-	***0***
						Total	***11,085***

[20] Jacks are precocial male salmon that have spent one winter less in the ocean than the youngest females of a given species. Jacks are determined based on length: < 18 inches for Coho and < 22 inches for Chinook are categorized a jack salmon. However, it is possible that some fish categorized as jacks (male by definition) could actually be adult female salmon. Time of year and fish size can make it very difficult to determine sex.

Table 4.1-3 Annual totals of salmonids transported upstream of Swift Dam for years 2013 through 2021.

Year	Coho			Chinook			Steelhead		Cutthroat	Total Transported Upstream
	Male	Female	Jack	Male	Female	Jack	Male	Female	>13 in	
2013	3,858	3,104	73	270	243	66	440	301	0	8,355
2014	4788	4217	174	0	0	0	452	581	42	10,254
2015	2,030	1,694	30	0	0	0	746	477	31	5,008
2016	3,430	3,377	539	0	0	0	382	390	73	8,191
2017	3,254	3,494	65	370	430	310	331	261	54	7,459
2018	3,930	2,659	402	491	177	32	685	540	77	8,293
2019	2,946	2,373	268	12	12	85	527	482	45	6,750
2020	4,319	4,911	256	193	56	385	517	535	86	11,258
2021	4,063	4,993	357	663	230	289	127	195	168	11,085

4.2 Adult Passage Survival

4.2.1 Overview/Methods

Section 9.2.1(h) of the Settlement Agreement requires upstream passage survival (UPS) of adult salmonids and Bull Trout to be equal to or greater than 99.5 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:

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

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 11,084 adult salmonids (6,174 early Coho, 3,239 late Coho, 1,184 Spring Chinook, 321 winter Steelhead, and 168 Cutthroat) were transported upstream in 2021. Late Coho, winter Steelhead, and spring Chinook demonstrated the highest overall survival rate (99.7 percent), followed by early Coho (99.6 percent), and Cutthroat Trout (98.2 percent). Most (83.7 percent) of the mortalities encountered in 2021 were fish of hatchery origin (25 early Coho, nine late Coho, and two spring Chinook). Similar to all previous years of operation, the majority (93.0 percent) of mortalities observed in 2021 occurred during the trapping process (23 early Coho, 10 late Coho, three spring Chinook, three Cutthroat Trout, and one winter Steelhead). The remaining 7.0% occurred during transport (three early Coho). A total of 43 mortalities were observed across all species, resulting in a UPS of 99.6 percent (Table 4.2-1).

Table 4.2-1. Overall upstream passage survival for Merwin Trap in 2021.

Species	Number Transported	Trap Mortalities	Transport Mortalities	Upstream Passage Survival (%)
Early Coho	6,174	23	3	99.6
Late Coho	3,239	10	0	99.7
Spring Chinook	1,184	3	0	99.7
Winter Steelhead	321	1	0	99.7
Cutthroat	168	3	0	98.2
Total	**11,084**	**40**	**3**	**99.6**

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 weir to prevent fish from returning to the tailrace once they have entered the trap. The V-style weir 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 weir 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 and subsequently in 2019.

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. Further study was completed in 2019, which built 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$_{PF}$) – approximately 15 river miles downstream of Merwin Dam. This additional group was introduced to asses if release location may affect 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 due to low numbers of returning Coho and spring Chinook in 2019.

No evaluation for adult trap efficiency was completed in 2020 or 2021.

4.3.2 Results/Discussion

In review of the past five years (2013 – 2019) of evaluation, the ACC determined that reliable operation of the facility's fish lift and conveyance system was the largest contributor to the success of fish being captured at Merwin Dam. At the December 12, 2019 ACC meeting, members agreed to postpone the ATE Evaluations in 2020 and requested PacifiCorp to develop a memorandum outlining the proposed steps for moving forward with the Merwin Trap for the ACC to review. In early 2020, PacifiCorp began reviewing possible alternative designs to the current lift and conveyance system, particularly aimed toward modifying the system's crowder that automatically crowds adults from the head of the fish ladder into the lifting hopper. As of December 2020, PacifiCorp had begun the formal process of redesigning the facility's crowding mechanism. While it was originally anticipated that a final design would be reach reached by late-2021 with construction occurring sometime in 2022, delays in the process occurred to the COVID-19 pandemic. It is currently anticipated that construction will now occur sometime during the summer of 2023. Once the redesigned crowder is in place, it is intended that the ATE studies will resume for the target transport species.

4.4 Spawn Timing, Distribution, and Abundance of Transported Fishes

4.4.1 Overview/Methods

Section 9.2.2 of the Settlement Agreement identified the need to determine the spawn timing, distribution, and abundance for transported anadromous species that are passed upstream of Merwin Dam, 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 2014) 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 and spring Chinook salmon, comprehensive spawning ground surveys were conducted in the potentially accessible river and stream reaches upstream of Swift Dam in 2021. 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, and ground surveys of reservoir tributaries were to 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

Salmon spawning surveys were conducted from September 2, 2021 through December 21, 2021. Per Objective 15 of the current M&E Plan (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. Concurrently with conducting spawning surveys in 2021, the Lewis River Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2017) was undergoing a 5-year review and revision in consultation with the Lewis River Aquatics Coordination Committee – Aquatic Technical Subgroup (ATS). The decision was made that Coho and Chinook spawning surveys should focus on distribution rather than spawner abundance. Therefore, spawning surveys were conducted across as many reaches as possible each month (census survey) in 2021 rather than a subsample of reaches as was conducted in previous years. However, data was still collected in the same discrete uniquely identified reaches as used for past surveys. The report summarizing these data is provided in Appendix D.

Nearly all accessible habitat was surveyed at least once during the spring Chinook spawning period from September to early-October. Most small streams were dry or too low for fish to access in September and October until heavy precipitation began in late-October. This caused most stream reaches to be unsurveyable by November due to flood conditions and high turbidity, which also greatly hindered Coho spawning surveys. Coho surveys were further hindered in December by continuing high flows, snow, and locked gates also precluded surveys in most stream reaches.

A total of 240 spring Chinook redds were counted in 2021; more than in all other years combined. However, prior years used a subsampling approach, whereas surveys in 2021 used a census approach. Most Chinook redds were counted in the mainstem of the North Fork Lewis River (78 percent), followed by Clearwater Creek (14 percent), Little Creek (4 percent), Clear Creek (2 percent), and the Muddy River mainstem (2 percent). The distribution pattern of Chinook redds counted in 2021 is consistent with the prior observations from all other years combined. However, a larger proportion of Chinook redds were counted in Clearwater Creek (a tributary to the Muddy River) than in prior years and a smaller proportion were counted in the Muddy River mainstem. Based on observations of spring Chinook spawners, occupied redds, and carcasses, the spawn timing of Chinook was likely late-August to early-October during the 2021 survey season, which is consist with prior years' observations. Assuming approximately one redd per female, the spring Chinook redd count suggests that likely all female Chinook successfully spawned as 230 female spring Chinook were transported upstream in 2021.

A total of 419 Coho redds were counted in 2021, which is the second highest count since surveys began in 2012. Most Coho redds were counted in the NF Lewis River mainstem (29 percent), followed by Clear Creek (14 percent). The Muddy River mainstem, Drift Creek, S20 Creek, and Swift Creek also contained a significant portion of the total Coho redds counted. In aggregate, the NF Lewis River mainstem and small tributaries also had the highest Coho redd count in 2021 (39 percent), followed by the aggregate of Swift Reservoir small tributaries (29 percent). The distribution pattern of Coho redds counted in 2021 is approximately consistent with the prior observations from all prior years combined since surveys started in 2012. Based on the observations of Coho spawners, carcasses, and redds, in 2021 early-Coho began spawning in early-October and likely continued somewhat into early-November, which is similar to that observed in prior years. Late-Coho continued spawning until the end of the survey season and likely continued spawning in to January. The peak of early-Coho spawning was observed the week of October 18 in 2021 and the week of October 19 in 2020. Due to the lack of surveyable conditions over the majority of the Coho spawning season, the total number of Coho redds and the proportion of transported Coho that spawned could not be reliably estimated.

Winter Steelhead

Aerial surveys scheduled to detect the distribution of spawning radio tagged winter Steelhead in the upper basin above Swift Dam were again canceled in 2021 due to COVID-19 restrictions. Because of this cancellation, winter Steelhead were not radio tagged in 2021. However, winter Steelhead spawning “ground” surveys were conducted on immediate tributaries to Swift Reservoir on seven different surveys from April 15, 2021 through June 15, 2021.

The intent of the ground surveys along reservoir tributaries was to provide some reference to spawning activity lower in the system and in areas that could be accessible by foot. The ground surveys were to be performed weekly from early-April until spawning activity was no longer observed, which generally occurs by early-June. A survey consists of visiting each Swift Reservoir tributary and surveying the lower approximately half mile. The Swift Reservoir tributaries surveyed are Swift, Diamond, Range, S10, Drift, S15 and S20 Creeks While every attempt to survey each tributary weekly is made, some restriction may occur due to high flows during spring runoff.

A total of 19 winter Steelhead redds were observed throughout the surveyed reservoir tributaries in 2021 (Table 4.4-1). Spawning occurred from mid-April through mid-June with peak spawning activity taking place during mid-May. Swift Creek and to a lesser extent S15 creek accounted for nearly all (95 percent) of the observed winter Steelhead redds in 2021. While the primary use of these watersheds is consistent with observations made in 2020, the use of Drift Creek was considerably lower in 2021 than the previous year. In 2020, 11 of the 33 redds observed that year we made in Drift Creek, whereas Swift and S15 creeks had 10 and 4 observed redds, respectively (PacifiCorp 2021). Only one redd was observed in Drift Creek in 2021.

Table 4.4-1. Summary of 2021 winter Steelhead redd counts of Swift Reservoir immediate tributaries.

Survey Date (2021)	Swift Creek	Diamond Creek	Range Creek	Drift Creek	S10	S15	S20	Total
4/15	2	0	0	0	0	0	0	**2**
4/29	0	0	0	0	0	1	0	**1**
5/14	8	0	0	0	0	2	0	**10**
5/26	3	0	0	1	0	0	0	**4**
6/4	1	0	0	0	0	0	0	**1**
6/15	1	0	0	0	0	0	0	**1**
Total	***15***	***0***	***0***	***1***	***0***	**3**	***0***	***19***

5.0 OCEAN RECRUIT ANALYSIS

5.1 Overview/Methods

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

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

For this analysis, the average number of ocean recruits over a five-year period will be evaluated (i.e., five consecutive brood years). These data will be evaluated to determine if and when hatchery production levels should be altered. A detailed description of the methodology for this analysis is outlined in Objective 12 of the current M&E Plan (2017). The current M&E Plan also calls for utilizing three different methods of estimation including: 1) return-year recruitment estimates; 2) brood year recruitment estimates; and, 3) fishery plus escapement. These three approaches are to 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.

During 2021, the Lewis River Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2017) began undergoing a 5-year review and revision in consultation with the Lewis River Aquatics Coordination Committee – Aquatic Technical Subgroup (ATS). During this review and revision process, it was identified Ocean Recruit analysis had not been previously conducted based on methods outline in the current M&E Plan for several reason including: 1) the use of double index tag (DIT) hatchery fish to estimate the mortality associated with mark-selective fisheries did not work as intended because creel surveys did not consistently scan ad-present fish for the presence of coded-wire tags; 2) there was a lack of creel data for the Lewis River Fisheries; and 3) to date, there was not a consistently high number of NOR adult fish returning from supplementation efforts upstream. Because of these reasons, adjustments were made to the established methodologies to simply run reconstruction and incorporate the use of integrated population models to supplement results. This review also established threshold numbers of returning NOR adults to Merwin Dam required to trigger completion of Ocean Recruit Analysis.

5.2 Results/Discussion

No Ocean Recruit analysis was conducted in 2021. Based on the revised Lewis River M&E Plan (2022), estimates of ocean recruits will be developed for each brood year and species throughout the term of the licenses when NOR returns to Merwin meet the triggers outlined in Table 5.2-1. The triggers are calculated using baseline total exploitation rates for each of the three species based on the harvest rate assumptions from recent analyses (Mitchell Act Final EIS and NPCC Master Plans) and assuming the only impacts of terminal harvest on NORs would be due to incidental catch and release mortality. Recent returns of natural origin spring Chinook have been far too low to meet the newly established triggers as part of the ongoing 5-year review (1,905 adults). Natural origin returns of coho were as high as 5,395 in 2020, but have not generally come close to meeting the anticipated trigger of 8,372 adults. Similarly, natural origin returns of late winter steelhead have been as high as 456 in 2020, but have not met the established threshold of 2,210 adults.

Table 5.2-1. Natural return thresholds to Merwin Dam required to trigger completion of Ocean Recruits Analysis.

Threshold	Spring Chinook	Late Winter Steelhead	Coho (Type S and Type N)
1. Natural Production Threshold (Ocean Recruits)	2,977	3,070	13,953
2. Baseline Total Exploitation Rate – NORs (est. range)*	15-20%	5-10%	20-25%
3. Natural origin returns to Merwin Dam required to meet Natural Production Threshold	2,381-2,530	2,763-2,917	10,465-11,162
4. Natural origin returns to Merwin Dam required to trigger Ocean Recruits Analysis (80% of low threshold in 3.)	1,905	2,210	8,372

Note: Conservative (high range) estimates based on harvest rate data used in recent analyses (Mitchell Act Final EIS and NPCC Master Plans).

6.0 PERFORMANCE MEASURES FOR INDEX STOCKS

6.1 Overview/Methods

The H&S Plan (PacifiCorp and Cowlitz PUD 2014) recommends that Lewis River hatchery production and 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. Methods to address this recommendation are outlined in Objective 13 of the current M&E Plan (2017).

In past years (pre-2019) adult returns of NOR fish from the upper Lewis River had not occurred in numbers large enough for meaningful analysis of metrics related to performance. The first attempt to derive performance metrics was in 2020, when there were sufficient numbers of NOR winter Steelhead and Coho salmon returning to the upper basin above Swift Dam. This initial analysis indicated that the performance metrics derived for these stocks as described by recruits per spawner (R/S), smolts per spawner (Smolt/S), and smolt-to-adult ratio (SAR) were higher than estimates for complementary Lewis River HOR populations of the same species returning in 2020. While this initial analysis also indicated that for both populations replacement (i.e., R/S ≥1) was not achieved, it did indicate that survival of NOR juveniles captured at the Swift FSC and transported downstream appeared to be higher than for HOR releases below Merwin Dam. No attempt was made in 2020 to derive performance metrics for adult spring Chinook, as there were too few NOR adults to make meaningful inference that year.

Similar to 2020, there were sufficient numbers of NOR Coho and winter Steelhead returning from the upper basin above Swift Dam to make some inference on performance metrics. Also similar to 2020, there was a marginal number (n=268) of returning natural origin spring Chinook from the upper basin to perform meaningful run reconstruction and derive performance metrics on adult Chinook in 2021. In addition, this was confounded by the life history of spring Chinook (adults may return 3-5 years after outmigration), combined with the limited data on cohort classification for both out-migrating juveniles and returning adults to accurately assign fish counts to a given brood or return year. As a result, this analysis was again omitted for spring Chinook in 2021.

Productivity was calculated for returning adult Coho and winter Steelhead as R/S, or the number of adult offspring produced per parent. For Coho, the number of adults transported above Swift Reservoir in 2018 were used to represent the number of spawners (S), and those NOR adults returning to the Merwin Trap in 2021 were the recruits (R). Jacks were not included in this analysis. For winter Steelhead, the number of adults transported in 2017 were used as spawners (S) for the adults returning to Merwin Trap in 2021.

In addition to R/S, performance was also estimated for returning Coho and winter Steelhead in 2021 by deriving brood year freshwater productivity from the Smolt/S and SAR metrics. The total number of juvenile out-migrants from each species transported downstream of Swift Dam provided the abundance estimates for "smolts" produced by each spawning cohort (S). For this analysis, all parr and fry were excluded. For Coho, smolts out-migrating in 2020 were used, and for winter Steelhead all smolts out-migrating in 2018 were used. While it is recognized that these are overly simplified direct comparisons for spawners and subsequent out-migrants, they are generally supported by PIT tag detections and comparing date of tagging and origin for returning adults in 2021. A majority of returning adult Coho that had PIT tags from the upper basin in 2021 (191/216 – 88 percent) were tagged in 2020. To address this 10 percent of returning adult Coho in 2021 were assumed to be from smolts out-migrating in a year other than 2020. Very few juvenile winter Steelhead were tagged at the FSC in 2020 (n=56) and sent immediately downstream; because of this we are assuming all returning adult Steelhead in 2021 were from 2018 out-migrating smolts. Data from 2020 suggests this assumption is reasonable as 94 percent of returning PIT-tagged wild winter Steelhead in 2020 were from 2018 out-migrating smolts. It should also be noted that this simplified comparison does not take into account any loss associated with recreational or commercial fisheries both in freshwater and in the ocean, and also assumes that all natural origin adults returning to Merwin Trap or Lewis River Hatchery are offspring from adults transported above Swift Dam. SARs for hatchery reared (HOR) Coho and Blank Wire Tag winter Steelhead returning in 2021 as adults were also used for comparison. These data were provided by WDFW. No out-of-basin comparisons were made at this time.

6.2 Results/Discussion

Based on metrics related to performance for NOR Coho and winter Steelhead adults returning in 2021, it appears that for both populations, replacement still has not been achieved. However, SARs for NORs were considerably higher than SARs for Lewis River HOR populations returning in 2021 (Tables 6.2-1 and 6.2-2).

The R/S values for NOR Coho and winter Steelhead were 0.24 and 0.30, respectively. Both R/S values being less than one signifies that recruitment in 2021 was not at a level of replacement. That is, additional returning adults will be needed to sustain the population. Only R/S values greater than or equal to one lead to a self-sustaining population.

SAR values for both NOR Coho (6.2 percent) and winter Steelhead (5.9 percent) were high. While these numbers may be inflated by the assumption that all NOR Coho and wild winter Steelhead returning to Merwin Trap or Lewis River Hatchery are offspring of adults transported above Swift Dam, they are considerably higher than SARs observed for hatchery Coho (2.2 percent) and blank wire tag (BWT) winter Steelhead (0.5 percent) returning over the same time period. It is worth noting that the BWT winter Steelhead are offspring of NOR adults that are captured from the lower river and used as broodstock for the reintroduction program.

The number of smolts produced per spawner (Smolt/S) was 4.0 for Coho (2020 out-migrants from 2018 parents) and 5.0 for NOR winter Steelhead (2019 out-migrants from 2017 parents). [It is important to note here that smolts in this smolt per spawner ratio are smolts that were captured at the FSC and transported downstream alive. This is not 'produced' number of smolts that would typically be calculated in a passable riverine system.] For a R/S value of greater than or equal to one, the Smolt/S ratio needs to be 16.1 for NOR Coho and 20.0 for NOR winter Steelhead (Table 6.2-1). The collection efficiency of the FSC is likely the main bottleneck holding R/S values below one. For instance, the FSC collection efficiency was 39 percent for Coho (2020) and 27 percent for wild winter Steelhead (2019). To achieve a smolt per spawner for replacement (R/S ≥ 1), collection efficiency needs to be at least 100 percent for 2020 wild Coho smolts and 92 percent for 2019 wild winter Steelhead smolts. These very high collection efficiency rates signify that, although FSC collection efficiencies are surely a bottleneck, there appear to be other factors heavily influencing smolt production (e.g., flood scouring, sex ratio, weather patterns etc.).

Table 6.2-1. Performance metrics for 2021 returning natural origin adult Coho and late-winter Steelhead.

Species (NOR)	Adults Transported Above Swift Dam [A]	Smolts Transported Downstream [B]	NOR Adults Returning to Lewis River 2020 [C]	Smolt to Adult Return (SAR%)	Recruit per Spawner (R/S)	Smolt per Spawner [D]	Smolt per Spawner for Replacement [E]
Coho	6,658	26,353	1,627	6.2%	0.24	4.0	16.1
Late-Winter Steelhead	592	2,950	175	5.9%	0.30	5.0	20

[A] For Coho, the number of adults transported in 2018 were used to represent the number of spawners (S), and for winter Steelhead, the number of adults transported in 2017 were used as spawners (S).
[B] For Coho, smolts out-migrating in 2020 were used, and for winter Steelhead all smolts out-migrating in 2019 were used.
[C] This is all NOR adults (less 10% to account for cross brood-year cohort) returning to both Merwin Trap and Lewis River Hatchery. This includes any mortalities, fish returned downstream, and fish used for brood.
[D] The smolts in this smolt per spawner ratio are smolts that were captured at the FSC and transported downstream alive. This is not 'produced' number of smolts that would typically be calculated in a passable riverine system.
[E] This is the number of smolts that need to be caught by the FSC and transported downstream alive to have a recruit per spawner ratio of 1 (replacement) for the 2021 return year.

Table 6.2-2. Smolt to adult performance metrics for 2021 returning adult hatchery Coho and late-winter Steelhead.

Species (HOR)	Smolts Downstream	Adults Returning to Lewis River 2020	Smolt to Adult Return (SAR%)
Coho	1,916,165	42,405	2.2%
Late-Winter Steelhead (BTW)	44,861	211	0.5%

7.0 REINTRODUCED AND RESIDENT FISH INTERACTIONS

7.1 Overview/Methods

During the five-year Monitoring and Evaluation Plan re-write process, it was identified that at this time some aspects of the 2016 USGS/UW resident/anadromous interaction study should be replicated given the fully operational status of the anadromous reintroduction program. The Lewis River Bull Trout Recovery Team (LRBTRT) was tasked with developing a Study Plan to assess interactions in 2022 as this group was also interested in this endeavor, especially as it pertained to trophic interactions between bull trout and anadromous species at varying life-stages.

7.2 Results/Discussion

The LRBTRT identified the tasks below to be completed in 2022:

1) Provide proportional estimates of predation and consumption of juvenile anadromous salmonids by resident native species across different seasons using stable isotope analysis (SIA);

2) Provide proportional estimates of predation and consumption of juvenile bull trout and resident native species by anadromous salmonids across different seasons using SIA;

3) Provide estimates of potential competition among different resident species and anadromous salmonids for resources using SIA;

4) Provide estimates of predation and competition among species in Pine Creek using SIA;

5) Provide estimates of predation and competition among species in Rush Creek using SIA.

8.0 LITERATURE CITED

Anchor QEA. 2018. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Study (Final Report – February 2018). Prepared for PacifiCorp.

Caldwell, L., D. Stroud, F. Carpenter, L. Belcher, K. Ross, and K. Ceder. 2017. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Evaluation – 2016 Annual Report (Final). Prepared by Cramer Fish Sciences (Gresham, OR). Prepared for PacifiCorp.

Courter, I., T. Garrigon, and F. Carpenter. 2013. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Pilot Study. Prepared by: Cramer Fish Sciences (Gresham, Oregon). Prepared for: PacifiCorp.

Four Peaks Environmental. 2020. Swift Reservoir Floating Surface Collector Collection Efficiency Evaluation 2019: Annual Report. Prepared by: Four Peaks Environmental (Wenatchee, Washington). February 2020.

Four Peaks Environmental. 2021. Swift Reservoir Floating Surface Collector Collection Efficiency Evaluation 2020: Annual Report. Prepared by: Four Peaks Environmental (Wenatchee, Washington). January 2021.

PacifiCorp and Cowlitz PUD. 2014. Lewis River Hatchery Supplementation Plan. PacifiCorp Energy and Public Utility District No.1 of Cowlitz County. (FERC Project Nos. 935, 2071, 2111, 2213). December 26, 2014. Version 2.0

PacifiCorp and Cowlitz PUD. 2017. Aquatic Monitoring and Evaluation Plan for the Lewis River. Prepared by PacifiCorp and the Public Utility District No. 1 of Cowlitz County. April 3, 2017.

PacifiCorp and Cowlitz PUD. 2020. Lewis River Hatchery and Supplementation Plan - Final. (FER Project Nos. 935, 2071, 2111, 2213). Version 3. Prepared by PacifiCorp and the Public Utility District No.1 of Cowlitz County. December 2020.

PacifiCorp. 2009. Lewis River Upstream Transport Plan (Interim Final). Prepared by Frank Shrier, Principle Fish Biologist, PacifiCorp Energy. Issued: December 18, 2009.

PacifiCorp. 2015. Lewis River Fish Passage Program 2015 Annual Report. Prepared by PacifiCorp. Final Report issued April 15, 2016.

PacifiCorp. 2019. Lewis River Fish Passage Program 2018 Annual Report – Final. Prepared by PacifiCorp.

PacifiCorp. 2020. Lewis River Fish Passage Program 2019 Annual Report – Final. Prepared by PacifiCorp.

PacifiCorp. 2021. Lewis River Fish Passage Program 2020 Annual Report – Final. Prepared by PacifiCorp.

Reynolds, E., L. Belcher, and P. Stevens. 2015. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency: 2015 Annual Report Memo. *Prepared by*: Cramer Fish Sciences (Gresham, OR). *Prepared for*: Pacific Power (A Division of PacifiCorp).

Stevens, P., M. Morasch, L. Belcher, F. Carpenter, and E. Reynolds. 2016. Merwin Upstream Passage Adult Trap Efficiency – 2015 Report (Final). Prepared by Cramer Fish Sciences (Gresham, OR). Prepared for PacifiCorp. March 14, 2016.

Stroud, D., F. Carpenter, and P. Stevens. 2014. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency: 2014 Annual Report Memo – Final. Prepareed by: Cramer Fish Sciences (Gresham, Oregon). Prepared for: Pacific Power (A Division of PacifiCorp).

Thedinga J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837 851.

Volkhardt, G.C., S.L. Johnson, B. Miller, T.E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane traps. Pages 235-266 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A.

APPENDICES

APPENDIX A

RESULT FROM FISH SURVEYS OF THE NORTHWOODS AREA, SWIFT RESERVOIR IN 2020 AND 2021 – TECHNICAL MEMORANDUM

August 23, 2021

To: Aquatic Coordination Committee (ACC)

From: Erik Lesko, PacifiCorp

Subject: Results from fish surveys of the Northwoods area, Swift Reservoir in 2020 and 2021.

Introduction and Background

At our November 14, 2019 ACC meeting, Matt Harding, a Northwoods Community Member, provided pictures of fish collected in the Northwoods area in July 2019. Pictures showed several three-spine sticklebacks (*Gasterosteus aculeatus*) in isolated pools near the Northwoods boat docks on Swift Reservoir. Mr. Harding expressed concern that these pools become isolated as the reservoir is drafted during the summer months. Mr. Harding indicated that they observed one salmonid (unknown species) and one lamprey at the time the pictures were taken (no picture provided).

Due to the uncertainty in determining the species present in these isolated pools, the ACC agreed that biologists from PacifiCorp would coordinate with Mr. Harding to conduct surveys of the area in the summer of 2020 to identify fish species and overall species composition within isolated pools that form near the Northwoods Community (Figure 1). Results from these surveys were presented to the ACC in September 2020. After review of these results, the ACC agreed to continue surveys in 2021 to provide additional data on species composition and relative abundance and to obtain more information on the influence of reservoir elevation and isolated pool formation.

This memorandum summarizes fish survey data collected in 2020 and 2021. A total of four surveys were completed in the Northwoods area – two in 2020 and two in 2021 at various reservoir elevations (Figure 2, Table 1). For each of the surveys, photos are provided of isolated pools and fish species captures. A summary of the total captures is also provided in this summary, including a discussion of next steps as discussed at our August ACC meeting. All fish captures were released into the free flowing portion of the NFK Lewis River and no sampling or handling mortalities were observed on any of the surveys.

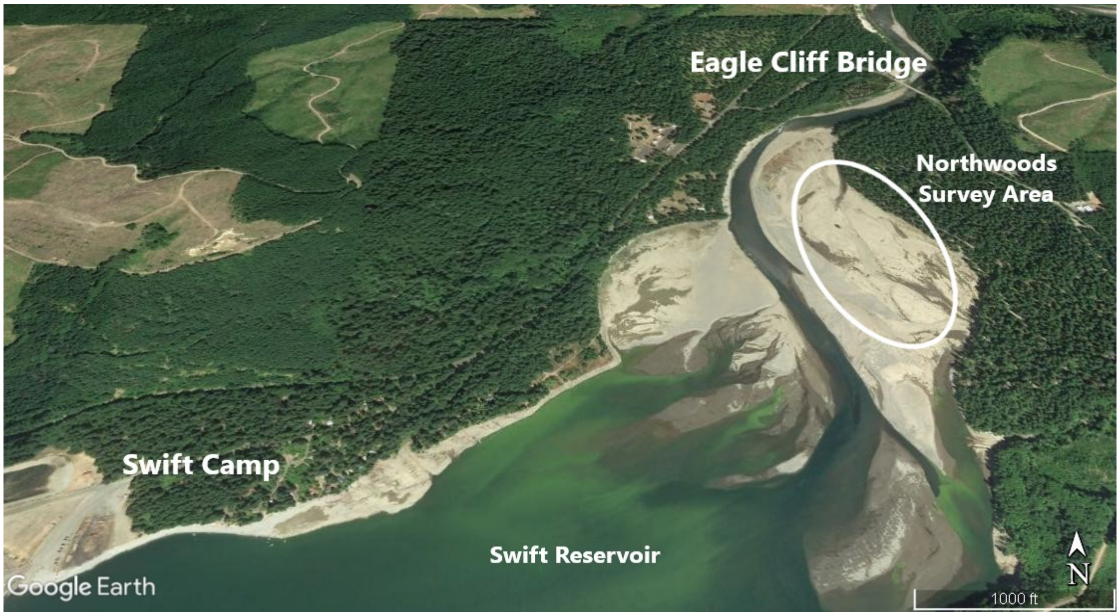


Figure 1. Location of survey area *(photograph taken on July 25, 2018 at reservoir elevation 981.22 feet, msl.)*

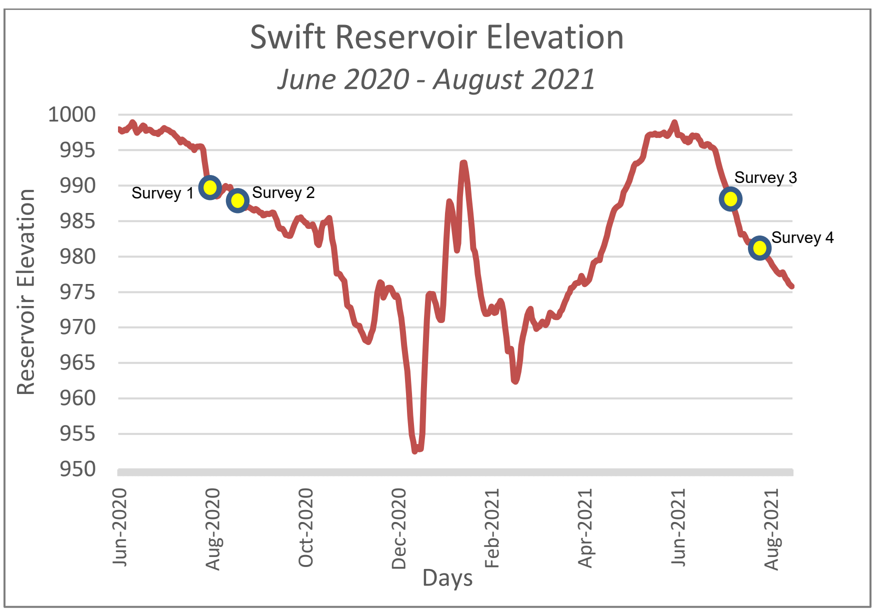


Figure 2. Swift Reservoir daily pool elevations: July 1, 2020 – August 23, 2021

Table 1. Survey dates and respective reservoir elevation between July 2020 and August 2021.

Survey Number	Survey Date	Reservoir Elevation (feet, msl)
1	July 31, 2020	989.3
2	August 21, 2020	987.0
3	July 12, 2021	988.5
4	August 5, 2021	980.5

Survey 1: July 31, 2020

PacifiCorp fish biologists Mark Ferraiolo and Erik Lesko accessed the site by boat. Reservoir elevation was 989.3 feet (10.7 feet down from full pool). The purpose of this survey was to visually observe and identify (if possible) any fish species observed in isolated pools surrounding the Northwoods area.

There were six (6) isolated pools (no connection to the reservoir) present and some areas that had recently dewatered. We observed (about 200) larval/fry life stage fish which were predominately sticklebacks and possibly some suckers in isolated pools. Approximately 60 of the total sticklebacks observed were mortalities (see photos). We also observed (less than a dozen) live salmonid fry which were either steelhead (rainbow) or cutthroat trout. We measured water depth out from the docks in the reservoir that was still connected and it was roughly 3 to 4 feet deep – indicating that additional isolated pools may form at reservoir elevations around 986 feet. Numerous bird and raccoon tracks were observed surrounding the isolated pools.

Survey 1 photos

Isolated Pools



Observed fish (Three-spine stickleback fry)


Survey 2: August 21, 2020

PacifiCorp biologist Erik Lesko along with Matt Harding, another Northwoods Community Member (Tom) and two environmental biologists that work with Matt (Hannah Mortensen and Sophie Ernst) surveyed the area with a backpack electrofisher (Smith-Root LR-24) operated by Erik Lesko. The team conducted single pass collection method in all observed pools that were isolated from the reservoir. Reservoir elevation was 987.0 feet representing a net loss of 2.30

feet of reservoir elevation between surveys 1 and 2. There were five (5) isolated pools present at the time of the survey. Fish were collected in two of the five pools surveyed.

Table 2. Species observed and captured during Survey No. 2, August 21, 2020.

Species	Number Captured	Number Observed (estimated)
Three-spine Stickleback (*Gasterosteus aculeatus*)	10	250
Coho Salmon *(Oncorhynchus kisutch)*	60	120
Sculpin (*Cottus* sp.)	15	70
Bull Trout *(Salvelinus confluentus)*	1	1

Survey 2: Photos

Northwoods docks

Isolated pools

Coho Salmon

Bull Trout (~150 mm)

Survey 3, July 12, 2021

PacifiCorp fish biologists Mark Ferraiolo and Erik Lesko accessed the site by boat. The purpose of this survey was to identify the number and location of isolated pools and to remove and identify any fish observed in these pools.

We identified four (4) isolated pools (no connection to the reservoir) on this survey. Three of the pools were small (surface area between 50 and 100 ft^2). The fourth pool consisted of what is referred to as the old river channel. This channel has no surface flow connection to the reservoir or NFK Lewis but does appear to be fed by hyporheic flows from the river. The old river channel contained both coho and trout/steelhead fry or parr. No bull trout were observed during this survey. The old river channel while puddled in some areas extends approximately 150 meters along the Northwoods bank (east bank of the reservoir). Nearly all the fish captured were at the head end of the channel – presumably where hyporheic flows enter the channel. No salmonids were observed in the three smaller pools, however, each of the smaller pools contained hundreds of three-spine sticklebacks and we estimated over 1,000 total sticklebacks for the three smaller pools.

Table 3. Species captured during Survey No. 3. July 12, 2021

Species	Number Captured	Size Range FL (mm)
Coho Salmon *(Oncorhynchus kisutch)*	80	44 to 83
Trout *(Oncorhynchus sp.)* *	6	41 to 54
Three-spine Stickleback (*Gasterosteus aculeatus*)	1000+ (observed)	< 60
Sculpin *(Cottus sp.)*	9	NA

* *Captured trout are too small to be identified to species. Trout are potentially steelhead, rainbow, cutthroat or a hybrid of these species.*

Survey 3: Photos

Survey area showing recently dewatered pools

Very small pool containing
three-spine sticklebacks

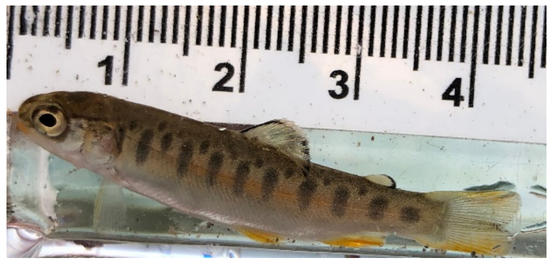
Puddled portion of old river channel

Head end of old river channel

Dewatered portion of old river channel

Smaller isolated pool containing sticklebacks

Coho salmon parr



Trout or steelhead parr

Survey 4, August 5, 2021

This survey focused on the old river channel that was the only existing pool remaining that contained any fish at the reservoir elevation of 980.5. The channel had less water than was observed during the July 12, 2021 survey indicating that this pool is likely to become dewatered as the reservoir continues to draft and natural inflow decreases through the summer. A single pass efishing methodology was used to sample the remaining pools of the channel. Water temperature at the time of the survey was 64 degrees F and deepest pool depth was 2.5 feet and pool length was approximately 550 feet. The smaller pool size condensed fish residing in the in the pool which allowed much higher capture rates than was possible during the July survey. It should be noted that conductivity of the water is very low, which hinders capture efficiency using straight DC current (i.e., no pulsed DC is used) as prescribed under our existing collection permits.

Table 4. Fish species captured during survey number 4, August 5, 2021.

Species	**Number Collected**	**Size Range (FL, mm)**
Coho Salmon *(Oncorhynchus kisutch)*	268	45-100
Trout *(Oncorhynchus sp.)* *	7	35-70
Bull Trout *(Salvelinus confluentus)*	9	110, 120(x3),125,135,140,105,180
Three-spine Stickleback (*Gasterosteus aculeatus*)	3	10-60
Sculpin *(Cottus sp.)*	19	30-120
Lamprey sp.	1	110

* *Captured trout are too small to be identified to species. Trout are potentially steelhead, rainbow, cutthroat or a hybrid of these species.*

Survey 4 Photographs

Refer to Attachment 1 (prepared by Kelley Jorgensen, Karen Adams and Hannah Mortensen, Plas Newydd LLC.)

Summary Discussion

Isolated pools begin to form during the summer months when drafting of Swift Reservoir (Swift) is required to meet FERC minimum stream flows downstream of Merwin Dam (See FERC license and Section 6.2.4 of the Lewis River Settlement Agreement). The rate of drafting depends primarily on the rate of natural (summer) inflow into Swift, which depends on variables such as the volume and water content of upstream snowpack and seasonal precipitation each year.

A total of 4 surveys have been conducted between 2020 and 2021 and varying reservoir elevations. For all surveys, fish were observed in isolated pools. In the smaller pools, three-spine sticklebacks were the predominant species present. However, this may be a function of warming of the pooling water or avian predation leading to loss of salmonids earlier than the more resilient sticklebacks. The vast majority of salmonids captured were from the old river channel which remains watered (and puddled) to at least reservoir elevation 980 ft msl. Water temperature in the old river channel was 64 °F on August 5, 2021, which allows salmonids to survive in this channel as opposed to the isolated pools that have sand substrate and are substantially warmer.

The predominant salmonid species observed are coho salmon, which is consistent with large numbers of adults transported upstream of Swift Dam each year to spawn naturally. Interestingly, no spring Chinook juveniles were observed on any of the surveys. While the numbers of spring Chinook transported upstream are much less than coho, we would expect to see some spring Chinook in the captures.

Bull trout were captured on two of the surveys with the August 2021 survey capturing 9 bull trout in the old river channel. The size range of bull trout captures is between 100 and 180 mm indicating that these fish are 2 to 4-year-old bull trout which may have become stranded in the old channel on their migration to the reservoir.

Next Steps

This question was discussed during our August ACC meeting. There were no options presented at the meeting to prevent stranding that occurs along the reservoir. It is known that stranding is a natural occurrence in streams and lakes as flows or lake levels recede during the summer months. This can be especially true for coho that spawn predominately along margins or more often within side channel habitats. These side channels may become dry or pooled during summer low flow periods. Also, it is unknown whether the stranding issue poses a risk to the bull trout population.

The Utilities are operating the reservoirs in full compliance with their FERC license and the Settlement Agreement. Additionally, under the FERC licenses and Settlement Agreement there is no obligation to mitigate stranding observed in the Northwoods area. However, the Utilities volunteered resources to address the original stranding concern identified by Mark Harding in the fall of 2019. Since that time, there have been additional activities proposed to define the extent of the stranding issue (e.g., identification of other potential stranding areas, quantification of shoreline stranding, use of drones, etc.). While the Utilities support these efforts, we believe additional efforts should be a cooperative effort among the ACC representatives, Northwoods members and Plas Newydd LLC staff.

At some point, the ACC and Services should decide how best to address this issue in the future and what if any measures can be proposed to help alleviate fish stranding in the Northwoods area. Of particular importance is whether the Northwoods stranding issue poses risks to listed species, particularly bull trout which are present in all three reservoirs and self-sustaining in Yale and Swift. If measures to limit stranding are developed, the use of Aquatic Habitat funding could be justified to fund future projects in the area that would help minimize stranding.

Table 5. Total number of fish collected during 3 electrofishing surveys in the Northwoods area.

Species	**Survey 2**	**Survey 3**	**Survey 4**	**Total Captures**
Coho Salmon *(Oncorhynchus kisutch)*	60	80	268	408
Trout *(Oncorhynchus sp.)* *	0	6	7	13
Bull Trout *(Salvelinus confluentus)*	1	0	9	10
Three-spine Stickleback (*Gasterosteus aculeatus*)	10	0	3	13
Sculpin (Cottidae)	15	9	19	43
Lamprey	0	0	1	1
Total Captures	**86**	**95**	**307**	**488**
Total Salmonid Captures	**61**	**86**	**284**	**431**

* *Captured trout are too small to be identified to species. Trout are potentially steelhead, rainbow, cutthroat or a hybrid of these species.*

APPENDIX B

EAGLE CLIFF ROTARY SCREW TRAP OPERATION SUMMARY-TECHNICAL MEMORANDUM 2021

Meridian Environmental, Inc.

Environmental Sciences
Regulatory Planning
Project Management

Memorandum

To: Erik Lesko, PacifiCorp
From: Jason Shappart, Senior Fisheries Scientist
Date: December 17, 2021
Re: North Fork Lewis River Upstream of Swift Reservoir Rotary Screw Trap Summary – 2021

This memorandum summarizes results of rotary screw trap sampling conducted in the North Fork Lewis River upstream of Swift Reservoir in 2021. Meridian biologists operated an 8-foot diameter rotary screw trap located adjacent to Eagle Cliff at the upstream end of Swift Reservoir (Figure 1) under contract with PacifiCorp to estimate the migration timing and abundance of naturally produced salmonids entering Swift Reservoir during the monitoring period. Methods and results are presented below.

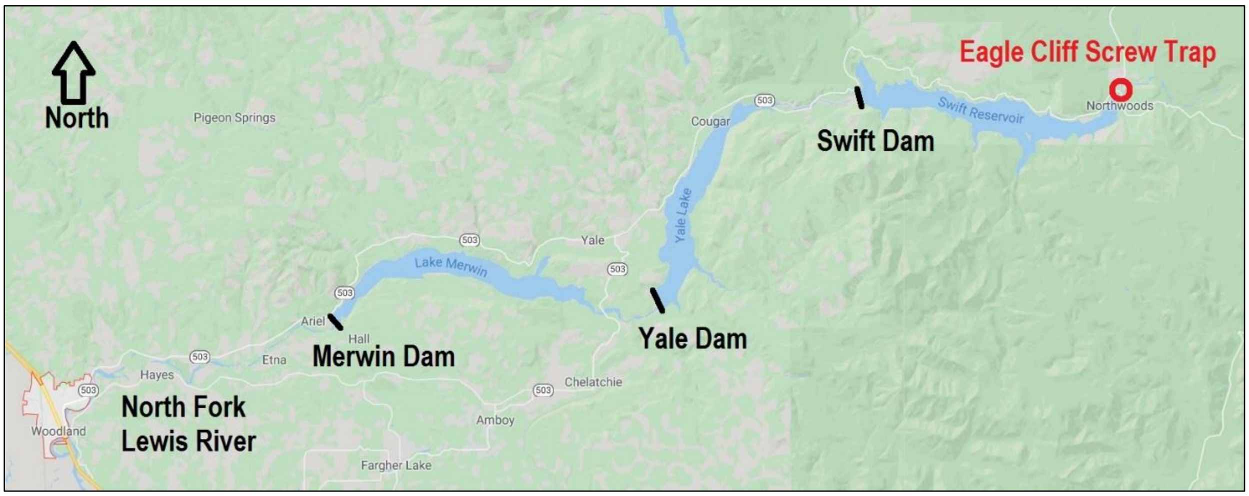


Figure 1. Study area.

Methods

Methods for rotary screw trapping followed those described under Task 7.1 (Estimate the Timing and Number of Juveniles Entering Swift Reservoir from the Upper North Fork Lewis River Subbasin) of the Aquatic Monitoring and Evaluation Plan for the Lewis River (PacifiCorp and Cowlitz PUD 2017). The trap was operated continuously from March 23 to July 30, 2021 with no interruption. Marked juvenile Coho, Chinook, Steelhead/Rainbow, and Cutthroat were released upstream of the trap daily (as fish were available from trap captures) to estimate trap efficiency via mark-recapture methods. Naturally produced salmonids ≥60 mm fork length (FL) were PIT-tagged; naturally produced salmonids ≥50mm FL, but <60 mm FL were marked with an Alcian Blue tattoo or Bismark Brown dye; and salmonid fry <50mm FL were marked with Bismark Brown dye. On excessively hot days in July, salmonids of sufficient length were PIT-tagged, but released downstream to avoid the stress of upstream transport. All Bull Trout were released downstream and not used for trap efficiency tests as stipulated in the U.S. Fish and Wildlife Service Biological Opinion (USFWS 2006), though Bull Trout of sufficient size were

PIT tagged. Because relatively few fish were available to determine mark-recapture rates in 2021, all salmonid species efficiency tests were combined to generate weekly trap efficiency estimates. Note that Steelhead and Rainbow Trout were not differentiated for the purposes of this analysis.

Salmonid fish species migration timing was calculated by estimating total fish passing the trap on a weekly basis using the adjusted weekly trap efficiencies (all salmonid mark-recapture combined each week). Efficiency estimates across weeks were pooled to increase mark-recapture sample size if the stream flow and cone rotations per minute (RPMs) were similar. Total estimates of naturally produced juvenile Coho, Chinook, Steelhead/Rainbow, Cutthroat, and Bull Trout passing the trap by inferred age class (based on size) and the associated 95% confidence intervals (CI) were generated using the Bootstrap Method (Thidenga et al. 1994). Age class was determined by examining the fork length distribution for each species over time. Kalama River age at length data was also reviewed to aid in assessing potential age-length brackets (WDFW 2019). The age class brackets are shown on the length scatter plot distributions for each species. 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 using the measured weekly trap efficiencies for the same specific fork length ranges and species mark-recapture combinations of efficiency used for the Bootstrap estimates.

Results

Stream flow was below median conditions during the entire monitoring period as measured at the Lewis River Above Muddy River Near Cougar, WA (USGS gage No. 14216000, Figure 2). Stream flow during the 2021 monitoring period was the lowest recorded within the recent period of record dating back to 2005 at this gage site. Record peak air temperature measurements were also recorded during late July throughout southwest Washington.

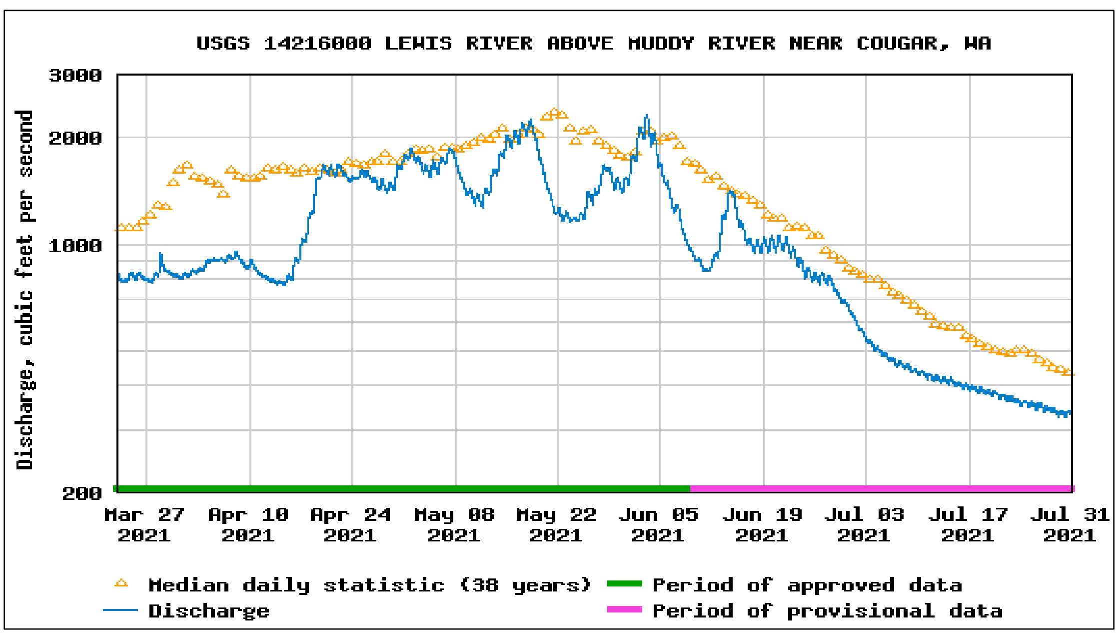


Figure 2. Instantaneous stream flow at the Lewis River above Muddy River gage.

In summary, a total of 4,128 maiden[1] naturally produced salmonids were captured in the Eagle Cliff trap during the 2021 monitoring period (Table 1). Very few adult Chinook were transported upstream to spawn in 2020 (among them only 56 adult female Chinook), which resulted in the low number of Chinook captured in the Eagle Cliff screw trap during the 2021 monitoring period. A total of 1,724 naturally produced salmonids were PIT-tagged, and of those, 1,630 were released upstream of the screw trap for efficiency testing. In addition, a total of 1,017 fish were marked with an Alcian Blue tattoo or Bismark Brown dye and released upstream of the screw trap for efficiency testing during the monitoring period.

Fork length distributions of salmonid fish species are presented in Figure 3 (salmon) and Figure 4 (trout/char). Scatter plots of fork lengths of salmonids captured daily by species are presented in Figure 5 (Coho), Figure 6 (Chinook), Figure 7 (Steelhead/Rainbow), Figure 8 (Cutthroat), and Figure 9 (Bull Trout). Salmonid fish species migration timing by inferred age class is presented in Figure 10 (salmon) and Figure 11 (trout/char) as calculated by estimating total fish passing the trap on a weekly basis using the adjusted weekly trap efficiencies summarized in Table 2. These data suggest that during the 2021 monitoring period, most juvenile Coho (age 1 and 2+) passed the trap in May, while most subyearling Coho (age 0+) passed the trap in July as did subyearling Chinook. Steelhead/Rainbow, Cutthroat, and Bull Trout passed the trap over a more protracted period, but mostly in April and May, though Steelhead/Rainbow fry were captured in July after emergence began.

Total estimates of naturally produced juvenile Coho, Chinook, Steelhead/Rainbow, and Cutthroat passing the trap during the monitoring period by inferred age class, associated 95% CI, and coefficient of variation (CV) are summarized in Table 3. Note that age class length-brackets are shown on the length scatter plot distributions for each species (see figures 4 through 8).

Table 1. Summary of total maiden fish captured at Eagle Cliff screw trap in 2021.

Species	Naturally Produced Subyearling 0+	Naturally Produced 1+ Year Old	Naturally Produced 2+ Year Old	Grand Total	Marked/ Released Upstream ≥50 mm FL	Total Recaptured
Coho Salmon	2,549	661	38	**3,248**	2,008	72
Chinook Salmon	45	2	2	**49**	28	2
Steelhead/ Rainbow Trout	144	406	124	**674**	517	16
Cutthroat Trout	7	58	43	**108**	94	2
Bull Trout	2	27	20	**49**	0	0
Total	**2,747**	**1,154**	**227**	**4,128**	**2,647**	**92**

Species	Total
Hatchery Rainbow Trout	11
Longnose Dace	10
Sculpin	80
Sucker	78

[1] Fish captured for the first time.

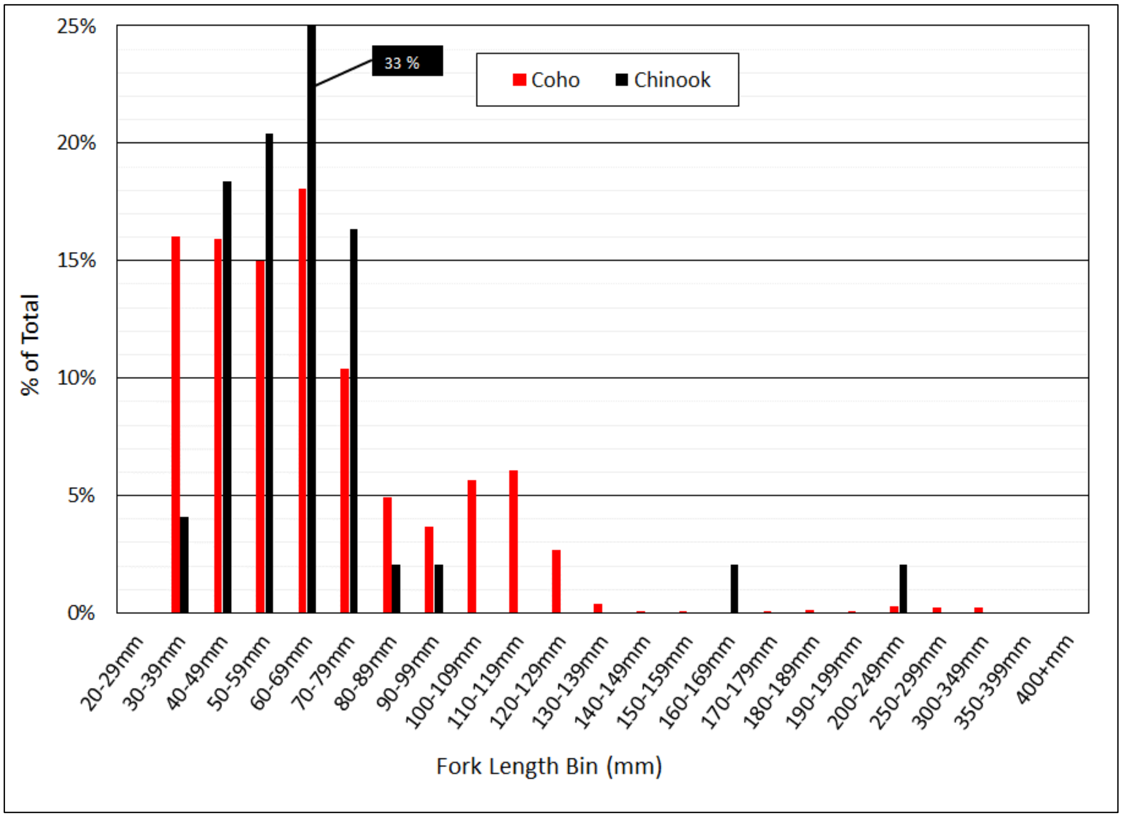


Figure 3. Length frequency of naturally produced salmon (Eagle Cliff trap 2021).

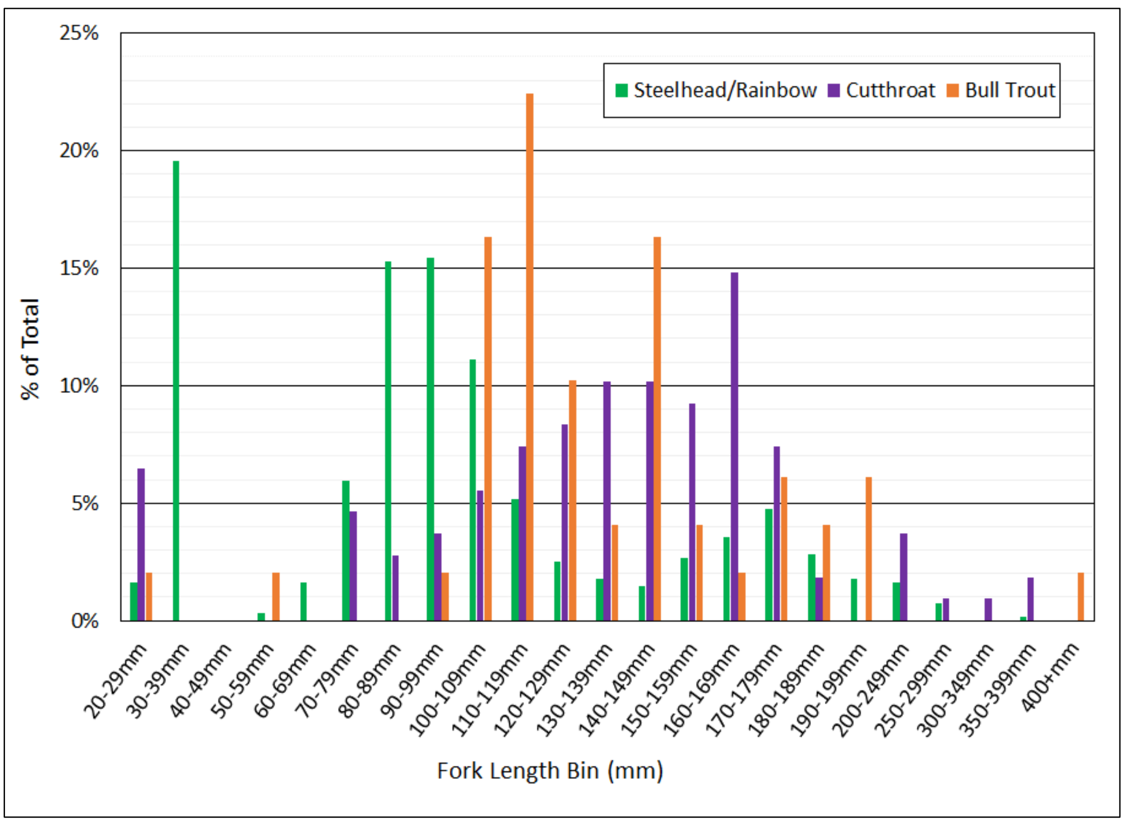


Figure 4. Length frequency of naturally produced trout/char (Eagle Cliff trap 2021).

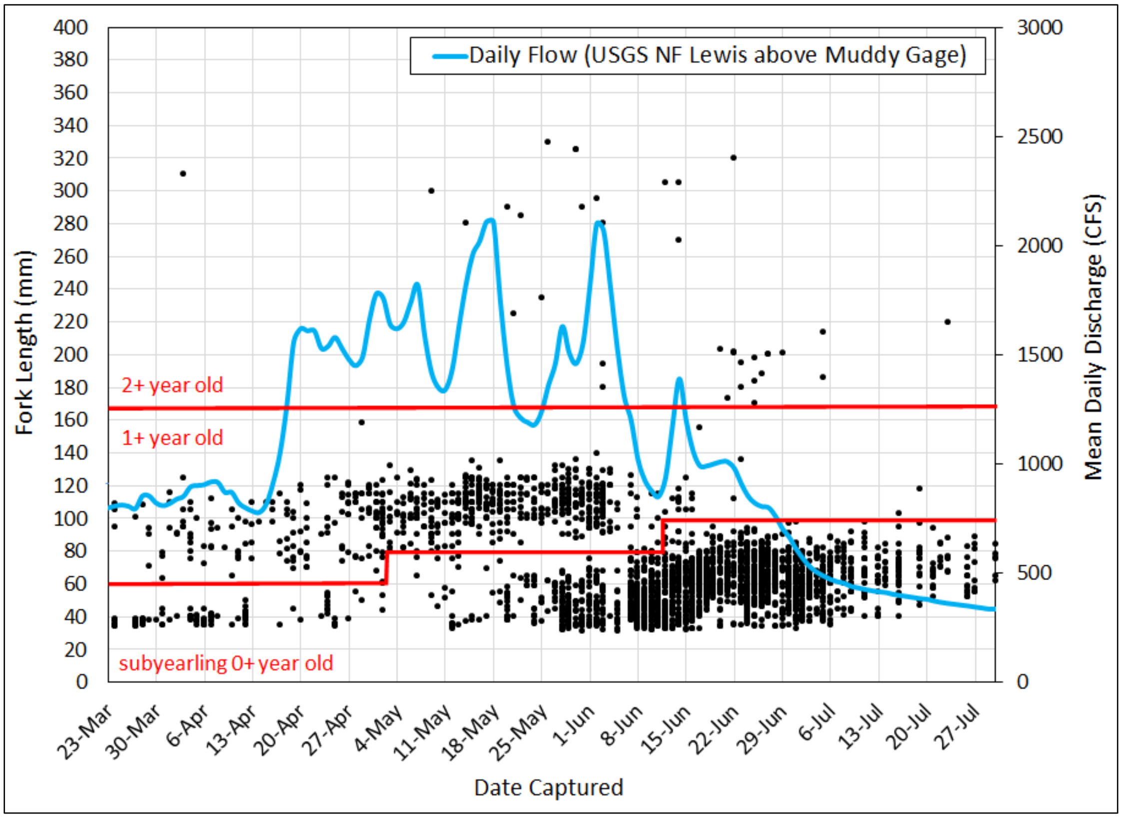


Figure 5. Fork length of maiden Coho captured daily (Eagle Cliff trap 2021).

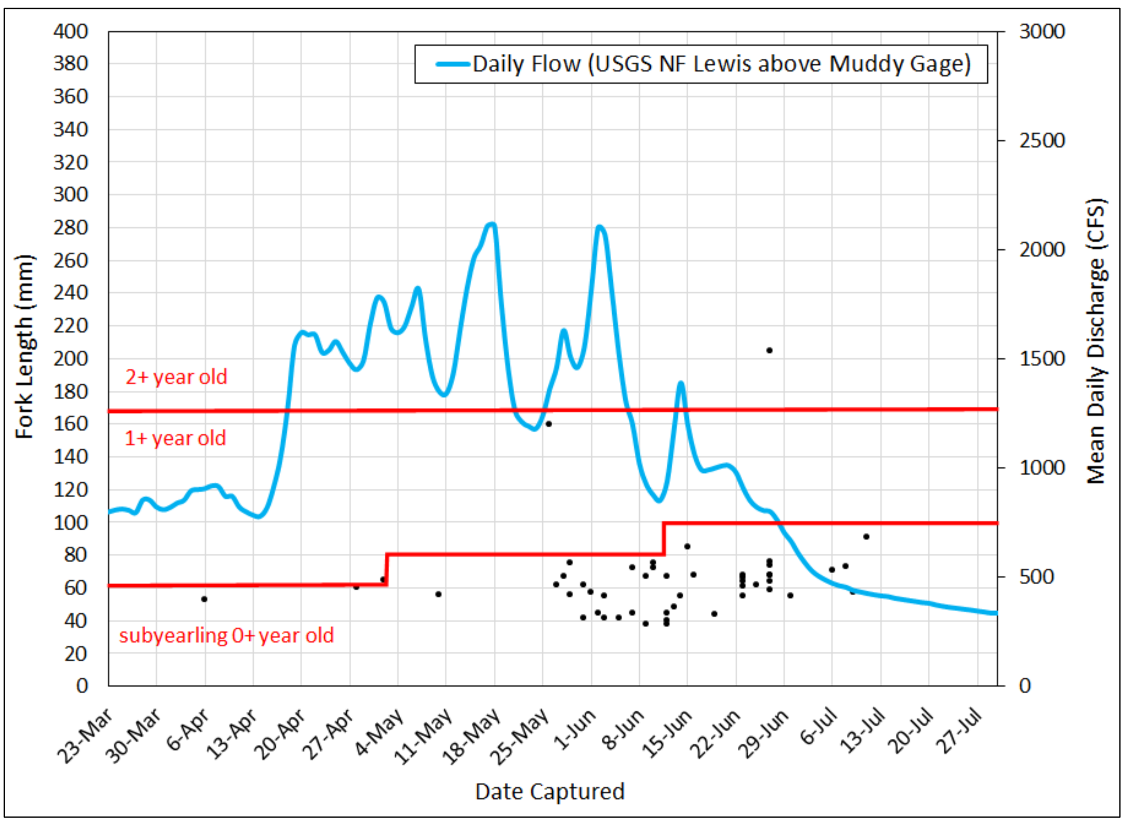


Figure 6. Fork length of maiden Chinook captured daily (Eagle Cliff trap 2021).

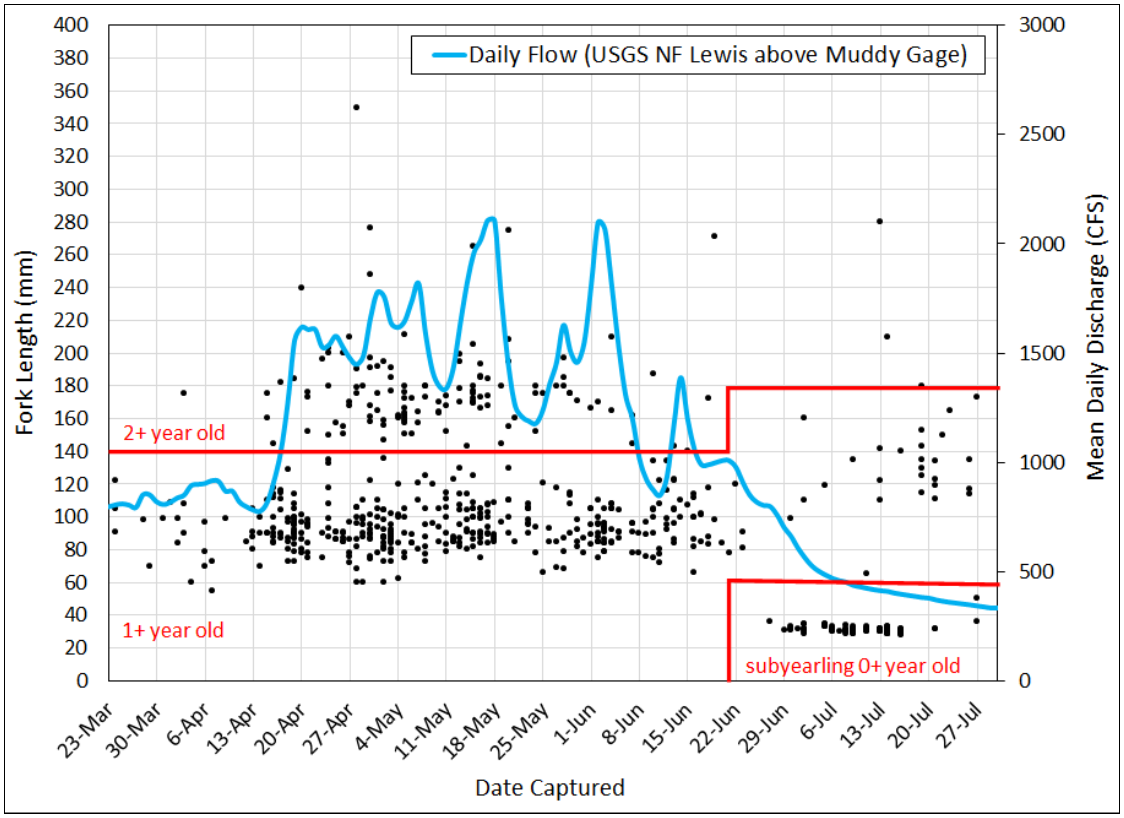


Figure 7. Fork length of maiden Steelhead/Rainbow captured daily (Eagle Cliff trap 2021).

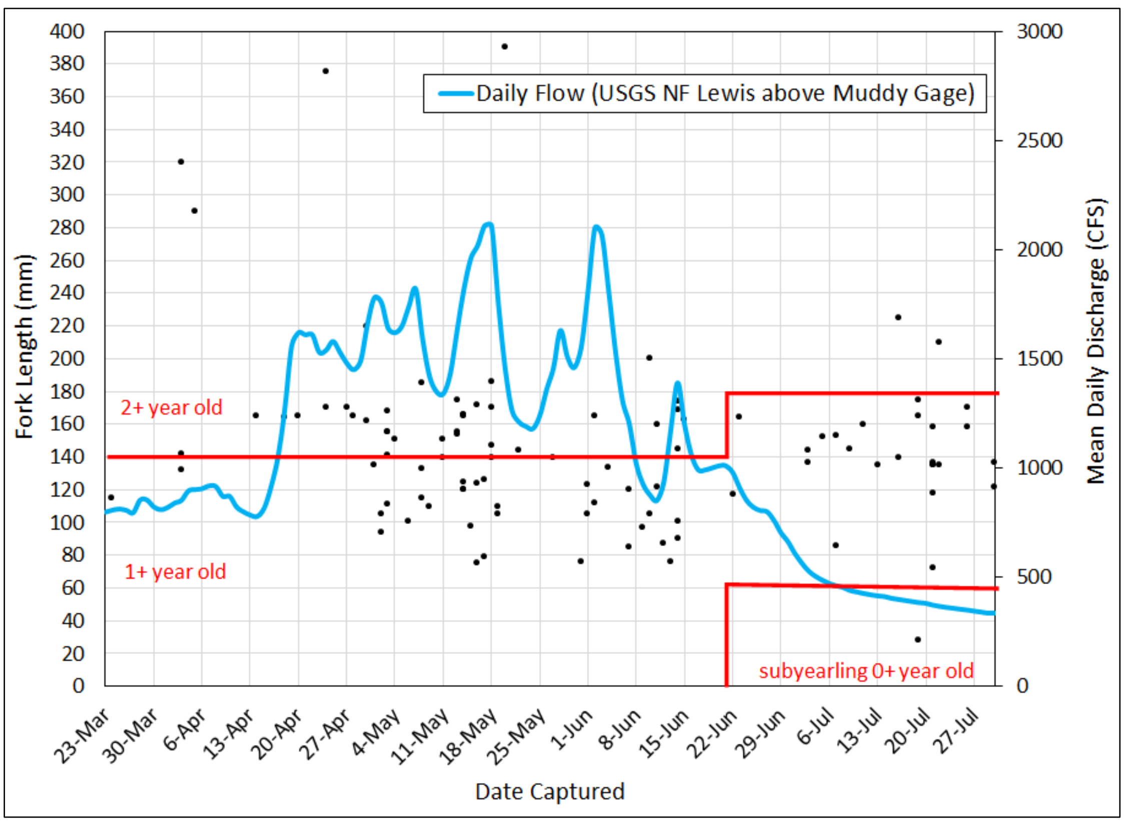


Figure 8. Fork length of maiden Cutthroat captured daily (Eagle Cliff trap 2021).

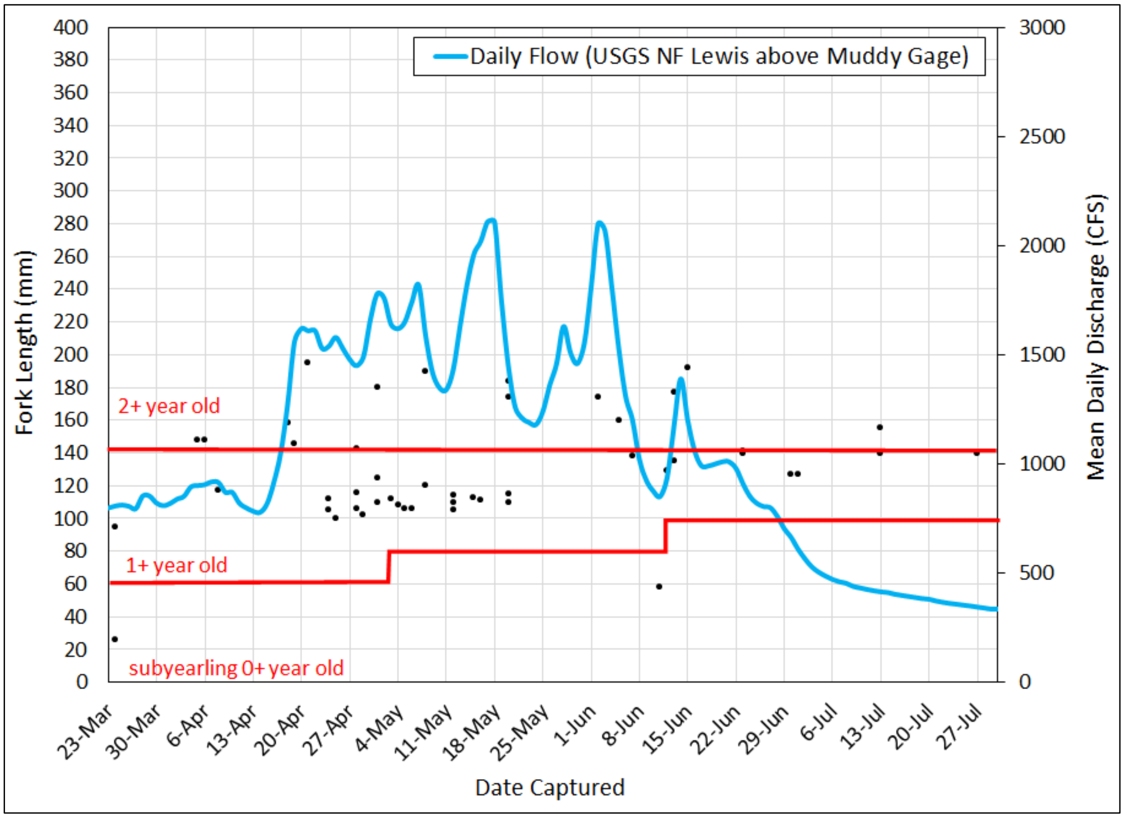


Figure 9. Fork length of maiden Bull Trout captured daily (Eagle Cliff trap 2021).

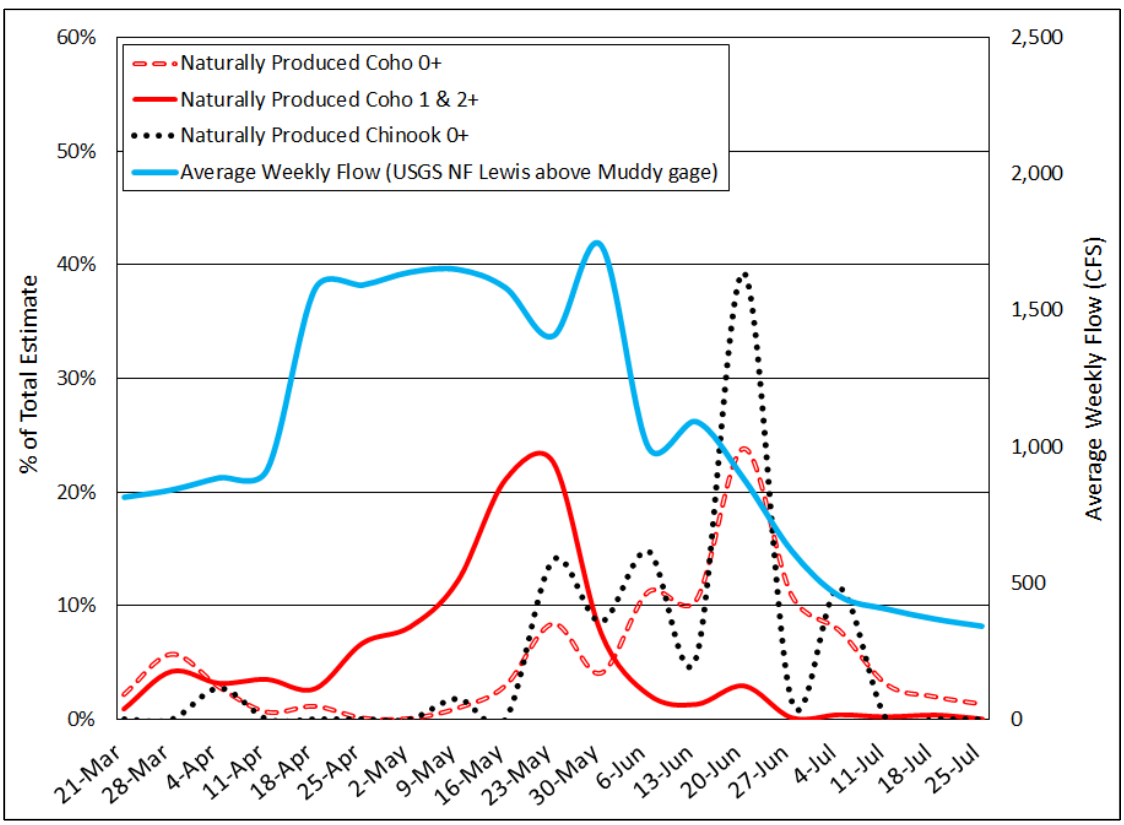


Figure 10. Naturally produced salmon migration timing (Eagle Cliff trap 2021).

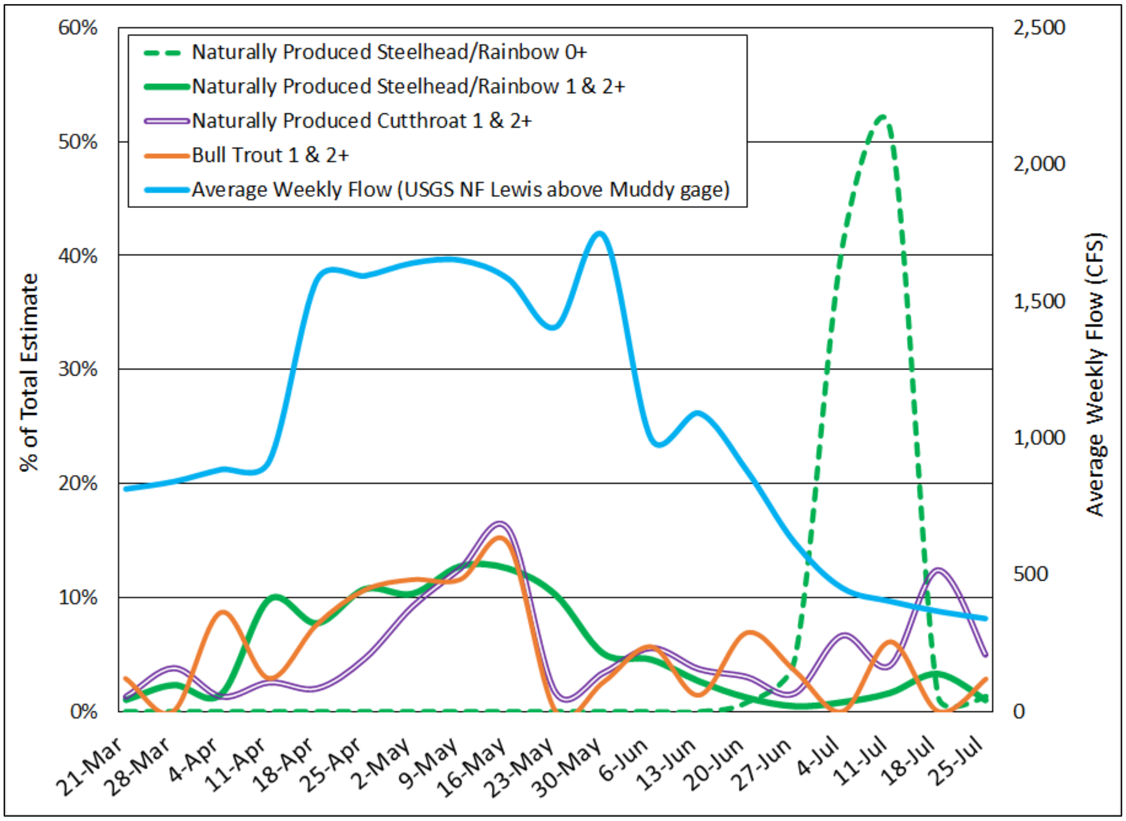


Figure 11. Naturally produced trout/char migration timing (Eagle Cliff trap 2021).

Table 2. Summary of weekly mark-recapture efficiency tests for Coho, Chinook, Steelhead/Rainbow, and Cutthroat combined (≥50 mm FL) at the Eagle Cliff trap (2021).

Week (1st day)	Total[a] Caught	Total[a] Marked & Released Upstream	Total[a] Recaptured	Trap Efficiency	Average Weekly Flow (cfs)[b]	Average Weekly Cone RPMs	Adjusted Weekly Efficiency Based on Flow/RPMs
22-Mar	10	10	1	0.100	814	4.8	0.0234[c]
29-Mar	36	35	0	0.000	841	4.9	0.0234[c]
5-Apr	26	23	2	0.087	886	4.7	0.0234[c]
12-Apr	61	60	0	0.000	916	4.2	0.0234[c]
19-Apr	93	86	2	0.023	1,579	6.1	0.0447[d]
26-Apr	164	160	9	0.056	1,593	6.0	0.0447[d]
3-May	144	144	6	0.042	1,640	5.9	0.0353[e]
10-May	202	196	6	0.031	1,650	6.2	0.0353[e]
17-May	175	145	3	0.021	1,583	6.4	0.0184[f]
24-May	185	181	3	0.017	1,406	5.8	0.0184[f]
31-May	188	171	9	0.053	1,740	6.3	0.0526
7-Jun	265	261	6	0.023	997	4.3	0.0479[g]
14-Jun	366	365	24	0.066	1,092	4.6	0.0479[g]
21-Jun	380	305	6	0.020	882	3.3	0.0197
28-Jun	287	236	9	0.038	619	2.4	0.0381
5-Jul	137	129	1	0.008	452	2.0	0.0222[h]
12-Jul	60	51	3	0.059	404	1.7	0.0222[h]
19-Jul	64	56	2	0.036	367	1.1	0.0238[i]
26-Jul	36	28	0	0.000	341	0.5	0.0238[i]
Total	**2,879**	**2,642**	**92**	**0.035**			

Table 2 Notes:
[a]Total naturally produced Coho, Chinook, Steelhead/Rainbow, and Cutthroat.
[b]USGS Gage No. 14216000 – Lewis River Above Muddy River Near Cougar, WA.
[c]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 22-March and 12-April).
[d]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 19-April and 26-April).
[e]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 3-May and 10-May).
[f]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 17-May and 24-May).
[g]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 7-June and 14-June).
[h]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 5-July and 12-July).
[i]Combined efficiency measured during weeks with similar stream flow and trap cone RPMs (weeks of 19-July and 26-July).

Table 3. Estimates of total naturally produced salmonids by species and inferred age class passing the Eagle Cliff trap (2021).

Species (Age Class)	Cohort/ Brood-Year	Bootstrap Method Mean Estimate (95% CI) (CV%)	Volkhardt Method Estimate (95% CI) (CV%)
Coho (subyearling 0+)	Sep 20-Jan 21	74,617 (+/- 17796) (12%)	71,871 (+/- 17625) (13%)
Coho (1+ year old)	Sep 19-Jan 20	22,200 (+/- 7927) (18%)	19,745 (+/- 7302) (19%)
Coho (2+ year old)	Sep 18-Jan 19	944 (+/- 365) (20%)	1,016 (+/- 467) (23%)
Total Coho Estimate		**97,761 (+/- 19485) (10%)**	**92,632 (+/- 19083) (11%)**
Chinook (subyearling 0+)	2020	1,326 (+/- 509) (20%)	1,338 (+/- 567) (22%)
Chinook (1+ year old)	2019	97 (+/- 123) (65%)	89 (+/- 107) (61%)
Chinook (2+ year old)	2018	28 (+/- 53) (97%)	32 (+/- 61) (98%)
Total Chinook Estimate		**1,451 (+/- 526) (19%)**	**1,459 (+/- 580) (20%)**
Steelhead/Rainbow (subyearling 0+)	2021	6,015 (+/- 3100) (26%)	4,772 (+/- 3438) (37%)
Steelhead/Rainbow (1+ year old)	2020	10,373 (+/- 2715) (13%)	10,141 (+/- 2874) (14%)
Steelhead/Rainbow (2+ year old)	2019	3,132 (+/- 922) (15%)	3,387 (+/- 1177) (18%)
Total Steelhead Estimate		**19,520 (+/- 4222) (11%)**	**18,301 (+/- 4633) (13%)**
Cutthroat (subyearling 0+)	2021	285 (+/- 255) (46%)	392 (+/- 576) (75%)
Cutthroat (1+ year old)	2020	1,695 (+/- 677) (20%)	1,486 (+/- 612) (21%)
Cutthroat (2+ year old)	2019	1,475 (+/- 564) (19%)	1,191 (+/- 485) (21%)
Total Cutthroat Estimate		**3,455 (+/- 918) (14%)**	**3,069 (+/- 970) (16%)**
Bull Trout (subyearling 0+)	2020	59 (+/- 86) (75%)	50 (+/- 69) (70%)
Bull Trout (1+ year old)	2019	874 (+/- 446) (26%)	705 (+/- 327) (24%)
Bull Trout (2+ year old)	2018	538 (+/- 256) (24%)	532 (+/- 259) (25%)
Total Bull Trout Estimate		**1,471 (+/- 521) (18%)**	**1,287 (+/- 423) (17%)**

References

PacifiCorp and Cowlitz PUD. 2017. Aquatic monitoring and evaluation plan for the Lewis River – first revision, objective 15 - determine spawner abundance, timing and distribution of transported anadromous adults, dated February 28, 2017. Prepared by PacifiCorp and Public Utility district No. 1 of Cowlitz County.

Thedinga J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837 851.

U.S. Fish and Wildlife Service (USFWS). 2006. Biological Opinion for the FERC Relicensing of the Lewis River Hydroelectric Projects: Merwin (No. 935), Yale (No. 2071), Swift No. 1

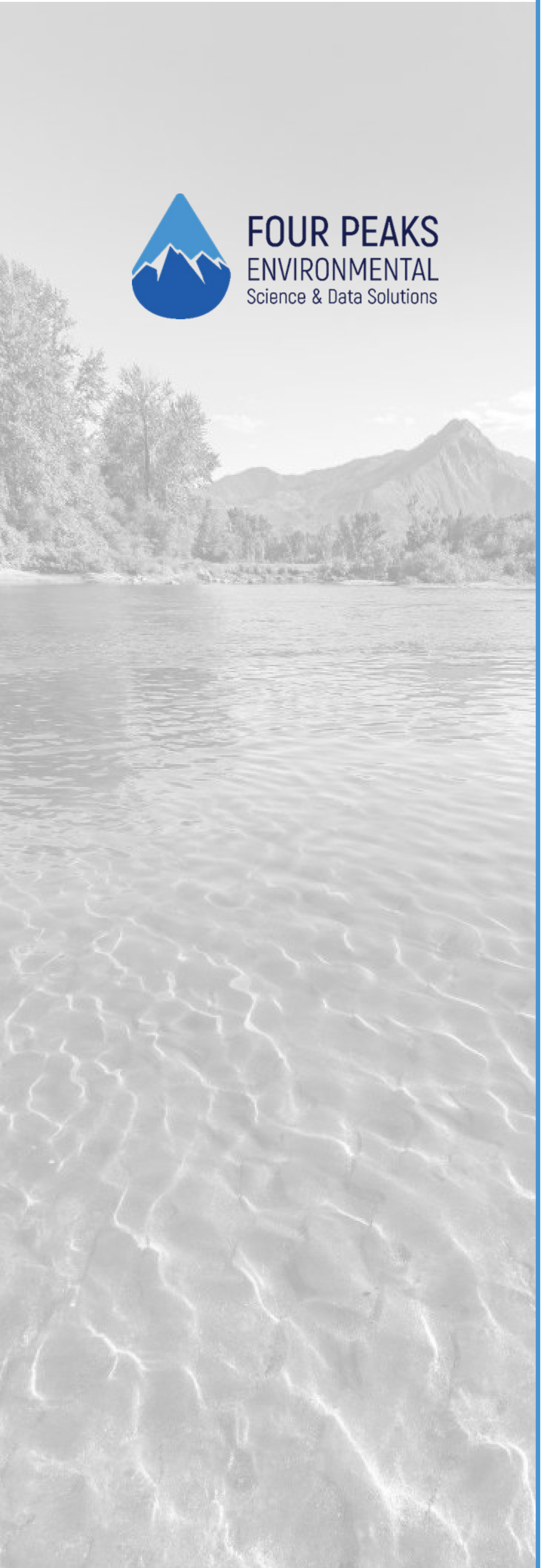
(No. 2111), and Swift No. 2 (No. 2213).USFWS Reference Number: 1-3-06-F-0177. Lacey, WA. September 15, 2006.

Volkhardt, G.C., S.L. Johnson, B. Miller, T.E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane traps. Pages 235-266 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Washington Department of Fish and Wildlife. 2019. JMX smolt trap protocols and reporting, Kalama River 2019. Project supervisor: Jeremy Wilson, Science Leader: Thomas Buehrens.

APPENDIX C

SWIFT RESERVOIR FLOATING SURFACE COLLECTOR SMOLT COLLECTION EFFICIENCY EVALUATION – 2021 FINAL REPORT



SWIFT RESERVOIR FLOATING SURFACE COLLECTOR COLLECTION EFFICIENCY EVALUATION 2021: ANNUAL REPORT (FINAL)

March 2022

Prepared for
PacifiCorp
Lewis River Hydroelectric Facility
105 Merwin Village Court
Ariel, Washington 98603

Prepared by
Four Peaks Environmental
Science & Data Solutions
338 South Mission Street
Wenatchee, Washington 98801

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Abbreviations

Abbreviation	Definition
2004 Settlement Agreement	Relicensing of the Lewis River Hydroelectric Projects – FERC Project Nos. 935, 2071, 2111, 2213, Cowlitz, Clark and Skamania Counties, Washington
2021 Study	2021 Swift Reservoir Floating Surface Collector Passage Evaluation
AICc	Akaike's information criterion corrected for small samples
ATS	Advanced Telemetry Systems
CCH	collection channel
downstream secondary channel	downstream secondary screen collection channel
FBY	forebay
FERC	Federal Energy Regulatory Commission
Four Peaks	Four Peaks Environmental Science & Data Solutions
FSC	floating surface collector
IQR	interquartile range
M&E Plan	Aquatic Monitoring and Evaluation Plan for the Lewis River
NTS	net transition structure
PIT	passive integrated transponder
primary channel	primary screen collection channel
Project	PacifiCorp Swift No. 1 Project FERC No. 2111
TOAD	time-of-arrival difference
upstream secondary channel	upstream secondary screen collection channel
ZOI	zone of influence
ZPC	zone presence criteria
ZPTS	zone presence time series

Executive Summary

The 2021 Swift Reservoir Floating Surface Collector Passage Evaluation (2021 Study) measured the collection efficiency of the Swift floating surface collector (FSC) and assessed the behavior of juvenile salmonids (Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*, and steelhead *O. mykiss*) released near the head of Swift Reservoir as they approached and interfaced with the Swift FSC. The major goals of the 2021 Study were:

- To evaluate FSC effectiveness, primarily as measured by collection efficiency (P_{CE}), but also using additional performance metrics and a series of behavioral analyses to investigate factors that influence how juvenile salmonids interact with the FSC
    - *This included experimentally manipulating FSC pumping rates to change water velocity within the channel and monitoring environmental and operational factors to evaluate their relationship with passage activity and success.*
- To increase the resolution of behavioral inference within the fish collection channel, so that the point of fish rejection could be more precisely determined

To monitor study fish movements, a telemetry array, comprised of 28 acoustic receivers, was deployed in Swift Reservoir, in the Swift Dam forebay, near the entrance of the FSC, and within the FSC collection channel. The receivers were deployed as groups within distinct subarrays covering the forebay (installed near the Devil's Backbone feature at the forebay entrance up-reservoir from the FSC), the zone of influence (ZOI, installed in the Swift Dam forebay upstream of the FSC), the net transition structure (NTS, installed within the FSC that guides fish into the collection channel), and the fish collection channel that leads directly to the collector's fish sorting building. For behavioral analyses (but not calculation of performance metrics), the NTS and collection channel subarrays were further partitioned into the following subsections:

- The NTS was subdivided into an upstream and a downstream section.
- The collection channel was subdivided into the primary screen collection channel, upstream secondary screen collection channel, and downstream secondary screen collection channel.

A total of 443 fish were dual-tagged with a passive integrated transponder and acoustic transmitter and released at the upper end of Swift Reservoir between April 1 and June 3, 2021, to measure FSC performance and monitor fish behavior. The 443 study fish comprised 39 Chinook Salmon, 212 Coho Salmon, and 192 steelhead. Target sample sizes were determined to provide similar numbers of Coho Salmon and steelhead as in 2020; however, juvenile Chinook Salmon outmigrant abundance was anticipated to be lower than in 2020 so a smaller target sample size was set. Due to lower than anticipated abundance of juvenile Chinook Salmon outmigrants in 2021, the reduced target sample size for Chinook Salmon was not met. The remaining acoustic transmitters were used to tag additional Coho Salmon and steelhead.

The proportion of fish successfully transiting the reservoir during the study period was quantified in 2021 using the reservoir passage metric (P_{PASS}, referred to in previous FSC evaluation reports as reservoir survival, P_{RES}). P_{PASS} summarizes the proportion of all dual-tagged study fish that were detected at the Devil's Backbone before the conclusion of the 2021 Study. In 2021, P_{PASS} was 74% for Chinook Salmon, 89% for Coho Salmon, and 73% for steelhead.

The proportion of fish entering the forebay that were subsequently detected in the ZOI was quantified in 2021 using the FSC encounter rate (P_{ENC}) metric. In 2021, P_{ENC} was 86% for Chinook Salmon, 95% for Coho Salmon, and 94% for steelhead.

Collection efficiency (P_{CE}) is a key performance metric that represents the proportion of dual-tagged study fish reaching the ZOI that were subsequently collected. In 2021, P_{CE} was 52% for Chinook Salmon, 40% for Coho Salmon, and 48% for steelhead. Compared to 2020 results, these proportions represent an 18% (8 percentage point) increase for Chinook, a 3% (1 percentage point) decrease for Coho, and a 14% (6 percentage point) increase for steelhead.

Entrance efficiency (P_{ENT}), quantifies the proportion of dual-tagged fish in the ZOI that were then detected within the NTS at the entrance of the FSC. P_{ENT} was near 100% for all three species, ranging from 95% for steelhead to 100% for Chinook Salmon. Together, these results suggest that, although 11% to 26% of study fish (by species) did not reach the forebay during the study period (either due to mortality, premature tag failure, or delayed migration), once study fish reached the ZOI, most entered the NTS.

The proportion of study fish that entered the NTS and then were detected proceeding into the collection channel (P_{CHAN}) was 79% overall and ranged among species from 57% for Chinook Salmon to 84% for steelhead. Among these fish that entered the NTS, however, less than half (45%) were retained within the FSC and ultimately collected (P_{RET}). P_{RET} was 52% for Chinook Salmon, 41% for Coho Salmon, and 50% for steelhead.

Once in the collection channel, 57% of study fish were captured in the FSC (P_{CAP}, referred to in previous FSC evaluation reports as P_{COL}). P_{CAP} was 92% for Chinook Salmon (noting very low sample size for Chinook in 2021), 52% for Coho Salmon, and 60% for steelhead.

Thus, the relatively low observed collection efficiency appears to reflect low rates of retention of study fish after they enter the collection channel, rather than reduced attraction of study fish to the FSC. These relatively low retention rates reflect three apparent “turnaround” points that were located (1) between the downstream NTS and the primary channel, (2) between the primary channel and the upstream secondary channel, and (3) between the downstream secondary channel and the sorting building entrance (i.e., collection). Among these three turnaround points, it appears that the largest bottleneck for successful passage occurs within the downstream portion of the secondary channel. This is an area where flow velocity within the fish channel decelerates just upstream of the weir that fish pass over before entering the sorting building. Increasing the retention of fish that have transited to this area appears to be the single action that would result in the biggest increase in collection efficiency.

In 2019, adjustments were made to the NTS to increase attraction velocity at the entrance to the FSC. While attraction velocity was increased at the FSC entrance, these adjustments also resulted in inconsistent flow acceleration within the fish channel. As a result, the 2021 Study included an experimental Pumping Rate Study to determine whether fish rejection occurred at locations with reduced flow. The test consisted of reducing the number of attraction pumps operating at the FSC from ten to eight with the intent to improve the smoothness of flow acceleration within the collection channel.

Overall, the reduction in the number of operational attraction pumps appeared to lower FSC performance. First, slightly fewer fish attempted passage when only eight pumps were operating. This reduction in attempt rate was greatest for steelhead. Secondly, while operating only eight pumps did not appreciably change the proportion of successful passage attempts or of successful fish attempting passage, results of a set of statistical models that controlled for the effects of additional covariates did indicate that passage attempts made when eight pumps were operating had a lower probability of resulting in collection. These model results suggest that retention was slightly reduced with eight pumps operating instead of ten. In sum, the combined net effect of reduced passage attempt rate and similar or lower retention when only eight pumps were operated was that fewer fish were collected when eight pumps were operated compared to when ten were.

The 2021 Study included substantially more receivers in the collection channel than previous years. The greater coverage allowed finer scale analyses of fish behaviors in the collection channel and of factors contributing to successful passage. Modeling efforts using these data revealed that smaller steelhead were more likely to be recaptured than larger steelhead. The daily number of passage attempts increased after strong east wind events and on days after large forebay debris events but decreased (for steelhead) on the day of a debris event. The proportion of steelhead passage attempts that were successful showed the opposite response, increasing on days with more debris and slightly decreasing on the day following a debris event. For all species, passage attempts tended to be more successful when initiated outside of mid-day hours. This diel behavioral pattern appears to be driven by circadian rhythms or daylight rather than human activity.

In summary, the 2021 Study indicated that the lead net continues to successfully attract outmigrating juvenile anadromous salmonids to the entrance of the Swift FSC once they enter the forebay of Swift Reservoir. Results also indicate that retention of study fish that have entered the NTS and collection channel remains low and appears to be the bottleneck for successful passage. After evaluating many environmental and operational factors hypothesized to affect collection efficiency, it appears that poor retention is driven primarily by patterns of flow within the channel, including areas where flow accelerates and decelerates and areas of relatively low velocity. The single greatest bottleneck to passage occurs within the low velocity deceleration region just before the entrance of the sorting building. It is thought that fish can rest in this area before attempting to exit the fish channel. Given the higher resolution of acoustic receivers deployed within the fish collection channel during the 2021 Study, it now appears that increasing retention of fish that have reached the downstream portion of the secondary collection channel is the most critical area for improvement and offers potential for a considerable net increase of collection efficiency at the Swift FSC.

1 Introduction

1.1 Study Purpose and Objectives

The Swift floating surface collector (FSC) is a floating barge in the Swift Dam forebay that captures juvenile salmonids migrating near the surface of the reservoir. The 2021 Swift Reservoir Floating Surface Collector Passage Evaluation (2021 Study) was conducted to collect and analyze data to understand the performance of the Swift FSC, so that inferences and insights can be developed to inform and support PacifiCorp's decisions related to operation of the Swift FSC and to direct any future facility adjustments and modifications per Section 4.1.6 of the Lewis River Settlement Agreement (PacifiCorp et al. 2004). Within the framework of this study, Swift FSC performance is evaluated using metrics that summarize fish behaviors within the Swift Reservoir and FSC. These metrics are computed for a sample of smolts (study fish) that were captured at the Swift FSC, dual tagged with passive integrated transponder (PIT) and active acoustic tags, then released 7.5 miles upstream (east) of the FSC, at the head of Swift Reservoir, near Swift Forest Camp Boat Launch. After release, study fish were monitored as they approached, interacted with, and were potentially collected in the FSC.

Studies conducted in 2017 and 2018 (Anchor QEA 2018; Smith et al. 2018) and following the installation of the 650-foot lead net, found that most study fish successfully locate and enter the net transition structure (NTS), the fish collection channel transition structure located at the entrance of the FSC. However, too many fish reject collection after entering the collection channel to achieve the performance standard for collection efficiency of 95% for each species as set out in the Settlement Agreement. More recent studies conducted in 2019 and 2020 identified areas within the collection channel (the reach between the NTS and the entrance to the sorting building) as the primary bottleneck to achieving performance targets (Four Peaks 2020, 2021). Thus, the 2021 Study focused on fine-scale fish behaviors within the NTS and collection channel by including more acoustic receivers than previous years in this area and on the environmental and operational factors that may influence those behaviors.

Consistent with previous study years, the performance of the FSC was evaluated primarily using collection efficiency (P_{CE}). P_{CE} is calculated as the proportion of study fish arriving in the attraction flow field of the FSC (i.e., the zone of influence or ZOI) that are ultimately collected. Additional performance metrics were calculated to evaluate transitions among sub-reaches between the ZOI and collection within the FSC. Given the changes in study design and acoustic telemetry array layout over the years, these metrics are as consistent with previous study years as possible to enable comparisons. As needed, other metrics were added to provide additional resolution within the FSC collection channel.

The following metrics were calculated for the 2021 Study as pooled values to include all study fish, per the Aquatic Monitoring and Evaluation Plan for the Lewis River (M&E Plan, PacifiCorp and Cowlitz County PUD 2017):

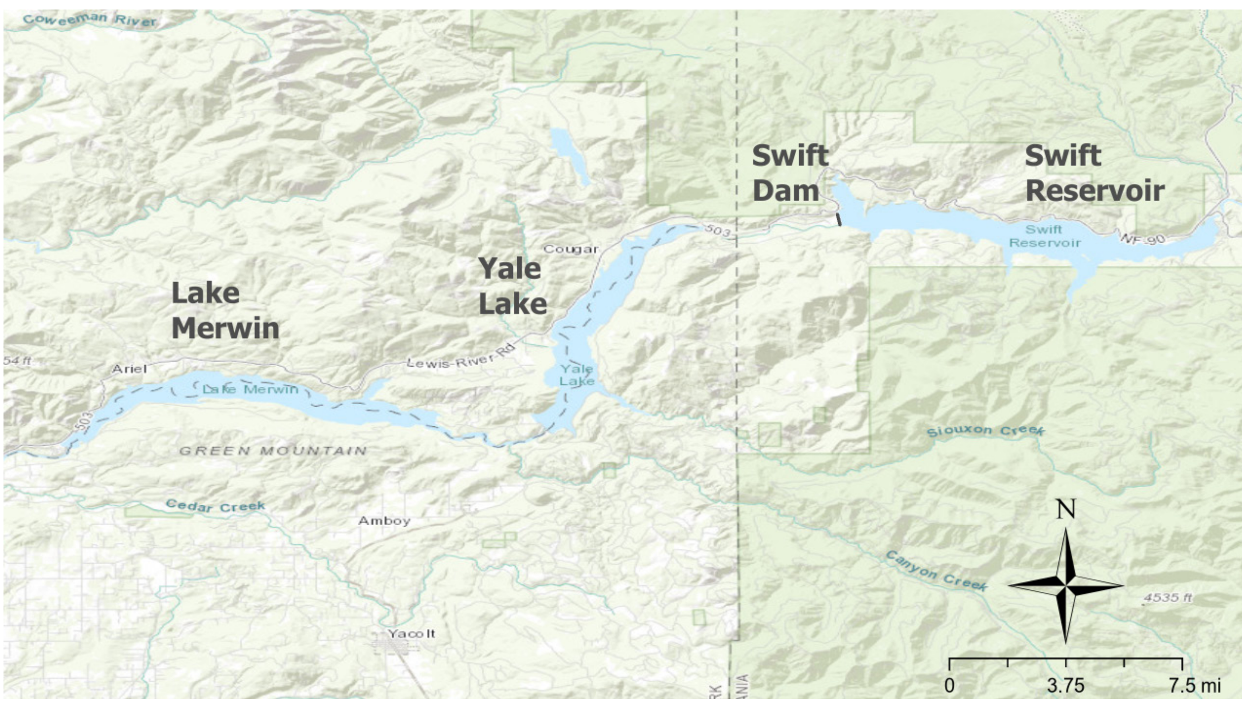
- Estimated reservoir passage (P_{PASS}) – the proportion of released study fish that are detected entering the forebay as defined by the Devil's Backbone acoustic hydrophone array
- Estimated FSC encounter rate (P_{ENC}) – the proportion of study fish that are detected at the Devil's Backbone array and subsequently detected in the ZOI just outside the entrance of the FSC
- Estimated entrance efficiency (P_{ENT}) – the proportion of study fish detected in the ZOI that enter the NTS

- Estimated collection efficiency (P_{CE}) – the proportion of study fish detected in the ZOI that are re-captured at the FSC
- Estimated retention efficiency (P_{RET}) – the proportion of study fish detected in the NTS that are re-captured at the FSC
- Estimated channel efficiency (P_{CHAN}) – the proportion of study fish detected in the NTS that enter the collection channel
- Estimated channel-collector transition rate (P_{CAP}) – the proportion of study fish detected in the collection channel that are re-captured at the FSC

The 2021 Study also examined fine-scale fish behavior within the collection channel to identify locations within the extent of the structure where fish reject collection and where focused efforts could improve collection efficiency. These fine-scale behavioral analyses also examined environmental and operational factors that might explain rejection rates. These environmental and operational factors included meteorological data (e.g., water temperature, wind direction, and wind speed), plus observations of forebay debris loading, human activity levels, and underwater (i.e., acoustic) sound.

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 (Figure 1). The Project consists of Swift Dam No. 1, which is a 412-foot-high by 2,100-foot-long embankment dam, and the 4,600-acre reservoir impounded by this dam, which is 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 2004 Settlement Agreement (PacifiCorp et al. 2004). These measures include 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. The 2004 Settlement Agreement requires monitoring and evaluation of P_{CE} at the FSC and identified a P_{CE} performance target of 95% at a 0.05 precision level for the FSC (PacifiCorp et al. 2004). For the purposes of performance evaluation, P_{CE} is defined for each of the anadromous fish species designated in the 2004 Settlement Agreement[1] as the proportion of juveniles available for collection that is actually collected. Consistent with previous studies and as defined in the M&E Plan, the 2021 Study considered fish that had reached the ZOI as "available for collection."

1.3 Summary of 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; Caldwell et al. 2017; Anchor QEA 2018; PacifiCorp and Cowlitz County PUD 2019, 2020; Four Peaks 2020, 2021). Although study design has been refined over the years, and results have varied year-to-year, several trends have emerged from these studies (Figure 2). Most importantly, observed P_{CE} for facility performance for all species tested has been consistently lower than the 95% performance target in all years, ranging from 6% in the 2013 pilot study year (Courter et al. 2013) to 55% in 2019 (Four Peaks 2020), when averaged across test species (Table 1).

Although P_{CE} estimates consistently have been below the target, these previous studies demonstrate that comparatively high percentages of fish do successfully locate and enter the FSC, even if they ultimately are not collected (Table 1) (Reynolds et al. 2015; Caldwell et al. 2017; Anchor QEA 2018; PacifiCorp and Cowlitz County PUD 2019, 2020; Four Peaks 2020, 2021). The occurrence of fish migrating to but not being successfully collected within the FSC suggests that FSC effectiveness continues to be constrained by the ability of the FSC to retain, rather than attract, outmigrating juvenile salmonids that are emigrating from Swift Reservoir.

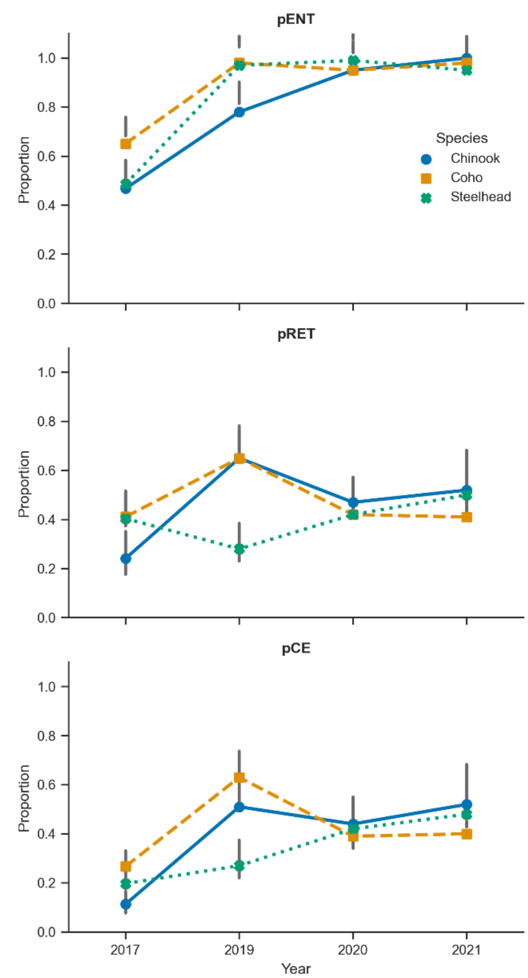


Figure 2. Swift floating surface collector performance metrics computed during 2017, 2019, 2020, and 2021 study years. Error bars indicate +/- one standard deviation returned using the mark-recapture model.

[1] Species designated in Section 4.1.7 of the 2004 Settlement Agreement are spring-run Chinook Salmon *Oncorhynchus tshawytscha*, winter steelhead *O. mykiss*, Coho Salmon *O. kisutch*, Bull Trout *Salvelinus confluentus*, and sea run Cutthroat Trout *O. clarkii*.

Table 1. Summary of results from Swift floating surface collector collection efficiency studies conducted between 2013 and 2021.

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_{ZOI} Estimate**	**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	79%	NA	NA	0%
				Coho Salmon	82	NA	44	6	54%	NA	NA	6%
				Steelhead	NA	NA	NA	NA	NA	NA	NA	NA
2014	Radio Telemetry	FSC	2 miles east of FSC	Chinook Salmon	20	NA	3	0	15%	NA	NA	0%
				Coho Salmon	157	NA	31	9	20%	NA	NA	29%
				Steelhead	16	NA	4	1	25%	NA	NA	25%
2015	Dual PIT/Acoustic Telemetry	Eagle Cliff Rotary Screw Trap/Hook and Line	Swift Forest Camp Boat Launch	Chinook Salmon	14	9	6	0	28%	NA	NA	0%
				Coho Salmon	139	126	110	13	72%	NA	NA	12%
				Steelhead	47	43	43	8	84%	NA	NA	19%
2016	Dual PIT/Acoustic Telemetry	FSC and Eagle Cliff Rotary Screw Trap	Swift Forest Camp Boat Launch	Chinook Salmon	3	1	1	0	11%	NA	NA	0%
				Coho Salmon	156	140	98	30	56%	NA	NA	31%
				Steelhead	40	28	17	4	30%	NA	NA	24%
2017	Dual PIT/Acoustic Telemetry	FSC	Swift Forest Camp Boat Launch	Chinook Salmon	108	75	62	7	57%	47%	24 %	11%
				Coho Salmon	232	184	164	46	74%	65%	41%	27%
				Steelhead	180	117	107	21	59%	49%	40%	20%
2018	PIT	FSC	Swift Forest Camp Boat Launch	Chinook Salmon	396	--	--	94	--	NA	NA	24%[2]
				Coho Salmon	484	--	--	191	--	NA	NA	40%[2]
				Steelhead	278	--	--	136	--	NA	NA	49%[2]
2019	Dual PIT/Acoustic Telemetry	FSC	Swift Forest Camp Boat Launch	Chinook Salmon	155	88	75	42	54%	78%	65%	51%
				Coho Salmon	300	175	167	156	82%	98%	65%	64%
				Steelhead	70	40	37	11	58%	97%	28%	27%
2020	Dual PIT/Acoustic Telemetry	FSC	Swift Forest Camp Boat Launch	Chinook Salmon	183	--	104	47	58%	95%	47%	44%
				Coho Salmon	185	--	112	45	62%	95%	42%	39%
				Steelhead	153	--	110	47	73%	99%	42%	42%
2021	Dual PIT/Acoustic Telemetry	FSC	Swift Forest Camp Boat Launch	Chinook Salmon	39	29	25	13	64%	100%	52%	52%
				Coho Salmon	212	186	179	71	84%	98%	41%	40%
				Steelhead	192	140	132	63	69%	95%	50%	48%

Notes:
Source: Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015; Caldwell et al. 2017; Anchor QEA 2018; PacifiCorp and Cowlitz County PUD 2019; Four Peaks 2020, 2021
1. For 2019 through 2021, seasonal performance metrics have been corrected for array detection efficiency.
2. In 2018, survival probability through reservoir (SRES) was used as a surrogate for collection efficiency.
-- = not calculated
NA = not applicable

1.4 Summary of Floating Surface Collector Adjustments

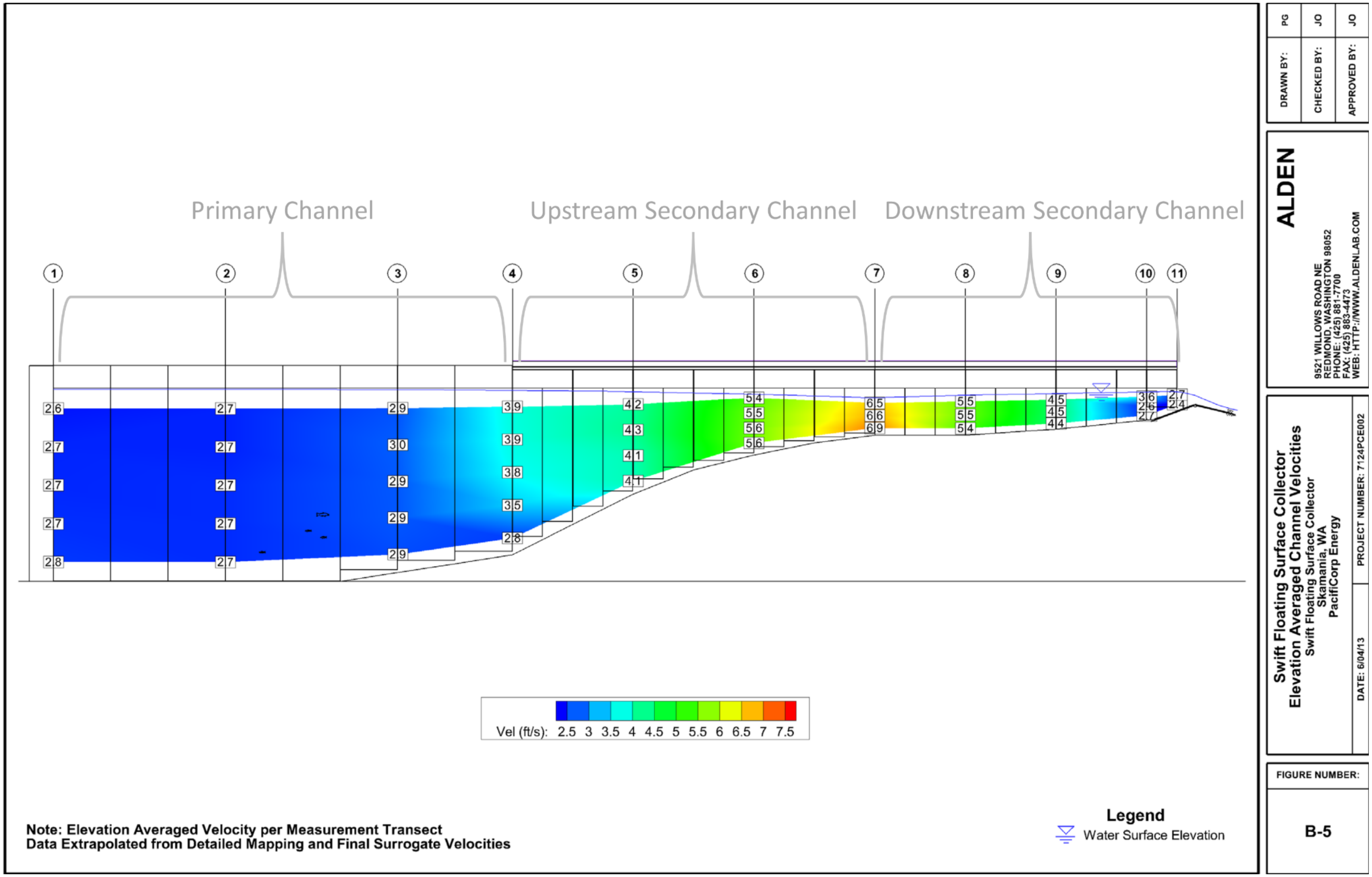
A series of adjustments have been made by PacifiCorp to improve FSC performance, and these appear to have increased P_{CE}. This section summarizes the more relevant changes to the FSC over the last 5 years. For example, installation of a 650-foot fish lead net in front of the FSC in early 2016 appeared to have resolved fish not locating the entrance of the FSC, but had limited success in getting them to transition in the NTS and collection channel (Caldwell et al. 2017).

In late 2017, FSC sorting area flow pumps were discovered to be creating noise within the audible range for juvenile salmonids that may have deterred smolts from entering the FSC. Thus, operation of the pumps was reprogrammed to reduce the acoustic noise signature produced (PacifiCorp and Cowlitz County PUD 2019). Results from a PIT-tag only study in spring 2018 indicated an increase in recapture rate of study fish released at the head of Swift Reservoir, suggesting that pump modifications may have further increased P_{CE} (PacifiCorp and Cowlitz County PUD 2019).

In 2019, additional adjustments were made to the FSC to increase the attraction flow through the NTS in an attempt to draw fish into the FSC. This was accomplished by installing a false floor in the bottom of the NTS and thereby decreasing the overall depth by 40% (from 37 feet to 22 feet). In addition to the false floor, adjustments were also made to the primary screen baffles to allow for operation of additional attraction pumps within the primary portion of the collection channel, increasing the attraction flow from 600 cfs to just under 860 cfs. By reducing the area of NTS and increasing attraction flow, water velocity at the entrance of the FSC increased from 0.5 ft/sec to approximately 1.3 ft/sec. Increased water velocity at the entrance of the FSC substantially increased the number of fish that entered the collection channel. However, results of the 2019 and 2020 collection efficiency studies showed that a large portion of fish that entered the fish collection channel still were not being collected, and that understanding the factors that are contributing to this is important for improving collection efficiency at the facility (Four Peaks 2020).

In 2021, PacifiCorp identified areas within the collection channel where hydraulic features (hydraulics) may affect fish passage by causing avoidance behavior in outmigrating smolts. These hydraulics were a side effect from adjustments made to the NTS in 2019 to increase attraction velocity at the entrance of the FSC. As a result of these adjustments, flow acceleration within the channel is no longer smooth and areas of slight but abrupt acceleration and deceleration now exist at transitions in channel geometry and materials (Figure 3).[2] Previous studies found that locations within the channel where fish rejected were similar to those of anticipated flow deceleration. Based on discussions with facility engineers, it was hypothesized that adjusting the pumping rate within the FSC could reduce the magnitude of these hydraulics and improve fish collection rates. To test this hypothesis, the pumping rates were systematically varied during the 2021 Study by switching between periods operating with all ten pumps running and with only eight pumps running. This experiment was carried out by following a block study design, which is described further in Section 2.4.1.

[2] Despite these adjustments, the overall pattern of relatively faster and slower areas noted in Figure 3 has remained consistent since facility design and construction (Chris Karchesky, personal communication, November 16, 2021).



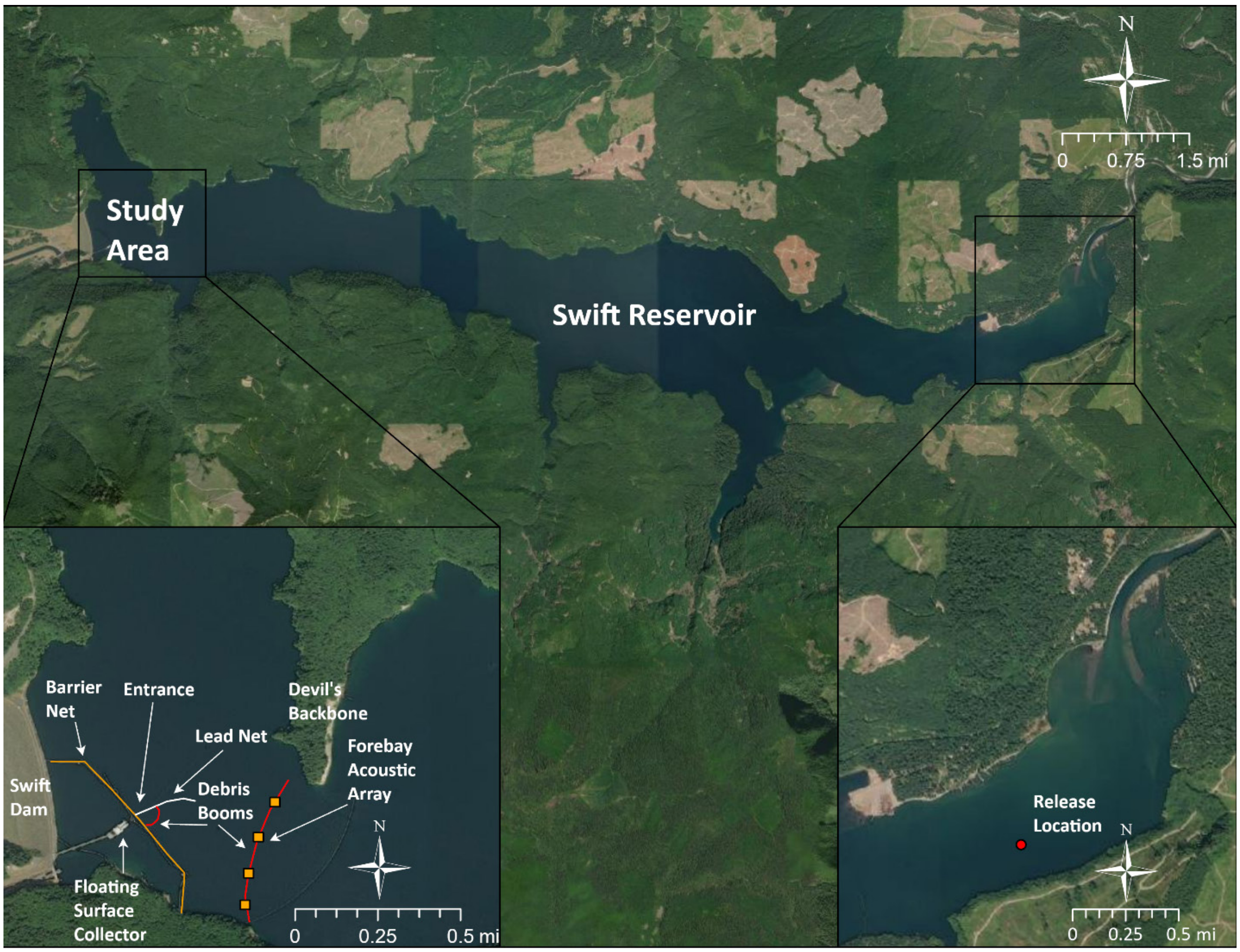
Notes: Source Christensen and Grant (2013). Actual water velocities have changed in response to modifications, but overall pattern remains (Chris Karchesky, personal communication, November 16, 2021).

Figure 3. Mapped and interpolated water velocities within the floating surface collector collection channel in 2013.

2 Methods

2.1 Study Location and Timing

The 2021 Study examined behavior of fish that were captured at the FSC, dual PIT- and acoustic-tagged, and released near the head of Swift Reservoir. After release, these tagged fish were then tracked to describe their behaviors in front of and within the Swift FSC. Fish are guided to the FSC by attraction flows created using pumps within the barge, and by the barrier and lead nets (Figure 4), a series of booms extending into the forebay help to shield the collector from large logs and debris.



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

Fish enter the FSC via the NTS, a rigid structure affixed to the FSC that funnels water and fish into an artificial stream channel (the collection channel). The collection channel entrains and guides fish from the NTS into the collection facility, where fish are size sorted into separate general life-stages (i.e., fry/parr, smolt, and adult), before being routed to holding tanks for biological sampling. Most fish are then transported and released downstream. However, fish included in the current study (study fish) are subsampled as they enter the collector, tagged, held in recovery tanks for 24 hours, then transported back upstream and released near the head of the Swift Reservoir, approximately 7.5 miles east of the FSC, near the south shore of the reservoir opposite from Swift Forest Camp Boat Launch.

Figure 5 provides a timeline of key milestones during the 2021 Study. On nine occasions between April 1 and June 1, 2021, a total of 443 study fish were selected from the run-at-large collected at the FSC. These study fish were tagged, transported to the upstream end of the reservoir, and released, after which they were monitored using acoustic receivers deployed in the forebay, ZOI, and FSC.

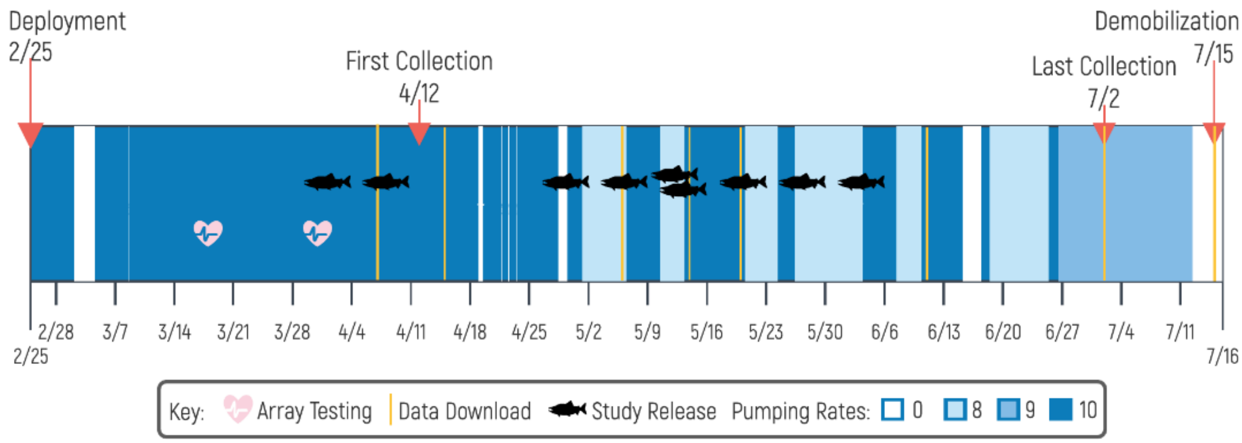


Figure 5. 2021 Swift floating surface collector passage evaluation timeline of key milestones and pumping rates.

On seven occasions during the study, the FSC was shut down to clear debris that had accumulated in the collection channel and perform any necessary repairs. Only the following two shutdown periods lasted longer than 1 hour:

- From 1013 on April 28 to 1123 on April 29
- From 0513 on June 15 to 0953 on June 17

Unless otherwise noted, all passage attempts during these periods when the collector was shut down were omitted from analyses and visualizations. On July 12, 2021, daily catch rates at the FSC had decreased to the level at which the collector could be shut down for summer maintenance (PacifiCorp 2015). The receivers were then removed from the water on July 15, 2021, at which point 34 study fish were still being detected on the array, almost entirely in the ZOI. The 2021 Study period thus spans from April 1, when the first study fish were released, to July 12, when the FSC was shut down.

2.2 Biotelemetry

2.2.1 Fish Tagging and Release

On nine occasions between April 1, 2021, and June 1, 2021, PacifiCorp staff selected study juvenile fish with fork length greater than 100 mm from the run-at-large captured by the Swift FSC (APPENDIX A, Appendix Table A.4). This collection strategy is consistent with that employed during the 2017, 2019, and 2020 studies. For studies prior to 2017, attempts were made to collect test fish from a screw trap at Eagle Cliff (just upstream of the head of Swift Reservoir). However, fish available for collection at Eagle Cliff were generally smaller than, and thus not representative of, fish collected at the FSC (Caldwell et al. 2017). Thus, since 2017, all fish have been collected and tagged at the FSC. For the purpose of comparing results between 2017 and subsequent study years, any non-naïve bias is assumed to be consistent across years.

Target sample sizes for 2021 were developed to provide a 6% margin of error within a 90% confidence interval for computations based on all study fish. The targets were based on counts of juvenile fish collected at the Swift FSC in 2019, the most recent available data (PacifiCorp and Cowlitz PUD 2020) (Table 2). Chinook Salmon target sample size was adjusted downward because run size for that species was anticipated to be lower in 2021. Even so, lower than expected abundance of outmigrating juvenile Chinook Salmon prevented achievement of this adjusted target sample size for Chinook. Extra tags were thus apportioned among Coho Salmon and steelhead.

Table 2. Recommended, adjusted, and actual sample sizes for 2021.

Species	Juveniles Collected at Swift FSC in 2019	Target Margin of Error	Target Confidence Interval	Recommended Sample Size for 2021	Adjusted Sample Size for 2021	Actual Sample Size in 2021	Actual Margin of Error
Chinook	10,951	6%	90%	185	90	39	13%
Coho	99,057	6%	90%	188	188	212	5.60%
Steelhead	3,085	6%	90%	178	178	192	5.80%

After collection, each fish was anesthetized with MS-222 (Tricaine methanesulfonate) and surgically implanted with an Advanced Telemetry Systems (ATS) SS400 acoustic transmitter (Table 3) and a Biomark 12.5 mm, 134.2 kilohertz ISO FDX-B PIT tag using the methodology described in Reynolds et al. (2015). Following tagging, fish were allowed to recover overnight and then transported by boat to the Swift Forest Camp release site at the eastern end of Swift Reservoir (Figure 4) where they were subsequently released.

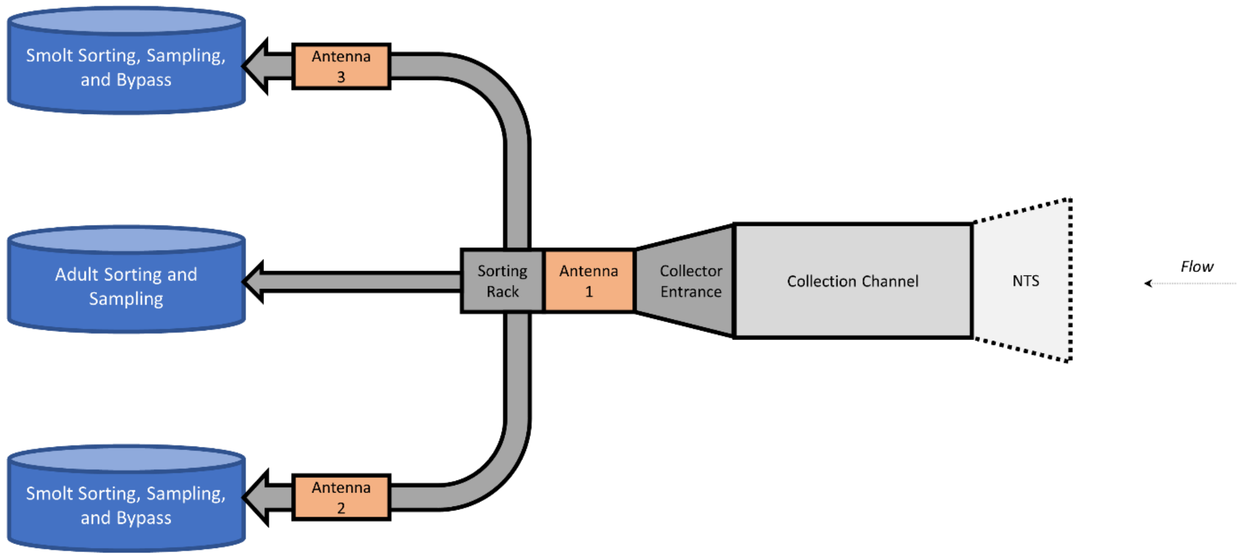
PIT tags were scanned using an HPR Plus reader after implantation, and data were uploaded to PTAGIS using P4 software with associated information on species, length, and paired acoustic tag code. Acoustic tag activation, implantation, and functionality after implantation were confirmed using a hydrophone and receiver that were deployed in the recovery tank to monitor acoustic tag signals. Following each release, PacifiCorp and Four Peaks Environmental Science & Data Solutions (Four Peaks) staff confirmed data consistency by comparing receiver data and tagging files.

Table 3. Technical specifications for acoustic tags used in the 2021 Swift floating surface collector passage evaluation.

Parameter	Value
Length	14.98 mm
Diameter	3.21 mm
Mass	217 mg
Ping Rate	3 seconds
Nominal Tag Life	48 days
Minimum Fish Size (FL)	95 mm

2.2.2 Fish Detection and Recapture

Tagged fish were tracked as they approached and interacted with the Swift FSC by using a combination of PIT and acoustic technology. The acoustic monitoring encompassed an array of hydrophones and associated acoustic telemetry receivers deployed in the forebay and FSC, focusing on the NTS and collection channel, with coarser resolution in the ZOI. This array detected fish as they entered the forebay, approached the collector, entered the collector through the NTS, and transited the collection channel as they approached the entrance to the collection facility. Collection in the FSC was confirmed with a series of PIT antennas on the sorting and collection flumes inside the FSC (Figure 6).

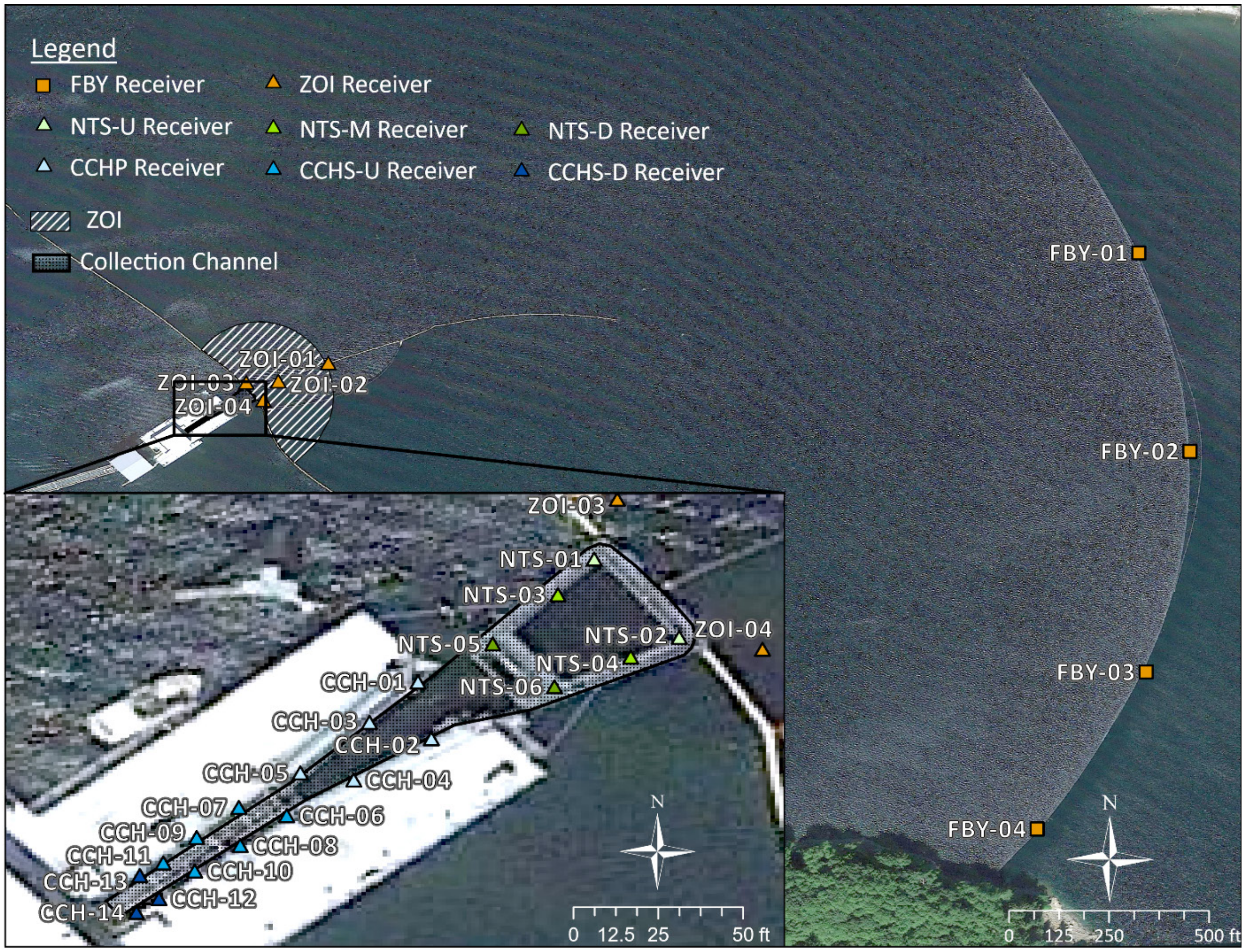


Source: Redrawn, after https://www.ptagis.org/sites/interrogation-site-metadata?IntSiteCode=SHP
Figure 6. Swift hydroelectric project passive integrated transponder interrogation site antenna configuration inside the floating surface collector.

2.2.3 Acoustic Telemetry Array

From February 22 through 28, 2021, Four Peaks staff installed an acoustic telemetry array comprising 28 receivers in the Swift Dam forebay (Figure 7), plus a remote receiver within the recovery tank for confirming tag activation. The 28 forebay receivers covered four zones that were defined in terms of 2D areas: forebay (FBY), ZOI, NTS, and collection channel (CCH). For the purposes of fine-scale behavioral analyses, the NTS was further divided into upstream and downstream sub-zones, and the collection channel was further divided into the primary screen collection channel (primary channel), the upstream secondary screen collection channel (upstream secondary channel), and the downstream secondary screen collection channel (downstream secondary channel) sub-zones. Each zone or sub-zone was monitored using a dedicated subarray of telemetry receivers, as described below:

- Four autonomous receivers in the FBY (FBY-01 to FBY-04)
- Four cabled receivers in the ZOI (ZOI-01 to ZOI- 04)
- Six cabled receivers in the NTS (NTS-01 to NTS-06)
- Five cabled receivers in the primary channel (CCH-01 to CCH-05)
- Six cabled receivers in the upstream secondary channel (CCH-06 to CCH-11)
- Three cabled receivers in the downstream secondary channel (CCH-12 to CCH-14)



Spatial Reference: GCS WGS 1984; Aerial imagery source: Google. Additional cartography data sources: ESRI. Map conceived and drawn using ArcGIS Pro.

Figure 7. Overview of acoustic telemetry receiver array locations within the Swift floating surface collector and forebay. Squares depict SR3001 autonomous receivers while triangles depict SR3017 cabled receivers.

Hydrophone deployments in the collection channel required consideration of the fast-flowing water and confined area, the combined effects of which create an acoustically noisy environment that make it difficult to detect tags in the channel. To address these challenges, a dense array of hydrophones was deployed behind the dewatering screens, in a cone shaped baffle, with the tip of each hydrophone pointed towards the dewatering screen, perpendicular to the direction of flow (Figure 8). This deployment kept the collection channel hydrophones out of the fast-moving collection channel water and reduced noise levels at the hydrophone enough to detect study tags. Details of deployment methods are provided in APPENDIX A.

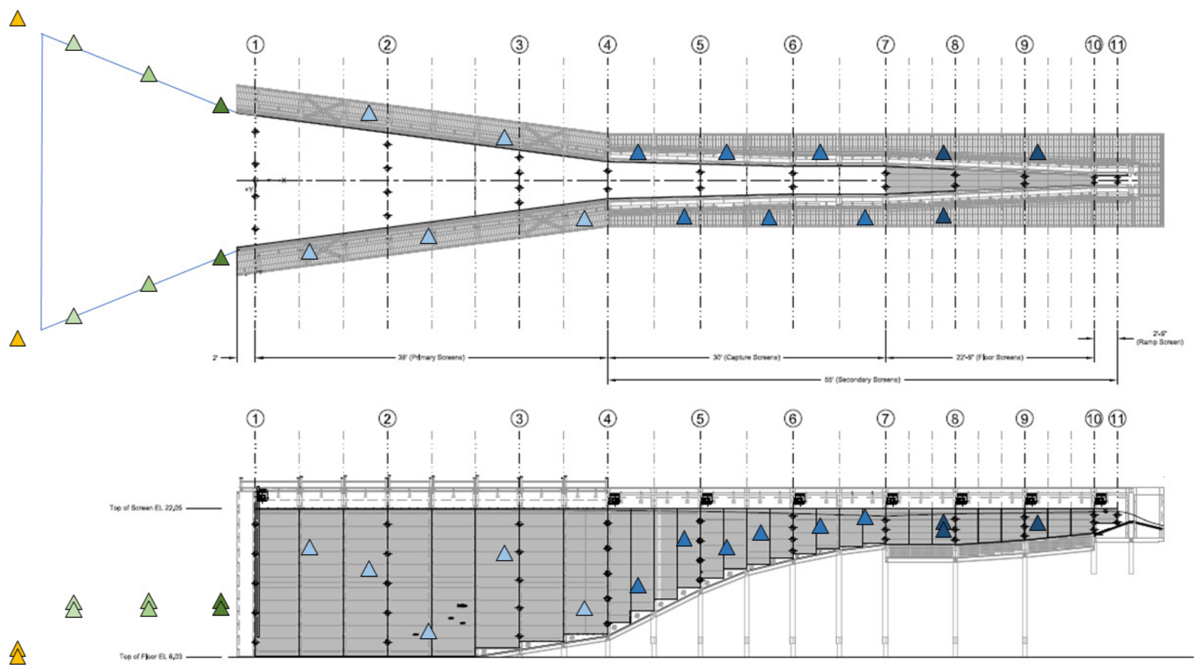


Figure 8. Swift floating surface collector schematic diagram, showing plan view (top) and longitudinal cross-section (bottom) of the collection channel. The net transition structure is shown with blue lines in the top plan view, and approximate locations of hydrophones are shown as triangles. Colors correspond to zones listed in Figure 7.

2.2.4 Telemetry Array Testing and Validation

Field testing of the acoustic telemetry equipment was conducted during and after deployment (Figure 5). Field testing included a series of tag drags, floats, and holds, using test acoustic telemetry tags. Data collected during testing included known time and position of the test tags during the tests and the detection data collected by the acoustic receivers. These data were used to verify that the receivers were functioning and to evaluate the ability of the data processing computer code to determine the presence of a tag within a given zone (Section 2.2.6). This preseason testing verified that equipment was deployed properly and could accurately assess tag presence within the subarray zones (ZOI, NTS, and collection channel). Detailed testing methods are described in APPENDIX A.

2.2.5 Data Processing and Quality Control

Throughout the study season, Four Peaks staff maintained and downloaded the array on a regular basis (Figure 5 and APPENDIX A).This regular schedule of maintenance verified that the acoustic telemetry equipment deployed as part of this study functioned as expected, and that malfunctions were detected and addressed before having major impacts on the data collected for the study.

2.2.5.1 Acoustic Telemetry Data

Detection data were downloaded from the receivers on an approximately bi-weekly schedule (Figure 5) and backed-up to secure cloud-based storage. Forebay receivers were downloaded less frequently, due to the logistical constraints around access to these receivers by boat. After downloading data from each receiver, a formatted (blank) memory card was placed back in the receiver. A detailed data processing schedule is provided in APPENDIX A.

After each download, acoustic data were filtered to remove multipath and false positive signals using methods described in Weiland et al. (2009). In the forebay and ZOI, an additional filtering step was performed to limit spurious tag detections. This filter required three detections of an acoustic tag within a 180-second window on a given receiver to be considered a valid detection. This filter was not applied to data collected on receivers in the NTS and the collection channels because the faster-flowing water in the NTS and collection channel areas limited the number of detection opportunities for a tag on a single receiver in these areas. The filtered data were combined across multiple receivers to create a single file with all acoustic detections in the period, which was carried forward for further processing (Section 2.2.6).

Automated diagnostic processing scripts were applied to the acoustic data after each download to check data quality. These diagnostics enabled the team to quickly verify that receivers were functioning correctly and that corrupt records were removed. Furthermore, these diagnostics provided insight into ambient noise conditions at the FSC enabling detection of conditions that required additional investigation.

2.2.6 Zone Presence Estimates

After initial filtering (Section 2.2.5), acoustic detection data were further processed to determine when fish were present within a given zone (e.g., ZOI, NTS) along the approach to collection. The output of this additional processing was the time series of zone presences for each tag, which is termed the zone presence time series (ZPTS).

ZPTS processing uses a simplified time-of-arrival difference analysis (Deng et al. 2011). As described by Deng et al., time-of-arrival difference is a method for 3D positioning. However, the array design used in the 2021 Study did not provide the spatial coverage required for enough simultaneous detections to support 3D positioning. Instead, the simplified time-of-arrival difference method applied was a form of 1D positioning, with a target of identifying longitudinal position within a linearized array schema.

This positioning method estimates which zone the tag is in when it transmits a signal (ping) by comparing detection times of a ping on multiple receivers. The method relies on grouping together detections across receivers for a single tag code and then ordering them chronologically to provide an understanding of where an individual is in the array. Figure 9 provides a visual depiction of this process, in which a single ping is detected by receivers in the NTS, primary channel, and ZOI. The order in which this detection occurs is then combined with logic developed empirically using the test data collected during deployment to estimate which zone the individual is in within the acoustic array.

The zone presence processing computer code was developed by establishing, testing, and then iteratively adjusting a suite of zone presence criteria (ZPC). These criteria evaluate an acoustic signal logically and quantitatively to determine its location. ZPC were initially constructed by using acoustic data collected during pre-season testing (Section 2.2.4) and then developing logical criteria that correctly assigned zones for tags at known times and locations during test holds, floats, and drags. After formulating the initial set of ZPC for each zone, these criteria were verified by running them on a separate set of test data that were collected during tests performed throughout the early part of the season. Their performance then was evaluated by calculating zone presence efficiency, which is defined as the frequency at which the tag was positioned in the correct zone. The final ZPC are explained in detail in APPENDIX A. Establishment of these ZPC then enabled the construction of a presence-absence matrix for the entire study that was used to inform mark-recapture models.

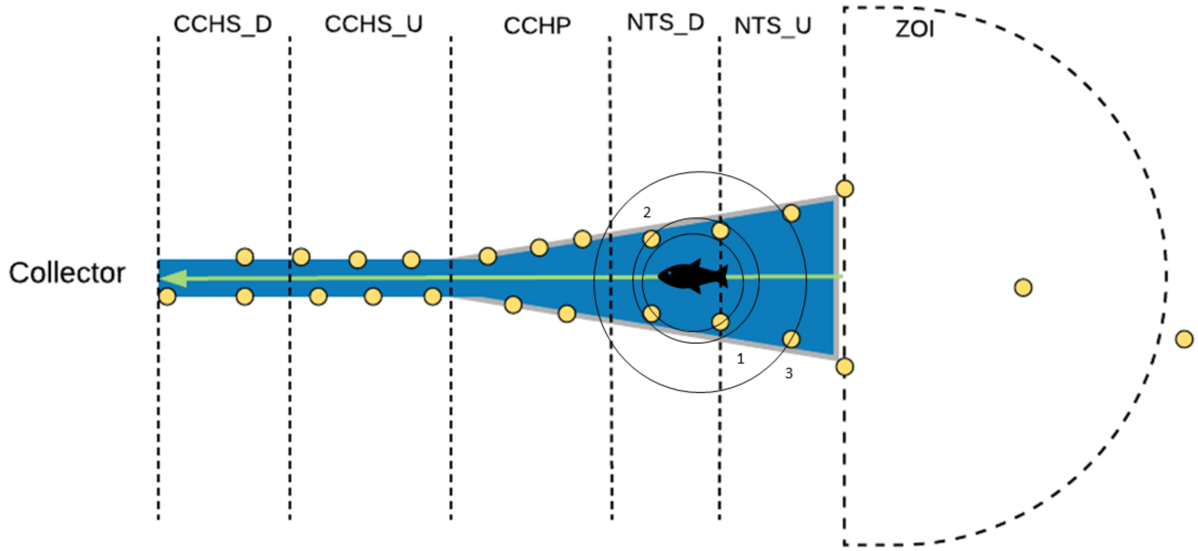


Figure 9. Visual depiction of an acoustic signal being emitted from a tag within a fish and being detected in the net transition structure, primary screen collection channel, and zone of influence. The numbers depict the order in which each receiver picks up the tag signal; in this case, the signal is heard first on NTS-01, then on CCH-01, and finally on ZOI-02. Based on time-of-arrival difference values across these receivers, the tag would be positioned within the net transition structure.

2.3 Performance Metrics

Key performance metrics for the 2021 Study included P_{PASS}, P_{ENC}, P_{ENT}, P_{CE}, P_{RET}, P_{CHAN}, and P_{CAP} (Table 4). These metrics quantify the probability that a study fish within a given zone will transition downstream. Each is calculated as a proportion of fish in two zones, where the denominator is the number of fish detected in the upstream zone, and the numerator is the number of fish detected in both the upstream and downstream zones. Correction factors based on downstream detections are then applied to these raw proportions to account for receiver detection efficiency (White and Burnham 1999). Discussion of how individual metrics were calculated is provided in Table 4 and APPENDIX A.

Table 4. Performance metrics.

Metric	Description	Calculation (Uncorrected)[1]
Reservoir passage (P_{PASS})	The proportion of study fish released that enter the forebay.	$P_{PASS} = \frac{DET_{FBY}}{R}$
FSC encounter rate (P_{ENC})	The proportion of study fish detected in the forebay that enter the ZOI.	$P_{ENC} = \frac{(DET_{FBY} \cap DET_{ZOI})}{DET_{FBY}}$
Entrance efficiency (P_{ENT})	The proportion of study fish detected in the ZOI that enter the NTS.	$P_{ENT} = \frac{(DET_{ZOI} \cap DET_{NTS})}{DET_{ZOI}}$
Collection efficiency (P_{CE})	The proportion of study fish detected in the ZOI that are re-captured at the FSC.	$P_{CE} = \frac{(DET_{ZOI} \cap C)}{DET_{ZOI}}$
Retention efficiency (P_{RET})	The proportion of study fish detected in the NTS that are re-captured at the FSC.	$P_{RET} = \frac{(DET_{NTS} \cap C)}{DET_{NTS}}$
Channel efficiency (P_{CHAN})	The proportion of study fish detected in the NTS that enter the collection channel.	$P_{CHAN} = \frac{(DET_{NTS} \cap DET_{CHAN})}{DET_{NTS}}$
Channel-collector transition rate (P_{CAP})	The proportion of study fish detected in the collection channel that are re-captured at the FSC.	$P_{CAP} = \frac{(DET_{CHAN} \cap C)}{DET_{CHAN}}$

Note:
1. Equations associated with Program MARK computations are presented in APPENDIX A.
∩ symbol indicates the intersection of two sets, i.e., fish detected in both zones.

2.3.1 Floating Surface Collector Performance Metrics Computation

After zone presence was established for all individuals (Section 2.2.6), the corresponding presence-absence matrix was computed. The presence-absence matrix describes the detection history for each study fish (APPENDIX B). The presence-absence matrix was used to fit Cormack-Jolly-Seber mark-recapture models to estimate zonal survival and detection probabilities. The R (R Core Team 2020) package RMark (Laake 2019) was used to implement a version of Program MARK (White and Burnham 1999), which itself constructs a Cormack-Jolly-Seber mark-recapture model. All survival and detection probability parameters were estimated within this mark-recapture model framework fit using maximum likelihood methods.

These parameter estimates were used to provide estimates of the key project metrics along with associated confidence intervals, which were computed by pooling all study fish to develop seasonal estimates. A separate set of mark-recapture models was also constructed to estimate survival and detection through the primary and secondary channels, also as pooled seasonal estimates. This allowed transition into each of these reaches to be individually estimated to determine if areas within the channel impeded migration. While the estimates corresponding to these models were not used to directly inform collection efficiency metrics, they are useful in identifying bottlenecks within the FSC that might affect overall passage.

Although the daily rate of passage attempts and relative success of these attempts does vary through the season at the Project (Sections 3.3 and 3.4), the appropriateness of pooled seasonal estimation of metrics for the 2021 Study is supported by two observations. First, the study period encompasses the entire spring-summer phase of outmigration for each study species within Swift Reservoir (Section 3.2 and Figure 11, below). This means that study fish encompass subsamples of the run-at-large from the entire time distribution of the run, providing adequate representativeness of the overall parent population from which the sample of study fish are drawn. Second, passage through the Swift FSC is the only route for fish to outmigrate from Swift Reservoir, meaning that there is no need to indirectly infer how many additional fish outmigrated via alternate passage routes.

2.4 Passage Attempt Behavioral Analysis

To develop insights about specific locations of collector rejection and about factors hypothesized to affect recapture, behaviors of study fish that entered the collector were examined further. This process included categorizing the sequence of inferred zone presences into groups representing distinct "passage attempts." Consistent with previous Swift FSC evaluations, a passage attempt was considered to encompass the behaviors from the time a given fish was first detected transitioning into the collection channel until the time when it exited (including being collected). Attributes of these passage attempts were then analyzed for patterns at the seasonal and daily time scale and to evaluate the importance of biometric and conditional (operational and environmental) factors hypothesized to affect passage success. Analyses focused on passage attempts that occurred during periods when the collector was operational. The goal of these efforts was to increase understanding regarding specific environmental, operational, and biological factors that may influence fish passage success at the Swift FSC. These factors include the effects of an experimental manipulation of the pumping rate within the FSC (Section 2.4.1). To support these behavioral analyses, a suite of monitoring data was collected to characterize the environmental and operational conditions in and around the collector throughout the study period (Section 2.4.2).

2.4.1 Pumping Rate Study

Hydraulic modeling of the flow field within the collector indicated that adjustments made prior to the 2020 season to encourage fish to enter the collector may have resulted in areas of slight deceleration at the interface between the NTS and primary fish channel and again between the interface between the primary and secondary fish collection channels that could deter fish from entering the collection channel (Chris Karchesky, personal communication, April 22, 2021). Assuming that these areas of slight deceleration could be lessened by changing the FSC pumping rate, two of the attraction flow pumps were experimentally shut off during periods within a subset of the study period, following a blocked design (Figure 10). This experiment was run over the course of 56 days, from April 26 to June 20, following a 3-7-4 pattern for the duration (in days) of each block. This design split each calendar week throughout the experiment between the two treatments, while also balancing each treatment in terms of the following parameters:

- The total number of days
- The total number of blocks
- The number of each type of block (3-day, 4-day, and 7-day)
- The composition of days of the week

Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday
				April 26	April 27	April 28
				All 10 On (3d block)		
April 29	April 30	May 1	May 2	May 3	May 4	May 5
8 On (7d block)						
May 6	May 7	May 8	May 9	May 10	May 11	May 12
All 10 On (4d block)				8 On (3d block)		
May 13	May 14	May 15	May 16	May 17	May 18	May 19
All 10 On (7d block)						
May 20	May 21	May 22	May 23	May 24	May 25	May 26
8 On (4d block)				All 10 On (3d block)		
May 27	May 28	May 29	May 30	May 31	June 1	June 2
8 On (7d block)						
June 3	June 4	June 5	June 6	June 7	June 8	June 9
All 10 On (4d block)				8 On (3d block)		
June 10	June 11	June 12	June 13	June 14	June 15	June 16
All 10 On (7d block)						
June 17	June 18	June 19	June 20			
8 On (4d block)						

Figure 10. Blocked pumping rate study design calendar schematic.

2.4.2 Environmental and Operational Monitoring

Environmental and operational monitoring data were collected during the 2021 study period and used to analyze how conditions influence fish interactions with the FSC and, ultimately, collector performance metrics. The following subsections summarize methods associated with this monitoring; details are provided in APPENDIX A.

2.4.2.1 Weather

A weather station was installed on the northeast corner of the FSC deck and deployed with sensors that recorded wind speed, wind direction, barometric pressure, rainfall, and air temperature observations at 15-minute intervals. Water temperature in the forebay was monitored with wireless temperature loggers deployed off the northeast corner of the FSC deck at 5, 10, 15, and 20 feet below the water surface. Light levels on the FSC deck were monitored using an array of five wireless light level loggers affixed to the north side (port) deck rails with cable ties, spaced evenly along the length of collection channel and positioned to face directly upward (i.e., at the zenith angle).

2.4.2.2 Forebay Debris Loading

Forebay debris loading was monitored using two trail cameras affixed to the upstream end of the NTS deck and positioned to capture timelapse images of the forebay. Data from these systems were downloaded during each data download site visit (Figure 5).

2.4.2.3 Human Activity

Human activity on the FSC deck was monitored using seven trail cameras affixed at various positions on the deck and overlooking the collection channel. Three cameras were positioned on the collector deck, one of which was pointed at the collector entrance stairs at the downstream end of the FSC. These documented human presence on the FSC, as may create an auditory disturbance by producing sounds that startle fish. Four additional cameras were positioned overlooking the collection channel, to capture images of human activity within the visible prism directly above the channel, as may create a visual disturbance for fish attempting passage. Data from these cameras were downloaded during each data download site visit (Figure 5).

2.4.2.4 Operational Sound

To investigate whether operational sound is transmitted through the FSC deck and into the water of the collector environment, two sound monitoring hydrophones were installed at the upstream end of the collector, one off the north side of the FSC deck and one in the channel at the upstream end of the NTS, on April 7, 2021. Data from the sound monitoring equipment were collected on the site visits that occurred after this date (Figure 5). Equipment malfunctions corrupted some of these data resulting in data loss. Valid sound monitoring data were obtained for the study periods spanning the following date ranges:

- May 6 to 7, 2021
- May 14 to 18, 2021
- May 20 to July 12, 2021

Although sound monitoring data were not available for a portion of the study season, the date ranges above—for which sound data were available—comprised 94% of the passage attempts included in the behavioral analysis.

Additional evaluations of sound were conducted by analyzing patterns of false detections on the acoustic telemetry receivers. The JSATS telemetry receivers continuously process sound pressure in the water to identify pings originating from JSATS acoustic transmitters. Other sound in the water can be misidentified as a tag code, and thus generate a false detection. Higher noise levels in the water are usually associated with a greater number of false detections. The frequency of false tag detections on the JSATS receivers were therefore used as a surrogate for operational sound levels in the collection channel. The patterns of these false detections can provide insight into prevalence and duration of noise levels above the normal background noise in the water and be used to infer operational activity. Following this approach, false detections from the JSATS receivers were used to identify periods of relatively higher and lower background noise, which were then compared with operational records to identify changes in pumping rates and periods during which the secondary screen cleaners were operated.

2.4.3 Initial Data Processing to Identify Passage Attempts

The ZPTS (Section 2.2.6 and APPENDIX A) for fish that entered the collector were processed to build a dataset of passage attempts. As described in Section 2.4, a passage attempt encompassed detections between the time when a given fish was first detected transitioning into the collection channel until the time when it exited. “Exits” include fish moving downstream to collection within the FSC and fish moving back upstream and exiting the collection channel via the NTS. Data were processed to assign each passage attempt with start and end times and with the furthest downstream zone reached during the attempt. Biometric attributes of each study fish (e.g., species, length), associated metadata (e.g., date of tagging), and environmental conditions (e.g., water temperature) were also assigned to each passage attempt.

2.4.4 Attempt Filtering

After acoustic detections of dual-tagged study fish were grouped into passage attempts, time series plots depicting the sequence of zone presence for each fish were developed (APPENDIX A). Using the following set of logical criteria (see APPENDIX A for details), these plots were then evaluated to remove detection sequences that likely do not represent true passage attempts:

1. Attempt duration must be longer than 10 seconds. Filtering these very short attempts eliminated spurious channel zone presences that were more likely caused by fish holding in the NTS near the entrance to the channel than actual attempts to enter the collection channel.
2. Attempt duration must be shorter than 6 hours. Filtering these very long attempts eliminated attempts for which one or more detections were missed during channel entry or exit, as may arise due to tag battery failure. Including these apparently very long attempts would bias analyses that consider attempt duration.
3. Time series plots of the ZPTS must resemble active fish behavior. This eliminated spurious detections associated with noise, fish holding near zone boundaries, and other activity not likely to reflect an actual attempt.

This process resulted in a filtered set of passage attempts, with each fish exhibiting a mean of approximately 16 attempts (range 1 to 528). Unless otherwise indicated, the resulting group of retained attempts was used for visualizations and statistical comparisons presented in the sections below.

2.4.5 Analyses

2.4.5.1 Exploratory Data Analysis

The set of reliable passage attempts (Section 2.4.4) was analyzed for differences among groups of fish. An initial phase of exploratory data analysis was conducted by summarizing and visualizing the passage attempts dataset across multiple parameters. Results from these efforts (presented in APPENDIX B) informed statistical analyses and modeling described in the following section.

2.4.5.2 Statistical Analysis and Modeling

Four sets of statistical models were developed to investigate the factors that might affect passage attempt success. The purpose of these efforts was to understand how environmental, operational, and inherent biological factors affect juvenile fish passage at the Swift FSC. These model sets included the following:

1. A set of models to evaluate the effects of pumping rate on passage success and attempt rate
2. A set of models to evaluate the effects of inherent biological attributes like fish length on passage success for individual fish
3. A set of models to evaluate the effects of environmental and operational factors on the success of individual attempts (i.e., including all attempts for fish that made multiple attempts). To account for the gap in operational sound data (Section 2.4.2.4), a separate set of models were constructed for the period that did include sound monitoring data. Inferences regarding effects of sound were based on these models, unless otherwise indicated.
4. A set of models to evaluate the effects of environmental and operational factors on the number of fish attempting passage per day.

Each model included a subset of the variables shown in Table 5 (see APPENDIX A for details).

Table 5. Potential environmental, operational, and inherent biological factors affecting juvenile fish passage at the Swift floating surface collector that were considered in models of passage success.

Variable	Description
Number of pumps	Number of FSC pumps in operation at the time of passage
Species	The species of the fish: Chinook Salmon, Coho Salmon, steelhead
Fork length	Fork length at tagging
Date of release	Date that the fish was released back to the water after tagging
Date of passage attempt initiation	Date that the fish began a given passage attempt
Luminosity	Average luminosity within the channel at time of passage attempt initiation
Hour of passage attempt initiation	Hour that the fish began a given passage attempt
Water temperature	Water temperature at 5-foot depth at time of passage attempt initiation
East wind	Speed of mean hourly winds from the east, averaged over the 48 hours prior to the passage attempt initiation
Pressure	Cumulative change in pressure over the 48 hours prior to the passage attempt initiation
Debris loading (current)	Forebay debris loading score on the day of the attempt initiation
Debris loading (prior)	Forebay debris loading score on the day prior to the attempt initiation
SPL	Sound pressure level at the time of the attempt initiation
Sound pressure	Averaged sound pressure level on the day of the attempt initiation
SEL	Sound exposure level integrated over the day of the attempt initiation
Human activity	Indicator of human activity captured by cameras at the time of the attempt initiation
Total human activity	Total human activity score (based on photographs) on the day of the attempt initiation
Spray bar	Indicator of spray bar operation at the time of the attempt initiation
Operational noise	Operational noise level at the time of the attempt initiation

Additional statistical comparisons among groups were conducted using Welch's unequal variance (independent) *t*-tests (*t*-tests), Tukey's honestly significant difference tests (Tukey's HSD), or chi-squared (χ^2) tests for equality of proportions, depending on the metric and number of groups being compared. Because a priori hypotheses did not predict a direction of the effect examined, all tests were conducted "two-sided." Detailed methods are provided in APPENDIX A.

3 Results

3.1 Array Performance

Equipment testing conducted during deployment and throughout the 2021 Study indicated that the acoustic telemetry array performed as designed, and that algorithms and in-person testing developed to process detection data was capable of accurately positioning acoustic tags within each zone. Detailed array performance results are provided in APPENDIX A.

3.2 Tagging Operations

Release of study fish followed a typical seasonal pattern: from study initiation through 8 April, only Chinook Salmon were tagged and released. From 8 April through 12 May, the number of Chinook Salmon tagged decreased, while the numbers of Coho Salmon and steelhead tagged increased. Peak tagging occurred on 8 April for Chinook Salmon, 12 May for Coho Salmon, and 27 May for steelhead. A total of 443 individuals (39 Chinook Salmon, 212 Coho Salmon, and 192 steelhead) were dual-tagged and released between 1 April and 1 June 2021 (Table 6). Acoustic release proportions generally paralleled the run-at-large for each species (Figure 11).

Table 6. Summary of the number and fork length (mm) of salmonids tagged with dual passive integrated transponder and acoustic tags during the 2021 Swift floating surface collector passage evaluation.

Release Date	Chinook Salmon			Coho Salmon			Steelhead		
	No. Tagged	FL Mean (SD) (mm)	FL Median (Range) (mm)	No. Tagged	FL Mean (SD) (mm)	FL Median (Range) (mm)	No. Tagged	FL Mean (SD) (mm)	FL Median (Range) (mm)
4/1/2021	10	144 (14.1)	142 (121 – 166)	-	-	-	-	-	-
4/8/2021	26	153 (9.8)	154 (131 – 169)	-	-	-	-	-	-
4/29/2021	-	-	-	5	144 (20.7)	142 (117 – 175)	51	188 (19.2)	185 (153 – 225)
5/6/2021	2	137 (26.2)	137 (118 – 155)	29	159 (17.9)	155 (125 – 209)	27	197 (23.0)	190 (165 – 257)
5/12/2021	1	152 (--)	152 (--)	32	161 (12.2)	160 (142 – 183)	27	195 (20.2)	190 (169 – 239)
5/13/2021	-	-	-	31	159 (15.1)	156 (135 – 197)	28	196 (21.9)	196 (160 – 243)
5/20/2021	-	-	-	30	153 (15.1)	155 (125 – 185)	29	193 (19.2)	194 (161 – 240)
5/27/2021	-	-	-	30	154 (16.5)	153 (125 – 191)	30	188 (15.4)	191 (156 – 227)
6/1/2021	-	-	-	55	152 (17.1)	148 (122 – 182)	-	-	-
Total	**39**	**150 (12.5)**	**152 (118 – 169)**	**212**	**156 (16.2)**	**155 (117 – 209)**	**192**	**192 (19.9)**	**190 (153 – 257)**

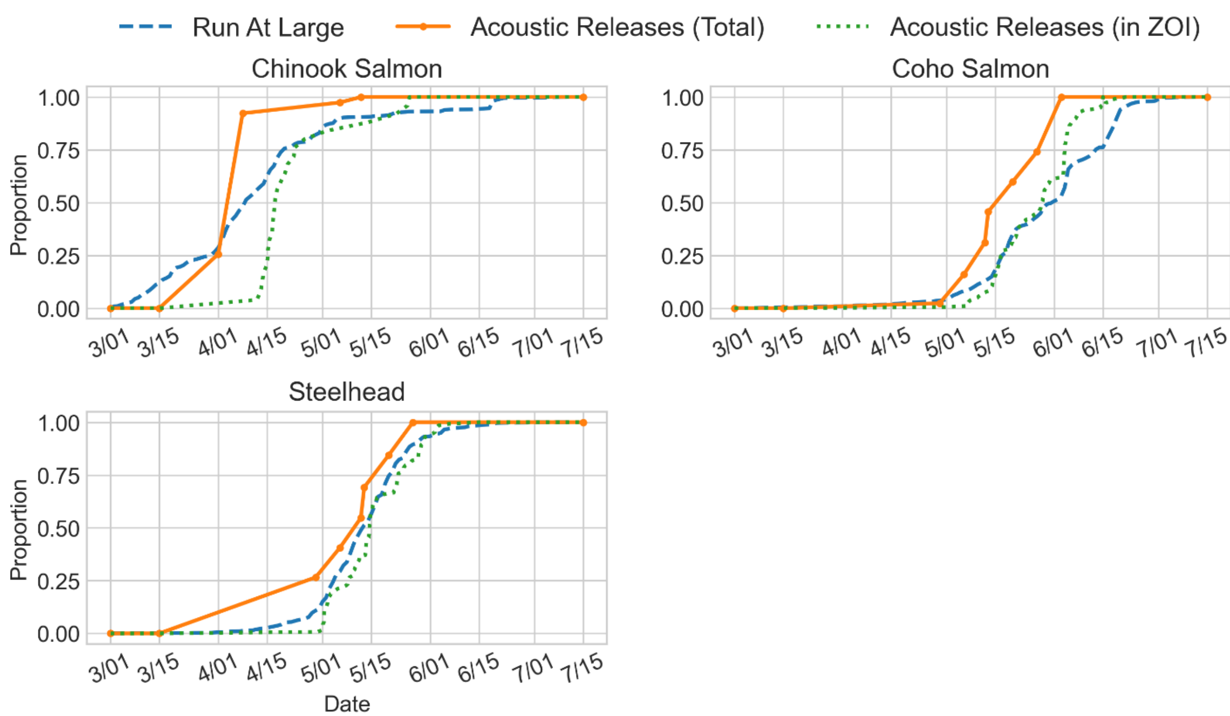


Figure 11. Cumulative distribution functions for each species, showing proportions of the total number of fish acoustically-tagged and released (solid orange lines), the total number of fish acoustically tagged and appearing in the ZOI (dotted green line), and of the background run-at-large collected at the Swift floating surface collector for transport and release downstream (dashed blue lines) in 2021.

Dual-tagged Chinook Salmon and steelhead in 2021 were similar in length as compared to study fish from 2020, while Coho Salmon were approximately 12 mm longer in 2021 than in 2020 (Figure 12). The magnitude of differences in fish length among years varied across species, but differences in length were generally small to moderate (2-38 mm difference between years). All differences in length among years that are depicted as statistically significant in Figure 12 were highly significant (Tukey's HSD, $p \leq 0.004$).

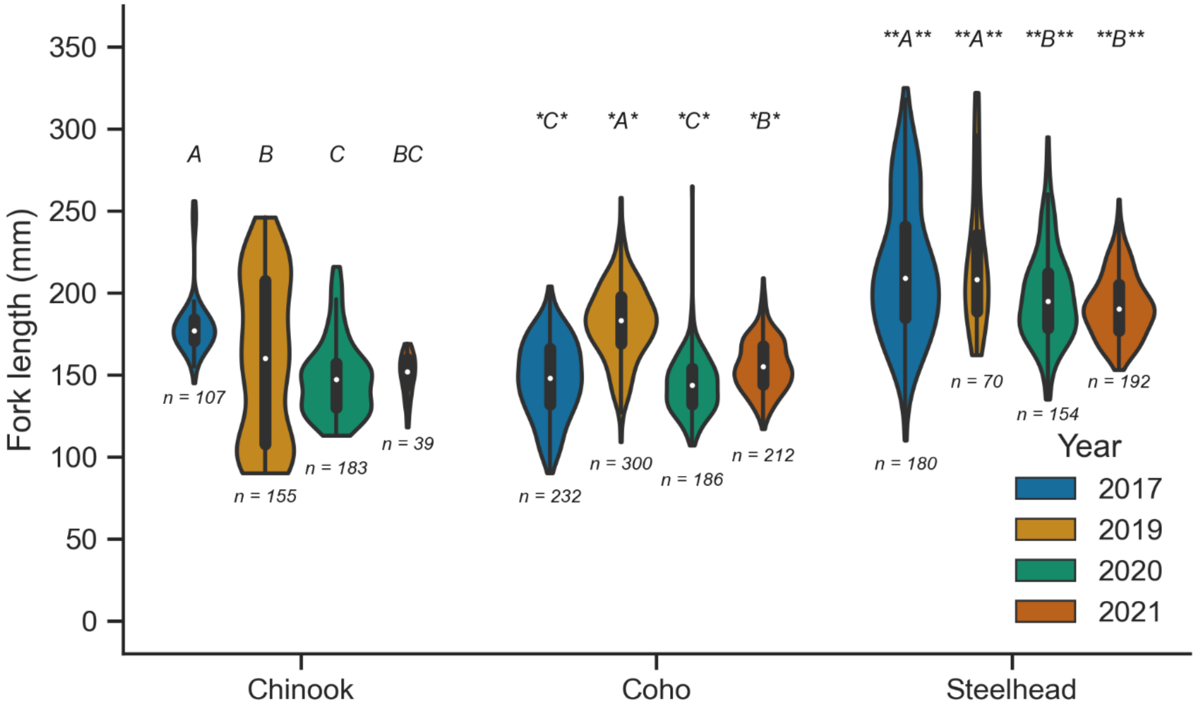


Figure 12. Fork length of dual-tagged study fish during years spanning 2017 to 2021. Each violin shape represents a kernel density estimate of the underlying distribution, using Scott's Rule (Scott 1992) for kernel density bandwidth selection. Violin widths are scaled proportional to the sample size for each group, which is annotated under each violin. Symbology within each violin is similar to a traditional boxplot: the white dot denotes the median, the thick line represents the interquartile range (IQR, i.e., 25th – 75th percentile), and the thin lines extend to "Tukey's fences," 1.5*IQR beyond the IQR in each direction. Letters above each violin indicate Tukey's test grouping. Within each species, lengths in years that share a letter are not statistically different. Comparisons among species were not conducted.

3.3 Floating Surface Collector Performance Metrics

3.3.1 Collection Efficiency Metrics

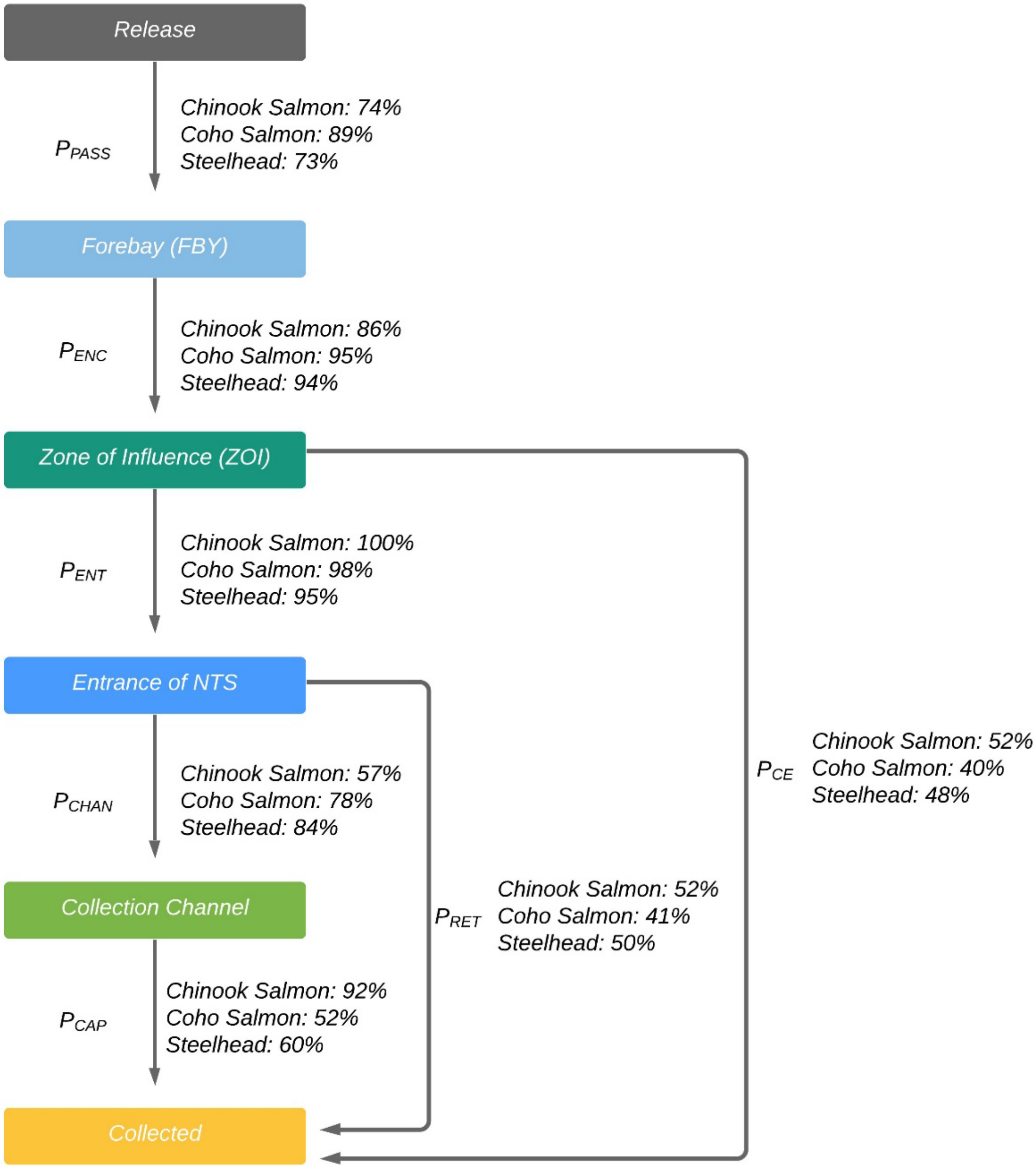
FSC performance metrics calculated for this study are summarized in Table 7 and Figure 13. Note that 90% confidence intervals are reported here as specified in the 2017 M&E Plan (PacifiCorp and Cowlitz County PUD 2017), as opposed to 95% confidence intervals reported elsewhere. Reservoir survival (P_{PASS}) was high: of the dual tagged fish released at the upper end of Swift Reservoir, 81% were detected in the forebay. The FSC encounter rate (P_{ENC}) was also high: 94% of fish that made it to the forebay were detected subsequently in the ZOI. Entrance efficiency (P_{ENT}) was 95% or greater for all species. Once detected in the NTS, approximately four out of five (79%) study fish transitioned into the collection channel (P_{CHAN}). P_{CHAN} ranged from 57% for Chinook Salmon to 84% for steelhead. Once in the collection channel, however, only slightly more than half (57%) of study fish were successfully collected (P_{CAP}). The ability of the collector to retain fish is reflected by retention efficiency (P_{RET}), the proportion of fish detected in the NTS that were subsequently collected. P_{RET} was 45% overall, ranging from 41% for Coho Salmon to 52% for Chinook Salmon. The overall ability of the collector to capture fish that are considered available for collection is represented by collection efficiency ($P_{\boldsymbol{CE}}$). P_{CE} was 44% overall, ranging from 40% for Coho Salmon to 52% for Chinook Salmon.

Table 7. 2021 Performance metric summary.

Species	Released	DET_{FBY}	DET_{ZOI}	DET_{NTS}[1]	DET_{CHAN}	DET_{COL}	$\hat{P}_{PASS}$ (90% CI)[2]	$\hat{P}_{ENC}$ (90% CI)	$\hat{P}_{ENT}$ (90% CI)	$\hat{P}_{CHAN}$ (90% CI)	$\hat{P}_{CAP}$ (90% CI)	$\hat{P}_{CE}$ (90% CI)	$\hat{P}_{RET}$ (90% CI)
Chinook Salmon	39	29	25	25	12	13	74% *(63%, 86%)*	86% *(76%, 97%)*	100% (--)[3]	57% *(40%, 73%)*	92% *(79%, 100%)*	52% *(36%, 68%)*	52% *(36%, 68%)*
Coho Salmon	212	186	179	175	137	71	89% *(86%, 93%)*	95% *(92%, 97%)*	98% *(96%, 100%)*	78% *(73%, 83%)*	52% *(45%, 59%)*	40% *(34%, 46%)*	41% *(34%, 47%)*
Steelhead	192	140	132	124	105	63	73% *(68%, 78%)*	94% *(91%, 98%)*	95% *(92%, 98%)*	84% *(78%, 89%)*	60% *(52%, 68%)*	48% *(41%, 55%)*	50% *(43%, 58%)*
All	443	355	336	324	254	147	81% *(78%, 84%)*	94% *(92%, 96%)*	97% *(95%, 98%)*	79% *(75%, 83%)*	57% *(52%, 62%)*	44% *(39%, 48%)*	45% *(41%, 50%)*

Notes:

1. Counts of fish in the NTS and collection channel are presented as the union of counts in any sub-zone of those zones.
2. 90% Wald's confidence intervals (CI) are reported for each collection metric.
3. MARK estimated confidence intervals for parameter estimates near the boundaries (0% and 100%) are unstable and thus not reported.



Note: P_{CAP} here represents the proportion of individuals that were positioned in the collection channel that made it to collection.

Figure 13. Flow chart summarizing 2021 performance metrics.

3.3.2 Zone Detection Efficiency

Mark-recapture models were used to estimate detection efficiencies for each zone in order to correctly estimate the collection efficiency metrics (Table 8). Detection efficiency is estimated by determining the number of individuals positioned in a given zone that were not positioned in the previous (upstream) zone. Because there is no reliable detection station located a reasonable distance downstream from the release ponds, detection efficiency associated with collection is not estimated, but rather assumed to be 100% for the purpose of these computations.

Detection efficiencies were high across each zone and for each species (Table 8). No fish were missed in the ZOI, and only one fish was missed in the NTS, two zones that are critical for computation of the performance metrics P_{CE} and P_{RET}. High efficiency in these zones imparts high confidence in these key performance metrics.

Table 8. Zone detection efficiency by species.

Species	DET_{ZOI} (95% CI)[1]	No. of Fish Missed in ZOI	DET_{NTS} (95% CI)	No. of Fish Missed in NTS	DET_{CCH} (95% CI)	No. of Fish Missed in Channel
Chinook Salmon	100% (--)[2]	0	100% (--)	0	85% (65%, 100%)	2
Coho Salmon	100% (--)	0	100% (--)	0	100% (--)	0
Steelhead	100% (--)	0	99% (97%, 100%)	1	100% (--)	0
All	100% (--)	0	99% (98%, 100%)	1	99% (97%, 100%)	2

Notes:
1. 95% Wald's confidence intervals (CI) are reported for each detection efficiency metric.
2. MARK estimates near the boundary of 0 and 1 are unstable and thus not reported.
3. Detection efficiency at the collector is assumed to be 1.0 to provide tangible detection efficiency estimation for previous zones in the mark-recapture model.

3.3.3 Collection Channel Results

To better understand where fish reject collection within the channel, the mark-recapture model was refined to estimate transition probabilities among (Table 9) and detection efficiencies within (Table 10) the sub-zones comprised within the NTS and collection channel zones. Almost all (98%) study fish transition from the upstream to the downstream section of the NTS, and once there, 81% of study fish then transition into the primary channel. Once in the primary channel, 87% of fish transition into the upstream secondary channel, from which all fish transition to the downstream secondary channel. Only 65% of fish in the secondary channel are collected however. Confidence in results for Chinook Salmon is lower than results for other species. When comparing Coho Salmon and steelhead, transition rates among zones were generally similar.

Zone detection efficiencies for the primary and secondary channel subarrays were calculated in the same manner as for the collection channel as a whole (Section 2.2.6) and was similarly variable among species (Table 10). Detection efficiencies within the collection channel were generally more comparable among species in 2021 than what was observed in the 2020 acoustic study. Comparable numbers of steelhead and Coho Salmon were missed in most zones, although there were more steelhead missed in the upstream NTS (Table 10). Chinook Salmon exhibit lower rates of detection efficiency throughout the channel. Partitioning transitions between channel sub-zones increases uncertainty associated with these sub-zone detection efficiency estimates, but this may be an artifact of low sample size. Attempt duration may also play a role in lower detection efficiencies for Chinook Salmon compared to Coho Salmon and steelhead, as Chinook tended to pass more quickly (Figure 14). However, differences in final attempt duration among species were not significant (Tukey's honest significant difference test $p > 0.2$ for all comparisons).

Table 9. Transition probabilities between channel sub-zones.

Species	Upstream NTS to Downstream NTS *(90% CI)*[1]	Downstream NTS to Primary Channel *(90% CI)*	Primary Channel to Upstream Secondary Channel *(90% CI)*	Upstream Secondary Channel to Downstream Secondary Channel *(90% CI)*	Downstream Secondary Channel to Collection *(90% CI)*
Chinook Salmon	96% (90%, 100%)	59% (42%, 75%)	100% (--)[2]	100% (--)[2]	92% (80%, 100%)
Coho Salmon	98% (96%, 100%)	80% (75%, 86%)	86% (81%, 92%)	100% (--)[2]	60% (52%, 67%)
Steelhead	98% (95%, 100%)	87% (81%, 92%)	86% (80%, 92%)	100% (--)[2]	69% (61%, 77%)
All	98% (96%, 99%)	81% (78%, 85%)	87% (83%, 91%)	100% (--)[2]	65% (60%, 71%)

Notes:
1. 90% Wald's confidence intervals are reported for each collection metric.
2. MARK estimates near the boundary of $p = 1$ are unstable and thus not reported.

Table 10. Sub-zone detection efficiency, by species.

Species	DET_{ZOI}	Missed in ZOI	DET_{NTS_U}	Missed in Upstream NTS	DET_{NTS_D}	Missed in Downstream NTS	DET_{CCHP}	Missed in Primary Channel	DET_{CCHS_U}	Missed in Upstream Secondary Channel	DET_{CCHS_D}	Missed in Downstream Secondary Channel
Chinook Salmon	100% (--)[2]	0	80% (64%, 96%)	5	100% (--)	0	64% (39%, 89%)	5	57% (31%, 83%)	6	50% (23%, 76%)	7
Coho Salmon	100% (--)	0	98% (95%, 100%)	4	99% (98%, 100%)	1	96% (92%, 99%)	5	90% (84%, 95%)	11	76% (69%, 84%)	19
Steelhead	100% (--)	0	93% (88%, 97%)	9	98% (95%, 100%)	2	94% (90%, 99%)	5	87% (79%, 94%)	11	68% (58%, 78%)	21
All	100% (--)	0	94% (92%, 97%)	18	99% (98%, 100%)	3	93% (90%, 97%)	15	86% (81%, 91%)	28	71% (65%, 77%)	47

Notes:
1. 95% Wald's confidence intervals are reported in parentheses after each detection efficiency metric.
2. MARK estimates near the boundary of 0 and 1 are unstable and thus not reported.
3. Detection efficiency at the collector is assumed to be 1.0, to provide tangible detection efficiency estimation for previous zones in the mark-recapture model.

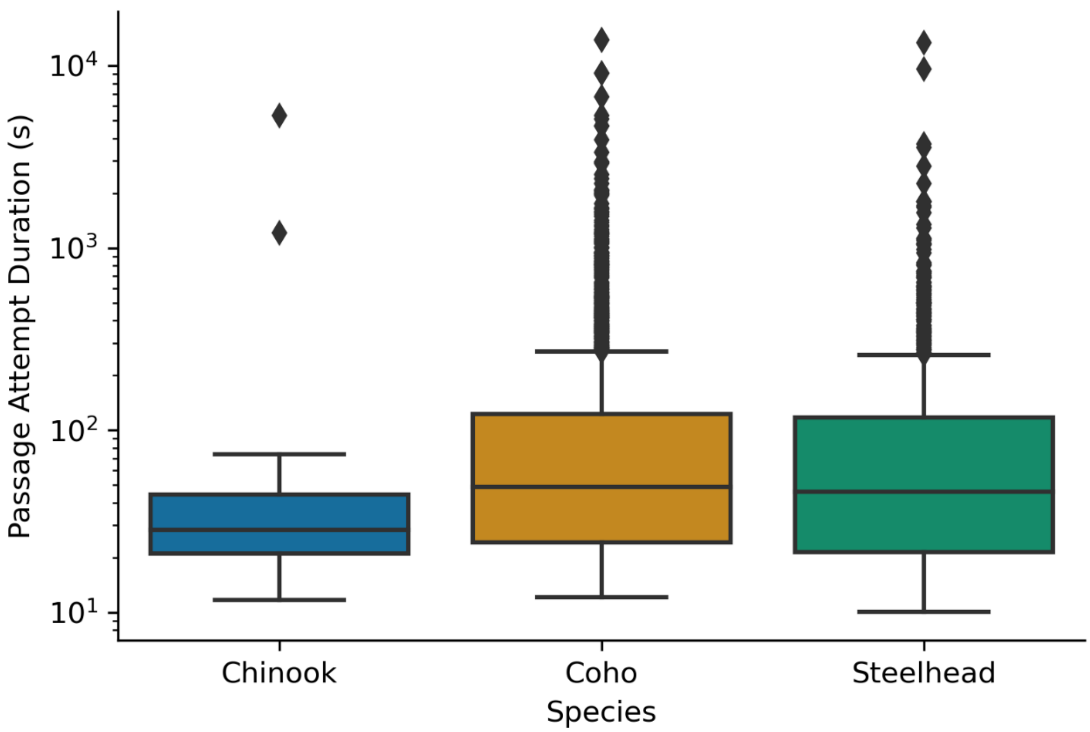


Figure 14. Duration of successful passage attempts for each species. Note log scale y-axis. Midline within each box indicates the median duration of successful attempts for each species, ends of boxes indicate interquartile range (IQR, i.e., 25th – 75th percentile), thin "whiskers" extend to "Tukey's fences," 1.5*IQR beyond the IQR in each direction, and markers beyond the whiskers indicate outlier values.

3.3.4 Identifying Passage Bottlenecks

The transition probabilities from the refined mark-recapture model were applied to counts of study fish within each sub-zone to help visualize bottlenecks that prevent fish from moving downstream and to develop model estimated counts of fish reaching each sub-zone (Figure 15). After release, four out of five (81%) dual-tagged study fish returned to the forebay within the study period (Table 7, Figure 13, Figure 15). Steelhead returned to the forebay at a lower rate than did Coho Salmon and Chinook Salmon. Once in the forebay, almost all (94%) fish transitioned to and were detected within the ZOI. Once in the ZOI, most (97%) fish entered and were detected in the NTS. Once in the upstream portion of the NTS, almost all (98%) fish transitioned to the downstream NTS (Table 9). At the transition between the downstream NTS and the primary channel, approximately one of every five fish (19%) rejected moving downstream into the primary channel. A greater proportion of Coho than steelhead rejected downstream movement at this transition. Another 13% of study fish rejected at the transition between the primary and upstream secondary channel, but once in the secondary channel, all fish proceeded from the upstream to the downstream portion of the secondary channel. The final transition, between the downstream secondary channel and the collector itself appears to be the poorest single transition point: 35% of all study fish reject in this sub-zone, with Coho Salmon apparently rejecting within this sub-zone at a greater rate than did steelhead.

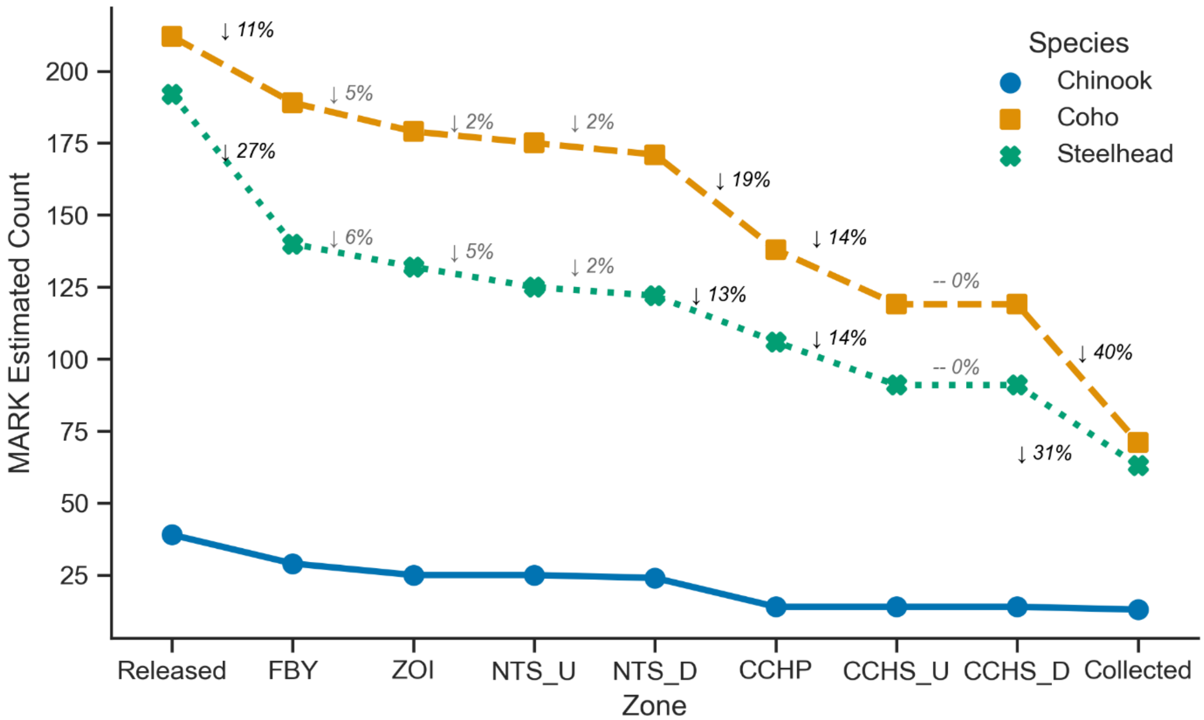


Figure 15. Counts of study fish detected within each zone of the Swift floating surface collector array. Annotation indicates magnitude of species-averaged rejection rates associated with each transition.

Recapture rates varied among release groups for steelhead, but not for Coho (Figure 16). Chinook were omitted.

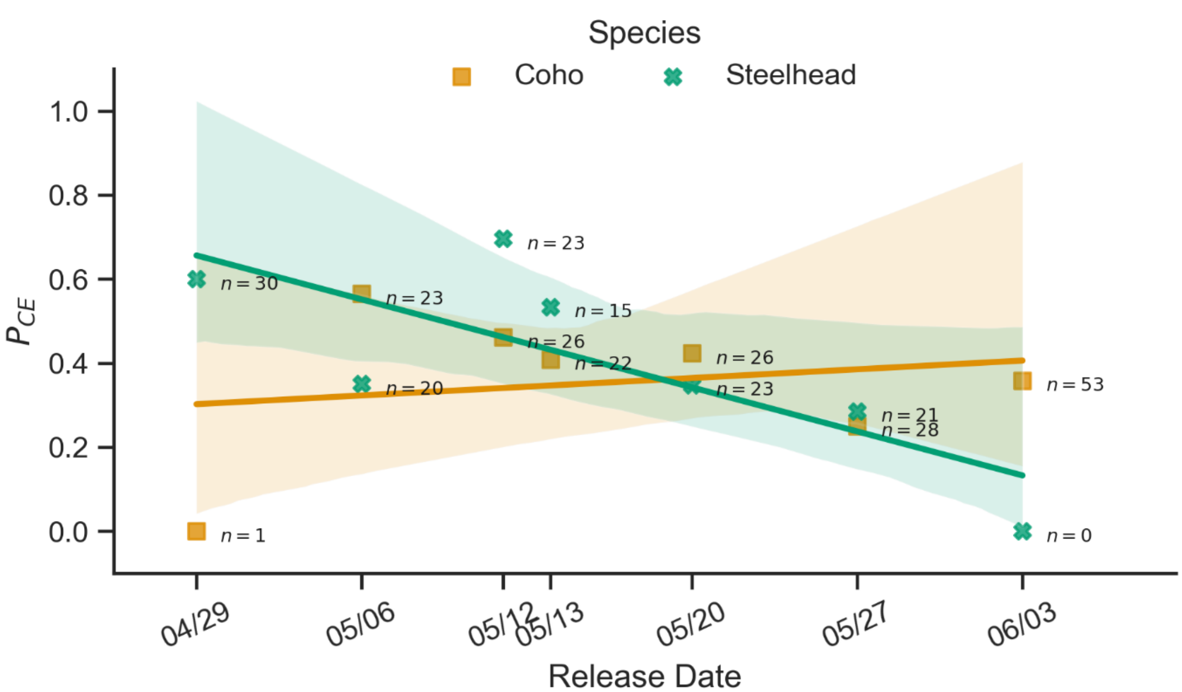


Figure 16. Values of P_{CE} for release groups of Coho Salmon and steelhead. Lines show linear regression for each species. Shaded areas indicate 95% confidence interval. Chinook Salmon not shown due to very low sample size.

3.4 Passage Attempt Behavioral Analysis

Behavioral analyses focused on all passage attempts for each fish, with each attempt defined as in Section 2.4. The set of filtered passage attempts included 2,705 attempts made by 241 fish (11 Chinook Salmon, 131 Coho Salmon, and 78 steelhead). Attempts that occurred while the collector was off were included in data visualizations but not considered in modeling efforts.

Since these fish included in the behavioral analyses had already entered the channel, recapture rates among this group are analogous to P_{CAP} for the overall group of study fish. As a result, these two quantities should be similar if the fish included in behavioral analyses are representative of the larger group of study fish. To test this assumption, recapture rates among fish included in the behavioral analysis were compared with overall P_{CAP} values for all study fish, for each species of study fish. In all three species, the two quantities were nearly identical (Figure 17). This indicates that, indeed, the group of fish included in the behavioral analyses is representative of the overall study group.

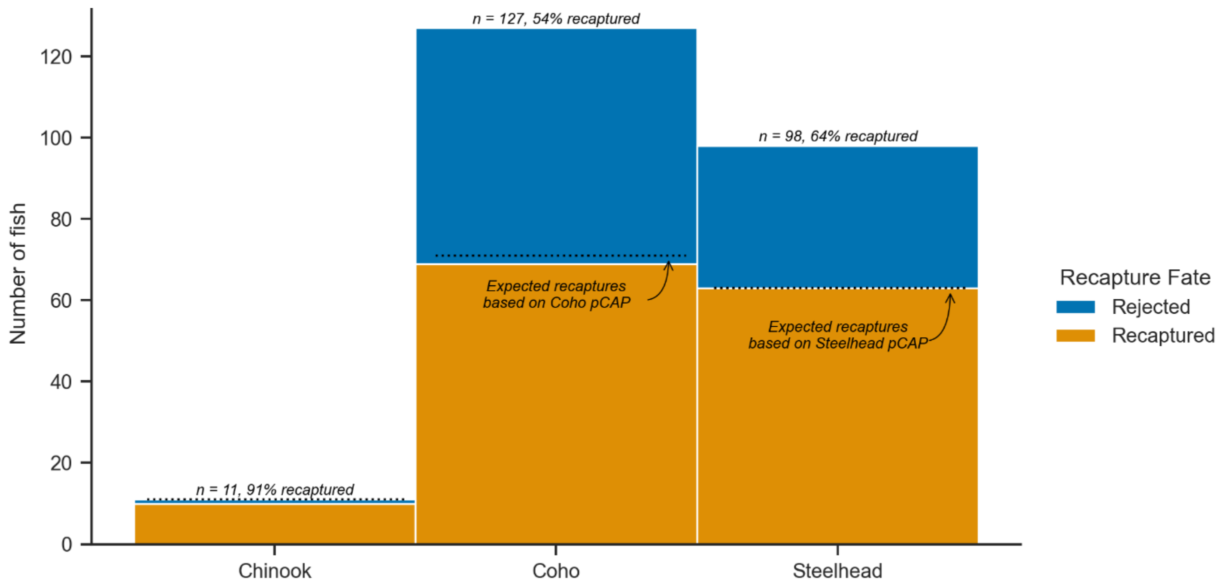


Figure 17. Counts of fish included in behavioral analyses, stacked to show recapture rates (number of fish collected divided by number of fish included in behavioral analysis) for each species. Dotted black line and annotation indicates expected recapture numbers based on P_{CAP} values for each species. All p-values based on results of χ^2 were not significant ($p > 0.5$).

Of the 2,705 passage attempts occurring over the season, 280 of them (approximately 10%) occurred during periods when the collector was off. These periods were omitted from further analyses, yielding a total of 2,425 attempts made by 236 individual fish. In this refined data set, more than one third of fish (38%) made only one attempt, 50% attempted less than 3 times, 90% attempted less than 21 times, and 95% attempted less than 30 times (Figure 18). Three Coho Salmon and four steelhead attempted 50 or more times, with the maximum number of attempts being 301 by one Coho Salmon and 226 by one steelhead. The number of passage attempts per individual was similar between rejected and recaptured Coho Salmon and Chinook Salmon, but steelhead that rejected (mean = 20 attempts) made significantly more attempts (Welch's t-test, $p < 0.05$) than those that were recaptured (mean = 3 attempts). In general, fish that rejected made many more attempts in aggregate (Coho Salmon = 843, steelhead = 715) compared to fish that were ultimately recaptured (Coho Salmon = 672, steelhead = 176), which was similar to results from the 2020 study.

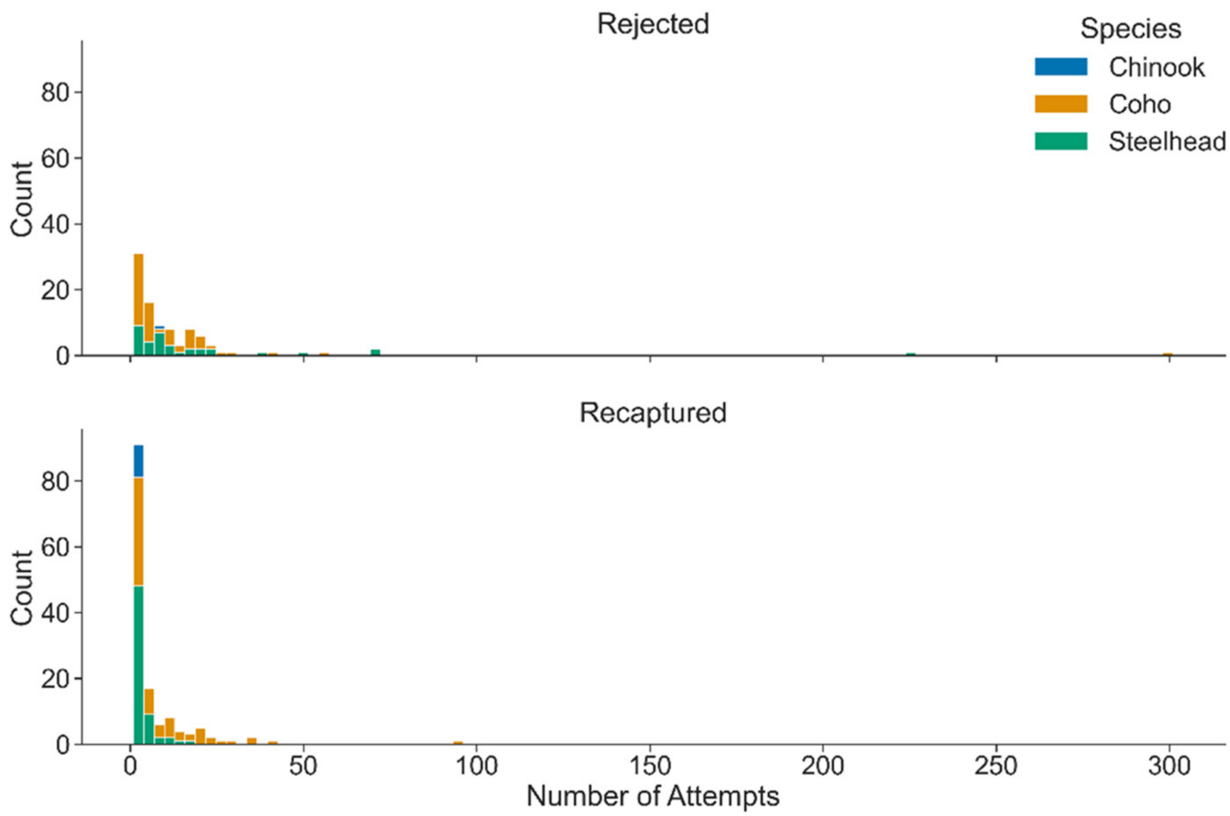


Figure 18. Distribution of the number of Swift floating surface collector passage attempts made by recaptured study fish and study fish that rejected collection during 2021.

Chinook Salmon, Coho Salmon, and steelhead outmigration timing was somewhat staggered: 50% of the run-at-large had passed the FSC by April 7 for Chinook Salmon, by May 15 for steelhead, and by June 1 for Coho Salmon (Figure 11). Study fish tagging operations generally tracked the runs-at-large, although the later portions of the runs may have been slightly underrepresented.

The daily counts of study fish attempting passage at the FSC (i.e., counting each fish once per day) indicate distinct but overlapping modes for each species (Figure 19), which generally track the seasonal trend in daily counts of study fish collected at the FSC (Figure 20), and FSC collections of the runs-at-large for each species (Figure 21), indicating that study fish outmigration dynamics paralleled the run-at-large. Chinook Salmon outmigration began in mid-April, but juvenile abundance was low, and daily counts of study fish attempting passage did not exhibit any distinct peaks. Steelhead outmigration began in early May and exhibited small peaks between mid-May and early June, before tapering off to low levels that persisted through mid-July. Coho Salmon outmigration also began in early May and exhibited large pulses in the number of fish attempting per day from the beginning through the middle of June. Except for a small number of Chinook passing in mid-April, fish passage generally began when daily averaged water temperature 5 feet below the surface at the FSC reached 50° F, and ended once daily averaged water temperature reached 70° F.

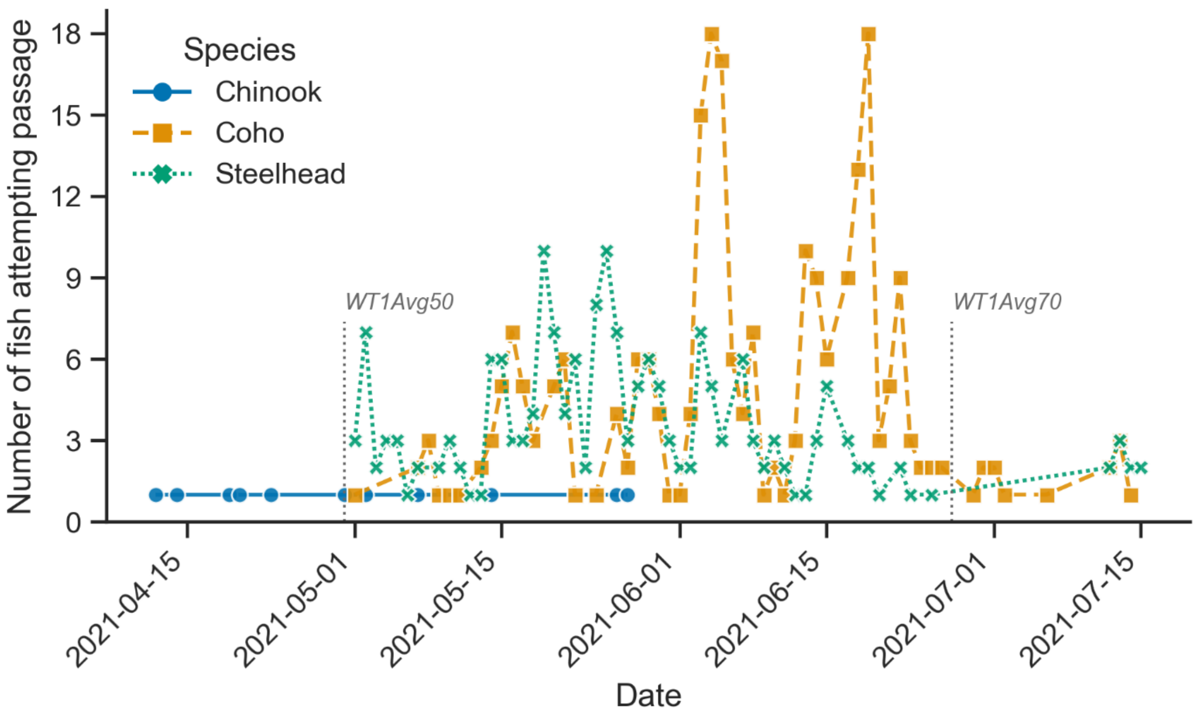


Figure 19. Daily counts of number of study fish attempting passage at the Swift floating surface collector during the 2021 season. Annotations and vertical, gray, dotted lines indicate dates on which daily averaged water temperature measured 5 feet below the water surface exceeded 50° F and 70° F.

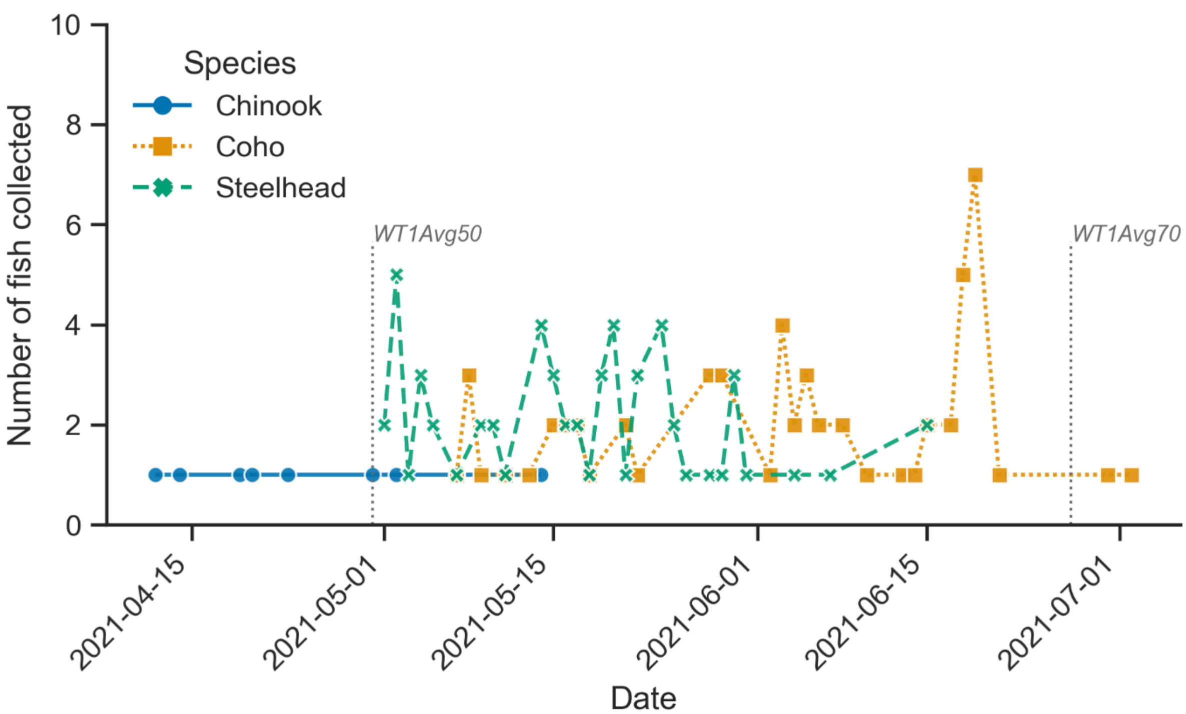


Figure 20. Daily counts of number of study fish recaptured at the Swift floating surface collector during the 2021 season. See Figure 19 for explanation of annotations.

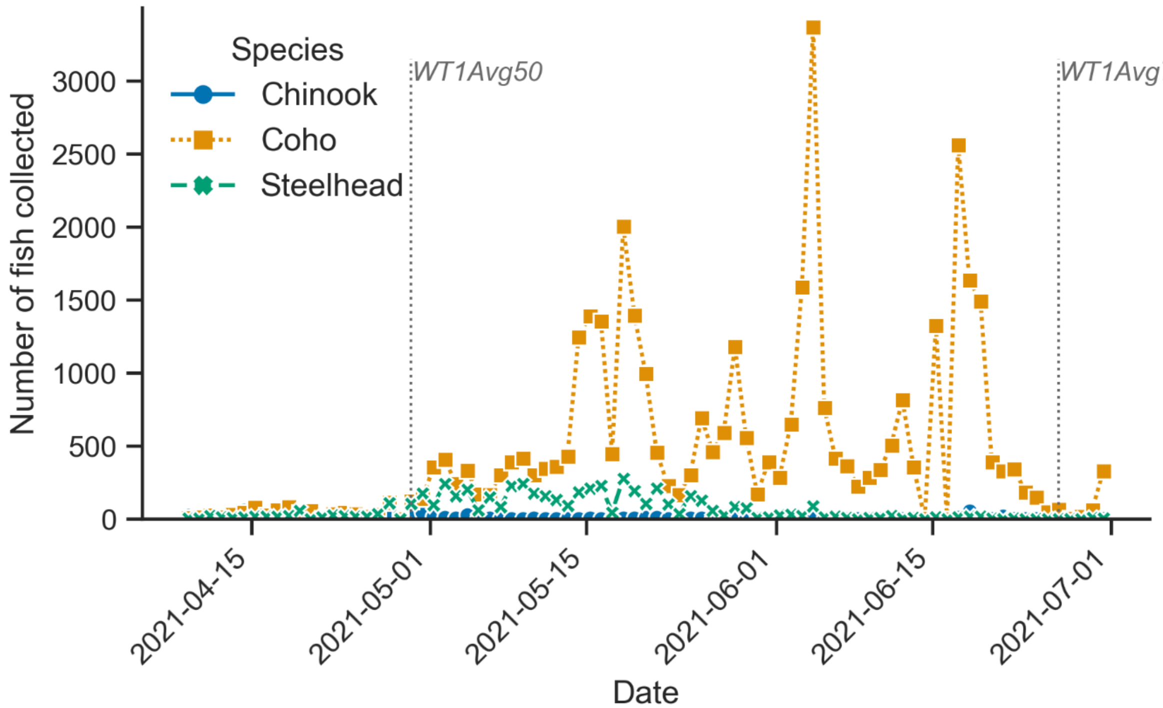


Figure 21. Daily counts of numbers of run-at-large fish collected at the FSC in 2021.

Study fish initiated passage attempts at the Swift FSC during all hours of the day, but were more successful when attempting outside of the mid-day hours (Figure 22), which could have been related to human (worker) activity or photoperiod. Human activity on the FSC, as evaluated using trail cameras deployed on the FSC deck and within the channel, varied throughout the year. During late April, human activity was essentially continual throughout the day. Then, from mid-May onward, human activity tended to cluster between 09:00 and 13:00 (purple solid line and green dashed line in Figure 22). Daylength at the FSC varied throughout the season but extended from 05:00 to 21:00 during May and June. These factors were explored more using the statistical modeling methods described in Section 3.4.5.

Both the noise in the channel (as measured by JSATS false detections) and sound pressure levels (as measured with the sound monitoring hydrophones) covaried with the number of pumps in operation (Figure 23). Higher levels of sound pressure levels were observed as more pumps were operated. This pattern was reversed in the false detection data, likely because of internal threshold filtering by the JSATS receiver firmware and canceling interference that can occur with increasing amounts of noise. The result of this was that the apparent number of false JSATS detections that composed the “noise floor” of this dataset decreased as more pumps were turned on.

However, this pattern within the noise floor was also overlaid with spikes in the number of false detections (Figure 24). Spikes longer than 5 minutes were attributed to operation of the secondary channel screen cleaners (“spray bars”), while those that lasted only 30 to 90 seconds were attributed to regularly scheduled deactivation of two pumps within the collector for debris-clearing off the sorting bars, per operational input from PacifiCorp (Chris Karchesky, Personal Communication, December 6, 2021).

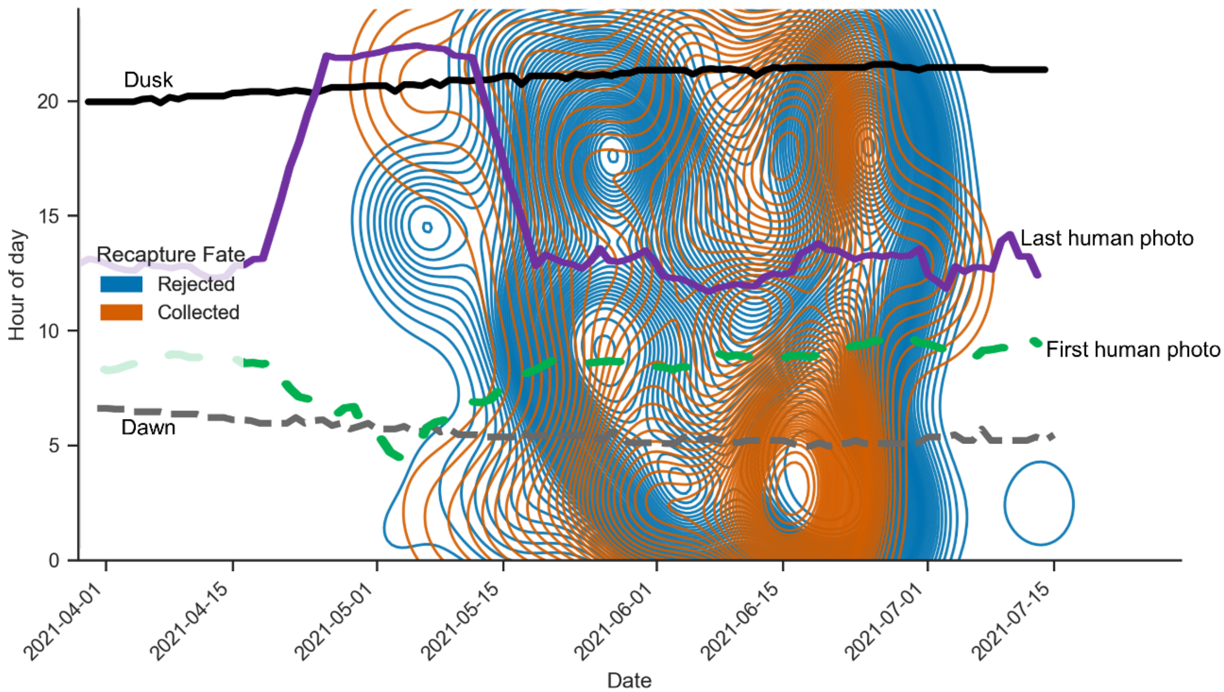


Figure 22. Diel patterns of Swift floating surface collector passage behavior during 2021. Plot shows the seasonal variation in timing of successful (orange contours) and unsuccessful (blue contours) passage attempts, across all species. Contours depict kernel density estimator bandwidths of 0.2, and omit the 25% least dense regions. Apparent "peaks" shown by concentric contours indicate dates and times with a high density of attempts. Overlaied lines indicate approximate time of dawn and dusk, as measured using light level loggers within the channel, and first and last human activity photos, as annotated.

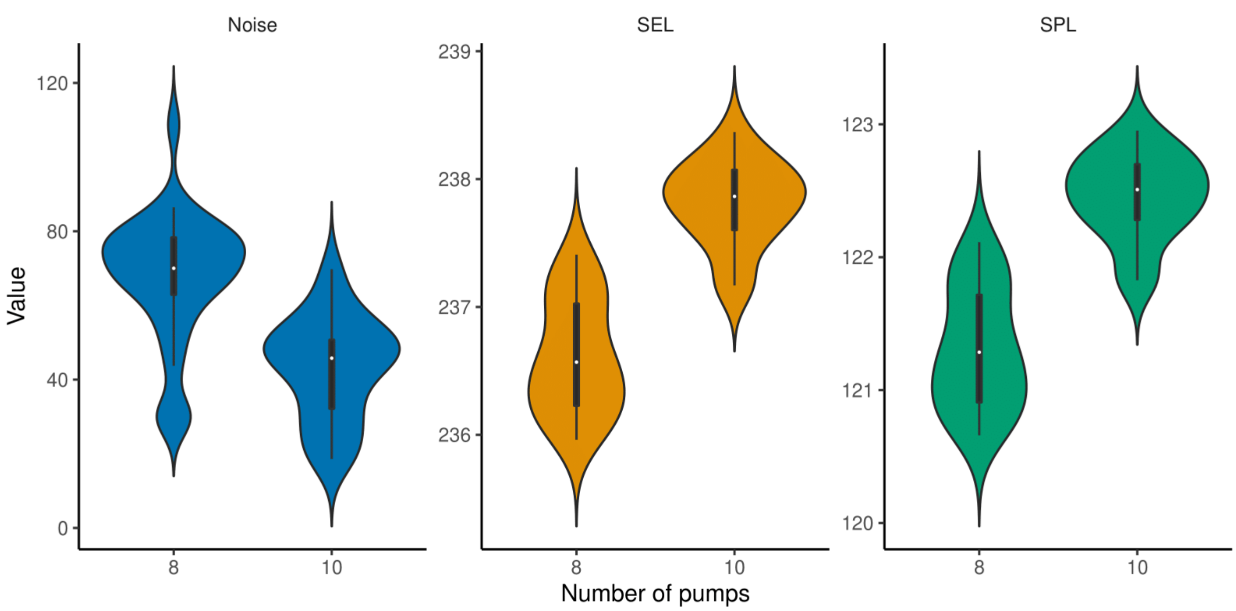


Figure 23. Violin plots of the distribution of levels of operational noise (Noise; counts of false detections per period), sound exposure level (SEL; dB re 1uPa), and sound pressure level (SPL; dB re 1uPa) by number of pumps.

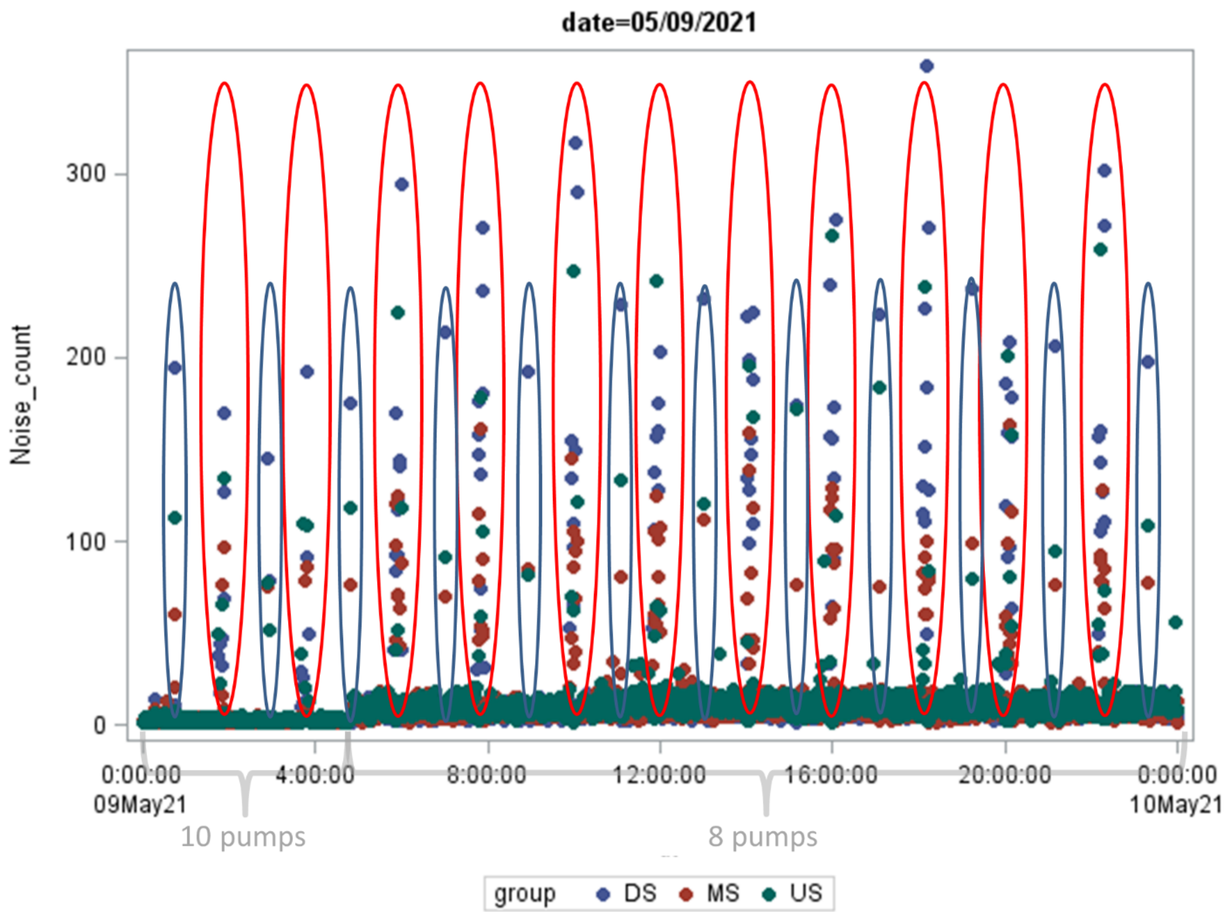


Figure 24. Example plot of operational noise data, based on counts of false JSATS detections per minute on JSATS receivers positioned in the downstream (DS), middle (MS) and upstream (US) sections of the secondary channel. Red ovals indicate periods when spray bars were inferred to be operating, based on a duration of at least five minutes of noise level increased above baseline noise floor. Blue ovals indicate periods when to the flush system was inferred to be operating and increased noise levels that lasted 30 to 90 seconds. Baseline noise floor variance in response to number of pumps in operation is shown by bracketed time periods.

In addition to detecting changing sound levels with pump operation, the sound monitoring revealed a 22 Hz sound signal that was detected continuously throughout the monitoring period. This is within the range that can elicit a behavioral response from salmonids (Hastings and Popper 2005). However, because the sound was continuous, the behavior analysis was not able to determine whether it influences behavior in the channel (i.e., because there were no periods when the signal was not present, a comparison of how fish behave in the absence of the signal was not possible). The source of the 22 Hz signal has not been determined, though it does not appear to be related to the pumps in the fish channel, as the signal persisted even after the pumps were shut down for the season.

3.5 Model Results

Model results are summarized in the following subsections. Detailed modelling methods are provided in APPENDIX A. Low sample size of Chinook Salmon limited the ability to meaningfully compare them with other species, so they are generally omitted in the results presented below, except when considering all fish together, or if Chinook results appeared robust to small sample size effects.

3.5.1 Factors that Affect the Passage Success of Individual Fish

When considered across the entire group of study fish, statistical models indicated that shorter fish were more likely to be successfully recaptured (Table 11). This relationship was especially strong for steelhead and weaker for Coho Salmon. Longer Chinook Salmon were slightly more likely to be successfully recaptured, but this effect was not strong. Steelhead that were recaptured at the FSC were significantly shorter than those that rejected the collector (*t*-test, $p < 0.05$, Figure 25). Lengths of both Coho Salmon and Chinook Salmon did not differ significantly between fish that rejected the FSC and those that were recaptured (Figure 25).

Table 11. Estimated effect influence (Sign) and variable importance (Importance) from models of factors affecting passage success of individual fish.

	Chinook[1]		Coho		Steelhead	
	Sign[2]	Importance[3]	Sign	Importance	Sign	Importance
Intercept	-	1.00	-	1.00	-	1.00
Length	+	0.39	-	0.38	-	1.00
Release day			✓	0.10	✓	0.85
Length x Release day			✓	0.01	✓	0.04

Notes:
1. Higher order models and those with release day did not converge.
2. Sign is the direction (positive or negative) of the estimated effect, averaged across all models in the candidate set weighted by the Akaike weight for each model. Check marks indicate categorical covariates, potentially with multiple levels, for which assigning a single effect direction is inappropriate.
3. Variable importance was calculated as the sum of Akaike weights of all models in which the covariate occurred.

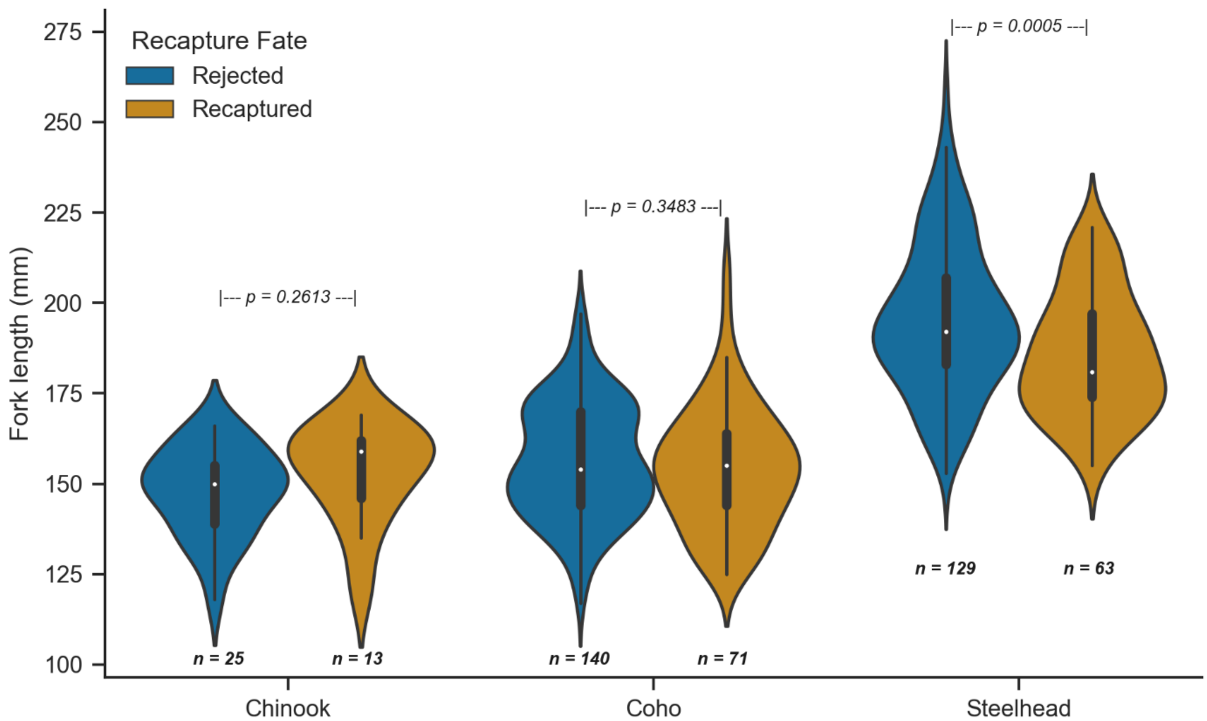


Figure 25. Comparison of fork length between study fish that were recaptured and those that rejected the Swift floating surface collector during 2021, grouped by species. All study fish are included in this plot. See Figure 12 for explanation of violin symbology. Sample size for each group is noted below each violin. *P*-values summarize results of *t*-tests of difference in length between rejected and recaptured fish, for each species.

3.5.2 Factors that Affect the Daily Rate of Fish Attempting Passage

Water temperature, the number of pumps in operation, daily median operational noise, strong east wind events, and forebay debris all affected the number of fish that attempted passage on a given day (Figure 26). The relative strength of these effects differed among species (Table 12).

Table 12. Estimated effect influence (Sign) and variable importance (Importance) from models of factors affecting daily rate of passage attempts.

	All		Coho		Steelhead	
	Sign[1]	Importance[2]	Sign	Importance	Sign	Importance
Intercept	-	1.00	-	1.00	-	1.00
Operational noise[3]	+	1.00	+	1.00	+	1.00
Number of pumps	✓	1.00	✓	1.00	✓	0.20
Temperature	+	1.00	+	1.00	-	1.00
East wind	-	1.00	-	0.98	-	1.00
Debris (prior)	+	1.00	+	0.29	+	0.99
Debris (current)	-	0.99	+	0.49	-	1.00
Pressure	+	0.56	+	0.80	+	0.22
Human activity (h)	+	0.24	-	0.38	+	0.59

Notes:
1. Sign is the direction (positive or negative) of the estimated effect, averaged across all models in the candidate set weighted by the Akaike weight for each model. Check marks indicate categorical covariates, potentially with multiple levels, for which assigning a single effect direction is inappropriate.
2. Variable importance was calculated as the sum of Akaike weights of all models in which the covariate occurred.
3. As measured by the number of false detections on the JSATS receivers.

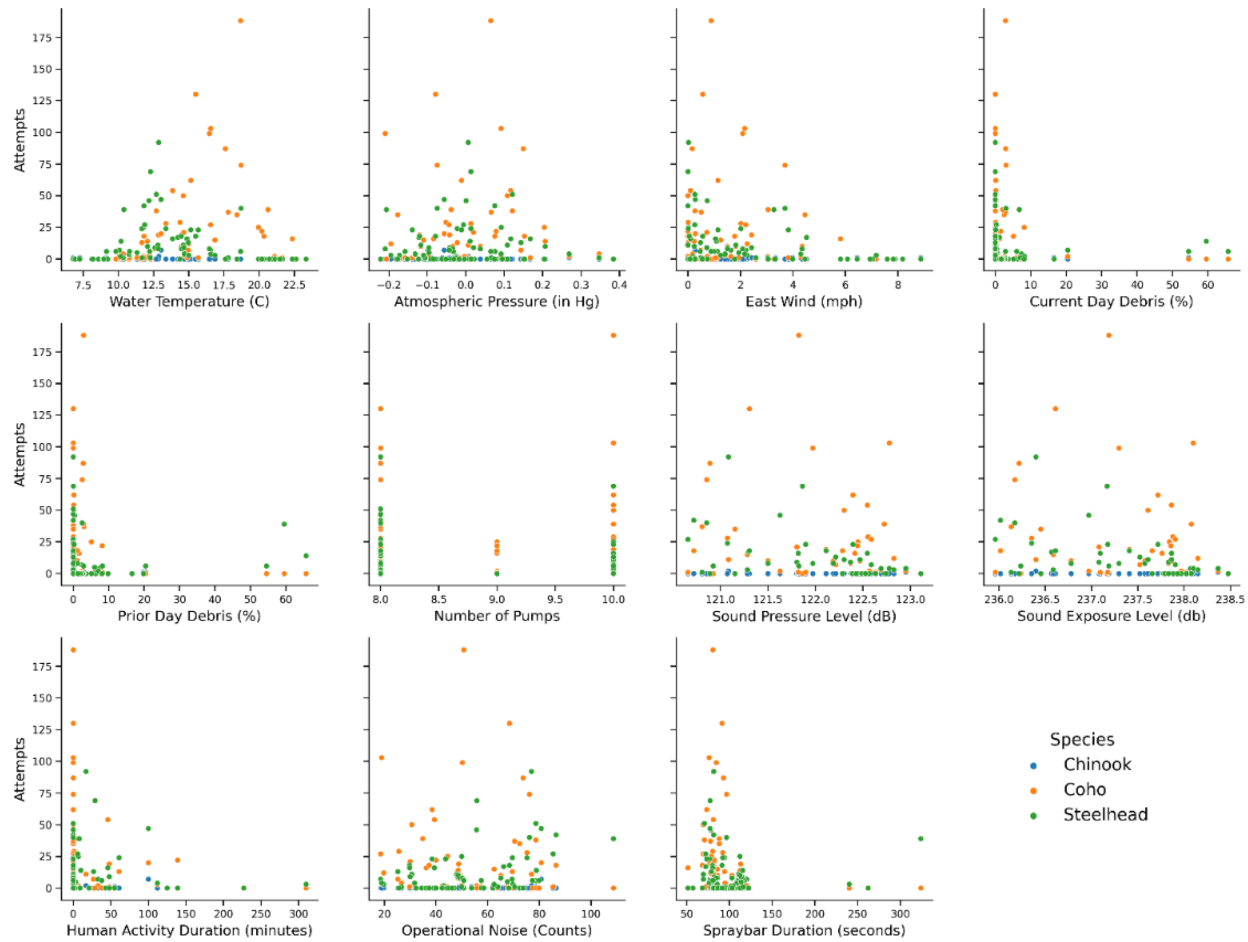


Figure 26. The daily number of passage attempts plotted as a function of the factors included in a series of models of passage attempt rate. Markers are colored by species.

For all species, reducing the number of pumps from ten to eight appeared to result in a reduced daily rate of passage attempts. Fewer steelhead and a similar number of Coho Salmon attempted passage on days when eight pumps were operated compared to when ten pumps were operated (Table 13). Modeling for Chinook Salmon was constrained by very low sample size.

Table 13. Summary output for model relating pumping rate to daily attempt count, separated by species.

Species	χ^2 Statistic	Degrees of Freedom	*P*-value
Coho	1.9	1	0.166
Steelhead	5.9	1	*0.015*

3.5.3 Factors that Affect the Success of Individual Passage Attempts

Maximum operational noise during an attempt, the number of pumps in operation at the time of attempt initiation, species, and time of day and day of year of attempt initiation were all strong predictors of the success of individual passage attempts (Table 14). Debris loading, human activity, wind, air pressure, and water temperature did not appear to affect passage success. For the study period during which sound monitoring data were available, sound level appeared to affect passage success (results not included in Table 14), but this may have been an artifact of the relationship of sound metrics with pump operation. Statistical support for an effect of spray bar operation—as inferred from patterns of false detections on the JSATS receivers—was marginal.

Table 14. Estimated effect influence (Sign) and variable importance (Importance) from models of factors affecting success of individual passage attempts.

	All		Coho		Steelhead	
	Sign[1]	Importance[2]	Sign	Importance	Sign	Importance
Intercept	-	1.00	-	1.00	-	1.00
Time of day	+	1.00	+	1.00	+	1.00
Length	-	1.00	-	0.31	-	1.00
Operational noise[3]	+	1.00	+	0.88	+	0.99
Number of pumps	✓	1.00	✓	0.90	✓	0.95
Species	✓	0.99				
Attempt date	-	0.95	-	0.48	-	0.99
Spray bar	✓	0.79	✓	0.51	✓	0.55
Debris (prior)	-	0.45	+	0.35	-	0.65
Temperature	-	0.44	-	0.80	+	0.30
Debris (current)	+	0.35	+	0.28	-	0.29
Light	+	0.32	+	0.27	+	0.27
East wind	+	0.32	+	0.30	+	0.33
Human activity	✓	0.30	✓	0.29	✓	0.33
Barometric Pressure	+	0.29	+	0.28	+	0.28

Notes:
1. Sign is the direction (positive or negative) of the estimated effect, averaged across all models in the candidate set weighted by the Akaike weight for each model. Check marks indicate categorical covariates, potentially with multiple levels.
2. Variable importance was calculated as the sum of Akaike weights of all models in which the covariate occurred.
3. As measured by the number of false detections on the JSATS receivers.

While operational noise levels were greater when eight pumps were operating compared to ten (Figure 23), after controlling for the number of pumps in operation, successful passage attempts tended to occur during periods of greater operation noise (Figure 27). For both steelhead and Coho Salmon, the number of pumps operating at the time of the initiation of an attempt predicted whether it was successful (Table 14). For all species, the proportion of successful attempts initiated when eight pumps were operating was lower than when ten pumps were operating (Figure 28). The combined effect of fewer attempts and similar or slightly lower likelihood of success rate of those attempts that were made when eight versus ten pumps were operated was that more study fish of each species were collected when ten pumps were operated than when eight pumps were operated (Figure 29).

Date of passage attempt initiation was a strong predictor of success for attempts made by steelhead but not by Coho Salmon (Table 14). Time of passage attempt initiation strongly predicted success for both steelhead and Coho Salmon, and the time distributions of successful and unsuccessful attempts were moderately distinct (Figure 30). For both species, this diel pattern in passage success appeared to be driven primarily by inherent circadian rhythms or photoperiod, rather than human activity (Table 14, Figure 22).

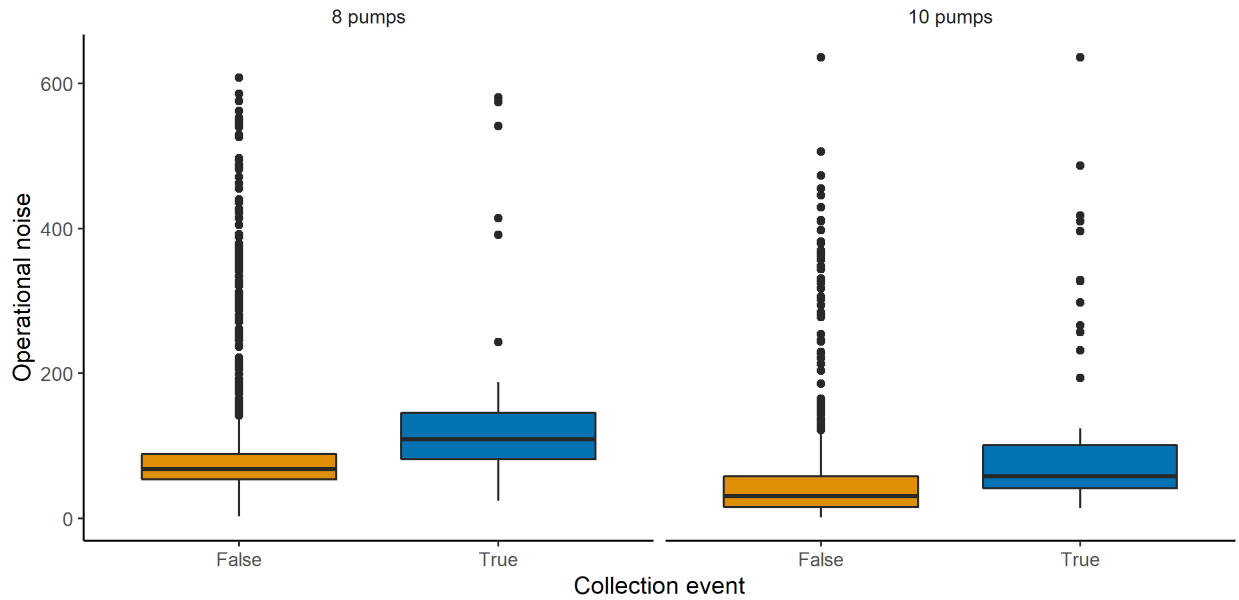


Figure 27. Operational noise as inferred from counts of false detections per minute on channel JSATS receivers, compared between successful (Collection event = "True") and unsuccessful (Collection event = "False") passage attempts.

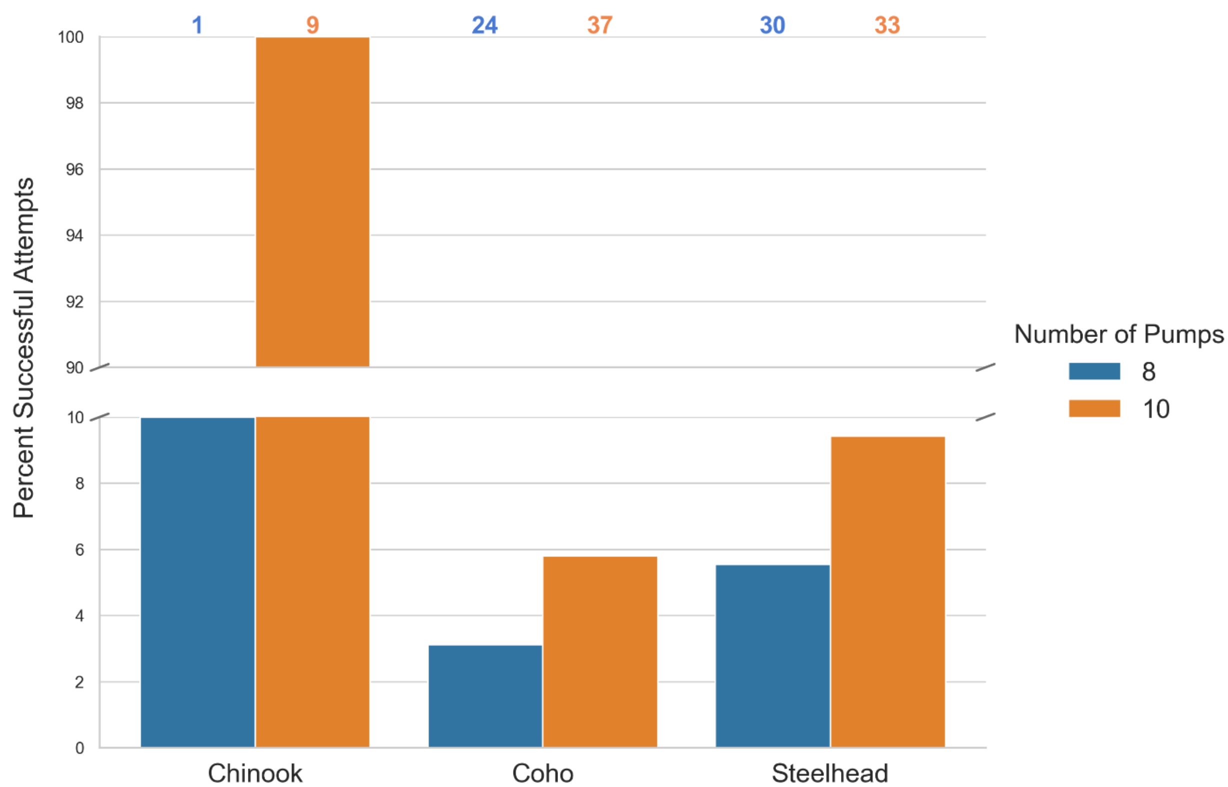


Figure 28. Relative proportions of success for attempts made by each species when eight and ten pumps were operating. Note broken y-axis to effectively visualize low success for Coho Salmon and steelhead on the same axes as Chinook Salmon, which exhibited 100% success for the nine attempts that were made when all ten pumps were operating. Numbers above each bar indicate sample size (number of attempts).

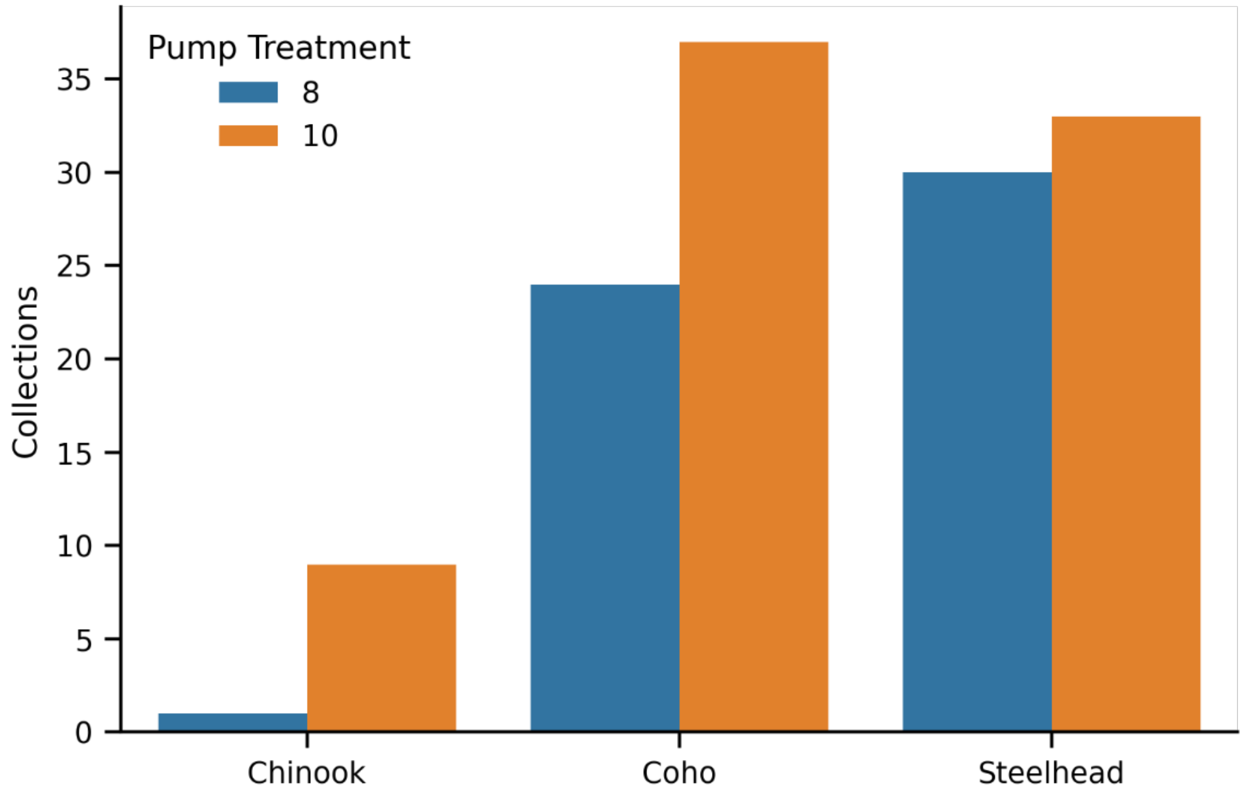


Figure 29. Total number of fish collected under each pumping rate treatment during pumping rate study for each species.

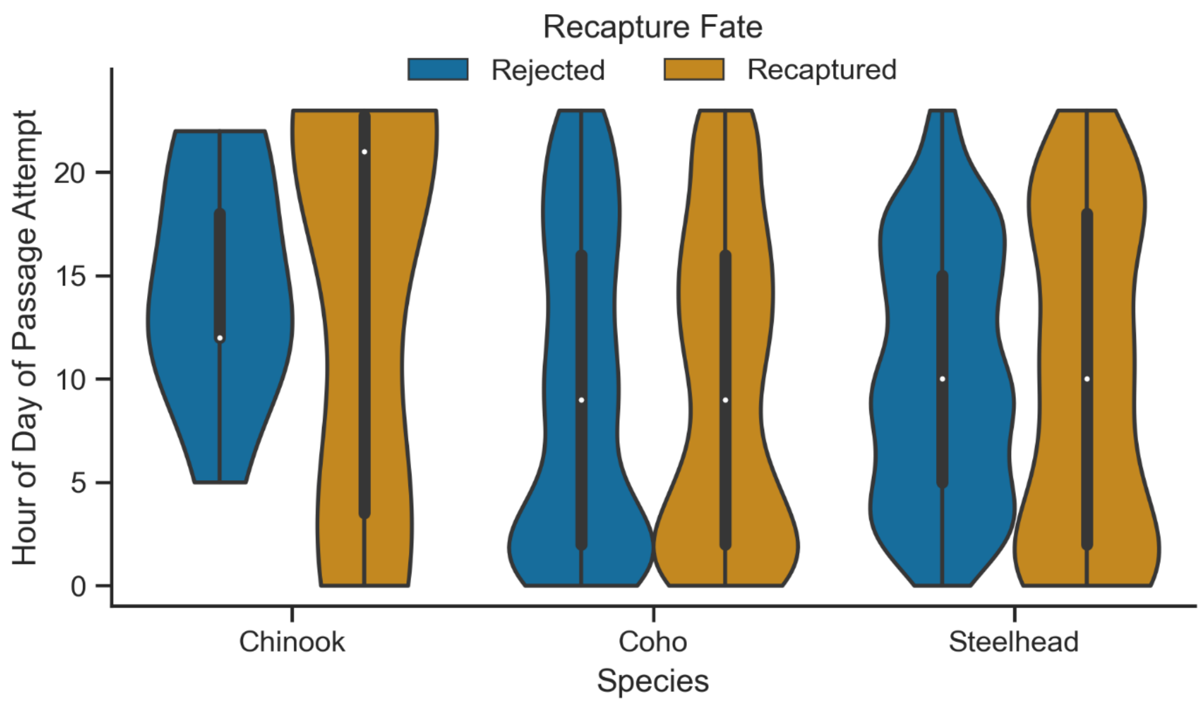


Figure 30. Hour of day of passage attempt by species and recapture fate. All passage attempts are represented here, meaning individual fish contribute to multiple replicates if they performed multiple attempts.

4 Discussion

This section discusses the results of the 2021 Study, compares the results among study years, and addresses principal questions related to the behavior and operation of the FSC. In 2021, sample size for Chinook Salmon was low, resulting in low statistical power for Chinook results. The 2021 sampling regime appeared to yield study fish whose outmigration dynamics represented the run-at-large.

In the 2021 Study, the re-establishment of a forebay sub-array enabled computation of reservoir passage (P_{PASS}, previously referred to in FSC evaluation reports as reservoir survival, P_{RES}), which was 81% for all study fish combined, and ranged from 73% for steelhead to 89% for Coho Salmon. For all species evaluated, reservoir passage in 2021 was within the range of observations from previous years in which P_{PASS} (or, previously, P_{RES}) was measured. Reservoir passage estimates suggest that approximately one in five study fish did not return to the forebay after being released during the study period after initial capture. Of those fish that did reach the forebay, most oriented to and then entered the FSC. Nearly all fish that were detected at the Devil's Backbone subsequently transitioned into the ZOI, which is reflected by the 94% encounter rate (P_{ENC}) for all species combined. The encounter rate was lower for Chinook Salmon (86%) than for Coho Salmon or steelhead, which is similar to results from previous years in which P_{ENC} was reported. However, this should be interpreted within the context of very low sample sizes for Chinook Salmon, which were approximately one fifth those for Coho Salmon and steelhead.

Encouragingly, nearly all fish that were detected within the ZOI continue to locate and enter the FSC. Entrance efficiency (P_{ENT}) was greater than 95% for all species in 2021. Compared to results from the three previous years in which entrance efficiency was evaluated, P_{ENT} in 2021 was similar to observations from 2019 and 2020, and substantially higher than in 2017. These findings indicate that increasing the entrance velocity of the FSC (in 2019) continues to attract outmigrating juvenile anadromous salmonids at a high rate.

After study fish oriented to the FSC and entered the NTS, however, many fish rejected the collector within the channel. This rejection within the channel is reflected in the relatively low transition rates from the NTS into the channel (P_{CHAN}), from the channel into the collector (P_{CAP}), and in the associated low retention rate (P_{RET}) and collection efficiency (P_{CE}).

Although retention and collection in 2021 were below targets, both were similar or slightly improved compared to 2020 (Table 1). In 2021, retention efficiency for steelhead was 50%, which is nearly 20% (8 percentage points) higher than the 42% observed in 2020. This increase in steelhead retention resulted in a 14% (6 percentage point) increase in collection efficiency for steelhead, from 42% to 48%. Similar increases were observed for Chinook Salmon, but Chinook sample sizes are too low to invest much confidence in this finding. Retention and collection remained relatively unchanged for Coho Salmon. Possible causes include differences in weather or other environmental conditions, and differences in fish size between years. However, without comprehensively evaluating differences among years within an appropriate retrospective analytical framework, it is difficult to confidently assert that this change was meaningful, or to assign an underlying mechanism for this increase.

After entering the collection channel, study fish rejected the collector at three locations: the transition from the NTS into the primary channel, the transition from the primary channel to the upstream secondary channel, and the transition from the downstream secondary channel into the collector (Figure 15). The last of these rejection areas had the highest rate of rejection, with approximately one third of all fish that had reached the downstream secondary channel turning around before being collected. Addressing this apparent limitation in the back of the secondary channel offers the greatest opportunity for improving collection at the Swift FSC. To illustrate the importance of low retention at Swift, if all fish that entered the channel were captured, then overall P_{CE} in 2021 would have been 76% (254/336), which is 72% (32 percentage points) higher than what was observed. Retaining those fish that reached the downstream secondary channel but were not retained in 2021 would have resulted in 60 more fish being collected in 2021 and an overall P_{CE} of 62% (207/336), representing a 41% (18 percentage point) improvement compared to what was observed.

Results from 2021 substantiated previous results that Swift FSC collection is limited by retention rather than by attraction, while also increasing the understanding of the precise locations of fish rejection within the channel. These findings help answer the questions, "What limits collection?" and its corollary, "Where do fish reject?"

To address the logical next question, "Why do fish reject being collected?" the 2021 Study evaluated a suite of hypothesized environmental and operational factors that could cause fish to reject collection while in the channel. This was done primarily by conducting a series of behavioral analyses that leveraged additional monitoring conducted in 2021 to test whether environmental (e.g., weather) or operational (e.g., human activity and systems) factors could explain rejection. Results from these behavioral analyses were used to provide insight into why fish reject collection within the channel and may provide the basis for operational modifications to address rejection rates within the channel. The results of many of these analyses did not support the hypotheses that these factors were influencing collection. For example, in 2020 it was found that successful passage attempts are more likely to occur in off-work hours, leading to the hypothesis that fish may reject the collector if they see or hear workers on the deck. However, the results of the 2021 behavioral analysis did not suggest that either human activity within the visible prism above the collection channel or more generalized human presence on the collector deck notably affected collection. It also bears noting that substantially more debris was removed from in front of the NTS during the 2020 study period, while operations in 2021 were adjusted to more proactively manage debris loading without allowing it to appreciably accumulate (Mark Ferraiolo, personal communication, December 15, 2021).

Human activity was evaluated in this context by using both trail camera images and sound monitoring data. The photographs collected by these trail cameras, and the associated metadata attributed to these photographs (e.g., timestamps, hourly and daily frequency), provide both general information about periods of human presence on the FSC deck, and specific information about when humans were present at locations where they could have been visible to fish within the collection channel. Human presence on the FSC does not appear to affect fish collection. The diel pattern of recapture appears to be unrelated to human presence on the FSC. Instead, it is more likely the result of inherent biological circadian rhythms. Time of day of passage attempt initiation was the strongest factor affecting passage attempt success across all species in 2021 (Table 14). Among the factors with a strong diel pattern that were evaluated at Swift in 2021, light levels in the channel appeared to influence passage success more than human activity (Table 14). Among fishes, photoperiod—the relative length of light and dark periods—is the primary factor that entrains circadian rhythms (Frøland Steindal and Whitmore 2019). As such, light contributes to the regulation of both diel patterns in behavior and seasonal patterns in reproductive physiology (Duston and Bromage 1988; Migaud et al. 2010), including smoltification and outmigration in salmonids (McCormick 2009). However, light is not the only factor that regulates circadian rhythms: they also are set by the interaction of light and temperature, stress, and other factors (Sánchez-Vázquez et al. 2019). The finding that time of day was more important than light levels indicates that light is not the sole driver of this observed diel pattern in passage attempt success. Other conditions that were not evaluated in 2021, but which cyclically vary on a daily scale, may also be responsible.

Evaluations of sound levels within and near the collection channel led to the counterintuitive finding that increasing sound levels were associated with increasing passage success. However, this finding may be explained by the observation that operating ten pumps resulted in greater sound levels than operating eight pumps. Although the statistical modeling supported both factors as important, the effect of pumping rate on passage success was both stronger and more consistent across species than was the effect of sound levels. Results from the blocked pumping rate study were consistent with these observations, providing strong support from an experimental manipulation of the factor of interest: reducing the number of pumps operating within the FSC appears to have reduced collection. When eight pumps were running, study fish made fewer attempts, and these attempts were slightly less successful than when ten pumps were running. The overall effect was that more study fish were collected when ten pumps were operating (Figure 29).

Sound monitoring also revealed a continuous 22 Hz sound signal emanating from the collector. This signal is within the range known to elicit a behavioral response from juvenile salmonids and could be affecting fish passage, though it was not possible to determine this with the data collected for this study because the sound was continuous and did not vary. The 22 Hz signal is audible at the entrance to the collector and did not appear to discourage fish from entering the collector (as evidenced by high entrance efficiency). However, it is unknown how this sound may influence behavior in the channel. Further sound monitoring in the collection channel and use of an accelerometer from the deck may help isolate the source of the signal. If the signal is caused by a sound pressure wave, then fish will likely not react to the sound. However, if the sound is vibrating through the hull of the collector and entering the water within the channel with a particle motion component, then fish are much more likely to react to the sound.

Patterns of false detections on the JSATS receivers in the secondary channel were also used to evaluate levels of operational noise within the collection channel. The results from this evaluation indicated that increasing operational noise was associated with increases in both the daily rate of attempts and the success rate of individual attempts. Interpretation of these results is difficult due to several factors. The JSATS receivers have variable thresholding to help filter out false positive detections. As the background noise level increases the thresholding adjusts to lower the number of false positive detections being processed so true detections aren’t lost. Due to the thresholding, the noise level can be interpreted as higher, but the magnitude of change is not known. In addition, there are multiple operational noise sources that may have differing effects on if fish are collected or if they reject collection. Two of the sources of noise that were detectable in the JSATS noise data were from operation of the secondary channel screen cleaners and the debris flushing operation.

The secondary channel screen cleaner is composed of three separate sprayers that clean in a progression from the upper end to the middle and lower sections of the secondary channel. Depending on the location of the fish when the cleaning cycle is initiated, the fish may move back upstream if they are upstream of the system or be collected if the fish is downstream. The debris flushing operation function causes a wave to move down the channel, flushing debris off the collection facility’s separator bars and into the adult collection tank from where it can be removed (Chris Karchesky, personal communication, December 6, 2021). These two systems function differently, and they probably have different effects on fish behavior, but the effects from each are difficult to separate without a more targeted state-space or network type analysis that accounts for starting conditions.

It seems likely that the wave caused by the debris flushing operation may push fish into the collector and this may explain why JSATS false detections were positively correlated with number of passage attempts and the success rate of attempts. Spray bar operation may also positively influence the probability that a passage attempt is successful, for example if a fish is downstream of the spray bar when the cleaner turns on, it may startle downstream and be collected. But, if the fish is upstream of the spray bar when the cleaner turns on, it may startle upstream and reject collection. However, inferred operation of the spray bars based on pattern of false JSATS detections had only moderate statistical support for influencing collection. Passage attempts were slightly less successful when they occurred during a period in which the spray bars were active. This effect did not have strong statistical support when considering all species together and had even weaker support when analyses were conducted on individual species. There may be additional noise sources that are being missed in the interpretation of this data due to filtering of the signal or if the signal is not within the frequency band or of the appropriate structure to be detected by the JSATS receivers.

Aside from pumping rate and spray bar/debris flushing operations, other environmental and operational factors did not affect fish passage success. A strong east wind did appear to cause more steelhead and Coho Salmon to attempt passage, perhaps via surface wave action simply pushing fish down the reservoir and towards the collector. However, east wind had no effect on whether these attempts were successful. Other environmental factors evaluated exhibited weakly supported effects that frequently differed in sign between species.

The importance of water velocity within the channel as a factor limiting fish retention is supported by the observation that smaller fish were more likely to be recaptured. Smaller salmonids (and other fishes) exhibit lower maximum burst swimming speeds than do longer fish of the same species (Cano-Barbacil et al. 2020). It therefore stands to reason that smaller fish may have been recaptured more successfully at the Swift FSC because they were less able to swim back upstream through the relatively high velocity zone within the secondary collection channel (transect station 7 in Figure 3). Additionally, larger fish are more able to swim upstream and escape the downstream currents in the collection channel when presented with stimuli that elicit an avoidence response.

Further supporting this inference, the two transitions in the FSC with the highest rejection rates were the entrance of the primary channel and the transition from the downstream secondary channel to collection (Figure 13), which are both characterized by lower velocity water (transect stations 1 and 11 in Figure 3). Conversely, the area of highest velocity water, the transition from the upstream to downstream secondary channel (transect station 7 in Figure 3) also happens to have the the lowest rejection rate. Moreover, the relationship between fish length and successful recapture was most pronounced for juvenile steelhead, which are both larger and stronger swimmers than either Chinook Salmon or Coho Salmon (reviewed in Bell 1991). Juvenile steelhead (and, to a degree, Coho Salmon and Chinook Salmon) may be capable of holding station in the low velocity water near the downstream end of the secondary collection channel, then swimming back out of the collector if conditions change or they are presented with stimuli that causes them to swim back upstream.

The most obvious recommendation considering these findings would be to increase capture velocity within the channel. Although, increasing flow within the Swift FSC may be complicated by technical constraints associated with the amount of water coming into the collector, it is recommended that the possibilities for increasing capture velocity within the collection channel be fully explored, especially if velocities within the channel are still below velocities that effectively capture most juvenile salmonids. Similarly, smoothing velocity gradients in areas within the channel where water rapidly speeds up and slows down—as was attempted using the pumping rate manipulation—may improve retention. Increasing velocities at the end of the collection channel, where fish may be able to hold before swimming back upstream through what is supposed to be a velocity impediment within the secondary channel, would likely help retain the many fish that make it that far before rejecting. Alternatively, physical retention structures like a low-profile fyke or similar debris-resistant trap near the downstream end of the collection channel could help retain fish in that zone and prevent them from moving back upstream. Such a trap would require appropriate design and fabrication materials to withstand the substantial hydraulic forces and debris loading that can be present in the collection channel, but not impede flow so much that capture velocities are reduced or incoming fish are deterred, which certainly is a nontrivial combination.

An additional possibility to explain apparent rejection within the collector, which may also partially explain diel patterns in fish rejection and overall low rates of retention and collection efficiency, is the presence of predatory fishes. Predatory fishes within the channel could both prey upon and exert non-consumptive behavioral effects (Laundré et al. 2014) on outmigrating juvenile salmonids. Circumstantial evidence supports this hypothesis, including results from a previous Swift FSC evaluation (Caldwell et al 2017), the periodic capture of adult predatory fish in the collector, and evaluations of a similar surface collector where the presence of predators in front of the collector was determined to exhibit a strong diel pattern (Adams et al 2017; Smith et al. 2021). Although the evidence supporting this at the Swift FSC is not strong, this possibility of predation within or adjacent to the collector may warrant further evaluation.

Conclusions

- Once fish have oriented to the FSC and are available for collection, the greatest bottleneck to collection occurs after fish have proceeded all the way to the downstream portion of the secondary channel and just before entering the sorting building.
- Neither human activity on or around the collector nor local weather at the FSC appear to affect collection.
- Velocities in the downstream secondary channel may allow fish to reverse course in the secondary channel and turn back upstream.
- Lower velocity areas within the collection channel—like the area of deceleration at the back of the collection channel, immediately before the collector entrance—may allow fish to hold and recover, then burst back upstream through the higher velocity reaches located upstream that currently retain primarily smaller or weaker swimmers, as evidenced by the observation that larger fish are less likely to be collected.
- Improving the transition rate from the downstream secondary zone into the collector, for example by increasing retention within the secondary collection channel, is the most promising avenue for improving collection.

- To improve Swift FSC collection, it is also recommended that PacifiCorp focus on increasing retention and smoothing out the areas of slight deceleration created by the 2019 NTS adjustments so that station holding locations of low velocity are eliminated.
- Alternatively, a physical retention device, like a fyke or similar directional trap could be effective, if designed to withstand the hydraulics within the channel and minimize debris loading.
- It is also recommended that PacifiCorp continue to evaluate low frequency sound, specifically 22 Hz, to identify the source and isolate it to determine if it is influencing fish collection rates.

5 References

Adams, N. S., and Smith, C. D. 2017. *Spatial and Temporal Distribution of Bull Trout (*Salvelinus confluentus*)-Size Fish near the Floating Surface Collector in the North Fork Reservoir, Oregon, 2016*. Open-File Report 2017–1080. U.S. Geological Survey (Cook, WA).

Anchor QEA (Anchor QEA, LLC). 2018. *Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Study 2017 Annual Report*. Prepared for PacifiCorp (Portland, OR).

Bell, M. C. 1991. *Fisheries handbook of engineering requirements and biological criteria (Final Report)*. U.S. Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program (Portland, OR).

Caldwell, L., Stroud, D., Carpenter, F., Belcher, L., Ross, K., and Ceder, K. 2017. *Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency: 2016 Annual Report - Final*. Prepared by Cramer Fish Sciences for Pacific Power (A Division of PacifiCorp).

Cano-Barbacil, C., Radinger, J., Argudo, M., Rubio-Gracia, F., Vila-Gispert, A., and García-Berthou, E. 2020. "Key factors explaining critical swimming speed in freshwater fish: A review and statistical analysis for Iberian species." *Scientific Reports* 10:18947.upstream

Christensen, P., and Grant, P. 2013. *2012 Hydraulic Evaluation of Swift Reservoir Fish Screens (DRAFT)*. Prepared by ALDEN Research Laboratory, Inc. (Redmond, WA). Prepared for Black & Veatch (Seattle, WA), Under Contract to PacifiCorp (Portland, OR).

Courter, I., Garrison, T., and Carpenter, F. 2013. *Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Pilot Study*. Prepared by Cramer Fish Sciences for Pacific Power, A Division of PacifiCorp (Portland, OR).

Deng, Z. D., Weiland, M. A., Fu, T., Seim, T. A., LaMarche, B. L., Choi, E. Y., Carlson, T. J., and Eppard, M. B. 2011. "A cabled acoustic telemetry system for detecting and tracking juvenile salmon: Part 2. Three-dimensional tracking and passage outcomes." *Sensors* 11:5661-5676.

Duston, J., and Bromage, N. 1988. "The entrainment and gating of the endogenous circannual rhythm of reproduction in the female rainbow trout (*Salmo gairdneri*)." *Journal of Comparative Physiology, A: Neuroethology, Sensory, Neural, and Behavioral Physiology* 164(2):259-268.

FERC (Federal Energy Regulatory Commission). 2008. Order on Offer of Settlement and Issuing New License. PacifiCorp and Public Utility District No. 1 of Cowlitz County, Washington. Project Nos. 2111-018, 2071-013, 935-053, 2213-011.

Four Peaks (Four Peaks Environmental Science & Data Solutions). 2020. *Swift Reservoir Floating Surface Collector Collection Efficiency Evaluation 2019 Annual Report*. Prepared for PacifiCorp (Ariel, WA).

Four Peaks. 2021. *Swift Reservoir Floating Surface Collector Collection Efficiency Evaluation 2020 Annual Report*. Prepared for PacifiCorp (Ariel, WA).

Frøland Steindal, I. A., and Whitmore, D. 2019. "Circadian clocks in fish—What have we learned so far?" *Biology* 8(1):17.

Hastings, M. C., and Popper, A. N. 2005. "Effects of Sound on Fish." Prepared by Jones & Stokes (Sacramento, CA). Prepared for California Department of Transportation (Sacramento, CA).

Kendall, N. W., McMillan, J. R., Sloat, M. R., Buehrens, T. W., Quinn, T. P. Pess, G. R. Kuzishchin, K. V. McClure, M. M. and Zabel, R. W. 2015. "Anadromy and residency in steelhead and rainbow trout

(*Oncorhynchus mykiss*): A review of the processes and patterns." *Canadian Journal of Fisheries and Aquatic Sciences* 72:319-342.

Laake, J. 2019. Package 'RMark'. National Oceanic and Atmospheric Administration, Alaska Fisheries Science Center, Juneau, AK.

Laundré, J. W., Hernández, L., Medina, P. L., Campanella, A., López-Portillo, J., González-Romero, A., Grajales-Tam, K. M., Burke, A. M., Gronemeyer, P. and Browning, D. M. 2014. "The landscape of fear: The missing link to understand top-down and bottom-up controls of prey abundance?" *Ecology* 95:1141-1152.

Mazeaud, M. M., Mazeaud, F., and Donaldson, E. M. 1977. "Primary and secondary effects of stress in fish: Some new data with a general review." *Transactions of the American Fisheries Society* 106:201-212.

McCormick, S. D. 2009. "Evolution of the hormonal control of animal performance: Insights from the seaward migration of salmon." *Integrative and Comparative Biology* 49(4):408-422.

Midwood, J. D., Larsen, M. H., Aarestrup, K., and Cooke, S. J. 2016. "Stress and food deprivation: Linking physiological state to migration success in a teleost fish." *The Journal of Experimental Biology* 219:3712-3718.

Migaud, H., Davie, A., and Taylor, J. F. 2010. "Current knowledge on the photoneuroendocrine regulation of reproduction in temperate fish species." *Journal of Fish Biology* 76(1): 27-68.

PacifiCorp. 2015. *Operational Guidelines in Consideration of Suspending Summer Operations at the Swift Floating Surface Collector (FSC) (Memorandum)*. Prepared by PacifiCorp. Reviewed and Accepted by the Aquatic Coordination Committee, Portland, OR.

PacifiCorp and Cowlitz County PUD (Public Utility District No. 1 of Cowlitz County). 2017. *Lewis River DRAFT Aquatic Monitoring and Evaluation Plan – First Revision - December 19, 2016*. PacifiCorp Energy (Portland, OR) and Public Utility District No. 1 of Cowlitz County (Longview, WA).

PacifiCorp and Cowlitz County PUD 2019. *Lewis River Fish Passage Program 2018 Annual Report (Final): Monitoring and Evaluation (M&E) Plan Metrics*. PacifiCorp Energy (Portland, OR) and Public Utility District No. 1 of Cowlitz County (Longview, WA).

PacifiCorp and Cowlitz County PUD 2020. *Lewis River Hatchery and Supplementation Plan (Final)*. PacifiCorp Energy (Portland, OR) and Public Utility District No. 1 of Cowlitz County (Longview, WA).

PacifiCorp, Public Utility District No. 1 of Cowlitz County, National Marine Fisheries Service, National Park Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Forest Service, Confederated Tribes and Bands of the Yakama Nation, Washington Department of Fish And Wildlife, Washington Interagency Committee for Outdoor Recreation, Cowlitz County, Cowlitz-Skamania Fire District No. 7, North Country Emergency Medical Service, City of Woodland, Woodland Chamber of Commerce, Lewis River Community Council, Lewis River Citizens at-Large, American Rivers, Fish First, I. Rocky Mountain Elk Foundation, Trout Unlimited, and The Native Fish Society. 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. PacifiCorp Energy.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Reynolds, E., Belcher, L., and Stevens, P. 2015. *Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency: 2015 Annual Report Memorandum*. Prepared by Cramer Fish Sciences for Pacific Power (A Division of PacifiCorp).

Sánchez-Vázquez, F. J., López-Olmeda, J. F., Vera, L. M., Migaud, H., López-Patiño, M. A., and Míguez, J. M. 2019. “Environmental cycles, melatonin, and circadian control of stress response in fish.” *Frontiers in Endocrinology* 10(Article 279):.

Scott, D. W. 1992. “Kernel Density Estimators.” Pages 125-193 in *Multivariate Density Estimation: Theory, Practice, and Visualization*. Wiley-Interscience, New York, NY.

Smith, C., Adams, N., Weiland, M., and Karchesky, C. 2018. *Exploratory analysis of imaging sonar data from Swift Reservoir*. Prepared in Cooperation with U.S. Geological Survey (Cook, WA), Four Peaks Environmental Science & Data Solutions (Wenatchee, WA), and PacifiCorp (Portland, OR).

Smith, C. D., Plumb, J. M., Adams, N. S., and Wyatt, G. J. 2021. “Predator and prey events at the entrance of a surface-oriented fish collector at North Fork Dam, Oregon.” *Fisheries Management and Ecology* 28(2):172-182.

Stroud, D., Carpenter, F., and Stevens, P. 2014. *Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency: 2014 Annual Report Memorandum - Final*. Prepared by Cramer Fish Sciences for Pacific Power (A Division of PacifiCorp).

Weiland, M., Ploskey, G., Hughes, J., Deng, Z., Fu, T., Monter, T., Johnson, G., Khan, F., Wilberding, M., Cushing, A., Zimmerman, S., Durham, R., Faber, D., Townsend, R., Skalski, J., Kim, J., Fischer, E., and Meyer, M. 2009. *Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008*. Prepared by Pacific Northwest National Laboratory (Richland, WA) for the U.S. Army Corps of Engineers, Portland District (Portland, OR).

White, G. C., and Burnham, K. P. 1999. “Program MARK: Survival estimation from populations of marked animals.” *Bird Study* 46:S120-S139.

APPENDIX A Detailed Study Methods

A.1 Acoustic Telemetry Array

Overview

From February 22 to 28, 2021, Four Peaks Environmental Science & Data Solutions (Four Peaks) staff installed an acoustic telemetry array comprising 28 receivers in the Swift Dam forebay and in and around the floating surface collector (FSC), plus a remote receiver within the FSC for confirming tag activation (2021 Swift Reservoir Floating Surface Collector Passage Evaluation [2021 Study] Figure 7). The 28 receivers covered four zones: the forebay (FBY), zone of influence (ZOI), net transition structure (NTS), and the collection channel (CCH), which was further broken up into the primary screen collection channel (primary channel) and the secondary screen collection channel (secondary channel), with the secondary channel further divided into upstream and downstream sections. Each of these zones was monitored with a subarray of receivers: four autonomous receivers in the FBY, two autonomous and two cabled receivers in the ZOI, six cabled receivers in the NTS, five cabled receivers in the primary channel, five cabled receivers in the upstream secondary channel, and three cabled receivers in the downstream secondary channel. Receiver codes and the approximate depths of their hydrophones are provided in Appendix Table A.1.

Appendix Table A.1. Acoustic receiver model and approximate depths of hydrophones associated with each receiver within the Swift floating surface collector acoustic telemetry array.

Zone	Receiver ID	Receiver Model	Approximate Hydrophone Depth (ft)
FBY	FBY-01	Autonomous SR3001	30
FBY	FBY-02	Autonomous SR3001	30
FBY	FBY-03	Autonomous SR3001	30
FBY	FBY-04	Autonomous SR3001	30
ZOI	ZOI-01	Cabled SR3017	50
ZOI	ZOI-02	Cabled SR3017	40
ZOI	ZOI-03	Cabled SR3017	30
ZOI	ZOI-04	Cabled SR3017	30
NTS	NTS-01	Cabled SR3017	7
NTS	NTS-02	Cabled SR3017	7
NTS	NTS-03	Cabled SR3017	7
NTS	NTS-04	Cabled SR3017	7
NTS	NTS-05	Cabled SR3017	7
NTS	NTS-06	Cabled SR3017	7
Primary Channel	CCH-01	Cabled SR3017	4.2
Primary Channel	CCH -02	Cabled SR3017	5.75
Primary Channel	CCH -03	Cabled SR3017	10.2
Primary Channel	CCH -04	Cabled SR3017	5.5
Primary Channel	CCH -05	Cabled SR3017	8.75
Secondary Channel	CCH -06	Cabled SR3017	7
Secondary Channel	CCH -07	Cabled SR3017	4

Zone	Receiver ID	Receiver Model	Approximate Hydrophone Depth (ft)
Secondary Channel	CCH -08	Cabled SR3017	5
Secondary Channel	CCH -09	Cabled SR3017	3.75
Secondary Channel	CCH -10	Cabled SR3017	3.2
Secondary Channel	CCH -11	Cabled SR3017	1.7
Secondary Channel	CCH -12	Cabled SR3017	2
Secondary Channel	CCH -13	Cabled SR3017	2
Secondary Channel	CCH -14	Cabled SR3017	2
Recovery Tank	FSC Transfer Tank	Modified Mobile SR3000	*Not Applicable*

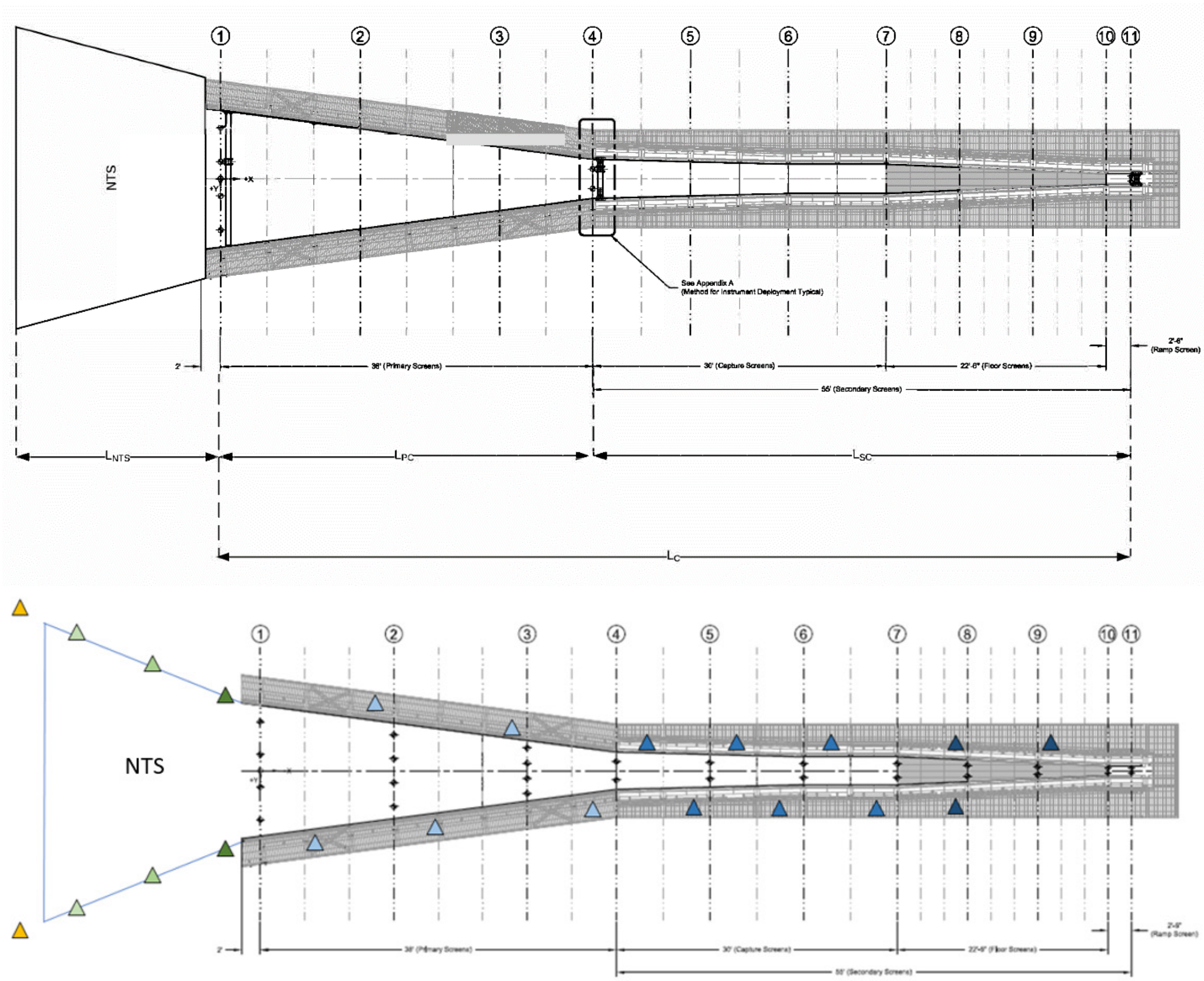
Context, Approach, and Design

Results from the Swift FSC 2019 and 2020 evaluations (Four Peaks 2020, 2021) identified low retention efficiency as the main factor limiting FSC collection efficiency. During the 2019 and 2020 studies, fish appeared to enter the collection channel but then returned upstream instead of continuing to collection. Consequently, the acoustic array for the 2021 Study was designed to focus on these areas of interest, providing higher spatial resolution within the NTS and collection channel with coarser resolution in the ZOI.

Collection Channel Subarrays

An array of 20 shore-based, hydrophones cabled directly to acoustic receivers (Advanced Telemetry Systems [ATS] SR3017 Trident) was designed to provide comprehensive coverage of the channel with minimal exposure to noise and minimal prominence within the channel (Appendix Figure A.1).

The collection channel array was designed to identify areas within the collection channel where tagged fish hold or turnaround and focus on areas where fish were appearing to turn around during the 2019 and 2020 studies. This was accomplished by installing a dense array of hydrophones in the collection channel. Six hydrophones were deployed in the NTS, to monitor movement and holding within the NTS, and separate the NTS into upstream and downstream zones (Appendix Figure A.1). Five hydrophones were deployed in the primary channel (the area bounded by cross sections 1 and 4 in Appendix Figure A.1). Six hydrophones were deployed in the upstream section of the secondary channel (the area bounded by cross sections 4 and 7 in Appendix Figure A.1) and three hydrophones were deployed in the downstream secondary channel (the area bounded by cross sections 7 and 10 in Appendix Figure A.1).



Appendix Figure A.1. Swift floating surface collector schematic diagram, showing plan (overhead) view of the collection channel, including primary screen and secondary screen zones.

Deployment of hydrophones in the high-velocity, acoustically challenging aquatic environment of the collection channel required careful consideration to achieve acceptable detection efficiency while minimizing the impact of equipment on fish passage and operations. Several deployment options were tested that did not involve direct placement of hydrophones within the collection channel, but on the sides of the channel, in the areas behind the dewatering screens (Appendix Figure A.2). This technique kept the hydrophones out of high-water velocities in the channel that create acoustically noisy conditions and could have made it difficult to detect tagged fish. Moreover, confined space means that deploying hydrophones and their mounts directly within

Appendix Figure A.2. Deployment of a collection channel hydrophone and mount, showing location behind the dewatering screens on the collection channel platform.

the channel would result in reduced detection ranges for these receivers. Placing hydrophones directly within the channel could also affect fish movement or otherwise negatively influence retention and collection efficiency.

The receivers were deployed in the area along the sides of the collection channel, between the wedge wire dewatering screens and perforated plates. This is out of the direct in-channel flow paths and provides a desirable acoustic environment in which to deploy the hydrophones.

Mounts for hydrophones deployed in the primary and secondary channels were designed to meet the narrow gap tolerance between the wedge wire dewatering screens and the perforated plates along the walls of the primary and secondary channel and allow room for the hydrophone cable. A baffle to reduce flow noise and acoustic multipath noise was fitted into the hydrophone mount and the hydrophone attached inside the baffle. The mount was attached to three-quarter-inch (19 mm) steel pipe, lowered into the gap to the appropriate depth, then pressed against the wedge wire screen and pipe attached to the screen stiffener bars using beam clamps. The hydrophone cable was then routed to deck level and attached in position to avoid contact with the screen cleaning assembly.

Net Transition Structure and Zone of Influence

To detect tagged fish as they transition from the ZOI into the collection channel by way of the NTS, two additional SR3017 Trident receivers (one port, one starboard) were deployed along the sides and near the mid-point of the NTS. The hydrophones for these receivers were mounted to a three-quarter-inch (19 mm) steel pipe using an assembly that was similar to the mounts described above for use in the collection channel (Appendix Figure A.3). This pipe was then passed through a 90° (three-socket) tee horizontally, to which a second length of three-quarter-inch (19 mm) steel pipe was attached vertically. This assembly was then lowered into position and the mount pressed against the outer wall of the NTS before being attached with beam clamps.

Appendix Figure A.3. Cabled hydrophone and pipe mount.

Four SR3017 cabled receivers were used to detect fish within the ZOI. Two of these were located approximately 6 feet (2 m) in front of the NTS entrance. These receivers detected fish as they entered the ZOI and enabled estimation of the times when tagged fish entered the NTS. The other two receivers were deployed 30 feet (9 m) and 150 feet (46 m) upstream of the NTS entrance, along the guide net that extends from the mouth of the FSC east into the forebay, to detect fish entering the ZOI.

The receivers mounted off the front (upstream) end of the NTS were attached with ropes to aluminum poles and suspended 6 feet upstream from the NTS. A 25-pound kettlebell was attached below the autonomous receiver to keep the receiver at the target depth. The receivers on the guide net were attached to the guide net with a rope and a shackle and a 10-pound kettlebell attached. The cables from these hydrophones were routed along the float line back to the FSC and connected to their receivers in the deck boxes.

Appendix Figure A.4. Autonomous receivers deployed in the zone of influence, showing rope and shackles that held kettlebell weights.

Appendix Figure A.5. ATS reference beacons attached to steel pipe for deployments in the NTS.

Forebay Entrance

Four ATS SR3001 autonomous receivers were deployed along the debris boom at the entrance to the forebay near Devil's Backbone detecting fish as they entered the forebay. The receivers were attached to ropes with weights at the bottom and deployed 30 ft depth (Appendix Figure A.4**).**

Monitoring the Fish Transfer Tank

Inside the FSC, a cabled hydrophone was placed in the fish transfer tank where fish recovered after tagging. The hydrophone was coupled with a modified mobile receiver (ATS SR3000) located immediately behind the tank. Data from this receiver were used to verify tag activation after tagging and prior to release.

Acoustic Reference Beacons

Ten 60-second ping rate acoustic reference beacons (ATS, Appendix Figure A.5**,** Appendix Table A.2) were deployed within the array. These beacons emit a known tag signal at the stated frequency (1 per minute) that can be used to verify the consistent operation of each hydrophone-receiver pair within the array.

Appendix Table A.2. Beacon tag associations and locations across the deployment.

Beacon ID	Tag Code	Depth (feet)	Location
FBY-01	G727DBEB2	30	On receiver
FBY-02	G721FFC83	30	On receiver
FBY-03	G727DB592	30	On receiver
FBY-04	G727DC005	30	On receiver
ZOI-01	G72YDA9AC	50	On receiver
ZOI-02	G727DADCD	40	On receiver
ZOI-03	G721F2077	30	On receiver
ZOI-04	G727DB1F3	30	On receiver
NTS-01	G721F1BE9	7	On receiver
NTS-02	G721F14A8	7	On receiver
NTS-03	G721F27F4	7	On receiver
NTS-04	G721F3E5	7	On receiver
NTS-05	G727DAA4E	7	On receiver
NTS-06	G727DB931	7	On receiver

A.2 Array Testing Methods

Performance evaluations for equipment within the array and for data processing algorithms were conducted before and during the season, according to the following schedule (Appendix Table A.3). Before deployment, field testing of the full system was conducted twice, to verify that deployment methods and assumptions were valid and to ensure that resulting data were of sufficient quality to answer the project research questions. Testing within the collection channel included static monitoring of tags at fixed positions as well as controlled tag drifts through the channel. The purpose of these tests was to determine if tags were detectable in this environment and to test positioning algorithms for identifying location and movement of acoustic tags through the channel.

Appendix Figure A.6. Bottom portion of test tag stringer, showing two tags, stringer cord, and weight.

Appendix Table A.3. Receiver array testing schedule.

Zone	Type	Dates	Notes
NTS and CCH	Static	2/27/21	Conducted during array deployment.
NTS and CCH	Drag	2/27/21	Conducted during array deployment.
FBY and ZOI	Static/Drag	2/27/21	Conducted during array deployment.
NTS and CCH	Static	2/28/21	Conducted during array deployment.

Drags and Holds

Field testing included a series of tag drags, floats, and holds, using two to six acoustic tags affixed at a range of depths to a length of cord that was buoyed at the top using a float and anchored at the bottom using a large shackle (test stringer, Appendix Figure A.6). The test stringer was deployed by boat within the ZOI and by hand from the deck of the NTS (Appendix Figure A.7). The basic test protocol involved one person deploying the test stringer at a static location or across a transect, a second person tracking time and calling out transitions of the test stringer between acoustic zones, and a third person recording relevant data. In addition, a series of beacon tags were deployed within the array, to estimate idealized detection efficiency and provide basic quality assurance of the performance of each receiver. This generated a set of test data which included a time series of “true” zone positions for the set of test tags by which to calibrate zone positioning criteria (Appendix A.5).

During deployment, all receiver systems were tested as they were deployed, to verify function and to ensure that the hydrophone had direct “line-of-sight” with the environment it was monitoring. After deployment, once the collector was turned on, both static and drift testing was conducted using stringers of multiple test tags. Data were then processed and analyzed, to verify function of all receivers and test for detection efficiency and deployment positioning effectiveness.

Appendix Figure A.7. Deploying test stringer by hand within the floating surface collector collection channel.

Detection Efficiency During Testing

Detection efficiency of acoustic receivers was evaluated prior to deployment and periodically during the study season to ensure that acoustically-tagged individuals would be properly detected in the ZOI, NTS, and collection channel. Detection efficiency was evaluated by determining the number of acoustic transmissions omitted from a stringer of test tags ("pings") expected within a given time interval (based on a 3-second ping rate interval; 2021 Study Table 2) and then finding the number of pings detected on a group of receivers within a given zone. The ratio of these two counts provided the proportion of pings detected among a group of receivers and was used to quantify detection efficiency during deployment of the acoustic array. Detection efficiency values were then summarized by test ID, depth of the test tag, and location of the test within the particular area of interest.

During in-season reporting, detection efficiency was evaluated on a per receiver basis using a series of automated diagnostics that were performed during periodic receiver download trips (Appendix Table A.3). Diagnostic reports provided visualizations of the detection history of acoustic tags known to be part of the acoustic study (i.e., "study tags") as well as beacon tags deployed within the acoustic array to provide a constant acoustic transmission on which to determine in-season detection efficiency. Diagnostics also enumerated the amount of detections heard by the receiver that were not associated with any known deployed acoustic tag and deemed noise, in order to understand the signal-to-noise ratio experienced by each acoustic receiver in the array. Visual diagnostics were reviewed following each receiver download to identify unusual tag detection histories or periods when receivers were potentially overloaded with background ambient noise.

A.3 Array Testing Results

Pre-Season Array Testing Results

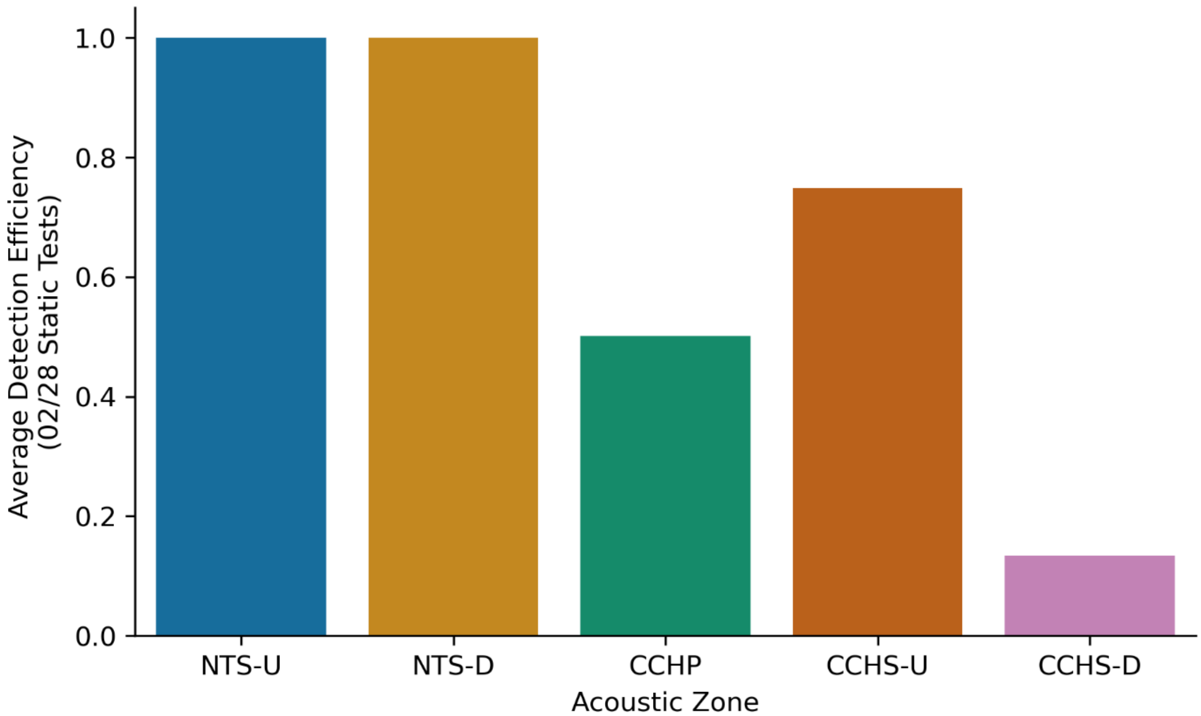
Pre-season array testing confirmed that the receivers were functioning properly and were detecting tags at acceptable ranges, providing ample detection ability for each zone. Results for the ZOI, NTS, and collection channel subarrays are discussed in the following subsections.

Forebay and Zone of Influence

On February 27, 2021, a series of tests were conducted that involved holding three stringers of test and beacon tags at various depths (approximately 3-15 feet) at a series of locations throughout the ZOI and the forebay. Results from these tests indicated that detection efficiency of the forebay and ZOI arrays was at least 90% across the range of depths tested. In the ZOI, the combined performance of all four receivers and the redundancy provided by having two receivers monitoring the ZOI from the front of the collector (ZOI-03 and ZOI-04) provided ample coverage of the ZOI, even during short periods where individual receivers did not function optimally.

Net Transition Structure and Collection Channel

Test results in the NTS and collection channel suggested that the receivers within each zone were able to effectively detect individual tags moving through the NTS, primary channel, and secondary channel. depicts average detection efficiency during one static test on February 28, 2021, in the NTS and collection channel. Detection efficiency was between 90% and 100% for tags at a variety of depths in the NTS, both for static tests and drag tests (Appendix Figure A.8). In the primary and secondary channel, detection efficiency ranged from 20% to 75% for the individual subzones making up the larger channel, with detection in the downstream secondary channel being lowest (Appendix Figure A.8). While individual detection efficiency was low in this zone, redundancy in the channel subarrays mitigated noise interference and achieved sufficient detection efficiency in the entire channel to track individuals moving and holding in this zone, despite high flow rates.



Appendix Figure A.8. Example of detection efficiency results from static testing in the net transition structure and collection channel on February 28, 2021. Values depict the average detection efficiency across test tags deployed at various depths in the channel.

In-Season Array Performance

The acoustic telemetry array was stable and performed as expected throughout the study period. The acoustic environment within the array differed among the subarrays covering each zone. Acoustic noise manifests itself on the acoustic receivers used for the study as detections of random tag codes, or false signals. In the ZOI, the acoustic environment was relatively quiet and there were few false signals in the data from the subarray. Noise levels increase moving towards the channel, peaking in the primary channel before dropping substantially in the secondary screen channel. This is due largely to the structure of these zones, with the ZOI being more open and having a relatively low water velocity environment compared to the more confined areas in the NTS and collection channel that have higher velocity.

Despite high levels of ambient noise in the collection channel, continuous tag drags and diagnostic reports confirmed that study tags were detected regularly, indicating that tags could be detected despite the background noise in this zone. Additionally, digital signal processors on the receivers were effective in filtering out a larger proportion of ambient noise, especially in the primary and secondary channel where flow noise was greatest. Receiver and acoustic diagnostic information retrieved with each data download indicated this detection ability was sustained within each zone throughout the season and kept the team informed of possible issues.

A.4 Zone Presence Criteria Development and Testing

After raw acoustic detection data were summarized into a filtered form, they were summarized to position fish within a given zone along the approach to collection (zone presence). This process included establishing, testing, and then iteratively adjusting a suite of zone presence criteria (ZPC) that logically and quantitatively evaluate an acoustic signal to determine its location. ZPC were initially constructed by using acoustic data collected during pre-season tests outside the ZOI and within the NTS and the collection channel. After formulating the initial set of ZPC for each zone using these data, Four Peaks continued to evaluate the efficiency of criteria by using a combination of in-season acoustic data and continual tag drag tests performed throughout the season. This allowed the construction of a final set of ZPC that were used to inform presence-absence through the entire array across the entire study period, which was used to inform mark-recapture models.

The final set of ZPC used estimated positions along the channel calculated through a simplified time-of-arrival difference (TOAD) analysis (Deng et al. 2011). This 1D positioning method approximates longitudinal location within the channel by comparing detection times of an acoustic tag signal (ping) on multiple receivers. The method relies on grouping together detections across receivers for a single tag code (in intervals based on the ping rate interval; 3 seconds for ATS SS400 tags, 2021 Study Table 2), and then ordering them chronologically to provide an understanding of where an individual is in the array. The order in which this detection occurs allows the estimation of the position of an individual within the acoustic array.

TOAD analyses for each tag were used in conjunction with other criteria to construct a presence-absence matrix across the entire array and throughout the study period. The final set of criteria used TOAD comparisons between each zone to independently position fish within seven zones: the forebay, ZOI, upstream NTS, downstream NTS, primary channel, upstream secondary channel, and downstream secondary channel. Once ZPC were established, it allowed the construction of a total presence-absence matrix for the entire array across the entire season, which was used to inform mark-recapture models (APPENDIX C).

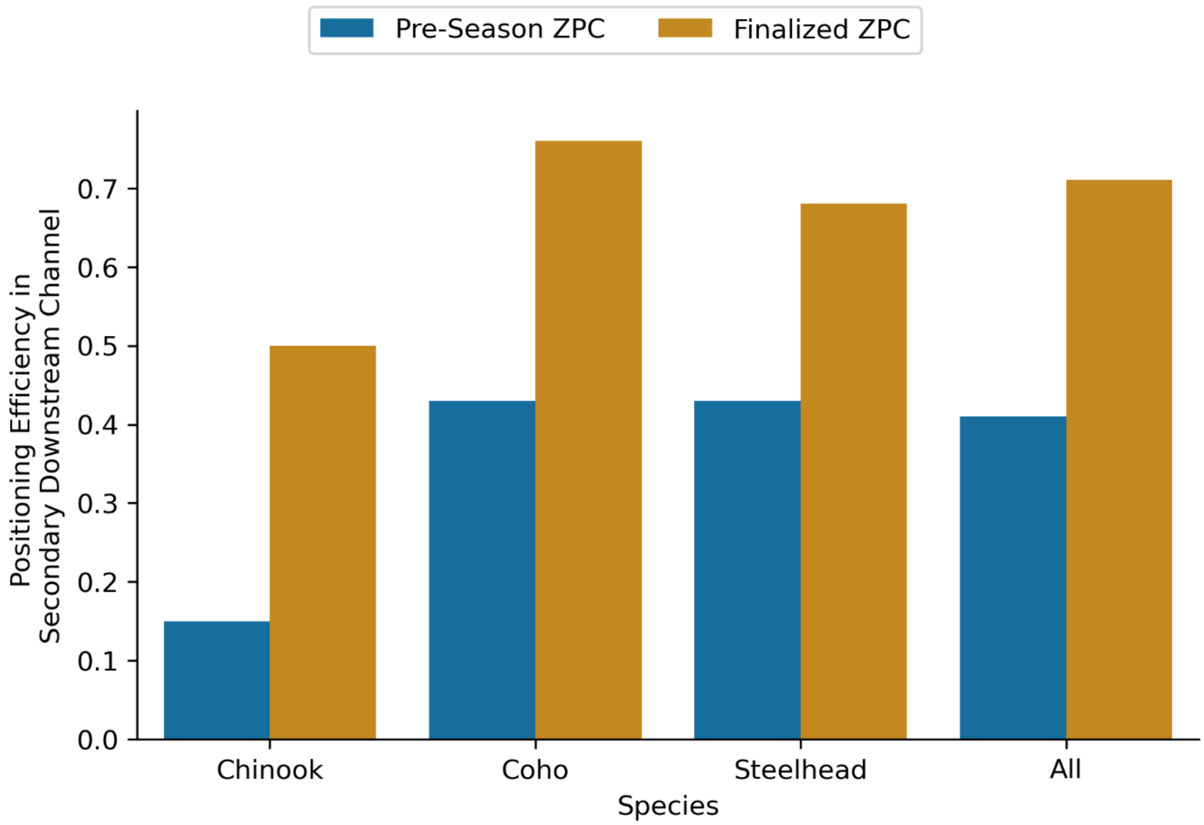
ZPC were initially constructed by maximizing the sensitivity and specificity of tag drag results from testing occurring during deployment (see Appendix A.5). These criteria informed in-season estimates of zone presence, which were then evaluated for accuracy based largely on zone presence time series and passive integrated transponder (PIT)-array detections in the collector. ZPC were then finalized prior to construction of final mark-recapture models. The final set of zone-presence criteria were as follows:

- An individual was considered within the forebay if there was at least one ping satisfying one of the following criteria:
  - First detected on either FBY-01, FBY-02, FBY-03, or FBY-04
- An individual was considered within the ZOI if there was at least one ping satisfying one of the following criteria:
  - Detected on either ZOI-01, ZOI-02, ZOI-03, or ZOI-04 with an amplitude of 200 or greater
  - First detected on either ZOI-01 or ZOI-02 and subsequently detected on any ZOI or NTS receiver
  - First detected on either ZOI-03 or ZOI-04 and then immediately afterwards detected on either ZOI-01 or ZOI-02

  - First detected on ZOI-03 or ZOI-04 and subsequently detected on any ZOI receiver

- An individual was considered within the upstream NTS if there was at least one ping satisfying one of the following criteria:
  - First detected on either NTS-01 or NTS-02 and then immediately afterwards detected on either NTS-03 or NTS-04
  - First detected on either NTS-03 or NTS-04 and then immediately afterwards detected on either NTS-01 or NTS-02
- An individual was considered within the downstream NTS if there was at least one ping satisfying one of the following criteria:
  - First detected on either NTS-05 or NTS-06 and then immediately afterwards detected on either NTS-03 or NTS-04
  - First detected on either NTS-03 or NTS-04 and then immediately afterwards detected on either NTS-05 or NTS-06
- An individual was considered within the primary channel if there was at least one ping satisfying one of the following criteria:
  - First detected on CCH-01, CCH-02, CCH-03, CCH-04, or CCH-05, and then immediately afterwards detected on any other receiver
- An individual was considered within the upstream secondary channel if there was at least one ping satisfying one of the following criteria:
  - First detected on CCH-06, CCH-07, CCH-08, or CCH-09, and then immediately afterwards detected on CCH-06, CCH-07, CCH-08, CCH-09, CCH-10, CCH-11, CCH-12, CCH-13, or CCH-14
- An individual was considered within the downstream secondary channel if there was at least one ping satisfying one of the following criteria:
  - First detected on CCH-12, CCH-13, or CCH-14 with an amplitude of 210 or greater
  - Detected on either CCH-12, CCH-13, or CCH-14 with an amplitude of 210 or greater with subsequent detections on any other receiver
  - First detected on CCH-10, CCH-11, CCH-12, CCH-13, or CCH-14 with an amplitude of 200 or greater, with either the previous or subsequent ping having its first detection on CCH-10, CCH-11, CCH-12, CCH-13, or CCH-14 with an amplitude of 200 or greater

Initial ZPC for the secondary downstream channel established during array testing struggled to position fish in-season, only positioning 40% of all collected individuals into the secondary downstream channel (Appendix Figure A.9). This was largely due to the constrained nature of this subzone, the limited detection aperture of the three acoustic receivers in this zone, and the fast hydrologic flows limiting potential detection events. To improve detection efficiency in this zone, sensitivity analyses around the ZPC were conducted as well as investigations of acoustic signatures for those individuals that were not positioned in the zone. These analyses were used to expand ZPC, and finalized criteria successfully detected 71% of all collected individuals (2021 Study Table 10; Appendix Figure A.9).



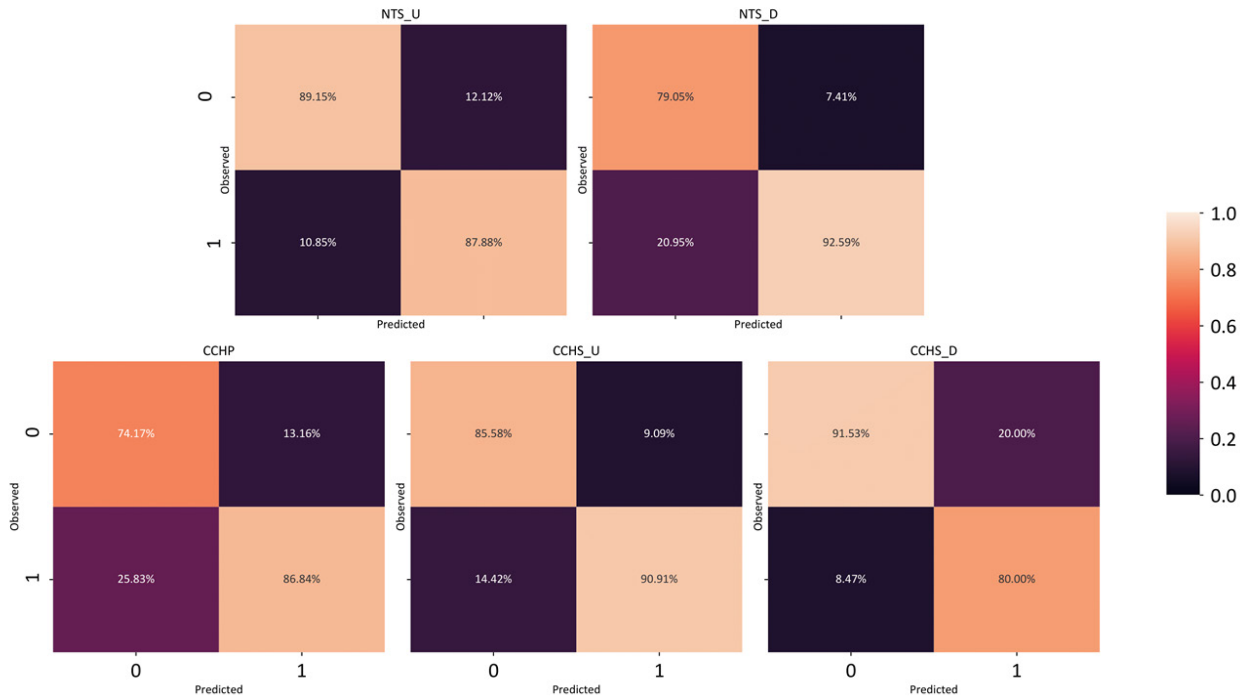
Appendix Figure A.9. Zone positioning efficiency in secondary downstream channel between initial and finalized zone presence criteria.

Because this update was focused on collected individuals and minimizing the false negative rate (i.e., fish that were present in the zone but not positioned), there was the potential for updated criteria to overcorrect and position uncollected fish in the secondary downstream channel when not actually present (i.e., false positives). Indeed, five fish (1 Chinook Salmon and 4 steelhead) had zone presence time series that included spurious positions in the downstream secondary channel following the update. These five individuals had their detection histories manually edited in order to fix these false positive detections following the ZPC update, and are noted in the presence-absence matrix provided in APPENDIX C.

Zone positions were determined by selecting only those pings which resolved to be within a single zone; if a ping was resolved to be in more than one zone, it was considered indeterminate and was not assigned to any zone. Zone presence time series for tags were used to inform mark-recapture models and subsequent behavioral analyses.

A.5 Zone Positioning Accuracy

Static and drag testing in the ZOI, NTS, and collection channel produced zone presence time series that included documented positions of test tags. The comparison of these observed positions to positions predicted by ZPC allowed for the measurement of accuracy of criteria for each zone via a confusion matrix (Appendix Figure A.10). For each subzone, the confusion matrix depicted four outcomes of zone positioning criteria: detections outside the zone that were positioned outside the zone (upper left quadrant, true negatives); detections outside the zone that were positioned inside the zone (upper right quadrant, false positives); detections inside the zone that were positioned outside the zone (lower left quadrant, false negatives); and detections inside the zone that were positioned inside the zone (lower right quadrant, true positives). Updates to ZPC were focused on maximizing the true positive rate (sensitivity) while also trying to maintain a high true negative rate (specificity). Refinement and evaluation of ZPC on a select subset of pre-season drag tests in the NTS and channel allowed for a set of ZPC that had 80-90% true positive rates for all subzones, ranging from 93% in the downstream NTS to 80% in the downstream secondary channel ().



Appendix Figure A.10. Sets of confusion matrices for pre-season zone presence criteria developed from February 28, 2021, drag testing. From left to right, zones depicted are the upstream net transition structure, downstream net transition structure, primary channel, upstream secondary channel, and downstream secondary channel. Colors indicate the rate depicted in each quadrant, with the quadrant meanings explained in the section above.

A.6 Fish Tagging, Receiver Data Download, and Array Maintenance Schedule

After initial receiver deployment during the week of February 22, 2021, data were downloaded from all receivers on as close to a bi-weekly schedule as possible (Appendix Table A.4). This schedule was partly dependent on weather, boat availability, and unanticipated receiver maintenance requirements. Forebay receivers were downloaded on a roughly bi-weekly basis, dependent on weather and boat availability. Throughout the season, there were three instances of acoustic data going missing on a receiver. The first instance occurred during the download on May 6, when the SD card on receiver CCH-03 was corrupted. The majority of data were retrieved off the receiver using an HXD cable, but detections recorded immediately following the previous download (from April 15 18:00 to April 16 2:50) were lost. The second instance occurred during the download on June 11, when the SD card holder on NTS-04 appeared to malfunction and failed to accept a new SD card. This compromised the receiver and it had to be sent back to the manufacturer for repair. A new SR3017 receiver was used to replace this one, and a there was a lapse in data on this receiver from June 11 9:00 to June 11 11:00. There were also corrupted SD cards on receivers NTS-05 and CCH-07, but these data were fully recovered using the HXD cable to download directly from these receivers. Finally, during the download on July 2, the SD card on receivers CCH-10 and CCH-11 were corrupted, and the data were fully recovered using the HXD cable to download directly from these receivers. Redundancy in the acoustic array in the NTS and the collection channel ensured lapses in periods of acoustic data did not impact overall detection efficiency and zone positioning in these zones. A timeline of these issues and other activities occurring on the FSC is provided in Appendix Table A.4.

Appendix Table A.4. Receiver data download and maintenance schedule for the 2021 Swift Reservoir Floating Surface Collector Passage Evaluation.

Date	Event	Notes
02/28	Deployment, Array Testing, and Receiver Download	Deployment took place from 02/22 to 02/28.
03/18	Receiver Download	Receiver download prior to first study fish release for diagnostics.
03/31	Receiver Download	Receiver download prior to first study fish release for diagnostics. Forebay receivers downloaded.
04/01	Receiver Download	Downloaded over 2 days (03/31 and 04/01). Forebay receivers downloaded.
04/01	Study Fish Release	
04/07	Receiver Download	
04/08	Study Fish Release	
04/15	Receiver Download	
04/29	Study Fish Release	
05/06	Study Fish Release/Receiver Download	SD card corrupted on CCH-03, data partially recovered. Forebay receivers downloaded.
05/12	Study Fish Release	
05/13	Study Fish Release	
05/14	Receiver Download	
05/20	Study Fish Release/Receiver Download	Mobile receiver not downloaded. Forebay receivers downloaded.
05/27	Study Fish Release/Receiver Download	
06/03	Study Fish Release	
06/11	Receiver Download	SD card corrupted on NTS-05 and CCH-07, data fully recovered. Hardware issue on NTS-04, data partially recovered and receiver replaced. Forebay receivers downloaded.
07/02	Receiver Download	SD card corrupted on CCH-10 and CCH-11, data fully recovered. Forebay receivers downloaded.
07/15	Receiver Download and Demobilization	Forebay receivers downloaded.

A.7 Performance Metrics Computation

The estimation of survival and detection probabilities happens concurrently within a multinomial mark-recapture framework, in which zonal detection probabilities are estimated based on apparent missed "detections" (i.e., the number of individuals positioned within a zone that were not positioned within the previous zone), and then survival probabilities are estimated based on these detection probabilities.

The logit link function was used in the construction of all mark-recapture models, as this is the most commonly used function associated with a binary outcome ("present" or "absent").

The modelling framework had the following assumptions:

1. The PIT-array within the collector has 100% detection efficiency (p=1).
2. All fish act independently.
3. Survival probabilities are the same for all individuals between sampling occasions.
4. Detection probability is the same for all individuals at each sampling occasion.
5. There is no unaccounted tag loss or handling mortality.
6. The study area is constant throughout the season.

We note that assumption (1) is required in order to correctly partition survival probability and detection probability within the final reach, from the collection channel into the collector. Data from PIT antennas at the Woodland Release Ponds and from hand-wanding in the collector were queried from PTAGIS to ensure that no individuals were missed across the collector PIT array, and thus providing ensuring that assumption (1) was valid.

Survival through the FSC was partitioned into five parameters representing survival through reaches defined by our zones:

1. Between the release location and the forebay (p_{RES})
2. Between forebay and the ZOI (p_{ENC})
3. Between the ZOI and the NTS (p_{ENT})
4. Between the NTS and the collection channel (p_{CHAN})
5. Between the collection channel and the collector (p_{COL})

This yields a multinomial likelihood with 2^5 = 32 possible capture histories representing zone positioning results. The survival probabilities estimated in the mark-recapture model provided estimates to the reported project metrics (2021 Study Table 4). Although ZPC were constructed for seven zones separately, presence in subzones was used to indicate presence in larger zones; that is, an individual was considered present in the NTS if it was present in either the upstream or downstream NTS, and an individual was considered present in the collection channel if it was present in the primary channel, the upstream secondary channel, or the downstream secondary channel. The presence-absence matrix used to inform mark-recapture models across all nine zones, including release and collection, is provided in APPENDIX C.

These survival probabilities were then used to further calculate collection efficiency and retention efficiency; here collection efficiency p_{CE} is estimated as:

$$p_{CE} = p_{ENT} \cdot p_{CHAN} \cdot p_{COL}$$

with the associated variance term estimated via the Delta Method (Seber 1982):

$$Var(\widehat{p_{CE}}) = \widehat{p_{CHAN}}^2\, \widehat{p_{COL}}^2 Var(\widehat{p_{ENT}}) + \widehat{p_{ENT}}^2\, \widehat{p_{COL}}^2 Var(\widehat{p_{CHAN}}\,) + \widehat{p_{ENT}}^2 \widehat{p_{CHAN}}^2 Var(\widehat{p_{COL}}) + 2\widehat{p_{CE}} \cdot (\widehat{p_{ENT}} Cov(\widehat{p_{CHAN}}\,, \widehat{p_{COL}}) + \widehat{p_{CHAN}}\, Cov(\widehat{p_{ENT}}, \widehat{p_{COL}}) + \widehat{p_{COL}} Cov(\widehat{p_{ENT}}, \widehat{p_{CHAN}}\,))$$

Similarly, retention efficiency p_{RET} is estimated as:

$$p_{RET} = p_{CHAN} \cdot p_{COL}$$

with the associated variance term:

$$Var(\widehat{p_{RET}}) = \widehat{p_{COL}}^2 Var(\widehat{p_{CHAN}}) + \widehat{p_{CHAN}}^2 Var(\widehat{p_{COL}}) + \widehat{p_{CE}} \cdot Cov(\widehat{p_{CHAN}}, \widehat{p_{COL}})$$

A.8 Environmental and Operational Monitoring

Weather Station

On March 30, 2021, a weather station (Onset HOBO U-30) was mounted to a 10-foot mast (Onset HOBO M-TPA) and installed on the northeast corner of the FSC deck, to collect meteorological data. The weather station was deployed with the following cabled sensors configured to record observations at 15-minute intervals:

- Wind speed and direction (Onset HOBO S-WCF-M003)
- Barometric pressure (Onset HOBO S-BPB-CM50)
- Rainfall (Onset HOBO S-RGE-M002)

In addition, air temperature was monitored using a wireless temperature logger (Onset HOBO MX2201) affixed to the weather station mast and protected by a solar radiation shield (Onset HOBO RS1).

Water Temperature

Water temperature in the forebay was monitored using a stringer of four wireless temperature loggers (Onset HOBO MX2201) that were deployed off the northeast corner of the FSC deck. The loggers were affixed with cable ties to loops tied in a length of paracord, with ballast provided by a 5-pound kettlebell. Using this array, loggers were deployed at 5, 10, 15, and 20 feet below the water surface.

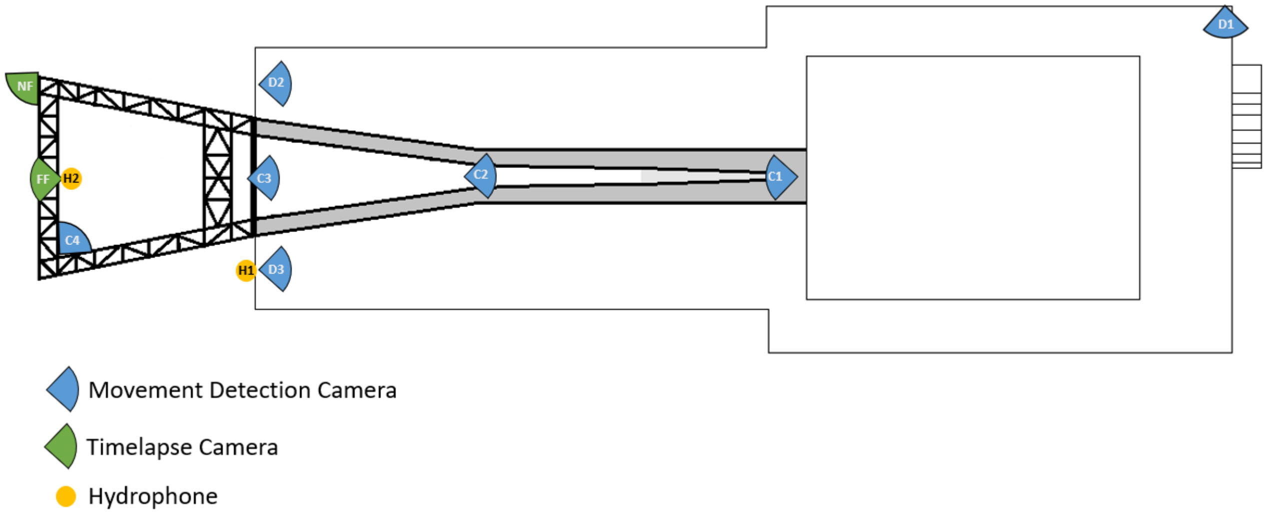
Light Levels

Light levels on the FSC deck were monitored using an array of five wireless light level loggers (Onset HOBO MX2202) that were affixed to the deck rails with cable ties and positioned to face directly upward (i.e., at the zenith angle). Loggers were spaced evenly between the secondary channel and the NTS.

Forebay Debris Loading

Forebay debris loading was monitored using two trail cameras (Browning Strike Force Pro XD, Model BTC-5PXD) affixed to the upstream end of the NTS deck and positioned to capture images of the forebay (Appendix Figure A.11). The cameras were programmed to take a picture every 30 minutes so that debris buildup in the forebay in front of the FSC could be monitored. The cameras were installed on February 22, 2021. One camera was positioned to capture images of the nearfield forebay, immediately in front of the NTS, and the other was positioned to capture images of the far field forebay, extending out into the ZOI.

Nearfield images at an hourly frequency were reviewed and debris was annotated using polygons. A percentage of the polygon areas to the image frame area was calculated as a metric to quantify debris loading. Due to the location and angle of the camera view, closer objects will carry more weight than further objects. The percent of frame metric is not an exact measure of debris loading but a relative indicator of debris build-up at the mouth of the collector. The collector deck obstructed views of the far field images and therefore these images were reviewed for qualitative assessments of extreme debris events and clean-up activity.



Appendix Figure A.11. Locations of nine trail cameras and two sound monitoring hydrophones (H1 and H2) deployed on the floating surface collector for the 2021 Swift Reservoir Floating Surface Collector Passage Evaluation.

Human Activity Monitoring

Human activity on the FSC deck was monitored using seven trail cameras (Browning Strike Force Pro XD, Model BTC-5PXD) affixed at various positions on the deck and within the collection channel (Appendix Figure A.11). The cameras were installed on February 22, 2021. Three cameras were positioned on the collector deck, to document human activity in this area that may produce anthropogenic sounds that could startle fish. Additionally, four cameras were positioned above the collection channel, to capture images of human activity within the visible prism directly above the channel, as may create a visual disturbance for fish attempting passage.

Images were reviewed and sorted for human presence. The length of time of human activity was quantified by analysis of the image timestamps. Consecutive images were grouped to define working periods using a threshold of 1 hour, whereby a span longer than 1 hour between consecutive photos defined a new working period. The time between first and last photo of each working period was calculated to quantify human activity.

Operational Sound Monitoring

Sound Monitoring Hydrophones

To investigate whether operational sound is transmitted through the FSC deck and into the waters of the collector environment, Four Peaks installed two sound monitoring hydrophones [Cetacean Research, CR1] at the front of the collector, off the north side of the FSC deck in spring 2021. Signals were conditioned through a Teledyne Reason VP2000 preamplifier and bandpass filtered (High pass – 1 Hz, Low pass – 10 kHz), no gain was applied to the signals. The signals were then passed through a SpectraDAQ-200 data acquisition sound card, digitized, and recorded to a hard drive. Data collection and configuration was controlled with SpectraPLUS-SC software from Pioneer Hill Software LLC.

Sound Monitoring Using False Detections on JSATS Hydrophones

Four Peaks conducted an additional analysis of operational sound occurring in the collection channel by using the nine telemetry hydrophones deployed in the secondary channel. For this analysis, detections by these hydrophones were divided into three groups, upstream (US), middle (MS), and downstream (DS) secondary channel hydrophones, relative to the three pairs of screen cleaners in the secondary channel. Detections were filtered to include only false positive tag codes that were not associated with released study tags or beacon signals, signal resulting from background and operational noise (i.e., "noise detections"). The number of detections by group in each minute was then calculated to form a time series of noise detections for the entire season. Plotting these time series illustrated periodic events in these data that appear to be collector operations. The events were inferred because they match the timing cycles of cleaning operations in the collection channel. For example, secondary channel screen cleaning typically occurs once every 2 hours for about 10 minutes at a time, and these events appeared to be represented in these noise data as manifesting as an increase in the number of noise detections over a 10-minute period. The second identified event was the debris flushing operation that occurred for less than 1-minute and also occurred every 2 hours. Thus, Four Peaks inferred secondary screen cleaner and debris flushing operation periods from these data and used these inferences in the analysis of fish passage. These noise detections will not impact results of acoustic processing in the channel because these detections are filtered out during data processing.

Sound Monitoring Data Processing

Audio files were captured at 7 minute and 14 second interval recordings and at a sampling rate of 48,000 samples/second and bit depth of 24. Recording parameters had a sensitivity of -199 dB re 1V per micropascal, gain of 0 dB, and voltage reference of 0.15625 volts.

Audio samples were compressed to a sampling rate of 5,750 samples/second and bit depth of 16 for processing and analysis. A discrete Fourier transform was applied to decompose the mixed audio signal for frequency filtering. Audio was filtered for frequencies less than or equal to 1 kHz to select for the audible range of fish. Additionally ubiquitous frequencies from utility lines that occur strongest at 60 Hz and subsequently at multiples of 60 Hz were zeroed.

Sound metrics were calculated on 5 second intervals and included sound pressure minimum to maximum, zero to maximum, sound pressure level, sound exposure level, main frequency, and average sound pressure of the main frequency.

A.9 Statistical Modeling and Analysis Methods

Pumping Rate Analysis

Data collected during the pumping rate study were analyzed using a systematic block design (Myers et al. 2010). Periods of each treatment (i.e., eight pumps or ten pumps) were paired sequentially to produce six periods that included applications of both treatments. The model took the form of:

$$g(y_{ij}) = \mu + \alpha_i + \beta_j + \alpha\beta_{ij}$$

where y_{ij} is the response of the ith treatment in the jth period, $g(\cdot)$ is the link function, μ is the grand mean, α_i is the effect of the ith treatment, β_j is the effect of the jth period, and $\alpha\beta_{ij}$ is the interactive effect of period and treatment.

Three different responses were considered for the experiment: proportion of fish successfully collected, proportion of successful attempts, and number of passage attempts. The proportion of fish successfully collected during each period and treatment were calculated as the number of fish collected out of the total number of fish making attempts and modeled such that y_{ij} represented the proportion of fish collected and $g(\cdot)$ was the logit function. The proportion of successful attempts was calculated as the total number of successful passage attempts out of the total number of attempts, and was modeled similarly to proportion of successful collections. Finally, the number of attempts was calculated such that y_{ij} was the number of attempts by unique fish during each treatment period and $g(\cdot)$ was the natural logarithm. In addition, the attempt rate model also included an offset for the duration of each treatment period to account for differing lengths of time when each treatment was applied.

Significance of effects were evaluated using analysis of deviance (ANODEV), which is an extension of analysis of variance for generalized linear models. Likelihood-ratio tests using a Chi-squared distribution and $\alpha = 0.05$ were used to evaluate significance according to the principal of marginality, where each effect was tested after inclusion of all other terms, save higher order terms (Fox 2015). Models were fit separately for Coho Salmon and steelhead, in addition to all species combined.

Individual Effects Models

Logistic regression was used to evaluate effects of individual fish-level covariates on the probability of collection. Preliminary data exploration indicated that effects varied by species, therefore models were fit separately for Chinook Salmon, Coho Salmon, and steelhead. Models took the form of:

$$logit(p_i) = \boldsymbol{x}_i\boldsymbol{\beta}$$

where p_i is the probability that individual i was ever collected, $\boldsymbol{x}_i$ is the vector of covariate values for fish i, and $\boldsymbol{\beta}$ is a vector of coefficients corresponding to each covariate. The probability of collection was assumed to follow a binomial distribution, and logistic regression models were estimated using maximum likelihood. Covariates included release group (i.e., day of year of release), length, and their interaction. Candidate sets of models were constructed from all combinations of effects and fit to data for Coho and steelhead. Because there were a limited number of observations for Chinook, only length and intercept-only models were compared. Models were ranked according to Akaike's information criterion corrected for small samples (AICc; Burnham and Anderson 2004).

Passage Attempts Models

Logistic regression was used to evaluate effects of individual, environmental, and operational covariates on the probability that an attempt was successful. Typically, classical regression models assume that responses are independent and identically distributed (Fox 2015). For this set of models, however, multiple attempts by the same fish were included, which may be correlated. Ideally, this fish-level variation could be accounted for using a fish-specific indicator variable, modeled as a fixed or random effect. However, because not all fish made multiple attempts, these quantities may be difficult or impossible to estimate. Instead, a "complete pooling" model (*sensu* Gelman and Hill 2006) was estimated, without any effect for individual fish. When there is very little group-level (e.g., between fish) variation, these models are equivalent to models that account for group-level variation. To help meet this assumption, important drivers of between-fish variability were considered in the model set, including species and length. Additionally, models were fit to all data combined and to observations from steelhead and coho separately.

Models took the form of:

$$logit(p_i) = \boldsymbol{x}_i\boldsymbol{\beta}$$

where p_i is the probability that attempt i was successful, $\boldsymbol{x}_i$ is the vector of covariate values for attempt i, and $\boldsymbol{\beta}$ is a vector of coefficients corresponding to each covariate. The probability of a successful attempt was assumed to follow a binomial distribution, and logistic regression models were estimated using maximum likelihood.

Covariates are listed in 2021 Study Table 5. Time of day was transformed using trigonometric functions to account for the non-linear correlation structure. Time of day was represented as:

$$cos\ (\pi h/12)$$

and

$$sin\ (\pi h/12)$$

where h is the hour of the day. All other continuous covariates were mean centered and scaled to standard deviation of one to facilitate model convergence and interpretation of coefficient estimates for parameters of different scales.

Candidate sets of models were constructed from all combinations of first order effects. Models were constrained to include both transformations of time. Models could not include both day of year and temperature because these variables were found to be problematically collinear. Models were ranked according to AICc (Burnham and Anderson 2004), which was calculated as:

$$AICc = -2\ log\big[\boldsymbol{\mathcal{L}}(\widehat{\boldsymbol{\theta}})\big] + 2K\left(\frac{n}{n-K-1}\right)$$

where $\boldsymbol{\mathcal{L}}$ is the likelihood function, $\widehat{\boldsymbol{\theta}}$ the vector of maximum likelihood estiamtes, $K$is the number of parameters, and n the number of observations. Models within two AICc units were considered to have equal support from the data. Additionally, to evaluate the relative support for models in the candidate set, Akaike weights w were calculated for each model i:

$$w_i = \frac{exp\left(-\frac{1}{2}\Delta_i\right)}{\sum_{r=1}^{R} exp\left(-\frac{1}{2}\Delta_r\right)}$$

where Δ_i is the difference in AICc value from model i and the model with the lowest AICc value, and R is the total number of models in the set. To evaluate the importance of covariates, relative variable importance was calculated by summing the w_i of all models where the covariate was included. Fitted global models (i.e., fully saturated models containing all possible covariates under consideration) were evaluated for violations of assumptions using residuals simulated with the DHARMa package (Hartig 2021).

Attempt Rate Models

Attempt rates were evaluated on a daily timestep for each species. Because the number of fish available to make attempts changed over the course of the season, the number of fish available for collection was incorporated into the model and inference was made on the probability of making an attempt, conditional on availability. Fish were determined to be available to make attempts once they had been detected in the ZOI and were no longer available once they were collected. Total fish available was determined as the cumulative number of fish detected at the ZOI minus the number collected on the previous day. Attempts were considered for unique fish each day. Models took the form of:

$$logit(p_i) = \boldsymbol{x}_i\boldsymbol{\beta}$$

where p_i is the proportion of available fish that made attempts on day i, $\boldsymbol{x}_i$ is the vector of covariate values for day i; and $\boldsymbol{\beta}$ is a vector of coefficients corresponding to each covariate.

Covariates are listed in 2021 Study Table . All continuous covariates were mean centered and scaled to standard deviation of one to facilitate model convergence and interpretation of coefficient estimates for parameters of different scales.

Candidate sets of models were constructed from all combinations of first order effects. Models were ranked according to AICc (Burnham and Anderson 2004), where models within two AICc units were considered to have equal support from the data. Additionally, to evaluate the relative support for models in the candidate set, Akaike weights w were calculated for each model and to evaluate the importance of covariates, relative variable importance was calculated. Fitted global models (i.e., fully saturated models containing all possible covariates under consideration) were evaluated for violations of assumptions using residuals simulated with the DHARMa package (Hartig 2021).

A.10 Statistical Modeling and Analysis Results

Pumping Rate Analysis

Tests of the proportion of fish successfully collected indicated significant effects of block ($X_5^2 = 42.2, p < 0.001$) for all species combined and for steelhead ($X_5^2 = 33.9, p < 0.001$), but no significant effects for Coho Salmon. The effect of treatment was not significant for any species. Tests of the proportion of successful attempts indicated that the effect of block was significant for all species combined ($X_5^2 = 86.0, p < 0.001$) and Coho Salmon ($X_5^2 = 30.2, p < 0.001$). For steelhead, both block ($X_5^2 = 50.6, p < 0.001$) and treatment effects ($X_1^2 = 4.9, p = 0.03$) were significant. Tests for passage attempts indicated significant differences by block ($X_5^2 = 71.9, p < 0.001$), marginal significance by treatment ($X_5^2 = 3.3, p = 0.071$), and significant effects of block by treatment interaction ($X_5^2 = 21.9, p = 0.001$) for all species combined. Steelhead results indicated significant variability by block ($X_5^2 = 29.0, p < 0.001$) and treatment ($X_1^2 = 5.9, p = 0.015$), but not the interaction. Coho Salmon exhibited significant effects by block ($X_5^2 = 84.2, p < 0.001$).

Individual Effects Models

Appendix Table A.5. Estimated coefficients for top logistic regression models of the effect of individual covariates on the probability of collection for Chinook Salmon.

					Intercept		Length	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**
1	1	49.51	0.00	0.61	-0.77	0.35		
2	2	50.43	0.92	0.39	-0.81	0.36	0.43	0.39

Appendix Table A.6. Estimated coefficients for top logistic regression models of the effect of individual covariates on the probability of collection for Coho Salmon.

					Intercept		Length	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**
1	1	271.54	0.00	0.57	-0.68	0.15		
2	2	272.65	1.11	0.33	-0.68	0.15	-0.14	0.15

Appendix Table A.7. Estimated coefficients for top logistic regression models of the effect of individual covariates on the probability of collection for steelhead.

					Intercept		Length		Rel day (126)		Rel day (132)		Rel day (133)		Rel day (140)		Rel day (147)	
Rank	***K***	**AICc**	**Δ**	***w***	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**	**Est.**	**SE**
1	7	232	0	0.8	-0.81	0.3	-0.64	0.2	-0.23	0.6	1.32	0.5	-0.08	0.5	-0.21	0.5	-0.78	0.6

Passage Attempts Models

Appendix Table A.8. Estimated coefficients for top logistic regression models of the probability that an attempt was successful for all species combined.

					Intercept		Attempt DOY		Attempt Time (cos)		Attempt Time (sin)		Length		Operational Noise		Pumps (8)		Pumps (9)		Species (Chinook)		Species (Steelhead)		Spray Bar (on)		Temperature		Debris Prior		Debris Current		Light		Pressure		Human Activity		Wind	
Rank	*K*	AICc	Δ	*w*	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
1	11	853.8	0	0.19	-3.49	0.21	-1	0.1	0.75	0.2	0.15	0.2	-0.83	0.2	0.42	0.1	-0.7	0.2	1.72	0.6	1.45	0.6	1	0.3	-0.88	0.4														
2	12	854.6	0.75	0.13	-3.52	0.22	-0.76	0.3	0.79	0.2	0.14	0.2	-0.83	0.2	0.42	0.1	-0.7	0.2	2.11	0.7	1.41	0.6	0.95	0.3	-0.88	0.4	-0.34	0.3												
3	12	854.7	0.83	0.12	-3.56	0.22	-1.06	0.1	0.75	0.2	0.12	0.2	-0.84	0.2	0.41	0.1	-0.62	0.2	1.84	0.6	1.38	0.6	1.02	0.3	-0.87	0.4			-0.09	0.1										
4	13	855.2	1.36	0.1	-3.5	0.23	-1.02	0.1	0.73	0.2	0.11	0.2	-0.81	0.2	0.42	0.1	-0.67	0.2	1.74	0.6	1.37	0.6	0.97	0.3	-0.9	0.4			-0.16	0.1	0.09	0.1								
5	12	855.3	1.47	0.09	-3.48	0.21	-1	0.1	0.93	0.3	0.14	0.2	-0.82	0.2	0.42	0.1	-0.71	0.2	1.66	0.6	1.48	0.6	1	0.3	-0.91	0.4							0.17	0.2						
6	12	855.5	1.68	0.08	-3.5	0.22	-1.01	0.1	0.75	0.2	0.15	0.2	-0.83	0.2	0.42	0.1	-0.69	0.2	1.72	0.6	1.46	0.6	1	0.3	-0.88	0.4									0.06	0				
7	13	855.7	1.82	0.08	-3.57	0.23	-0.83	0.3	0.78	0.2	0.12	0.2	-0.85	0.2	0.41	0.1	-0.63	0.2	2.18	0.7	1.36	0.6	0.98	0.3	-0.87	0.4	-0.3	0.3	-0.08	0.1										
8	12	855.7	1.82	0.08	-3.46	0.23	-0.98	0.1	0.75	0.2	0.15	0.2	-0.81	0.2	0.42	0.1	-0.74	0.2	1.67	0.6	1.46	0.6	0.97	0.3	-0.89	0.4					0.03	0.1								
9	12	855.7	1.9	0.07	-3.51	0.22	-0.98	0.1	0.79	0.2	0.14	0.2	-0.82	0.2	0.41	0.1	-0.72	0.2	1.69	0.6	1.45	0.6	0.99	0.3	-0.87	0.4											0.11	0.3		
10	12	855.8	2	0.07	-3.49	0.22	-1	0.1	0.75	0.2	0.15	0.2	-0.83	0.2	0.42	0.1	-0.7	0.2	1.74	0.6	1.45	0.6	0.99	0.3	-0.88	0.4													-0.01	0

Appendix Table A.9. Estimated coefficients for top logistic regression models of the probability that an attempt was successful for Coho Salmon.

					Intercept		Attempt Time (cos)		Attempt Time (sin)		Operational Noise		Pumps (8)		Pumps (9)		Spray Bar (on)		Temperature		Debris Prior		Attempt DOY		Wind		Length		Debris Current		Human Activity		Light	
Rank	*K*	AICc	Δ	*w*	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
1	8	501.6	0	0.17	-3.26	0.3	0.34	0.2	0.09	0.2	0.42	0.2	-0.56	0.3	1.91	0.7	-0.99	0.7	-0.82	0.2														
2	7	501.9	0.3	0.15	-3.38	0.2	0.29	0.2	0.1	0.2	0.24	0.1	-0.49	0.3	1.94	0.7			-0.86	0.2														
3	9	502.7	1.07	0.1	-3.21	0.3	0.31	0.2	0.1	0.2	0.43	0.2	-0.59	0.3	1.73	0.8	-1.02	0.7	-0.82	0.2	0.11	0.1												
4	9	503	1.38	0.09	-3.27	0.3	0.31	0.2	0.08	0.2	0.41	0.2	-0.5	0.3	1.76	0.8	-0.97	0.7	-0.59	0.3			-0.21	0.3										
5	8	503.1	1.5	0.08	-3.33	0.2	0.27	0.2	0.1	0.2	0.24	0.1	-0.52	0.3	1.77	0.8			-0.86	0.2	0.11	0.1												
6	8	503.2	1.61	0.08	-3.38	0.2	0.27	0.2	0.08	0.2	0.23	0.1	-0.43	0.3	1.78	0.8			-0.62	0.3			-0.22	0.3										
7	9	503.3	1.69	0.07	-3.27	0.3	0.33	0.2	0.08	0.2	0.42	0.2	-0.55	0.3	1.94	0.7	-1	0.7	-0.84	0.2					0.09	0.2								
8	9	503.4	1.77	0.07	-3.26	0.3	0.33	0.2	0.11	0.2	0.41	0.2	-0.56	0.3	1.9	0.7	-0.98	0.7	-0.84	0.2							-0.07	0.1						
9	9	503.4	1.79	0.07	-3.23	0.3	0.32	0.2	0.09	0.2	0.42	0.2	-0.57	0.3	1.82	0.8	-1	0.7	-0.81	0.2									0.06	0.1				
10	9	503.5	1.88	0.07	-3.23	0.3	0.28	0.3	0.11	0.2	0.42	0.2	-0.55	0.3	1.97	0.8	-0.99	0.7	-0.83	0.2											-0.19	0.5		
11	9	503.6	2	0.06	-3.26	0.3	0.39	0.4	0.09	0.2	0.42	0.2	-0.56	0.3	1.89	0.7	-1.01	0.7	-0.82	0.2													0.05	0.3

Appendix Table A.10. Estimated coefficients for top logistic regression models of the probability that an attempt was successful for steelhead.

					Intercept		Debris Current		Debris Prior		Operational Noise		Temperature		Wind		Human Activity (h)		Pumps (8)	
Rank	*K*	AICc	Δ	*w*	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
1	6	573.7	0	0.31	-1.37	0.1	-0.37	0.1	0.22	0.1	0.49	0.1	-0.39	0.1	-0.24	0.1				
2	7	573.7	0.09	0.3	-1.37	0.1	-0.37	0.1	0.23	0.1	0.49	0.1	-0.37	0.1	-0.25	0.1	0.09	0.1		
3	8	574.3	0.66	0.22	-1.48	0.1	-0.4	0.1	0.25	0.1	0.42	0.1	-0.39	0.1	-0.26	0.1	0.11	0.1	0.19	0.1
4	7	574.9	1.25	0.17	-1.46	0.1	-0.39	0.1	0.23	0.1	0.43	0.1	-0.41	0.1	-0.24	0.1			0.15	0.1

Attempt Rate Models

Appendix Table A.11. Estimated coefficients for top logistic regression models of the daily proportion of passage attempts for all species combined.

					Intercept		Debris Current		Debris Prior		Operational Noise		Pressure		Pumps (8)		Pumps (9)		Temperature		Wind	
Rank	*K*	AICc	Δ	*w*	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
1	9	1,104.48	0	0.55	-1.21	0.1	-0.2	0.1	0.24	0.1	0.41	0	0.06	0	-0.43	0.1	-3.05	0.1	0.47	0.1	-0.35	0.1
2	8	1,104.90	0.42	0.45	-1.21	0.1	-0.19	0.1	0.23	0.1	0.42	0			-0.46	0.1	-3.07	0.1	0.47	0.1	-0.39	0

Appendix Table A.12. Estimated coefficients for top logistic regression models of the daily proportion of passage attempts for Chinook Salmon.

					Intercept		Debris Prior		Operational Noise		Temperature		Human Activity (h)		Pressure	
Rank	*K*	AICc	Δ	*w*	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
1	4	91	0	0.46	-5.23	0.5	-0.65	0.3	0.94	0.3	-1.31	0.5				
2	5	91.7	0.7	0.33	-5.23	0.5	-0.65	0.4	0.92	0.3	-1.21	0.5	0.19	0.1		
3	5	92.5	1.56	0.21	-5.33	0.6	-0.74	0.4	0.98	0.3	-1.41	0.5			-0.22	0.3

Appendix Table A.13. Estimated coefficients for top logistic regression models of the daily proportion of passage attempts for Coho Salmon.

					Intercept		Debris Current		Operational Noise		Pressure		Pumps (8)		Pumps (9)		Temperature		Wind		Human Activity (h)		Debris Prior	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
1	8	985.8	0	0.29	-0.64	0.1	0.35	0	0.38	0.1	0.1	0	-0.65	0	-3.26	0.2	0.7	0.1	-0.17	0.1				
2	7	985.9	0.08	0.27	-0.73	0.1			0.4	0.1	0.11	0	-0.67	0	-3.26	0.2	0.73	0.1	-0.16	0.1				
3	8	987	1.21	0.16	-0.73	0.1			0.4	0.1	0.1	0	-0.69	0	-3.23	0.2	0.71	0.1	-0.17	0.1	-0.08	0.1		
4	9	987.1	1.26	0.15	-0.64	0.1	0.34	0	0.38	0.1	0.09	0	-0.67	0	-3.23	0.2	0.68	0.1	-0.18	0.1	-0.08	0.1		
5	8	987.3	1.52	0.13	-0.67	0.1			0.39	0.1	0.1	0	-0.66	0	-3.26	0.2	0.71	0.1	-0.16	0.1			0.23	0.2

Appendix Table A.14. Estimated coefficients for top logistic regression models of the daily proportion of passage attempts for steelhead.

					Intercept		Debris Current		Debris Prior		Operational Noise		Temperature		Wind		Human Activity (h)		Pumps (8)	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
1	6	573.7	0	0.31	-1.37	0.1	-0.37	0.1	0.22	0.1	0.49	0.1	-0.39	0.1	-0.24	0.1				
2	7	573.7	0.09	0.3	-1.37	0.1	-0.37	0.1	0.23	0.1	0.49	0.1	-0.37	0.1	-0.25	0.1	0.09	0.1		
3	8	574.3	0.66	0.22	-1.48	0.1	-0.4	0.1	0.25	0.1	0.42	0.1	-0.39	0.1	-0.26	0.1	0.11	0.1	0.19	0.1
4	7	574.9	1.25	0.17	-1.46	0.1	-0.39	0.1	0.23	0.1	0.43	0.1	-0.41	0.1	-0.24	0.1			0.15	0.1

References

Burnham, K. P., and Anderson, D. R. 2004. “Multimodel Inference: Understanding AIC and BIC in Model Selection.” *Sociological Methods & Research* 33(2):261–304.

Deng, Z. D., Weiland, M. A., Fu, T., Seim, T. A., LaMarche, B. L., Choi, E. Y., Carlson, T. J., and Eppard, M. B. 2011. “A cabled acoustic telemetry system for detecting and tracking juvenile salmon: Part 2. Three-dimensional tracking and passage outcomes.” *Sensors* 11:5661-5676.

Fox, J. 2015. Applied Regression Analysis and Generalized Linear Models. SAGE Publications.

Gelman, A., and Hill, J. 2006. Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge University Press.

Hartig, F. 2021. DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models.

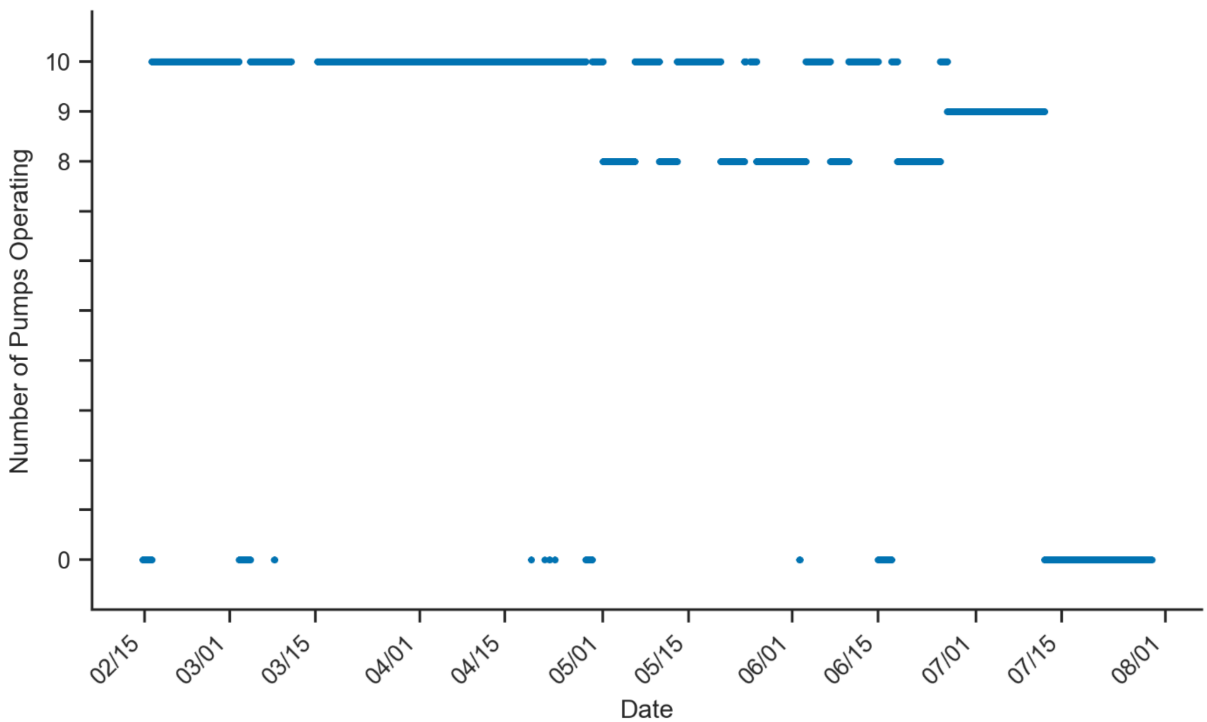
Myers, J. L., Well, A. D., Lorch Jr, R. F., Woolley, T., Kimmins, S., Harrison, R., and Harrison, P. 2010. *Research Design and Statistical Analysis: Third Edition*. Taylor & Francis Group, London, United Kingdom.

Seber, G. A. F. 1982. *The Estimation of Animal Abundance and Related Parameters*. Griffin, London, UK.

APPENDIX B Operational and Environmental Monitoring Data Summaries

B.1 Pumping Rate

The actual pumping rates during the 2021 Swift Reservoir Floating Surface Collector Passage Evaluation (2021 Study) are presented in Appendix Figure B.1. Pumping data was extracted from the Lewis River database. There are 10 pumps in total operating in the primary channel, and all pumps were turned on at the beginning of the study. Several outage events occurred prior to the pumping block study, which was initiated April 26 (Figure 10). During the block study, Pumps 5 and 6 in the primary channel were turned off to create an 8-pump "treatment" period contrasted against the 10-pump "control" period. Towards the end of the study (June 26 to July 12), 9 pumps were activated, with Pump 5 being kept off. The collector was shut off on July 12, 2021.



Appendix Figure B.1. Actual pumping rates during the 2021 Study.

B.2 Environmental Conditions

The sections below present summaries of the environmental monitoring data. These include information about the weather, water temperature, light levels, and forebay debris loading. The effects of these factors were analyzed with the behavioral analysis modeling efforts described in the 2021 Study Section 3.4.

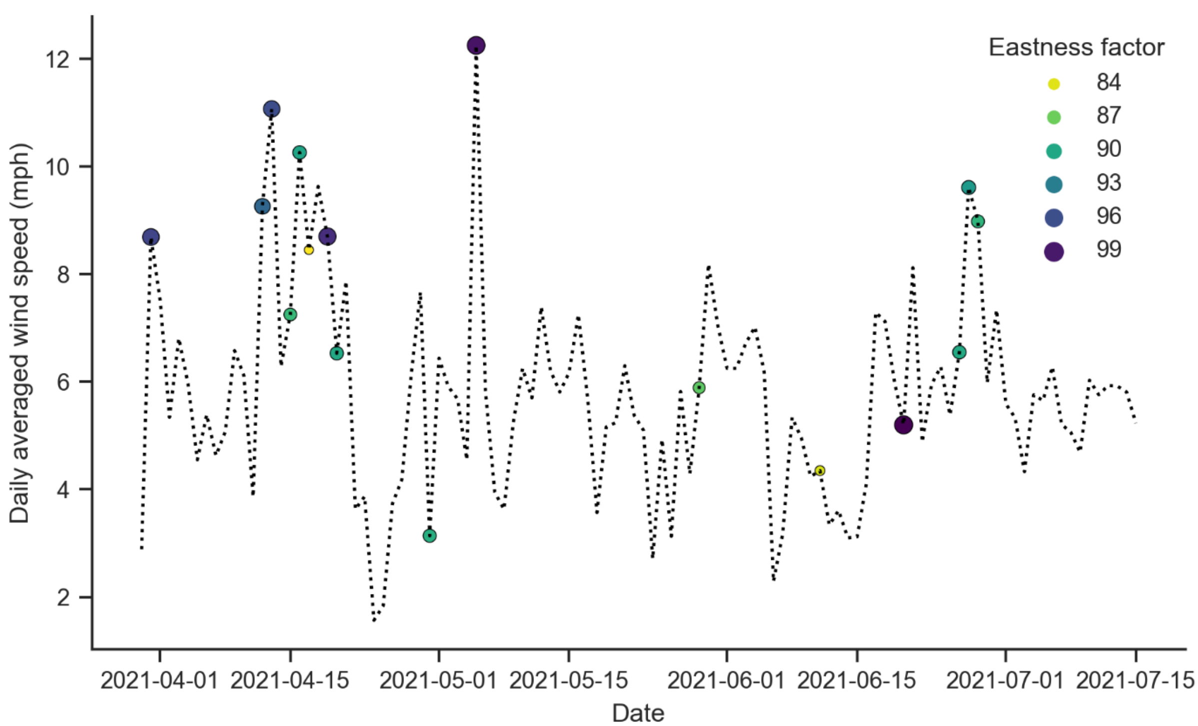
Weather

The weather station deployed on the Swift floating surface collector (FSC) collected measurements of wind speed and direction (Appendix Figure B.2), barometric pressure (Appendix Figure B.3), rainfall (Appendix Figure B.4), and air temperature (Appendix Figure B.5). All measurements were collected at 15-minute intervals; however, these figures present daily averaged values. Averaged wind direction was converted to an “Eastness Factor” by calculating the absolute difference between the daily averaged wind direction and due east (90°), then scaling this difference from 0 to 100, based on the range of observations for mean wind direction:

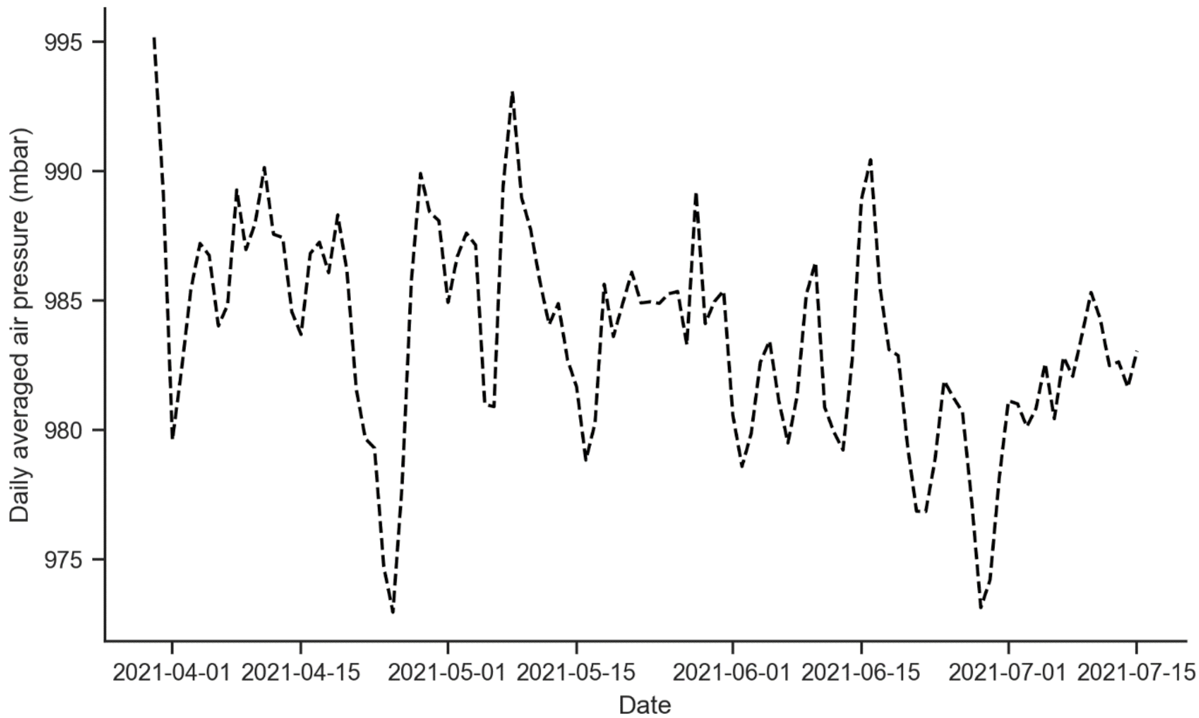
$$Eastness\ Factor\ = \frac{204.6 - |(daily\ averaged\ wind\ direction - 90)|}{2.02}$$

A stringer of temperature thermistors was deployed off the front of the net transition structure (NTS) to measure water temperature at 5-, 10-, 20-, and 30-foot depths below the water surface. As above, measurements were collected at 15-minute intervals, but daily averaged values are presented below (Appendix Figure B.6).

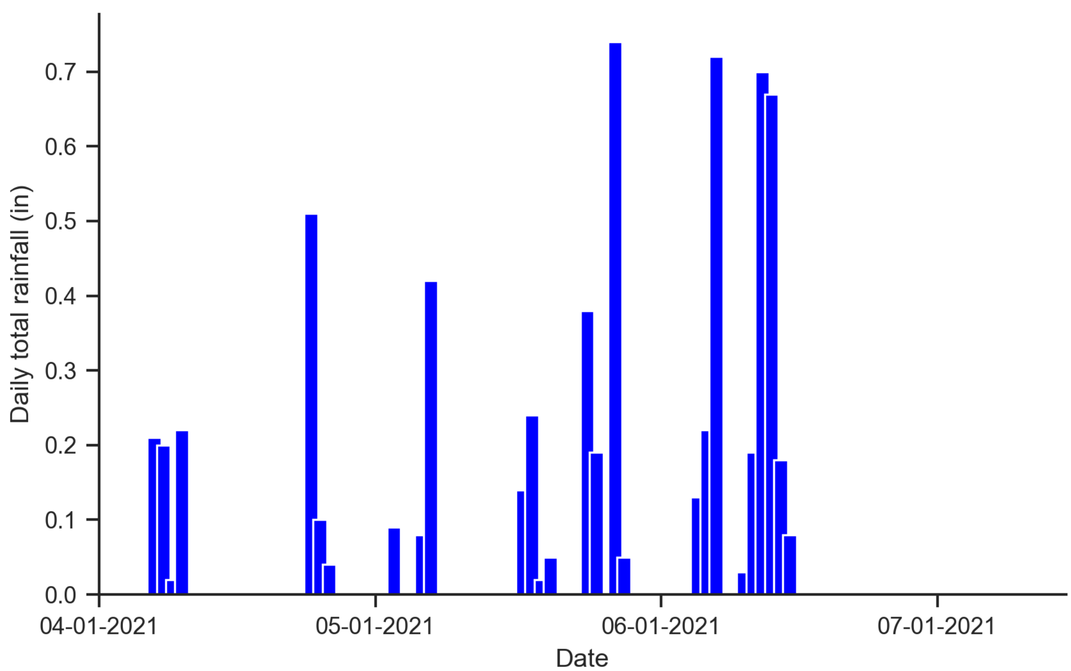
Five light level loggers were also deployed within the collection channel, facing up. Measurements of light intensity were recorded at 15-minute intervals. For each day, the timestamp of the first measurement from any logger that exceeded 10 lumens per square foot was established as dawn, and the timestamp of the last measurement to exceed 10 lumens per square foot was established as dusk, which is summarized below in Appendix Figure B.7.



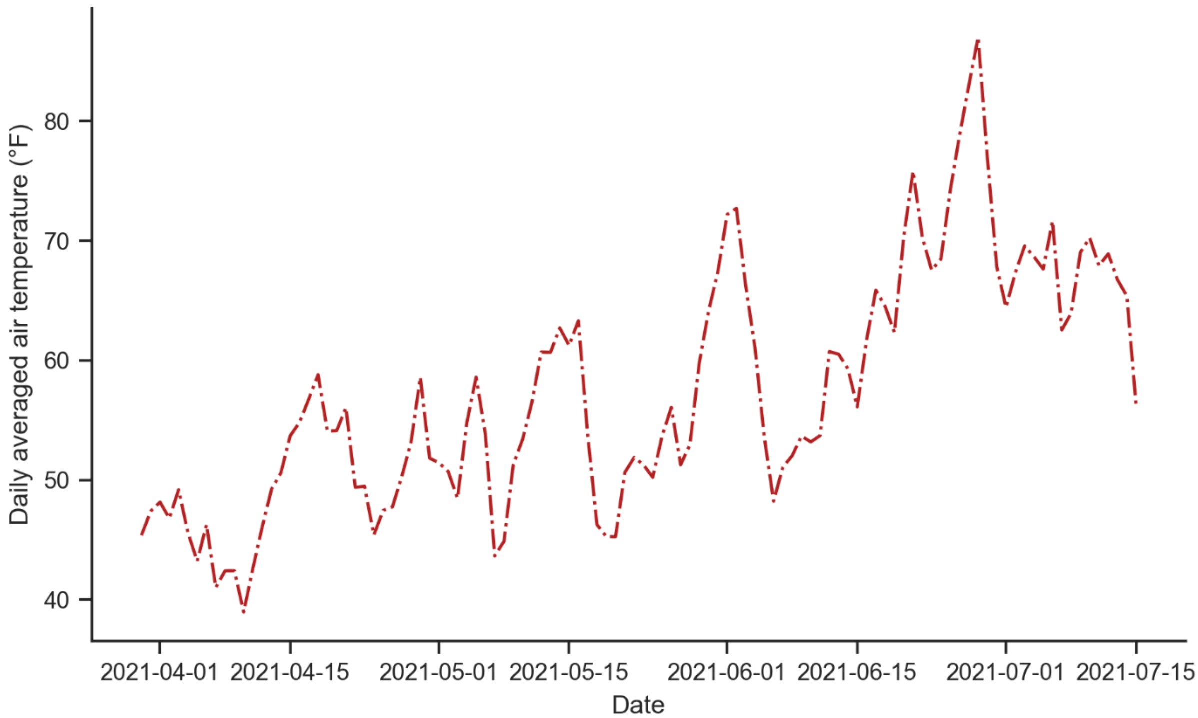
Appendix Figure B.2. Daily averaged wind speed and direction on the floating surface collector during the 2021 study period.



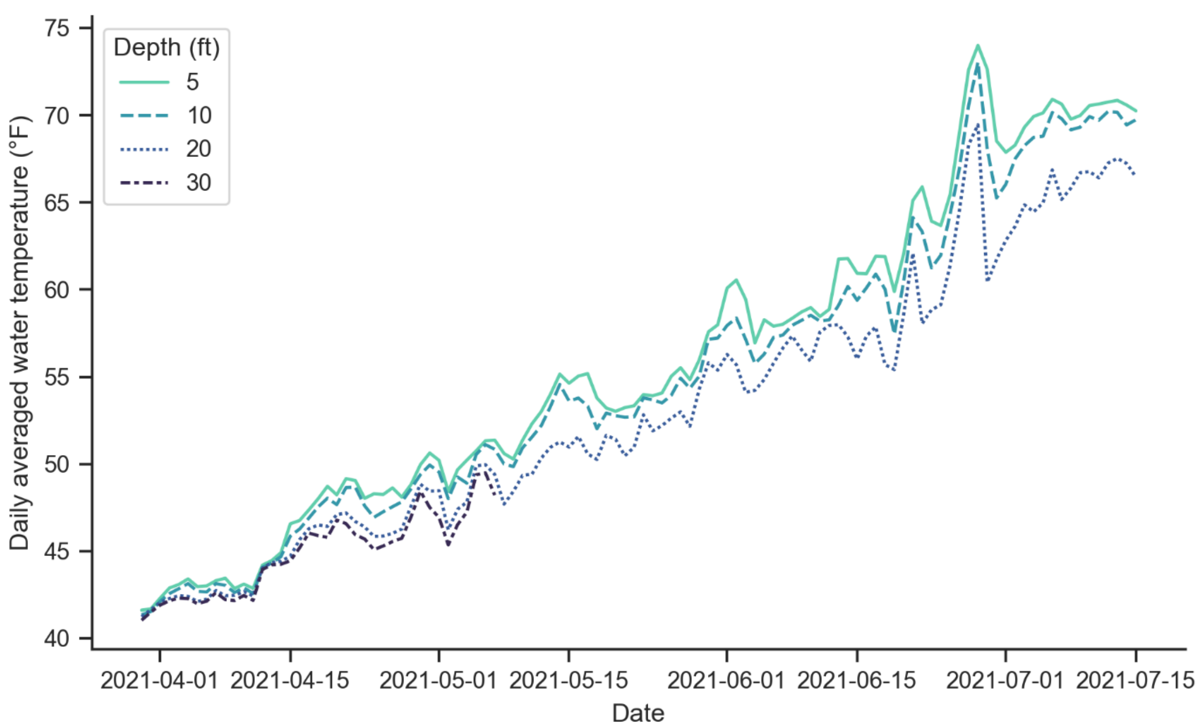
Appendix Figure B.3. Daily averaged air pressure on the floating surface collector during the 2021 study period.



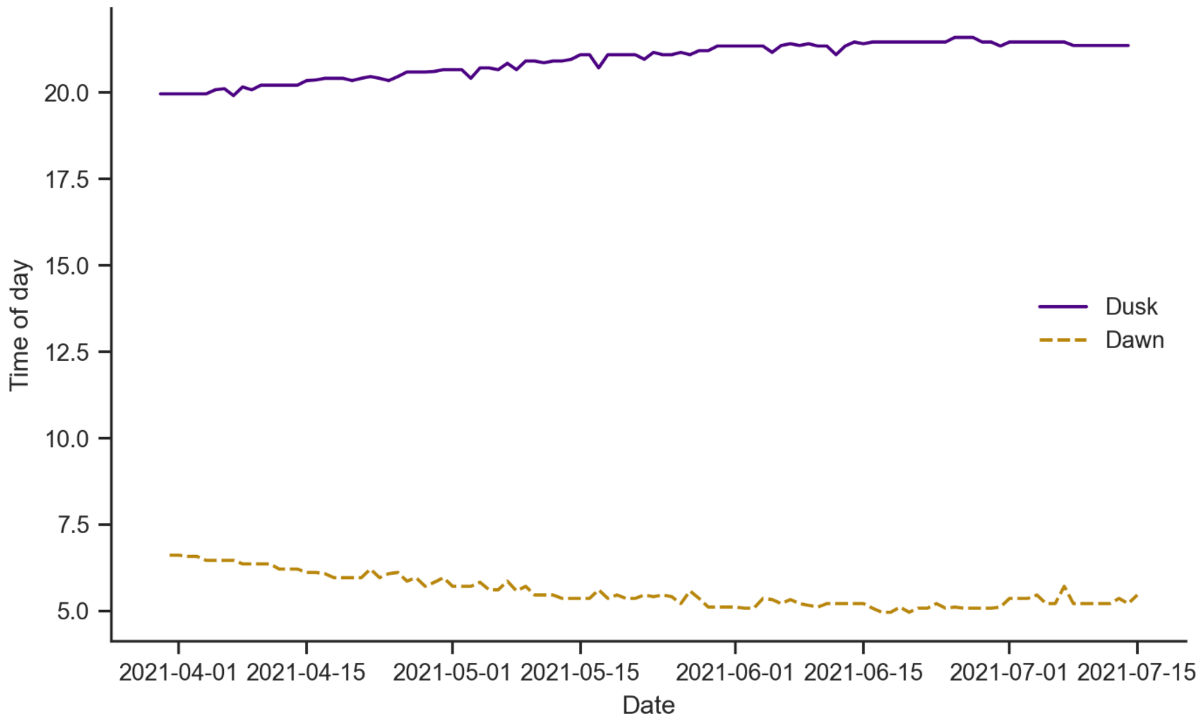
Appendix Figure B.4. Daily total rainfall on the floating surface collector during the 2021 study period.



Appendix Figure B.5. Daily averaged air temperature on the floating surface collector during the 2021 study period.



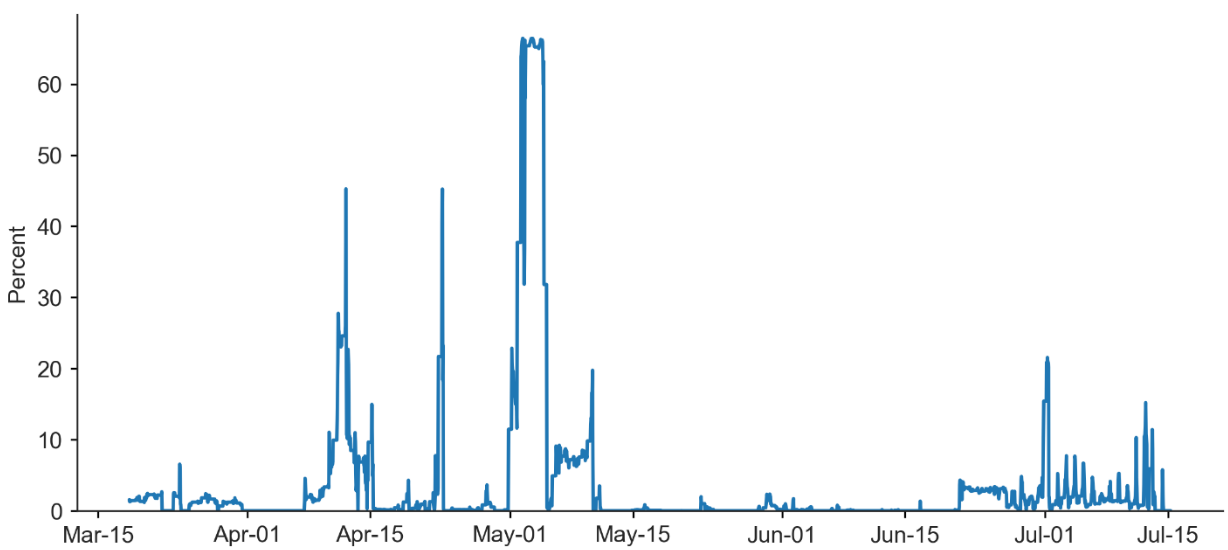
Appendix Figure B.6. Daily averaged water temperature in front of the floating surface collector during the 2021 study period.



Appendix Figure B.7. Dawn and dusk times during the 2021 study period, as inferred from five light level loggers deployed within the floating surface collector collection channel. Time of dawn and dusk correspond to first and last measurement greater than 10 lumens per square foot, respectively.

Forebay Debris Loading

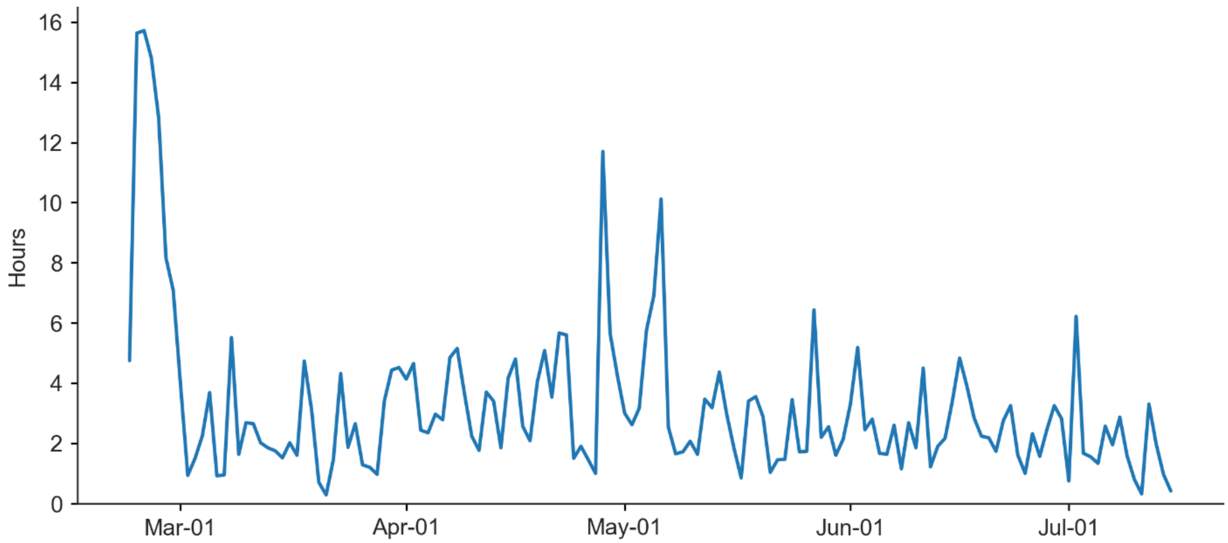
Forebay debris loading, as estimated from 30-minute interval photographs collected by timelapse cameras trained on the forebay immediately in front of the NTS are summarized in Appendix Figure B.8.



Appendix Figure B.8. Percent of debris in photo frame during the 2021 Study Period.

B.3 Human Activity Cameras

Daily summed duration of human activity on the FSC is presented in Appendix Figure B.9.



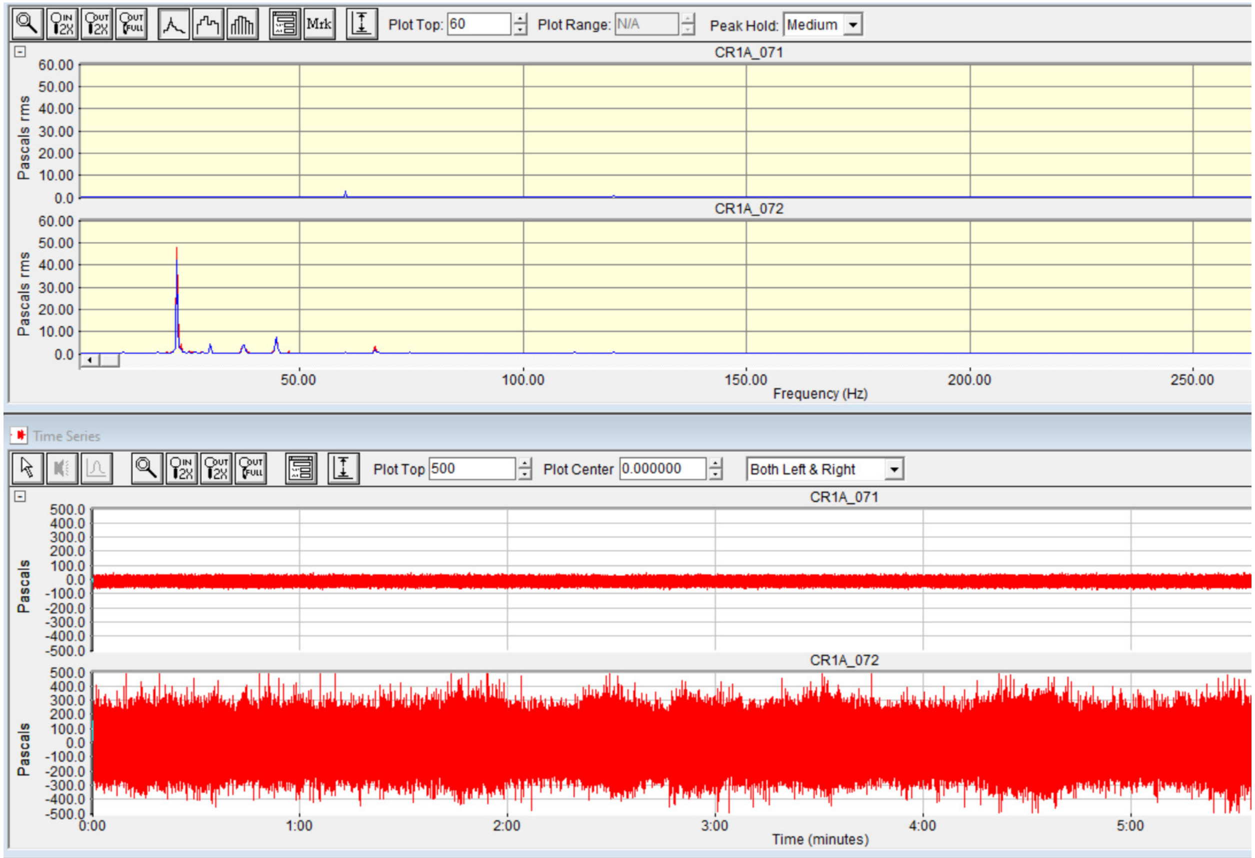
Appendix Figure B.9. Number of hours of human activity detected on the collector from motion capture cameras during the 2021 study period. Working period durations were calculated by the difference between start and end timestamps of consecutive photos sets with less than 1-hour gap between photos.

B.4 Operational Noise Monitoring

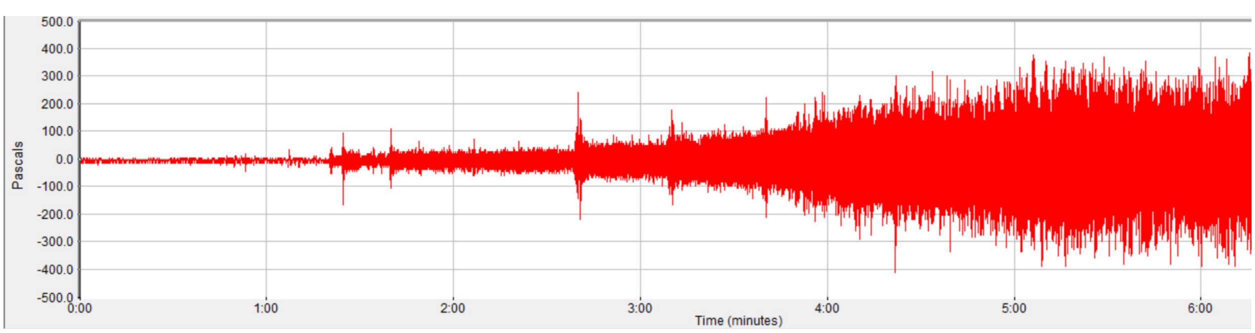
This section summaries the operational noise data collected in and around the FSC collection channel and provided observational insight into the noise levels and frequencies of sound within the collection channel and around the collect. During the season, two hydrophones were deployed to monitor sound in the collection channel and were mounted at the upper end of NTS (hydrophone CR1A_072) and a second mounted next off the northeast side of the collector to monitor for any noise radiating through the hull of the FSC (hydrophone CR1A_071).

The noise floor outside of the channel on hydrophone CR1A_071 was relatively quiet and there were no noticeable noise peaks (note: the small peak at 60 Hz is from the AC power the laptop was pulled into). The noise within the channel recorded on hydrophone CR1A_072 was much higher due to flow noise and a peak signal at 22 Hz. The second highest peak at 44 Hz is a harmonic of the 22 Hz signal (Appendix Figure B.10). The 22 Hz signal was continuous and was the peak frequency seen in the data for over 93%

of the season. The noise floor in the collection channel increased with increasing number of pumps running (Appendix Figure B.10).

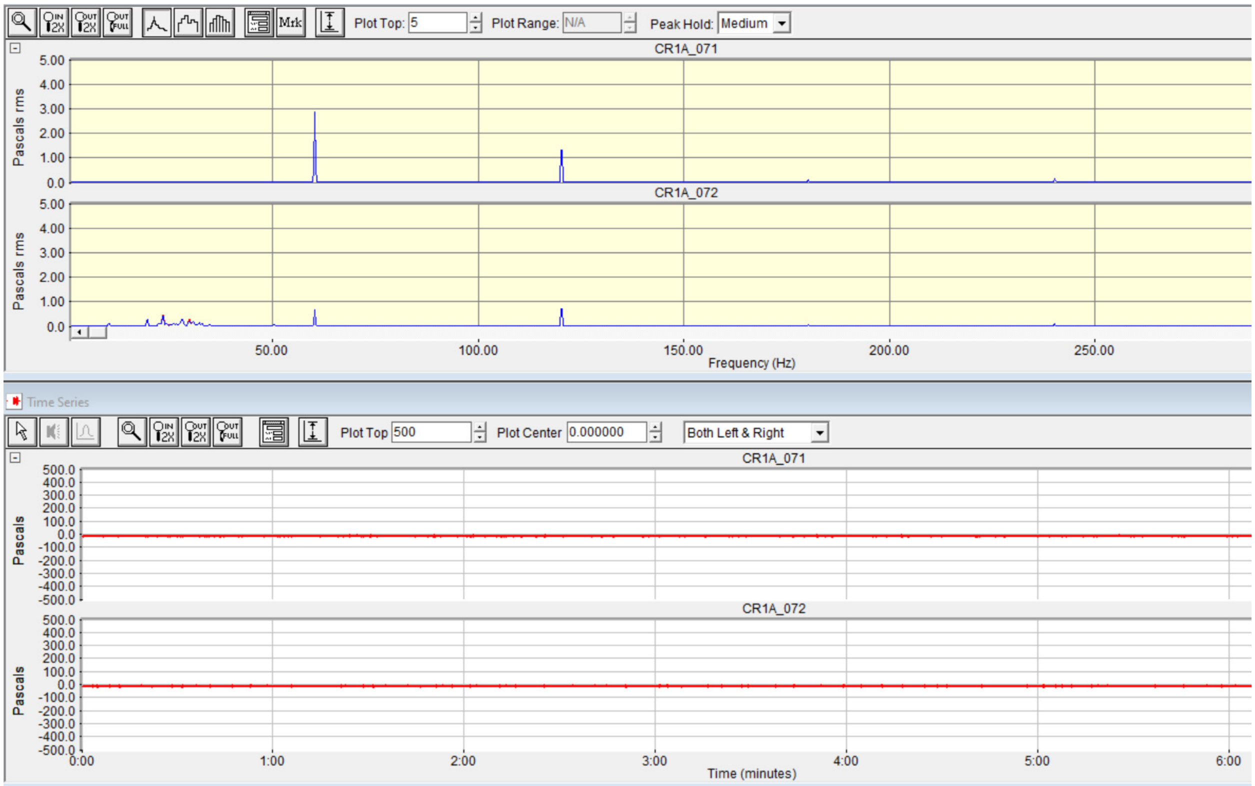


Appendix Figure B.10. Sound monitoring plots for the floating surface collector when ten pumps were operating for both hydrophones deployed on the floating surface collector. Top two panel show the frequency spectrum for the averaged (root mean square) sound pressure level, measured in dB, across the lower range of frequencies measured, at a single time point within the series. Bottom two panels show the time series waveform of total sound pressure across all frequencies, measured in Pascals. The top panel for both the frequency and timeseries plots is representative of hydrophone CR1A_71 located off the side of the floating surface collector, and bottom panels are associated with hydrophone CR1A_72 is located at the upper end of the net transition structure.



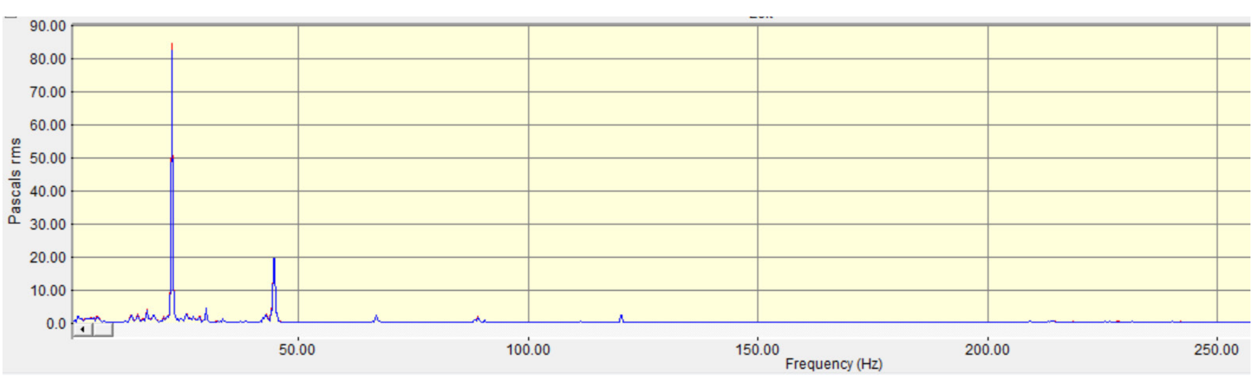
Appendix Figure B.11. Time series waveform of total sound pressure (in Pascals) as the pumps were turned on, from 0 to 10 pumps.

After the FSC shut off on July 12, 2021, the noise floors inside and outside of the collection channel were significantly lower and both locations had similar background noise levels (Appendix Figure B.11). A small frequency spike at 22 Hz was still seen on the hydrophone at the upper end of the NTS even after the collector was shut down. The 60 Hz frequency was from AC power to the computer, and its harmonic at 120 Hz were the main frequencies detected on both hydrophones but are associated with electrical power to the computer and not noise in the water.

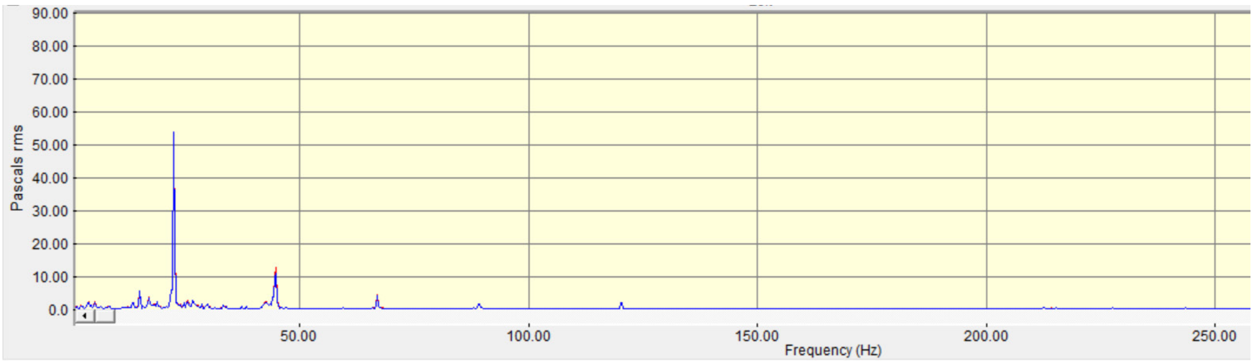


Appendix Figure B.12. Sound monitoring plots for the floating surface collector after the collector was turned off at the end of the season for both hydrophones deployed on the floating surface collector.

Additional testing showed that the 22 Hz signal was present when a hydrophone was deployed off the south side of the FSC when the collector was operating (Appendix Figure B.12). The signal was also detected at the upstream end of the secondary channel (Appendix Figure B.13).



Appendix Figure B.13. Frequency plot of sound data collected off the south side of the floating surface collector after the collector was turned off.



Appendix Figure B.14. Frequency plot of sound data collected at the upper end of the primary channel of the floating surface collector after the collector was turned off.

APPENDIX C Zonal Presence-Absence Matrix

The following table provides a presence-absence matrix of all 443 acoustically-tagged individuals in the study. This matrix was constructed by performing in-season estimates of zone presence of individuals from available acoustic data, and iteratively updating the zones at one point occupied by an individual at any point in the study. As such, presence in any given zone (indicated by a 1 value) is presented regardless of when the individual occupied the zone. Columns for the zone of influence, net transition structure, and collection channel were used as detection histories to fit mark-recapture models.

Appendix Table C.1. Presence-absence matrix of all study tags released in the 2021 Swift Reservoir Floating Surface Collector Passage Evaluation.

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	0074	3DD.003DE942B4	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-05-28 14:28:01
Coho	00F7	3DD.003DE942CC	2021-05-20 09:45:00	1	1	1	1	1	0	0	0	
Steelhead	0106	3DD.003D91E79E	2021-04-29 08:00:00	1	1	1	0	0	0	0	0	
Coho	013A	3DD.003D91D1A2	2021-05-13 09:15:00	1	1	1	1	1	0	0	0	
Steelhead	021B	3DD.003DE94307	2021-05-20 09:45:00	1	1	1	1	1	1	0	0	
Coho	027B	3DD.003E00157A	2021-06-03 11:00:00	1	1	0	1	0	0	0	0	
Coho	029D	3DD.003D91D178	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	03F4	3DD.003D91D158	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Steelhead	040D	3DD.003D91D102	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Coho	041D	3DD.003E001594	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	04D7	3DD.003DE942F4	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-30 16:04:26
Steelhead	05FE	3DD.003D91D1A1	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	0630	3DD.003D91E798	2021-04-29 08:00:00	1	1	1	1	1	0	1	1	2021-05-02 11:27:54
Coho	0710	3DD.003DE942BB	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-19 18:30:27
Coho	080E	3DD.003D91D185	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-21 04:31:04
Coho	0A65	3DD.003E00156D	2021-06-03 11:00:00	1	1	1	1	1	0	0	0	
Steelhead	0AC6	3DD.003D91D19C	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	0AE5	3DD.003DE942FF	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-05-26 03:06:38
Steelhead	0AEA	3DD.003D91D196	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-20 04:23:39
Coho	0B0E	3DD.003D91D18F	2021-05-13 09:15:00	1	1	0	0	0	0	0	0	
Coho	0B37	3DD.003E00154C	2021-06-03 11:00:00	1	1	1	1	1	0	0	0	
Steelhead	0CA9	3DD.003DE9430A	2021-05-20 09:45:00	1	1	1	1	1	1	0	0	
Steelhead	0D30	3DD.003D91DBC7	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-04 23:09:48
Steelhead	0D49	3DD.003D91D14B	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Steelhead	0D55	3DD.003D91DBC9	2021-04-29 08:00:00	1	1	1	1	1	1	1	0	
Coho	0E39	3DD.003E001589	2021-06-03 11:00:00	1	1	1	0	0	0	0	0	
Steelhead	0E3A	3DD.003DE942C7	2021-05-20 09:45:00	1	0	0	0	0	0	0	0	
Coho	0F20	3DD.003E00155E	2021-06-03 11:00:00	0	1	0	1	1	1	0	1	2021-06-04 01:20:47
Steelhead	0F4A	3DD.003D91D125	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	0F8E	3DD.003E00159D	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-19 12:54:09
Steelhead	0FE2	3DD.003D91D0FE	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Coho	1060	3DD.003D91D153	2021-05-27 09:00:00	1	1	1	0	0	0	0	0	
Steelhead	10B1	3DD.003D91D149	2021-05-27 09:00:00	1	1	1	1	1	1	0	1	2021-06-07 01:20:24
Steelhead	126D	3DD.003DE942E6	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Steelhead	1389	3DD.003DE94316	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Coho	13C6	3DD.003E00158B	2021-06-03 11:00:00	1	1	1	1	1	1	0	0	
Coho	144F	3DD.003D91D103	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Steelhead	148B	3DD.003DE942E5	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Coho	1506	3DD.003E001556	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	1550	3DD.003D91D12F	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	155F	3DD.003E0015A7	2021-06-03 11:00:00	0	1	1	1	1	1	1	1	2021-06-05 01:39:07
Steelhead	15AE	3DD.003D91D15B	2021-05-27 09:00:00	1	1	0	0	0	0	0	0	
Steelhead	166E	3DD.003D91D174	2021-05-13 09:15:00	1	1	1	1	0	0	0	0	
Coho	16AB	3DD.003E001576	2021-06-03 11:00:00	1	1	1	1	1	1	0	1	2021-06-03 20:33:42
Coho	16AD	3DD.003DE942BD	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-18 04:32:32
Steelhead	16F9	3DD.003D91E75E	2021-04-29 08:00:00	1	1	0	0	0	0	0	0	
Coho	172B	3DD.003D91D135	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Coho	1814	3DD.003D91D1B9	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-28 17:10:53
Steelhead	189D	3DD.003DE94318	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Steelhead	1990	3DD.003DE942C4	2021-05-20 09:45:00	1	1	1	1	1	1	0	0	
Steelhead	1997	3DD.003DE9430E	2021-05-20 09:45:00	1	1	0	0	1	0	0	0	
Coho	1A06	3DD.003D91D5B0	2021-05-12 12:00:00	1	1	1	1	0	1	0	1	2021-05-15 04:26:20
Steelhead	1A92	3DD.003D91D11D	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	1AC9	3DD.003DE942D2	2021-05-20 09:45:00	1	1	1	0	0	1	0	1	2021-05-26 04:11:33
Coho	1C4B	3DD.003E00156B	2021-06-03 11:00:00	1	1	1	1	1	1	0	1	2021-06-04 01:32:28
Coho	1C7A	3DD.003E00155A	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	1CED	3DD.003E00156C	2021-06-03 11:00:00	1	1	1	1	1	1	0	1	2021-06-17 17:20:32
Coho	1D8A	3DD.003DE942FC	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-19 09:00:47
Coho	1EC8	3DD.003DE9430B	2021-05-20 09:45:00	1	1	1	1	1	0	0	0	
Coho	2065	3DD.003E001599	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	20B8	3DD.003DE944F2	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	
Steelhead	22B3	3DD.003DE942F7	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	230E	3DD.003D91D16F	2021-05-13 09:15:00	1	0	0	0	0	0	0	0	
Coho	2323	3DD.003DE942DB	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	23C1	3DD.003D91D1A5	2021-05-13 09:15:00	1	1	1	1	1	0	1	1	2021-05-24 12:43:49
Steelhead	23DA	3DD.003D91D163	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-29 07:40:02
Coho	24B1	3DD.003DE94305	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Steelhead	25AD	3DD.003D91D5C8	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-15 03:20:55

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	25B7	3DD.003D91D172	2021-05-13 09:15:00	1	1	1	1	1	1	0	0	
Steelhead	262F	3DD.003D91DBCC	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	2687	3DD.003D91D1C1	2021-05-13 09:15:00	1	0	0	0	0	0	0	0	
Chinook	26E4	3DD.003D91DBE0	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	
Coho	2717	3DD.003D91D139	2021-05-27 09:00:00	1	0	0	0	0	0	0	0	
Coho	2730	3DD.003D91D16D	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	2766	3DD.003DE942CB	2021-05-20 09:45:00	1	1	1	1	1	1	0	0	
Coho	27A0	3DD.003E001553	2021-06-03 11:00:00	1	1	1	1	1	1	0	1	2021-06-21 22:49:31
Coho	27CB	3DD.003E001583	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Steelhead	2829	3DD.003D91D1C4	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	28CA	3DD.003D91E77E	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	28D2	3DD.003D91D16C	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-16 19:00:53
Coho	28E6	3DD.003E001582	2021-06-03 11:00:00	1	1	1	1	1	0	0	1	2021-06-05 19:42:13
Coho	2A1D	3DD.003DE942DE	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Coho	2A8B	3DD.003E00158C	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-14 18:50:44
Coho	2A8E	3DD.003E00159C	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-19 04:08:42
Coho	2AD4	3DD.003D91D1BE	2021-05-13 09:15:00	1	1	1	1	0	1	1	1	2021-05-18 22:30:16
Coho	2B2D	3DD.003E001585	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-07-02 13:35:56
Coho	2B30	3DD.003E00159F	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-07-01 15:39:38
Coho	2B6E	3DD.003E001591	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Steelhead	2B78	3DD.003DE942E0	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Coho	2B9A	3DD.003E001560	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	2C82	3DD.003DE94310	2021-05-20 09:45:00	1	1	1	1	0	0	0	0	
Coho	2F6C	3DD.003D91D5D9	2021-05-12 12:00:00	1	1	1	1	1	0	0	0	
Coho	301E	3DD.003DE942B8	2021-05-20 09:45:00	1	1	1	1	1	0	0	0	
Coho	30C3	3DD.003D91D116	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Steelhead	3179	3DD.003D91D17D	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-24 17:51:50
Coho	31DF	3DD.003E001558	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Steelhead	326E	3DD.003DE944BD	2021-05-06 09:30:00	1	1	0	1	0	0	0	0	
Coho	329F	3DD.003DE944AD	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-29 22:21:24
Coho	32C0	3DD.003D91D168	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	333E	3DD.003DE942D0	2021-05-20 09:45:00	1	1	1	1	1	1	0	1	2021-05-24 04:57:04
Steelhead	333F	3DD.003D91D0FF	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	3423	3DD.003E00156A	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	3596	3DD.003DE942F5	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	3602	3DD.003DE942E9	2021-05-20 09:45:00	1	1	1	1	1	0	0	0	
Steelhead	3676	3DD.003D91D14A	2021-05-27 09:00:00	1	1	1	1	0	0	1	1	2021-06-01 00:03:53
Steelhead	368A	3DD.003D91E78F	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	3751	3DD.003D91D156	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	3756	3DD.003D91D171	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	3776	3DD.003D91D1B0	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	382E	3DD.003E00155D	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	38B7	3DD.003DE942B6	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-17 19:40:56
Coho	3912	3DD.003D91D112	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	391B	3DD.003D91D12B	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	392C	3DD.003D91D140	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-03 23:12:46
Coho	3AAD	3DD.003E00157F	2021-06-03 11:00:00	0	0	0	0	0	0	0	0	
Coho	3B3B	3DD.003DE942EA	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-19 19:54:47
Steelhead	3BD3	3DD.003DE942C2	2021-05-20 09:45:00	1	1	0	0	0	0	0	0	
Coho	3C3E	3DD.003D91D148	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Coho	3C7B	3DD.003DE942E1	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-30 11:21:19
Steelhead	3D92[1]	3DD.003D91D18A	2021-05-13 09:15:00	1	1	1	1	1	0	0	0	
Coho	3D96	3DD.003E001580	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	3D9C	3DD.003D91D138	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Steelhead	3DC5	3DD.003D91D130	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Chinook	3DD0	3DD.003D91DBAA	2021-04-08 11:00:00	1	1	1	1	0	0	0	0	
Steelhead	3DF8	3DD.003D91D192	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	3EC4	3DD.003D91E764	2021-04-29 08:00:00	1	1	1	1	1	1	1	0	
Steelhead	3F60	3DD.003D91DBBF	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-10 19:45:31
Coho	3F9D	3DD.003E001588	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	40B3	3DD.003E001578	2021-06-03 11:00:00	1	1	0	1	0	0	0	0	
Steelhead	4160	3DD.003D91D15F	2021-05-27 09:00:00	1	0	0	0	0	0	0	0	
Coho	418E	3DD.003E001573	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Steelhead	4196	3DD.003D91D104	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-04 03:31:18
Steelhead	41E0	3DD.003D91D16E	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	4254	3DD.003D91D134	2021-05-27 09:00:00	1	1	1	1	1	0	0	1	2021-05-29 05:13:48
Steelhead	4272	3DD.003D91D60C	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-14 19:18:18
Coho	4273	3DD.003E0015A8	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	4344	3DD.003D91D5BE	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-02 23:24:29
Coho	439A	3DD.003D91D18E	2021-05-13 09:15:00	1	1	0	1	0	0	0	0	
Coho	4414	3DD.003E00158E	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	449B	3DD.003D91D131	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Steelhead	45BA	3DD.003DE942FD	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-05-21 22:50:21
Steelhead	45DB	3DD.003D91E772	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	4636	3DD.003DE942F3	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Coho	46DB	3DD.003E001587	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Steelhead	4766	3DD.003DE94308	2021-05-20 09:45:00	1	1	1	1	1	0	0	1	2021-05-22 19:07:50
Coho	47A9	3DD.003E00159A	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-19 05:28:11

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	47D9	3DD.003D91D1B4	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	482B	3DD.003D91E785	2021-04-29 08:00:00	1	1	1	1	1	1	0	1	2021-05-08 15:39:53
Steelhead	483F	3DD.003DE942C1	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Coho	4881	3DD.003D91D133	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-15 03:42:04
Steelhead	4927	3DD.003D91D100	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Steelhead	495D	3DD.003D91D124	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	49B6	3DD.003DE94314	2021-05-20 09:45:00	1	1	1	1	0	0	0	0	
Steelhead	4C35	3DD.003D91D137	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Steelhead	4C61	3DD.003D91D110	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	4CA7	3DD.003E001566	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Steelhead	4D03	3DD.003D91D162	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	4D92	3DD.003D91D141	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	4D9D	3DD.003D91D5B8	2021-05-12 12:00:00	1	1	1	1	1	1	0	0	
Coho	4E49	3DD.003DE942E3	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Coho	4E4F	3DD.003D91D107	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Steelhead	4E7E	3DD.003D91D1B2	2021-05-13 09:15:00	1	1	1	1	1	1	0	1	2021-05-15 22:58:19
Coho	4FAC	3DD.003DE942D8	2021-05-20 09:45:00	1	1	0	0	0	0	0	0	
Coho	4FD0	3DD.003D91D15C	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Steelhead	5005	3DD.003D91E76F	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-02 01:19:58
Coho	512D	3DD.003D91D1B8	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	51DE	3DD.003E00158F	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Steelhead	5314	3DD.003D91D14D	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Coho	5410	3DD.003D91D146	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	5472	3DD.003E001561	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-14 19:44:50
Coho	5484	3DD.003D91D12E	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Coho	55A2	3DD.003D91D17F	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	55A5	3DD.003D91D128	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	56B3	3DD.003D91D17A	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	56B7	3DD.003D91D183	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Chinook	56BD	3DD.003D91D5DA	2021-05-12 12:00:00	1	1	1	1	0	1	0	1	2021-05-14 23:57:50
Steelhead	570E	3DD.003DE942BC	2021-05-20 09:45:00	1	1	1	1	0	0	0	0	
Steelhead	5786	3DD.003D91D106	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Coho	5870	3DD.003D91D164	2021-05-13 09:15:00	1	1	1	1	1	1	0	1	2021-05-17 22:31:33
Steelhead	588D	3DD.003D91D5F9	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Chinook	58D3	3DD.003D91DBB6	2021-04-08 11:00:00	1	1	1	1	0	0	0	0	
Chinook	58EB	3DD.003D91DBC3	2021-04-08 11:00:00	1	1	1	1	1	1	1	1	2021-04-20 05:24:07
Chinook	5939[1]	3DD.003D91DB9B	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	5945	3DD.003D91D5CF	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Steelhead	5971	3DD.003D91E762	2021-04-29 08:00:00	1	1	1	1	1	0	1	1	2021-05-01 11:13:49

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	59FF	3DD.003D91E752	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Chinook	5A85	3DD.003D91DBE8	2021-04-08 11:00:00	1	1	1	1	0	0	0	0	
Coho	5A87	3DD.003D91D60B	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Coho	5AF2	3DD.003D91DBA3	2021-04-29 08:00:00	1	1	1	1	1	0	0	0	
Coho	5B2D	3DD.003D91D5DB	2021-05-12 12:00:00	1	1	1	1	0	0	0	0	
Steelhead	5B4F	3DD.003D91D5D6	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Coho	5BF0	3DD.003DE944CF	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Coho	5C79	3DD.003D91D1AB	2021-05-13 09:15:00	1	1	1	0	0	0	0	0	
Steelhead	5C7E	3DD.003D91D5FA	2021-05-12 12:00:00	1	1	0	1	1	1	0	1	2021-05-15 02:44:41
Coho	5D54	3DD.003D91D5C2	2021-05-12 12:00:00	1	1	1	1	1	1	0	1	2021-05-16 23:31:55
Steelhead	5D78[1]	3DD.003DE944B7	2021-05-06 09:30:00	1	1	0	1	0	0	0	0	
Coho	5D90	3DD.003D91D5EB	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-13 14:04:51
Chinook	5D93	3DD.003D91DBC6	2021-04-01 11:00:00	1	0	0	0	0	0	0	0	
Steelhead	5E99	3DD.003D91DBDF	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	5EDD	3DD.003DE944DE	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-10 21:16:39
Steelhead	5F23	3DD.003DE944FB	2021-05-06 09:30:00	1	1	1	1	1	0	1	1	2021-05-11 00:22:33
Coho	5F82	3DD.003D91D5C3	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-06 03:48:54
Chinook	601B	3DD.003D91DBB5	2021-04-01 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	608A	3DD.003DE944DF	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-19 00:13:26
Steelhead	60F2	3DD.003D91E74C	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-05 19:34:21
Coho	6115	3DD.003D91D5D0	2021-05-12 12:00:00	1	1	0	0	0	0	0	0	
Chinook	613C	3DD.003D91DB99	2021-04-08 11:00:00	1	1	1	1	1	0	0	1	2021-04-19 21:05:00
Steelhead	61BE	3DD.003D91D5BD	2021-05-12 12:00:00	1	1	1	1	1	1	0	0	
Steelhead	6300	3DD.003DE944FC	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-09 22:17:07
Steelhead	6323	3DD.003D91D5DC	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-22 18:31:32
Steelhead	6338	3DD.003D91DBD4	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	636B	3DD.003DE94501	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Steelhead	63C2	3DD.003D91DB91	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Chinook	63D7	3DD.003D91DBF0	2021-04-08 11:00:00	1	1	0	1	0	0	0	1	2021-04-19 01:42:23
Steelhead	6409	3DD.003D91E74B	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-04 05:29:52
Steelhead	6502	3DD.003D91E781	2021-04-29 08:00:00	1	1	1	1	1	0	1	1	2021-05-07 01:03:21
Coho	683D	3DD.003D91D609	2021-05-12 12:00:00	1	1	1	1	0	0	0	0	
Steelhead	68D2	3DD.003D91DBC5	2021-04-29 08:00:00	1	1	1	1	1	1	0	1	2021-05-02 21:24:12
Steelhead	694B	3DD.003DE944D2	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Steelhead	694C	3DD.003D91DBA5	2021-04-29 08:00:00	1	1	1	1	1	0	0	0	
Coho	69F1	3DD.003D91DBD8	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	69F8	3DD.003D91E756	2021-04-29 08:00:00	1	1	1	1	1	1	1	0	
Steelhead	6A1F	3DD.003D91E77A	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	6A52	3DD.003D91D17E	2021-05-13 09:15:00	1	1	1	0	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	6A55	3DD.003D91DBEC	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Chinook	6ACD	3DD.003D91DB94	2021-04-08 11:00:00	1	0	0	0	0	0	0	0	
Coho	6C57	3DD.003DE94504	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	
Chinook	6CAC	3DD.003D91DBEA	2021-04-01 11:00:00	1	1	1	1	0	0	0	0	
Chinook	6CC2	3DD.003D91DB8D	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	6CCF	3DD.003D91D5DD	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Steelhead	6D88	3DD.003D91E791	2021-04-29 08:00:00	1	1	1	1	1	0	1	1	2021-05-03 21:44:40
Steelhead	6D93	3DD.003D91D5CD	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-22 21:36:44
Chinook	6D97	3DD.003D91DBCA	2021-04-08 11:00:00	1	1	1	1	1	0	0	1	2021-05-07 00:30:20
Steelhead	6DD2	3DD.003D91D5E9	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-18 12:24:09
Coho	6DE0	3DD.003D91E782	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	6E21	3DD.003D91D5B1	2021-05-12 12:00:00	1	1	1	0	0	0	0	0	
Coho	6F50	3DD.003D91D5C1	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-15 00:00:56
Steelhead	70D2	3DD.003DE944B5	2021-05-06 09:30:00	1	0	0	0	0	0	0	0	
Steelhead	70EF	3DD.003D91E754	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-01 11:13:57
Coho	7291	3DD.003D91D167	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-06-10 16:01:07
Steelhead	72E6	3DD.003D91D5C6	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-20 16:46:39
Steelhead	730B	3DD.003D91DBDB	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	732A	3DD.003D91E771	2021-04-29 08:00:00	1	1	1	1	0	0	0	0	
Steelhead	7332	3DD.003DE944DC	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Steelhead	735F	3DD.003DE944ED	2021-05-06 09:30:00	1	1	1	0	0	0	0	0	
Steelhead	7393	3DD.003D91D610	2021-05-12 12:00:00	1	1	1	1	1	1	0	1	2021-05-14 23:26:06
Steelhead	73B9	3DD.003D91D5B5	2021-05-12 12:00:00	1	1	1	1	0	1	1	1	2021-05-19 22:23:48
Steelhead	74C4	3DD.003D91E78D	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	7543	3DD.003D91D5E8	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Steelhead	75B0	3DD.003DE944C7	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Coho	75E1	3DD.003D91D5B4	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-07 19:00:53
Coho	76E5	3DD.003D91D60A	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Chinook	76F6	3DD.003D91DBE2	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	
Chinook	7716	3DD.003D91DB95	2021-04-01 11:00:00	1	1	0	1	0	0	0	0	
Steelhead	776A	3DD.003DE944E9	2021-05-06 09:30:00	1	1	0	1	0	0	0	0	
Steelhead	7828	3DD.003D91D60F	2021-05-12 12:00:00	1	1	1	1	1	0	0	0	
Steelhead	7894	3DD.003DE94503	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Chinook	78E1	3DD.003D91DB97	2021-04-01 11:00:00	1	1	0	1	0	0	0	0	
Coho	7A64	3DD.003DE944CC	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-07 22:49:37
Coho	7A67	3DD.003DE944BC	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-22 01:01:11
Coho	7A68	3DD.003D91D165	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	7AA3	3DD.003D91D1AE	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Steelhead	7AC8	3DD.003DE944F4	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	7AE5	3DD.003DE944C3	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-08 23:45:17
Coho	7B18	3DD.003DE944D4	2021-05-06 09:30:00	1	0	0	0	0	0	0	0	
Steelhead	7B43	3DD.003D91D5E6	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-19 08:03:10
Coho	7B64	3DD.003D91D5C5	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Coho	7BCD	3DD.003DE944F6	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-13 21:54:01
Steelhead	7C17	3DD.003DE944AF	2021-05-06 09:30:00	1	1	1	1	1	0	0	0	
Coho	7C30	3DD.003DE944B9	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Coho	7C57	3DD.003DE944B3	2021-05-06 09:30:00	1	1	1	1	0	0	1	1	2021-05-08 00:49:13
Steelhead	7CF6	3DD.003D91E75F	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	7F0D	3DD.003DE944FD	2021-05-06 09:30:00	1	1	1	1	1	1	0	0	
Chinook	7F4E	3DD.003D91DB98	2021-04-08 11:00:00	1	1	1	1	1	1	0	1	2021-05-02 22:18:36
Coho	7FA2	3DD.003DE944B4	2021-05-06 09:30:00	1	0	0	0	0	0	0	0	
Coho	802B	3DD.003D91D194	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	8038	3DD.003D91D5EC	2021-05-12 12:00:00	1	1	1	1	1	1	0	0	
Steelhead	8066	3DD.003D91D5FE	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-14 21:47:34
Steelhead	80A3	3DD.003DE944E3	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Coho	80FD	3DD.003D91D5D4	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Steelhead	8157	3DD.003D91E750	2021-04-29 08:00:00	1	1	0	0	0	0	0	0	
Coho	8161	3DD.003DE944E2	2021-05-06 09:30:00	1	1	1	1	1	0	0	0	
Chinook	832A	3DD.003D91DBBA	2021-04-08 11:00:00	1	1	0	1	0	0	0	0	
Coho	8385	3DD.003D91D180	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	8386	3DD.003D91D1A7	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-06-05 19:37:56
Coho	83AE	3DD.003D91DBA8	2021-04-29 08:00:00	1	0	0	0	0	0	0	0	
Coho	849F	3DD.003D91D195	2021-05-13 09:15:00	1	1	1	1	0	0	0	0	
Coho	84A5	3DD.003D91D5B3	2021-05-12 12:00:00	1	0	0	0	0	0	0	0	
Coho	84AD	3DD.003D91D170	2021-05-13 09:15:00	1	1	1	1	1	0	1	1	2021-06-19 07:34:17
Steelhead	8505	3DD.003DE944E8	2021-05-06 09:30:00	1	1	0	1	1	0	0	0	
Chinook	8525	3DD.003D91DBD0	2021-04-08 11:00:00	1	1	1	1	1	1	1	1	2021-04-23 02:54:51
Coho	857A	3DD.003D91D5E2	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-05 01:38:44
Coho	85A6	3DD.003D91D5D1	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-17 04:13:09
Steelhead	86C6	3DD.003DE944C5	2021-05-06 09:30:00	1	1	0	0	0	0	0	0	
Steelhead	885C	3DD.003DE944EB	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Chinook	8947	3DD.003D91DBB3	2021-04-01 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	89A2	3DD.003D91E747	2021-04-29 08:00:00	1	1	1	1	0	1	1	1	2021-05-05 03:52:00
Steelhead	89A4	3DD.003D91D608	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Coho	89BF	3DD.003DE944B8	2021-05-06 09:30:00	1	0	0	0	0	0	0	0	
Coho	89EB	3DD.003DE944BE	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-28 10:42:04
Steelhead	8B08	3DD.003D91DBC4	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	8B26	3DD.003D91D169	2021-05-13 09:15:00	1	1	1	1	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Chinook	8B34	3DD.003D91DBD7	2021-04-08 11:00:00	1	1	1	1	0	1	1	1	2021-04-14 21:53:51
Chinook	8B3C	3DD.003D91DB9D	2021-04-08 11:00:00	1	1	1	1	0	0	1	1	2021-04-20 21:14:23
Chinook	8B59	3DD.003D91DBDE	2021-04-08 11:00:00	1	1	1	1	1	0	1	1	2021-04-12 03:09:41
Coho	8B8B	3DD.003DE944F7	2021-05-06 09:30:00	1	1	1	1	1	0	0	0	
Steelhead	8B96	3DD.003DE944B2	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-20 04:46:32
Coho	8BEA	3DD.003D91E795	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	8C2E	3DD.003D91DBE4	2021-04-29 08:00:00	1	1	1	1	1	1	1	0	
Chinook	8C7B	3DD.003D91DBAE	2021-04-08 11:00:00	1	0	0	0	0	0	0	0	
Coho	8CC6	3DD.003DE944E1	2021-05-06 09:30:00	1	1	1	1	1	1	0	1	2021-05-08 02:15:55
Steelhead	8D2F	3DD.003D91E755	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-04 23:25:08
Coho	8E0A	3DD.003D91D5E0	2021-05-12 12:00:00	1	1	1	1	1	0	0	0	
Steelhead	8E49	3DD.003D91DB9F	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Chinook	8EB1	3DD.003DE944C2	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Chinook	8F02	3DD.003DE944E0	2021-05-06 09:30:00	1	1	1	1	0	0	0	0	
Coho	8F3A	3DD.003DE944AE	2021-05-06 09:30:00	1	1	1	1	1	0	1	1	2021-05-11 02:32:55
Steelhead	8FA8[1]	3DD.003D91E780	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Chinook	8FB9	3DD.003D91DBBC	2021-04-01 11:00:00	0	0	0	0	0	0	0	0	
Coho	8FF4	3DD.003DE94506	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	
Coho	9005	3DD.003DE944CA	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-09 00:17:55
Steelhead	9027	3DD.003D91D5E7	2021-05-12 12:00:00	1	1	1	1	1	0	0	1	2021-05-14 04:16:08
Steelhead	90D2	3DD.003D91E75A	2021-04-29 08:00:00	1	1	1	1	0	0	0	0	
Coho	919A	3DD.003DE944EC	2021-05-06 09:30:00	1	1	0	0	0	0	0	0	
Coho	91C1	3DD.003DE944CB	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	
Steelhead	91C2	3DD.003D91DBE5	2021-04-29 08:00:00	1	1	0	1	0	0	0	0	
Coho	91D9	3DD.003D91D5BC	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Steelhead	91E5	3DD.003D91D5B9	2021-05-12 12:00:00	1	1	0	0	0	0	0	0	
Coho	92DF	3DD.003D91D5CA	2021-05-12 12:00:00	1	1	1	1	1	0	0	0	
Coho	9371	3DD.003DE944EA	2021-05-06 09:30:00	1	1	1	1	1	0	0	1	2021-05-29 22:30:04
Steelhead	9443	3DD.003D91D5C0	2021-05-12 12:00:00	1	0	0	0	0	0	0	0	
Coho	94CA	3DD.003D91D5AE	2021-05-12 12:00:00	1	1	1	1	1	1	0	1	2021-05-21 09:19:03
Steelhead	9524	3DD.003DE944BB	2021-05-06 09:30:00	1	1	1	1	1	1	0	0	
Chinook	95E3	3DD.003D91DBEE	2021-04-08 11:00:00	1	1	1	1	1	1	1	0	
Steelhead	9616	3DD.003DE944BF	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Steelhead	9637	3DD.003D91D611	2021-05-12 12:00:00	1	1	1	1	1	1	0	1	2021-05-20 01:14:02
Chinook	9667	3DD.003D91DBCF	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	96D0	3DD.003D91E751	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	973C	3DD.003D91D5B7	2021-05-12 12:00:00	1	1	1	1	0	0	0	0	
Chinook	9749	3DD.003D91DBAB	2021-04-08 11:00:00	1	1	1	1	1	1	1	1	2021-04-30 23:51:29
Chinook	976C	3DD.003D91DBA7	2021-04-08 11:00:00	0	0	0	0	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	9878	3DD.003D91E76E	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-17 11:30:47
Steelhead	987E	3DD.003D91E766	2021-04-29 08:00:00	1	1	1	1	1	0	0	1	2021-05-02 11:27:23
Steelhead	98D3	3DD.003D91D5BA	2021-05-12 12:00:00	1	1	1	1	1	1	0	1	2021-05-16 19:55:17
Steelhead	98F5	3DD.003D91DBB7	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-02 21:54:14
Steelhead	995F	3DD.003DE94507	2021-05-06 09:30:00	1	0	0	0	0	0	0	0	
Chinook	99DC	3DD.003D91DBBB	2021-04-08 11:00:00	1	1	0	1	0	0	0	0	
Coho	99F2	3DD.003D91D5D3	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-06-03 10:15:08
Steelhead	9A0F	3DD.003D91D5AF	2021-05-12 12:00:00	1	1	1	1	1	1	1	1	2021-05-30 02:31:06
Steelhead	9A3F	3DD.003D91E793	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Coho	9A46	3DD.003D91D5BF	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Steelhead	9D4A	3DD.003D91DBD9	2021-04-29 08:00:00	1	1	1	1	1	1	1	1	2021-05-24 08:23:14
Coho	9DAD	3DD.003D91D5E4	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Coho	9DC7	3DD.003DE94505	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Coho	9EB1	3DD.003DE944D8	2021-05-06 09:30:00	1	1	1	1	1	0	0	0	
Steelhead	9ECD	3DD.003D91E775	2021-04-29 08:00:00	1	0	0	0	0	0	0	0	
Coho	9F80	3DD.003DE944FF	2021-05-06 09:30:00	1	1	1	1	1	0	0	1	2021-05-08 00:20:15
Steelhead	9F8C	3DD.003D91E768	2021-04-29 08:00:00	1	1	1	1	0	0	0	0	
Steelhead	9FF7	3DD.003D91DBCB	2021-04-29 08:00:00	0	0	0	0	0	0	0	0	
Steelhead	A03C	3DD.003D91E76C	2021-04-29 08:00:00	1	0	0	0	0	0	0	0	
Coho	A09E	3DD.003D91D606	2021-05-12 12:00:00	1	1	1	1	1	0	1	1	2021-05-16 03:33:36
Chinook	A0EC	3DD.003D91DB90	2021-04-08 11:00:00	1	0	0	0	0	0	0	0	
Chinook	A10B	3DD.003D91DBB0	2021-04-08 11:00:00	1	1	1	1	1	1	0	1	2021-05-19 23:09:13
Coho	A160	3DD.003DE9450A	2021-05-06 09:30:00	1	1	1	1	1	1	1	0	
Coho	A161	3DD.003D91D19E	2021-05-13 09:15:00	1	1	1	1	1	0	0	1	2021-06-18 08:14:21
Coho	A1A0	3DD.003D91D5C9	2021-05-12 12:00:00	0	0	0	0	0	0	0	0	
Steelhead	A230	3DD.003DE94510	2021-05-06 09:30:00	1	1	1	1	0	1	0	1	2021-05-09 21:03:20
Chinook	A2B2	3DD.003D91DBB8	2021-04-01 11:00:00	1	1	1	0	0	0	0	0	
Coho	A2BC	3DD.003D91D5F5	2021-05-12 12:00:00	1	0	0	0	0	0	0	0	
Steelhead	A360	3DD.003D91D122	2021-05-27 09:00:00	1	1	1	1	1	1	0	1	2021-05-30 01:52:13
Steelhead	A44D	3DD.003D91D13F	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Steelhead	A481	3DD.003DE942F8	2021-05-20 09:45:00	1	1	1	1	1	1	0	1	2021-05-25 17:43:35
Coho	A4C7	3DD.003E00157E	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Steelhead	A4F5	3DD.003DE942BE	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	A57C	3DD.003D91D1A4	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	A5A9	3DD.003E001577	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-19 10:54:07
Chinook	A5B9	3DD.003D91DBEF	2021-04-01 11:00:00	0	0	0	0	0	0	0	0	
Steelhead	A5F3	3DD.003DE944DD	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-05-28 21:31:36
Coho	A610	3DD.003D91D129	2021-05-27 09:00:00	1	1	1	1	1	0	1	1	2021-06-03 19:20:18
Steelhead	A63E	3DD.003D91D114	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	A654	3DD.003D91D108	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	A6E6	3DD.003D91D155	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-18 08:30:58
Coho	A752	3DD.003D91D1C3	2021-05-13 09:15:00	1	1	1	1	1	1	0	0	
Coho	A84C	3DD.003D91D17C	2021-05-13 09:15:00	1	0	0	0	0	0	0	0	
Steelhead	A8CF	3DD.003D91D189	2021-05-13 09:15:00	1	1	0	0	0	0	0	0	
Coho	A8E9	3DD.003E00158A	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-07-02 13:36:00
Steelhead	A963	3DD.003D91D11E	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	A98D	3DD.003E00154E	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	A9E0	3DD.003E001555	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	AAF0	3DD.003DE9430C	2021-05-20 09:45:00	1	1	1	1	0	0	0	0	
Steelhead	AB01	3DD.003D91D150	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-15 01:10:07
Steelhead	ABCF	3DD.003DE942DD	2021-05-20 09:45:00	1	1	0	1	0	0	0	0	
Steelhead	ABFB	3DD.003D91D19D	2021-05-13 09:15:00	1	1	1	1	1	1	0	1	2021-05-17 01:11:08
Steelhead	ACC0	3DD.003D91D198	2021-05-13 09:15:00	1	1	1	1	1	1	1	0	
Coho	ACD2	3DD.003DE942CF	2021-05-20 09:45:00	1	0	0	0	0	0	0	0	
Coho	ACE3	3DD.003DE94312	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-18 06:47:00
Steelhead	ADF2	3DD.003D91D14C	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Coho	AE0D	3DD.003DE942C5	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-06-18 06:58:35
Steelhead	AE14	3DD.003D91D159	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Steelhead	AE39[1]	3DD.003D91D1A9	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	AF05	3DD.003D91D132	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-08 02:13:28
Steelhead	AFE6	3DD.003DE942DC	2021-05-20 09:45:00	1	1	0	1	0	0	0	0	
Steelhead	AFE9	3DD.003DE94300	2021-05-20 09:45:00	1	1	1	1	1	1	1	1	2021-05-31 14:59:56
Coho	B011	3DD.003E001581	2021-06-03 11:00:00	1	1	1	1	1	1	0	0	
Steelhead	B04C	3DD.003D91D13C	2021-05-27 09:00:00	1	1	1	1	1	1	0	1	2021-05-30 00:06:26
Steelhead	B069	3DD.003D91D600	2021-05-12 12:00:00	1	1	1	1	1	1	1	0	
Coho	B0A8	3DD.003D91D14F	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	B0B7	3DD.003E001593	2021-06-03 11:00:00	0	1	1	1	0	0	1	1	2021-06-03 20:39:58
Coho	B175	3DD.003E001552	2021-06-03 11:00:00	1	1	1	1	1	1	0	0	
Coho	B187	3DD.003E001568	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-22 05:15:44
Coho	B1E7	3DD.003E00158D	2021-06-03 11:00:00	1	1	1	1	0	0	0	0	
Coho	B26A	3DD.003E0015A3	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	B2DA	3DD.003DE944EF	2021-05-06 09:30:00	0	0	0	0	0	0	0	0	
Coho	B31A	3DD.003DE944DB	2021-05-06 09:30:00	1	1	1	1	1	1	1	1	2021-06-08 18:26:55
Coho	B347	3DD.003D91D177	2021-05-13 09:15:00	1	1	1	1	1	1	1	1	2021-05-15 02:33:51
Coho	B394	3DD.003D91D13A	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	
Steelhead	B3A1	3DD.003DE942D5	2021-05-20 09:45:00	1	1	1	1	1	1	0	1	2021-06-15 02:23:47
Coho	B3AC	3DD.003E001546	2021-06-03 11:00:00	0	0	0	0	0	0	0	0	
Coho	B3E7	3DD.003D91D12C	2021-05-27 09:00:00	1	1	1	1	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	NTS-U	NTS-D	CCHP	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	B400	3DD.003DE942BF	2021-05-20 09:45:00	1	1	1	1	1	1	0	0	
Steelhead	B41D	3DD.003DE942E8	2021-05-20 09:45:00	0	0	0	0	0	0	0	0	
Steelhead	B4CA	3DD.003D91D19F	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Steelhead	B50A	3DD.003DE94309	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	B539	3DD.003D91D19B	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Coho	B551	3DD.003DE942C9	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	B5B9	3DD.003D91D190	2021-05-13 09:15:00	1	1	1	1	1	0	0	0	
Steelhead	B5ED	3DD.003D91D144	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Steelhead	B60B	3DD.003D91D5E3	2021-05-12 12:00:00	1	1	1	1	0	1	1	1	2021-06-05 01:38:59
Steelhead	B61F	3DD.003DE94313	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Coho	B6DC	3DD.003DE94304	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	
Steelhead	B73C	3DD.003D91D175	2021-05-13 09:15:00	1	1	1	0	1	1	1	1	2021-05-16 00:19:56
Steelhead	B774	3DD.003D91D13D	2021-05-27 09:00:00	1	1	1	1	1	0	0	0	
Coho	B787	3DD.003E001597	2021-06-03 11:00:00	1	1	1	1	1	0	0	0	
Steelhead	B793	3DD.003D91D10B	2021-05-27 09:00:00	0	0	0	0	0	0	0	0	
Steelhead	B7D1	3DD.003DE942CD	2021-05-20 09:45:00	1	1	1	1	1	0	1	1	2021-05-25 04:38:45
Coho	B830	3DD.003E00156F	2021-06-03 11:00:00	1	1	1	1	1	0	0	0	
Coho	B870	3DD.003D91D113	2021-05-27 09:00:00	1	1	1	1	1	1	1	0	
Coho	BA1D	3DD.003D91D1B6	2021-05-13 09:15:00	0	0	0	0	0	0	0	0	
Chinook	BA42	3DD.003D91DBA0	2021-04-01 11:00:00	1	1	1	1	0	0	0	1	2021-06-07 02:23:01
Coho	BA5C	3DD.003E001547	2021-06-03 11:00:00	1	1	1	1	1	1	1	1	2021-06-04 16:18:05
Coho	BA8E	3DD.003E00157C	2021-06-03 11:00:00	1	1	1	1	1	1	1	0	
Coho	BC13	3DD.003D91D13B	2021-05-27 09:00:00	1	1	1	1	1	1	1	1	2021-06-06 13:25:52
Coho	BC27	3DD.003DE942BA	2021-05-20 09:45:00	1	1	1	1	1	1	1	0	

Notes:
1. Detection history was manually updated to remove presence in the downstream secondary channel following update to zone presence criteria.
Four-digit acoustic tag codes and passive integrated transponder-tag codes are displayed.
Zone columns are shown for the forebay (FBY), zone of influence (ZOI), upstream net transition structure (NTS-U), downstream net transition structure (NTS-D), primary channel (CCHP), upstream secondary channel (CCHS-U), downstream secondary channel (CCHS-D).
“0” indicates no presence in the zone over the course of the entire study (based on zone presence criteria), while “1” indicates a presence at least once at some point of the study.

APPENDIX D

SPAWN TIMING, DISTRIBUTION AND ABUNDANCE OF TRANSPORTED FISHES – 2021 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: April 26, 2022

Re: NF Lewis River upstream of Swift Dam – 2021 Salmon Spawning Survey Results

Introduction

Coho and Spring Chinook Salmon spawning surveys were conducted from September 2 through December 2021 by Meridian Environmental, Inc. (Meridian) under 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 basin upstream of Swift Dam.

Methods

The original spawning survey sample design was developed in 2012. All known 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. Since beginning spawning surveys in 2012, one of the randomly-stratified survey panels was surveyed each year. Concurrently with conducting spawning surveys in 2021, the Lewis River Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2017) was undergoing a 5-year review and revision in consultation with the Lewis River Aquatics Coordination Committee – Aquatic Technical Subgroup (ATS). The decision was made by PacifiCorp that Coho and Chinook spawning surveys should focus on distribution rather than spawner abundance. Therefore, spawning surveys were conducted across as many reaches as possible each month (census survey) in 2021 rather than a subsample of reaches as was conducted in previous years. However, data was still collected in the same discrete uniquely identified reaches as used for past surveys.

Field survey methods followed those described in PacifiCorp and Cowlitz PUD (2017). All surveys were conducted by foot, except North Fork Lewis River mainstem and Muddy River mainstem surveys were conducted by kayak[1]. Note that in 2021, all surveys were conducted by the same Meridian biologists who have been conducting these surveys since 2016. During the survey of each reach, the number of live Coho were enumerated. Coho carcasses were enumerated by species, sex, and origin. The tail was removed from each carcass after counting so that it would not be counted as a new carcass on subsequent surveys. All new redds were counted and given a uniquely numbered flag by date and

[1]Note that due to narrow passages through several rapids, larger craft such as rafts and catarafts cannot be used to conduct float surveys.

2136 Westlake Ave N, Seattle, WA 98109
Tel 206 522-8282 Fax 206 522-8277 www.meridianenv.com

reach. GPS coordinates were recorded for all redds and salmon (live or dead) observed. On subsequent surveys the visibility of each previously flagged redd was recorded. Once a redd was deemed no longer visible, the flag was removed.

Survey Conditions

The USGS North Fork Lewis River above Muddy River gage approximates general flow patterns relative to median conditions throughout the NF Lewis River basin upstream of Swift Dam during the survey season (Figure 1). Flows were generally well below daily median flows from September through mid-October 2021 during the Chinook spawning period. Small tributary streams were either totally dry or too low to allow upstream migration of spawning salmon until flows rose at the end of October, including several reservoir tributaries and small tributaries to the NF Lewis River, Muddy River, and Pine Creek. Intense rain occurred that resulted in a significant flow spike in late-October and a flood in mid-November, with a peak instantaneous discharge of nearly 20,000 cfs as measured at the USGS Lewis River above Muddy River gage (Figure 1). Flows during November were significantly above median conditions (Figure 1). These high flows resulted in unsurveyable conditions for most stream reaches from late-October to early-December, and also limited kayak surveys of the NF Lewis River and Muddy River mainstems. Note that flows over about 1,000 cfs (Lewis River above Muddy River gage) are considered unsafe for conducting spawning surveys via kayak on the NF Lewis River and Muddy River mainstems, and visibility is also generally greatly reduced. Seasonally locked gates limited access to the upper Muddy River watershed beginning in early-November. Sporadic snow-storms limited access to most streams in December, and heavy snow after December 21 precluded access to all stream reaches for the remainder of the spawning season.

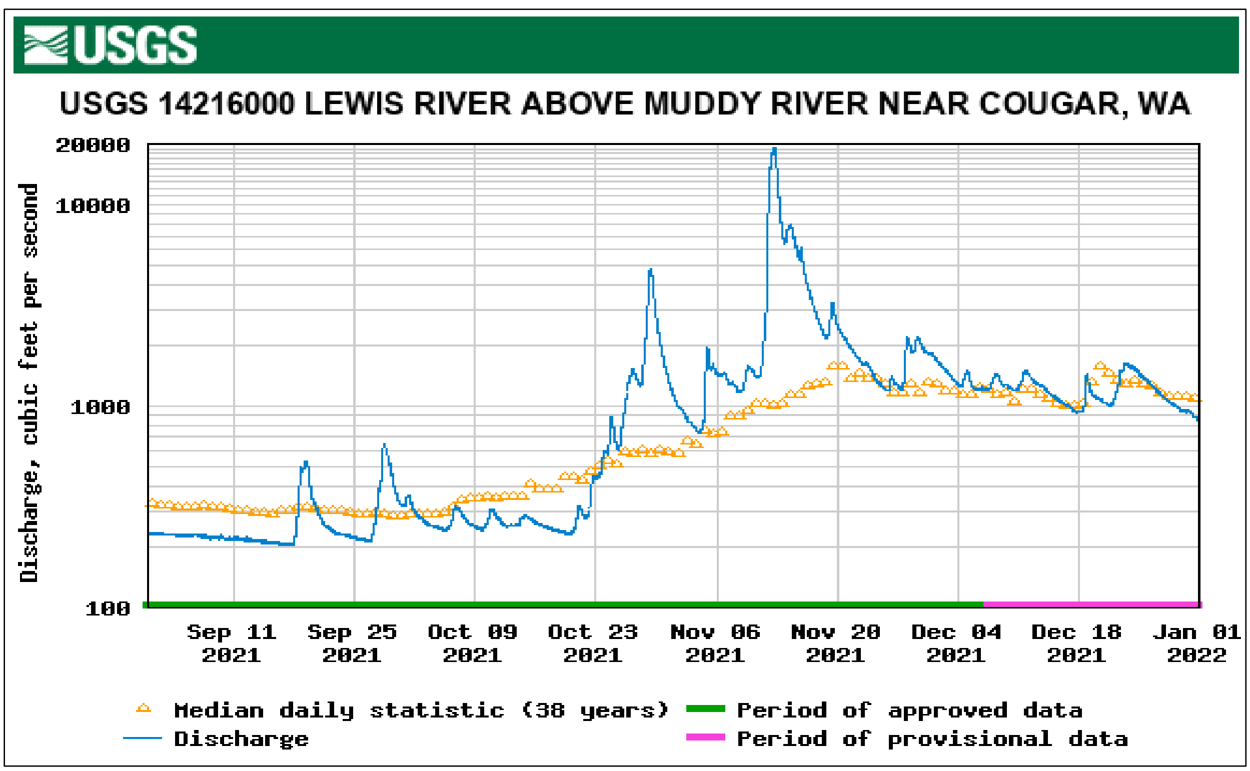


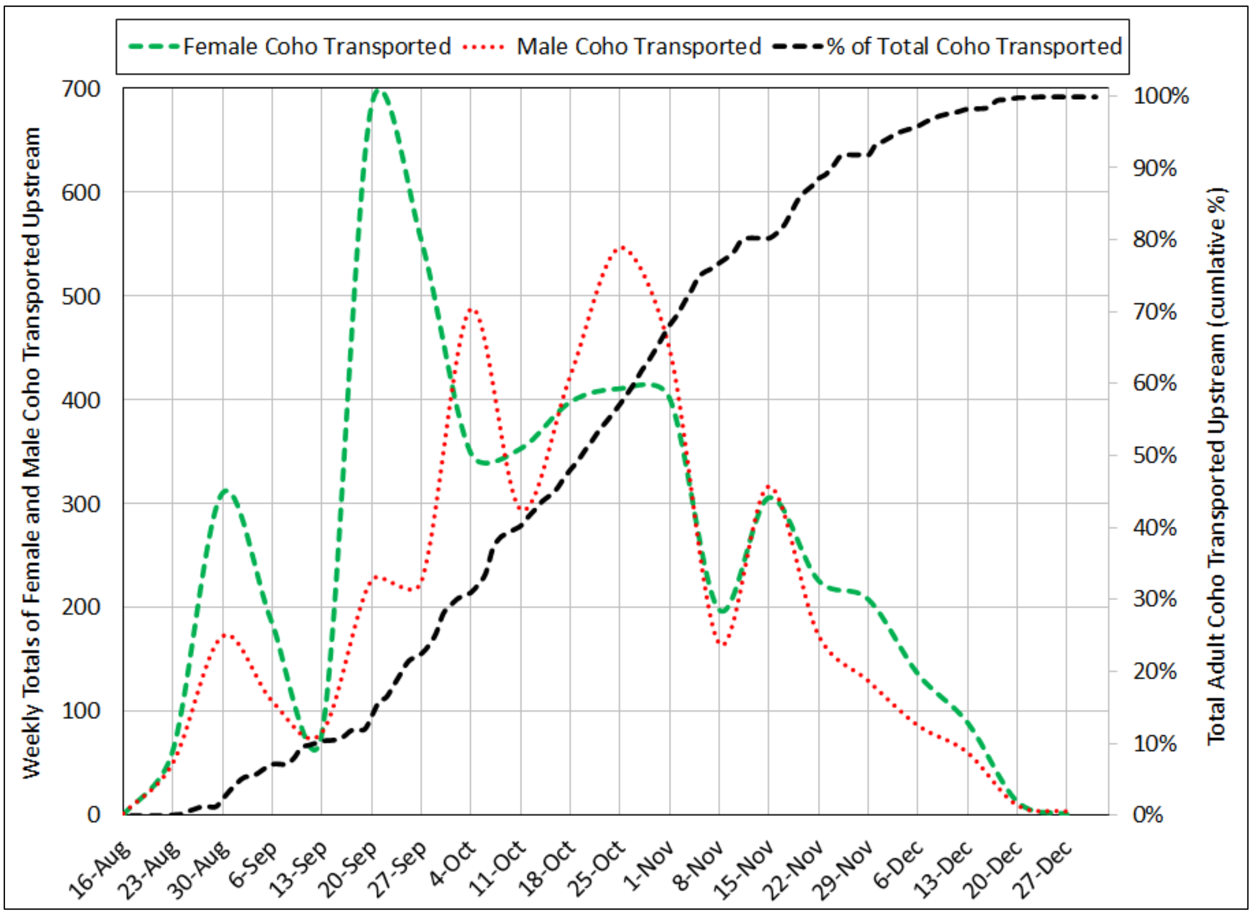
Figure 1. USGS North Fork Lewis River above Muddy River flows (Sep-Dec 2021).

Results

Spring Chinook and Coho Transported Upstream

A total of 230 female and 663 male adult Chinook were transported upstream of Swift Dam to spawn for the 2021 run. In addition, 289 Chinook jacks were transported upstream (defined as returning Chinook <24 inches in length). By the time spawning surveys started on September 2, 91% of the Chinook had already been transported upstream. The remainder (9%) were transported upstream by September 21, 2021.

A total of 4,961 female and 4,021 male adult Coho were transported alive upstream of Swift Dam to spawn for the 2021 run. In addition, 356 Coho jacks were transported upstream (defined as returning Coho <18 inches in length). Most of the adult Coho transported upstream in 2021 were classified as early-Coho (6,174, 66%, percent) and the remaining 34% (3,164) were classified as late-Coho. By the time spawning surveys started on September 2, only 5% of the Coho had been transported upstream. The remaining Coho (95%) were transported upstream at a fairly constant rate until the end of December (Figure 2). However, more females were transported upstream early in the run (Figure 2).



Note: Weekly males transprted upstream (red dotted line) does not include jacks.

Figure 2. Total Coho transported upstream by week (female and male) and cumulative % of total Coho transported upstream per day.

Survey Effort

Nearly all accessible habitat was surveyed at least once during the Chinook spawning period from September to early-October (Table 1). Most small streams were dry or too low for fish to access in September and October (as previously discussed) until heavy precipitation began in late-October, which then caused most stream reaches to be unsurveyable in November due to floods and high turbidity. Continuing high flows, snow, and locked gates also precluded surveys in most stream reaches in December.

Table 1. Percent of 0.3-mile-long reaches surveyed in each stream by month.

Stream Name (alphabetical order)	Total 0.3 Mile Reaches[1]	September	October	November	December
Big Creek	1	too low	too low	not surveyable	not surveyable
Chickoon Creek	1	too low	100%	not surveyable	not surveyable
Clear Creek[2]	37	65%	65%	19%	32%
Clearwater Creek	18	89%	100%	0%	0%
Cussed Hollow Creek	1	too low	100%	not surveyable	not surveyable
Diamond Creek	1	too low	too low	100%	not surveyable
Drift Creek	5	100%	100%	20%	100%
Forest Camp Creek	1	too low	too low	100%	100%
Little Creek	1	100%	100%	100%	not surveyable
M1 Creek	3	too low	too low	not surveyable	not surveyable
M2 Creek	1	too low	too low	not surveyable	not surveyable
Muddy River mainstem[3]	40	45%	43%	not surveyable	not surveyable
NF Lewis River mainstem	43	100%	100%	not surveyable	28%
P1 Creek	3	too low	too low	not surveyable	not surveyable
P3 Creek	4	too low	too low	25%	25%
P7 Creek	4	too low	too low	not surveyable	100%
P8 Creek[4]	14	43%	43%	43%	43%
P10 Creek	1	too low	100%	not surveyable	100%
Pepper Creek	5	too low	too low	40%	not surveyable
Pine Creek mainstem	27	100%	100%	not surveyable	not surveyable
Range Creek	3	too low	too low	33%	not surveyable
Rush Creek[5]	6	33%	33%	33%	not surveyable
S10 Creek	2	too low	too low	100%	50%
S15 Creek	5	too low	too low	not surveyable	not surveyable
S20 Creek	3	too low	too low	33%	67%
Smith Creek[6]	19	very low	58%	not surveyable	not surveyable
Spencer Creek	2	too low	100%	not surveyable	not surveyable
Swift Creek[7]	1	0%	100%	100%	100%

[1]Note: For each stream, the accessible length to anadromous fish/migratory salmonids is segmented into spatially discrete and uniquely identified approximately 0.3-mile-long reaches starting from its mouth to the identified upstream limit of potential fish migration.

[2]Note: Clear Creek is divided into 37 reaches; the upper 13 reaches (35% of the total) are not accessible by foot due to steep canyon walls/rock gorge.

[3]Note: The approximately lower half of the Muddy River was surveyed in September and the upper half was surveyed the first week of October. Therefore, 88% of the Muddy River was surveyed during the Chinook spawning period.

[4]Note: PacifiCorp biologists only surveyed the approximately lower 1.5 miles of P8 Creek in September and October for Bull Trout spawning.

[4]Note: PacifiCorp biologists only surveyed the lower 1/3rd of Rush Creek in September and October for Bull Trout spawning, the remaining habitat upstream is not likely accessible to Coho and Chinook due to gradient near 20% slope in many areas.

[6]Note: The upper 40% of Smith Creek is too far to access by foot in one day.

[7]Note: The Swift Creek survey was missed in September due to mechanical issues with the jetboat used to access this stream.

Spring Chinook Redd Counts

A total of 240 Chinook redds were counted in 2021; more than in all other years combined (Table 2). However, prior years used a subsampling approach, whereas surveys in 2021 used a census approach. Most Chinook redds were counted in the NF Lewis River mainstem (78%), followed by Clearwater Creek (14%). The distribution pattern of Chinook redds counted in 2021 is consistent with the prior observations from all other years combined (Table 2, Figure 3). However, a larger proportion of Chinook redds were counted in Clearwater Creek than in prior years and a smaller proportion were counted in the Muddy River mainstem (Table 2). Note that Clearwater Creek is a Muddy River tributary.

While no Chinook redds were counted in Smith Creek, one Chinook carcass was observed in mid-October. A few spring Chinook redds have been found in Drift Creek in prior years. However, flows were very low during the Chinook spawning period in 2021, which likely precluded access of Chinook into Drift Creek.

The entire mainstem of Pine Creek and approximately the lower 1.5 miles of P8 Creek (tributary to Pine Creek) were surveyed by foot every week from September through October 2021 for Bull Trout spawning surveys. No spring Chinook or potential spring Chinook redds were observed in the Pine Creek watershed during this time period. This is consistent with all prior years' results. No spring Chinook or potential Chinook redds have been observed in Pine Creek during any of the prior spawning survey years when spring Chinook have been transported upstream of Swift Dam. However, two adult male spring Chinook (not associated with a redd) were observed in Pine Creek during September 2013. Rush Creek was also surveyed weekly in September and October of 2021 for Bull Trout surveys and no spring Chinook or suspected Chinook redds were observed.

Table 2. Length of habitat accessible to spring Chinook in potential spawning streams[2] and redd count total: 2021 and 2012-2020 (combined).

Stream Name	Accessible to Anadromous Fish Length (miles)	Surveyable[1] Length (miles)	Total Chinook (live and dead) Counted 2021	Total (%) Chinook Redds Count 2021	Total (%) Chinook Redd Count 2012-2020
Clear Creek	11.1	7.5	4	5 (2.1%)	5 (2.2%)
Clearwater Creek	5.8	3.3	38	34 (14.2%)	6 (2.6%)
Drift Creek	1.5	1.5	0	0 (0%)	3 (1.3%)
Little Creek	0.3	0.3	25	10 (4.2%)	9 (4.0%)
NF Lewis River mainstem	12.9	12.9	179	187 (77.9%)	185 (81.5%)
Muddy River mainstem	9.3	9.2	1	4 (1.7%)	13 (5.7%)
Pine Creek mainstem & P8 Creek combined	12.2	12.2	0	0 (0%)	0 (0%)
Smith Creek	5.7	5	1	0 (0%)[3]	1 (0.4%)
Swift Creek	0.3	0.3	NA	NA	5 (2.2%)
Rush Creek	0.6	0.6	0	0 (0%)	0 (0%)
Total	**59.7**	**52.8**	**248**	**240**	**227**

[1]Note: Some areas are not accessible due to steep canyon slopes and/or are not logistically feasible to survey in one day.

[2]Note: All other streams upstream of Swift Dam potentially accessible to anadromous fish do not typically have enough water for spring Chinook to access from summer to mid-October.

[3]Note: While no Chinook redds were counted in Smith Creek, one Chinook carcass was observed in mid-October 2021.

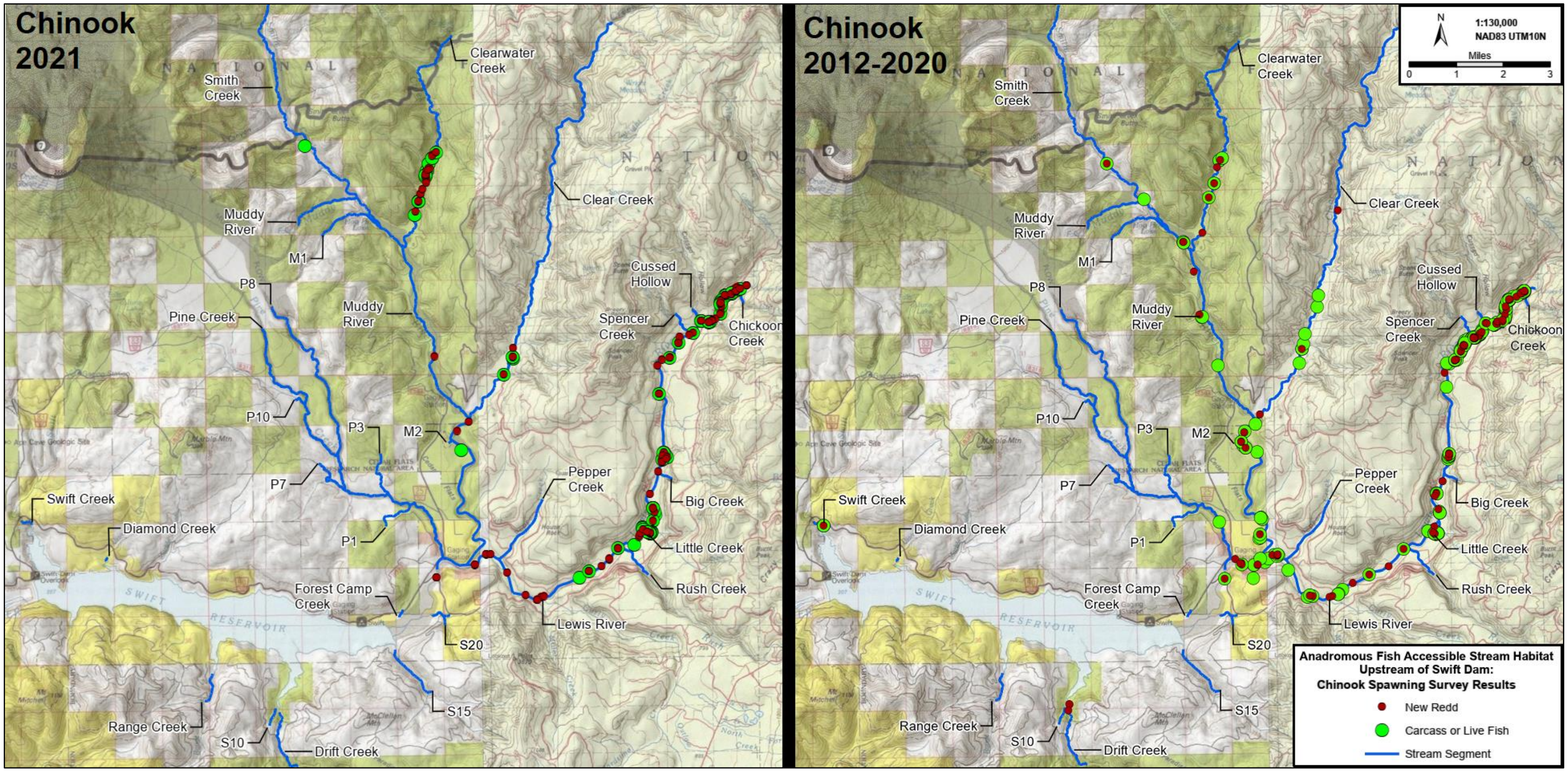


Figure 3. Chinook redd and fish observations made during spawning suveys in 2021 and all Chinook spawning survey observations combied from 2012-2020.

Coho Redd Counts

A total of 419 Coho redds were counted in 2021. Most Coho redds were counted in the NF Lewis River mainstem (29%), followed by Clear Creek (14%). The Muddy River mainstem, Drift Creek, S20 Creek, and Swift Creek also contained a significant portion of the total Coho redds counted. In aggregate, the NF Lewis River mainstem and small tributaries also had the highest Coho redd count in 2021 (39%), followed by the aggregate of Swift Reservoir small tributaries (29%) (Table 3). The distribution pattern of Coho redds counted in 2021 is approximately consistent with the prior observations from all prior years combined since surveys started in 2012 (Table 3, Figure 4).

Table 3. Coho fish and redd count total: 2021 and 2012-2020 (combined).

Stream Name	Total Coho (live and dead) Counted 2021	Total (%) Coho Redd Count 2021	Total (%) Coho Redd Count 2012-2020
NF Lewis River and Small Tributaries	**249**	**162 (38.7%)**	**840 (44.0%)**
Big Creek	0	0 (0%)	0 (0%)
Chickoon Creek	22	13 (3.1%)	6 (0.3%)
Cussed Hollow Creek	4	1 (0.2%)	0 (0.0%)[1]
Little Creek	15	15 (3.6%)	57 (3.0%)
Spencer Creek	3	6 (1.4%)	31 (1.6%)
Pepper Creek	7	6 (1.4%)	0 (0%)[1]
NF Lewis River mainstem	198	121 (28.9%)	746 (39.1%)
Muddy River Watershed	**33**	**97 (23.2%)**	**523 (27.4%)**
Clear Creek	21	58 (13.8%)	292 (15.3%)
Clearwater Creek	4	3 (0.7%)	38 (2.0%)
M1 Creek	0	0 (0%)	0 (0%)[1]
M2 Creek	0	0 (0%)	4 (0.2%)
Muddy River mainstem	8	32 (7.6%)	189 (9.9%)
Smith Creek	0	4 (1.0%)	0 (0%)[1]
Pine Creek Watershed	**22**	**40 (9.5%)**	**113 (5.9%)**
P1 Creek	0	0 (0%)	0 (0.0%)
P3 Creek	10	15 (3.6%)	15 (0.8%)
P7 Creek	9	9 (2.1%)	5 (0.3%)
P8 Creek	0	3 (0.7%)	9 (0.5%)
P10 Creek	0	0 (0%)	3 (0.2%)
Pine Creek mainstem	3	13 (3.1%)	81 (4.2%)
Swift Reservoir Small Tributaries	**43**	**120 (28.6%)**	**431 (22.6%)**
Diamond Creek	0	1 (0.2%)	43 (2.3%)
Drift Creek	5	36 (8.6%)	193 (10.1%)
Forest Camp Creek	26	14 (3.3%)	10 (0.5%)
Range Creek	0	0 (0%)	38 (2.0%)
Rush Creek	0	0 (0%)	10 (0.5%)
S10 Creek	0	5 (1.2%)	24 (1.3%)
S15 Creek	0	0 (0%)	45 (2.4%)
S20 Creek	5	32 (7.6%)	28 (1.5%)
Swift Creek	7	32 (7.6%)	40 (2.1%)
Grand Total	**347**	**419**	**1,907**

[1]Note: While no redds or carcasses have been observed, a few live Coho have been observed in Cussed Hollow, Pepper, and Smith creeks between 2012 and 2020.

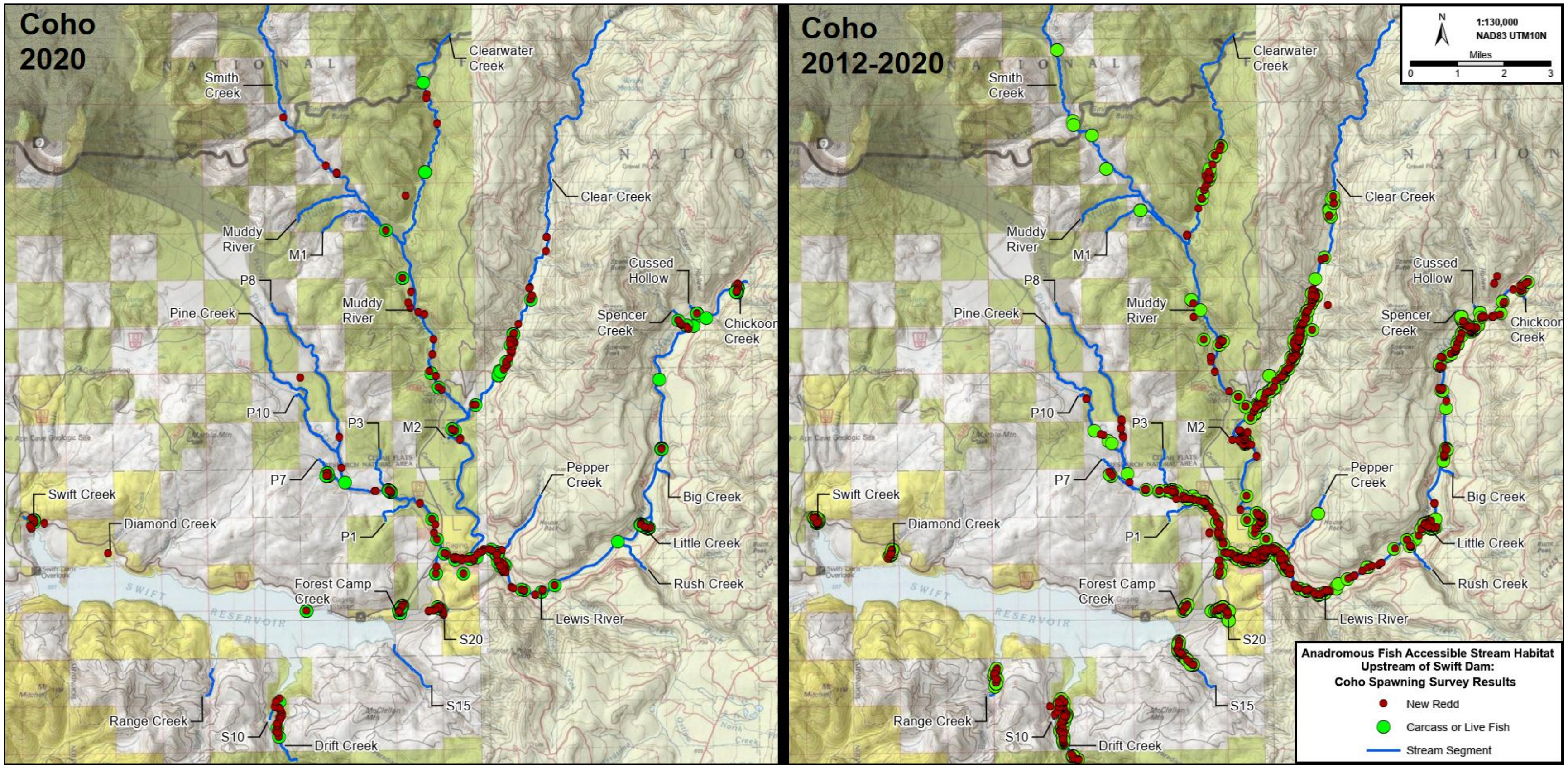


Figure 4. Coho redd and fish observations made during spawning suveys in 2021 and all Coho spawning survey observations combied from 2012-2020.

The 2021 Coho redd count is the 2nd highest count since surveys began in 2012 (highest = 839 redds counted in 2020, 3rd highest = 282 redds counted in 2014). A similar number of female Coho were transported upstream in these three years: 4,961 in 2021, 4,909 in 2020, and 4,217 in 2014. Note that the same reach survey panel was also surveyed in 2020 and 2014, though a larger census survey was attempted in 2021. Total redd counts are highly dependent on survey conditions. Survey conditions in 2020 were the best out of all years with the lowest overall stream flows, generally well below median conditions through December (Figure 5), which likely resulted in high redd detection probability compared to all other survey years since 2012. Conversely, stream flows in 2021 and 2014 were well above median conditions (Figure 5) with poor to non-surveyable conditions persisting after late-October, which likely largely reduced Coho redd detection probability compared to 2020. Survey conditions in 2014 were worse than 2021 as stream flows were generally higher and longer in duration (Figure 5), which likely resulted in a lower overall redd count in 2014 even though a similar number of female Coho were transported upstream.

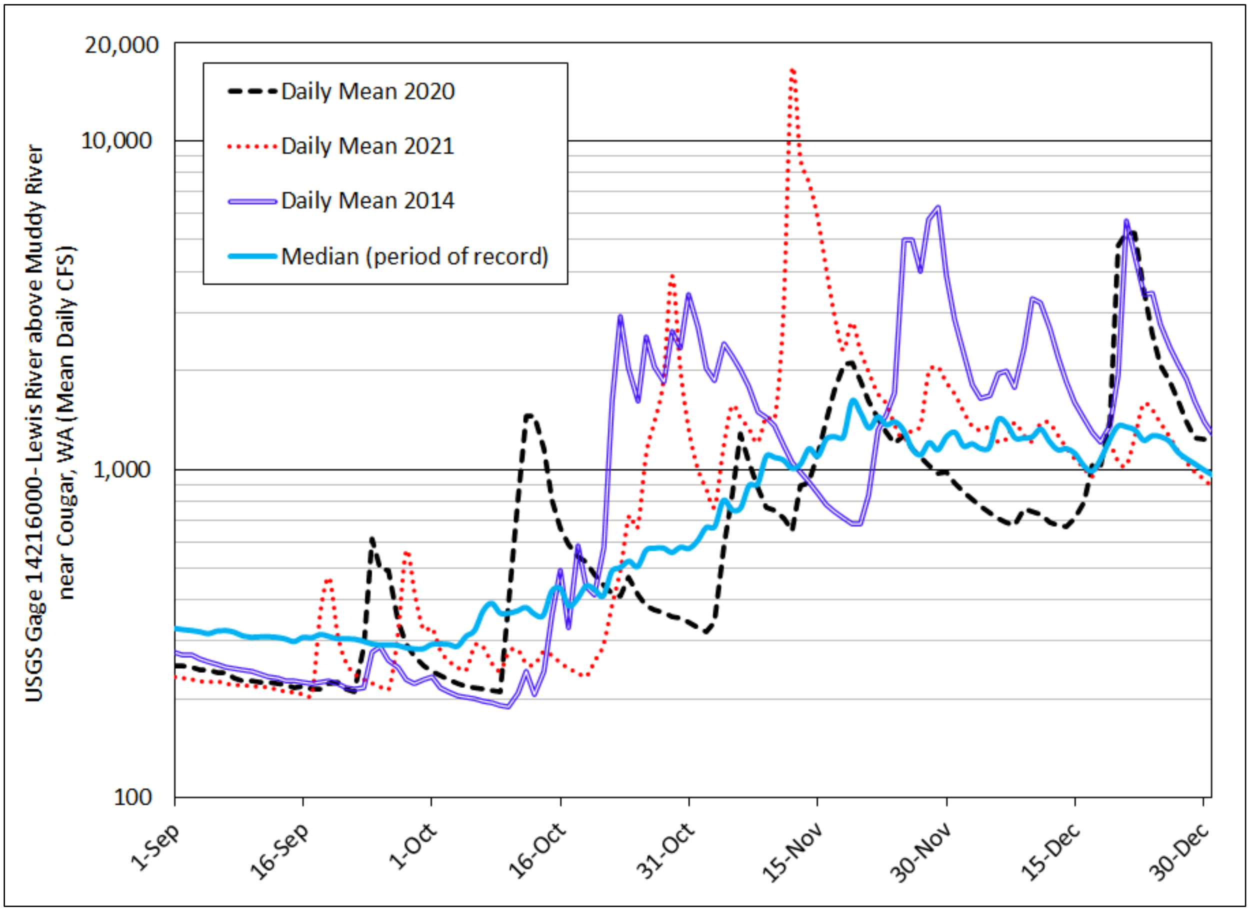


Figure 5. USGS North Fork Lewis River above Muddy River Gage mean daily flow (cfs) September through December (2021, 2020, and 2014).

Spawn Timing

Three new Chinook redds were observed on the first survey on September 2, 2021 in the mainstem Muddy River and 1 new redd was counted in the NF Lewis River mainstem downstream of the Muddy River confluence. By September 2, over 90% of the total number of Chinook had already been transported upstream of Swift Dam for the season (Figure 6).

The following week, 96 new redds were counted in the NF Lewis River mainstem, 18 in Clearwater Creek, 6 in Little Creek and 1 in Clear Creek. Total redds counted through the second week of September accounted for 52% of the total Chinook redds observed for the 2021 spawning season (Figure 6). The last new redd occupied by Chinook spawners was observed on October 8, 2021 in the NF Lewis River mainstem. Based on observations of Chinook spawners, occupied redds, and carcasses (Table 4), the spawn timing of Chinook was likely late-August to early-October during the 2021 survey season. The 2021 Chinook spawn timing is consist with 2018, which is the most recent year when a substantial number of Chinook were transported upstream of Swift Dam (2018 upstream transport = 177 females, 491 males, and 32 jacks) and when Chinook-specific spawning surveys occurred in September (Table 4). However, it appears that Chinook spawning in 2021 may have continued into October slightly longer than was observed in 2018 as the last occupied new redd in 2021 was observed 12 days later than in 2018 (Table 4).

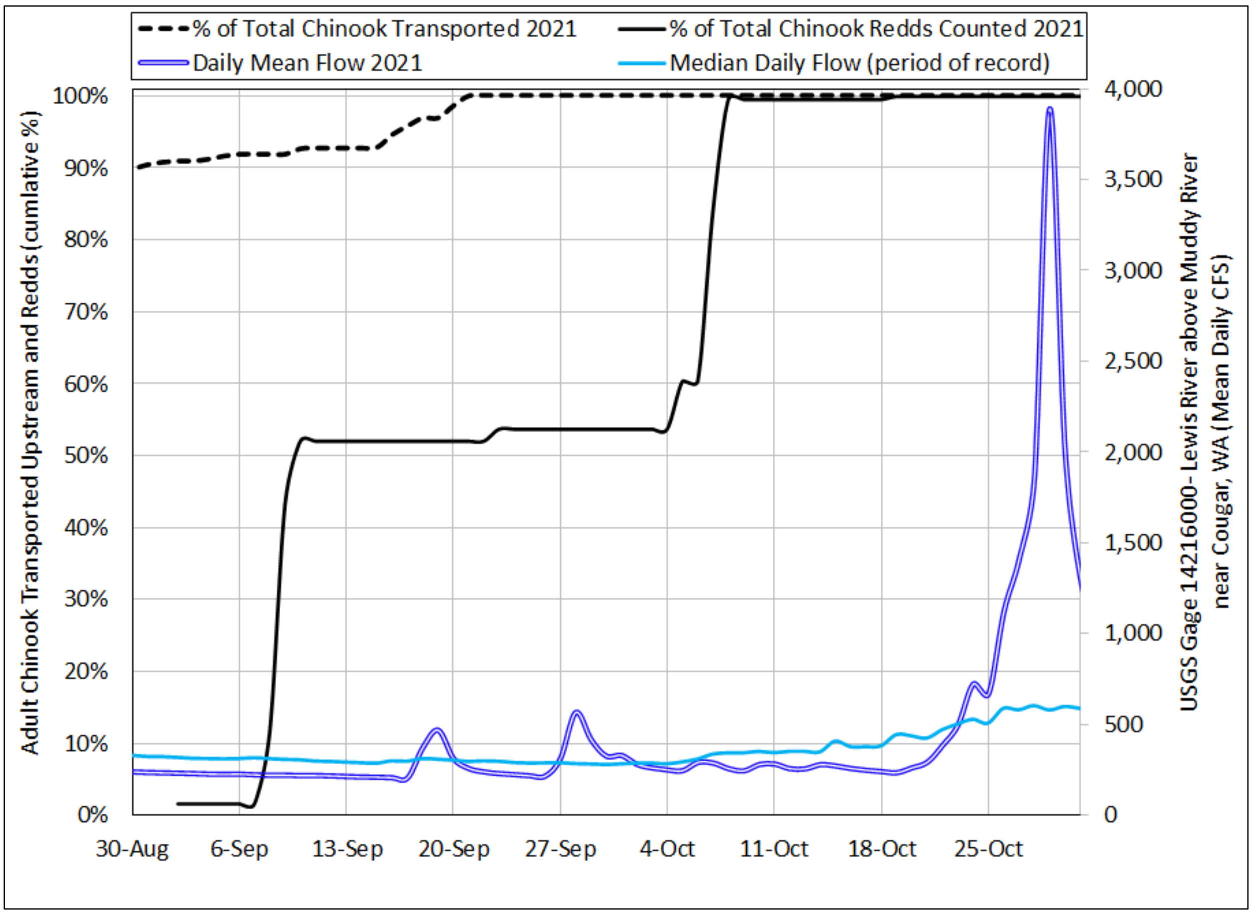


Figure 6. Chinook cumulative % redd count vs. cumulative % adult Chinook transported upstream vs flow (2021).

Table 4. Key spawn timing observations.

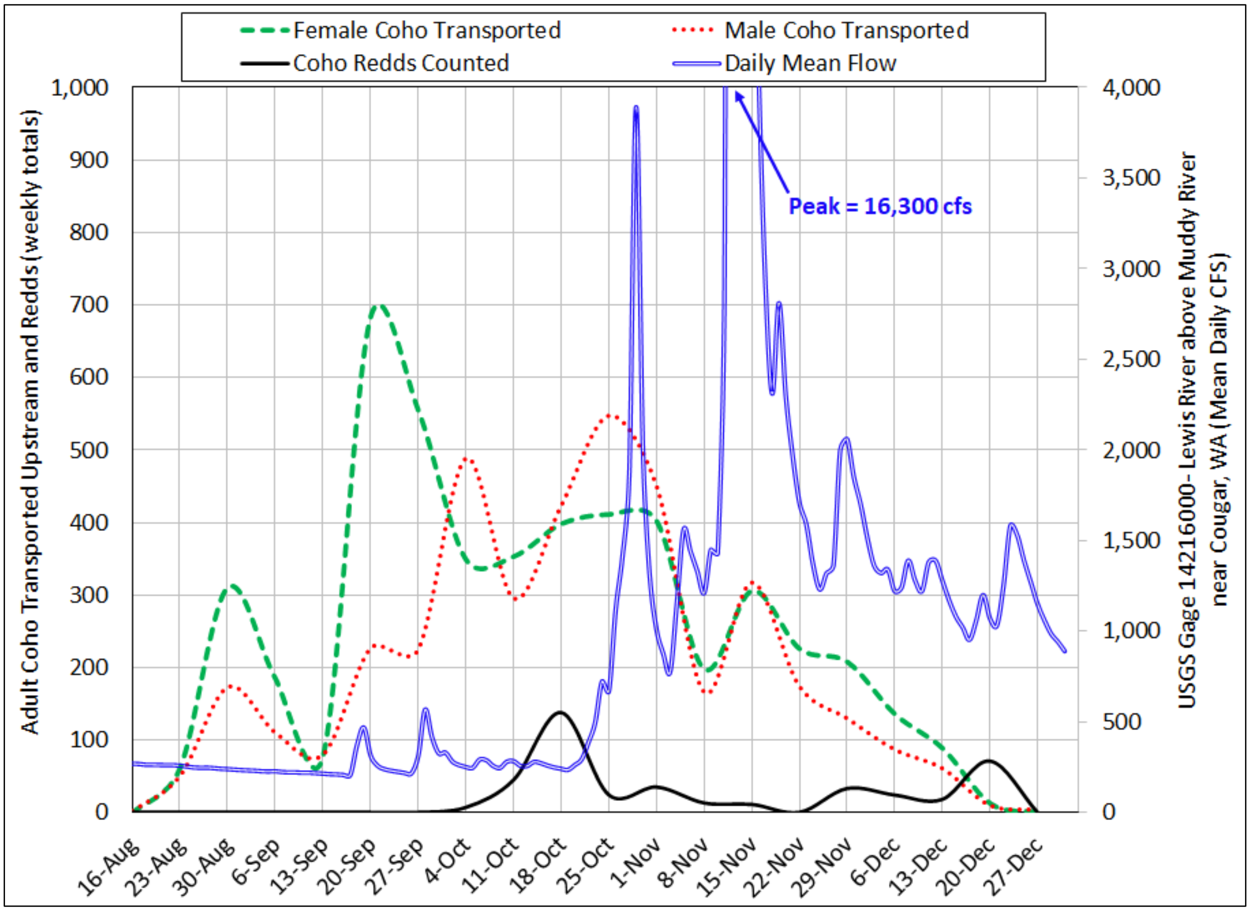
Timing Parameter	2021 Chinook	2018 Chinook	2021 Coho	2020 Coho
1st redd observed[1]	9/2/2021[2]	9/6/2018[2]	10/5/2021	10/1/2020
1st occupied redd observed	9/8/2021	9/7/2018	10/7/2021	10/8/2020
1st carcass observed	9/2/2021	9/7/2018	10/20/2021	10/15/2020
Last carcass observed	10/14/2021	10/4/2018	12/21/2021	12/20/2020
Last occupied new redd observed	10/8/2021	9/26/2018	12/21/2021[3]	12/29/2020[3]

[1]Note: First redd attributed to each species based on overall fish observations, distribution, and timing.
[2]Note: Date of first survey of the season.
[3]Note: Date of last survey of the season.

The first new Coho redds observed (3 total) with active Coho spawners present were counted in the NF Lewis River mainstem on October 7, 2021 (Table 4). The following week 38 new Coho redds were counted in Clear Creek, along with 3 in Clearwater Creek, and 4 in Smith Creek. The peak Coho redd count in October occurred the week of October 18, 2021 (Figure 7) when 138 new redds were counted: 97 in the NF Lewis River mainstem, 21 in the Muddy River mainstem, 13 in the Pine Creek mainstem, and 7 in Drift Creek. However, only about 50% of the total Coho had been transported upstream of Swift Dam by that time (Figure 2). By the end of September, 1,871 adult female Coho had been transported upstream, while only 868 adult males (excluding jacks) had been transported upstream (Figure 7). By the peak October redd count the week of October 18, many more male Coho had been transported upstream (2,074 total) compared to females (2,971 total), which likely contributed to the increase in Coho spawning activity once the sex ratio was more balanced (closer to 1 adult female per adult male).

Coho continued to be transported upstream at nearly an even rate after October (see Figure 2), but Coho spawning surveys were hindered due to high flows and turbidity in November and high flows, seasonally locked gates and snow accumulation in December as previously discussed. These conditions resulted in the overall low number of Coho redds counted after late-October, not the lack of actual spawning. Note that 43% of the total number of Coho were transported upstream after high flows began in late-October. The last Coho survey occurred on December 21, 2021 in Swift Reservoir tributaries and new occupied Coho redds were observed. After this date, heavy snow precluded access to all streams upstream of Swift Dam for the remainder of the Coho spawning season.

During 2021, 66% of the total adult Coho transported upstream were classified as early-Coho run type, and 86% were classified as early-Coho in 2020. The spawning surveys conducted in 2021 likely best represent the early-Coho spawn time due to the survey conditions latter that hindered surveys for late-Coho. Based on the observations of Coho spawners, carcasses, and redds, in 2021 early-Coho began spawning in early-October and likely continued somewhat into early-November, which is similar to that observed for early-Coho in 2020 (Table 4). Late-Coho continued spawning until the end of the survey season in both years (Table 4) and likely continued spawning in to January. The peak of early-Coho spawning was observed the week of October 18 in 2021 and the week of October 19 in 2020.



Note: Weekly males transprted upstream (red dotted line) does not include jacks.

Figure 7. Coho redd count vs. adult Coho transport timing vs. flow (2021).

Estimate of Total Redds and Proportion of Transported Females that Spawned

Due to the lack of surveyable conditions over the majority of the Coho spawning season, the total number of Coho redds and the proportion of transported Coho that spawned could not be reliably estimated. However, survey conditions during the spring Chinook spawning period were excellent over the entire spawning period. Therefore, Chinook redd counts were used to make estimates of total redds by watershed (Starcevich 2022). Total Chinook redds were estimated at 278 (bootstrap 95% confidence interval of 168 to 377).

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 1.21 (bootstrap 95% confidence interval of 0.73 to 1.64) as the proportion of transported female Chinook that spawned in 2021 (Starcevich 2022). Proportions of 1.0 (or greater) suggest that all transported females spawned (assuming 1 redd per female). Proportions substantial greater than 1.0 indicate that actual detection probabilities are higher than assumed and/or that female Chinook build more than 1 redd on average. It is also possible that some Chinook classified as jacks (small precocial males) during the upstream sorting and transport process, were actually mis-identified smaller females. It can be difficult to visually determine sex of small spring Chinook, particularly early in the run. It is also possible that some redds identified as Chinook redds may have actually been misidentified early-Coho redds.

Discussion and Conclusions

Redd counts and estimates of spawning success suggest that most (if not all) adult Chinook females transported upstream during 2021 spawned, similar to 2018 results. Similar to 2018, Chinook adults in 2021 appear to have distributed well within the Muddy River watershed and throughout the NF Lewis River mainstem. However, unusually low stream flows appear to have limited Chinook spawning use of smaller tributary streams in both years. 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 either year, when weekly surveys were conducted over the entire mainstem during the Chinook spawning season.

Although the total number of Coho redds and spawner success could not be reliably estimated due to poor survey conditions over the majority of the survey season, overall, Coho spawning was observed to be widely distributed throughout the accessible stream network upstream of Swift Dam in 2021. However, unusually low flows in the reservoir tributaries from September to late-October likely limited spawning habitat for early-Coho, which have been shown to widely use the reservoir tributaries for spawning in previous years. Once flows rose due to heavy rainstorms in late-October, many Coho were observed spawning in small tributaries throughout the accessible habitat (including the smaller reservoir tributaries).

Due to the inherently poor survey conditions typically observed since surveys started in 2012 during the majority of the Coho spawning season upstream of Swift Reservoir, future surveys will focus on quantifying the number of Coho that may spawn in the Swift Reservoir drawdown zone (PacifiCorp and Cowlitz PUD 2022). The drawdown zone is thought to be accessible and surveyable for the majority of the Coho spawning season. Drawdown zone spawning is generally considered as unsuccessful. Quantifying the proportion of drawdown zone spawners will then be used to estimate the proportion of successful spawners upstream of the drawdown zone (i.e., 1 – the proportion of drawdown zone spawners) as described in the newly revised Lewis River aquatic monitoring and evaluation plan (PacifiCorp and Cowlitz PUD 2022).

References

PacifiCorp and Cowlitz PUD. 2017. Aquatic monitoring and evaluation plan for the Lewis River – first revision, dated February 28, 2017. Prepared by PacifiCorp and Public Utility District No. 1 of Cowlitz County.

PacifiCorp and Cowlitz PUD. 2022. Aquatic monitoring and evaluation plan for the Lewis River – second revision, dated April 1, 2022. Prepared by PacifiCorp and Public Utility District No. 1 of Cowlitz County.

Starcevich, L.A. 2019. Redd Estimates from Surveys Conducted on the Upper North Fork Lewis River: 2018 – analysis report, dated February 19, 2019. Prepared for Meridian Environmental, Inc., prepared by Prepared by Leigh Ann Starcevich, PhD, Biometrician, West Inc., Environmental & Statistical Consultants, Corvallis, Oregon.

Starcevich, L.A. 2022. Redd Estimates from Surveys Conducted on the Upper North Fork Lewis River: 2021 – analysis report, dated April 26, 2022. Prepared for Meridian Environmental, Inc., prepared by Prepared by Leigh Ann Starcevich, PhD, Biometrician, West Inc., Environmental & Statistical Consultants, Corvallis, Oregon.