Lewis River Fish Passage Program
2022 Annual Report (Final)

Monitoring and Evaluation (M&E) Plan Metrics

FERC Project Nos. 935, 2071, 2111 and 2213

Coho Salmon out-migrants collected at the Swift Reservoir Floating Surface Collector.
Photo by Tyler McClure

PacifiCorp
&
Public Utility District No.1 of Cowlitz County

June 2023

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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
BY	Brood year
CE	Collection Efficiency
cfs	Cubic Feet Per Second
CI	Confidence interval
Cowlitz PUD	Public Utility District No. 1 of Cowlitz County
CS	Combined Survival Rate
CWT	Coded Wire 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
HPP	Habitat Preparation Plan
IPM	Integrated population model
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

[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.

R/S	Recruits per Spawner
SA	Settlement Agreement
SAR	Smolt-to-adult ratio
Services	National Marine Fisheries Service and U.S. Fish and Wildlife Service
SIA	Stable Isotope Analysis
Smolt	A juvenile salmon or trout that is ready to migrate out to the sea, and are in the process of physiological changes that allow them to survive a shift from freshwater to saltwater.
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
YOY	Young of year (salmon and trout fry)
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 2022. 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 2022. The following is a brief summary of relevant performance metrics documented in this report[3]:

Description	Ref. to Page	M&E Obj.	Performance Goal	2022 Estimate	Summary
Number of Juveniles Passing Eagle Cliff During Screw Trap Operations	Page 16	Obj. 7 Task 7.1	Monitoring	130,478 Coho 6,341 Chinook 5,138 Steelhead 1,067 Cutthroat 6,431 Trout Fry[4] 548 Bull Trout	Estimates of the total number of juvenile salmonids were made over a 21-week period using screw trap catch information. The trap was located at the head of Swift Reservoir at Eagle Cliff.

[2] The methods used in this report follow the revised methods for the M&E Plan dated April 1, 2022 (PacifiCorp and Cowlitz PUD 2022).

[3] Summary table only references M&E metrics relevant to the fish passage program and that are contained in this report. For a comprehensive summary of all M&E Plan objectives and associated metrics reported on in 2022, see the Aquatic Monitoring and Evaluation Program 2022 Annual Report.

[4] Unidentified trout fry, most likely Rainbow/Steelhead and/or Cutthroat Trout fry.

Description	Ref. to Page	M&E Obj.	Performance Goal	2022 Estimate	Summary
Numbers of Juveniles Entering Swift Reservoir	Page 17	Obj. 7 Task 7.2	Monitoring	Feasibility Study (Year One): RELEASED Swift FSC (Non-Naïve) Coho = 1,331 Steelhead = 200 Eagle Cliff (Naïve) Coho = 1,481 Steelhead = 216	A two-year feasibility study was initiated in 2022. The primary goal of this study is to evaluate whether there is a difference in recapture probability between naïve and non-naïve release groups by age/size classes. Information from this study will be used to develop methodologies for estimating the number of juveniles entering Swift Reservoir as well as aid in estimating Overall Downstream Survival (ODS). As part of the 2022 effort, juvenile Coho and Steelhead of similar size were captured at the Swift FSC and Eagle Cliff Screw Trap, PIT tagged, and released about 1 mile upstream of Swift Reservoir. A portion of these fish were recaptured in 2022 at the Swift FSC. Additional releases and further detection of these fish as they pass through the system will continue into 2023.
Number of Fish Collected at the Swift Floating Surface Collector (FSC)	Page 31	Obj. 6	Monitoring	64,694 Coho 2,534 Chinook 5,526 Steelhead 876 Cutthroat 16 Bull Trout 4,336 hatchery Rainbow Trout	A total 78,375 salmonids were captured by the Swift FSC in 2022. Of these fish, 72,684 were transported and released downstream of Merwin Dam.
Juvenile Migration Timing	Page 36	Obj. 8	Monitoring	Various	Overall, the run timing in 2022 was consistent with previous years with two general out-migration periods occurring; a larger one occurring during the spring and smaller one occurring during late-fall and winter. Approximately 84 percent of all fish collected in 2022 were caught between April 15 and July 1.

Description	Ref. to Page	M&E Obj.	Performance Goal	2022 Estimate	Summary
FSC Collection Efficiency (CE)	Page 51	Obj. 2	Juvenile Collection Efficiency ≥ 95%	Coho 62% Steelhead 48%	In 2022 CE was evaluated with acoustic transmitters. The 2022 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. No Chinook were tagged in 2022 due to low abundance.
Swift FSC Injury	Page 55	Obj. 5	Smolt and Fry ≤ 2%	COMBINED: Fry (0.0%) Smolt (1.3%) Adult (0.0%)	Annual injury rates for Chinook and Steelhead smolts were higher than the performance standard of 2.0% overall, but all other fish were lower. Observed injuries were largely attributed to heavy debris accumulation that occurred at the facility during early spring 2022. Parr were combined with smolt to derive estimates of injury for smolt.
Swift FSC Survival	Page 55	Obj. 4	Fry ≥ 98.0% Smolt ≥ 99.5% Bull trout = 99.5%	COMBINED: Fry (99.6%) Smolt (97.4%) Bull trout (100.0%)	The survival rate for salmonid fry (S_{COL}) met the 98% performance standard in 2022. However, despite improvements in smolt survival rates (CS) across all species in 2022, relative to 2021, the survival rate for smolts did not meet the performance standard of 99.5%. Heavy debris accumulation that occurred at the facility during early spring largely contributed to lower survival rates in 2022. Parr were combined with smolt to derive estimates of CS for smolt.

Description	Ref. to Page	M&E Obj.	Performance Goal	2022 Estimate	Summary
Overall Downstream Survival (ODS)	Page 62	Obj. 1	≥ 80%	Feasibility Study (Year One): <u>RELEASED</u> Swift FSC (Non-Naïve) Coho = 1,331 Steelhead = 200 Eagle Cliff (Naïve) Coho = 1,481 Steelhead = 216	A two-year feasibility study was initiated in 2022. The primary goal of this study is to evaluate whether there is a difference in recapture probability between naïve and non-naïve release groups by age/size classes. Information from this study will be used to develop methodologies for estimating the number of juveniles entering Swift Reservoir as well as aid in estimating Overall Downstream Survival (ODS). As part of the 2022 effort, juvenile Coho and Steelhead of similar size were captured at the Swift FSC and Eagle Cliff Screw Trap, PIT tagged, and released about 1 mile upstream of Swift Reservoir. A portion of these fish were recaptured in 2022 at the Swift FSC. Additional releases and further detection of these fish as they pass through the system will continue into 2023.
Number of Adult Fish Collected at the Merwin Fish Collection Facility	Page 69	Obj. 11	Monitoring	Various	A total 47,729 fish were captured at the Merwin Trap in 2022, which is more than any other year since the commissioning of the facility in 2014. A total of 594 winter Steelhead, 3,600 spring Chinook, 5,102 early Coho, 4,443 late Coho, and 102 Cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2022.
Adult Upstream Passage Survival (UPS)	Page 69	Obj. 9	≥ 99.50%	Coho (S) 99.7% Coho (N) 100% Chinook 100% Steelhead 100% Cutthroat 99.0%	Fourteen early (S) Coho and one Cutthroat mortalities were observed during the trap and haul process.

Description	Ref. to Page	M&E Obj.	Performance Goal	2022 Estimate	Summary
Adult Trap Efficiency (ATE)	Page 70	Obj. 10	≥ 98%	Not conducted in 2022	The ATE evaluation was not completed in 2022 as the facility lift and conveyance system is currently being redesigned. It is anticipated that modifications associated with redesign will be completed in summer of 2023. ATE studies will resume once the modifications have been completed.
Determine Spawner Abundance, Timing, and Distribution of Transported Adult Anadromous Fish	Page 71	Obj. 15	Monitoring	Total Chinook redd count = 911 (3 in Swift Reservoir Drawdown Zone), total Coho redd count in Swift Reservoir Drawdown Zone = 51	Chinook estimates suggest that most adult female Chinook transported upstream during 2022 spawned, and timing was consist with prior years (most Chinook spawn in September). Chinook spawning distribution was the largest ever observed, with spawning documented for the first time in the Pine Creek watershed and Rush Creek. A total of 51 Coho redds were counted in the Swift Reservoir drawdown zone, which suggests most Coho spawned in stream channels upstream of the reservoir drawdown zone. Steelhead redd surveys have been temporarily suspended per the M&E Plan.

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.

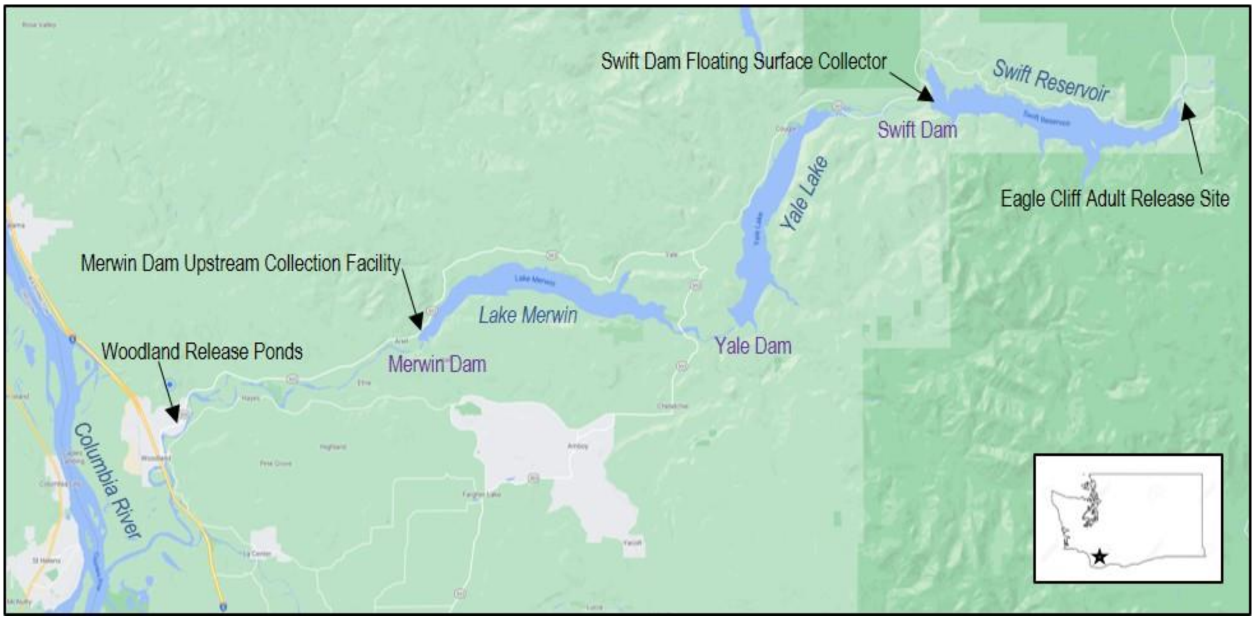

Figure 1.0-1. An overview of key features of the North Fork Lewis River Hydroelectric Project and key fish passage facilities and other infrastructure located in southwest Washington.

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 U.S. 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.

In response to these notices, on March 8, 2022, the Utilities provided a draft letter to the Services outlining a draft fish passage proposal for the Lewis River Hydroelectric Projects to resolve disputes under the Lewis River Settlement Agreement. On March 9, 2022, the Services responded to the Utilities draft fish passage proposal noting the Services support many aspects of the proposed passage framework and provided comments to help guide discussion to occur with the ACC.

In 2022, the PacifiCorp and the Cowlitz PUD provided quarterly updates on the progress of fish passage determinations with the FERC (March 31, 2022, June 30, 2022, September 30, 2022 and December 31, 2022). Key 2022 updates are further described in Section 3.2.25 of the Lewis River Hydroelectric Project 2022 Annual Report entitled SA Section 7.6 In Lieu Fund. Additional information on this decision can be found online 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 2022) 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). 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). In April 2022, the second revision of the M&E Plan was completed, and those methodologies were implemented that year (PacifiCorp and Cowlitz PUD 2022). The purpose of this report is to document results of the field assessments associated with implementation of the fish passage program in the existing M&E Plan during 2022.

Some noteworthy environmental conditions and procedural changes occurred, or continued to be implemented, in 2022, which are summarized below:

- *Minimum Flow Requirement Below Merwin Dam:* Inflows during 2022 allowed for minimum flow levels stipulated in the June 26, 2008 FERC licenses to be met. In general, annual flows below Merwin Dam were higher than the 20-year average (Figure 1.0-2). River flow as recorded at the Lewis River above Muddy River (Figure 1.0-3) were generally below average in the winter and early spring, above average in late-spring and summer and below average in the fall. The upper Lewis River gauge only has data available back to April 2006, hence the 16-year average metric. New annual data will be added to this average in futures years, eventually reaching the 20-year average metric.

- *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 decline precipitously, and collected fish also experience 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 2022. A detailed description of these changes can be found in the Lewis River Fish Passage Program Annual Report for 2015 (PacifiCorp 2015).

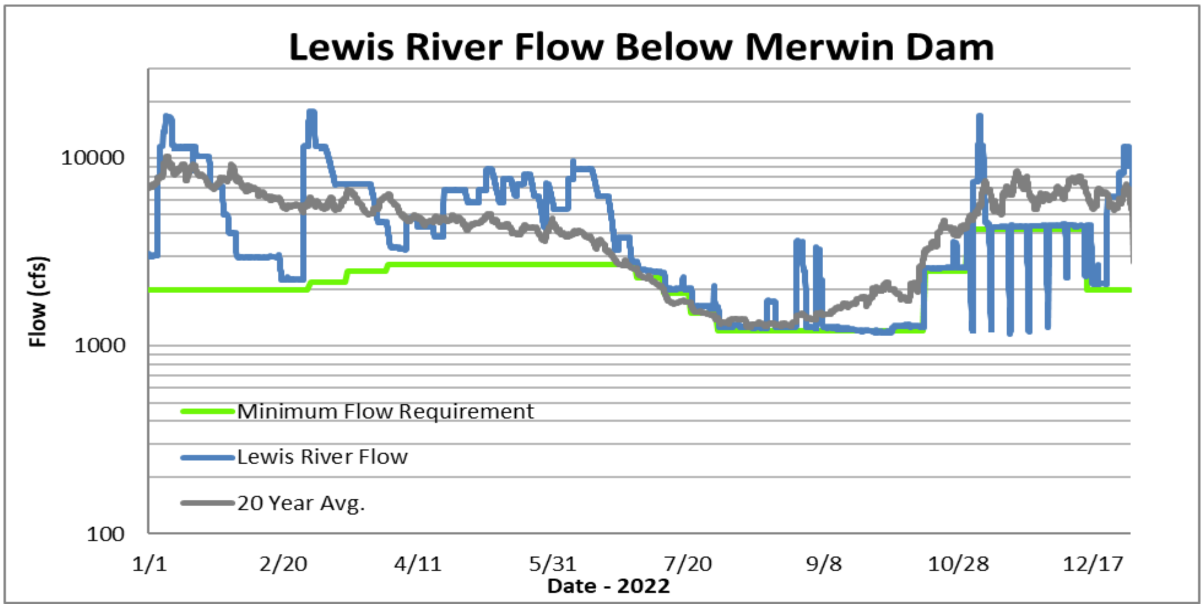

Figure 1.0-2. Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA), in 2022 and compared with the 20-year average.[5] Minimum flow requirements are also shown.

[5] 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.)

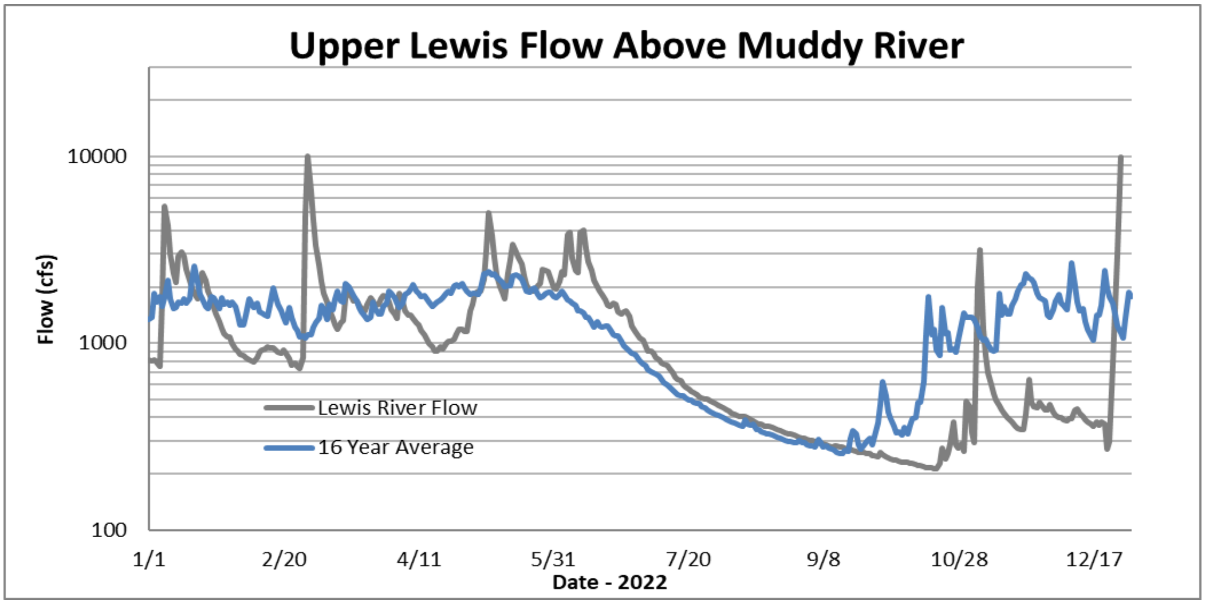

Figure 1.0-3. Lewis River flow above Muddy River as recorded by USGS Gauge (14216000 Lewis River Above Muddy River Near Cougar, WA) in 2022 compared to the 16 Year average flow.

- *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 2022.[6]

[6] 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 2022.

- *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[7] 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, 2018 and 2022 spawned widely across the available habitat (i.e., throughout the upper North Fork Lewis River and Muddy River watersheds[8]), 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 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 2022. 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

[7] 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 since 2012 are NOR.
[8] Spawning surveys of spring Chinook in 2022 presented in this report (see Section 4.4.2) further demonstrate Chinook distribute well throughout the available habitat upstream of Swift Dam. Spawning surveys conducted in 2022 resulted in the widest distribution of spring Chinook spawners observed to date. Chinook redds were observed in all streams with sufficient upstream passage flows. In addition, Chinook redds were observed in 2022 for the first time in the Pine Creek watershed and in Rush Creek.

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). From October 2022 through January 2023, the LCFEG placed carcasses throughout selected sites within the upper Lewis River basin and Cedar Creek, a tributary to the Lewis River below Merwin Dam. A detailed report summarizing the 2022 effort is provided in Appendix A.

- *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 2022 can be provided by WDFW upon request.

- *Upper Swift Reservoir Fish Surveys* – Beginning in the summer of 2020, annual surveys were conducted at the head of Swift Reservoir to document the presence of fish in isolated pools created in the drawdown zone. Surveys of the drawdown zone were continued in summer of 2022. A technical memorandum summarizing this effort is still being complied and will be submitted for ACC review in spring of 2023. The final technical memorandum along with ACC comments will be included as part of the 2023 reporting cycle.

- *Yale Habitat Preparation Plan (HPP)* – The transportation of adult hatchery fish into Yale Reservoir is intended to prepare and till Yale tributary stream gravels (through redd construction) and provide marine derived nutrient enhancement to spawning and rearing areas. Under Section 7.4 of the Settlement Agreement, the HPP should be develop and initiated 5-years prior to the expected completion of the Yale downstream fish passage facility. The ACC approved the 2022 Yale Habitat Preparation Plan in July 2022 and began releasing fish into Yale Reservoir in fall of that year. The plan stipulated that 1,800 adult Coho (early-Coho) were to be released at two sites (i.e., Saddle Dam and Yale Park boat launches) for six weeks beginning mid-September through mid-October. A copy of the Yale Habitat Preparation Plan implemented in 2022 is provided in Appendix B. Because of concern over potential interaction between adult Coho and Bull Trout spawning in Cougar Creek (a tributary to Yale Reservoir), additional monitoring activities were developed through consultation with the USFWS and outlined in the 2022 Bull Trout Annual Operating Plan. Results of the 2022 monitoring activities are provided in the Lewis River Bull Trout 2022 Annual Operations Report (PacifiCorp 2023).

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[9]. The artificial stream channel is

[9] 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.

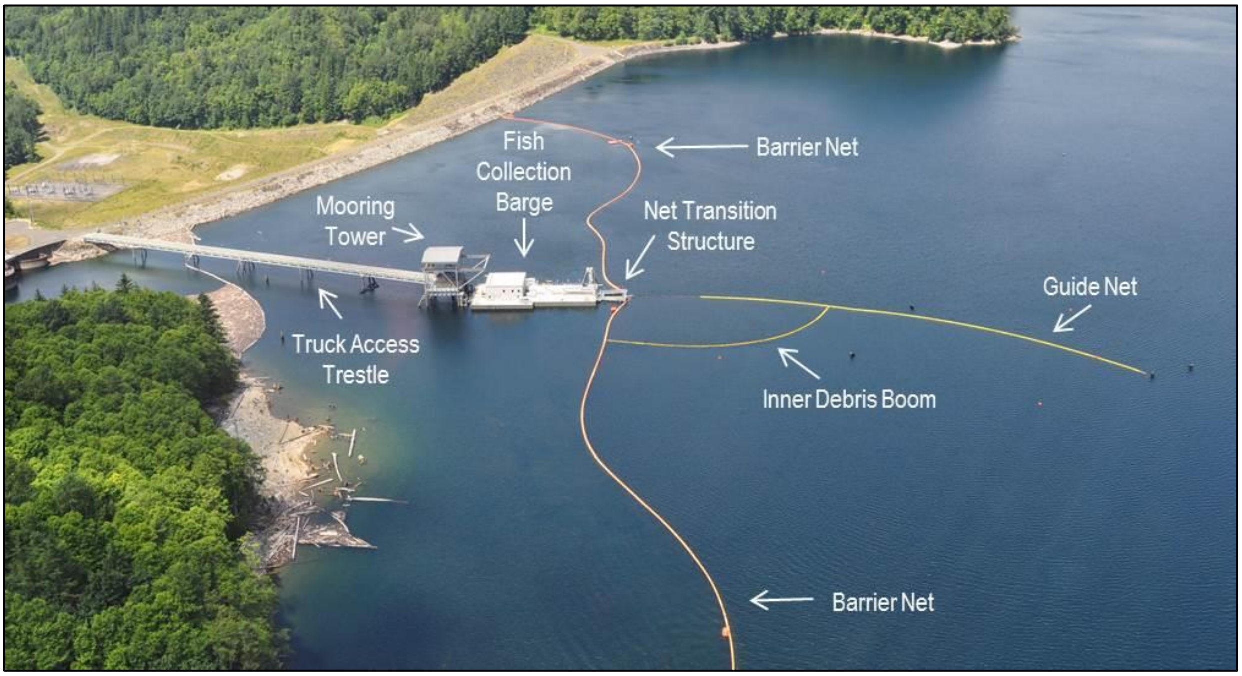

Figure 2.1-1. Aerial photo of the Swift Reservoir Floating Surface Collector layout.

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[10].

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.

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

In March 2016, a lead (guide) 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 ¼-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. A debris weir, which allows debris to pass behind the barrier net rather than through the FSC, has also been incorporated to help manage debris (Figure 2.1-2). PacifiCorp also actively manages debris on the reservoir by using containment and removal procedures. In July 2022, PacifiCorp procured a specialized debris removal vessel, specifically designed to skim woody debris and detritus from the surface of the reservoir before it can enter the FSC (Figure 2.1-3). 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/or high winds where the facility can still be overwhelmed by debris, which can cause unscheduled shutdowns and elevated fish mortality. The FSC operated 24-hours a day through 2022 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 2022.

Outage Duration	Reason For Outage
1/1/22 - 1/5/22	Snow loading
1/15/22 - 1/21/22	Communication issues with SAF pumps
3/16/22 - 3/17/22	Dive work in fish channel
7/19/22 - 10/21/22	Summer maintenance outage
12/1/22	Freezing temperatures/unsafe operating conditions
12/22/22 - 12/28/22	Freezing temperatures/unsafe operating conditions

Figure 2.1-2. The debris weir, located on the south side of the NTS, allows debris to bypass the FSC during periods of heavy debris loading.

Figure 2.1-3. The specialized debris boat that PacifiCorp purchased in 2022 is used to clear the forebay of debris before it can enter the Swift FSC.

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

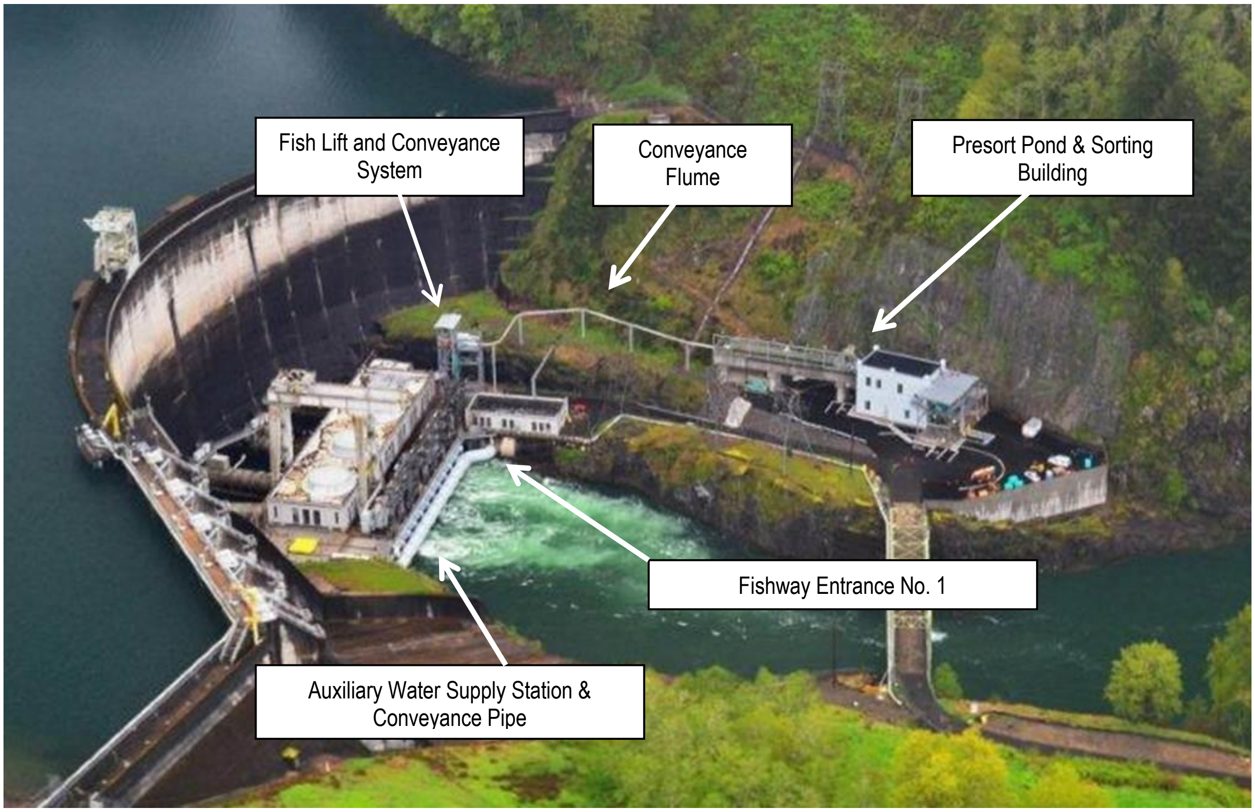

Figure 2.2-1. Merwin Dam Upstream Collection Facility.

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 the 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 2022 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).

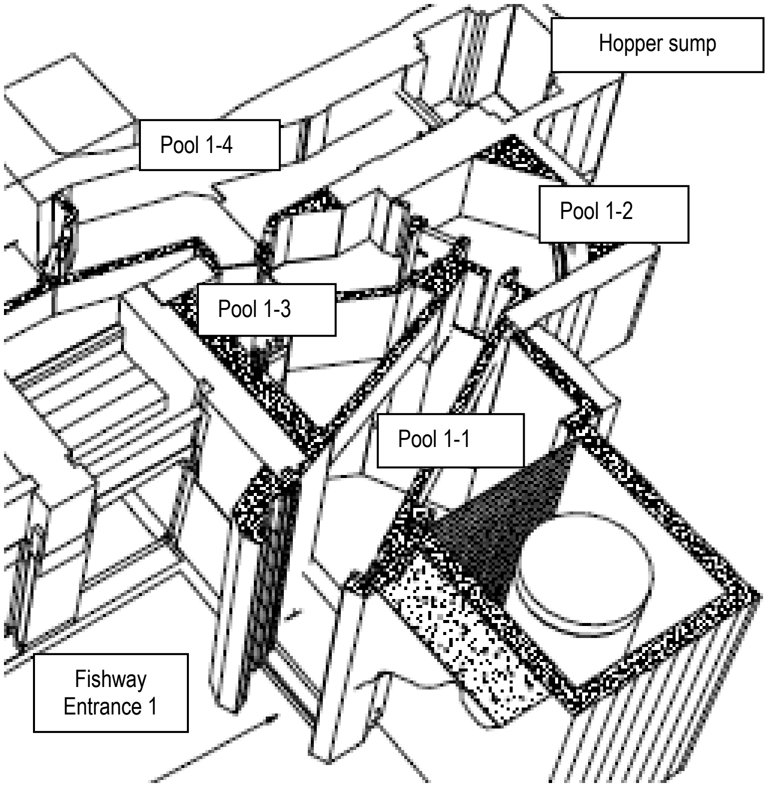

Figure 2.2-2. Merwin Dam fish ladder entrance and pool configuration.

Table 2.2-1. List of scheduled and unscheduled outages at the Merwin Fish Sorting Facility in 2022.

Outage Duration	Purpose for Outage
1/1/2022 - 1/4/22	Freezing temperatures/unsafe operating conditions
1/8/22 - 1/10/22	Spill at Merwin Dam
3/2/22 - 3/3/22	Spill at Merwin Dam
6/7/22 - 6/8/22	Scheduled quarterly maintenance
9/11/22	Defective limit switch on fish lift
12/6/22	Defective limit switch on conveyance system
12/13/22	Scheduled quarterly maintenance
12/22/22 - 12/26/22	Freezing temperatures/unsafe operating conditions

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 2022. 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 Road 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).

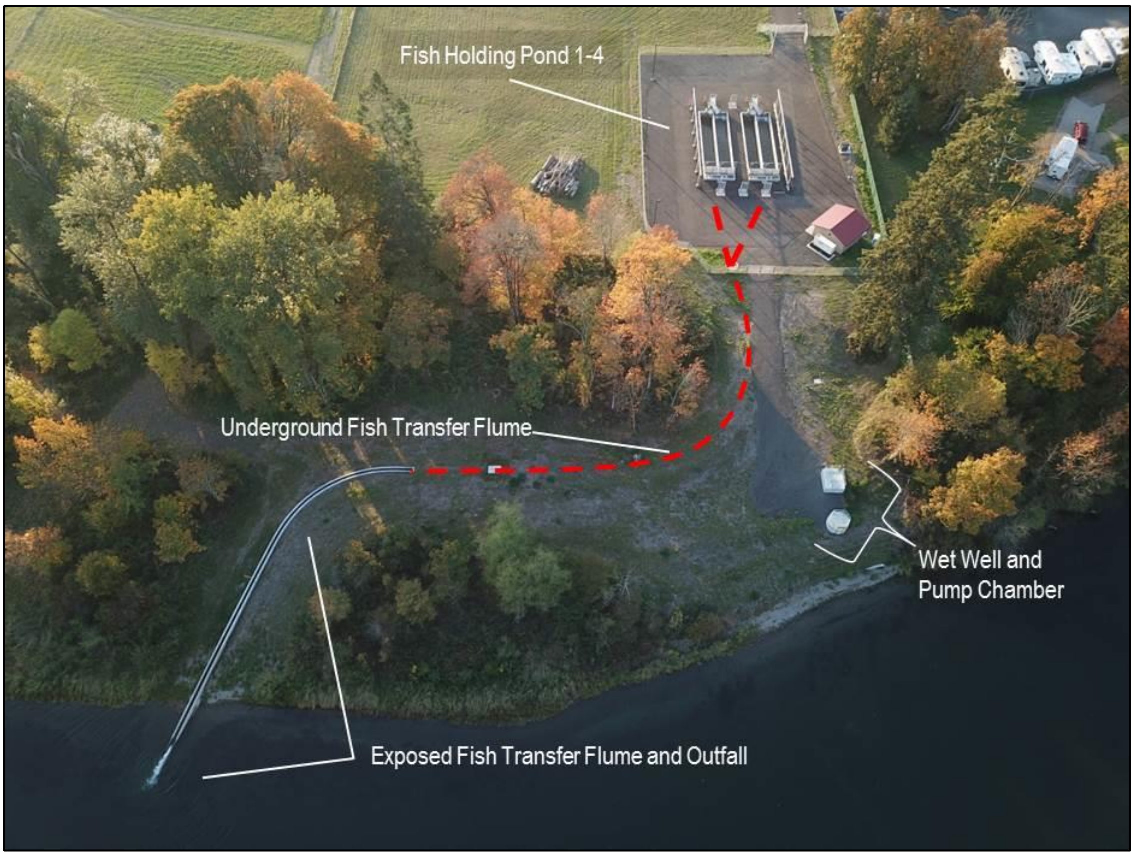

Figure 2.3-1. Aerial photo of the Woodland Release Ponds and associated infrastructure near Woodland, WA.

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 2022 M&E Plan addresses the issue of migration timing and abundance by recommending a two-year feasibility study to assess alternatives for increasing the number of PIT tag fish released at the head of Swift reservoir, which could lead to more accurate estimates of the total number of juvenile fish entering Swift Reservoir and overall downstream survival. Objective 7 was split into two separate tasks to effectively evaluate both metrics. This first task (Objective 7, Task 7.1) continues to estimate the timing and number of juveniles entering Swift Reservoir from the Upper North Fork Lewis River subbasin through traditional screw trapping operations near Eagle Cliff Park. However, operation of the screw trap would take place over a longer seasonal period (March through October) in order to characterize fish out-migration over a longer time frame, but also would presumably allow for more fish to be marked in order to better estimate fish abundance. The second task (Objective 7, Task 7.2) estimates the total number of juveniles entering Swift Reservoir. Fish captured at the Swift FSC would be PIT tagged and transported upstream and released at the head of Swift Reservoir to determine if there is no significant difference between recapture probability between the non-naïve test fish collected from the Swift FSC and those that are PIT tagged and released at the screw trap at Eagle Cliff Park (naïve fish). In addition to releasing PIT tagged fish from the Swift FSC at the head of Swift Reservoir, tributary sampling would be conducted to evaluate the efficacy of increasing the spatial distribution of tagged fish.

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:

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

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

Entire monitoring period variance:

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

95 percent Confidence Interval:

$$\hat{U} \pm 1.96\sqrt{V(\hat{U})}$$ **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

Following the M&E Plan, the two-year feasibility study to evaluate whether there is a difference in recapture probability between naïve and non-naïve release groups (i.e., fish captured at a screw trap operated at the head of Swift Reservoir at Eagle Cliff Park vs. at the Swift FSC) by size/age class was initiated in 2022. Additional information on the purpose of the feasibility study as well as a detailed outline of methodologies are discussed in Objectives 2 and 7 in the M&E Plan.

The general methods preformed during the 2022 effort included:

- A similar number and size of each target species were PIT tagged at the Swift FSC and at the Eagle Cliff Screw Park screw trap (as available).

- All salmonids captured ≥ 60mm in length were anesthetized, identified to species, measured to length, tagged with a 12mm PIT tag, and released upstream of the Eagle Cliff Park screw trap near the confluence of Pine Creek. Recaptures of fish at the Eagle Cliff Park screw trap were used to aid in estimating trap efficiency (discuss above for Objective 7, Task 7.2).

- All fish captured at the screw trap large enough to receive a PIT tag were tagged, Monthly tagging goals were established for fish collected at the Swift FSC based on the approximate number of fish needed for a sufficient sample size and to approximate in general the numbers of fish by size we general catch at the screw trap each year that are PIT taggable (Table 3.1-1).

- All PIT tag records, which included information on fish species, size at tagging, PIT tag ID, and timing and location of collection and release were imported into PITAGIS.

- The fixed antenna detection sites located at the Swift FSC and Woodland Release Ponds were used to track individual fish as they successfully passed downstream through the trap and haul system.

- Monthly collection efficiency evaluations were used as a control to establish a baseline of PIT antenna detection efficiency during operation of fish passage facilities.

Table 3.1-1. Monthly sample size targets for fish tagged at the Swift FSC and released at Pine Creek Confluence with NF Lewis River in 2022. Note: no Chinook were tagged at the Swift FSC due to the expected low numbers of taggable sized juveniles out-migrating in 2022.

Target Sample Size			
Month	**Length Frequency Target**	**Coho**	**Steelhead**
March	70-129mm	100	0
April	70-129mm	200	150
	150-199mm	0	50
May	70-129mm	500	150
	150-199mm	0	50
June	70-129mm	500	100
July	70-100mm	200	50
TOTAL		*1,500*	*550*

3.1.2 Results/Discussion

Objective 7 Task 7.1

A detailed technical memorandum describing the methods and results of the 2022 Eagle Cliff Park screw trap operations 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 25, 2022 to August 15, 2022, and checked the trap on a daily basis. It is important to note, that while the intent was operate the trap from March through October, the screw trapping field season was already underway by the time the current M&E Plan and work scope was approved. As it was, trap operation was extended into August until low flows precluded operation. The Eagle Cliff screw trap will be operated for a longer seasonal duration beginning in 2023.

Total maiden naturally produced salmonids caught at the Eagle Cliff trap included 4,173 Coho, 163 Chinook, 239 Steelhead, 49 Cutthroat, and 30 Bull Trout. In addition, 199 unidentified trout fry were caught and are likely either Rainbow/Steelhead or Cutthroat fry. A total of 4,338 Coho, 125 Chinook salmon, 425 Rainbow/Steelhead, 48 Cutthroat Trout, and 11 unidentified trout fry were marked and released upstream of the trap to estimate trap efficiency via mark-recapture, which also includes maiden fish captured at the screw trap and FSC that were marked and released upstream of the trap. 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, fin clip, 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 pooled weekly basis (Table 3.1-2). If not enough recapture data was available efficiencies were adjusted based on river flow and cone RPMs observed during for the applicable pooled time period.

Overall, out-migrating salmonids collected at the screw trap ranged in size from less than 25 mm to slightly greater than 300 mm in length (Figures 3.1-1 and 3.1-2). The majority of juvenile Coho (76 percent) and Chinook (91 percent) were less than 80 mm FL. For Steelhead/Rainbow, 55 percent were less than 150 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 (Figure 3.1-3 and 3.1-4); see Appendix B for further detail.

The data suggests that during the 2022 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. Subyearling Chinook passed the trap in April and June. Steelhead/Rainbow, Cutthroat, and Bull Trout passed the trap over a more protracted period, but mostly in April and May, though unidentified trout fry were captured in July and August after emergence began (Figures 3.1-5 through 3.1-8).

In total, 130,478 Coho, 6,341 naturally produced Chinook, 5,138 Rainbow/Steelhead,1,067 Cutthroat 6,431 unidentified trout fry, and 548 Bull Trout were estimated to have passed the trap during the monitoring period (March 25 to August 15, 2022) using the Bootstrap Method (Table 3.1-3). The majority of Coho (88 percent) and Chinook (99 percent), estimated to pass the trap were of the subyearling 0+ age class. The majority of Steelhead/Rainbow (60 percent) and Cutthroat (64 percent) passing the trap were of the 1+ year age class. These estimates should only be viewed as an index of the total fish that entered Swift Reservoir during the trapping period (~late-March through August) and not total species out-migration abundance for the year as the Eagle Cliff screw trap does not collect fish from other tributaries that enter the reservoir, such as Swift, Drift, and Range creeks.

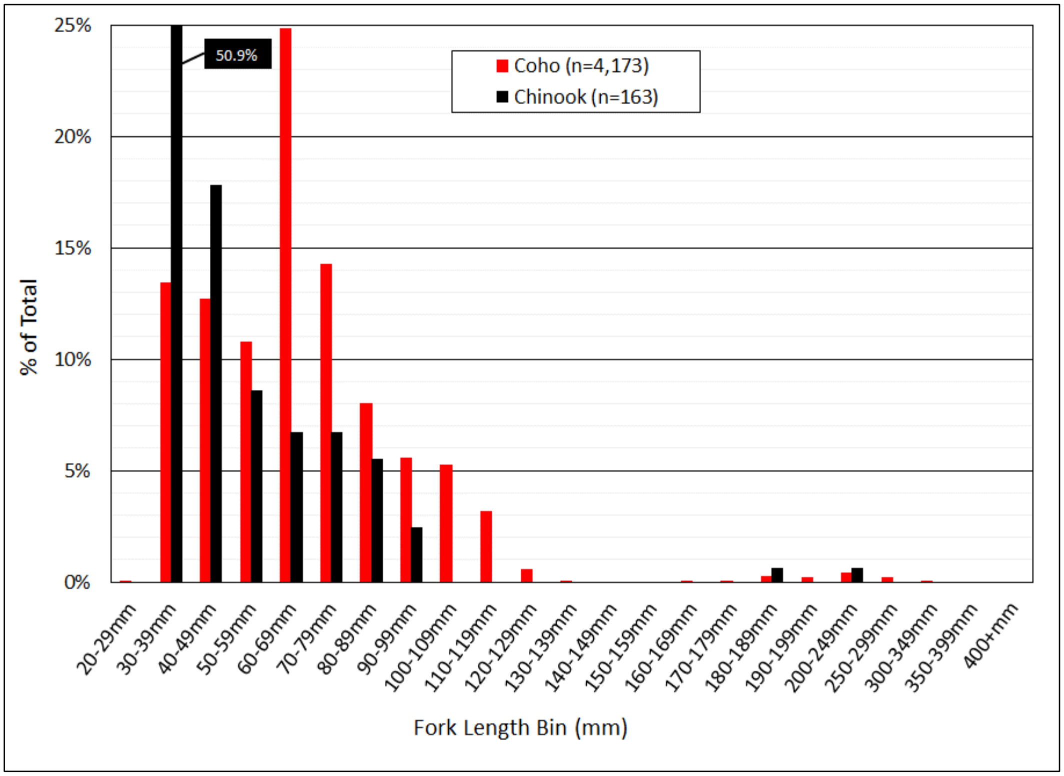

Figure 3.1-1. Length frequency distribution of juvenile salmon, 2022.

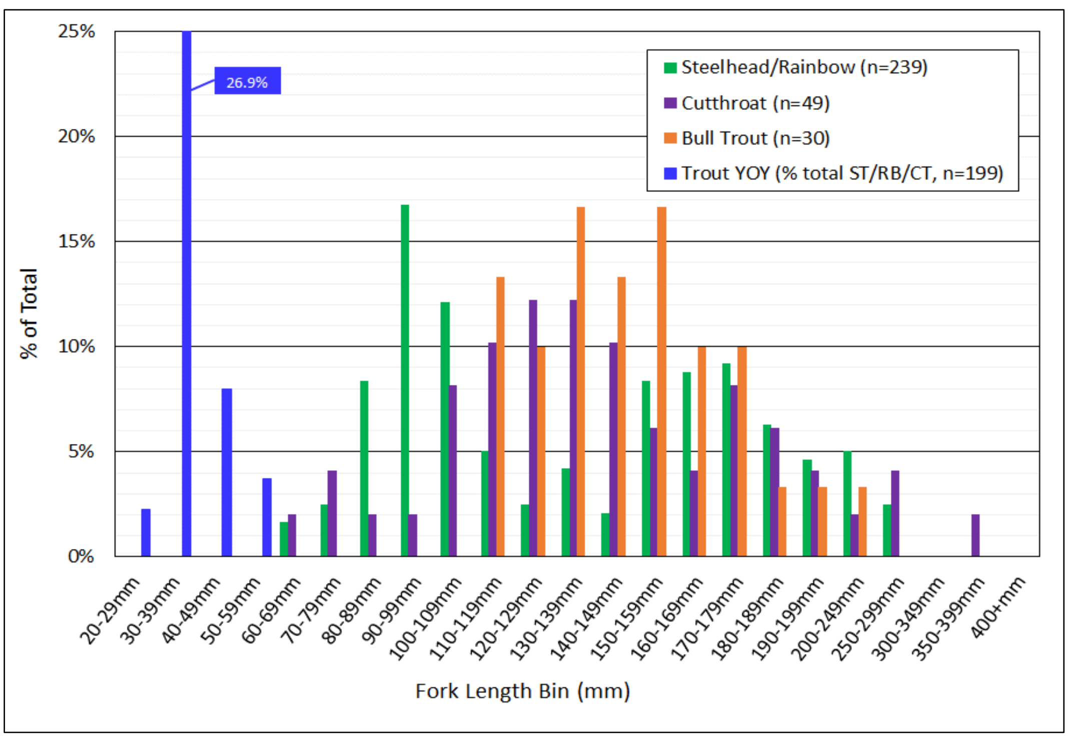

Figure 3.1-2. Length frequency distribution of naturally produced trout/char, 2022.

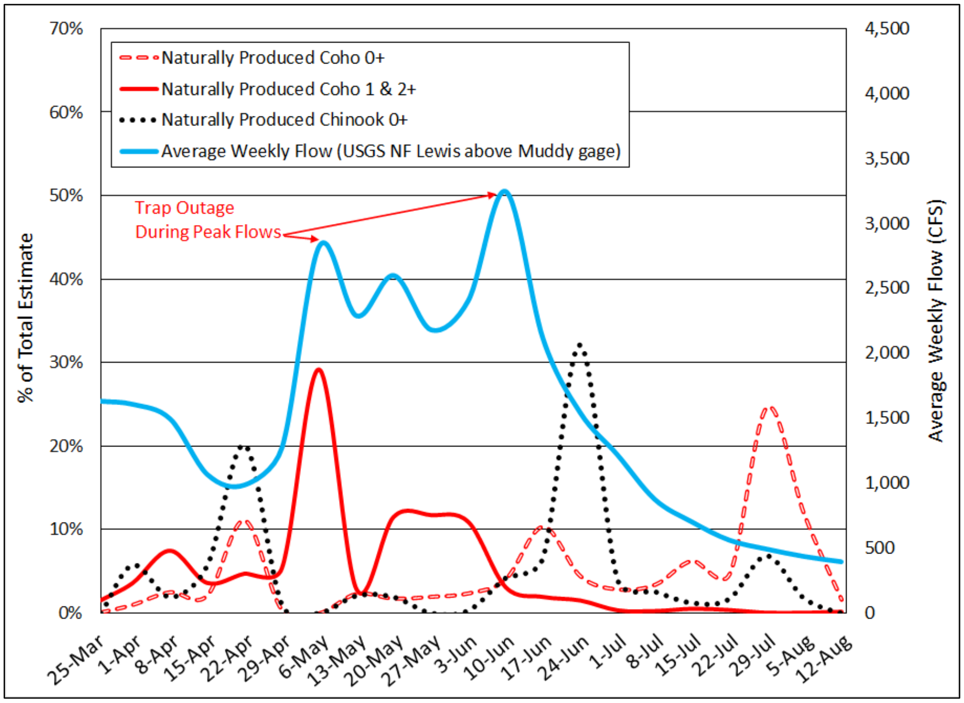

Figure 3.1-3. Percent of estimated total salmon species passing the trap by inferred age class in 2022.

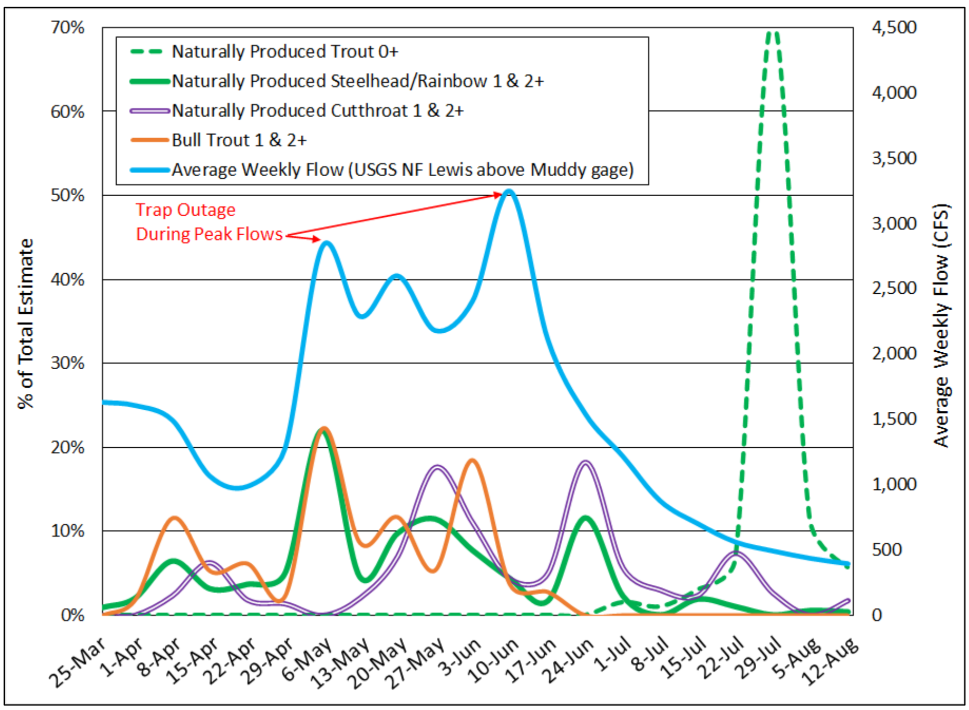

Figure 3.1-4. Percent of estimated total trout/char species passing the trap by inferred age class in 2022.

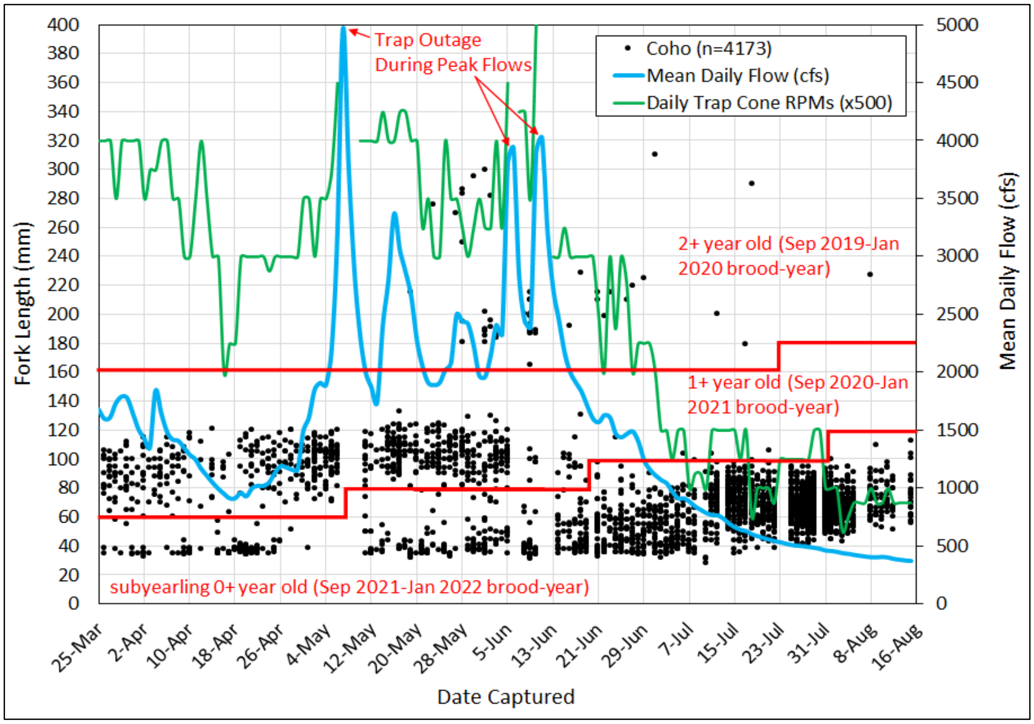

Figure 3.1-5. Naturally produced Coho migration timing, 2022.

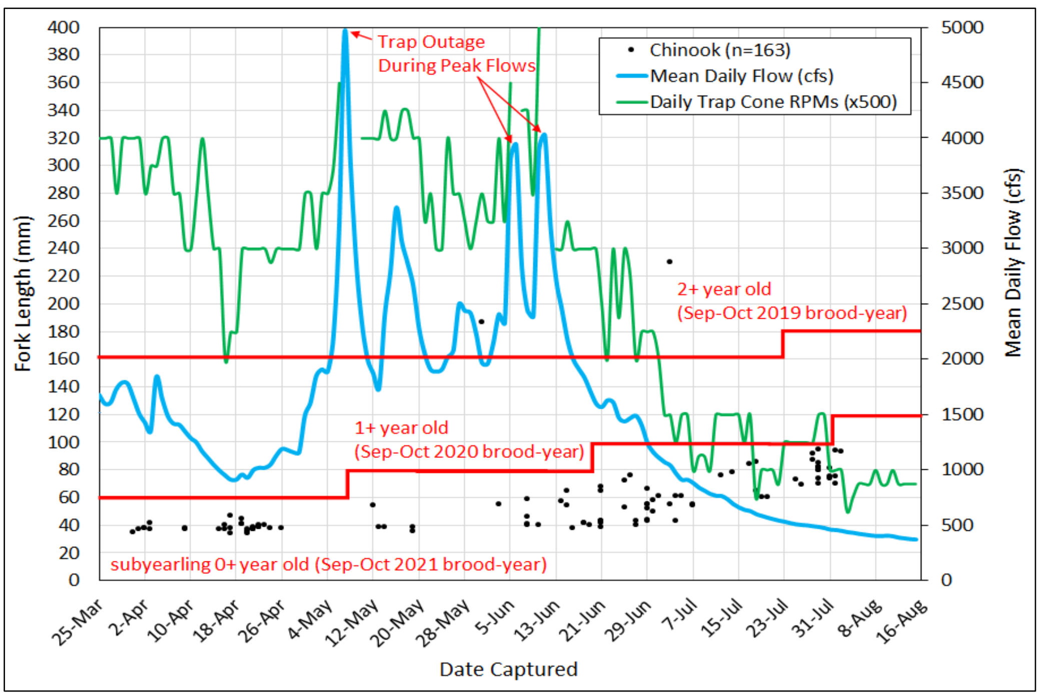

Figure 3.1-6. Naturally produced Chinook migration timing, 2022.

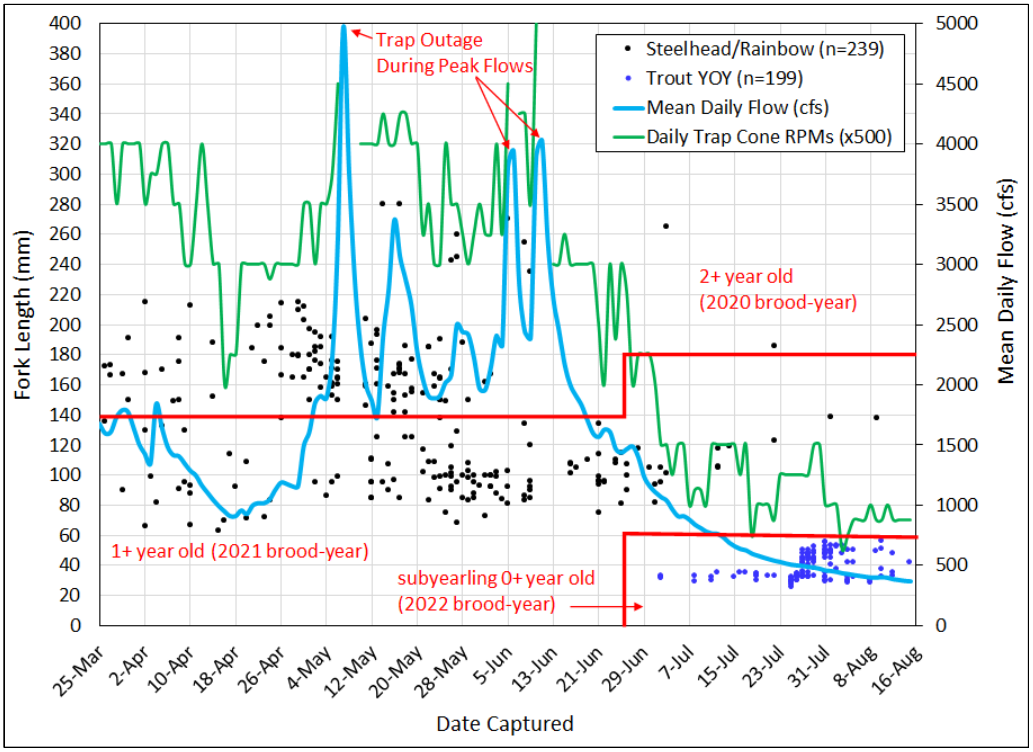

Figure 3.1-7. Naturally produced trout/char migration timing, 2022.

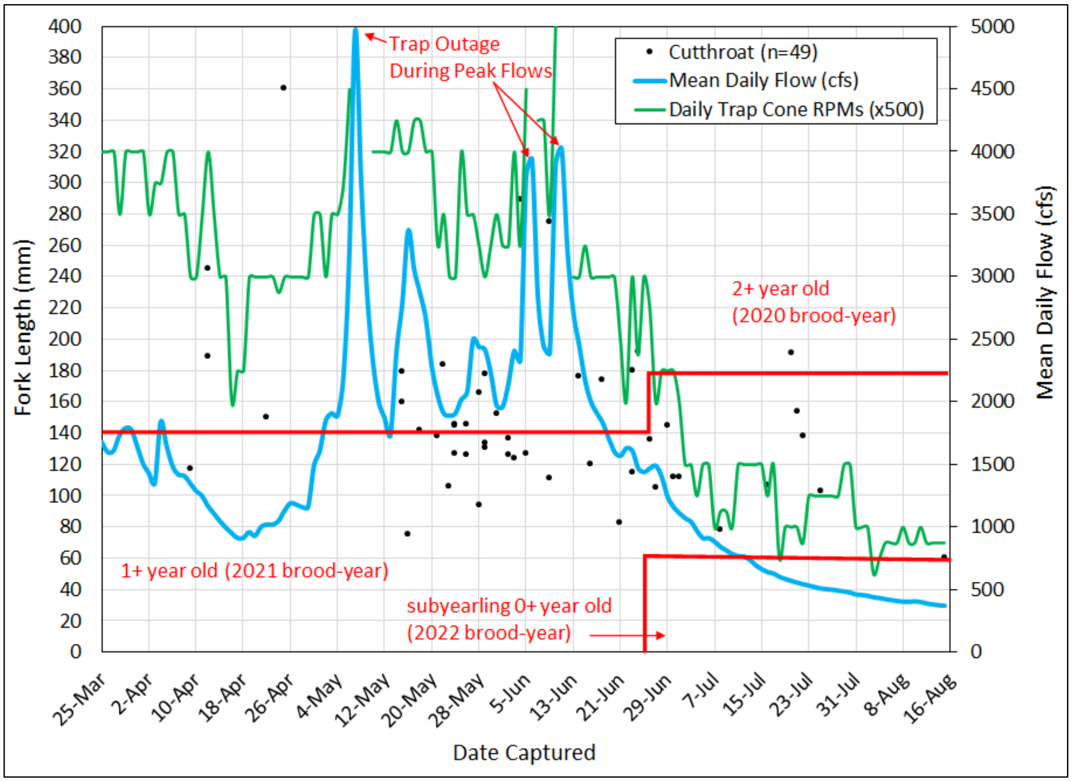

Figure 3.1-8. Naturally produced Cutthroat migration timing, 2022.

Table 3.1-2. Summary of mark-recapture tests of trap efficiency for the Eagle Cliff screw trap, 2022.

North Fork Lewis River above Swift Dam – 2022			All Coho, Chinook, Steelhead, and Cutthroat Combined								Ave. Weekly Cone RPMs[a]	Ave. Weekly Flow (cfs)[b]	Adjusted Efficiency	
			Maiden		Mark-Release Up		Recapture		Efficiency					
Period	Start	End	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm			<50mm	≥50mm
2	25-Mar	27-Mar	2	24		0					8.0	1,630	0.0152[f]	0.0769[d]
3	28-Mar	3-Apr	26	59		156		12		0.0769	7.6	1,606	0.0152[f]	0.0769[c]
4	4-Apr	10-Apr	53	63		109		4		0.0367	7.1	1,493	0.0152[f]	0.0367[c]
5	11-Apr	17-Apr	48	25	1	37		1		0.0270	6.1	1,063	0.0152[f]	0.0270[c]
6	18-Apr	24-Apr	246	50	106	65	1	3	0.0094	0.0462	5.8	984	0.0152[f]	0.0462[c]
7	25-Apr	1-May	10	77		147		9		0.0612	6.3	1,274	0.0152[f]	0.0612[c]
8	2-May	8-May		123		157		3		0.0191	5.2	2,826	0.0152[f]	0.0191[c]
9	9-May	15-May	48	73		182		15		0.0824	6.9	2,289	0.0152[f]	0.0824[c]
10	16-May	22-May	37	132		454		22		0.0485	7.8	2,600	0.0152[f]	0.0485[c]
11	23-May	29-May	39	160		340		18		0.0529	6.6	2,180	0.0152[f]	0.0529[c]
12	30-May	5-Jun	43	133		264		16		0.0606	7.1	2,409	0.0152[f]	0.0460[e]
13	6-Jun	12-Jun	85	38	42	214		6		0.0280	4.9	3,249	0.0152[f]	0.0390[e]
14	13-Jun	19-Jun	207	57	139	196	1	10	0.0072	0.0510	6.1	2,113	0.0152[f]	0.0510[c]
15	20-Jun	26-Jun	144	99	67	258	1	6	0.0149	0.0233	5.3	1,541	0.0287[g]	0.0233[c]
16	27-Jun	3-Jul	77	105	1	101		6		0.0594	3.9	1,216	0.0287[g]	0.0594[c]
17	4-Jul	10-Jul	67	71		71		2		0.0282	2.4	872	0.0287[g]	0.0282[c]
18	11-Jul	17-Jul	28	283	1	279		10		0.0358	2.9	698	0.0287[g]	0.0358[c]
19	18-Jul	24-Jul	30	205		204		7		0.0343	2.0	558	0.0287[g]	0.0343[c]
20	25-Jul	31-Jul	160	1038		814		26		0.0319	2.6	489	0.0287[g]	0.0319[c]
21	1-Aug	7-Aug	26	513		459		15		0.0327	1.7	432	0.0287[g]	0.0327[c]
22	8-Aug	15-Aug	10	109		83		4		0.0482	1.8	391	0.0287[g]	0.0482[c]
Total			*1,386*	*3,437*	*357*	*4,590*	*3*	*196*	*0.0084*	*0.0427*				

[a] Weekly average cone RPMs.
[b] Lewis River above Muddy River (USGS Gage 14216000).
[c] No adjustment to weekly mark-recapture efficiency estimate.
[d] Same as week 3 due to similar stream flow and cone RPMs.
[e] Combined efficiency with following week (trap off for part of period due to high water).
[f] Combined efficiency for weeks 1 to 14 for all salmonids <60mm FL applied to increase sample size (5 recapture of 328 marked-released upstream).
[g] Combined efficiency for weeks 15 to 22 for all salmonids <60mm FL applied to increase sample size (14 recapture of 487 marked-released upstream).

Table 3.1-3. Estimates of total naturally produced salmonids passing the Eagle Cliff trap (2022) by species and age class.

Species (Inferred age Class)	Cohort/Brood-Year	Bootstrap Method Mean Estimate (95% CI) (CV%)	Volkhardt Method Estimate (95% CI) (CV%)
Coho (subyearling 0+ YOY)	Sep 21-Jan 22	115,216 (+/- 28,347) (13%)	115,584 (+/- 35,597) (16%)
Coho (1+ year old)	Sep 20-Jan 21	14,513 (+/- 3,115) (11%)	13,021 (+/- 3,497) (14%)
Coho (2+ year old)	Sep 19-Jan 20	749 (+/- 445) (30%)	467 (+/- 265) (29%)
Total Coho Estimate		**130,478 (+/- 28,521) (11%)**	**129,072 (+/- 35,769) (14%)**
Chinook (subyearling 0+ YOY)	2021	6,318 (+/- 2,545) (21%)	6,946 (+/- 4043) (30%)
Chinook (1+ year old)	2020	0	0
Chinook (2+ year old)	2019	23 (+/- 37) (82%)	37 (+/- 52) (71%)
Total Chinook Estimate		**6,341 (+/- 2,546) (20%)**	**6,983 (+/- 4,043) (30%)**
Steelhead/Rainbow (1+ year old)	2021	3,095 (+/- 741) (12%)	2,725 (+/- 842) (16%)
Steelhead/Rainbow (2+ year old)	2020	2,043 (+/- 837) (21%)	1,827 (+/- 886) (25%)
Total Steelhead Estimate		**5,138 (+/- 1,118) (11%)**	**4,552 (+/- 1,222) (14%)**
Cutthroat (1+ year old)	2021	681 (+/- 272) (20%)	609 (+/- 261) (22%)
Cutthroat (2+ year old)	2020	386 (+/- 213) (28%)	342 (+/- 184) (27%)
Total Cutthroat Estimate		**1,067 (+/- 346) (17%)**	**951 (+/- 319) (17%)**
Trout YOY (subyearling 0+)		6,431 (+/- 4,767) (38%)	5,652 (+/- 3,131) (28%)
Total Trout YOY Estimate		**6,431 (+/- 4,767) (38%)**	**5,652 (+/- 3,131) (28%)**
Bull Trout (subyearling 0+)	2021	0	0
Bull Trout (1+ year old)	2020	272 (+/- 160) (30%)	263 (+/- 158) (31%)
Bull Trout (2+ year old)	2019	276 (+/- 166) (31%)	247 (+/- 159) (33%)
Total Bull Trout Estimate		**548 (+/- 231) (21%)**	**510 (+/- 224) (22%)**

Shown below in Table 3.1-4 is a comparison of migration estimates for fish passing Eagle Cliff based on seasonal screw trapping (similar to that described above) from 2018-2022. 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. It is important to note that the largest number of adult spring Chinook transported to the upper basin prior to 2022 was in 2021 when 893 adults were transported upstream, which likely explains the dramatic increase in Chinook young of the year (YOY) collected. Relatively high out-migration numbers occurred in 2019, when adult transport numbers were relatively high the previous year.

Table 3.1-4. A summary of screw trap Bootstrap Method estimates for each species from 2018-2022.

Year	Trap Operation Period	Coho		Chinook		Steelhead		Cutthroat	
		Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
2018	3/13 to 6/30	50,839	±9,870	2,676	±771	3,195	±767	1,365	±385
2019	3/5 to 7/19	144,514	±29,318	14,414	±3,557	4,855	±1,168	1,050	±348
2020	3/9 to 7/15	69,714	±14,152	539	±227	4,745	±1,505	1,047	±429
2021	3/23 to 7/30	97,716	±19,485	1,451	±526	13,505	±3,637	3,170	±1,241
2022	3/25 to 8/15	130,478	±28,521	6,341	±2,546	5,138	±1,118	1,067	±346

Objective 7 Task 7.2

Tagging of juvenile salmonids at the Swift FSC as part of the two-year feasibility study began in March and coincided with beginning operation of the Eagle Cliff Park screw trap. The 2022 effort focused on juvenile Coho and to the extent possible, juvenile Steelhead. No juvenile Chinook were targeted at the Swift FSC due to low anticipated numbers of taggable out-migrates in 2022. Weekly releases upstream occurred until the Swift FSC was turned off for summer maintenance in mid-July. In total 1,331 juvenile Coho and 200 Steelhead were tagged at the Swift FSC compared to 1,481 Coho and 216 juvenile Steelhead tagged at the screw trap in 2022 (Table 3.1-5).

A summary of the recapture data collected at the Swift FSC to date revealed that a number of the study fish that had been released as part of the first year of tagging, were already detected successfully passing the Swift FSC in spring 2022 (Table 3.7-1). Of the 2,812 Coho and 416 Steelhead tagged in 2022, approximately 22 percent (n=627) of the Coho and 21 percent of the Steelhead had been collected by the mid-July when the Swift FSC was turned off for summer maintenance. Initial comparison of length data for Coho and Steelhead of sufficient size to PIT tag (i.e., at least 69 mm FL) show that so far PIT taggable Coho and Steelhead are generally larger at the Swift FSC compared to the Eagle Cliff screw trap. Coho less than 80 mm FL and Steelhead less than 150 mm FL make up a substantial portion of PIT taggable fish at the screw trap, but are nearly absent at the Swift FSC (Tables 3.1-6 to 3.1-12).

The second year of the feasibility study will be completed in 2023, which will include additional fish being PIT tagged at the Swift FSC and Eagle Cliff screw trap and released upstream. Because it is anticipated that fish tagged during both years may be recaptured up to two years after release, it is expected that the final report summarizing the two-year feasibility study will be completed in in 2024. Detailed statistical analysis will be conducted and presented at that time. The full dataset will be use to evaluate whether a difference in recapture probability between naïve and non-naïve release groups by size/age class exists, and ultimately whether fish tagged at the Swift FSC can be used solely to estimate the abundance of fish entering the reservoir annually and to calculate ODS, or if other methodologies are needed to collect and tag fish before they reach the reservoir (e.g., electrofishing in the tributary streams).

Table 3.1-5. Total Fish PIT tagged and recaptured in 2022.

Tagging Location	No. Marks Released		No. Marks Recaptured (at FSC)		Percent Recaptured (as of July, 2022)	
	Coho	Steelhead	Coho	Steelhead	Coho	Steelhead
FSC (Non-naïve)	1,331	200	381	58	28.6	29.0
Screw Trap (Naïve)	1,481	216	246	31	16.6	14.4
TOTAL	***2,812***	***416***	***627***	***89***	***22.3***	***21.4***

Table 3.1-6. Number of Coho tagged by size and week at Swift floating service collector and released at Pine Creek.

Capture Type	Marked at Swift FSC and Released Upstream																			
Species	Coho																			
Week Start	3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8
Week End	3/27	4/3	4/10	4/17	4/24	5/1	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24	7/31	8/7	8/14
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm		3	3		1																
80-89mm		10	7	2																	
90-99mm		23	8	1			3	2	4	1	2										
100-109mm		26	11	1		3	2	3	25	11	11	5	3	1							
110-119mm		21	7	2		5	10	15	58	33	35	28	29	1							
120-129mm		16	12	5	2	8	14	30	89	52	50	65	42	13							
130-139mm						3	4	15	67	58	34	49	42	43							
140-149mm						2	3	8	14	18	6	15	19	58							
150-159mm							5			4		5	1	29							
160-169mm														14							
170-179mm														1							
180-189mm																					
190-199mm																					
200-249mm																					
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-7. Number of Coho tagged by size and week at Eagle Cliff screw trap and released at Pine Creek.

Capture Type	Marked Eagle Cliff Screw Trap and Released Upstream																			
Species	Coho																			
Week Start	3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8
Week End	3/27	4/3	4/10	4/17	4/24	5/1	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24	7/31	8/7	8/14
Week	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm		1											1				1		1	9	
70-79mm		4	5	2	1	5	5	1	1	1	3		4	3	8	15	76	56	207	126	21
80-89mm		10	10	2	5	11	13	2	2	7	6		2	2	4	5	60	23	104	30	14
90-99mm		9	11	8	11	17	13	14	22	19	24		7	1	1	2	15	9	19	6	7
100-109mm		6	13	1	12	15	34	11	35	36	27	2	4			1	1	1		1	
110-119mm		5	5	1	7	6	18	12	27	31	15		1								1
120-129mm				1	1	2		2	9	7	2										
130-139mm									1		1		1								
140-149mm																					
150-159mm																					
160-169mm												1									
170-179mm																	1				
180-189mm										1	6	2									
190-199mm											3	4	1	1							
200-249mm									1		1	6	1	3	2						1
250-299mm										3	1							1			
300-349mm											1										
350-399mm																					
400+mm																					

Table 3.1-8. Number of Swift floating service collector tagged Coho recaptured by size and week at Swift floating service collector.

Capture Type	Recapture of FSC Tagged Fish																				
Species	Coho																				
Recapture Week Start	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9
Recapture Week End	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm																	1				
80-89mm										2				1	1						
90-99mm								1	2		3	3			2						
100-109mm								2	2	3	5	7	3	4	3		2				
110-119mm						1		2	1	17	17	14	4	8	14	6					
120-129mm						1		2	5	27	21	16	9	25	14	5	1				
130-139mm									2	15	17	8	4	17	20	6	1				
140-149mm							1		2		2		4	5	9	2					
150-159mm														2	2						
160-169mm														1	2	1					
170-179mm															1						
180-189mm																					
190-199mm																					
200-249mm																					
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-9. Number of screw trap tagged Coho recaptured by size and week at Swift floating service collector.

Capture Type	Recapture of Screw Trap Fish																				
Species	Coho																				
Recapture Week Start	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9
Recapture Week End	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15
Recap Week	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm															3	1		1			
80-89mm										4	1		2		7		1				
90-99mm								1	6	9	5	6	7	6	12	2					
100-109mm								1	5	9	15	8	11	14	15	5	1				
110-119mm								1	4	9	14	10	6	6	15	2					
120-129mm									1	3	4	5			1	1					
130-139mm															1						
140-149mm																					
150-159mm																					
160-169mm																					
170-179mm																					
180-189mm												1			1						
190-199mm														1		1					
200-249mm														1							
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-10. Number of Steelhead tagged by size and week at Swift floating service collector and released at Pine Creek.

Capture Type	Marked at Swift FSC and Released Upstream																				
Species	Steelhead																				
Week Start	3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8
Week End	3/27	4/3	4/10	4/17	4/24	5/1	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24	7/31	8/7	8/14
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm																					
80-89mm																					
90-99mm				1		1				2											
100-109mm							1														
110-119mm						1															
120-129mm																					
130-139mm																					
140-149mm			1			1															
150-159mm						2		2	1												
160-169mm					1	4	2	5	8	1		1									
170-179mm					1	6	2	5	20			1	1								
180-189mm					5	13	3	4	16			2									
190-199mm					5	22	4	12	12	1		1		1							
200-249mm							3	10	9			4	2								
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-11. Number of Steelhead tagged by size and week at Eagle Cliff screw trap and released at Pine Creek.

Capture Type	Marked Eagle Cliff Screw Trap and Released Upstream																				
Species	Steelhead																				
Week Start	3/21	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8
Week End	3/27	4/3	4/10	4/17	4/24	5/1	5/8	5/15	5/22	5/29	6/5	6/12	6/19	6/26	7/3	7/10	7/17	7/24	7/31	8/7	8/14
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm				1	2					1				1							
80-89mm			2		1		1	2	2	2	5	3			1						
90-99mm		2	3		1		2	4	1	8	6	3		7	2						
100-109mm					1			1	2	7	6		4	2	3		2				
110-119mm				1				2	1	1			1	1	1		1				
120-129mm								1	2	1		1						1			
130-139mm		1	1			1				1		1		1						1	1
140-149mm			1					1	2	1											
150-159mm		1	1	1			3	2	6	4											
160-169mm		2				3	2	2	3	3	2										
170-179mm			2		1	3	4	2	5	1											
180-189mm				1	1	4	3	1	3	1								1			
190-199mm		1	1		2	1	3	2		1											
200-249mm		1	1		1	5		1		2		1									
250-299mm								1	1	1	1	1			1						
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-12. Number of Swift floating service collector tagged Steelhead recaptured by size and week at Swift floating service collector.

Capture Type	Recapture of FSC Tagged Fish																				
Species	Steelhead																				
Recapture Week Start	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9
Recapture Week End	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm																					
80-89mm																					
90-99mm																					
100-109mm																					
110-119mm																					
120-129mm																					
130-139mm																					
140-149mm								1													
150-159mm								1		1	1										
160-169mm								2		2	2										
170-179mm							2	1	1	4	1	2									
180-189mm					1		2	1	1	5	1	1									
190-199mm						2	3	7	5	1	1										
200-249mm									2	2	1	1									
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

Table 3.1-13. Number of screw trap tagged Steelhead recaptured by size and week at Swift floating service collector.

Capture Type	Recapture of Screw Trap Tagged Fish																				
Species	Steelhead																				
Recapture Week Start	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9
Recapture Week End	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15
20-29mm																					
30-39mm																					
40-49mm																					
50-59mm																					
60-69mm																					
70-79mm																					
80-89mm																					
90-99mm																					
100-109mm																					
110-119mm																					
120-129mm																					
130-139mm									1												
140-149mm											1										
150-159mm								1	1	2	2	1									
160-169mm								1		1	3										
170-179mm								1	1	1	2										
180-189mm								2		2		1									
190-199mm									1	1	1										
200-249mm						1		2		1											
250-299mm																					
300-349mm																					
350-399mm																					
400+mm																					

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 (PacifiCorp and Cowlitz PUD 2022). 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; 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, 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 total number of fish collected at the Swift FSC during 2022 was derived for each life-stage (i.e., “fry”, “parr”, “smolt” and “adult”) of out-migrants collected by species. This classification summary is similar to previous annual reports and was provided for consistency. However, in addition to tracking out-migrants by life-stage, beginning in 2022 they were also classified by cohort (brood years) based on size. Brood year assignments were determined based on length frequency data as described in more detail in Section 3.3 below. While using length frequency distribution is a widely accepted practice for determining size/age classes, there are inherent biases that may not accurately assign outliers to the appropriate Brood Year (i.e, extremely small or large fish in a given Brood Year may be assigned to a younger or older Brood Year). However, based on observed length frequencies, these outliers have been shown to make up a relatively minute component of the overall run.

3.2.2 Results/Discussion

The Swift FSC was operational for the entirety of 2022, 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 17 due to moderate fish collection totals. The subsample rate was incrementally adjusted downward beginning May 18, ultimately reaching a 10 percent rate through June 17. The subsample rate was adjusted to 50 percent from June 18 through July 16, when the facility was taken offline for summer maintenance. The subsample rate was set to 100 percent when the facility returned to service after the summer maintenance, where it remained until the end of the year. 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.

A total of 78,373 (95% CI range: 63,972 – 92,774) salmonids were captured by the Swift FSC in 2022 (Table 3.2-1). Of these fish, approximately 72,684 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, were pre-spawn adults and returned to Swift Reservoir, or were recorded as a mortality associated with collection as described below in Section 3.5.2. Coho accounted for the highest percentage of the overall estimated catch (82.9 percent), followed by Steelhead (7.1 percent), spring Chinook (3.2 percent), and Cutthroat Trout (1.1). A total of 3,697 hatchery Rainbow Trout and sixteen (16) Bull Trout were also collected in 2022 and returned to the reservoir. An additional estimated 639 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, 2022 was the third largest out-migration year (72,684 juvenile and adult fish transported downstream) since the FSC began operation in 2013, only being surpassed in 2019 and 2021, when an estimated 111,702 and 81,295 fish were transported downstream, respectively (Table 3.2-3). As with all previous years, juvenile Coho Salmon were the most abundant species transported downstream in 2022.

A comparison of numbers of fish collected by brood year in 2022, indicated that the 2020 brood year accounted for the majority of out-migrants collected for all years (Table 3.2-4). Of the 64,694 Coho collected in 2022, 82 percent from the 2020 brood year. Although less of the overall percentage, 61 percent of juvenile Chinook and 65 percent of the juvenile Steelhead were also from the 2020 brood year of their respective species. Additional information on brood year representation during the 2022 sample season is provided in Section 3.3 below.

Table 3.2-1. Estimated monthly and annual totals of all salmonids collected at the FSC in 2022.

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	38	3,175	420	124	0	28	388	4	2	40	1	0	0	29	5	1	27	**4,282**
Feb	14	5,757	473	4	0	90	344	1	2	15	2	0	2	10	0	1	28	**6,743**
Mar	189	4,685	2,506	0	34	20	445	0	5	61	13	0	0	73	1	4	555	**8,591**
Apr	145	408	2,624	0	4	5	324	0	9	679	15	0	0	31	9	2	1112	**5,367**
May	228	122	23,100	0	2	20	43	0	3	3,601	8	10	0	377	89	4	1,909	**29,516**
Jun	20	1	14,392	0	13	11	162	0	1	1,008	2	16	0	201	11	3	687	**16,528**
Jul	19	32	2,225	0	7	55	317	0	0	28	2	1	0	10	2	0	15	**2,713**
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	64	449	10	0	2	56	0	1	3	0	0	0	2	0	0	1	**588**
Nov	0	329	27,44	26	0	0	94	14	12	21	0	0	0	11	1	1	2	**3,255**
Dec	2	120	413	157	0	3	67	3	3	10	0	0	0	11	1	0	0	**790**
Annual Total	**655**	**14,693**	**49,346**	**321**	**60**	**234**	**2,240**	**22**	**38**	**5,466**	**43**	**27**	**2**	**755**	**119**	**16**	**4336**	**78,373**
95% CI	***±71***	***±705***	***±11,145***	***±0***	***±32***	***±46***	***±253***	***±0***	***±0***	***±1,430***	***±0***	***±0***	***±0***	***±221***	***±1,16***	***±0***	***±384***	***±14,401***

Table 3.2-2. Estimated annual totals of salmonids transported downstream in 2022.

Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Goldendales	[A]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	
651	14,617	48,574	0	60	234	2,166	0	22	38	5,423	0	26	2	753	118	0	639	72,684

[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 2022.

Year	Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Golden-dale	Target Species Downstream[A]
	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	17,237
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
2022	651	14,617	48,574	0	60	234	2,166	0	22	38	5,423	0	26	2	753	118	0	639	72,684

[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 3.2-4. Estimated annual totals of all salmonids collected at the FSC in 2022, classified by brood year (BY).

	Coho			Chinook			Steelhead			Cutthroat		
	BY2021	BY2020	BY2019	BY2021	BY2020	BY2019	BY2021	BY2020	BY2019	BY2021	BY2020	BY2019
Annual Total	4,727	53,329	6,638	355	1,543	636	45	3,601	1,880	26	496	354
95% CI (+/-)	70	10,752	1,401	60	232	73	0	1,260	319	0	163	210

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 Objectives 6 and 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, 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 above, and plotted on a daily basis.

In addition to estimating migration timing, PacifiCorp also measured juvenile fish length to describe, temporally, the life-stage and size (cohort) of fish entering the FSC. Size distributions for Coho, Chinook, Steelhead and Cutthroat were calculated on a monthly basis. Length frequencies in 2022 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-October as the FSC was off for annual summer maintenance and construction activities.

3.3.2 Results/Discussion

All juvenile Chinook collected in 2022 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.

The run timing in 2022 was consistent with previous years with two general out-migration periods occurring; one occurring during the spring and the other occurring during late-fall and winter. Also consistent with previous years, the spring-time migration period made up a greater proportion of the total number of fish collected for the year compared to the fall with highest overall catch (approximately 84 percent) occurring between April 15 and July 1 (Figures 3.3-1 and 3.3.-2). While the spring-time out-migration period represented the highest numbers of fish being collected, species composition, life-stage, and brood year prevalence varied temporally among all species throughout the year.

Out-migrating Coho were observed during all months the Swift FSC was in operation and was generally the dominated species collected throughout the year. Juvenile Coho collected during the late-fall and winter periods, predominately consisted of smaller parr-sized fish, which then transitioned into larger, smolt-sized fish by early spring (Figures 3.3-3 and 3.3-4). Similar to previous years, peak collection of out-migrating Coho smolts occurred during late-May and June.

Similar to Coho, juvenile spring Chinook salmon were also seen throughout the year, however their migration timing was more evenly distributed across the year (Figures 3.3-5 and 3.3-6). Both parr and smolt life-stages were collected throughout the winter and early-spring. However, by early-May, the overall numbers of spring Chinook declined until early-July when a surge of spring Chinook were again collected. This phenomenon has been observed in previous years and has been characterized as multiple cohorts of fish moving through the system over time as described by changes in fish size. Additional information on this is provided in below when describing changes in length frequency distribution for out-migrating spring Chinook throughout the year.

Over 90 percent of all juvenile Steelhead collected in 2022 were collected between April 15 and June 15, and comprised almost exclusively of larger, smolt-sized fish (Figures 3.3-7 and 3.3-8). This is consistent with previous years, and further confirms not only the compressed out-migration period for juvenile Steelhead, but also the relative absence of earlier life-stages that are observed at the Eagle Cliff screw trap emigrating from Swift Reservoir annually.

Coho Size Distributions

Length frequency data for Coho during 2022 demonstrated three general cohorts moved through the system and were transported downstream (Figures 3.3-11 through 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 2020 (i.e., brood year 2020). A smaller proportion (12.7 percent) of larger out-migrants (> 250 mm) were also seen during this timeframe. These much larger sized fish were likely holdovers from the previous outmigration year and represented juveniles produced by adults transported in 2019. From April through May, the median lengths of both cohorts increased, and over 75 percent of juvenile Coho that were captured 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 2020, and had a median length of 180 mm. Beginning in July, smaller Coho (fry) produced from adults transported in 2021 began appearing at the FSC. These smaller fish along with holdovers from the 2020 brood year comprised the catch from late October through December.

Chinook Size Distributions

Juvenile Chinook lengths observed from January through April encompassed a wide distribution range, with lengths ranging from less than 100mm up to 310 mm (Figures 3.3-14 through 3.3-16). The smaller fish collected prior to April were the progeny of adults transported upstream in 2020, while the larger fish from adult transported in 2019.

A similar brood size distribution for Chinook was also observed into the early spring with fish ranging in size from 80 mm to 230 mm being collected. As has been typical for Chinook out migrating from Swift Reservoir, very few fish were captured during the month of May and June, only to have a surge of smaller fish (<130mm) beginning to arrive in July. These early out-migrants arriving in July were produced from adults transported upstream in 2021. The number of Chinook collected drops precipitously as water temperature rises in the summer, but continue their out-migration in the fall when temperatures drop. Median lengths of Chinook in November were 150 mm, which is notably smaller than the median length observed in November 2021 (185mm). Too few Chinook were collected in December to make meaningful inference regarding length frequencies.

Steelhead Size Distributions

In general, juvenile Steelhead size distributions observed in 2022 were similar to those seen in previous years and appeared to be comprised of two distinct cohorts (Figures 3.3-17 through 3.3-19). These cohorts represent juveniles produced from adults transported upstream in 2020 and 2021. Because of the truncated run timing Steelhead exhibit, length frequency distributions were only generated for months of January through June. Length frequencies of Steelhead collected in January through May indicate two distinct cohorts (Brood Years 2019 and 2020), with a broad range of sized observed. By June, however, the larger size-class (>220 mm) seen in previous months were no longer present. Median fork length for Steelhead collected in June was 188 mm.

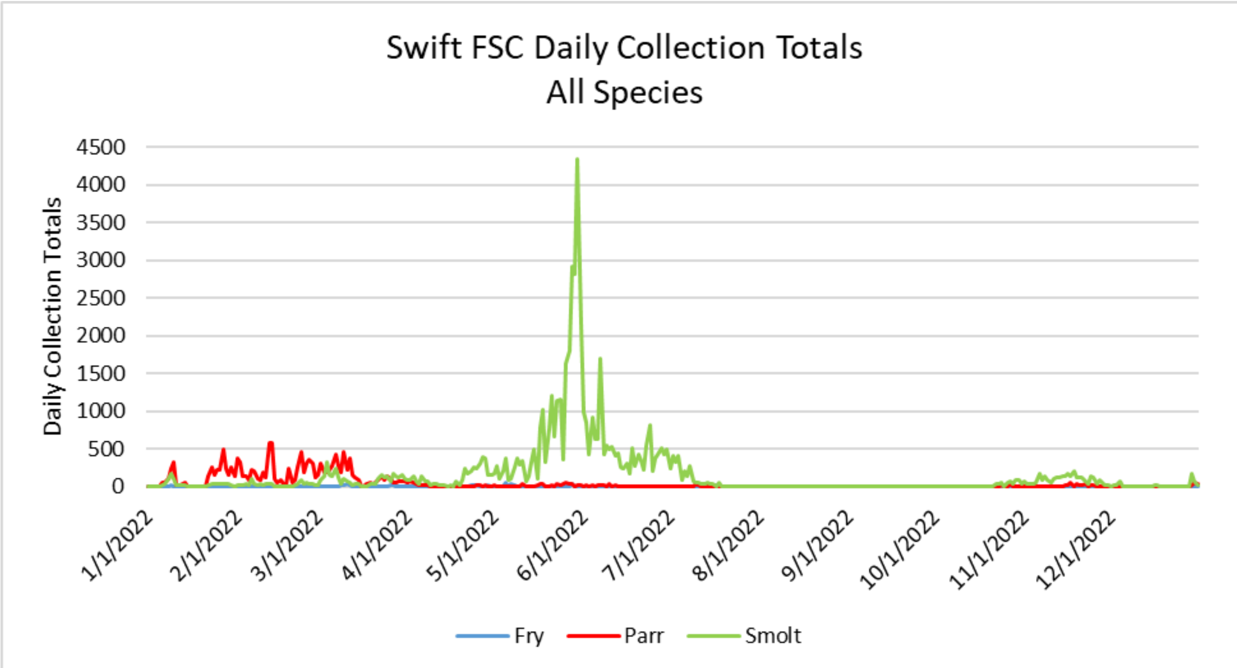

Figure 3.3-1. Estimated daily collection totals for all species at Swift FSC, 2022[11]

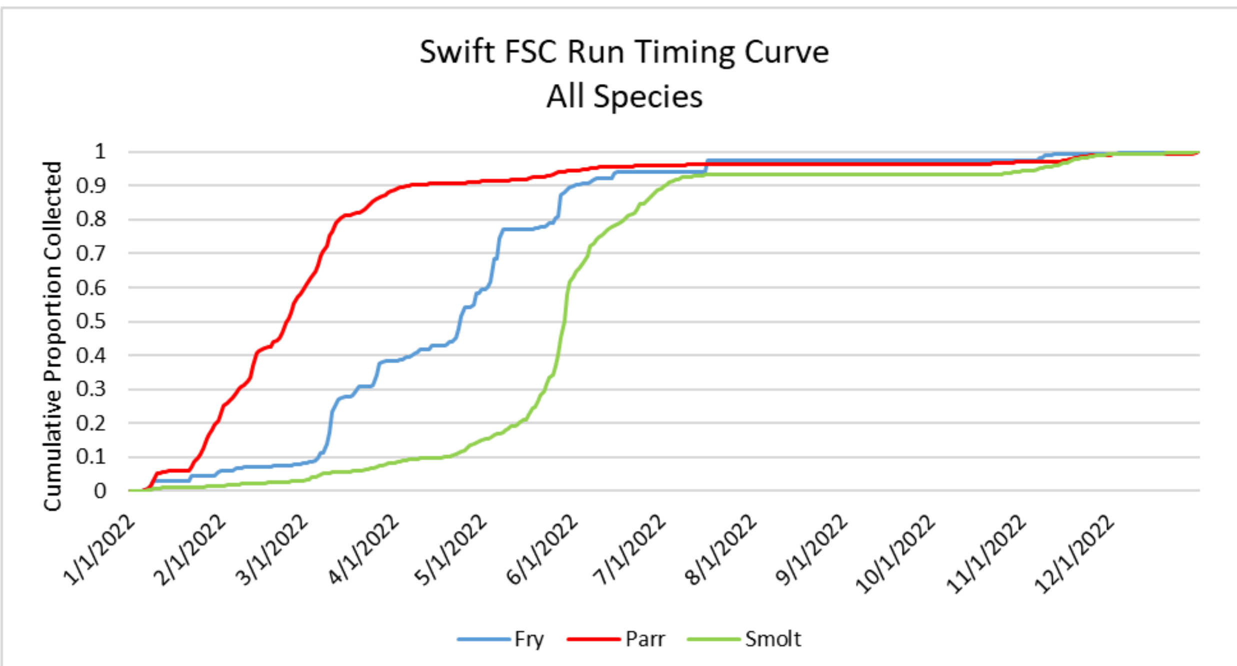

Figure 3.3-2. Cumulative migration timing among all species at Swift FSC, 2022

[11] The Swift FSC was not operational from July 19 through October 21, 2022 due to schedule outages.

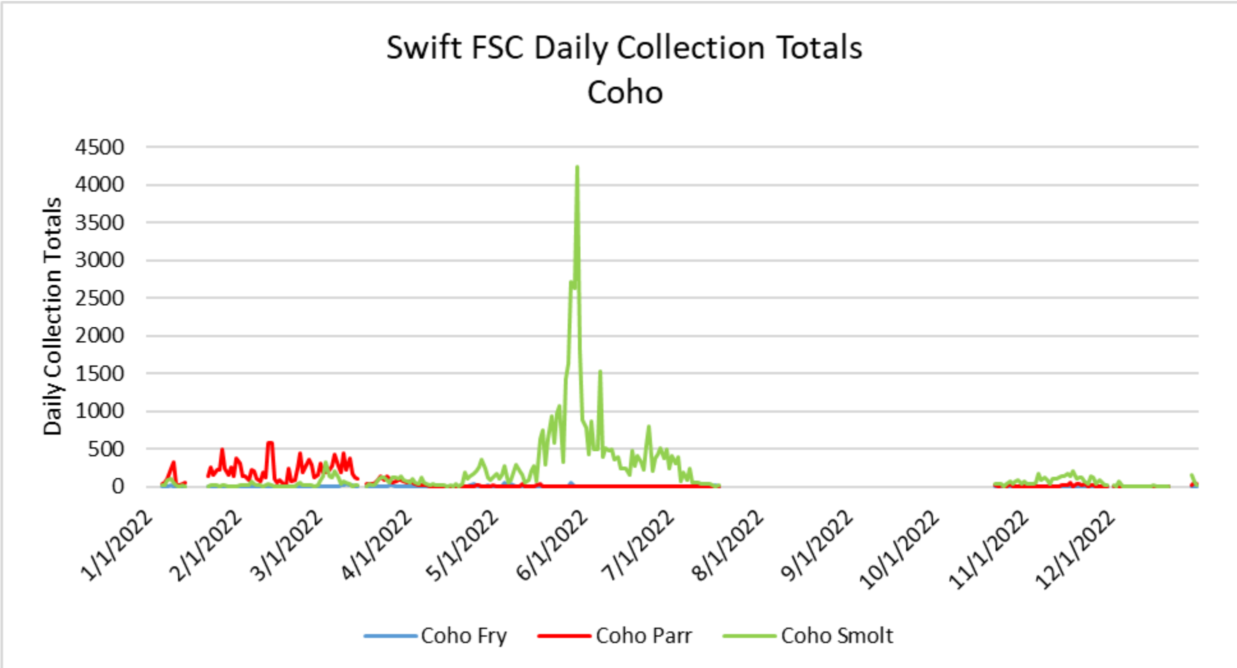

Figure 3.3-3. Estimated daily collection totals of juvenile Coho at Swift FSC, 2022[12]

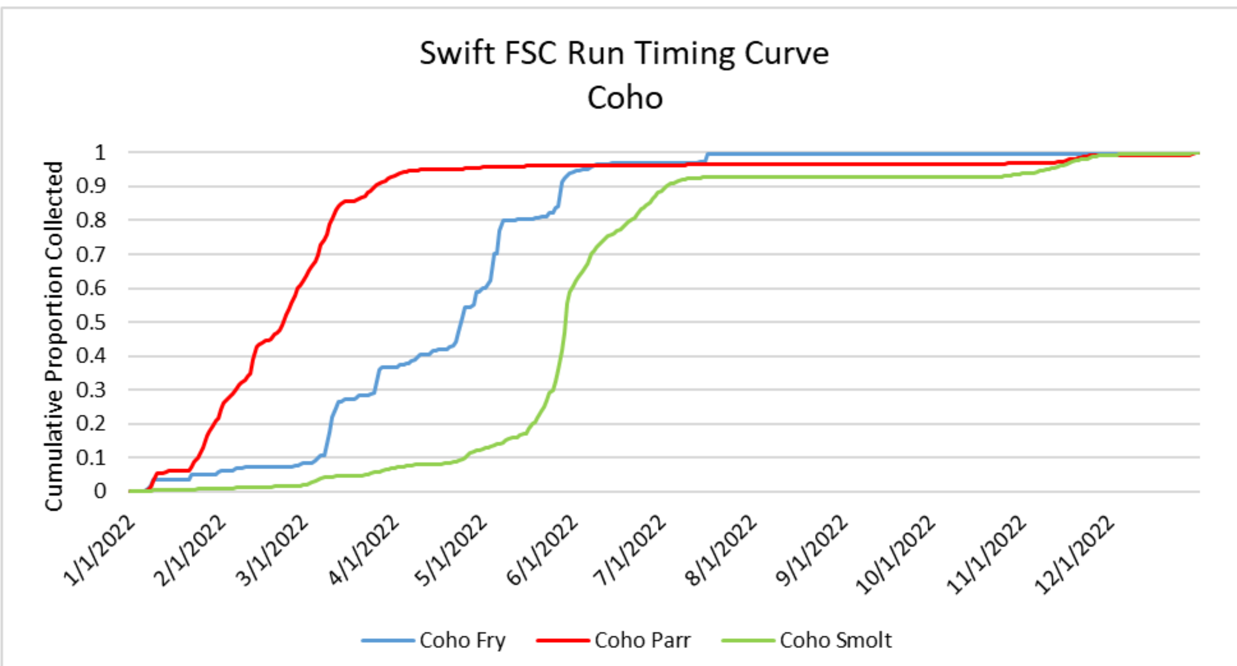

Figure 3.3-4. Cumulative migration timing of juvenile Coho at Swift FSC, 2022.

[12] The Swift FSC was not operational from July 19 through October 21, 2022 due to schedule outages.

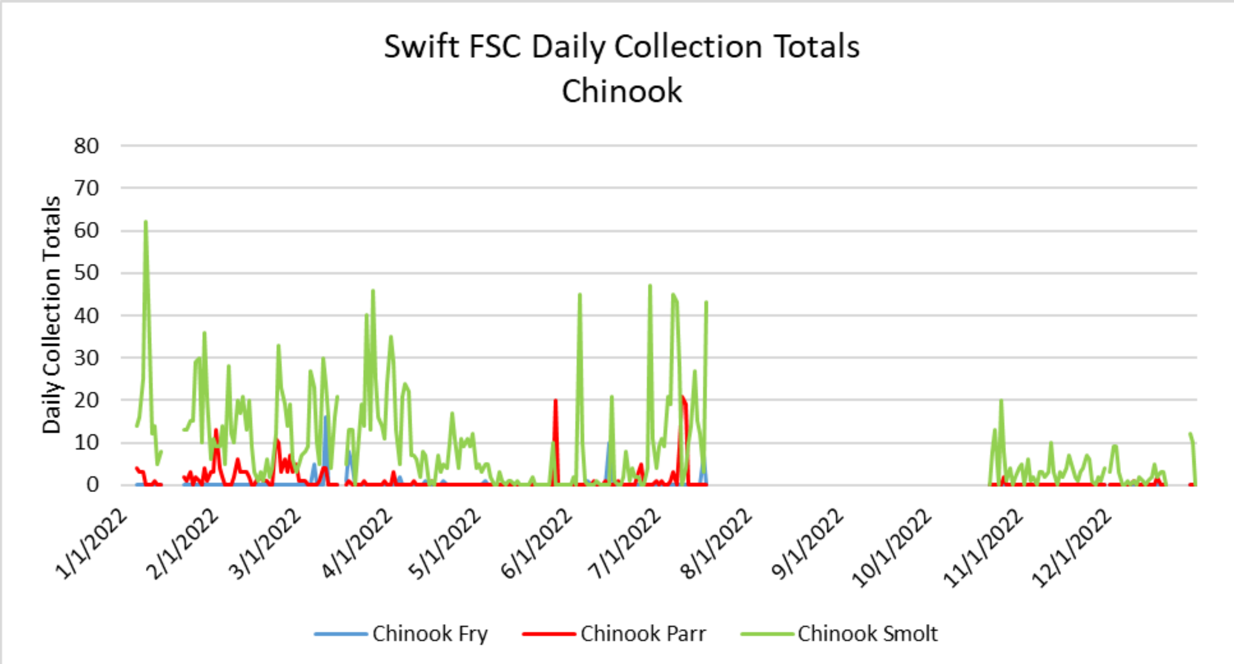

Figure 3.3-5. Estimated daily collection totals of juvenile Chinook at Swift FSC, 2022.[13]

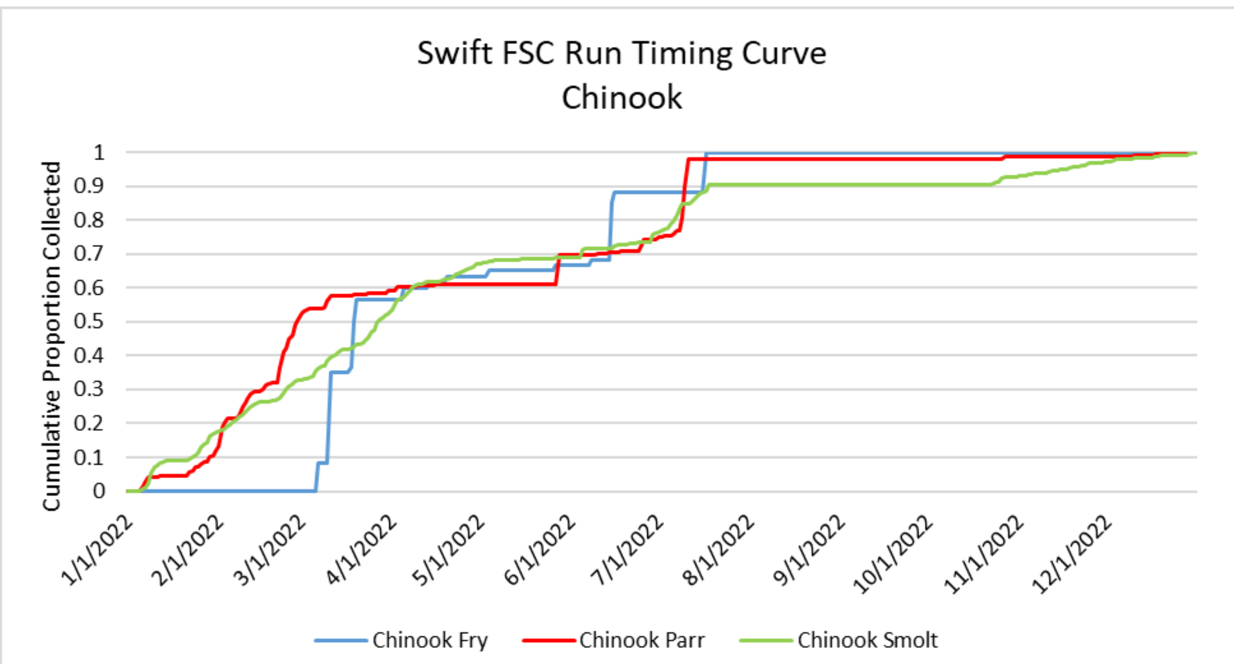

Figure 3.3-6. Cumulative migration timing of juvenile Chinook at Swift FSC, 2022.

[13] The Swift FSC was not operational from July 19 through October 21, 2022 due to schedule outages.

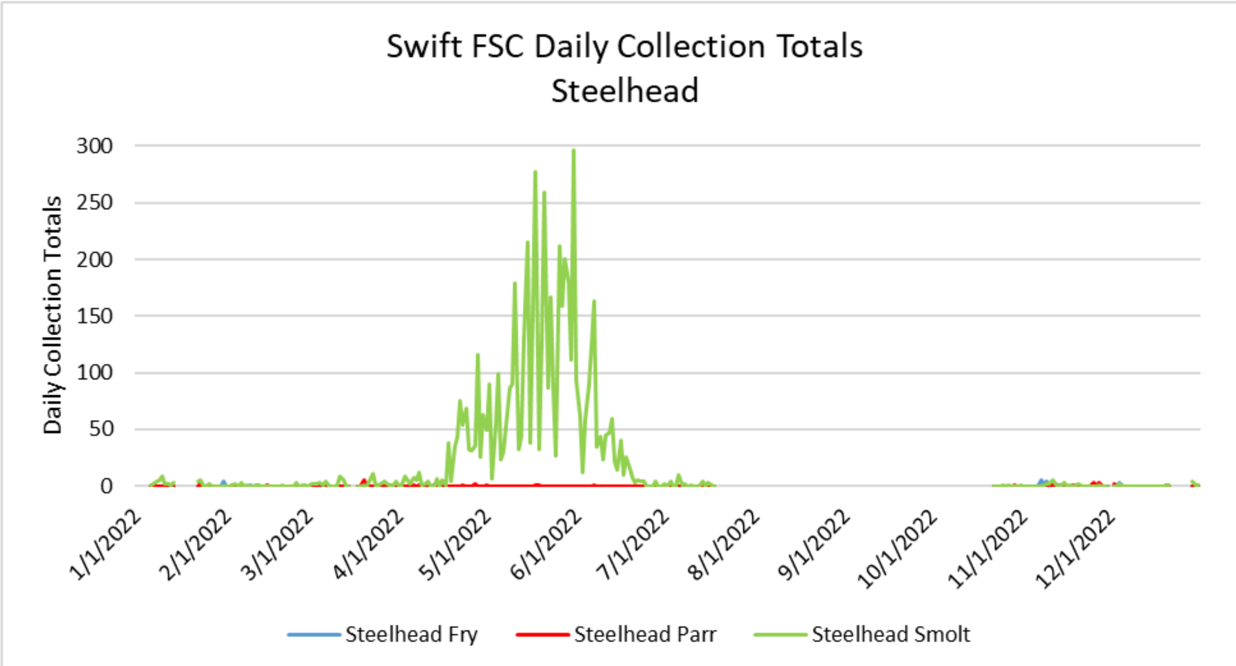

Figure 3.3-7. Estimated daily collection totals of juvenile Steelhead at Swift FSC, 2022.[14]

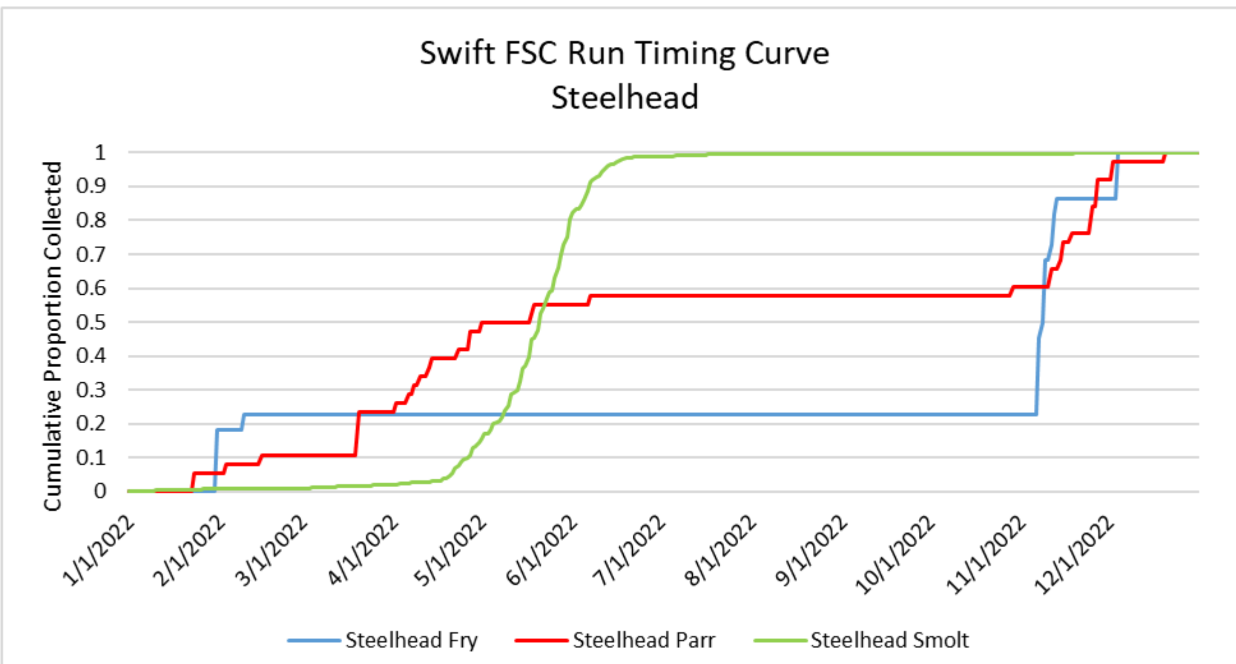

Figure 3.3-8. Cumulative run timing of juvenile Steelhead at Swift FSC, 2022.

[14] The Swift FSC was not operational from July 19 through October 21, 2022 due to schedule outages.

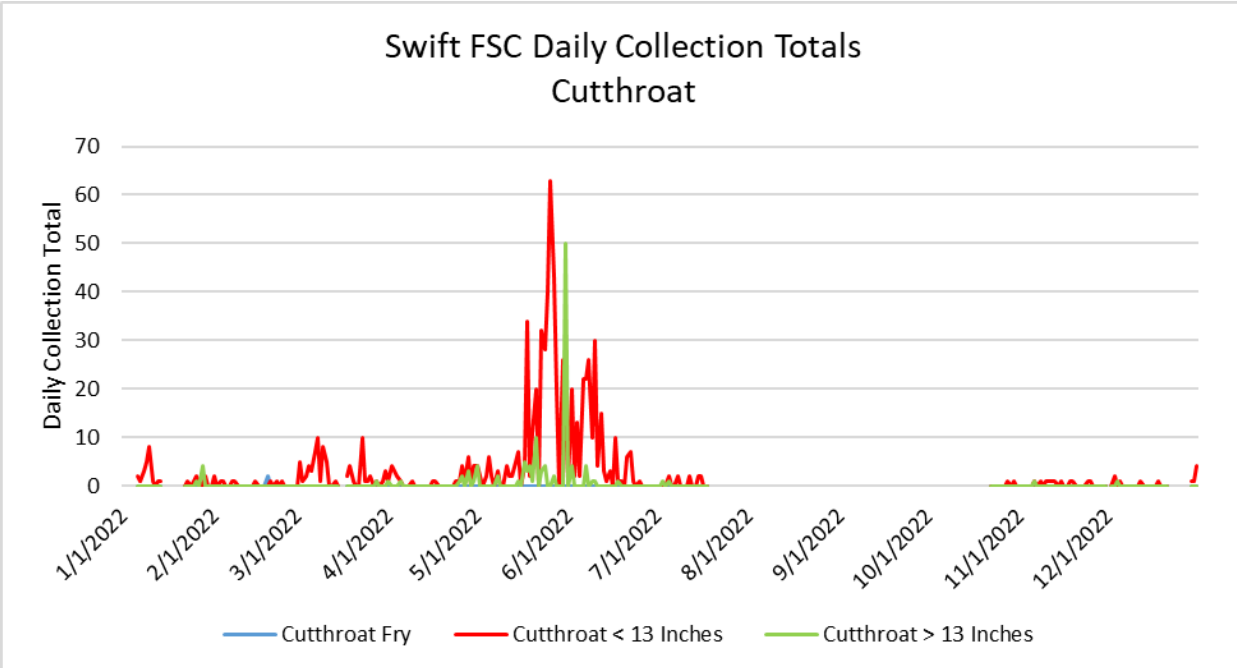

Figure 3.3-9. Estimated daily collection totals of juvenile Cutthroat Trout at Swift FSC, 2022. [15]

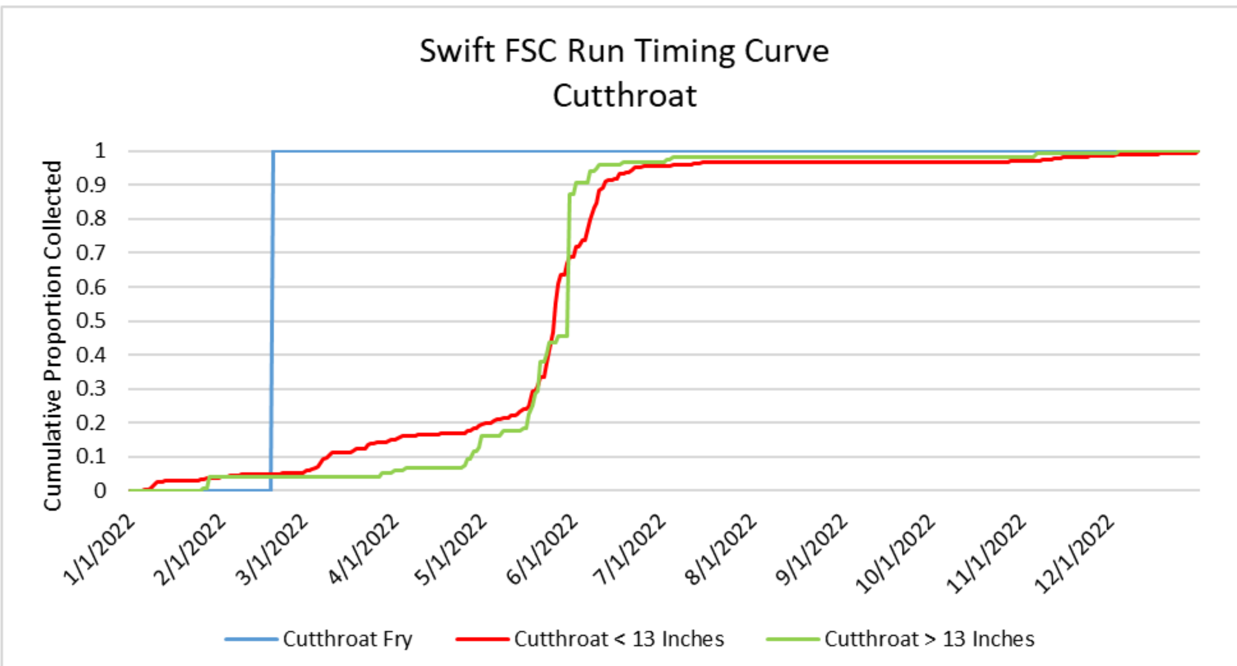

Figure 3.3-10. Cumulative run timing of juvenile Cutthroat Trout at Swift FSC, 2022.

[15] The Swift FSC was not operational from July 19 through October, 21 2022 due to schedule outages.

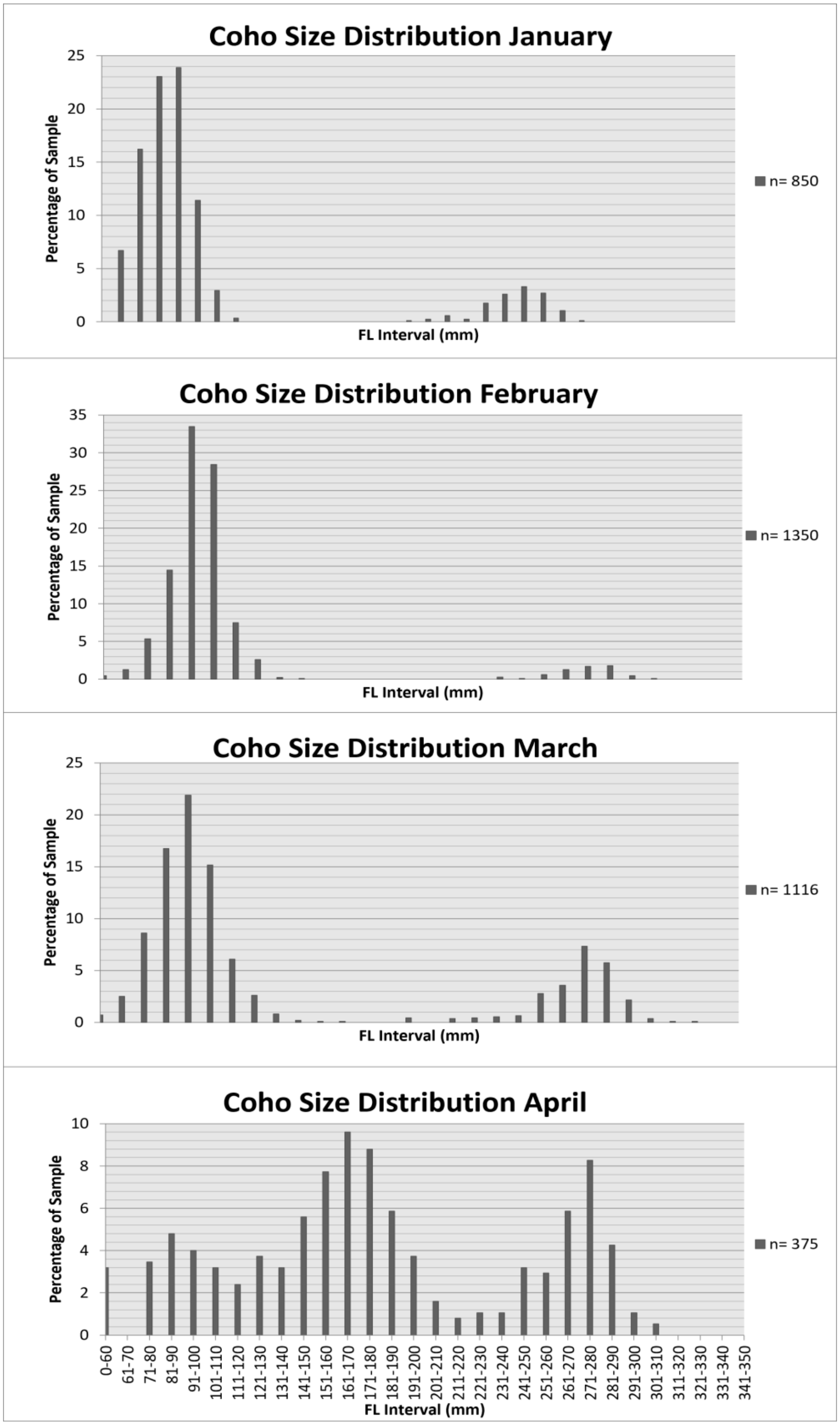

Figure 3.3-11. Size distribution of Coho migrants collected at the Swift FSC in 2022 (Jan-April).

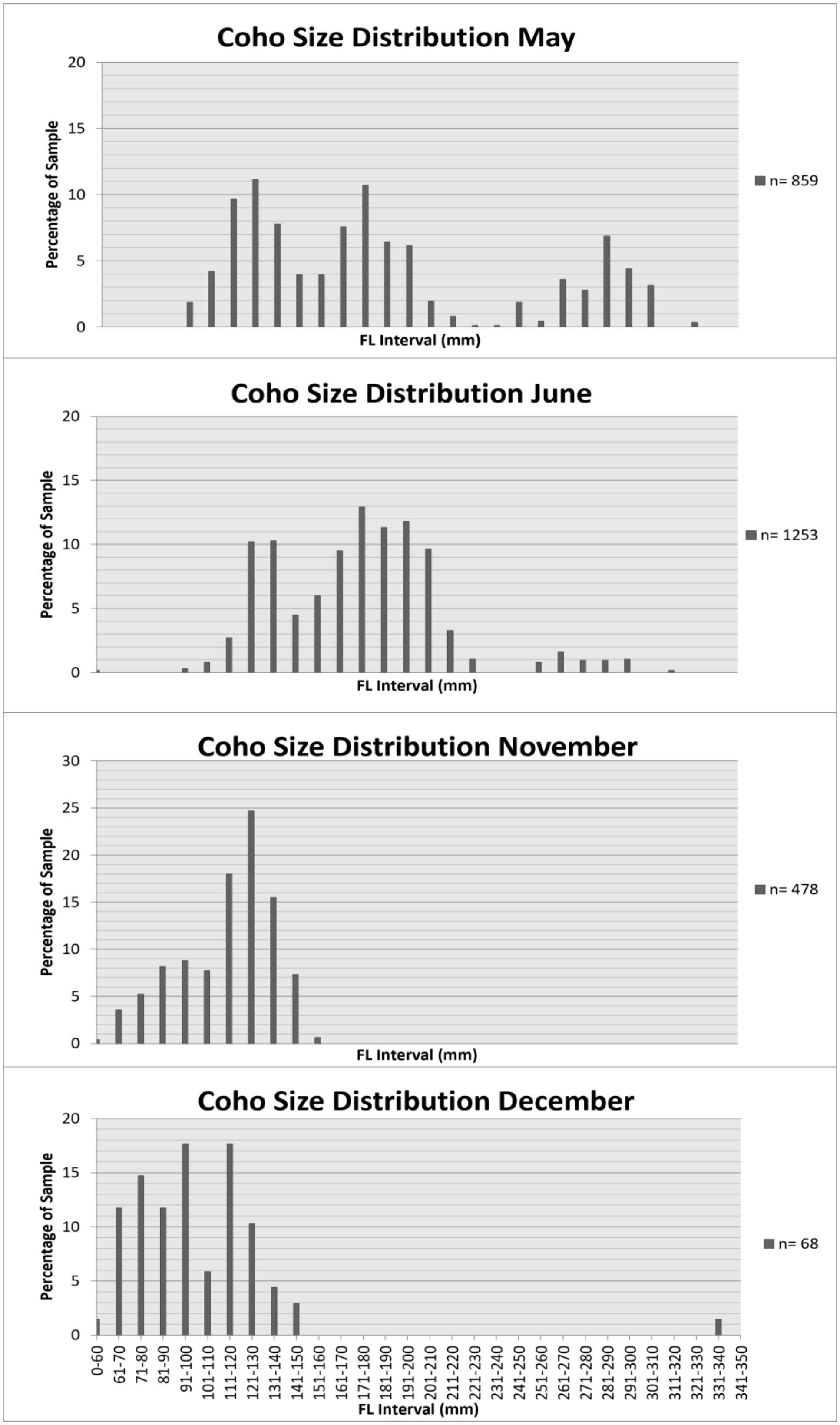

Figure 3.3-12. Size distribution of Coho migrants collected at the Swift FSC in 2022 (May-Dec).

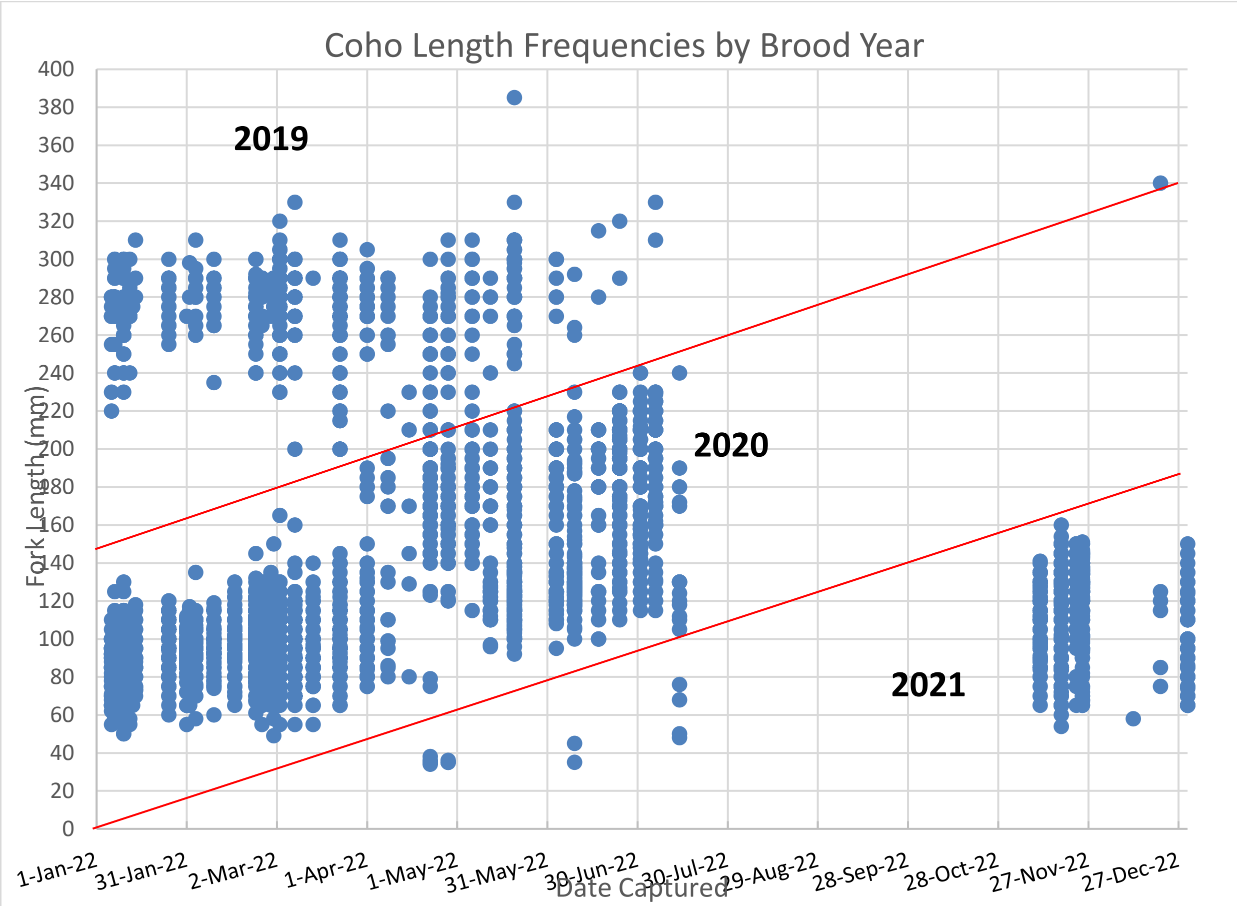

Figure 3.3-13. Size distribution of Coho migrants, by Brood Year, collected at the Swift FSC in 2022.

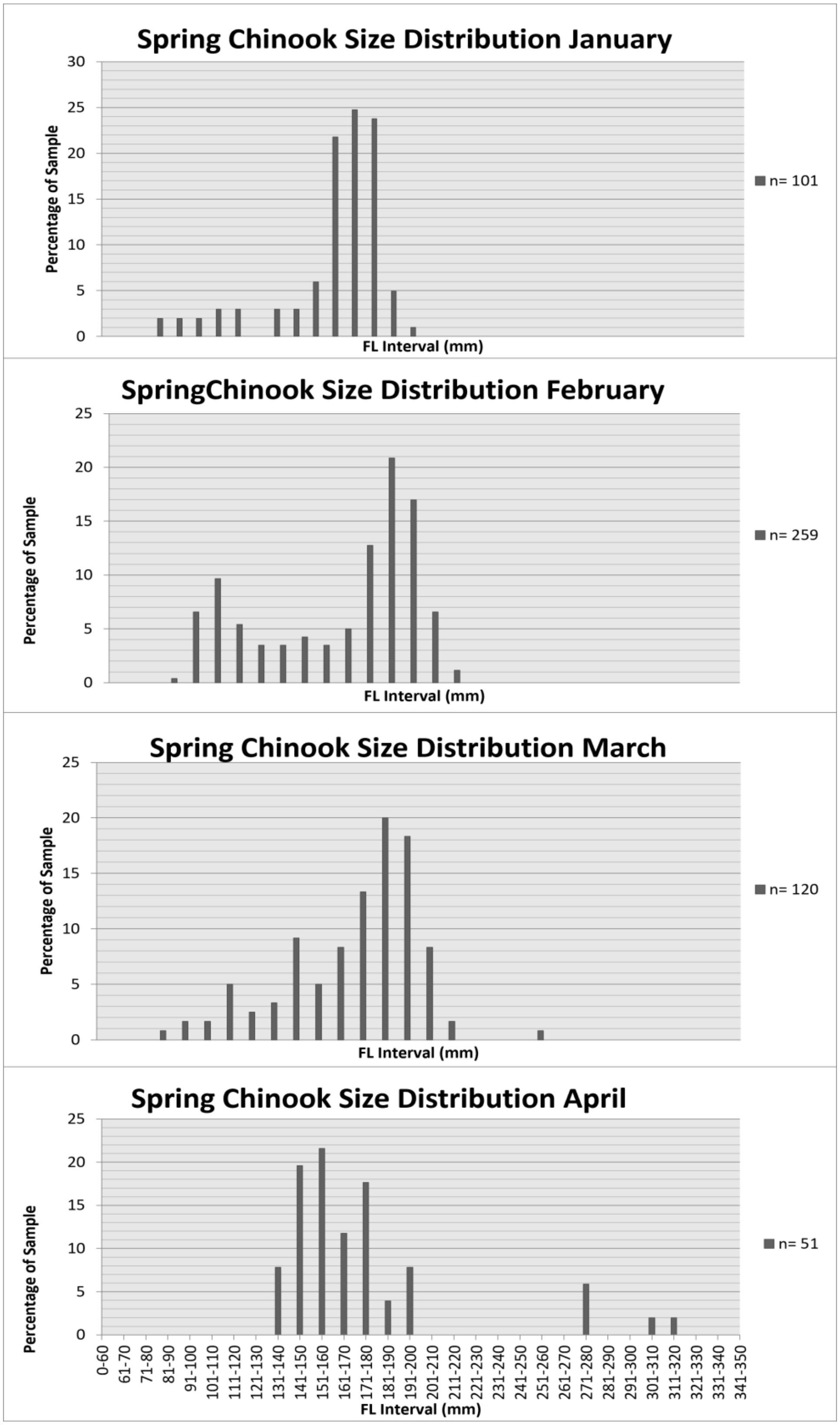

Figure 3.3-14. Size distribution of spring Chinook migrants collected at the Swift FSC in 2022 (Jan-April).

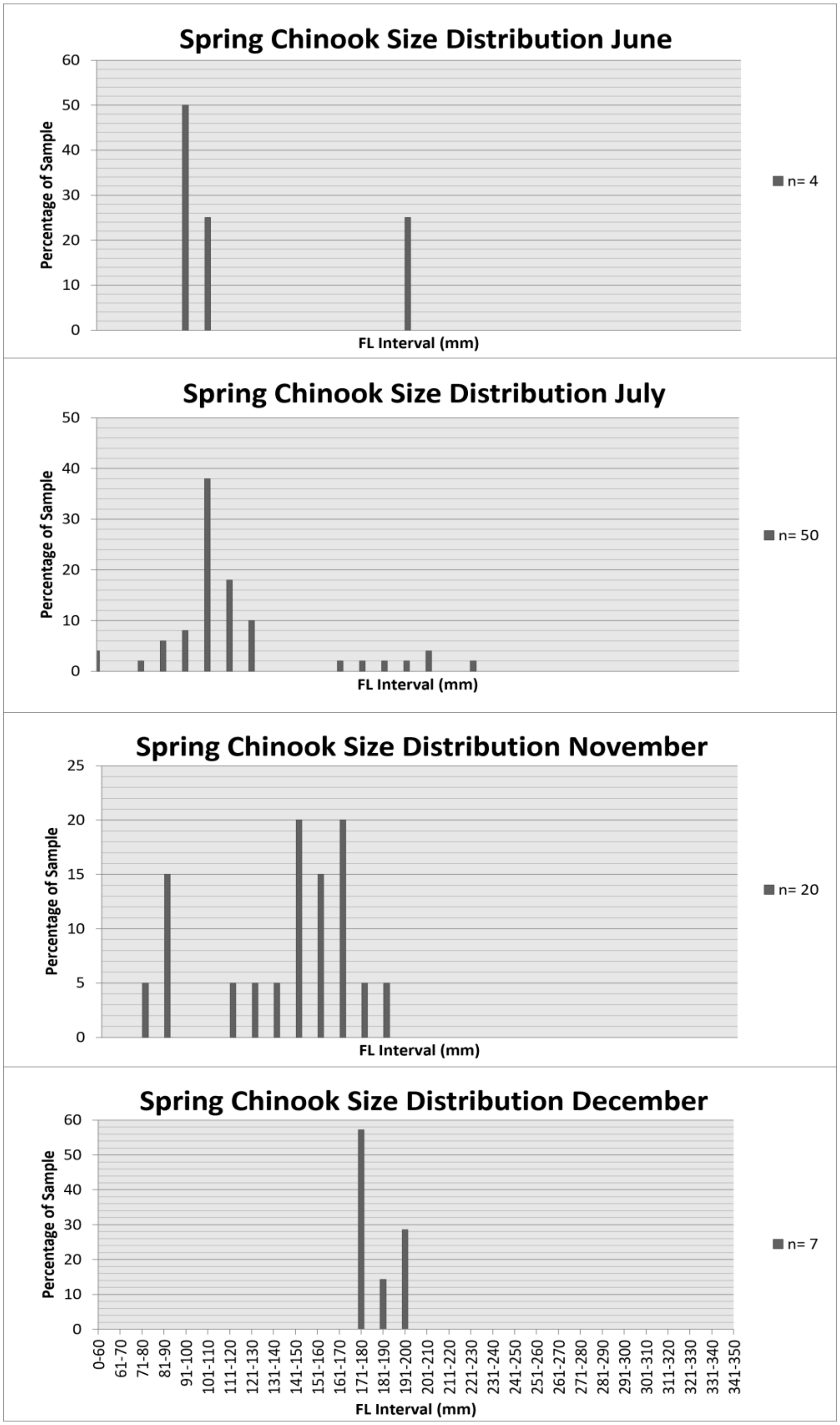

Figure 3.3-15. Size distribution of spring Chinook migrants collected at the Swift FSC in 2022 (Jul-Dec).

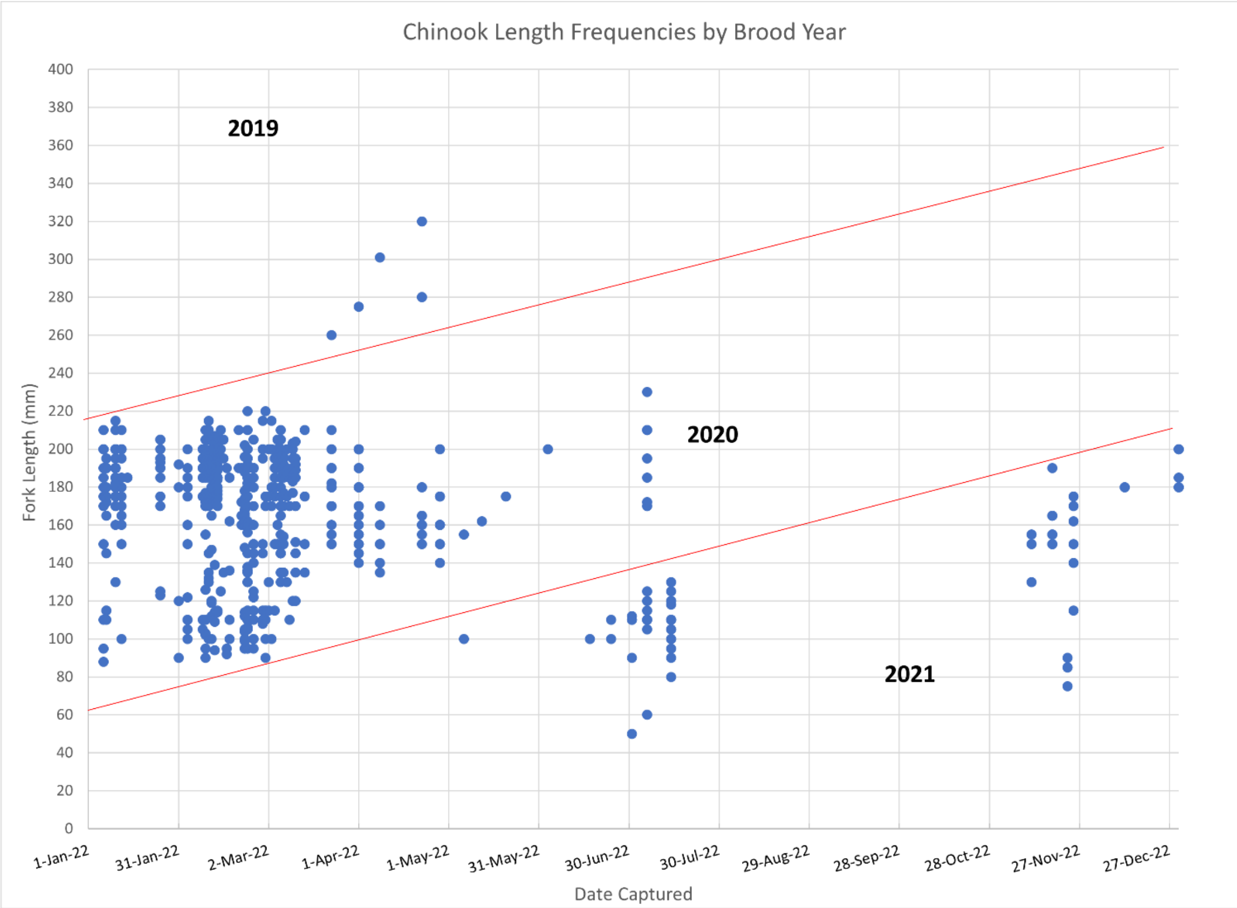

Figure 3.3-16. Size distribution of Chinook migrants collected at the Swift FSC in 2022.

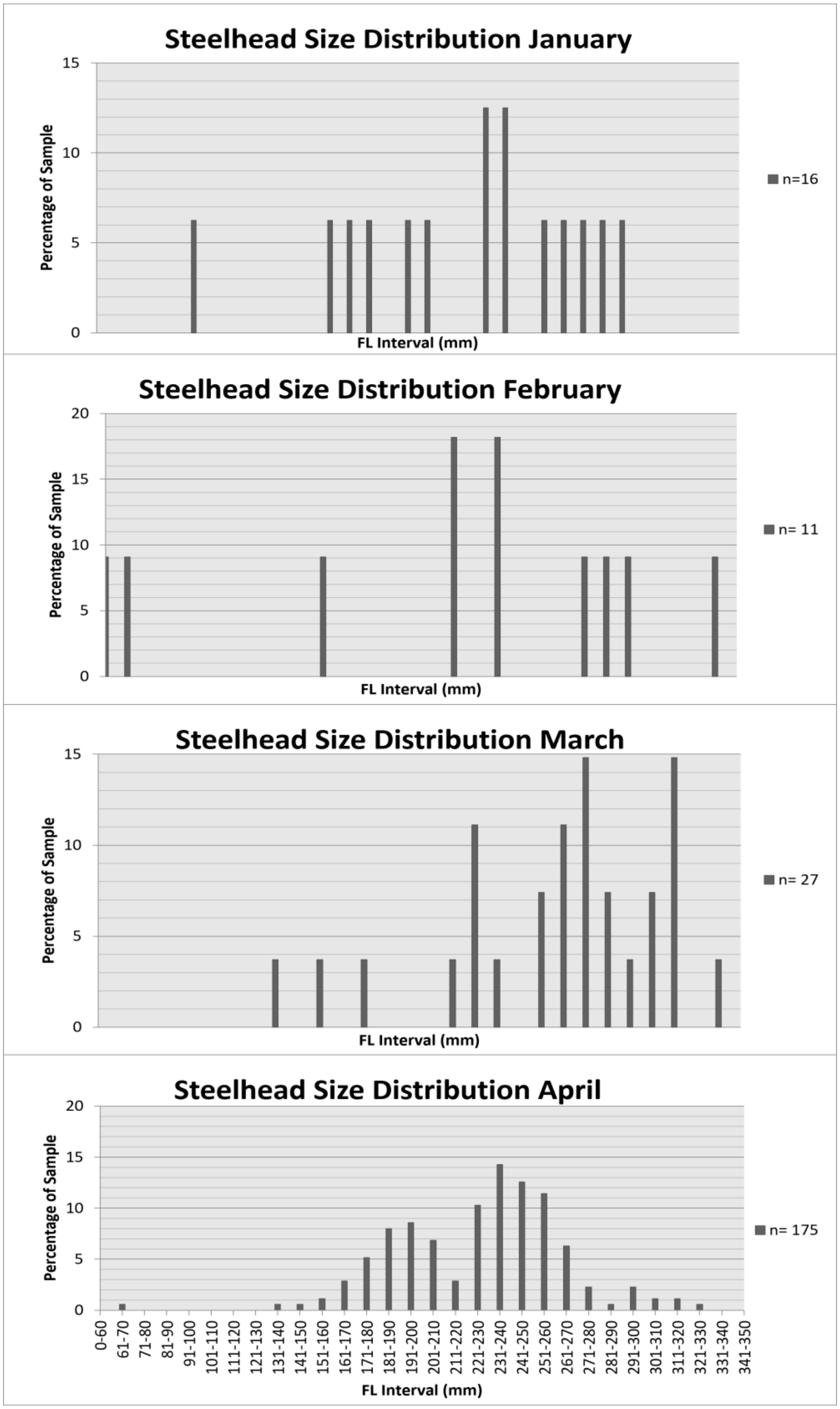

Figure 3.3-17. Size distribution of Steelhead migrants collected at the Swift FSC in 2022 (Jan-April).

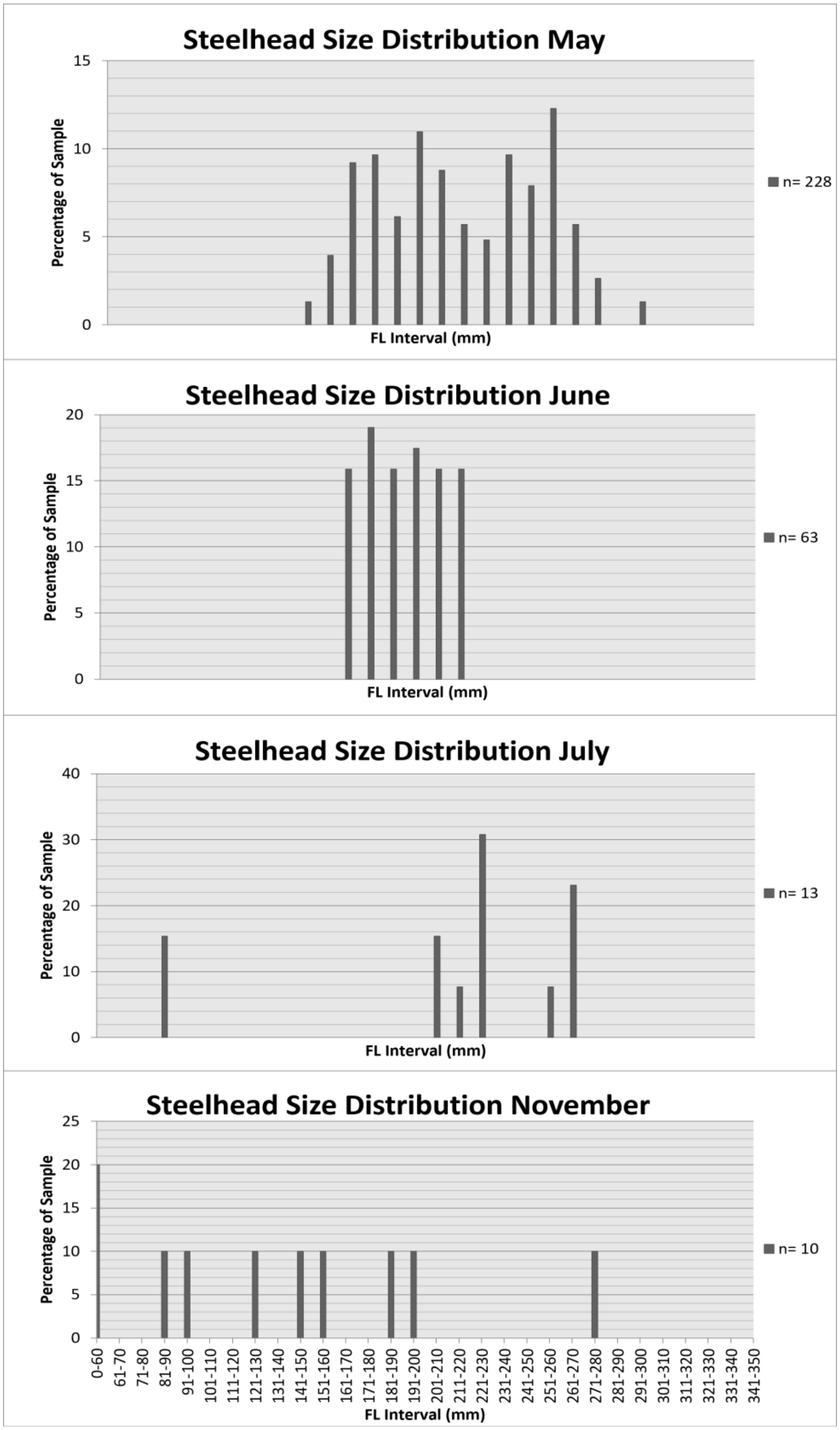

Figure 3.3-18. Size distribution of Steelhead migrants collected at the Swift FSC in 2022 (May - Nov).

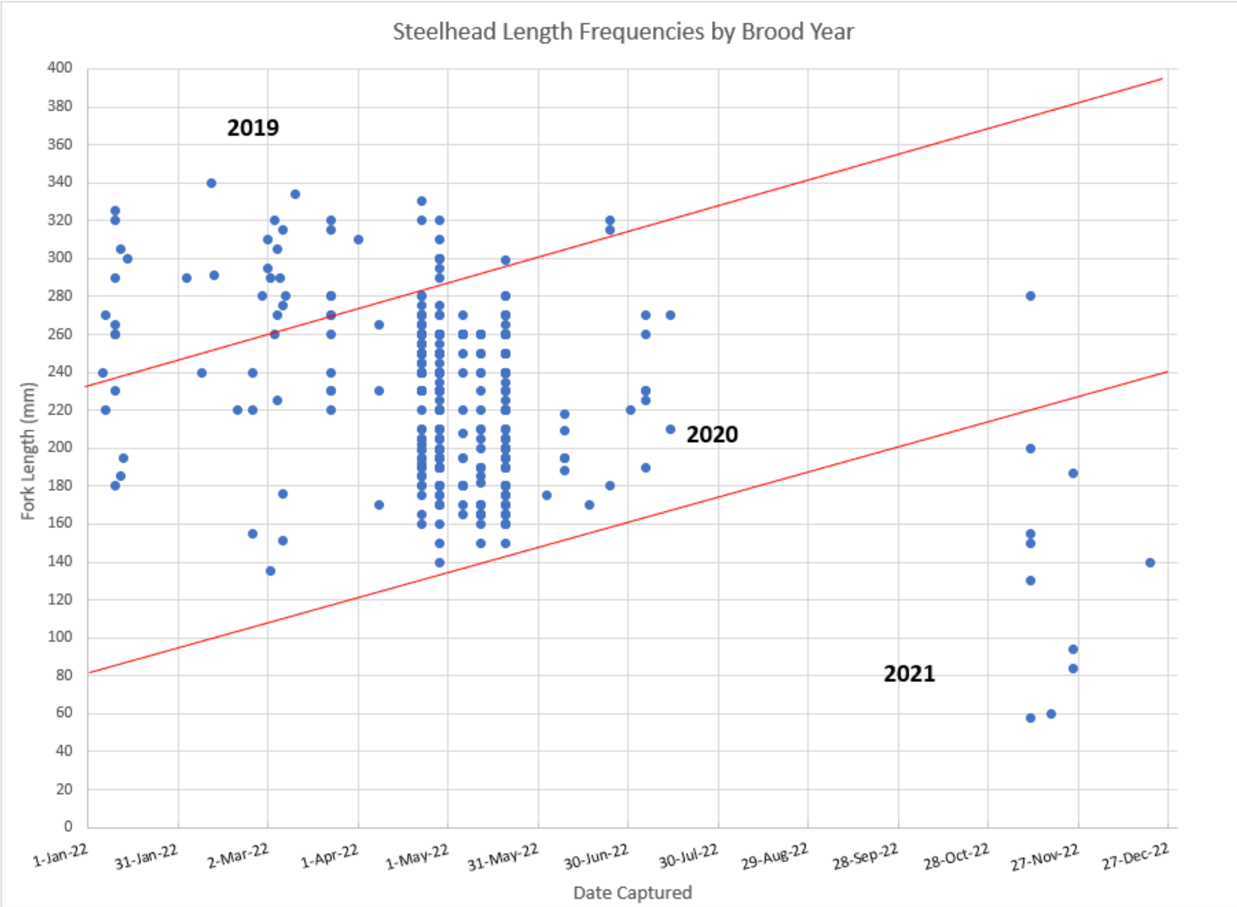

Figure 3.3-19. Size distribution of Steelhead migrants collected at the Swift FSC in 2022.

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 Swift FSC was further used in spring 2022. 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, 2020 and 2021 evaluations (Four Peaks Environmental 2020, 2021, 2022). Objective 2 of the current M&E Plan 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 exclusion net that is influenced by flow entering the FSC. A performance standard of 95 percent or greater for out-migrating smolts[16] was agreed upon for P_{CE}.

[16] 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.

The primary goals of the 2022 Swift Reservoir out-migration study were: 1) to determine collection efficiency for juvenile salmonids 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 entrance of the fish collection channel; 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 core study objectives of the 2022 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 the encounter rate (P_{ENC}), the proportion of study fish detected at the Devil's Backbone array and subsequently detected in the ZOI just outside the entrance of the Swift FSC;
3. Estimate entrance efficiency (P_{ENT}), the proportion of downstream migrants that enter the zone of influence and enter the FSC collection channel;
4. Estimate P_{CE}, the proportion of downstream migrants that enter the ZOI and successfully pass into the FSC and are captured;
5. Estimate collection efficiency (P_{RET}), the proportion of downstream migrants that enter the collection channel and successfully pass into the FSC and are captured;
6. Estimate channel efficiency ($P_{SEC\text{-}CHAN}$), the proportion of downstream migrants that enter the FSC and successfully pass into the collection channel; and
7. Estimate channel-collector transition rate (P_{CAP}), the proportion of study fish detected in the collection channel that are successfully captured.

In addition to the core passage metrics, the 2022 study also focused on fish behavior and capture success in the lower portion of the fish collection channel; an area that was identified during the 2021 evaluation as a significant bottleneck for fish passage (Four Peaks 2022). Results of this previous study found that a high proportion (greater than 60 percent) of fish that passed through the full extent of the fish collection channel were not retained, but rather swam back upstream through the collection channel and exited the FSC. Based on this information, PacifiCorp made both operational and physical adjustments to the lower portion of the fish collection channel between the 2021 and 2022 studies in an attempt to improve fish retention.

The first adjustment was eliminating a periodic backwash cycle that was implemented for cleaning the fish separation system immediately downstream of collection channel. It was thought that this periodic cleaning cycle was disrupting the high capture velocity flow through the lower portion of the collection channel and allowing fish to escape back upstream. The second adjustment was the addition of a low profile, horizontal V-trap that was installed on the floor of the secondary collection channel. Based on previous field observations, it appears that fish that do swim back upstream through the narrow, lower portion of the collection channel do so by holding close to the bottom of the collection channel and taking advantage of the slightly lower water velocities due to edge effect. The horizontal V-trap was installed to disrupt this phenomenon and prevent fish from swimming out along the bottom of the collection channel.

In addition to the two adjustments made in 2022, this evaluation also assessed the effects of control weir height on fish retention and capture success. An adjustable control weir separates the lower portion of the secondary fish channel and the fish separation system inside the sorting building. The weir controls the volume of water that fish use to enter the fish sorting building, as well as manipulates the speed of water in the lower portion of the fish channel. It was thought that flow volume passing over the control weir could influence fish passage success.

Similar to previous collection efficiency evaluations at the Swift FSC, environmental variables including water temperature, light level, wind speed, and precipitation as well as acoustic sound in and around the FSC were monitored and compared to evaluate their relationship with passage activity and collection.

3.4.2 Result/Discussion

A detailed report describing the methods and results of the 2022 effort can be found in Appendix C. A brief summary of this report is provided below.

A total of 421 fish were dual PIT and acoustic tagged and released upstream of FSC between April 20 and June 1, 2022, to measure system performance and monitor fish behavior. At total of 231 Coho, and 182 Steelhead juveniles were tagged and released (Table 3.4-1). It is important to note that Chinook Salmon were not included due to the low numbers of juvenile Chinook Salmon passing the FSC in 2022. 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 2022 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 2022 Study. In 2022, P_{PASS} was 83 percent for Coho Salmon, and 67 percent for Steelhead.

Consistent with annual study results since 2019, 96 percent of study fish of each species that found the zone of influence entered the Swift FSC in 2022. This proportion is reflected in the entrance efficiency metric (P_{ENT}). Since 2019, observed entrance efficiency for both Coho Salmon and Steelhead has varied between 95 and 99 percent.

After entering the Swift FSC, between half and two-thirds of study fish were retained in 2022, which was among the highest retention rates observed at the Swift FSC. In 2022, Swift FSC retention (P_{RET}) was 64 percent for Coho Salmon and 50 percent for Steelhead. Coho retention in 2022 was the second highest of any evaluation to date, behind retention observed during the 2019 Study. Steelhead retention in 2022 was tied for the highest on record. This shows that adjustments made to the fish collection channel between the 2021 and 2022 studies may have contributed to retaining a greater proportion of fish that attempt passage.

These improved retention rates translated to improvements in collection efficiency (P_{CE}). In 2022, collection efficiency for both species was among the highest recorded. Coho Salmon collection efficiency was 62 percent, the second highest on record, and Steelhead collection efficiency was 48 percent, among the top three highest on record. For both species, however, collection efficiency in 2022 remained below the performance target of 95 percent.

Some of the increase in retention efficiency observed in 2022 can be attributed to one or more of the above-described adjustments to the secondary collection channel that were made prior to the 2022 Study. Observations and historical comparisons indicate that discontinuing the secondary collection channel backwash screen cleaning cycle in 2022 likely resulted in the increase in retention efficiency. The low-profile horizontal V-trap did not appear to have been effective at retaining fish, and the operational position of the weir did not affect collection. Weather conditions did not affect collection, but, as in past studies, time of day did: more fish entered the Swift FSC and were collected at night or during late afternoon. Sound monitoring in 2022 detected a low frequency signal within the range that can affect juvenile salmonid behavior. The noise was determined to be coming from the primary and secondary channel pumps but does not appear to be a factor leading to fish rejection within the collection channel.

Acoustic telemetry data collected during the 2022 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 compared to previous evaluations, Swift FSC retention rates have improved, particularly in the lower portion of the secondary collection channel. Retention in 2022 was better than or similar to retention in all study years since 2017 for which this metric has been computed. This improvement in 2022 may have been the result of discontinuing operation of the secondary channel backwash screen cleaning cycle. Retention within the Swift FSC now appears to be constrained primarily by a bottleneck between the Swift FSC entrance and the secondary collection channel. This may be a result of hydraulic conditions within this region, particularly at the transition between the net transition structure and primary screen collection channel, as has been previously observed (Four Peaks 2020, 2021). Increasing retention of fish within this portion of the collection channel appears to be the most promising area for improving collection efficiency at the Swift FSC.

PacifiCorp plans to make additional adjustments to the entrance of the FSC during summer of 2023 and plans to retest collection efficiency through an acoustic tag study in the spring of 2024. The adjustments being made to the entrance to the FSC will improve the hydraulic conditions within the upper portion of the collection channel between entrance and the secondary collection channel. Results from the 2024 study will help inform whether the current bottleneck for fish passage can be eliminated or whether additional adjustments or modifications are needed.

Table 3.4-1. Summary of seasonal corrected passage metrics for tagged fish released at the head of Swift Reservior by species in 2022.

Species	No. Rel[1]	POS_{FBY}[2]	POS_{ZOI}	POS_{ENT}	$POS_{SECCHAN}$[3]	POS_{COL}
Coho Salmon	227	186	183	176	133	114
Steelhead	181	122	120	115	66	57

Species	$\widehat{P}_{PASS}$ (90% CI)[4]	$\widehat{P}_{ENC}$ (90% CI)	$\widehat{P}_{ENT}$ (90% CI)	$\widehat{P}_{SECCHAN}$ (90% CI)	$\widehat{P}_{CAP}$ (90% CI)	$\widehat{P}_{CE}$ (90% CI)	$\widehat{P}_{RET}$ (90% CI)
Coho Salmon	83% *(79%, 87%)*	98% *(96%, 100%)*	96% *(93%, 99%)*	78% *(72%, 83%)*	83% *(78%, 88%)*	62% *(56%, 68%)*	64% *(59%, 70%)*
Steelhead	67% *(62%, 73%)*	98% *(97%, 100%)*	96% *(93%, 99%)*	60% *(53%, 68%)*	82% *(75%, 90%)*	48% *(40%, 55%)*	50% *(42%, 57%)*

Notes:
1. This excludes five fish whose tags were assumed to have been shed or inactive at time of collection.
2. "POS" metrics refer to numbers of fish positioned within each zone, using ZPC developed for each. Actual detection counts may be higher if detections did not meet ZPC, but those detections are associated with lower confidence.
3. Counts of fish in the secondary collection channel are presented as the union of counts in either subzone.
4. 90% Wald's confidence intervals (CI) are reported for each collection metric.

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 2022 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, smolt injury and survival was evaluated based on fish collected in the subsample tanks. The methods outlined in the current M&E Plan 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%
Chinook, Coho, Steelhead, Cutthroat Adults	NA	NA

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

Recordable Injury		Non-Recordable Injury
Hemorrhaging	Open Wound	Minor Scrape 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 3.5-3, respectively.

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

Where:

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

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

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

With associated variance estimator:

$$\boldsymbol{Var(R_{Inj}) = \frac{R_{Inj}(1-R_{Inj})}{SS_{Total}}} \qquad \textbf{Equation 3.5-2}$$

$$\boldsymbol{CS =} \; S_{COL} * S_{TRAN} \qquad \textbf{Equation 3.5-3}$$

Where:

CS[17] = 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 ($Fish_{SUB}$) and the total number of fish examined ($Fish_{EX}$) 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 ($Fish_{ALIVE}$) to the total number of marked fish released in the transport system ($Fish_{REL}$). *Note: A detailed description of how S_{TRAN} is calculated is provided in Section 3.7 below.*

With associated variance estimator:

$$\boldsymbol{Var(CS) = \frac{CS(1-CS)_{Inj}}{Fish_{Rel}+Fish_{EX}}} \qquad \textbf{Equation 3.5-4}$$

3.5.2 Results/Discussion

Injury Rate

Combined annual injury rates for each target species ranged from 0 to 3.6 percent (Table 3.5-3). Juvenile Chinook had the highest overall injury rate (3.6 percent), followed by juvenile Steelhead (3.3 percent) , and Coho (1.1 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

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[17] CS was calculated for smolts (combined with parr), whereas only S_{COL} was recorded for fry. Fry were transported downstream in 2022; however, once collection efficiency at the FSC reaches >60 percent, it is intended that this life-stage be returned to the reservoir.

injuries observed (98.8 percent) in all species. Hemorrhaging made up the remaining 0.2 percent of the injuries observed in 2022 (Figure 3.5-1).

Annual injury rates for juvenile Chinook and Steelhead exceeded the required performance standard maximum of 2.0 percent. The observed injury rate for juvenile (parr and smolt) Coho and all salmonid fry fell below the 2.0 percent threshold stipulated in the Settlement Agreement. As in previous years, elevated injury rates for all species are largely attributed to heavy debris loading in the early Spring.

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: 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 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: 1) installation of several debris booms located at the head of the reservoir as well as in and around the forebay near the FSC; and 2) the addition of a passive debris weir located on the south side of the Net Transition Structure; and 3) operating a specialized debris-skimmer boat during periods of high debris loading. PacifiCorp also actively manages debris on the reservoir by using containment and removal procedures. 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	535	0
Chinook (Fry)	0	30	0
Steelhead (Fry)	0	19	0
Cutthroat (Fry)	0	2	0
Combined (Fry)	*0*	*586*	*0*
Coho (Parr & Smolt)	406	38,240	1.1 ± 0.1
Chinook (Parr & Smolt)	76	2,098	3.6 ± 0.8
Steelhead (Parr & Smolt)	105	3,174	3.3 ± 0.6
Cutthroat (Parr & Smolt)	0	421	0
Combined (Parr & Smolt)	*587*	*43,933*	***1.3 ± 0.1***
Steelhead Adults	0	45	0
Steelhead Kelts	0	27	0
Bull Trout	0	16	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.

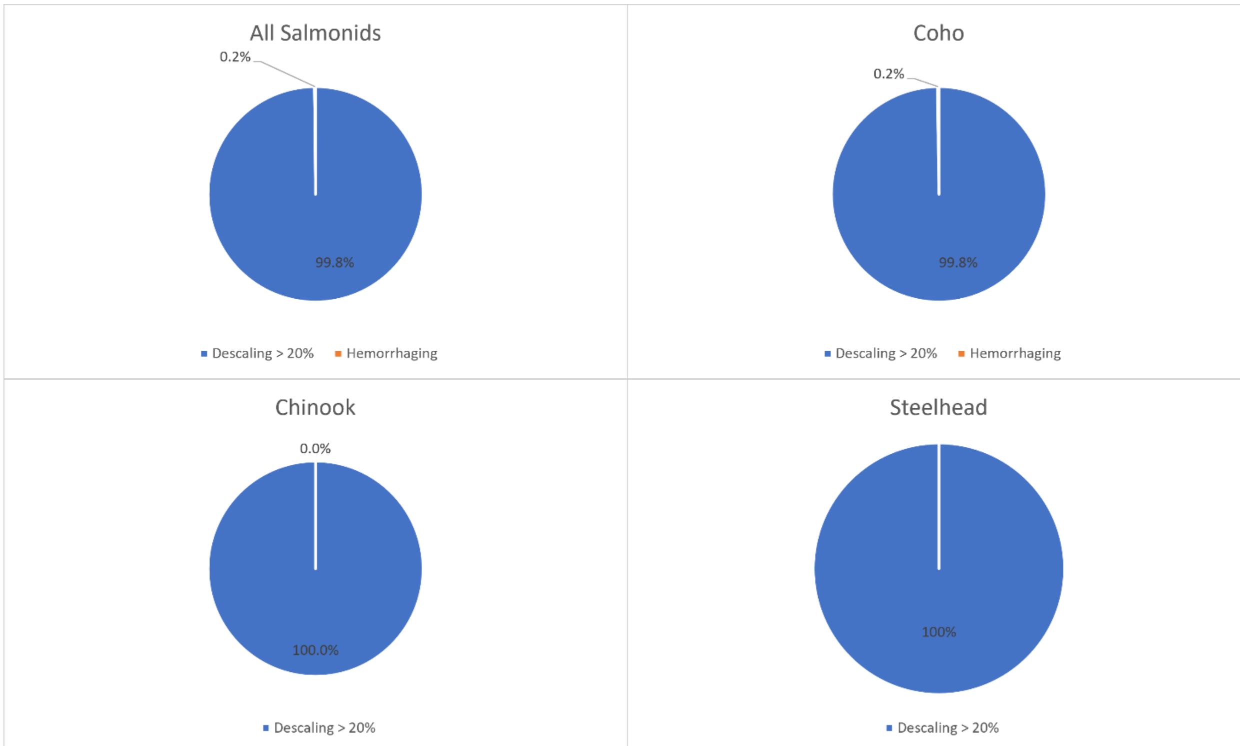

Figure 3.5-1. Composition of injury type occurrences by species in 2022. Percentages reflect the proportion of injury type observed of the total number of fish injured, not the total number of fish evaluated. Percentages reflect parr and smolts numbers sampled that are referenced in Table 3.5-3.[18]

[18] Note: Zero Cutthroat sampled were injured in 2022.

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 98.9 to 99.3 percent (Table 3.5-4), demonstrating a considerable increase in survival rates in 2022, relative to recent years. 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 that were completed in the winter of 2021, have dramatically improved debris management and removal, both from a personnel safety standpoint as well as from a fish health standpoint. 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 four mortalities were observed among the 586 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 four 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	99.3	99.8	99.1 ± 0.08
Chinook	96.5	96.0	92.6± 0.71
Steelhead	98.9	100.0	98.9 ± 0.35
Cutthroat	99.5	100.0	99.5± 0.73
Overall	**99.2**	**98.2**	**97.4 ± 0.09**

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	73	13,692	99.5	99.3 ± 0.1
Coho Smolts	183	24,548	99.3	
Chinook Parr	0	190	100.0	96.5 ± 0.8
Chinook Smolts	73	1,908	96.2	
Steelhead Parr	0	35	100.0	98.9 ± 0.4
Steelhead Smolts	34	3,139	98.9	
Cutthroat(< 13 inches)	2	361	99.4	99.5 ± 0.8
Cutthroat (> 13 inches)	1	60	98.3	
Total	366	43,933	99.2± 0.1	
Steelhead Adults	2	45	95.6	95.8 ± 4.6
Steelhead Kelts	1	27	96.3	
Bull Trout	0	16	100.0	100.0

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)	592	1	99.8 ± 0.3
Chinook (Parr/Smolt)	498	20	96.0± 1.7
Steelhead (Parr/Smolt)	40	0	100.0
Cutthroat (Parr/Smolt)	40	0	100.0
Overall	**1,170**	**21**	**98.2 ± 0.8**

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

Species	No. of Mortalities [A]	No. Sampled	Survival% (CS)
Coho Fry	4	535	99.6 ± 0.72
Chinook Fry	0	30	100.0
Steelhead Fry	0	19	100.0
Cutthroat Fry	0	2	100.0
		Overall:	**99.6 ± 0.7**

[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 2022.

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. Once these facilities are operational, the M&E Plan will be updated to include study protocols designed to determine turbine entrainment and loss.

3.7 Overall Downstream Survival

3.7.1 Overview/Methods

The Settlement Agreement (SA) requires that the Utilities achieve an overall downstream survival (ODS) rate of greater than (or equal) to 80 percent[19]. 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 SA 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 SA 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., below Merwin Dam). Estimates of ODS shall be 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. Also stipulated in the 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.

Developing an annual estimate of ODS Swift Reservoir is required under Section 4.1.4 of the Settlement Agreement and is identified as Objective 1 of the M&E Plan. Historically, estimates of ODS were derived through releases of PIT tagged fish collected 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 Swift FSC indicate that a considerable number of juvenile anadromous fishes likely migrate into Swift Reservoir out-side 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.). Also, previous calculations of ODS calculated for all cohorts of individual species exiting Swift Reservoir annually and did not account for cohort specific estimates of ODS. Tagging and subsequently capturing enough tagged fish at the Swift FSC to make meaningful inference also compromised previous estimates of ODS.

The revised 2022 M&E plan addresses the issues surrounding earlier attempts to calculate ODS by recommending a two-year feasibility study to assess alternatives for increasing the number of PIT tag fish released at the head of Swift Reservoir, which could lead to more accurate estimates of the total number

[19] An ODS of greater than or equal to 80 percent is required until such time as the Yale Downstream Facility is built, 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.

of juvenile fish entering Swift Reservoir (addressed in Section 3.1 above) and overall downstream survival.

The goals of the two-year feasibility study are to:

- Determine if overall downstream survival parameters are not significantly different ($p = 0.10$) between naïve fish of similar size/age class (fish tagged and released before entering Swift Reservoir) compared to non-naïve fish (captured and tagged at the Swift Floating Surface Collector (Swift FSC) then transported and released upstream at the head of Swift Reservoir).

- Determine if substantially more juvenile salmonids can be captured and tagged by running a screw trap at the head of Swift Reservoir over a longer seasonal time period and/or if tributary sampling and tagging may be more effective.

- Estimate the total number of juvenile target species captured and transported downstream of the Swift FSC by size/age class.

Following the current M&E Plan, the first year of the two-year the feasibility study was initiated in 2022. Additional information on the purpose of the feasibility study as well as a detailed outline of methodologies are discussed in Objectives 2 and 7 in the M&E Plan. The general methods preformed in during the 2022 effort included:

- A similar number and size of each target species were PIT tagged at the Swift FSC and at the Eagle Cliff Screw Park screw trap.

- All salmonids captured ≥ 60mm in length were anesthetized, identified to species, measure to length, tagged with a 12mm PIT tag, and released upstream of the Eagle Cliff Park screw trap near the confluence of Pine Creek. Recaptures of fish at the Eagle Cliff Park screw trap were used to aid in estimating trap efficiency (discuss in Section 3.1 for Objective 7, Task 7.2 above).

- All fish captured at the screw trap large enough to receive a PIT tag were tagged, however monthly tagging goals were established for fish collected at the Swift FSC (Table 3.1.1) as to not to remove to many juveniles from downstream transport.

- All PIT tag records, which included information on fish species, size at tagging, PIT tag ID, and timing and location of collection and release were imported into PITAGIS.

- The fixed antenna detection sites located at the Swift FSC and Woodland Release Ponds was used track individual fish as they successfully passed downstream through the trap and haul system.

- Monthly collection efficiency evaluations were used as a control to establish a baseline of PIT antenna detection efficiency during operation of fish passage facilities.

3.7.2 Results/Discussion

A summary of data collected during this initial year of the two-year feasibility study has been previously provided in Section 3.1 above. No estimates of ODS were derived in 2022. The second year of the feasibility study will be completed in 2023, which will include additional fish being release from the Swift FSC and the Eagle Cliff screw trap, as well as perform electrofishing surveys in tributaries to Swift Reservoir in an attempt to collect and PIT tag additional juvenile fish before they enter Swift Reservoir. Detection data of these additional fish will be combined with those already collected in 2022 to evaluate whether a difference in recapture probability between naïve and non-naïve release groups by size/age class exists, and ultimately whether fish tagged at the Swift FSC can be used to bolster fish releases at the head of Swift Reservoir to estimate fish abundance and overall downstream survival. Because it is anticipated that fish tagged during both years will pass over multiple seasons (that is, in year one or year two after release), it is expected that the final report summarizing the results of the two-year feasibility study will be completed in in 2024.

Once the feasibility study has been concluded, Results of the study will be presented to the ATS and evaluated to determine to best course of action for meeting the required sample size requirements for calculating ODS in the future. At that time a long-term methodology will be developed and proposed in consultation with the ATS, and/or additional recommendations will be made to further refine a selected methodology.

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 47,729 fish were captured at the Merwin Trap in 2022, which is the greatest number of adults collected at the facility since it was commissioned in 2014 (Table 4.1-1). Among the species collected, early Coho accounted for the largest proportion of fish captured (n=21,685), followed by late Coho (n= 13,545), spring Chinook (n=4,919), summer Steelhead (n=4,377), winter Steelhead (n=2,656), fall Chinook (n=430), Cutthroat (n=102), sockeye salmon (n=12), and chum salmon (n=3).

Of the 4,377 summer Steelhead collected at Merwin trap in 2022, 3,138 were naïve (had not previously encountered the Merwin Trap), while 1,239 were recaptured as part of WDFW’s Recreational Angler Recycle Program. A total of 2,023 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 five-year-old adults in 2022. Of the 4,919 spring Chinook collected in 2022, 21 (0.4 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 unlikely that many fish from this release group will be collected in future years, as six-year-old spring Chinook are exceedingly rare on the Lewis River. Overall, 117 Spring Chinook originating from the 2018 direct releases of 100,000 acclimation fish into the lower river below Merwin Dam have returned as jacks or adults. A total of 22 fish returned as jacks in 2020, 74 as four-year adults in 2021, and 21 in 2022. This resulted in a smolt-to-adult survival rate (SAR) of 1.2 percent for this release group.

A total of 165 PIT tagged adult salmonids returned to the Merwin Trap in 2022 (96 Coho, 30 Steelhead, 18 Cutthroat, 17 Chinook, and 4 tags with no origin, or “orphan tags”). All PIT tag interrogation records collected at Merwin Trap were uploaded to the PTAGIS database.

A total of 5,102 early Coho, 4,443 late Coho, 3,600 spring Chinook, 594 wild winter Steelhead (blank wire tag and NOR combined), and 102 Cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2022 (Table 4.1-2). More fish were transported upstream in 2022 than in any other year since the facility was commissioned in 2014 (Table 4.1-3). Of the fish transported upstream, Lewis River Hatchery provided 367 spring Chinook, 281 early Coho, 38 late Coho, and one wild winter Steelhead for upstream transport. All remaining fish transported upstream were collected at the Merwin Trap. Of the wild winter Steelhead transported upstream, 458 were blank wire tag fish while 136 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 2022. 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]	1,704	1,518	290	389	368	108	322	210	10									**4,919**	10.3
Fall Chinook	108	129	36	6	1	5	53	45	47									**430**	0.9
Early Coho	6,906	7,702	1,395	1,527	1,837	218	920	939	241									**21,685**	45.4
Late Coho	4,359	5,441	631	723	845	184	622	598	142									**13,545**	28.4
Summer Steelhead	1,097	2,031					2	8							357	882		**4,377**	9.2
Winter Steelhead	978	1,026					90	96					316	150				**2,656**	5.6
Sockeye Salmon							11	1										**12**	0.0
Chum Salmon							3											**3**	0.0
Pink Salmon																		**0**	0.0
Cutthroat (>13 inches)																	102	**102**	0.2
Cutthroat (< 13 inches)																		**0**	0.0
Rainbow (< 20 inches)																		**0**	0.0
Bull Trout (> 13 inches)																		**0**	0.0
Bull Trout (< 13 inches)																		**0**	0.0
																	Total	**47,729**	**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 2022 (totals include Merwin Trap and Lewis River Hatchery Trap captures).

Species	Male	Female	Jack*	Not sexed	Female:Male Ratio	Jack:Adult Ratio	Total
Spring Chinook	1,886	1,428	286	-	0.66	0.09	***3,600***
Early Coho	2,297	2,561	244	-	1.01	0.05	***5,102***
Late Coho	2,005	2,290	148	-	1.06	0.03	***4,443***
Winter Steelhead	374	220	-	-	0.59	-	***594***
Cutthroat (>13 inches)	-	-	-	102	-	-	***102***
Bull Trout (>13 inches)	-	-	-	-	-	-	***0***
						Total	***13,841***

* Jacks are defined as any Chinook salmon less than 24 inches and any Coho salmon less than 20 inches.

Table 4.1-3. Annual totals of salmonids transported upstream of Swift Dam for years 2013 through 2022.

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	3,999	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
2022	4,302	4,851	392	1,886	1,428	286	374	220	102	13,841

* Jacks are defined as any Chinook Salmon less than 24 inches and any Coho Salmon less than 20 inches.

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. 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 13,841 adult salmonids (5,102 early Coho, 4,443 late Coho, 3,600 Spring Chinook, 594 winter Steelhead, and 102 Cutthroat) were transported upstream in 2022, which is greater than any other year since the commissioning of the new Merwin Trap in 2014 (Table 4.2-1). Upstream passage survival continued to be very high for all transport species collected at the Merwin Adult Upstream Collection Facility, transported by truck, and released above Swift Reservoir. No species had a combined survival rate of under 99 percent. Of the 15 mortalities observed (all but one being Coho), nearly all (n = 12) occurred during passage through the facility compared to during truck transport. Additionally, this facility mortality was also largely the result of a single event occurring in the fall during peak migration Coho migration season. All mortality of natural origin fish were reported on the annual Incident Take Form provided by NOAA as stipulated in the current Biological Opinion and also included in Section 3.3.20 of the ACC/TCC 2022 Annual Report.

Table 4.2-1. Overall upstream passage survival for Merwin Trap in 2022.

Species	Number Transported	Trap Mortalities	Transport Mortalities	Upstream Passage Survival (%)
Early Coho	5,102	11	3	99.7
Late Coho	4,443	0	0	100
Spring Chinook	3,600	0	0	100
Winter Steelhead	594	0	0	100
Cutthroat	102	1	0	99.0
Total	**13,841**	**12**	**3**	**99.9**

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 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 has been conducted since 2020.

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 due 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 2020) and the Upstream Transport Plan (PacifiCorp 2009); and 2) guide the ACC in determining how to direct restoration efforts with the Aquatics Fund.

To fulfill this requirement, the licensees previously conducted comprehensive spawning ground surveys for adult Coho in the accessible river and stream reaches upstream of Swift Dam from 2012 through 2021 (reported annually in the Lewis River Fish Passage Annual Reports). Since 2012, spawning surveys specifically for adult spring Chinook were conducted in 2013, 2017, 2018, and 2021 when sufficient adults (more than 100 adult females) were transported upstream. Developing a sampling design to determine late winter Steelhead spawn timing, distribution and abundance upstream of Swift Dam has historically been challenging due to several factors including the large area, remoteness, seasonally poor access due to snow accumulation and/or high stream flows, and high turbidity from snow melt during the spawning season. Given these challenges, the licensees have conducted a combination of targeted redd surveys and aerial monitoring of radio tagged fish, but with limited success (see current M&E Plan (PacifiCorp and Cowlitz PUD 2022) for further information).

Through discussions within the ATS during the development of the current M&E Plan, it was determined that spawning ground surveys for adult Coho over the past nine years provided sufficient information regarding the distribution and timing of Coho spawning. However, the estimates of spawner abundance via redd based surveys are likely biased due to survey conditions, time periods, and violations of assumptions identified in the M&E Plan. Overall, these biases likely result in an underestimate of the total number of Coho redds each year, resulting in an underestimate of the proportion of transported Coho that spawned. Conversely, this has likely resulted in an overestimate of the proportion of fish that did not spawn.

While the adult Steelhead spawning survey data is less rich than Coho surveys, the information gathered to date suggests that adult Steelhead distribute widely throughout the watershed upstream of Swift Dam, and the targeted spawning surveys are thought to have adequately bounded Steelhead spawn timing.

Given the logistical constraints to improving estimates of spawner abundance, combined with the fact that adults transported upstream of Swift Dam are censused (i.e., known quantity transported upstream), the ATS deemed it was appropriate in 2022 to temporarily suspend Coho and winter Steelhead spawning surveys and adult Steelhead radio telemetry monitoring over the next five years (PacifiCorp and Cowlitz PUD 2022). The ATS will reevaluate the need for this information during the next review and rewrite of the M&E Plan schedule for 2027.

Due to lack of abundance of spring Chinook transported upstream of Swift Dam, spawning surveys have only been conducted in three of the last nine years. The ATS felt that surveys to determine spawn timing, distribution, and abundance of adult spring Chinook should continue annually to verify the trends observed in 2017, 2018, and 2021. Similar to previous years, surveys are to be conducted when sufficient adults (at least 100 female Chinook) are transported upstream to spawn using methods outlined in Objective 15 of the current M&E Plan.

While the overall distribution pattern of Coho spawning upstream of the Swift Reservoir full pool elevation is well understood based on the surveys conducted annually since 2012, in most prior survey, approximately 30 to 50 percent of adult Coho transported upstream did not spawn within the accessible stream habitat upstream of the full pool elevation of Swift Reservoir. The ATS hypothesized that the proportion of Coho transported upstream that did not successfully spawn was attributed to some level of pre-spawn mortality plus any Coho that spawned in the stream channels within the drawdown zone of Swift Reservoir. A preliminary analysis evaluating pre-spawn mortality of Coho adults in tributaries throughout the lower Columbia River basin revealed that rates are generally less than 10 percent for natural-origin spawners. Also, there has been no previous indication of abnormally high pre-spawn mortality occurring during Coho spawner surveys conducted in the upper basin of the Lewis River since 2012. With the information the ATS concluded that the proportion of Coho estimated to not successfully spawn may likely be the result of Coho spawning in the drawdown zone of Swift Reservoir – a zone that had not been previously surveyed. To better understand the use of this temporarily exposed region of the reservoir in the fall by spawning adult Coho, the ATS developed a five year survey of the reservoir drawdown zone to estimate the number of female Coho spawning in the drawdown zone annually. The methods used to estimate the number of female spawners in the drawdown zone are outlined in Objective 15 of the current M&E Plan.

4.4.2 Results/Discussion

Chinook Salmon

Chinook salmon spawning surveys were conducted from late-August through mid-October 2022. Per Objective 15 of the current M&E Plan, 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. Nearly all accessible habitat was surveyed at least twice during the Chinook spawning period from September to early October. Due to low stream flows and excellent visibility throughout the majority of streams during the spring Chinook Spawning period and measured redd visibility over time, we estimate that Chinook redd detection probability ranged between 0.80 to 0.90 during the Chinook spawning season. A few reaches were not surveyed due to accessibility issues, such as upper Clear Creek, which cannot be accessed due to steep impassable canyon walls.

A total of 908 Chinook redds were counted by surveyors in 2022. A total of 56 percent of redds were counted in the mainstem NF Lewis River, 33 percent were counted throughout the Muddy River watershed, and 4 percent were counted in the Pine Creek watershed. The remaining redds were distributed in smaller tributaries with enough water for spring Chinook to access, such as Drift, Swift, Little, and Rush Creeks. The spatial distribution of Chinook redds was more extensive in 2022 than in all previous years combined. Most notably, spawning was observed for the first time in 2022 in the mainstem of Pine Creek, in the P8 tributary of Pine Creek, and Rush Creek (NF Lewis River tributary). Four actively spawning spring Chinook adults and three Chinook redds were observed in the recently re-routed stream channel portion of Rush Creek below the Forest Road 90 bridge in September 2023. The Rush Creek channel was re-routed earlier in the summer of 2022 as part of a restoration project completed by the U.S. Forest Service under PacifiCorp's Aquatic Fund. Also of note is that a total of 60 redds (6.6 percent of total) were counted in Smith Creek, but from 2012-2021, only one Chinook redd total was observed in Smith Creek. Swift Creek had a total of 37 redds (4 percent) in 2022, but only five redds total (1 percent) from 2012-2021. 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 2022 survey season, which is consist with prior years' observations.

Chinook redd counts were used to make estimates of total redds by watershed. Total Chinook redds were estimated at 1,117 (bootstrap 95 percent confidence interval of 796 to 1,405). Based on the expanded total redd estimate, most redds (55 percent) were estimated in the NF Lewis River strata (NF Lewis River mainstem, and Little and Rush creeks); 36 percent were estimated in the Muddy River watershed strata (Muddy River mainstem, and Clear, Clearwater, and Smith creeks); 5 percent were estimated in the Swift Reservoir strata (Swift and Drift creeks); and 4 percent were estimated in the Pine Creek watershed strata (Pine Creek mainstem and P8 Creek).

Using the adjusted estimate of total redds based on the range of assumed detection probability and assuming one spawning spring Chinook female per redd (Murdoch et al. 2009), yields an estimate of 0.78 (bootstrap 95 percent confidence interval of 0.56 to 0.98) as the proportion of transported female Chinook that spawned in 2022. The 2022 estimate is based on the largest cohort of Chinook females transported upstream of Swift Dam to spawn, and the confidence interval of the estimate is most precise among the four years. However, the estimated proportion of spawning females is the lowest among all four years.

While it is important to note that surveys in 2017 and 2018 followed the subsampling approach described previously, whereas surveys in 2021 and 2022 attempted to survey all available Chinook spawning habitat, which may have contributed to increased precision in the 2021 and 2022 estimates compared to 2017 and 2018, it this is likely that this may be related to a spill event that occurred at Swift Dam. A planned spill event to test the spill gates at Swift Dam began on June 11, 2022 and lasted for approximately 52 hours. By June 10, 80.5% of adult spring Chinook had already been transported upstream of Swift Dam. Based on observations of spring Chinook pre-spawn holding behavior, adult Chinook frequently hold in the vicinity of Swift Dam during the summer months. It is likely that some adult Chinook passed downstream during the June spill event, which is evidenced by the observations of several hatchery-origin adult Chinook spawning in Cougar Creek (Yale Reservoir tributary) in fall 2022 and Chinook fry in the Cougar Creek screw trap catch in May 2023. If adult Chinook passed downstream via spill in June 2022, then the number of adult female Chinook used in the spawner success estimate is over estimated, which causes the spawner success estimate to be underestimated. For the reason listed above, we believe there is potential that the total Chinook redd count and estimated proportion of females that successfully spawned may be underestimated in 2022. The report summarizing these data in more detail provided in Appendix E.

Swift Reservoir Drawdown Zone Spawning Surveys for Chinook and Coho Salmon

Only three Chinook redds were counted within the DDZ of Swift Reservoir, all within the Swift Creek drawdown channel. Two redds were counted on September 19 and one redd was counted on October 13. Redds counted in the Swift Reservoir DDZ are not included in the redd count summary presented above. Three total redds is less than 1 percent of the total Chinook redds counted upstream of Swift Dam in 2022. Even assuming a very low detection probability of 0.3 yields a total DDZ Chinook redd estimate of about 1 percent of the total redds counted upstream of Swift Dam in 2022. Assuming one female Chinook per redd, it is likely that the proportion of total Chinook females that spawned in the Swift Reservoir DDZ was well below 1 percent during the 2022 spawning season. See Appendix D for further details.

A total of 51 Coho redds were counted in the Swift Reservoir DDZ. The Swift Creek drawdown channel contained the most redds (37 percent), followed by the NF Lewis River Mainstem (20 percent). Coho redds were observed in all DDZ channels of all streams previously documented to be used by Coho for spawning except S20 and Forest Camp creeks. Very little water from S20 and Forest Camp creeks reached Swift Reservoir due to low flows and percolation into the underlying substrate, which likely limited potential DDZ spawning associated with these streams. Most Coho DDZ spawning occurred when the reservoir water elevation was below 975 ft-msl. The lowest reservoir water surface elevation occurred between December 13 and 24, and about 35 percent of all Coho DDZ redds were observed during this time.

The total number of Coho redds in the DDZ was estimated per the methods described in the M&E Plan. Coho redd detection probabilities were assumed to range between 0.3 and 0.6 in previous years' analyses for spawning surveys conducted upstream of Swift Dam within accessible stream reaches. Assuming the redd detection probability in the DDZ was actually 0.3, a total of 178 redds were estimated in the Swift Reservoir for the 2022 spawning season (bootstrap 95 percent confidence interval of 87 to 269). Assuming the upper end of the 95 percent confidence interval at the lowest assumed detection probability (0.3) results in the highest estimate of potential drawdown zone spawners, 269 Coho females, assuming one spawning Coho female per redd. This represents 5.6 percent of the total number of females transported upstream of Swift Dam during 2022. Therefore, at most, approximately 5.6 percent of the female Coho transported upstream of Swift Dam in 2022 spawned in the Swift Reservoir DDZ.

Surveys suggest that very few Chinook and few Coho spawned in the Swift Reservoir DDZ during the 2022 spawning runs. Swift DDZ surveys will continue to be conducted in 2023. Detection probability will continue to be assessed and refined for the Swift DDZ and estimates of Chinook and Coho spawners will be revised as warranted at the end of the five-year DDZ spawning survey study. Objective 15 of the M&E Plan also stipulates that pre-spawn mortality will be assumed to fall within the range generally observed within the region by WDFW. The pre-spawn mortality range for Chinook and Coho will be incorporated into the spawning estimates presented in this document once provided by WDFW to further refine the estimate of the total number of successful Chinook and Coho spawners upstream of Swift Dam for the 2022 run. The report summarizing these data in more detail provided in Appendix E.

Winter Steelhead

Late winter Steelhead spawn timing and distribution has been determined by a combination of on-the-ground spawning surveys of reservoir tributary index reaches, and radio tracking using both fixed stations and aerial surveys in select years since 2014. While the adult Steelhead spawning survey data is less robust than the Coho survey data set, the information gathered to date demonstrates that Steelhead adults distribute throughout the potential available spawning habitat, and established methodology indicates that pre-spawn mortality is likely not a limiting factor to recovery. Therefore, adult Steelhead spawning surveys and radio telemetry monitoring will also be suspended unless an additional need is identified as the reintroduction program progresses over time.

Objective 15 of the M&E Plan also stipulates that pre-spawn mortality will be assumed to late winter Steelhead within the range generally observed within the region by WDFW. Once provided by WDFW, when pre-spawn mortality range for late winter Steelhead will be used to estimate the total number of successful Steelhead spawners upstream of Swift Dam for the 2022 run per the methods given described in the M&E Plan.

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 when hatchery production levels should be reduced (per SA Section 8.3.2.3). A detailed description of the methodology for this analysis is outlined in Objective 12 of the current M&E Plan. The M&E Plan describes three different methods for estimating recruitment: 1) return-year recruitment estimates; 2) migration year recruitment; and 3) brood year recruitment estimates.

For Coho adults (i.e., excluding jacks) definitions 1, 2, and 3 above are the same, because returning adults largely come from the same brood year and migration year.

Spring Chinook and late winter Steelhead have more diverse life histories, and the three estimates will generally be different. Return year recruitment tends to reflect variation in exploitation rates during a given return year. Migration year recruitment tends to be correlated with early marine survival, because mortality is high during the transition from freshwater to the marine environment and varies considerably depending on ocean conditions. Brood year recruitment is used to estimate recruits per spawner (R/S) and the smolt-to-adult survival rate (SAR) and thus provides information about productivity, especially when recruitment estimates are available for a range of spawning escapements over 10-15 years.

For the purpose of estimating ocean recruits for all three reintroduction species spawning upstream of Merwin Dam, the M&E Plan stipulates that brood year recruitment will be used. The methods to be used for this analysis are outlined in Objective 12 of the M&E Plan. Information from this analysis will also be used to calculate the performance measures outlined in Objective 13 of the M&E Plan and discussed below in Section 6.0.

5.2 Results/Discussion

No Ocean Recruit analysis was conducted in 2022. Based on the current M&E Plan, 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 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 2020) 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 (PacifiCorp and Cowlitz PUD 2022).

Similar to the analysis of Ocean Recruitment discussed in Section 5.0 above, the current M&E Plan (2022) stipulates the performance metrics for index stocks will be developed for each brood year and species throughout the term of the licenses when NOR returns to Merwin meet the adult thresholds identified in Table 5.2-1. However, since 2020, a coarse calculation of annual performance metrics (recruits per spawner, smolts per spawner and SAR) has been made for returning adult NOR Coho and winter Steelhead to provide some generalized indication of how those stocks are performing. To date, no attempt has made to derive performance metrics for adult spring Chinook, as there have been too few NOR adults to make even a generalized estimate of performance.

Similar to 2020 and 2021, there were generally enough NOR Coho and winter Steelhead returning from the upper basin above Swift Dam to make some inference on performance metrics in 2022. Because of 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, it was deemed that the number of returning adults in 2022 (n=542) was not sufficient for even a generalized estimate of stock performance. As a result, this analysis was again omitted for spring Chinook in 2022.

Productivity for returning adult Coho and winter Steelhead was calculated as R/S, or the number of adult offspring produced per parent. For Coho, the number of adults transported above Swift Reservoir in 2019 was used to represent the number of spawners (S), and those NOR adults returning to the Merwin Trap in 2022 were the recruits (R). Jacks were not included in this analysis. For winter Steelhead, the number of adults transported in 2018 was used as spawners (S) for the adults returning to Merwin Trap in 2022, which were the recruits (R).

In addition to R/S, generalized performance was also estimated for returning Coho and winter Steelhead in 2022 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 2021 were used, and for winter Steelhead all smolts out-migrating in 2020 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 2022. A majority of returning adult Coho that had PIT tags from the upper basin in 2022 (91 of 93, or 98 percent) were tagged in 2021. To address this, 2 percent of returning adult Coho in 2021 were assumed to be from smolts out-migrating in a year other than 2021. Few juvenile winter Steelhead were tagged at the FSC in 2020 (n=326) and sent immediately downstream. Additionally, just eight (8) 2022 returning adult wild winter Steelhead had been previously PIT tagged, resulting in too few data to make any meaningful inference. Because of this, we are assuming all returning adult Steelhead in 2022 were from 2020 out-migrating smolts. Data from 2020, a year of decent available data, suggests this assumption is reasonable as 94 percent (n=34) 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 account for 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 2022 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 2022, 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 0.64 and 0.14, respectively. Both R/S values being less than one signifies that recruitment in 2022 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 (7.5 percent) and winter Steelhead (4.1 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 (3.0 percent) and blank wire tag (BWT) winter Steelhead (0.8 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 8.6 for Coho (2021 out-migrants from 2019 parents) and 3.3 for NOR winter Steelhead (2020 out-migrants from 2018 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 the '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 13.3 for NOR Coho and 24.4 for NOR winter Steelhead (Table 6.2-1). The collection efficiency of the FSC is likely a major bottleneck holding R/S values below one. For instance, the FSC collection efficiency was 40 percent for Coho (2021) and 42 percent for wild winter Steelhead (2020). To achieve a smolt per spawner for replacement (R/S ≥ 1) in 2022, collection efficiency would have needed to be at least 62 percent for 2021 wild Coho smolts and over 100 percent (about 300 percent) for 2020 wild winter Steelhead smolts. Even if collection efficiency rate for Steelhead smolts reached 100 percent, other factors influencing smolt production (e.g., flood scouring, sex ratio, weather patterns, residualism, poor spatial distribution of spawning adults, in-reservoir predation, low egg to fry survival, etc.) would keep the R/S below 1.

Table 6.2-1. Performance metrics for 2022 returning natural origin adult Coho and late-winter Steelhead.

Species	Adults Transported Above Swift Dam [A]	Smolts Transported Downstream [B]	NOR Adults Returning to Lewis River 2022	Smolt to Adult Return (SAR%) [E]	Recruit per Spawner (R/S)	Smolt per Spawner [F]	Smolt per Spawner for Replacement [G]
Coho	5,319	45,691	3,417 [C]	7.5%	0.64	8.6	13.3
Late-Winter Steelhead	1,225	4,063	167 [D]	4.1%	0.14	3.3	24.4

A For Coho, the number of adults transported in 2019 were used to represent the number of spawners (S), and for winter Steelhead, the number of adults transported in 2018 were used as spawners (S).
B For Coho, smolts out-migrating in 2021 were used as recruits (R), and for winter Steelhead all smolts out-migrating in 2020 were used.
C Value is all NOR adults (less 2% 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 Value 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.
E Note assumption needed to be met for these estimates to be accurate likely have not been met.
F The smolts in this smolt per spawner ratio are smolts that were captured at the FSC and transported downstream alive. This is not the 'produced' number of smolts that would typically be calculated in a passable riverine system.
G 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 2022 return year.

Table 6.2-2. Smolt to adult performance metrics for 2022 returning adult hatchery Coho and late-winter Steelhead. Data provide by WDFW and can be found in the Lewis River Complex 2022 Annual Report.

Species (HOR)	Smolts Downstream	Adults Returning to Lewis River 2022	Smolt to Adult Return (SAR%)
Coho	2,206,115	65,767	3.0%
Late-Winter Steelhead (BWT)	57,498	466	0.8%

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 U.S. Geological Survey (USGS) / University of Washington (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

During 2022 data collection activities, fin clips were gathered from all encountered fish species from areas within Pine and Rush creeks and the Swift Reservoir. In all, 637 samples were collected and sent to the lab for stable isotope analysis. Results of the analysis and a Final Report will be completed in late 2023.

The LRBTRT identified the tasks below to be completed in 2023:

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 DETERMINING ACHIVEMENT OF OUTCOME GOAL

Determining when the outcome goal for fish reintroduction has been achieved is stipulated in Section 3.1.1 of the Settlement Agreement and is described in Objective 20 of the M&E Plan. Although it is the responsibility of the Services, the Utilities are interested in playing a significant role in putting forth viable approaches for the Services to consider in establishing the reintroduction Evaluation Methodology. The H&S Plan (PacifiCorp and Cowlitz PUD 2020) provides some ideas as to what type of information should be considered in determining program success. In general, the H&S Plan suggests:

1. Using other lower Columbia River spring Chinook, Coho and Steelhead as index stocks to track out-of-basin effects on the success of the Lewis River program.

2. Tracking similar reintroduction efforts on the Cowlitz River and other lower Columbia River tributaries.

3. Calculating annual harvest rates, smolt-to-adult survival rates, juvenile production, etc., to estimate when runs are self-sustaining.

Methods for conducting each of the three analyses are presented in different sections of the current M&E Plan and reported on this report. Yet to be defined is a numeric adult goal that dictates when run-size is sufficient for achieving both recovery and harvest goals. Until the Services develop numeric goals per Section 3.1.1 of the Settlement Agreement, the natural adult abundance targets presented under Objective 12 of the M&E Plan (Ocean Recruits; Section 5.0 above) will be used as the benchmarks for determining the success of the reintroduction effort.

In addition to these suggested analyses, a series of Integrated Population Models (IPMs) are to be developed and used to independently estimate adult and juvenile productivity and capacity, adult brood-year recruitment (ocean recruits), R/S and SARs for Coho, spring Chinook, and late winter Steelhead upstream of Swift Dam. IPMs are a type of life-cycle model that may be used to evaluate the potential effects of management activities and environmental variability on salmonid populations. A detailed description of IPMs and how they will be used to aid in determining the overall outcome goal in provided in Objective 20 of the M&E Plan. Model development began in late 2022 with the goal to have modeling of Phase 1 of the Reintroduction Program completed by the 5th year of this M&E Plan implementation

(2026), and prior to when downstream passage facilities are required to be operational at Yale Dam. It is also intended that these models will be refined over time as additional passage facilities are added.

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APPENDICES

APPENDIX A

LEWIS RIVER NUTRIENT ENHANCEMENT – 2022 PROGRESS REPORT

Lower Columbia Fish Enhancement

Lower Columbia Fish Enhancement Group (LCFEG) used ACC funds to conduct the first of four seasons of Nutrient Enhancement activities on the North Fork Lewis watershed. From October 2022-January 2023, LCFEG worked closely with WDFW hatchery staff and volunteers with Clark Skamania Fly Fishers to disperse a total of **4,579 Coho carcasses** into the basin. Carcass dispersal focused on the Muddy River and Pine Creek in the Upper Lewis, and Cedar Creek below Merwin Dam.

In total, LCFEG placed 982 carcasses into Pine Creek, an additional 1079 were placed into the Muddy, and 2518 were dispersed at various sites on Cedar Creek. This work could not have been accomplished without the assistance from LCFEG's long time partners at Clark Skamania Fly Fishers. Club members dedicated a total of **130 volunteer hours** to the project, assisting in tail cutting and carcass placement.

LCFEG staff spoke with one landowner along Cedar Creek who was excited that the program was starting back up again. While placing carcasses in the upper watershed, they spoke with several members of the community, who were glad this type of work was being done.

Plans for 2023 season include conducting outreach with landowners on Cedar Creek to gain access to additional carcass placement sites on the creek. LCFEG also plans to coordinate with USFS on additional sites within the Gifford Pinchot National Forest.

APPENDIX B

YALE HABITAT PREPARATION PLAN - 2022

Yale Habitat Preparation Plan

Yale Reservoir, North Fork Lewis River

August 4, 2022

I. Introduction

The purpose of this plan is to provide the necessary logistics and methods necessary to collect, transport, and distribute hatchery origin coho beyond those needed for Lewis River hatchery programs and above Swift Reservoir supplementation and reintroduction needs into Yale Reservoir (Figure 1). Coho salmon above hatchery and reintroduction needs are referred to as "excess hatchery coho". This plan proposes to transport and release excess hatchery coho into Yale Reservoir as part of the Habitat Preparation Plan (HPP) specified under Section 7.4 of the Lewis River Settlement Agreement.

7.4 Habitat Preparation Plan. Within six months after the Effective Date, PacifiCorp shall develop a plan (the "Habitat Preparation Plan") in Consultation with the ACC to release live adult hatchery anadromous salmonids into Swift Reservoir, Yale Lake, and Lake Merwin for the purpose of preparing the habitat in those locations for the reintroduction of anadromous salmonids. The objective of the Habitat Preparation Plan will be to make possible (1) nutrient enrichment in the waters through decay of the adult hatchery fish and, (2) tilling of the gravel by the released hatchery adults as they attempt to spawn. The number, sex, and species of hatchery adult salmonids shall be determined as part of the Habitat Preparation Plan. PacifiCorp's performance obligation under the Habitat Preparation Plan shall be limited to placing live adult hatchery anadromous salmonids for a period of five years in each of Swift Reservoir, Yale Lake, and Lake Merwin, commencing in each case five years prior to expected completion of the downstream fish passage facility from that reservoir. PacifiCorp shall implement the Habitat Preparation Plan at Swift Reservoir beginning as soon as practicable after the Habitat Preparation Plan is finalized and at the other reservoirs as provided in the Habitat Preparation Plan. PacifiCorp shall implement this program only to the extent there are excess hatchery fish available beyond those required for the Hatchery and supplementation Plan described in Section 8. PacifiCorp shall not be required to pass or collect the progeny of hatchery adult anadromous salmonids introduced under the Habitat Preparation Plan unless and until collection and transport facilities for such progeny are constructed in accordance with Section 4. For the Merwin and Yale Projects, PacifiCorp's obligations under this Section 7.4 shall cease if the Yale Downstream Facility or Merwin Downstream Facility, respectively, will not be constructed pursuant to Section 4.1.9.

II. Summary of past adult releases into Merwin and Yale reservoirs

Merwin and Yale dams were completed in 1931 and 1953, respectively. Soon after completion of each of the dams, efforts were initiated to move primarily coho salmon upstream of each dam. For Merwin, efforts were intended to increase juvenile production in response to precipitous declines in adult returns. After completion of the Yale Dam, coho were released at preselected locations to gain a better understanding of spawning site selection and distribution upstream of Yale.

Merwin Dam (Smith 1943)

Between 1933 and 1942, over 50,000 adult coho were transported and released upstream of Merwin Dam. In 1939, a total of 18,591 adult coho were released upstream of Merwin Dam. Following this release (prior to completion of Yale and Swift dams), Smith observed adult coho in several tributaries of the upper watershed. An estimated 2,000 coho salmon were observed in a large clear pool at the mouth of Clearwater Creek; 464 coho were observed in the Muddy River about one mile upstream from the confluence of Clear Creek; 48 coho salmon were observed in Siouxon Creek and smaller numbers were observed in Speelyai Creek and the mainstem Lewis River upstream of Merwin reservoir. In 1940, a total of 7,155 adult spring Chinook were released upstream of Merwin Dam; however, no observations were made regarding the distribution of these fish.

Cougar Creek holding ponds

To improve hatchery survival and provide additional support, Milo Bell, an engineer for the Washington Department of Game, designed and constructed hatchery holding ponds using source water from Cougar Creek. The holding ponds were completed in 1938 and were used primarily as a holding facility for adult coho and spring Chinook. In 1939, 256 spring Chinook adults from the holding ponds were released into Cougar Creek. A majority of the released adults successfully spawned in Cougar Creek and it was thought, at the time, that it may be possible to develop a natural spawning population of Cougar Creek spring Chinook (Smith 1942). For unknown reasons, the Cougar Creek holding ponds were abandoned in 1942.

Yale Dam (Chambers 1957)

In 1956 (prior to completion of Swift Dam in 1958), John Chambers of the Washington Department of Fisheries and J. Hamilton of Pacific Power and Light conducted a mark-resight study of adult coho released upstream of the Yale Dam. A total of 1,386 adult coho were released upstream of Yale Dam. Of these, 374 were tagged with numbered Peterson discs for later visual recovery (Chambers 1957). Table 1 shows the dates, release locations and recoveries of coho tags during the recovery surveys. Of all tributaries surveyed, Cougar Creek showed the highest incidence of spawning coho salmon. On November 14, 1956, a foot survey of Cougar Creek noted 46 redds, 28 lives, 13 carcasses and 4 tags recovered. Observations of live untagged coho and redds were also reported from both the researchers and anglers in Smith, Muddy, Clear and Clearwater creeks. Reports of redds and tag recoveries were also observed in the mainstem Lewis River upstream of Pine Creek. No redds or salmon were observed downstream of the Pine Creek confluence; however, spawning was observed in Range Creek.

Table 1. Date, release location, release numbers, and tag recovery location of adult coho released upstream of Yale Dam in 1956.

Date	Release Location	Total Release Number	Released with tags	Recovery Location	No. of tags recovered
Sep 4 - 21, 1956	Lewis River above Swift Creek	618	156	Muddy	1
				Cougar Creek*	2
				Smith Creek	1
				LR upstream of Eagle Cliff	2
Sep 23 – Oct 8, 1956	Cougar Creek	589	108	Cougar Creek	2
Oct 9 - 22, 1956	Lewis River above Swift Creek	129	60	Cougar Creek*	1
Oct 22, 1956	Lewis River below Swift Cr.	50	50	Cougar Creek	1
		1,386	374		

* *NOTE: While Swift Dam had not been completed at the time of this evaluation (completed in 1958), the bypass tunnel was completed and in operation. Therefore, tag recoveries in Cougar Creek from coho released above Swift Creek passed downstream through the bypass tunnel to spawn in Cougar Creek (total = 3). No tagged coho released downstream of the bypass tunnel were recovered upstream of bypass tunnel.*

III. Objectives

The transportation of adult hatchery fish into Yale Reservoir is intended to prepare and till Yale tributary stream gravels (through redd construction) and provide marine derived nutrient enhancement to spawning and rearing areas. Under section 7.4, the HPP should be initiated 5-years prior to the expected completion of the Yale downstream fish passage facility.

IV. Stock Selection

In 2022, the habitat preparation program proposes to use early coho salmon for transport and release into Yale Reservoir to take advantage of ongoing bull trout monitoring in Cougar Creek (see Planned Monitoring section). Late or transitional coho salmon may also be used if insufficient early run coho are available for the Yale habitat preparation program. This will be an in-season decision by the ATS once early coho begin returning to the Lewis River traps in September 2022. Adult coho transport to Yale under this plan should be of high quality to facilitate distribution of released coho. Coho salmon showing external signs of trauma (e.g., puncture wounds, lacerations, fungus, etc.) should not be transported upstream whenever possible.

The availability of adults for the Yale Reservoir HPP is dependent on the extent of hatchery fish available beyond those required for hatchery production (broodstock) programs and existing supplementation (reintroduction) activities to the Upper Lewis basin. Based on adult hatchery origin returns over the past 5 years, coho salmon are the only stock that consistently exceeds these needs (Figure 1). The 2022 preseason forecast for Lewis hatchery coho is over 78,000 adults including 53,000 early (Type S) and 25,000 late (Type N) coho. Therefore, this plan will rely on hatchery-origin trap returns of early coho salmon for transportation into Yale Reservoir.

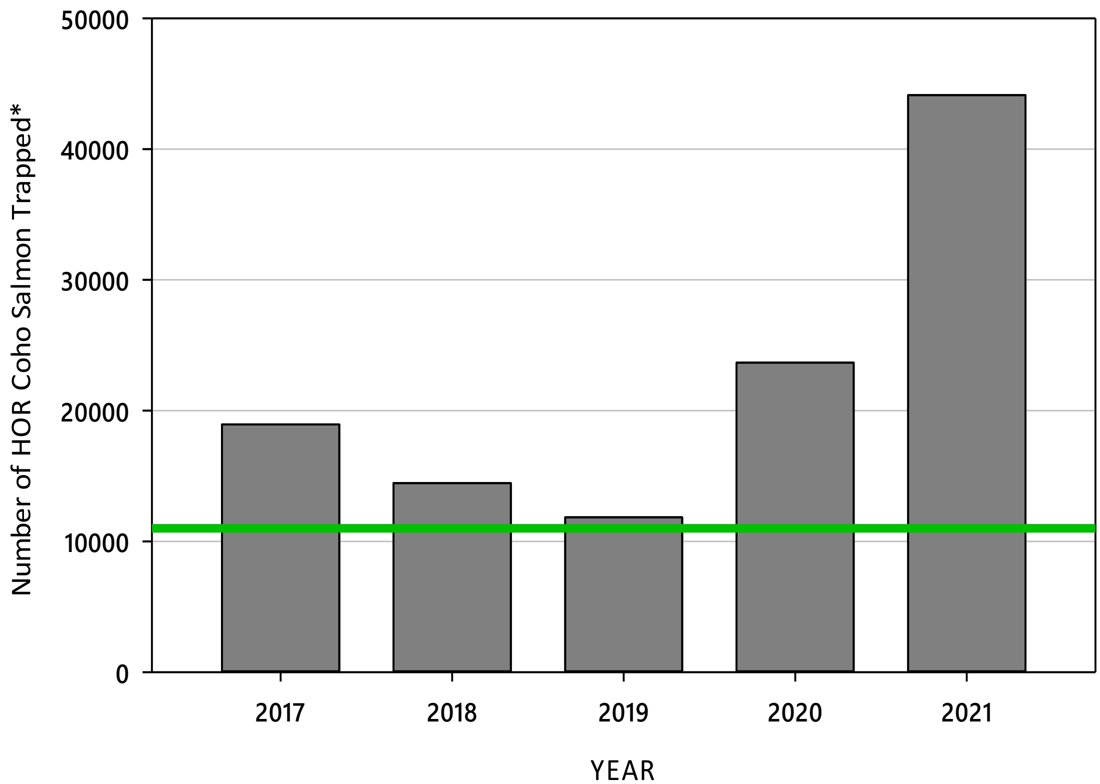

Figure 1. Total number of adult hatchery origin (HOR) coho collected at Lewis River trapping facilities by year: 2017 – 2021. Green line represents the total number of adults needed for existing hatchery broodstock and H&S program needs (green line = 11,000). Program needs are based on the number of adults needed to satisfy both hatchery production (broodstock) and supplementation (reintroduction) targets. *totals exclude jacks.

V. Transport Number

The proposed number of adult coho transported to the Yale basin is based on Ecosystem, Diagnostic and Treatment (EDT) modeling conducted in 2018 and as revised using model runs by NOAA in 2019.

EDT is a habitat-based model that is best used to assist planners in prioritizing restoration activities. However, the model does produce estimates of spawner capacity that can be used for course-level planning. For purposes of the Yale HPP, the Yale adult transport target relies on capacity estimates derived from EDT modeling.

"Capacity" represents the number of spawning adults the available habitat can support given the quantity and quality of that habitat for a specific reach or waterbody (e.g., Yale Reservoir). "Abundance" differs from capacity in that abundance represents the potential contribution (expressed as adult returns) of each waterbody. Unlike capacity, abundance estimates are influenced by factors such as overall downstream survival (ODS), harvest, predation, etc.

EDT modelling identified several Yale tributaries that would support coho spawning (Figure 2). EDT estimated that the current quality and quantity of spawning habitat available in Yale tributaries would support up to 1,842 spawning adults (Table 2). For the purposes of HPP, the maximum number of adult coho proposed for transport into Yale Reservoir each year is 1,840 adults (i.e., transport target).

The transport target represents the number of coho adults needed to fully seed available spawning habitat. However, factors such as predation, poaching, and transport survival may reduce the actual number of adults available to spawn. Therefore, the initial transport target may be modified during the period of the program.

<u>Male to Female Ratio</u>

The number of females and males transported should generally strive to achieve a 1 to 1 ratio to maximize potential spawning activity (redd construction). Using this ratio, a maximum 920 females and 920 males should be selected for transportation to Yale Reservoir.

VI. Collection Methods

Collection of adult coho will take place at both the Lewis River hatchery ladder and the Merwin Fish Collection Facility.

The timing and number of early coho available for release into Yale Reservoir depends first on satisfying priority adult targets for both the hatchery broodstock and Swift reintroduction programs. That is, early coho will only be available for Yale transport once these priority needs are met on a periodic basis throughout the run. As adult coho begin returning to the traps, in-season management decisions will be required. The ATS will provide recommended distribution protocols to trapping staff prior to the collection period. The ATS will modify these protocols as necessary to ensure that the priority goals of the hatchery broodstock and Swift reintroduction programs are met first while also trying to achieve the adult release targets under this plan.

VII. Transport Vehicles

PacifiCorp and WDFW fish trucks will be used to transport adults to Yale Reservoir. The number of trips depends on the number of available coho during the transport period. That is, it is unlikely that fish trucks will be loaded to capacity (120 adults) for each trip.

VIII. Release Locations

The Yale Park and Saddle Dam boat ramps will be used as release locations for transported adults (Figure 2). The goal will be to release approximately half of all transported adults at each location and distributed equally throughout the transport window. All released coho will be PIT tagged into the dorsal sinus (see planned monitoring section).

IX. Schedule and Timing

2022 – 2023: September through early October (early coho). *Note: If late coho are needed to meet transport targets, the release period will be extended to December 31.*

2024 – The HPP begins transitioning to a reintroduction program. That is, progeny from adults transported in 2024 (as part of the HPP) will be available for collection at the completed Yale downstream collection facility in 2026. During this transition, adaptive management of transport protocols related to adult transport numbers and composition may be necessary beginning in 2024. Adaptive management recommendations will be developed by the ATS for approval by the ACC prior to 2024 HPP operations.

2026 - HPP program ends and is replaced by the reintroduction program.

X. Pathology Screening

All fish transported and released into Yale will be sourced from either the Lewis River hatchery ladder or Merwin Fish Collection Facility. In-basin transfers do not require additional pathogen screening, beyond the annual surveillance of adult stocks at the minimum 5% assumed pathogen prevalence level (APPL) as required by the Co-Managers Salmonid Disease Policy. In the event out of basin transfers are planned, any additional screening will conducted according to the disease policy requirements.

XI. Harvest Restrictions

To help ensure the goals of the HPP are met, sportfishing regulations will be reviewed and modified by WDFW through emergency rule changes in the first year. Harvest rules will be evaluated and modified annually, if necessary, by WDFW. Prior to transport activities, signage should be posted on the PacifiCorp website and at Yale Reservoir boat ramps providing current regulations and program information. WDFW enforcement will be informed of the HPP actions and if necessary, may provide enhanced patrols to reduce the potential for poaching activities.

XII. Planned Monitoring

Coho transported and released into the Yale Reservoir will be allowed to self-sort and select tributaries in which to migrate into and spawn naturally. Based on previous fish distribution evaluations after construction of Merwin and Yale dams (Section II), it was shown that Cougar Creek is a preferred tributary stream for spawning coho salmon (Table 1). Based on these preliminary data, a potential exists for a large portion of the released coho to enter and spawn in Cougar Creek. To better define this potential and because Cougar Creek represents the only known Yale tributary that supports bull trout spawning, PacifiCorp proposes the following monitoring in 2022:

1. Estimate of the number of early coho that enter Cougar Creek

In July 2022, PacifiCorp installed a floating weir near the mouth of Cougar Creek as part of the company's ongoing bull trout monitoring program. To pass the weir, bull trout are directed through a narrow passage way and enumerated using an underwater camera in combination with a PIT tag array. PacifiCorp proposes using the weir to obtain estimates on the total number of early coho migrating into Cougar Creek. To facilitate accurate enumeration of early coho passing the weir, PacifiCorp will PIT tag (into the dorsal sinus) all adult coho released into Yale Reservoir. PIT tagged early coho will include the capture date, release date and release location. In addition to improving enumeration, PIT tag detections may show spatial or temporal patterns or differences between the two release locations and help validate redd survey observations upstream of the weir. The weir is scheduled for removal in early November, or sooner if justified by high flow event(s).

PacifiCorp will also conduct foot surveys in Cougar Creek as part of ongoing bull trout and kokanee surveys beginning in September and continuing into late October. Cougar Creek will be surveyed over its entire length to document the number and location (use of handheld GPS) of all new coho redds, lives and carcasses. All carcasses recovered will be scanned for PIT tags.

2. Estimate the relative use and spawning of coho salmon in Yale tributaries (other than Cougar Creek.

PacifiCorp and the WDFW will conduct informal foot surveys (as resources allow) of other potential Yale tributaries to document the number of lives, redds and carcasses observed. Potential spawning tributaries include the Swift bypass reaches, Siouxon Creek, Speelyai Creek and Dog Creek (Figure 2, Table 2). Surveys will be conducted during the peak spawning period for early coho. Specific methods of peak count surveys shall be developed by the ATS prior to implementation.

Foot surveys are intended to be a qualitative indicator of relative use by released coho into Yale Reservoir. Results from foot surveys should not be used as an indicator of spawning site preference. Variables such as weather and stream flows may increase or decrease the presence of coho observed on any given survey. Therefore, the presence or absence of coho should not be perceived as preference or avoidance by hatchery released coho into Yale Reservoir.

However, information obtained from these surveys could assist the ACC in determining whether the current transport target (1,840 adults) is appropriate or needs adjustment in future years.

Figure 2. Adult coho spawning capacity estimates for potential spawning tributaries of Yale Reservoir, including proposed release sites. Source: EDT modeling, 2019.

Table 2. Summary of adult coho capacity estimates for Yale Reservoir tributaries based on EDT modeling in 2019.

Tributary	Length (km)	Adult Capacity	Adult Capacity per km
Cougar and Panamaker creeks	3.08	114	38
Dog Creek	2.25	285	126
Bypass Reaches	3.21	318	99
Siouxon Creek	9.01	587	65
Speelyai Creek	9.89	537	54
TOTAL	**27.44**	**1,842**	**67**

XIII. Plan Modifications

Components of the plan may be modified annually by the Aquatics Coordination Committee (ACC) based on forecasted run sizes (after release by WDFW), hatchery and reintroduction needs, availability of excess hatchery coho and completion schedule of the Yale downstream collection facility. In-season modifications to the plan may also be required to address emergent issues (e.g., actual abundance vs. predicted run size). Proposed modifictions will be brought forward to the ATS and ACC as needed to initiate in-season modifications to this plan. Plan modifications shall be reflected and updated on the PacifiCorp website on an annual basis.

Merwin Habitat Preparation Plan

The Merwin downstream passage facility is scheduled for completion in 2028. According to Section 7.4 of the Settlement Agreement, transportation of adults into Merwin Reservoir should begin in 2023. Therefore, this plan will be modified to incorporate the transportation of adults into both Merwin and Yale reservoirs in 2023.

Other transport species

In 2022, only coho salmon are available for transportation (Figure 1). As run forecasts become available for the other transport species - spring Chinook and late winter steelhead, the habitat preparation program may include these species in annual planning to the extent that fish are available after hatchery broodstock and reintroduction targets are met.

XIV. References

Chambers, John. 1957. Report on the 1956 survey of the North Fork of the Lewi River above Yale Dam. State of Washington, Department of Fisheries, April 1957.

Smith, Richard, T. 1943. Report on the Lewis River Salmon Conservation Program.

Date: August 19, 2022

To: Aquatic Technical Subgroup (ATS)

From: Erik Lesko

Subject: Proposed addition of Yale HPP adult early coho transport goal to existing broodstock and Swift transport collection targets in the H&S Annual Operating Plan

In July 2022, the ACC approved the Yale Habitat Preparation Plan (HPP). Implementation of the Yale HPP will begin in September 2022. The Yale HPP transport goal is about 1,800 early coho (excluding jacks) in 2022. To meet the transport target of the Yale HPP, we have developed a proposed collection target by week for coho transport to Yale (Table 1). We have also proposed a 50 percent PIT tag rate of all released coho into Yale. This differs from the plan target of 100 percent tagging rate due to lower than expected number of tags available and longer than expected delivery times for new tag orders.

Table 1. Proposed release number and tagging rate by release site for adult early coho into Yale Reservoir in 2022.

Week Beginning	Release Site	Early Coho released*	Early Coho tagged
9/12/2022	Saddle Dam	100	50
	Yale Park	100	50
9/19/2022	Saddle Dam	100	50
	Yale Park	100	50
9/26/2022	Saddle Dam	200	100
	Yale Park	200	100
10/3/2022	Saddle Dam	200	100
	Yale Park	200	100
10/10/2022	Saddle Dam	200	100
	Yale Park	200	100
10/17/2022	Saddle Dam	100	50
	Yale Park	100	50
Total		1,800	900

** No jacks are to be released into Yale*

The addition of Yale HPP release targets requires updates to the AOP. Table 2 incorporates the proposed Yale HPP collection target into existing broodstock and Swift transport targets as part of the 2022 AOP. Target numbers by period have been rounded, but totals represent the actual values for broodstock, Swift upstream transport and Yale HPP. A total of 13,200 coho (earlies and lates) are needed to meet the collection goals of all three programs. Table 2 is formatted by priority in that broodstock are the first priority, followed by Swift upstream transport and then Yale HPP. That is, broodstock goals must be met before coho are available for Swift upstream transport, and Swift transport goals must be met before coho are available for Yale HPP.

Table 2. Collection targets for hatchery broodstock, Swift upstream transport and Yale HPP for 2022.

Period	Broodstock	Swift Transport	Yale Transport*	Period Total
Sep 1-15	100	350	200	650
Sep 16-30	350	1,450	700	2,500
Oct 1-15	400	1,500	700	2,600
Oct 16-31	550	2,400	200	3,150
Nov 1-15	250	800		1,050
Nov 16-30	350	1,000		1,350
Dec 1-15	250	800		1,050
Dec 16-31	150	700		850
	2,400	9,000	1,800	13,200

* *Represents early coho only as stipulated in the Yale HPP*

APPENDIX C

EAGLE CLIFF ROTARY SCREW TRAP OPERATION SUMMARY-TECHNICAL MEMORANDUM 2022

Washington Department of Fish and Wildlife
JMX Smolt Trap Protocols and Reporting
(April 26, 2023)

This document includes three sections:

- **Part 1 – Data Collection is to be completed prior to the trapping season.**
- **Part 2 – Implementation Notes is to be completed once data are collected in preparation for analysis.**
- **Part 3 – Analysis and Results is to be completed as the last step.**

All protocols reported in this document reflect standardized Region 5 smolt trapping and analysis methods. The purpose of this document is to ensure consistency among projects and to document protocols for posterity.

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Part 1: DATA COLLECTION PROTOCOLS

Protocol Name: North Fork Lewis River upstream of Swift Dam - 2022

Project Supervisor: Jason Shappart (Meridian Environmental, Inc. – PacifiCorp contractor)

Science Leader: Jason Shappart (Meridian Environmental, Inc. – PacifiCorp contractor)

ESA Take Permit No. (if applicable): ESA Section 7(a)(2) Consultation, 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). NMFS Log Number: 2005/05891. August 27, 2007.

ESA Section 7(a)(2) Consultation, 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

Trap information:

Trap Name	Type of Trap	Trap Location RKM	Start Date (Planned)	End Date (Planned)
Eagle Cliff Screw Trap	one 8-foot rotary screw trap	95	03/25/2022	08/15/2022

1.1 Field Objectives:

Trap Name	North Fork Lewis River upstream of Swift Dam							
Species	**Origin**	**Life Stage**	**Inferred age Class**	**Catch**	**Efficiency Trials**	**Fork Length**	**Scales**	**Other**
Chinook	NP	All	All	Y	Y	Y	N	
Unidentified Trout YOY	NP	F	Subyearling	Y	N	Y	N	
Steelhead	NP	All	P/T/S	Y	Y	Y	N	
Coho	NP	All	All	Y	Y	Y	N	
Cutthroat	NP	All	P/T/S	Y	Y	Y	N	
Bull Trout	NP	All	All	Y	N	Y	N	
Additional Comments/Narrative: Naturally Produced (NP), Fry (F), Parr (P), Transitional (T), Smolt (S), Adult (A), PIT Tag (PIT). Scan all (P/T/S) for previous PIT tag. All Bull Trout are released downstream per the USFWS Biological Opinion and not used for efficiency trials. Unidentified Trout YOY not used for efficiency due to relatively low abundance.								

1.2 Site Selection:	
• *Why was this site selected for the smolt trap?*	Anchoring, permitting, laminar flow, ease of access and downstream of the majority of spawning
• *Are there spawner estimates above the trap site that can be used to estimate freshwater productivity, capacity, and smolt-to-adult return?*	Prior to 2022 – Chinook, Coho, Bull Trout: Yes; Steelhead and Cutthroat: No
• *Describe the method used for adult escapement estimates (e.g., Carcass tagging, adult MR, AUC, redds, PCE, other).*	The total number of Chinook, Coho and Steelhead transported upstream is known (trap and haul). The proportion of Chinook and Coho that successfully spawn was estimated by redd surveys. Redd surveys are also conducted for Bull Trout throughout the majority of their potential spawning distribution.
• *Estimated % of the total basin-specific population that spawn above the trap. Include source for this information (% can be a range).*	Chinook: 99%; Coho: 70 to 90% ; Steelhead and Cutthroat: unknown; Bull Trout: 100%
• *Estimated % of yearling life stage juveniles that continuously rear) above the trap (summer and winter) prior to outmigrating. Include source for this information.*	Unknown
• *Additional Information*	Upstream and downstream passage is around Swift Dam is provided by trap and haul.

1.3 Collection Event:	
• *Describe the planned frequency for enumerating and sampling fish caught in the trap.*	Trap to be checked daily (between 09:00 and 15:00 hours).
• *Describe and explain any planned trap outages.*	None
• *Describe process of handling and anaesthetizing fish.*	Dip nets used to transfer all fish to buckets or bins with battery aeration units. Salmonids to be anesthetized in solution of 1 ml Aqui-S to 2 gallons river water prior to sampling.
• *Describe method for measuring rotation per minute (RPM)*	Visually for 1 minute (daily)
• *List flow gauge associated with the trap.*	Lewis River above Muddy River (USGS Gage 14216000) and Muddy River below Clear Creek (USGS Gage 4216500)
• *Describe method for measuring visibility and frequency of measurements.*	Not estimated
• *Describe method for measuring stream temperature and frequency of measurements.*	Not measured
• *Describe additional environmental variables measured, the method for the measurement, and the frequency of measurements.*	None

1.4 Fish Count by Group and Individual Measures:	
• *Life stage will be assigned according to the Region 5 Decision Tree (see appendix). Note any exceptions to the Decision Tree for species/life stage. Exceptions need to be approved by your Science Leader in advance!*	No exceptions to the Region 5 Decision Tree.
• *Describe how origin is assigned.*	All salmonids are naturally produced upstream of Swift Dam except for adipose fin clipped hatchery rainbow trout

• *Describe the characteristics of individual fish (species/life stage, condition, and mark status) that are sorted and released downstream of the trap.*	All non-salmonids to be released downstream of trap regardless of life stage and all Bull Trout are released downstream as required by the USFWS Biological Opinion.
• *Describe the characteristics of individual fish (species/life stage, condition, and mark status) that are selected for efficiency trials.*	All salmonids. Fish with visual injury or other impairment shall not be used for trials regardless of species or life stage.

Table 1.4a. Date and length criteria used for field calls of Chinook inferred age classes.

Life Stage	Inferred age Class	Date Range	Length Range (mm FL)	Phenotype
Fry		3/25 to 8/15	<50 mm	
Parr/Trans/Smolt		3/25 to 8/15	≥50 mm	Determined by using Region 5 Decision Tree based on physical appearance
Individual Fish Measures:				
• *Sample rate for fork length*		F – 10 per day; P/T/S – all		
• *Sample rate for scales*		NA		

Table 1.4b. Date and length criteria used for field calls of Coho inferred age classes.

Life Stage	Inferred age Class	Date Range	Length Range (mm FL)	Phenotype
Fry		3/25 to 8/15	<50 mm	
Parr/Trans/Smolt		3/25 to 8/15	≥50 mm	Determined by using Region 5 Decision Tree based on physical appearance
Individual Fish Measures:				
• *Sample rate for fork length*		F – 10 per day; P/T/S – all		
• *Sample rate for scales*		NA		

Table 1.4c. Date and length criteria used for field calls of Steelhead inferred age classes.

Life Stage	Inferred age Class	Date Range	Length Range (mm FL)	Phenotype
Fry		3/25 to 8/15	<50 mm	
Parr/Trans/Smolt		3/25 to 8/15	≥50 mm	Determined by using Region 5 Decision Tree based on physical appearance
Individual Fish Measures:				
• *Sample rate for fork length*		F – 10 per day; P/T/S – all		
• *Sample rate for scales*		NA		

Table 1.4d. Date and length criteria used for field calls of Cutthroat inferred age classes.

Life Stage	Inferred age Class	Date Range	Length Range (mm FL)	Phenotype
Fry		3/25 to 8/15	<50 mm	
Parr/Trans/Smolt		3/25 to 8/15	≥50 mm	Determined by using Region 5 Decision Tree based on physical appearance
Individual Fish Measures:				
• *Sample rate for fork length*		F – 10 per day; P/T/S – all		

• *Sample rate for scales*	NA

Table 1.4e. Date and length criteria used for field calls of Bull Trout inferred age classes.

Life Stage	Inferred age Class	Date Range	Length Range (mm FL)	Phenotype
Fry		3/25 to 8/15	<50 mm	
Juvenile		3/25 to 8/15	≥50 mm	No determination made for P/T/S
Individual Fish Measures:				
• *Sample rate for fork length*	F/P/T/S – all			
• *Sample rate for scales*	NA			

1.5 Marking and Release:	
• *Explain purpose of applying marks or tags to fish prior to release (if applicable).*	Marks are used to calibrate trap efficiency and to assist in calculating Overall Downstream Survival (ODS) at the Swift Floating Surface Collector (FSC)
• *Describe the schedule for which fish will be released to determine trap efficiency.*	Daily (seven days per week)
• *Describe the target number of fish for each release group (species/life stage/inferred age class).*	For all species in which outmigration estimates are planned (Chinook, Coho, Steelhead, and Cutthroat) all captured naturally produced fish ≥50 mm FL in good condition are marked and used in efficiency trials daily as feasible. Fry (<50 mm FL) are marked opportunistically when available
• *Describe marking or tagging method used for each species/origin/life stage/inferred age class.*	**For salmonid fry**: Bismarck brown dye. Use 0.4 grams of dye per approximately 4 gallons of water. **For all maiden capture salmonids (50 to 68 mm FL):** Alcian Blue tattoo marks varied by week. **For all maiden capture salmonids (≥69 mm FL):** PIT tagged.
• *Describe release location for efficiency trials (rkm).*	At confluence of Pine Creek with North Fork Lewis River at N46.071862, W-122.017715 about 0.45 miles upstream of trap site.
• *Describe where and how long marked or tagged fish are held prior to release for efficiency trials.*	Marked fish are held in aerated buckets for recovery after sampling and released once trap sampling is complete.
• *Describe what time of day marked or tagged fish are released for efficiency trials.*	Between 09:00 and 15:00 hours – depending on the number of fish sampled each day.
• *Describe plans to evaluate mark retention and mark-related mortality.*	None
• *Describe plans to evaluate mark-recapture assumption that the second sample is a random representative sample (i.e., marked and unmarked fish are completely mixed)*	None planned for 2022

Table 1.5. Marking Plan for Trap Efficiency Trials

Species	Origin	Life Stage	Inferred age Class	Start Date (Planned)	Stop Date (Planned)	Mark Rotation (Frequency)	Mark Type
Chinook	NP	F	<50 mm FL	3/25	8/15	Same all season	Bismark Brown dye
Chinook	NP	P	50-68 mm FL	3/25	8/15	Weekly	tattoo (dye)
Chinook	NP	P/T/S	≥69 mm FL	3/25	8/15	Same all season	PIT tag
Coho	NP	F	<50 mm FL	3/25	8/15	Same all season	Bismark Brown dye
Coho	NP	P	50-68 mm FL	3/25	8/15	Weekly	tattoo (dye)

Coho	NP	P/T/S	≥69 mm FL	3/25	8/15	Same all season	PIT tag
Steelhead	NP	P	50-68 mm FL	3/25	8/15	Weekly	tattoo (dye)
Steelhead	NP	P/T/S	≥69 mm FL	3/25	8/15	Same all season	PIT tag
Cutthroat	NP	P	50-68 mm FL	3/25	8/15	Weekly	tattoo (dye)
Cutthroat	NP	P/T/S	≥69 mm FL	3/25	8/15	Same all season	PIT tag
Bull Trout	NP	All	≥75 mm FL	3/25	8/15	Same all season	PIT tag

1.6 Recapture:	
• *Describe how fish are examined for all marks (visual, PIT scan, CWT wand).*	Visual inspection for Alcian Blue tattoo marks or Bismark Brown dye, and adipose fin clip (for hatchery Rainbow Trout). Scan all salmonids (excluding fry) for previous PIT tag
• *Describe how maiden/recapture status is assigned.*	Captured fish indicating the presence of Alcian Blue tattoo marks, Bismark Brown Dye, and PIT tag are considered recaptures. All unmarked fish are considered maiden captures
• *Describe effort to accurately detect marked fish used in efficiency trial. Include methods used to evaluate detection rates.*	All naturally produced salmonids captured are visually evaluated for a previous mark and all are scanned for previous PIT tag (excluding fry).

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Part 2: IMPLEMENTATION NOTES

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 2022). The Eagle Cliff screw trap was operated from March 25 to August 15, 2022. In 2022, the trap was located at Eagle Cliff on the North Fork Lewis River just upstream of Swift Reservoir in the same location has historically operated (Figure 2a). The trap was gradually moved upstream in June and July as flows receded to maintain trap cone RPMs (Table 2.1) as has been done historically. Missed trapping periods were caused by three high water spikes during the trapping season where the trap was turned off (cone raised) to prevent trap damage and to minimize fish mortality (Table 2.2).

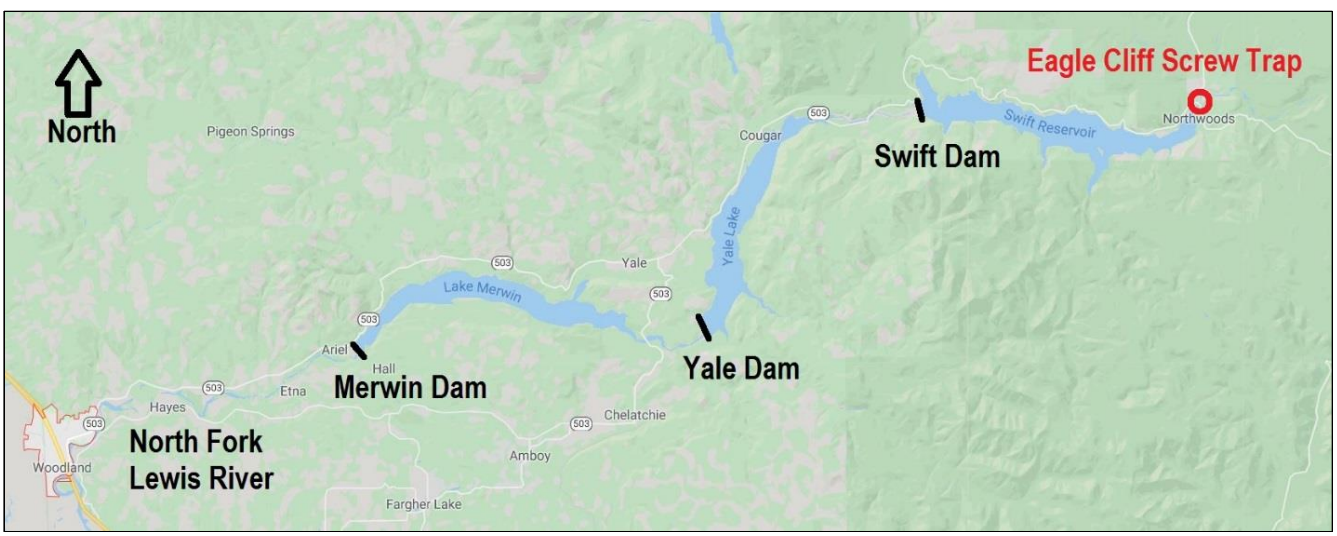


Figure 2a. Eagle Cliff screw trap fishing location (2022), same as in all prior years.

2.1 Trap Alterations		
Trap Name: Eagle Cliff Screw Trap		
Date	**Type of Alteration**	**Details**

6/24/2022	moved trap upstream	moved trap upstream to improve cone RPMs
7/22/2022	moved trap upstream	moved trap upstream to improve cone RPMs

2.2 Missed Trapping Periods

Trap Name: Eagle Cliff Screw Trap

Last Time Observed Fishing	Time Stopped Fishing	Method to Determine Trap Not Fishing	Time Start Fishing again	Comments
5/6/2022 13:01	5/6/2022 13:01	manually turned off trap	5/10/2022 11:30	cone raised due to high water to prevent trap damage
6/5/2022 10:47	6/5/2022 10:47	manually turned off trap	6/7/2022 10:47	cone raised due to high water to prevent trap damage
6/10/2022 10:18	6/10/2022 10:18	manually turned off trap	6/13/2022 10:00	cone raised due to high water to prevent trap damage

2.3 Raw Data for Mark-Recapture Analysis

The total number of salmonids captured, released upstream, and recaptured during each weekly period by origin and species from March 25 to August 25, 2022 are summarized in Table 2.3a (Coho and Chinook) and Table 2.3b (Steelhead, Cutthroat, Trout YOY, and Bull Trout). Total maiden naturally produced salmonids caught at Eagle Cliff included 4,173 Coho, 163 Chinook, 239 Steelhead, 49 Cutthroat, and 30 Bull Trout. In addition, 199 unidentified trout young-of-year (YOY) were caught and are likely either Rainbow/Steelhead or Cutthroat. In addition, the trap caught 19 Dace, one (1) Lamprey, 166 Sculpin, 107 Sucker, nine (9) Whitefish, and six (6) hatchery Rainbow Trout. Three (3) adult Steelhead were captured at the Eagle Cliff screw trap, which were originally PIT tagged at the Merwin adult trap. One (1) adult spring Chinook was also captured. These adult Steelhead and Chinook observations were excluded from the analyses presented in this document.

In addition to fish caught at the Eagle Cliff screw trap, Coho and Steelhead were PIT tagged at the Swift FSC and released upstream at the same location as fish marked at the Eagle Cliff Screw trap. Therefore, the total number of Coho and Steelhead marked and released upstream in tables 2.3a and 2.3b includes fish marked at the screw trap and Swift FSC and released upstream at the Pine Creek confluence. Fork length (FL) distributions of Coho and Chinook are summarized in Table 2.3c, and in Table 2.3d for Steelhead, Cutthroat, Trout YOY, and Bull Trout. Overall trap efficiency was significantly lower for fish <50 mm in length compared to fish ≥50 mm. Therefore, weekly trap efficiency estimates were estimated separately for these two discrete size classes. Relatively few recaptured fish ≥50 mm were available to determine weekly trap efficiency for all species except Coho. Therefore, weekly trap efficiency was calculated by pooling all naturally produced Coho, Chinook, Steelhead, and Cutthroat. Similarly, all salmonids <50 mm in length were pooled to estimate weekly trap efficiency for fry-sized fish.

Table 2.3a - Summary of Coho and Chinook captured at the Eagle Cliff screw trap by period (2022). Mark-release efficiency trials included additional fish captured at the FSC.

North Fork Lewis River above Swift Dam 2022			Coho									Chinook							
			Maiden		Mark-Release Up			Recapture		Efficiency		Maiden		Mark-Release Up		Recapture		Efficiency	
Period	Start	End	<50mm	≥50mm	<50mm	≥50mm[a]	≥50mm[b]	<50mm	≥50mm[c]	<50mm	≥50mm[c]	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm
2	25-Mar	27-Mar	2	20															
3	28-Mar	3-Apr	20	50		48	99		12		0.0816	6							
4	4-Apr	10-Apr	51	48		46	48		4		0.0426	2							
5	11-Apr	17-Apr	42	18	1	18	11		1	0.0000	0.0345	6							
6	18-Apr	24-Apr	225	39	97	39	3	1	3	0.0103	0.0714	21		9					
7	25-Apr	1-May	9	58		58	21		4		0.0506	1							
8	2-May	8-May		98		83	41		3		0.0242								
9	9-May	15-May	46	48		46	73		9		0.0756	2	1		1				
10	16-May	22-May	35	100		99	257		16		0.0449	2							
11	23-May	29-May	39	113		112	177		15		0.0519								
12	30-May	5-Jun	43	104		97	138		16		0.0681		2		2				
13	6-Jun	12-Jun	81	25	39	25	167		3	0.0000	0.0156	4	1	3	1				
14	13-Jun	19-Jun	201	46	134	46	136	1	9		0.0495	6	3	5	3		1		0.3333
15	20-Jun	26-Jun	87	73	10	71	160	1	6	0.1000	0.0260	57	5	57	5				
16	27-Jun	3-Jul	70	84	1	80			5	0.0000	0.0625	4	9		9		1		0.1111
17	4-Jul	10-Jul	64	66		66			1		0.0152	1	4		4		1		0.2500
18	11-Jul	17-Jul	22	275	1	272			10	0.0000	0.0368		3		3				
19	18-Jul	24-Jul	17	196		195			7		0.0359		4		4				
20	25-Jul	31-Jul	29	1,013		795			25		0.0314		15		15		1		0.0667
21	1-Aug	7-Aug	10	501		448			15		0.0335		4		4				
22	8-Aug	15-Aug		105		80			4		0.0500								
Total:			1,093	3,080	283	2,724	1,331	3	168	0.0106	0.0414	112	51	74	51	0	4	NA	0.0784

[a]Note: Maiden Coho captured and PIT tagged at the screw trap and placed upstream at Pine Creek confluence.

[b]Note: Maiden Coho captured and PIT tagged at the Swift FSC and placed upstream at Pine Creek confluence.

[c]Note: Includes all Coho marked at the screw trap and Swift FSC and released at Pine Creek confluence that were recaptured at the screw trap.

Table 2.3b - Summary of Steelhead, Cutthroat, Trout YOY, and Bull Trout captured at the Eagle Cliff screw trap by period (2022). Mark-release efficiency trials included additional fish captured at the FSC.

North Fork Lewis River above Swift Dam 2022			Steelhead					Cutthroat				Trout YOY[d]					Bull Trout
			Maiden	Mark-Release Up		Recaps	Efficiency	Maiden	Mark-Release Up	Recaps	Efficiency	Maiden		Mark-Release Up	Recaps	Efficiency	Maiden[e]
Period	Start	End	≥50mm	≥50mm[a]	≥50mm[b]	≥50mm[c]	≥50mm[c]	≥50mm	≥50mm	≥50mm	≥50mm	<50mm[d]	≥50mm	≥50mm	≥50mm	≥50mm	≥50mm
2	25-Mar	27-Mar	4														
3	28-Mar	3-Apr	9	9													1
4	4-Apr	10-Apr	14	13	1			1	1								3
5	11-Apr	17-Apr	5	5	1			2	2								1
6	18-Apr	24-Apr	10	10	12			1	1								2
7	25-Apr	1-May	18	17	50	4	0.0597	1	1	1	1.0000						1
8	2-May	8-May	25	18	15												3
9	9-May	15-May	22	22	38	5	0.0833	2	2	1	0.5000						5
10	16-May	22-May	28	28	66	5	0.0532	4	4	1	0.2500						4
11	23-May	29-May	36	36	4	3	0.0750	11	11								2
12	30-May	5-Jun	21	21				6	6								6
13	6-Jun	12-Jun	10	10	9	3	0.1579	2	2								1
14	13-Jun	19-Jun	5	5	3			3	3								1
15	20-Jun	26-Jun	16	16	1			5	5								
16	27-Jun	3-Jul	8	8				4	4			3					
17	4-Jul	10-Jul						1	1			2					
18	11-Jul	17-Jul	4	3				1	1			6					
19	18-Jul	24-Jul	2	2				3	3			13					
20	25-Jul	31-Jul						1	1			131	9	3			
21	1-Aug	7-Aug	1	1								16	7	6			
22	8-Aug	15-Aug	1	1				1				10	2	2			
Total:			239	225	200	20	0.0471	49	48	3	0.0625	181	18	11	0	NA	30

[a]Note: Maiden Steelhead captured and PIT tagged at the screw trap and placed upstream at Pine Creek confluence.
[b]Note: Maiden Steelhead captured and PIT tagged at the Swift FSC and placed upstream at Pine Creek confluence.
[c]Note: Includes all Steelhead marked at the screw trap and Swift FSC and released at Pine Creek confluence that were recaptured at the screw trap.
[d]Note: Unidentified Trout YOY (likely either Rainbow/Steelhead or Cutthroat).
[e]Note: All Bull Trout were released downstream per the USFWS Biological Opinion and not used for efficiency trials.

Table 2.3c - Summary of Coho and Chinook captured at the Eagle Cliff screw trap by size class (2022). Mark-release efficiency trials included additional fish captured at the FSC.

Fork Length Bin	Coho					Chinook			
	Maiden	Mark/ Release Up[a]	Mark/ Release Up[b]	Recapture[c]	Efficiency[c]	Maiden	Mark/ Release Up	Recapture	Efficiency
20-29mm	1								
30-39mm	562	143		1	0.0070	83	62		
40-49mm	530	140		2	0.0143	29	12		
50-59mm	451	433		14	0.0323	14	14	2	0.1429
60-69mm	1,036	766		31	0.0405	11	11	1	0.0909
70-79mm	595	575	7	25	0.0430	11	11		
80-89mm	336	321	19	10	0.0294	9	9	1	0.1111
90-99mm	232	221	44	12	0.0453	4	4		
100-109mm	219	204	102	12	0.0392				
110-119mm	133	130	244	26	0.0695				
120-129mm	25	24	398	15	0.0355				
130-139mm	3	3	315	9	0.0283				
140-149mm			143	6	0.0420				
150-159mm			44						
160-169mm	1	1	14	2	0.1333				
170-179mm	1	1	1	1	0.5000				
180-189mm	11	11		3	0.2727	1	1		
190-199mm	10	10		1	0.1000				
200-249mm	17	16		1	0.0625	1	1		
250-299mm	8	7							
300-349mm	2	1							
350-399mm									
400+mm									
Total	**4,173**	**3,007**	**1,331**	**171**		**163**	**125**	**4**	
<50 mm	1,093	283	0	3	0.0106	112	74	0	NA
≥50 mm	3,080	2,724	1,331	168	0.0414	51	51	4	0.0784

[a]Note: Maiden Coho captured and PIT tagged at the screw trap and placed upstream at Pine Creek confluence.
[b]Note: Maiden Coho captured and PIT tagged at the Swift FSC and placed upstream at Pine Creek confluence.
[c]Note: Includes all Coho marked at the screw trap and Swift FSC and released at Pine Creek confluence that were recaptured at the screw trap.

Table 2.3d - Summary of Steelhead, Cutthroat, Trout YOY, and Bull Trout captured at the Eagle Cliff screw trap by size class (2022). Mark-release efficiency trials included additional fish captured at the FSC.

Fork Length Bin	Steelhead					Cutthroat				Trout YOY[d]				Bull Trout
	Maiden	Mark/ Release Up[a]	Mark/ Release Up[b]	Recapture[c]	Efficiency[c]	Maiden	Mark/ Release Up	Recapture	Efficiency	Maiden	Mark/ Release Up	Recapture	Efficiency	Maiden[e]
20-29mm										11				
30-39mm										131				
40-49mm										39				
50-59mm										18	11			
60-69mm	4	4				1								
70-79mm	6	6				2	2							
80-89mm	20	20				1	1							
90-99mm	40	39	4	1	0.0233	1	1							
100-109mm	29	29	1			4	4							
110-119mm	12	11	1	3	0.2500	5	5							4
120-129mm	6	6		1	0.1667	6	6							3
130-139mm	10	8				6	6							5
140-149mm	5	5	2			5	5	1	0.2000					4
150-159mm	20	18	5	4	0.1739	3	3	1	0.3333					5
160-169mm	21	17	22			2	2							3
170-179mm	22	18	36	4	0.0741	4	4							3
180-189mm	15	15	43	1	0.0172	3	3							1
190-199mm	11	11	58	5	0.0725	2	2							1
200-249mm	12	12	28			1	1							1
250-299mm	6	6		1	0.1667	2	2							
300-349mm														
350-399mm						1	1	1	1.0000					
400+mm														
Total	**239**	**225**	**200**	**20**		**49**	**48**	**3**		**199**	**11**	**0**		**30**
<50mm	NA					NA				181	0	NA	NA	NA
≥50mm	239	225	200	20	0.0471	49	48	3	0.0625	18	11	0	NA	

[a]Note: Maiden Steelhead captured and PIT tagged at the screw trap and placed upstream at Pine Creek confluence.
[b]Note: Maiden Steelhead captured and PIT tagged at the Swift FSC and placed upstream at Pine Creek confluence.
[c]Note: Includes all Steelhead marked at the screw trap and Swift FSC and released at Pine Creek confluence that were recaptured at the screw trap.
[d]Note: Unidentified Trout YOY (likely either Rainbow/Steelhead or Cutthroat).
[e]Note: All Bull Trout were released downstream per the USFWS Biological Opinion and not used for efficiency trials.

2.4 Inferred age Results from Scale Data

Scale and inferred age data were not collected. Inferred age at length data are not available for this site. However, inferred age at length data based on scale analysis for the Kalama River was reviewed to aid in assessing potential inferred age-length brackets (WDFW 2019).

2.5 Data Collected to Evaluate Mark-Recapture Assumption that Marking the Fish Does Not Affect Behavior (e.g., Mark-Related Mortality) and that Marks Are Not Lost

Mark-recapture assumptions were not tested.

2.6 Data Collected to Evaluate Mark-Recapture Assumption that the Second Sample is a Random Representative sample (i.e., Marked and Unmarked Fish are Completely Mixed)

Mark-recapture assumptions were not tested.

2.7 Smolt Trapping Assumption Testing Summary

Trap Name: Eagle Cliff screw trap			
Species: All Salmonids	Origin(s): All	Life Stage(s): All	Inferred age Class(es): All

Place "X"	Method to test/satisfy assumption	Comments

Closure - Population is geographically closed to immigration, emigration, births, and deaths.

Unknown	Minimized by trapping over entire run	
	Minimized predation by checking trap box multiple times per day	
	Tested optimal release location to minimize predation on fry	
	Test predation by lavaging Coho, steelhead, and cutthroat and enumerating marked and unmarked fry [fry migrants only]	
	Adjusted for missed trapping days	

*Assumption Met? (**Unknown**) Comments: Trapping is conducted from early March to the end of June as specified by PacifiCorp Contract.*

Marks are not lost

X	Minimized by following standard marking/tagging protocols with known mortality	
	Minimized by double tagging experiment	
	Tested by holding fish for 1-3 days to test mark/tag retention and adjusted marks released	
	Tested by double tagging experiment, estimated tag loss, and adjusted marks released	

*Assumption Met? (**Yes**) Comments: Marking follows standard procedures.*

Marking does not affect behavior

X	Minimized by using standard procedures for marking and only releasing healthy marked fish	
	Tested by holding marked fish overnight to assess mark related mortality; adjust mark release numbers accordingly	

*Assumption Met? (**Yes**) Comments: Marking follows standard procedures.*

Capture probabilities are homogeneous by strata

X	Minimized heterogeneous capture probability by stratifying the trap efficiency data	
X	Tested for differences in capture probabilities among trap efficiency trials	
X	Tested for differences in initial capture probability (e.g., due to body size)	

*Assumption Met? (**Yes**) Comments:*

Second Sample is random representative sample (i.e., marked and unmarked fish are completely mixed)

X	Maximize mixing by releasing fish upstream of sinuous reaches above trap site	
	Maximize mixing by releasing fish during the time of migration (e.g., night releases)	
	Tested optimum release site for mixing (consider statistical power to detect differences)	

*Assumption Met? (**Unknown**) Comments: Typical recapture rates preclude statistical testing of release sites.*

Mark status is reported correctly

X	Minimized error through staff training and careful examination of all fish	
X	Minimize error associated with subsampling high catch numbers by obtaining a representative subsample for evaluating mark status	All fish are examined, no subsampling occurs
	Tested by having samplers counting known numbers of marked and unmarked fish mixed in a bin	
	Tested by having a second sampler check first samplers placement of fish into marked and unmarked bins	

*Assumption Met? (**Yes**) Comments:*

2.8 Graphical presentation of catch, trap efficiency, and flow

Inferred age class/brood-year size class brackets were determined by assessing the seasonal length distribution patterns over time. Kalama River inferred age at length data was also reviewed to aid in assessing potential inferred age-length brackets (WDFW 2019); note the Kalama River is the adjacent river basin to the north of the Lewis River. Length frequency is presented in figures 2.8a (Coho and Chinook) and 2.8b (Steelhead, Cutthroat, Trout YOY, and Bull Trout). Scatter plots of the fork lengths of all fish caught each day, average daily flow, and daily trap cone RPMs are presented in figure 2.8c (Coho), 2.8d (Chinook), 2.8e (Steelhead and Trout YOY), 2.8f (Cutthroat), and 2.8g (Bull Trout). The size class demarcations used to infer age classes for naturally produced salmonids are depicted on each of the length scatter plots of each species.

As discussed previously, because relatively few fish were available to determine specific mark-recapture rates by individual combinations of species and size class, trap efficiency by period (week) was calculated by pooling all Coho, Chinook, Steelhead, and Cutthroat separately for two size classes, <50 mm FL and ≥50 mm FL. As not all weekly periods had recaptured fish to estimate trap efficiency, efficiency estimates across weeks were pooled to increase mark-recapture sample size if the stream flow and/or cone RPMs were similar. These weekly trap efficiency estimates were applied to the total maiden catch to estimate the total number of fish passing the trap for each salmonid species by inferred age class. The pooled weekly mark-recapture data and weekly trap efficiencies applied are summarized in Table 2.8a. The migration timing (estimated percentage of the total number of fish passing the trap on a weekly basis for each salmonid species by inferred age class) is depicted in figures 2.8h (salmon species) and 2.8i (trout species). Estimates of total fish passing the trap during the monitoring period for each naturally produced salmonid species by inferred age class are presented in Section 3.

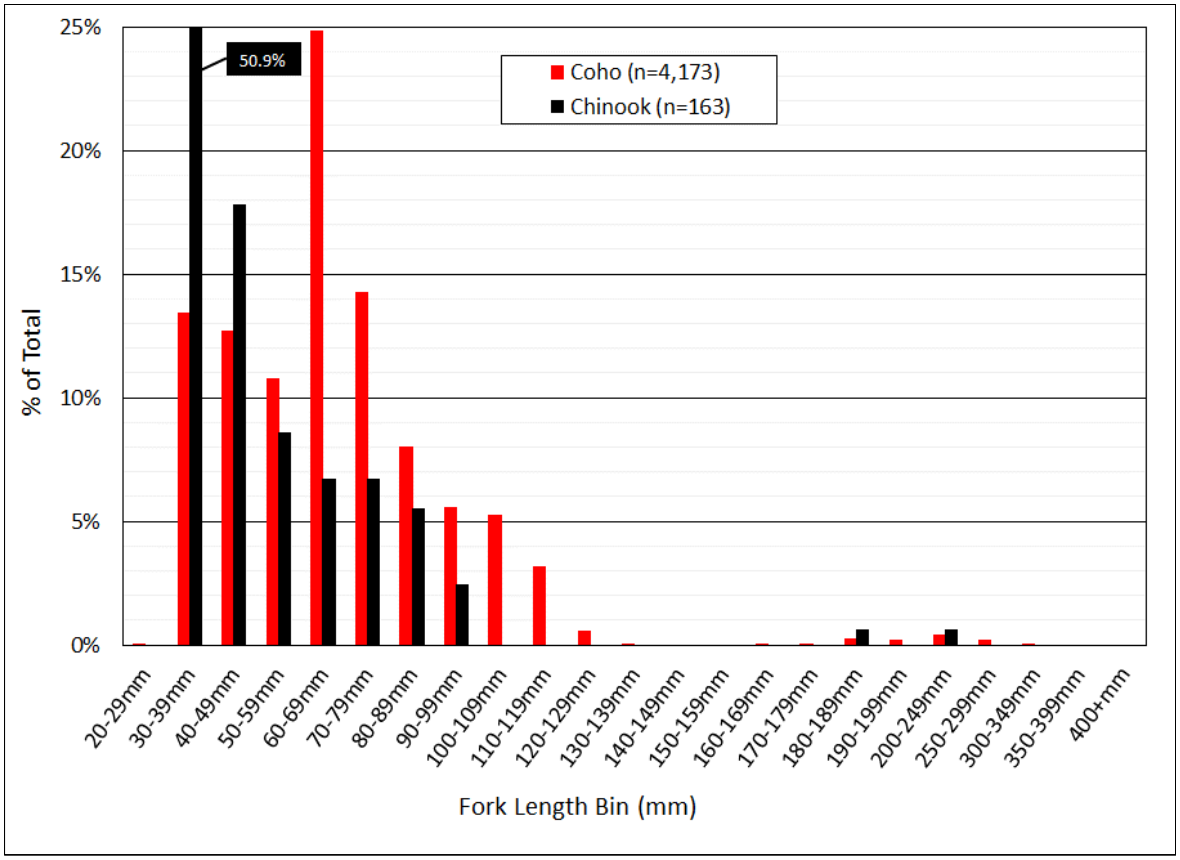
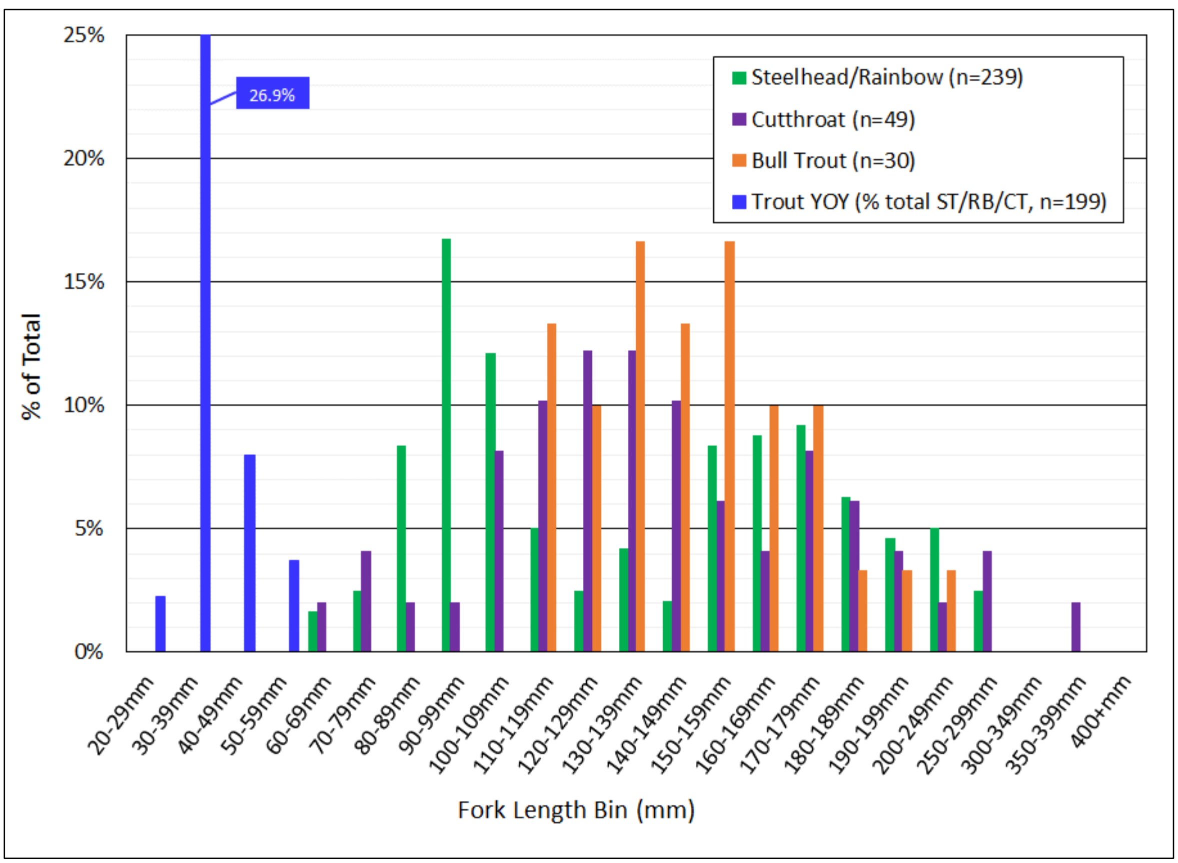
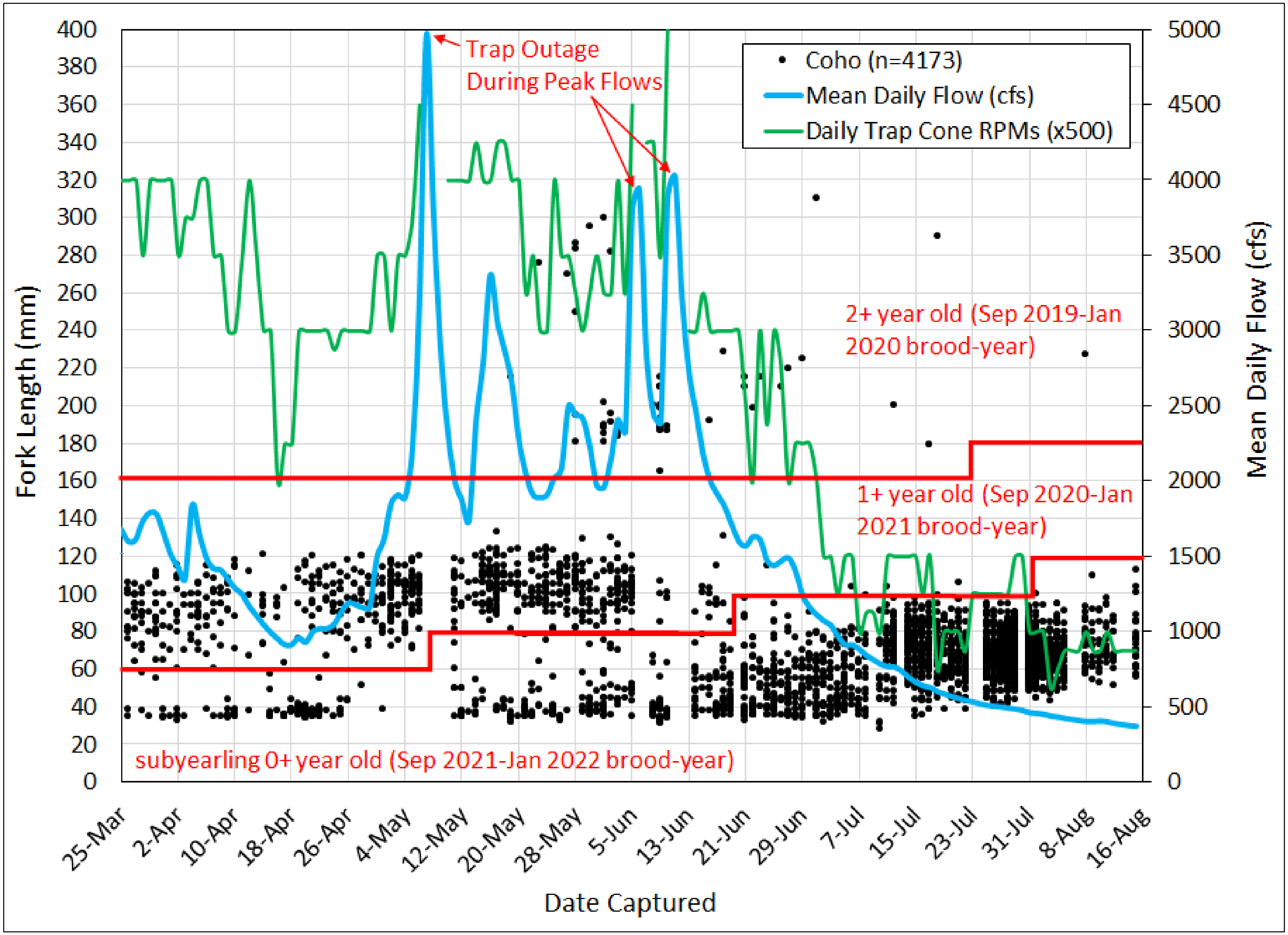


Figure 2.8a - Length frequency of all maiden Coho and Chinook catch in 2022.



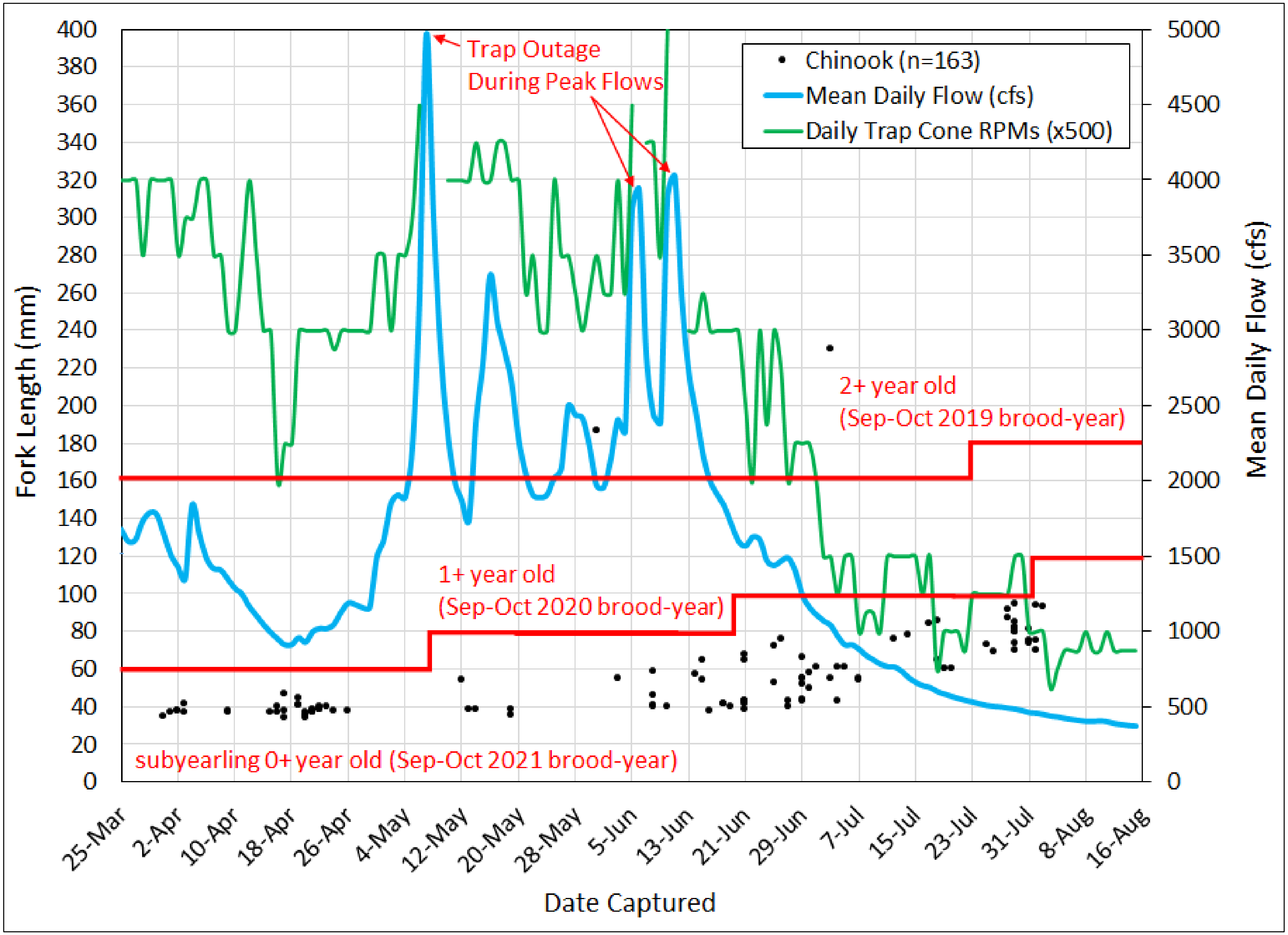
Note: Trout YOY represents total Steelhead/Rainbow, Cutthroat, and Trout YOY maiden catch combined.

Figure 2.8b - Length frequency of all maiden trout species catch in 2022.



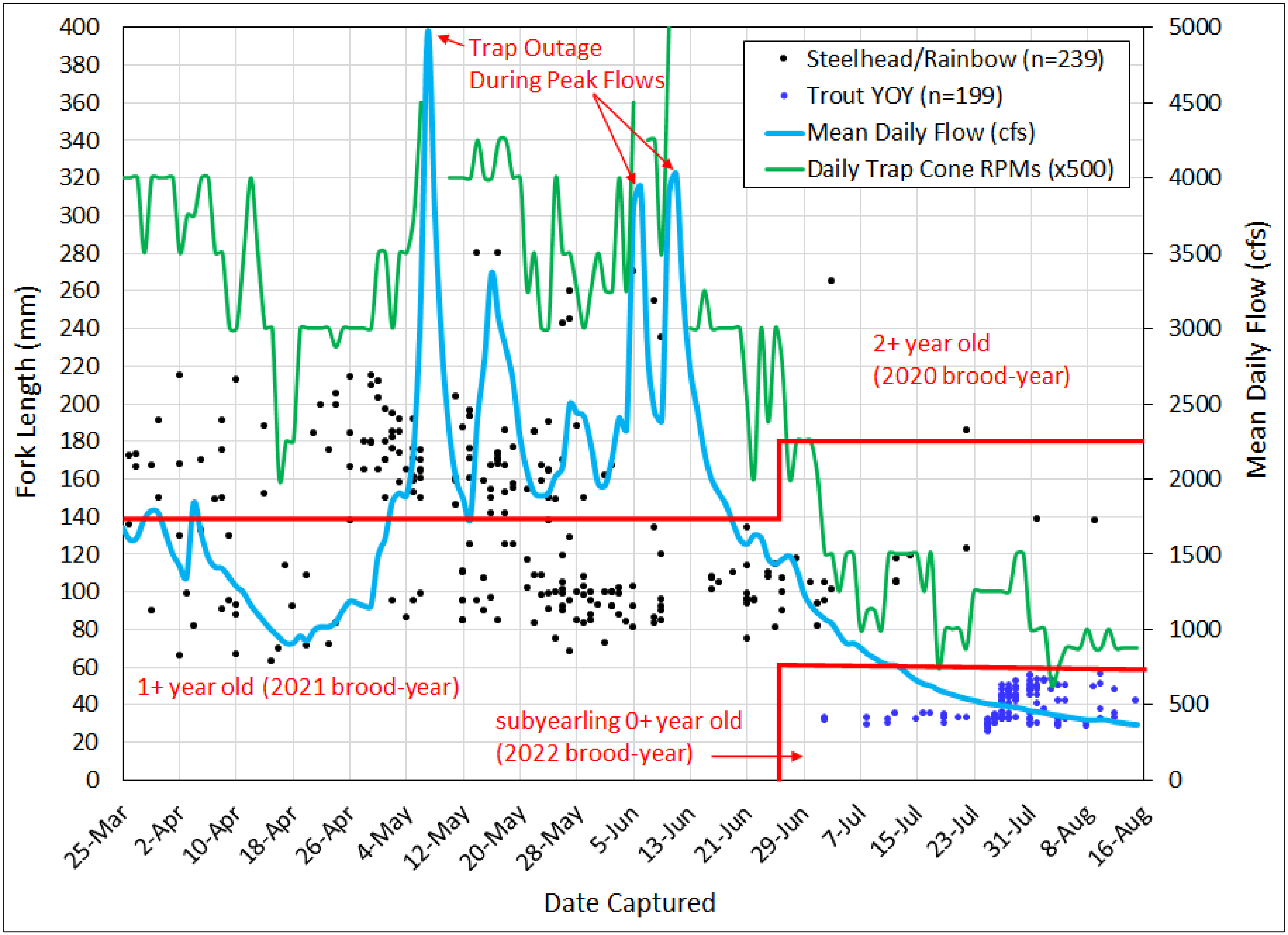
Note: Red lines demarcate inferred age classes/brood-years. Flow is at Lewis River above Muddy River gage.

Figure 2.8c - Fork lengths of all Coho maiden catch, stream flow, and trap cone RPMs by day in 2022.



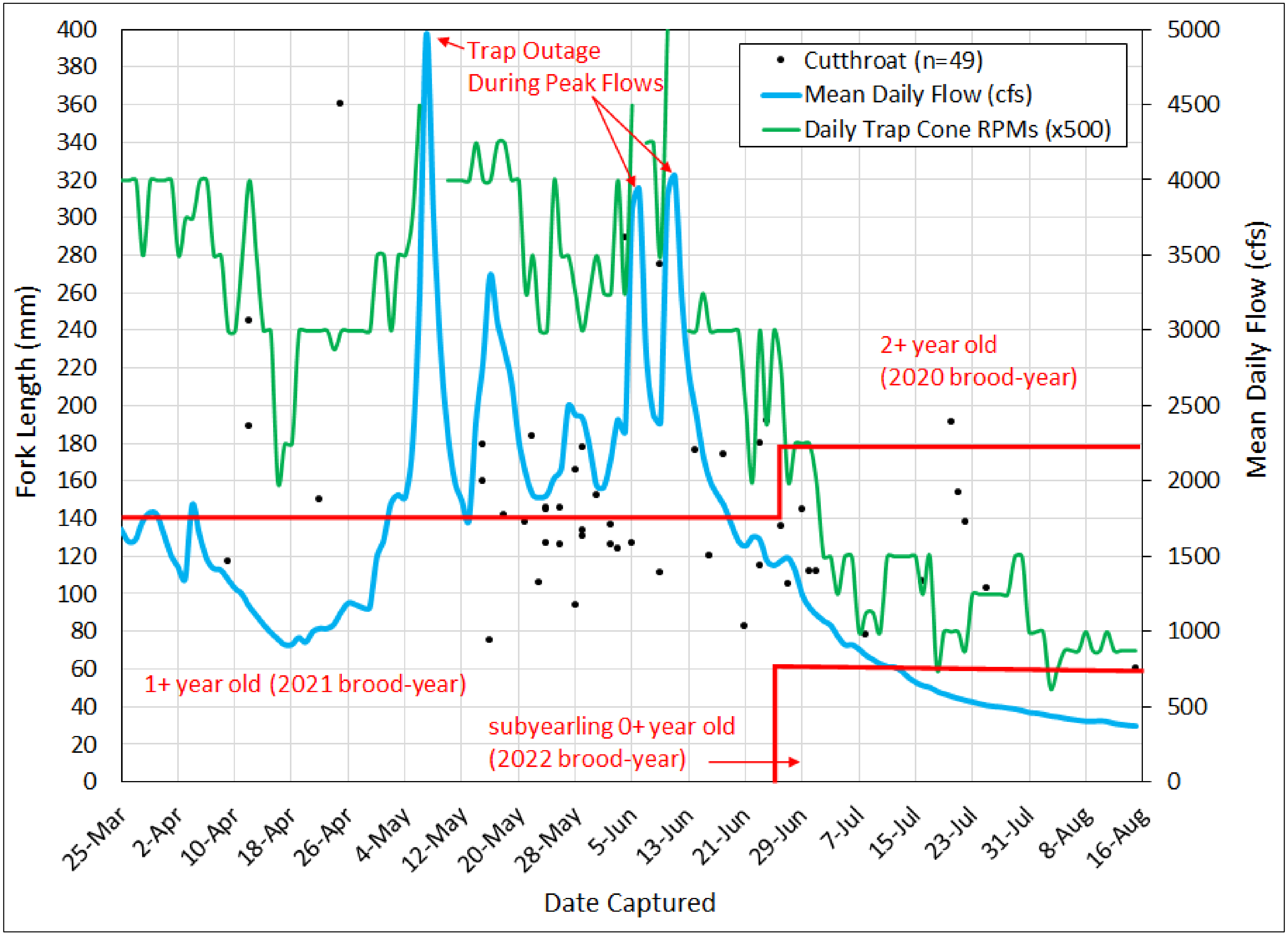
Note: Red lines demarcate inferred age classes/brood-years. Flow is at Lewis River above Muddy River gage.

Figure 2.8d - Fork lengths of all Chinook maiden catch, stream flow, and trap cone RPMs by day in 2022.



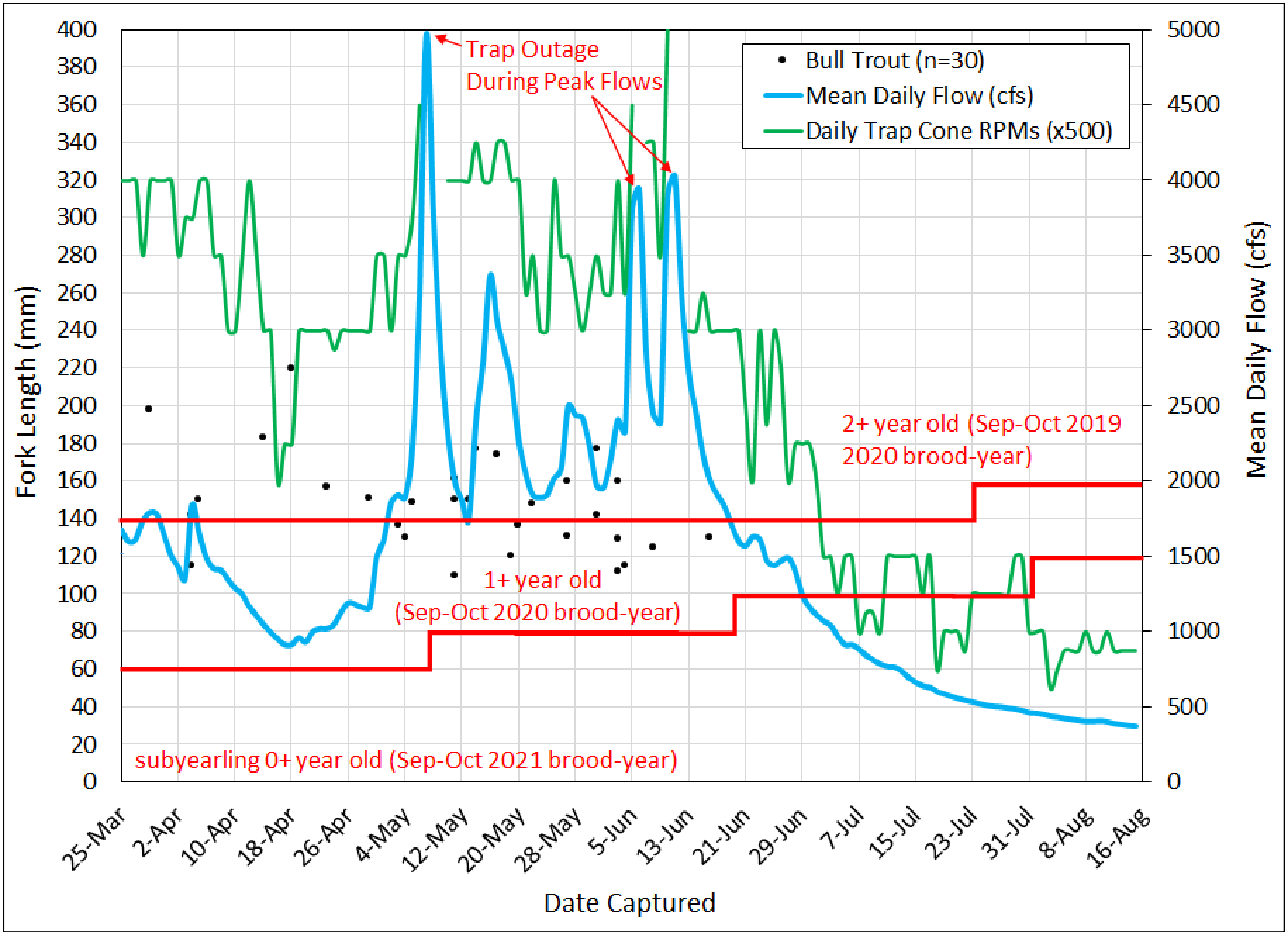
Note: Red lines demarcate inferred age classes/brood-years. Flow is at Lewis River above Muddy River gage.

Figure 2.8e - Fork lengths of all Steelhead and Trout YOY maiden catch, stream flow, and trap cone RPMs by day in 2022.



Note: Red lines demarcate inferred age classes/brood-years. Flow is at Lewis River above Muddy River gage.

Figure 2.8f - Fork lengths of all Cutthroat maiden catch, stream flow, and trap cone RPMs by day in 2022.



Note: Red lines demarcate inferred age classes/brood-years. Flow is at Lewis River above Muddy River gage.

Figure 2.8g - Fork lengths of all Bull Trout maiden catch, stream flow, and trap cone RPMs by day in 2022.

Table 2.8a - Weekly pooled mark-recapture estimates of trap efficiency.

North Fork Lewis River above Swift Dam – 2022			All Coho, Chinook, Steelhead, and Cutthroat Combined								Ave. Weekly Cone RPMs[b]	Ave. Weekly Flow (cfs)[a]	Adjusted Efficiency	
			Maiden		Mark-Release Up		Recapture		Efficiency					
Period	Start	End	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm	<50mm	≥50mm			<50mm	≥50mm
2	25-Mar	27-Mar	2	24		0					8.0	1,630	0.0152[f]	0.0769[d]
3	28-Mar	3-Apr	26	59		156		12		0.0769	7.6	1,606	0.0152[f]	0.0769[c]
4	4-Apr	10-Apr	53	63		109		4		0.0367	7.1	1,493	0.0152[f]	0.0367[c]
5	11-Apr	17-Apr	48	25	1	37		1		0.0270	6.1	1,063	0.0152[f]	0.0270[c]
6	18-Apr	24-Apr	246	50	106	65	1	3	0.0094	0.0462	5.8	984	0.0152[f]	0.0462[c]
7	25-Apr	1-May	10	77		147		9		0.0612	6.3	1,274	0.0152[f]	0.0612[c]
8	2-May	8-May		123		157		3		0.0191	5.2	2,826	0.0152[f]	0.0191[c]
9	9-May	15-May	48	73		182		15		0.0824	6.9	2,289	0.0152[f]	0.0824[c]
10	16-May	22-May	37	132		454		22		0.0485	7.8	2,600	0.0152[f]	0.0485[c]
11	23-May	29-May	39	160		340		18		0.0529	6.6	2,180	0.0152[f]	0.0529[c]
12	30-May	5-Jun	43	133		264		16		0.0606	7.1	2,409	0.0152[f]	0.0460[e]
13	6-Jun	12-Jun	85	38	42	214		6		0.0280	4.9	3,249	0.0152[f]	0.0390[e]
14	13-Jun	19-Jun	207	57	139	196	1	10	0.0072	0.0510	6.1	2,113	0.0152[f]	0.0510[c]
15	20-Jun	26-Jun	144	99	67	258	1	6	0.0149	0.0233	5.3	1,541	0.0287[g]	0.0233[c]
16	27-Jun	3-Jul	77	105	1	101		6		0.0594	3.9	1,216	0.0287[g]	0.0594[c]
17	4-Jul	10-Jul	67	71		71		2		0.0282	2.4	872	0.0287[g]	0.0282[c]
18	11-Jul	17-Jul	28	283	1	279		10		0.0358	2.9	698	0.0287[g]	0.0358[c]
19	18-Jul	24-Jul	30	205		204		7		0.0343	2.0	558	0.0287[g]	0.0343[c]
20	25-Jul	31-Jul	160	1038		814		26		0.0319	2.6	489	0.0287[g]	0.0319[c]
21	1-Aug	7-Aug	26	513		459		15		0.0327	1.7	432	0.0287[g]	0.0327[c]
22	8-Aug	15-Aug	10	109		83		4		0.0482	1.8	391	0.0287[g]	0.0482[c]
Total:			1,386	3,437	357	4,590	3	196	0.0084	0.0427				

[a]Note: Lewis River above Muddy River (USGS Gage 14216000).
[b]Note: Weekly average cone RPMs.
[c]Note: No adjustment to weekly mark-recapture efficiency estimate.
[d]Note: Same as week 3 due to similar stream flow and cone RPMs.
[e]Note: Combined efficiency with following week (trap off for part of period due to high water).
[f]Note: Combined efficiency for weeks 1 to 14 for all salmonids <60mm FL applied to increase sample size (5 recapture of 328 marked-released upstream).
[g]Note: Combined efficiency for weeks 15 to 22 for all salmonids <60mm FL applied to increase sample size (14 recapture of 487 marked-released upstream).

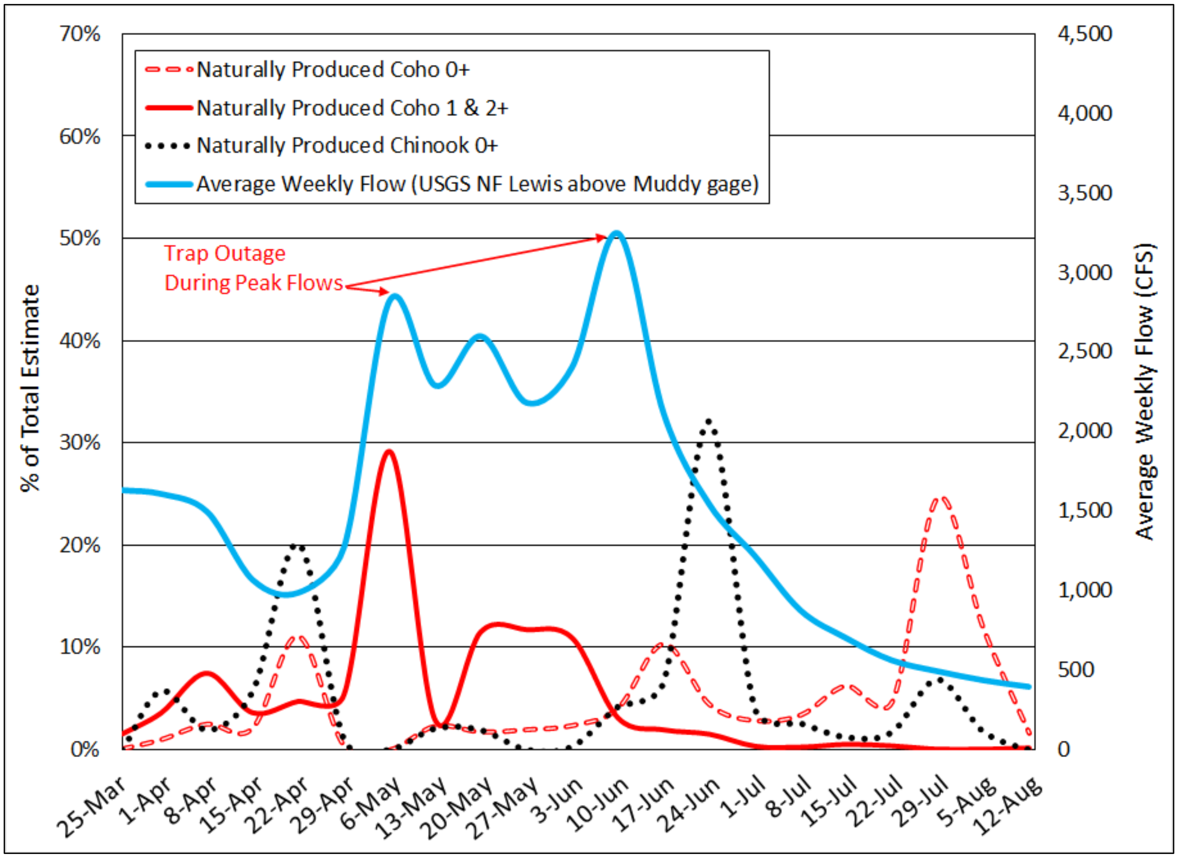


Figure 2.8h - Percent of estimated total Coho and Chinook passing the trap by inferred age class in 2022.

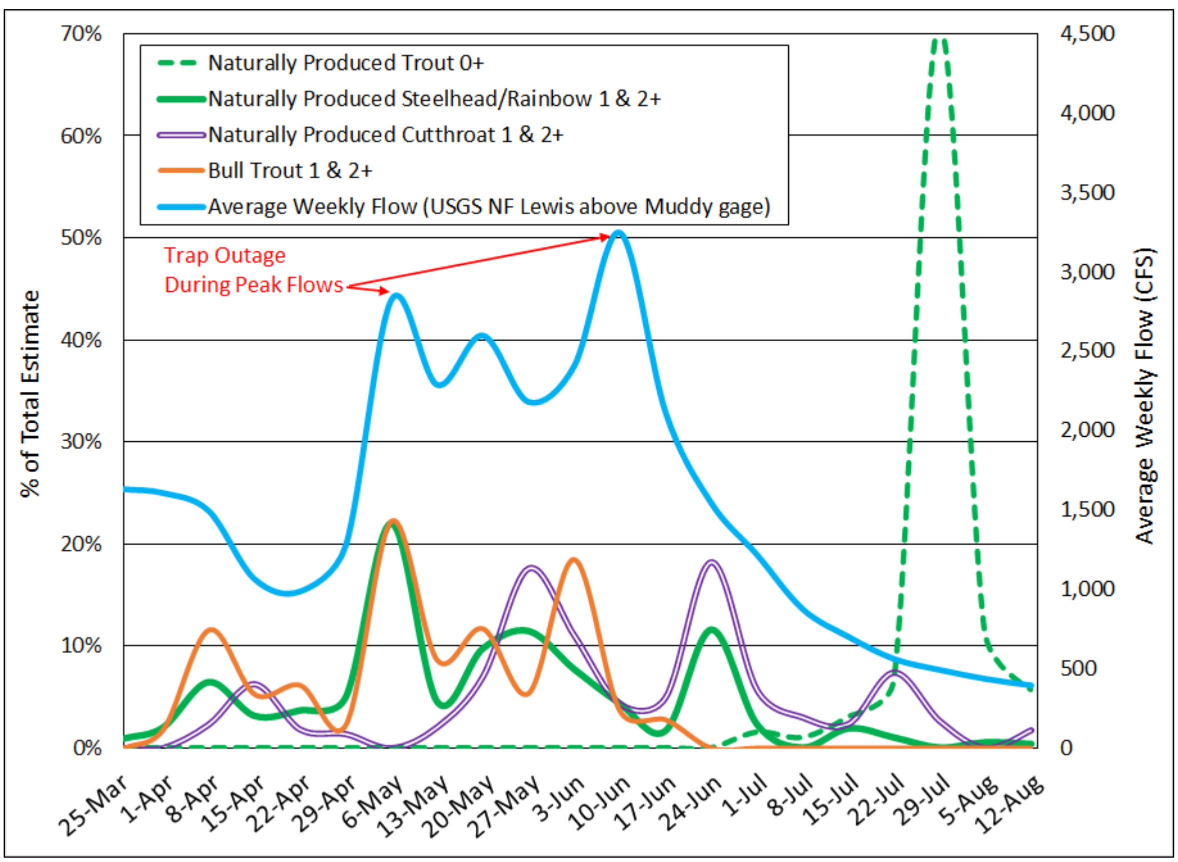


Figure 2.8i - Percent of estimated total trout species passing the trap by inferred age class in 2022.

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Part 3: ANALYSIS AND RESULTS

3.1 Description of changes made to raw Capture-Mark-Recapture Data (tables 2.3a and 2.3b) prior to generating the final Capture-Mark-Recapture Data (tables under 3.2). Add additional bullets as needed.		
• *Were capture, mark, and/or recapture data from multiple trapping periods combined (i.e., pooled)?*	Yes	All naturally produced Coho, Chinook, Steelhead, and Cutthroat were pooled
• *Were capture, mark, and/or recapture data from an entire period omitted prior to or as part of the analysis?*	No	
• *Were capture, mark, and/or recapture data from a single day or multiple days with a period or periods omitted?*	No	
• *Describe any additional changes that were made to the raw data set prior to generating the final data set*	None	

3.2 Final Data Summary for Mark-Recapture Analysis

Total estimates of naturally produced Coho, Chinook, Steelhead, Cutthroat, and Bull Trout passing the trap by inferred age class/brood-year (based on size) and the associated 95% confidence intervals (CI) were generated using the Bootstrap Method (Thedinga et al. 1994, Manly 2007, Efron and Tibshirani 1986). The trap efficiency used to make these estimates for each species-inferred age class was based on the total pooled mark-recapture data (all Coho, Chinook, Steelhead, and Cutthroat combined) corresponding to the individual timing and size class for each individual species-inferred age class. Individual estimates of the total number of fish <50 mm FL and ≥50 mm FL were then summed to estimate the total number of fish passing the trap for the inferred age 0+ bracket, where fish smaller and larger than 50 mm FL were captured over the trapping season unless otherwise specified. The pooled mark-recapture values over the entire season ("total" line in each table 3.2a through 3.2l) were used to produce the Bootstrap estimate for each species/inferred age class.

As described in the Aquatic Monitoring and Evaluation Plan for the Lewis River (PacifiCorp and Cowlitz PUD 2022), 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. The data used to generate the Bootstrap and Volkhardt et al. (2007) method estimates for each species inferred age class are summarized in tables 3.2a through 3.2l below. Shaded-bracketed periods depicted in the tables were combined and unshaded periods were used individually to produce the Volkhardt et al. (2007) method estimates. The data in these tables is presented in the Bayesian Time-Stratified Population Analysis (BTSPAS) model format for informational purposes. Note that all recaptured fish are summarized as if recaptured within "Period 0", which is defined as the same week as initially marked and released upstream (diagonal format). Note that following the JMX Protocol, fish recaptured with the same mark-type one day after the last day of the release week period were assigned to being recaptured in Period 0.

Table 3.2a - Final capture-mark-recapture data used to estimate total Coho (inferred age 0+).

Trap Name: Eagle Cliff screw trap						**Species:** Coho		**Origin:** Naturally Produced			**Inferred age Class/Brood Year:** 0+ / Sep 2021-Jan 2022			
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)														
Period	**Period Start Date**	**Period End Date**	**[c]Life Stage & Size Classes by Period:** Fry <50 mm (Periods 2 to 21)						**[c]Life Stage & Size Classes by Period:** Parr, Transitional, Smolt 50 to 59 mm (Periods 2 to 8) 50 to 79 mm (periods 9 to 14) 50 to 99 mm (periods 15 to 20) 50 to 119 mm (period 21 to 22)					
			Total Marked[a]	**Mark Group[d]**	**Period 0 Recaps[d]**	**Total Recaps[d]**	**Total Maiden Capture**	**Prop Fished[e]**	**Total Marked[b]**	**Mark Group[d]**	**Period 0 Recaps**	**Total Recaps[d]**	**Total Maiden Captured**	**Prop Fished[e]**
2	25-Mar	27-Mar					2	1						1
3	28-Mar	3-Apr	2	M, S			20	1	2	M, S			2	1
4	4-Apr	10-Apr		M, S			51	1		M, S				1
5	11-Apr	17-Apr	2	M, S			42	1	1	M, S			1	1
6	18-Apr	24-Apr	107	M, S	1	1	225	1	1	M, S			1	1
7	25-Apr	1-May	1	M, S			9	1	1	M, S			1	1
8	2-May	8-May		M, S				0.79		M, S				0.79
9	9-May	15-May	5	M, S			46	0.79	6	M, S			7	0.79
10	16-May	22-May	1	M, S			35	1	3	M, S			2	1
11	23-May	29-May	2	M, S	1	1	39	1	6	M, S	1	1	4	1
12	30-May	5-Jun	5	M, S			43	0.92	12	M, S	1	1	16	0.92
13	6-Jun	12-Jun	44	M, S			81	0.43	5	M, S			4	0.43
14	13-Jun	19-Jun	159	M, S	3	3	201	0.94	32	M, S	3	3	29	0.94
15	20-Jun	26-Jun	104	M, S	1	1	87	1	80	M, S	2	2	67	1
16	27-Jun	3-Jul	42	M, S	3	3	70	1	89	M, S	6	6	81	1
17	4-Jul	10-Jul	27	M, S			64	1	70	M, S	2	2	65	1
18	11-Jul	17-Jul	21	M, S			22	1	273	M, S	10	10	272	1
19	18-Jul	24-Jul	42	M, S	2	2	17	1	197	M, S	7	7	194	1
20	25-Jul	31-Jul	139	M, S	5	5	29	1	813	M, S	26	26	1,013	1
21	1-Aug	7-Aug	103	M, S	3	3	10	1	458	M, S	15	15	501	1
22	8-Aug	15-Aug						1	81	M, S	4	4	104	1
		Total:	806		19	19	1,093		2,130		77	77	2,364	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined <60 mm FL; included fish 50 to 59 mm FL to increase sample size.

[b]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Coho specific length brackets by period.

[c]Note: Same as inferred age backets based on size class as depicted in Figure 2.8c for Coho.

[d]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Coho specific length brackets by period.

[e]Note: Based on outages listed in Table 2.2.e.

Table 3.2b - Final capture-mark-recapture data used to estimate total Coho (inferred age 1+).

Trap Name: Eagle Cliff screw trap					**Species:** Coho	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 1+ / Sep 2020-Jan 2021								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	[b]**Life Stage & Size Classes by Period:** Parr, Transitional, Smolt 60 to 159 mm (Periods 2 to 8) 80 to 159 mm (periods 9 to 14) 100 to 159 mm (periods 15 to 19) 100 to 179 mm (period 20) 120 to 179 mm (period 21 to 22)					
			Total Marked[a]	**Mark Group**[c]	**Period 0 Recaps**[c]	**Total Recaps**[c]	**Total Maiden Captured**	**Prop Fished**[d]
2	25-Mar	27-Mar					20	1
3	28-Mar	3-Apr	150	M, S	12	12	48	1
4	4-Apr	10-Apr	105	M, S	4	4	48	1
5	11-Apr	17-Apr	33	M, S	1	1	17	1
6	18-Apr	24-Apr	47	M, S	3	3	38	1
7	25-Apr	1-May	84	M, S	5	5	57	1
8	2-May	8-May	131	M, S	3	3	98	0.79
9	9-May	15-May	129	M, S	12	12	41	0.79
10	16-May	22-May	372	M, S	18	18	97	1
11	23-May	29-May	314	M, S	16	16	102	1
12	30-May	5-Jun	235	M, S	11	11	75	0.92
13	6-Jun	12-Jun	182	M, S	4	4	6	0.43
14	13-Jun	19-Jun	157	M, S	7	7	15	0.94
15	20-Jun	26-Jun	155	M, S	2	2	1	1
16	27-Jun	3-Jul	8	M, S				1
17	4-Jul	10-Jul	1	M, S			1	1
18	11-Jul	17-Jul	5	M, S			1	1
19	18-Jul	24-Jul	4	M, S			1	1
20	25-Jul	31-Jul						1
21	1-Aug	7-Aug						1
22	8-Aug	15-Aug						1
		Total:	2,112		98	98	666	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Coho specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8c for Coho.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Coho specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2c - Final capture-mark-recapture data used to estimate total Coho (inferred age 2+).

Trap Name: Eagle Cliff screw trap					**Species:** Coho	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 2+ / Sep 2019-Jan 2020								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	[b]**Life Stage & Size Classes by Period:** Parr, Transitional, Smolt ≥160 mm (Periods 1 to 19) ≥180 mm (Periods 20 to 22)					
			Total Marked[a]	**Mark Group**[c]	**Period 0 Recaps**[c]	**Total Recaps**[c]	**Total Maiden Captured**	**Prop Fished**[d]
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr						1
4	4-Apr	10-Apr						1
5	11-Apr	17-Apr						1
6	18-Apr	24-Apr						1
7	25-Apr	1-May						1
8	2-May	8-May						0.79
9	9-May	15-May	47	M, S	3	3		0.79
10	16-May	22-May	79	M, S	4	4	1	1
11	23-May	29-May	20	M, S	1	1	7	1
12	30-May	5-Jun	17	M, S	4	4	13	0.92
13	6-Jun	12-Jun	27	M, S	2	2	15	0.43
14	13-Jun	19-Jun	7	M, S			2	0.94
15	20-Jun	26-Jun	23	M, S	2	2	5	1
16	27-Jun	3-Jul	4	M, S			3	1
17	4-Jul	10-Jul		M, S				1
18	11-Jul	17-Jul	1	M, S			2	1
19	18-Jul	24-Jul	3	M, S			1	1
20	25-Jul	31-Jul		M, S				1
21	1-Aug	7-Aug		M, S				1
22	8-Aug	15-Aug	1	M, S			1	1
		Total:	229		16	16	50	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Coho specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8c for Coho.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Coho specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2d - Final capture-mark-recapture data used to estimate total Chinook (inferred age 0+).

Trap Name: Eagle Cliff screw trap | **Species:** Chinook | **Origin:** Naturally Produced | **Inferred age Class/Brood Year:** 0+ / Sep-Oct 2022

Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)

Period	Period Start Date	Period End Date	[c]**Life Stage & Size Classes by Period:** Fry <50 mm (Periods 3 to 17)						[c]**Life Stage & Size Classes by Period:** Parr, Transitional, Smolt 50 to 59 mm (Periods 2 to 8) 50 to 79 mm (periods 9 to 14) 50 to 99 mm (periods 15 to 20) 50 to 119 mm (period 21 to 22)					
			Total Marked[a]	Mark Group[d]	Period 0 Recaps[d]	Total Recaps[d]	Total Maiden Capture	Prop Fished[e]	Total Marked[b]	Mark Group[d]	Period 0 Recaps	Total Recaps[d]	Total Maiden Captured	Prop Fished[e]
2	25-Mar	27-Mar						1						1
3	28-Mar	3-Apr	2	M, S			6	1						1
4	4-Apr	10-Apr		M, S			2	1						1
5	11-Apr	17-Apr	2	M, S			6	1						1
6	18-Apr	24-Apr	107	M, S	1	1	21	1						1
7	25-Apr	1-May	1	M, S			1	1						1
8	2-May	8-May		M, S				0.79						0.79
9	9-May	15-May	5	M, S			2	0.79	6	M, S			1	0.79
10	16-May	22-May	1	M, S			2	1	3	M, S				1
11	23-May	29-May	2	M, S	1	1		1	6	M, S	1	1		1
12	30-May	5-Jun	5	M, S				0.92	12	M, S	1	1	1	0.92
13	6-Jun	12-Jun	44	M, S			4	0.43	5	M, S			1	0.43
14	13-Jun	19-Jun	159	M, S	3	3	6	0.94	32	M, S	3	3	3	0.94
15	20-Jun	26-Jun	104	M, S	1	1	57	1	80	M, S	2	2	5	1
16	27-Jun	3-Jul	42	M, S	3	3	4	1	89	M, S	6	6	8	1
17	4-Jul	10-Jul	27	M, S			1	1	70	M, S	2	2	4	1
18	11-Jul	17-Jul	21	M, S				1	273	M, S	10	10	3	1
19	18-Jul	24-Jul	42	M, S	2	2		1	197	M, S	7	7	4	1
20	25-Jul	31-Jul	139	M, S	5	5		1	813	M, S	26	26	15	1
21	1-Aug	7-Aug	103	M, S	3	3		1	458	M, S	15	15	4	1
22	8-Aug	15-Aug						1						1
		Total:	806		19	19	112		2044		73	73	49	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; “total” line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined <60 mm FL; included fish 50 to 59 mm FL to increase sample size.

[b]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Chinook specific length brackets by period.

[c]Note: Same as inferred age backets based on size class as depicted in Figure 2.8d for Chinook.

[d]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Chinook specific length brackets by period.

[e]Note: Based on outages listed in Table 2.2.e.

Table 3.2e - Final capture-mark-recapture data used to estimate total Chinook (inferred age 2+).

Trap Name: Eagle Cliff screw trap					**Species:** Chinook	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 2+ / Sep-Oct 2019								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Parr, Transitional, Smolt ≥160 mm (Periods 1 to 19) ≥180 mm (Periods 20 to 22)					
			Total Marked[a]	**Mark Group[c]**	**Period 0 Recaps[c]**	**Total Recaps[c]**	**Total Maiden Captured**	**Prop Fished[d]**
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr						1
4	4-Apr	10-Apr						1
5	11-Apr	17-Apr						1
6	18-Apr	24-Apr						1
7	25-Apr	1-May						1
8	2-May	8-May						0.79
9	9-May	15-May						0.79
10	16-May	22-May						1
11	23-May	29-May						1
12	30-May	5-Jun	24	M, S	4	4	1	0.92
13	6-Jun	12-Jun	47	M, S	2	2		0.43
14	13-Jun	19-Jun	27	M, S	0	0		0.94
15	20-Jun	26-Jun	110	M, S	4	4		1
16	27-Jun	3-Jul	5	M, S	0	0	1	1
17	4-Jul	10-Jul						1
18	11-Jul	17-Jul						1
19	18-Jul	24-Jul						1
20	25-Jul	31-Jul						1
21	1-Aug	7-Aug						1
22	8-Aug	15-Aug						1
		Total:	213		10	10	2	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Chinook specific length brackets by period; also included fish 140 to 159 mm FL to increase sample size.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8d for Chinook.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Chinook specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2f - Final capture-mark-recapture data used to estimate total Trout YOY (inferred age 0+).

Trap Name: Eagle Cliff screw trap				**Species:** Trout YOY		**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 0+ / 2022								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** YOY <60 mm (Periods 16 to 22)					
			Total Marked[a]	**Mark Group**	**Period 0 Recaps**	**Total Recaps**	**Total Maiden Captured**	**Prop Fished[c]**
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr						1
4	4-Apr	10-Apr						1
5	11-Apr	17-Apr						1
6	18-Apr	24-Apr						1
7	25-Apr	1-May						1
8	2-May	8-May						0.79
9	9-May	15-May						0.79
10	16-May	22-May						1
11	23-May	29-May						1
12	30-May	5-Jun						0.92
13	6-Jun	12-Jun						0.43
14	13-Jun	19-Jun						0.94
15	20-Jun	26-Jun						1
16	27-Jun	3-Jul	42	M, S	3	3	3	1
17	4-Jul	10-Jul	27	M, S	0	0	2	1
18	11-Jul	17-Jul	21	M, S	0	0	6	1
19	18-Jul	24-Jul	42	M, S	2	2	13	1
20	25-Jul	31-Jul	139	M, S	5	5	140	1
21	1-Aug	7-Aug	103	M, S	3	3	23	1
22	8-Aug	15-Aug	9	M, S	0	0	12	1
		Total:	383		13	13	199	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Trout YOY specific length bracket by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8e for Trout YOY.

[c]Note: Based on outages listed in Table 2.2.

Table 3.2g - Final capture-mark-recapture data used to estimate total Steelhead (inferred age 1+).

Trap Name: Eagle Cliff screw trap					**Species:** Steelhead	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 1+ / 2021								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	[b]**Life Stage & Size Classes by Period:** Parr, Transitional, Smolt 60 to 139 mm (Periods 2 to 15) 60 to 179 mm (Periods 16 to 22)					
			Total Marked[a]	**Mark Group**[c]	**Period 0 Recaps**[c]	**Total Recaps**[c]	**Total Maiden Captured**	**Prop Fished**[d]
2	25-Mar	27-Mar					1	1
3	28-Mar	3-Apr	149	M, S	12	12	4	1
4	4-Apr	10-Apr	102	M, S	4	4	8	1
5	11-Apr	17-Apr	32	M, S	1	1	3	1
6	18-Apr	24-Apr	46	M, S	3	3	5	1
7	25-Apr	1-May	79	M, S	3	3	1	1
8	2-May	8-May	120	M, S	3	3	4	0.79
9	9-May	15-May	117	M, S	9	9	10	0.79
10	16-May	22-May	350	M, S	15	15	8	1
11	23-May	29-May	288	M, S	14	14	22	1
12	30-May	5-Jun	235	M, S	12	12	18	0.92
13	6-Jun	12-Jun	165	M, S	4	4	8	0.43
14	13-Jun	19-Jun	149	M, S	8	8	5	0.94
15	20-Jun	26-Jun	111	M, S	2	2	16	1
16	27-Jun	3-Jul	56	M, S	3	3	7	1
17	4-Jul	10-Jul	44	M, S	2	2	0	1
18	11-Jul	17-Jul	259	M, S	10	10	4	1
19	18-Jul	24-Jul	159	M, S	5	5	1	1
20	25-Jul	31-Jul	675	M, S	21	21	0	1
21	1-Aug	7-Aug	356	M, S	12	12	1	1
22	8-Aug	15-Aug	73	M, S	4	4	1	1
		Total:	3,565		147	147	127	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Steelhead specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8e for Steelhead.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Steelhead specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2h - Final capture-mark-recapture data used to estimate total Steelhead (inferred age 2+).

Trap Name: Eagle Cliff screw trap					**Species:** Steelhead		**Origin:** Naturally Produced	
Inferred age Class / Brood Year: 2+ / 2020								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Parr, Transitional, Smolt ≥140 mm (Periods 1 to 15) ≥180 mm (Periods 16 to 22)					
			Total Marked[a]	**Mark Group[c]**	**Period 0 Recaps[c]**	**Total Recaps[c]**	**Total Maiden Captured**	**Prop Fished[d]**
2	25-Mar	27-Mar					3	1
3	28-Mar	3-Apr	5	M, S			5	1
4	4-Apr	10-Apr	7	M, S			6	1
5	11-Apr	17-Apr	4	M, S			2	1
6	18-Apr	24-Apr	18	M, S			5	1
7	25-Apr	1-May	67	M, S	6	6	17	1
8	2-May	8-May	37	M, S			21	0.79
9	9-May	15-May	60	M, S	6	6	12	0.79
10	16-May	22-May	103	M, S	7	7	20	1
11	23-May	29-May	50	M, S	3	3	14	1
12	30-May	5-Jun	24	M, S	4	4	3	0.92
13	6-Jun	12-Jun	47	M, S	2	2	2	0.43
14	13-Jun	19-Jun	27	M, S				0.94
15	20-Jun	26-Jun	110	M, S	4	4		1
16	27-Jun	3-Jul	4	M, S			1	1
17	4-Jul	10-Jul		M, S				1
18	11-Jul	17-Jul		M, S				1
19	18-Jul	24-Jul	3	M, S			1	1
20	25-Jul	31-Jul						1
21	1-Aug	7-Aug						1
22	8-Aug	15-Aug						1
		Total:	566		32	32	112	32

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Steelhead specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8e for Steelhead.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Steelhead specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2i - Final capture-mark-recapture data used to estimate total Cutthroat (inferred age 1+).

Trap Name: Eagle Cliff screw trap					**Species:** Cutthroat	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 1+ / 2021								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Parr, Transitional, Smolt 60 to 139 mm (Periods 2 to 15) 60 to 179 mm (Periods 16 to 22)					
			Total Marked[a]	**Mark Group[c]**	**Period 0 Recaps[c]**	**Total Recaps[c]**	**Total Maiden Captured**	**Prop Fished[d]**
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr	149	M, S	12	12		1
4	4-Apr	10-Apr	102	M, S	4	4	1	1
5	11-Apr	17-Apr	32	M, S	1	1		1
6	18-Apr	24-Apr	46	M, S	3	3		1
7	25-Apr	1-May	79	M, S	3	3		1
8	2-May	8-May	120	M, S	3	3		0.79
9	9-May	15-May	117	M, S	9	9		0.79
10	16-May	22-May	350	M, S	15	15	2	1
11	23-May	29-May	288	M, S	14	14	6	1
12	30-May	5-Jun	235	M, S	12	12	4	0.92
13	6-Jun	12-Jun	165	M, S	4	4	1	0.43
14	13-Jun	19-Jun	149	M, S	8	8	1	0.94
15	20-Jun	26-Jun	111	M, S	2	2	3	1
16	27-Jun	3-Jul	56	M, S	3	3	4	1
17	4-Jul	10-Jul	44	M, S	2	2	1	1
18	11-Jul	17-Jul	259	M, S	10	10	1	1
19	18-Jul	24-Jul	159	M, S	5	5	2	1
20	25-Jul	31-Jul	675	M, S	21	21	1	1
21	1-Aug	7-Aug	356	M, S	12	12		1
22	8-Aug	15-Aug	73	M, S	4	4	1	1
		Total:	3,565		147	147	28	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Cutthroat specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8f for Cutthroat.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Cutthroat specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2j - Final capture-mark-recapture data used to estimate total Cutthroat (inferred age 2+).

Trap Name: Eagle Cliff screw trap					**Species:** Cutthroat		**Origin:** Naturally Produced	
Inferred age Class / Brood Year: 2+ / 2020								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Parr, Transitional, Smolt ≥140 mm (Periods 1 to 15) ≥180 mm (Periods 16 to 22)					
			Total Marked[a]	**Mark Group[c]**	**Period 0 Recaps[c]**	**Total Recaps[c]**	**Total Maiden Captured**	**Prop Fished[d]**
2	25-Mar	27-Mar					0	1
3	28-Mar	3-Apr	5	M, S			0	1
4	4-Apr	10-Apr	7	M, S			0	1
5	11-Apr	17-Apr	4	M, S			2	1
6	18-Apr	24-Apr	18	M, S			1	1
7	25-Apr	1-May	67	M, S	6	6	1	1
8	2-May	8-May	37	M, S			0	0.79
9	9-May	15-May	60	M, S	6	6	2	0.79
10	16-May	22-May	103	M, S	7	7	2	1
11	23-May	29-May	50	M, S	3	3	5	1
12	30-May	5-Jun	24	M, S	4	4	2	0.92
13	6-Jun	12-Jun	47	M, S	2	2	1	0.43
14	13-Jun	19-Jun	27	M, S			2	0.94
15	20-Jun	26-Jun	110	M, S	4	4	2	1
16	27-Jun	3-Jul	4	M, S			0	1
17	4-Jul	10-Jul		M, S			0	1
18	11-Jul	17-Jul		M, S			0	1
19	18-Jul	24-Jul	3	M, S			1	1
20	25-Jul	31-Jul					0	1
21	1-Aug	7-Aug					0	1
22	8-Aug	15-Aug					0	1
		Total:	566		32	32	21	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Cutthroat specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8f for Cutthroat.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Cutthroat specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2k - Final capture-mark-recapture data used to estimate total Bull Trout (inferred age 1+).

Trap Name: Eagle Cliff screw trap					**Species:** Bull Trout		**Origin:** Naturally Produced	
Inferred age Class / Brood Year: Sep-Oct 2020								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Juvenile 60 to 139 mm (Periods 2 to 8) 80 to 139 mm (periods 9 to 14) 100 to 139 mm (periods 15 to 19) 100 to 159 mm (period 20) 120 to 159 mm (period 21 to 22)					
			Total Marked[a]	**Mark Group[c]**	**Period 0 Recaps[c]**	**Total Recaps[c]**	**Total Maiden Captured**	**Prop Fished[d]**
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr						1
4	4-Apr	10-Apr	102	S	4	4	1	1
5	11-Apr	17-Apr	32	S	1	1		1
6	18-Apr	24-Apr	46	S	3	3		1
7	25-Apr	1-May	79	S	3	3		1
8	2-May	8-May	120	S	3	3	2	0.79
9	9-May	15-May	116	S	9	9	1	0.79
10	16-May	22-May	348	S	15	15	2	1
11	23-May	29-May	284	S	14	14	1	1
12	30-May	5-Jun	228	S	11	11	3	0.92
13	6-Jun	12-Jun	162	S	4	4	1	0.43
14	13-Jun	19-Jun	137	S	7	7	1	0.94
15	20-Jun	26-Jun						1
16	27-Jun	3-Jul						1
17	4-Jul	10-Jul						1
18	11-Jul	17-Jul						1
19	18-Jul	24-Jul						1
20	25-Jul	31-Jul						1
21	1-Aug	7-Aug						1
22	8-Aug	15-Aug						1
		Total:	1,654		74	74	12	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Bull Trout specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8g for Bull Trout.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Bull Trout specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

Table 3.2l - Final capture-mark-recapture data used to estimate total Bull Trout (inferred age 2+).

Trap Name: Eagle Cliff screw trap					**Species:** Bull Trout	**Origin:** Naturally Produced		
Inferred age Class / Brood Year: 2+ / Sep-Oct 2019								
Analysis: Bootstrap (listed below in BTSPAS diagonal format for informational purposes)								
Period	**Period Start Date**	**Period End Date**	**[b]Life Stage & Size Classes by Period:** Juvenile ≥140 mm (Periods 2 to 19) ≥160 mm (Periods 20 to 22)					
			Total Marked[d]	**Mark Group[a]**	**Period 0 Recaps**	**Total Recaps**	**Total Maiden Captured**	**Prop Fished**
2	25-Mar	27-Mar						1
3	28-Mar	3-Apr	5				1	1
4	4-Apr	10-Apr	7				2	1
5	11-Apr	17-Apr	4				1	1
6	18-Apr	24-Apr	18				2	1
7	25-Apr	1-May	67		6	6	1	1
8	2-May	8-May	37				1	0.79
9	9-May	15-May	60		6	6	4	0.79
10	16-May	22-May	103		7	7	2	1
11	23-May	29-May	50		3	3	1	1
12	30-May	5-Jun	24		4	4	3	0.92
13	6-Jun	12-Jun	47		2	2		0.43
14	13-Jun	19-Jun						0.94
15	20-Jun	26-Jun						1
16	27-Jun	3-Jul						1
17	4-Jul	10-Jul						1
18	11-Jul	17-Jul						1
19	18-Jul	24-Jul						1
20	25-Jul	31-Jul						1
21	1-Aug	7-Aug						1
22	8-Aug	15-Aug						1
		Total:	422		28	28	18	

Note: Shaded-bracketed periods combined and unshaded periods used individually for Volkhardt method estimate; "total" line data used to generate Bootstrap method estimate.

[a]Note: Mark/recapture group for all periods = all marked salmonids combined within listed Bull Trout specific length brackets by period.

[b]Note: Same as inferred age backets based on size class as depicted in Figure 2.8g for Bull Trout.

[c]Note: Includes all salmonids marked at the screw trap and Swift FSC and released at Pine Creek confluence within the listed Bull Trout specific length brackets by period.

[d]Note: Based on outages listed in Table 2.2.

3.3 Equations or Software Used to Complete Analysis

A nonparametric Bootstrap Method (Thedinga et al. 1994, Manly 2007, Efron and Tibshirani 1986) was used to calculate the mean population estimate, variance, and 95% confidence interval for naturally produced salmonids by inferred age class passing the Eagle Cliff screw trap during the 2022 monitoring period. The pooled mark-recapture values over the entire season ("total" line in each table 3.2a through 3.2l) were used to produce the Bootstrap estimate for each species/inferred age class. The Bootstrap was run with 1,000 iterations. The 95% confidence interval was calculated as the square root of the mean Bootstrap variance multiplied by 1.96. The coefficient of variation was calculated by dividing the standard deviation by the mean population estimate. No attempt was made to specifically estimate the number of fish passing the trap when the trap was off during high flow events (outages listed in Table 2.2).

As described in the Aquatic Monitoring and Evaluation Plan for the Lewis River (PacifiCorp and Cowlitz PUD 2022), 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. The values and periods used are summarized in tables 3.2a through 3.2l for each species/inferred age class. Shaded-bracketed periods depicted in the tables were combined and unshaded periods were used individually to produce the Volkhardt et al. (2007) method estimates.

Total juvenile outmigration was calculated by period for each species/inferred age class following 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 ($\hat{U}$), is dependent on actual recapture rates observed:

$$\hat{U}_i = \frac{u_i(M_i+1)}{m_i+1} ,$$

Where:

u_i = number of unmarked fish captured during discrete period I;
M_i = number of fish marked and released during period I; and
m_i = number of marked fish recaptured during period i.

With associated variance estimator:

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

Estimates by period of juvenile migration were combined to calculate the total number of juveniles migrating downstream during the monitoring period using the following formula:

$$\hat{U} = \sum_{i=1}^{n} \hat{U}_i$$

Entire monitoring period variance:

$$V(\hat{U}) = \sum_{i=1}^{n} V(\hat{U}_i)$$

95% Confidence Interval:

$$\hat{U} \pm 1.96\sqrt{V(\hat{U})}$$

The coefficient of variation was calculated by dividing the standard deviation by the mean population estimate. No attempt was made to specifically estimate fish passing the trap when the trap was off during high flow events (outages listed in Table 2.2).

3.4 Final Outmigrant Abundance Estimates

The final data tables listed in section 3.3 were used to generate total estimates of naturally produced salmonids passing the trap during the monitoring period for each species/inferred age class using the Bootstrap Method and Volkhardt et al. (2007) Method (Table 3.4a).

Table 3.4a – Estimates of total juvenile salmonids by species and inferred age class passing the Eagle Cliff screw trap for the period of March 25 to August 15, 2022.

Species (Inferred age Class)	Cohort/Brood-Year	Bootstrap Method Mean Estimate (95% CI) (CV%)	Volkhardt Method Estimate (95% CI) (CV%)
Coho (subyearling 0+ YOY)	Sep 21-Jan 22	115,216 (+/- 28,347) (13%)	115,584 (+/- 35,597) (16%)
Coho (1+ year old)	Sep 20-Jan 21	14,513 (+/- 3,115) (11%)	13,021 (+/- 3,497) (14%)
Coho (2+ year old)	Sep 19-Jan 20	749 (+/- 445) (30%)	467 (+/- 265) (29%)
Total Coho Estimate		**130,478 (+/- 28,521) (11%)**	**129,072 (+/- 35,769) (14%)**
Chinook (subyearling 0+ YOY)	2021	6,318 (+/- 2,545) (21%)	6,946 (+/- 4043) (30%)
Chinook (1+ year old)	2020	0	0
Chinook (2+ year old)	2019	23 (+/- 37) (82%)	37 (+/- 52) (71%)
Total Chinook Estimate		**6,341 (+/- 2,546) (20%)**	**6,983 (+/- 4,043) (30%)**
Steelhead/Rainbow (1+ year old)	2021	3,095 (+/- 741) (12%)	2,725 (+/- 842) (16%)
Steelhead/Rainbow (2+ year old)	2020	2,043 (+/- 837) (21%)	1,827 (+/- 886) (25%)
Total Steelhead Estimate		**5,138 (+/- 1,118) (11%)**	**4,552 (+/- 1,222) (14%)**
Cutthroat (1+ year old)	2021	681 (+/- 272) (20%)	609 (+/- 261) (22%)
Cutthroat (2+ year old)	2020	386 (+/- 213) (28%)	342 (+/- 184) (27%)
Total Cutthroat Estimate		**1,067 (+/- 346) (17%)**	**951 (+/- 319) (17%)**
Trout YOY (subyearling 0+)		6,431 (+/- 4,767) (38%)	5,652 (+/- 3,131) (28%)
Total Trout YOY Estimate		**6,431 (+/- 4,767) (38%)**	**5,652 (+/- 3,131) (28%)**
Bull Trout (subyearling 0+)	2021	0	0
Bull Trout (1+ year old)	2020	272 (+/- 160) (30%)	263 (+/- 158) (31%)
Bull Trout (2+ year old)	2019	276 (+/- 166) (31%)	247 (+/- 159) (33%)
Total Bull Trout Estimate		**548 (+/- 231) (21%)**	**510 (+/- 224) (22%)**

3.5 Graphical Presentation of Results

Period (weekly) specific outmigrant abundance with confidence intervals was not estimated due to the relatively low number of recaptures during each weekly period for specific species/inferred age class combinations. Therefore, time series abundance estimates with confidence intervals are not provided. However, the migration timing depicted in figures 2.8h (salmon species) and 2.8i (trout species) approximate total estimates of abundance by week.

3.6 Project Assessment

The relatively low number of recaptures limits the potential to make precise species/inferred age/period specific outmigration estimates based on mark-recapture data for the 2022 trapping season. However, pooled data allows overall estimates to be made. The estimates of fish passing the Eagle Cliff screw trap (Section 3.4) rely on the following key assumptions:

- The pooled trap efficiency used in this analysis is representative of the true trap efficiency for each species/size/origin/period specific categories for which estimates were made.
- The inferred age classes based on length distribution over time for each species are representative of the true proportion of the total fish captured by inferred age class.

- Marking does not affect catchability or survival.
- All fish (marked and unmarked) have an equal probability of being caught.
- Fish do not lose their marks and marks are recognizable.
- All recovered marks are reported.

3.7 Self-Assessment

Assessing trap efficiency relied solely on weekly mark-recapture testing. In 2022, most (89%) maiden-capture salmonids ≥50 mm FL were marked and placed upstream for efficiency trials (Table 3.7a). In 2022, species and life-stage/inferred age specific efficiency estimates for fish ≥50 mm FL were improved by marking additional Coho and Steelhead at the Swift FSC and releasing those fish at the Pine Creek confluence, which increased mark-recapture sample size by 49% for Coho and 89% for Steelhead (Table 3.7a). However, additional fish <50 mm FL could have been marked for efficiency trials to improve estimates for fry sized fish. In 2022, the target was to opportunistically mark Coho and Chinook fry as possible (which was not done in prior years). In the future, additional fry could be marked as available.

Table 3.7a – Mark sample size by marking location for Eagle Cliff screw trap efficiency trials in 2022.

Species	Total Maiden Screw Trap Catch	Mark at Screw Trap - Release Up	% Marked at Screw Trap for Efficiency	Marked at Swift FSC - Release Up	% Increase in Sample Size
≥50 mm FL					
Chinook	51	51	100%	0	NA
Coho	3,080	2,724	88%	1,331	49%
Cutthroat	48	47	98%	0	NA
Steelhead	239	225	94%	200	89%
Trout YOY	18	11	61%	0	NA
Total	**3,436**	**3,058**	**89%**	**1,531**	**50%**
<50 mm FL					
Chinook	112	74	66%	**0**	NA
Coho	1,093	283	26%		
Trout Fry	181	0	0%		
Total	**1,386**	**357**	**26%**		

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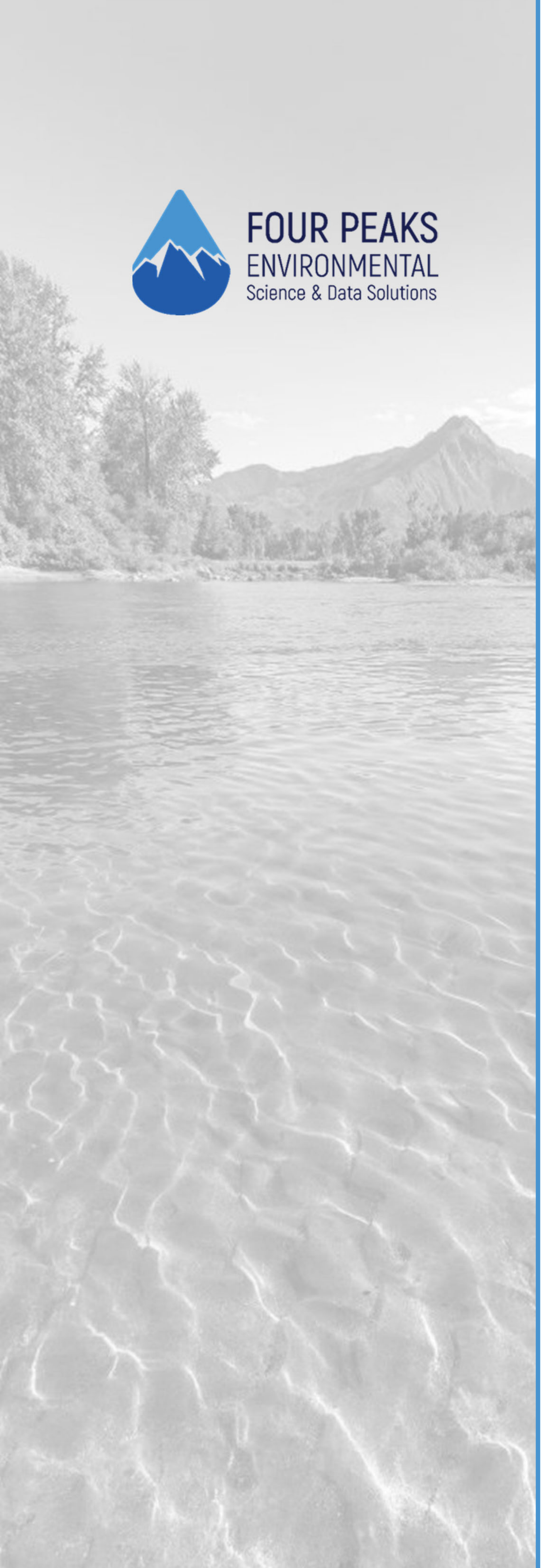
APPENDIX D

SWIFT RESERVOIR FLOATING SURFACE COLLECTOR SMOLT COLLECTION EFFICIENCY EVALUATION – 2022 FINAL REPORT



SWIFT RESERVOIR FLOATING SURFACE COLLECTOR COLLECTION EFFICIENCY EVALUATION 2022: ANNUAL REPORT

March 2023

Prepared for
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Abbreviations

Abbreviation	Definition
2022 Study	2022 Swift Reservoir Floating Surface Collector Passage Evaluation
ATS	Advanced Telemetry Systems
BPF	blade pass frequency
CCH	collection channel
ENT	entrance
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 collection channel	primary screen collection channel
Project	PacifiCorp Swift No. 1 Project FERC No. 2111
secondary collection channel	secondary screen collection channel
Settlement Agreement	Relicensing of the Lewis River Hydroelectric Projects – FERC Project Nos. 935, 2071, 2111, 2213, Cowlitz, Clark and Skamania Counties, Washington
ZOI	zone of influence
ZPC	zone presence criteria
ZPTS	zone presence time series

Executive Summary

Study Purpose and Objectives

The primary objective of the 2022 Swift Reservoir Floating Surface Collector Passage Evaluation (2022 Study) was to continue to evaluate the collection efficiency of the Swift floating surface collector (FSC) as outlined in Objective 2 of the Lewis River Monitoring and Evaluation Plan (M&E Plan; PacifiCorp and Cowlitz County PUD 2022). Collection efficiency is a key performance metric assessed annually that represents the proportion of study fish arriving in the attraction flow field of the Swift FSC (i.e., the zone of influence) that are ultimately collected. In addition to the core passage metrics identified in the M&E Plan, the 2022 study also focused on fish behavior and capture success in the lower portion of the fish collection channel; an area that was identified during the 2021 evaluation as a significant bottleneck for fish passage (Four Peaks 2022). Results of this previous study found that 35% of fish that passed through the full extent of the fish collection channel were not retained, but rather swam back upstream through the collection channel and exited the FSC. Based on this information, PacifiCorp made both operational and physical adjustments to the lower portion of the fish collection channel between the 2021 and 2022 studies in an attempt to improve fish retention.

The first adjustment was eliminating a periodic backwash cycle that was implemented for cleaning the fish separation system immediately downstream of collection channel. It was thought that this periodic cleaning cycle was disrupting the high capture velocity flow through the lower portion of the collection channel and allowing fish to escape back upstream. The second adjustment was the addition of a low profile, horizontal V-trap that was installed on the floor of the secondary collection channel. Based on previous field observations, it appears that fish that do swim back upstream through the narrow, lower portion of the collection channel do so by holding close to the bottom of the collection channel and taking advantage of the slightly lower water velocities due to edge effect. The horizontal V-trap was installed to disrupt this phenomenon and prevent fish from swimming out along the bottom of the collection channel.

In addition to the two adjustments made in 2022, this evaluation also assessed the effects of control weir height on fish retention and capture success. An adjustable control weir separates the lower portion of the secondary fish channel and the fish separation system inside the sorting building. The weir controls the volume of water that fish use to enter the fish sorting building and manipulates the speed of water in the lower portion of the fish channel. It was thought that flow volume passing over the control weir could influence fish passage success.

Similar to previous collection efficiency evaluations at the Swift FSC, environmental variables including water temperature, light level, wind speed, and precipitation as well as acoustic sound in and around the FSC were monitored, and their relationship with passage activity and collection was evaluated.

Approach

To accomplish the 2022 Study objectives, Swift FSC collection efficiency was measured by tracking and analyzing the behavior of juvenile Coho Salmon *O. kisutch* and steelhead *O. mykiss* released near the head of Swift Reservoir as they approached and interfaced with the Swift FSC.

413 study fish (231 Coho Salmon and 182 steelhead) were collected at the Swift FSC, implanted with passive integrated transponder and acoustic tags for tracking, and released at the head of the reservoir

between April 20 and June 1, 2022. These study fish then were tracked using acoustic telemetry as they entered the forebay of Swift Reservoir and approached the FSC. Fish behavior was monitored through July 18, 2022, when the Swift FSC was shut down for summer maintenance. Chinook Salmon were not included in this evaluation due to the anticipated low numbers of juvenile Chinook Salmon passing the FSC in 2022.

Study fish movements were monitored using an array of 19 acoustic receivers deployed in the Swift Dam forebay, near the entrance of the Swift FSC, and within the Swift FSC collection channel. These 19 receivers were grouped into subarrays that covered the following four zones within the Swift forebay.

1. Four receivers were installed near the Devil's Backbone, at the forebay entrance (FBY zone).
2. Four receivers were installed within the Swift FSC's zone of influence (ZOI zone) immediately up-reservoir of the Swift FSC.
3. Two receivers were installed within the net transition structure that forms the entrance to the Swift FSC (ENT zone).
4. Nine receivers were installed within the secondary collection channel zone (CCH zone) that leads directly to the Swift FSC fish collection and sorting facility. For behavioral analyses, the secondary collection channel zone was further partitioned into two subzones comprising the upstream (CCHU) and downstream (CCHD) portions.

Findings

Consistent with annual study results since 2019, 96% of study fish of each species that found the zone of influence entered the Swift FSC in 2022. This proportion is reflected in the entrance efficiency metric (P_{ENT}). Since 2019, observed entrance efficiency for both Coho Salmon and steelhead has varied between 95% and 99%. This shows that Swift FSC adjustments prior to 2019 have successfully encouraged fish to enter the Swift FSC.

After entering the Swift FSC, between half and two-thirds of study fish were retained in 2022, which was among the highest retention rates observed at the Swift FSC. In 2022, Swift FSC retention (P_{RET}) was 64% for Coho Salmon and 50% for steelhead. Coho retention in 2022 was the second highest of any evaluation to date, behind retention observed during the 2019 Study. Steelhead retention in 2022 was tied for the highest on record. This shows that Swift FSC adjustments made between the 2021 and 2022 studies may have contributed to retaining a greater proportion of fish that attempt passage.

These improved retention rates translated to improvements in collection efficiency (P_{CE}). In 2022, collection efficiency for both species was among the highest recorded. Coho Salmon collection efficiency was 62%, the second highest on record, and steelhead collection efficiency was 48%, among the top three highest on record. For both species, however, collection efficiency remains below the performance target of 95% described in the M&E Plan).

Some of the increase in retention efficiency observed in 2022 can be attributed to one or more of the above-described adjustments to the secondary collection channel that were made prior to the 2022 Study. Observations and historical comparisons indicate that discontinuing the secondary collection channel backwash screen cleaning cycle in 2022 likely resulted in the increase in retention efficiency. The low-profile horizontal V-trap does not appear to have been effective at retaining fish, and the operational position of the weir did not affect collection. Weather conditions did not affect collection, but, as in past studies, time of day did: more fish entered the Swift FSC and were collected at night or during late afternoon. Sound monitoring in 2022 detected a low-frequency signal within the range that can affect juvenile salmonid behavior. The noise was determined to be coming from the primary and secondary channel pumps but does not appear to be a factor leading to fish rejection within the collection channel.

Summary and Conclusions

In summary, the 2022 Study indicated that out-migrating juvenile Coho Salmon and steelhead successfully locate and enter the Swift FSC but reject collection once inside the collection channel. Compared to previous evaluations, Swift FSC retention rates have improved, particularly in the lower portion of the secondary collection channel. Retention in 2022 was better than or similar to retention in all study years since 2017 for which this metric has been computed. This improvement in 2022 may have been the result of discontinuing operation of the secondary channel backwash screen cleaning cycle.

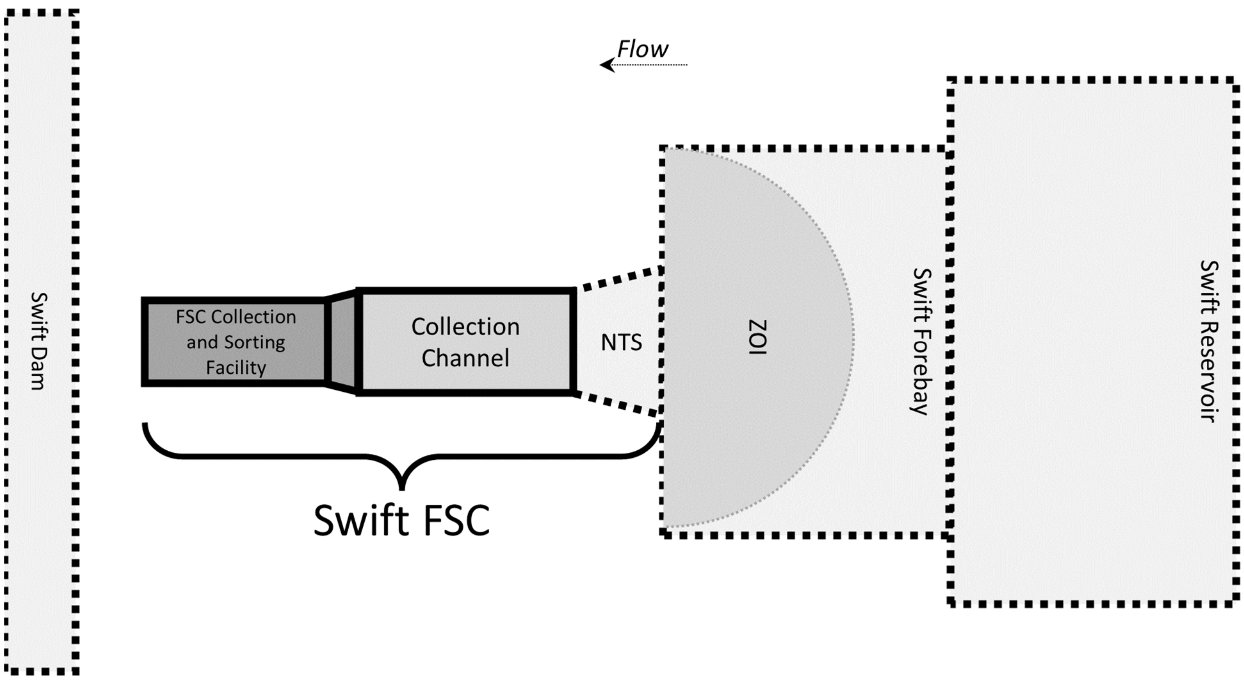
Retention within the Swift FSC now appears to be constrained primarily by a bottleneck between the Swift FSC entrance and the secondary collection channel. This may be a result of hydraulic conditions within this region, particularly at the transition between the net transition structure and primary screen collection channel, as has been previously observed (Four Peaks 2020, 2021). Increasing retention of fish within this portion of the collection channel appears to be the most promising area for improving collection efficiency at the Swift FSC.

1 Introduction

1.1 Study Purpose and Objectives

The purpose of the 2022 Swift Reservoir Floating Surface Collector Passage Evaluation (2022 Study) was to evaluate performance of PacifiCorp's Swift floating surface collector (FSC). The Swift FSC is a barge in the Swift Dam forebay that captures juvenile salmonids migrating near the surface of the reservoir (Note: Diagram not drawn to scale.

Figure 1). In addition to evaluating performance of the Swift FSC, the 2022 Study was conducted to support PacifiCorp's operation of the Swift FSC, including any future facility adjustments and modifications, per Section 4.1.6 of the Lewis River Settlement Agreement (Settlement Agreement; PacifiCorp et al. 2004).



Note: Diagram not drawn to scale.

Figure 1. Schematic diagram of Swift floating surface collector.

Within the framework of this study, Swift FSC performance was evaluated using metrics that summarize fish behaviors within the Swift Reservoir and FSC. These metrics were computed for a sample of out-migrating juvenile salmonids (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 Swift FSC, at the head of Swift Reservoir near the Swift Forest Camp Boat Launch. After release, study fish were monitored as they approached, interacted with, and were potentially collected in the Swift FSC.

Consistent with previous study years (Section 1.3), the performance of the Swift FSC in 2022 was evaluated primarily using collection efficiency (P_{CE}). Collection efficiency is calculated as the proportion of study fish arriving in the attraction flow field of the Swift FSC (i.e., the zone of influence or ZOI) that are ultimately collected. Additional performance metrics were calculated to evaluate transitions among zones between the ZOI and collection within the Swift FSC per Version 3 of the Aquatic Monitoring and Evaluation Plan for the Lewis River (M&E Plan; PacifiCorp and Cowlitz County PUD 2022). These metrics were calculated for the 2022 Study, by species, for the study period:

- Estimated reservoir transition rate (P_{PASS}) – the proportion of released study fish that are detected entering the forebay at the Devil's Backbone acoustic hydrophone array
- Estimated Swift 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 Swift FSC
- Estimated entrance efficiency (P_{ENT}) – the proportion of study fish detected in the ZOI that are detected entering the Swift FSC at the net transition structure (NTS)
- Estimated collection efficiency (P_{CE}) – the proportion of study fish detected in the ZOI that are re-captured at the Swift FSC. This calculation was also performed on a monthly basis, to provide collection efficiency, by species, for study fish released each month.
- Estimated retention efficiency (P_{RET}) – the proportion of study fish detected in the NTS (entrance) that are re-captured at the Swift FSC
- Estimated channel efficiency ($P_{SEC-CHAN}$) – the proportion of study fish detected in the entrance 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 Swift FSC

These metrics are presented as consistent with previous study years as possible, to enable comparisons. However, changes in study design and acoustic telemetry array layout over the years mean that some metrics have been refined and other metrics have been added to provide additional resolution within the Swift FSC collection channel.

Since 2013, the Swift FSC has been evaluated to determine how effectively it attracts and retains fish and to assess overall collection performance as PacifiCorp adaptively manages the facility. In 2016, a 650-foot lead net was constructed, extending into the reservoir from the NTS, which guides fish into the collection channel. Studies conducted in 2017 and 2018 (Anchor QEA 2018; Smith et al. 2018) found that, since construction of the lead net, most study fish successfully locate the NTS. This observation was supported by results from subsequent studies in 2019 through 2021, which also found that most study fish that enter the Swift forebay subsequently enter the Swift FSC (Four Peaks 2020, 2021, 2022). However, these studies have also indicated that too many fish reject collection after entering the collection channel to achieve the 95% collection efficiency performance standard defined in the Settlement Agreement.

Identifying the location of fish rejection has been the focus of recent Swift FSC performance evaluations. Studies conducted in 2019 and 2020 (Four Peaks 2020, 2021) identified the collection channel as the primary bottleneck to achieving the performance standard for fish collection. During the 2021 study, additional acoustic receivers were placed within the fish collection channel to more precisely identify the location of fish rejection. Information from the 2021 study showed that most rejection occurs within the downstream end of the collection channel, immediately in front of the entrance to the Swift FSC fish collection and sorting facility. Hydraulic modeling indicated that this was an area of low-velocity water, in which fish could potentially hold station before swimming back upstream. In addition, sound monitoring during the 2021 study consistently detected a low-frequency noise in and around the Swift FSC, which may contribute to avoidance behavior by salmonids (Hastings and Popper 2005).

Considering these findings and the goal to further improve retention within the collection channel, the following two adjustments were made before the beginning of the 2022 Study:

1. Operation of the secondary channel backwash screen cleaning cycle was discontinued. This process cleans the fish separation system downstream of the collection channel. PacifiCorp staff hypothesized that this cleaning cycle was disrupting the high-velocity capture flow in the lower portion of the collection channel and allowing fish to escape back upstream. Specifically, a wave of water created by this cleaning cycle pushes debris, and potentially fish attempting to enter the collector, back upstream. This effect may have contributed to the previously observed relatively high rejection rates within this region of the collector. Prior to the 2022 Study, additional equipment for cleaning the fish separation system had been added, eliminating the need for this backwash cycle.
2. A low profile, horizontal V-trap was installed along the bottom of the secondary screen collection channel (secondary collection channel) floor, at its approximate midpoint. Fish that reject within the secondary collection channel had been observed swimming back upstream by holding close to the bottom. Presumably, these fish were taking advantage of the slightly lower water velocities present within that boundary layer. The horizontal V-trap was installed to disrupt this behavior and prevent fish from swimming out along the bottom of the secondary collection channel.

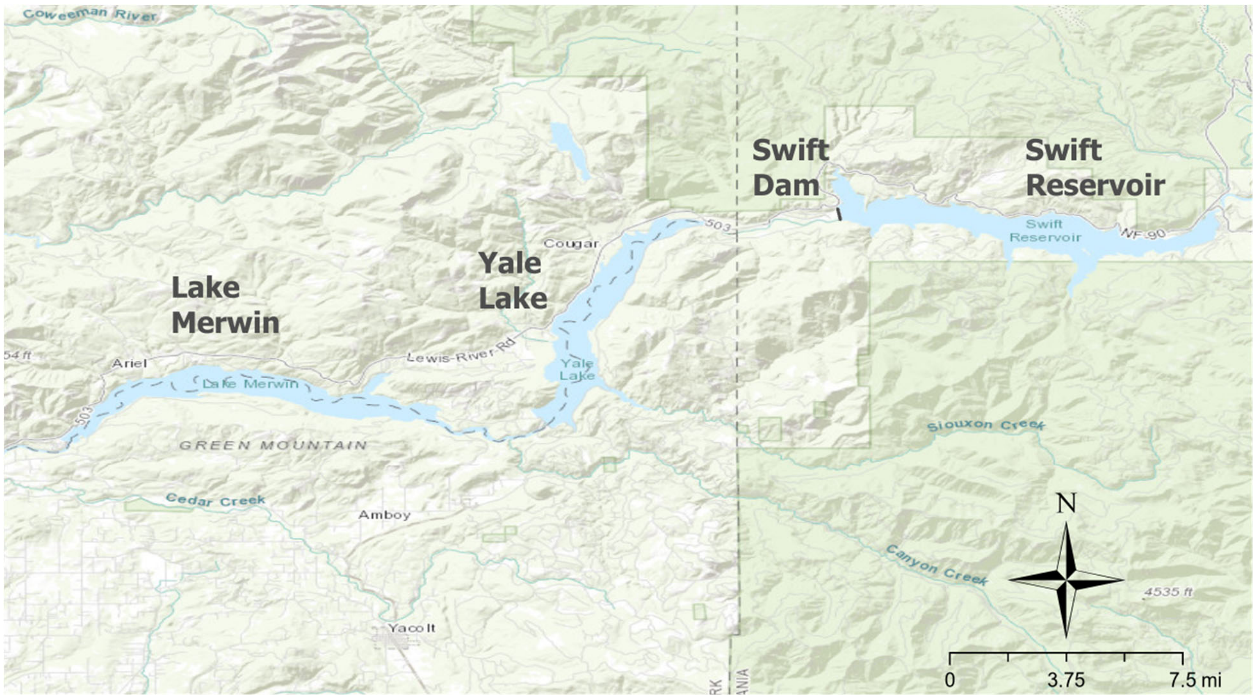
The 2022 Study evaluated the efficacy of these adjustments by monitoring fine-scale behaviors within the collection channel. For the 2022 Study, an acoustic receiver array similar to the one used in the 2021 study was implemented. This array design concentrates receivers in the secondary collection channel to provide additional detail on movements in this zone and refine understanding of locations where fish reject collection.

To further examine how operations affect retention in the downstream end of the secondary collection channel, a blocked experiment was conducted to systematically vary water velocity in that area. The experiment was designed to test if there was an optimal hydraulic condition for retaining fish in the downstream secondary collection channel that could be attained through simple changes in facility operations. This was done by systematically adjusting the height of the control weir, which regulates the flow of water into the Swift FSC fish collection and sorting facility, and thus the velocity of water within the lower portion of the collection channel. Over the duration of the study, the adjustable control weir was experimentally operated at two elevations ("high" and "low") to determine if collection efficiency improved at one of the elevations. The high weir setting reduced flow into the FSC fish collection and sorting facility and velocity within the downstream end of the secondary collection channel, while the low setting increased flow into the Swift FSC collection and sorting facility and velocity within the downstream end of the secondary collection channel.

The 2021 study was the first to conduct meteorological, solar radiation, and water temperature monitoring at the Swift FSC and evaluate the effects of these factors on fish behaviors. Similar environmental factors were monitored in 2022, including wind direction and speed, air pressure, rainfall, and water temperature throughout the 2022 Study, and underwater sound during a series of experimental tests near the end of the 2022 Study. Behavioral analyses were conducted to evaluate how each of these operational and environmental factors may affect fish passage behaviors and Swift FSC collection rates.

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 2). 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.

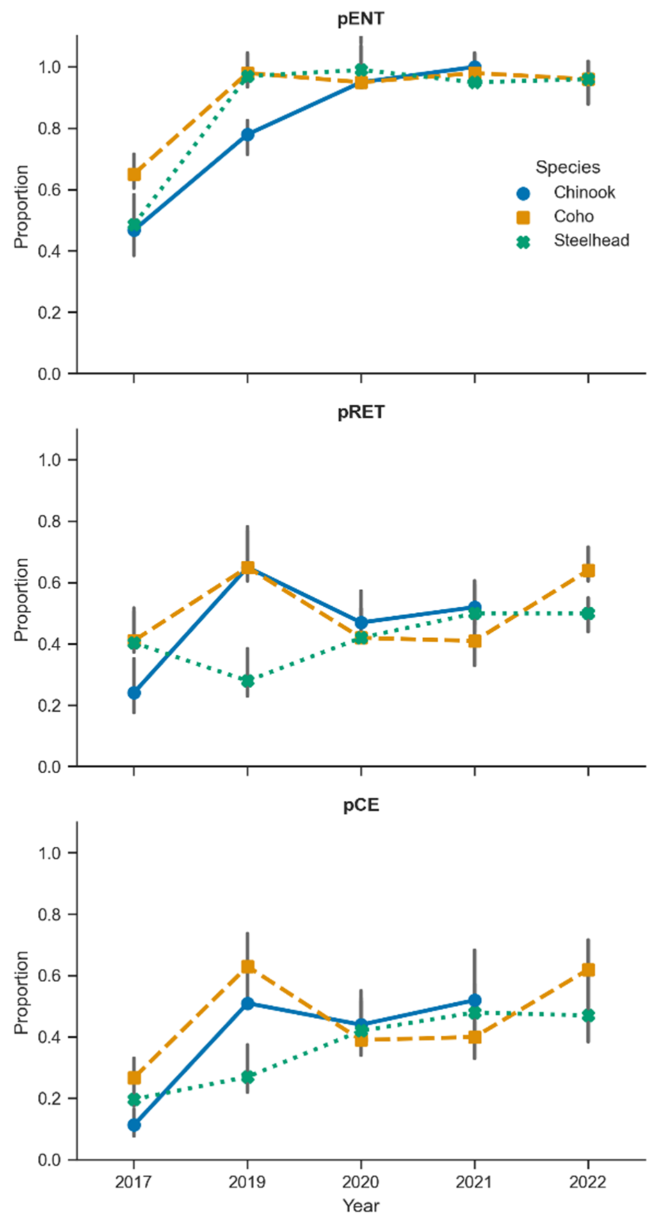
Figure 2. Vicinity map of the Swift Reservoir and Swift Dam on the Lewis River.

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 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 Settlement Agreement requires monitoring and evaluation of P_{CE} at the Swift FSC and identified a P_{CE} performance target of 95% at a 0.05 precision level for the Swift 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 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 2022 Study considered fish that had reached the ZOI as “available for collection.”

[1] Species designated in Section 4.1.7 of the 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*.

1.3 Summary of Previous Studies

Since 2013, the performance of the Swift 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 3; Table 1). 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 study species. 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 Swift FSC, even if they ultimately are not collected. The occurrence of fish migrating to but not being successfully collected within the Swift FSC suggests that Swift FSC effectiveness has been constrained by the ability of the Swift FSC to retain, rather than attract, out-migrating juvenile salmonids.



Note: Error bars indicate +/- one standard deviation returned using the mark-recapture model.

Figure 3. Swift floating surface collector performance metrics computed during 2017 – 2022 study years.

Table 1. Summary of results from Swift floating surface collector collection efficiency studies conducted between 2013 and 2022.

Study Attributes						Detection Numbers (Total)[1]			Detection Estimates (Total)[2]			
Year	Study Type	Capture Location	Release Location	Species	Release Numbers	Detected Forebay	Detected ZOI	Captured at Swift FSC	P_{ZOI}[4]	P_{ENT}	P_{RET}	P_{CE}
2013	Radio Telemetry	Swift FSC	<3.1 miles east of Swift 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	Swift FSC	2 miles east of Swift 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	Swift 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	Swift 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	Swift FSC	Swift Forest Camp Boat Launch	Chinook Salmon	396	--	--	94	--	NA	NA	24%[3]
				Coho Salmon	484	--	--	191	--	NA	NA	40%[3]
				Steelhead	278	--	--	136	--	NA	NA	49%[3]
2019	Dual PIT/Acoustic Telemetry	Swift 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	Swift 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	Swift 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%
2022	Dual PIT/Acoustic Telemetry	Swift FSC	Swift Forest Camp Boat Launch	Coho Salmon	231	187	183	118	81%	96%	64%	62%
				Steelhead	182	122	120	58	66%	96%	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, 2022
1. For 2019 through 2022, detection numbers are total numbers of fish positioned in each zone based on zone presence criteria.
2. For 2019 through 2022, seasonal performance metrics have been corrected for array detection efficiency.
3. In 2018, survival probability through reservoir (SRES) was used as a surrogate for collection efficiency.
4. P_{ZOI} represents the combined survival of individuals from release to the forebay and the forebay to the ZOI, equivalent to the product of P_{PASS} and P_{ENC}.
-- = not calculated; NA = not applicable

1.4 Summary of Swift Floating Surface Collector Adjustments

To address low capture efficiencies, a series of adjustments have been made by PacifiCorp to improve Swift FSC performance over the last decade, and these appear to have increased P_{CE}. This section summarizes the more relevant changes to the Swift FSC over the last 7 years.

Installation of a 650-foot fish lead net in front of the Swift FSC in early 2016 appeared to have greatly improved the ability of fish to locate the entrance of the Swift FSC but had limited success in getting them to transition in the NTS and collection channel (Caldwell et al. 2017).

In late 2017, Swift FSC sorting area flow pumps were discovered to be creating noise audible to juvenile salmonids, which may have deterred them from entering the Swift FSC. The pumps were reprogrammed to reduce their acoustic noise signature, and a subsequent PIT-tag only study in spring 2018 found this may have increased collection efficiency (PacifiCorp and Cowlitz County PUD 2019).

In 2019, a false floor was installed in the bottom of the NTS, decreasing the entrance depth by 40%, to increase the attraction flow through the NTS. Additional adjustments were made to the primary screen baffles, to allow operation of additional pumps within the primary screen collection channel (primary collection channel), which increased attraction flow by nearly 50%. The combination of reducing the entrance area of the NTS and increasing attraction flow resulted in a nearly threefold increase in water velocity at the entrance of the NTS (from 0.5 ft/sec to approximately 1.3 ft/sec), which substantially increased the number of fish that entered the collection channel. However, studies in 2019 and 2020 showed that a large portion of fish that entered the fish collection channel still were not being collected (Four Peaks 2020, 2021). Understanding the factors that are contributing to this continued lack of retention of fish within the channel is important for improving collection efficiency at the facility.

In 2021, PacifiCorp identified areas within the collection channel where hydraulic features (hydraulics) may affect fish passage by causing avoidance behavior in out-migrating juvenile salmonids. These hydraulics were a side effect of the adjustments described in the previous paragraph, which also resulted in uneven flow acceleration within the channel. Areas of slight but abrupt acceleration and deceleration now exist at transitions in channel geometry and materials (Figure 4).[2] Previous studies found that locations within the channel where fish rejected were areas of anticipated flow deceleration. Based on discussions with facility engineers, it was hypothesized that adjusting the pumping rate within the Swift FSC could reduce the magnitude of these hydraulic changes 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 periods with only eight pumps running, to see if running fewer pumps would smooth out the hydraulics and improve retention. However, reducing the number of operating pumps from ten to eight appears to have simply reduced the attraction velocity at the entrance to the Swift FSC, resulting in fewer passage attempts and a reduced likelihood of success for each attempt. The combined effect was that fewer fish were collected when only eight pumps were operated, opposite of the intent. This result further emphasizes the importance of attraction flow to achieving fish collection targets.

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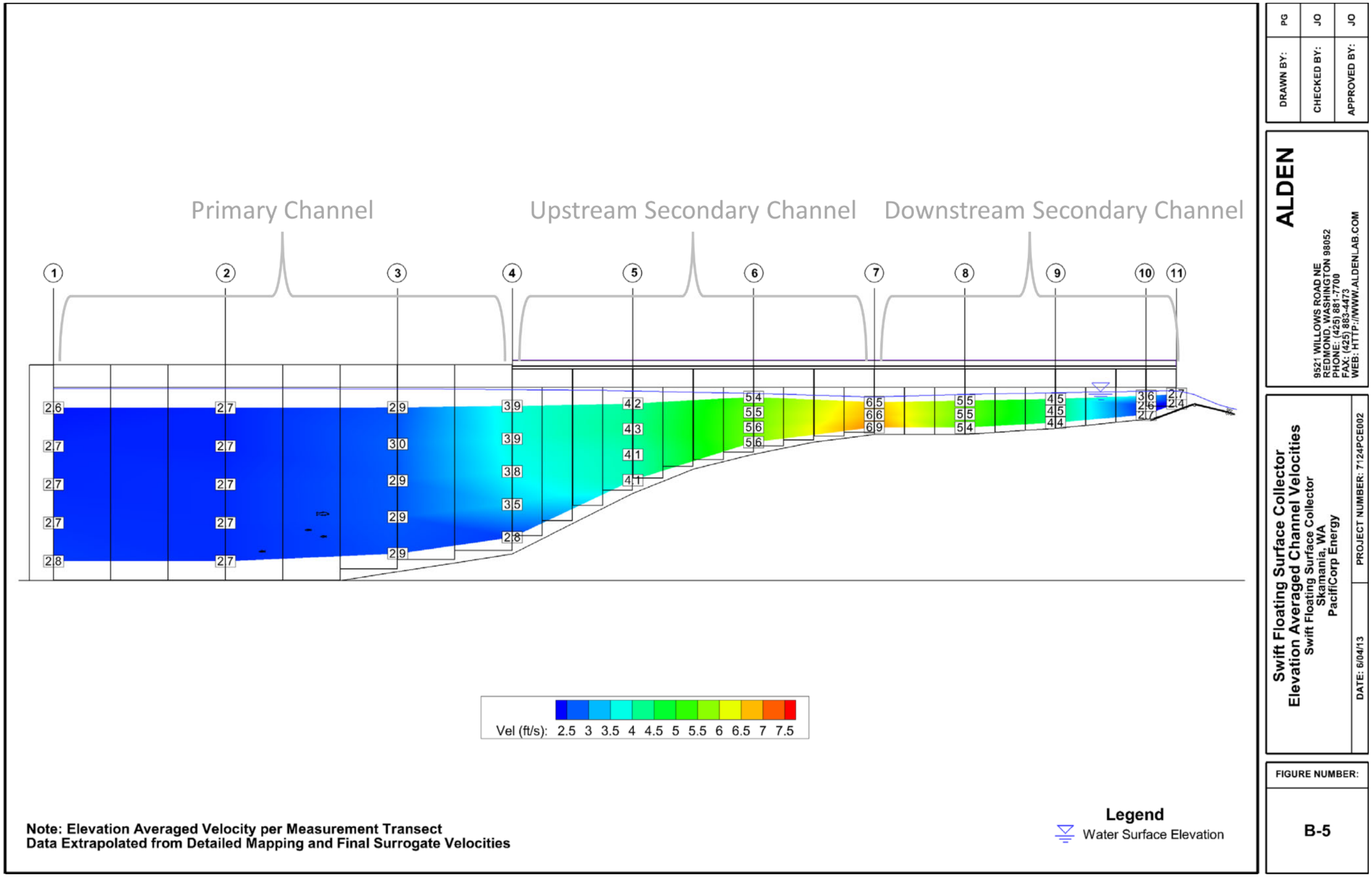
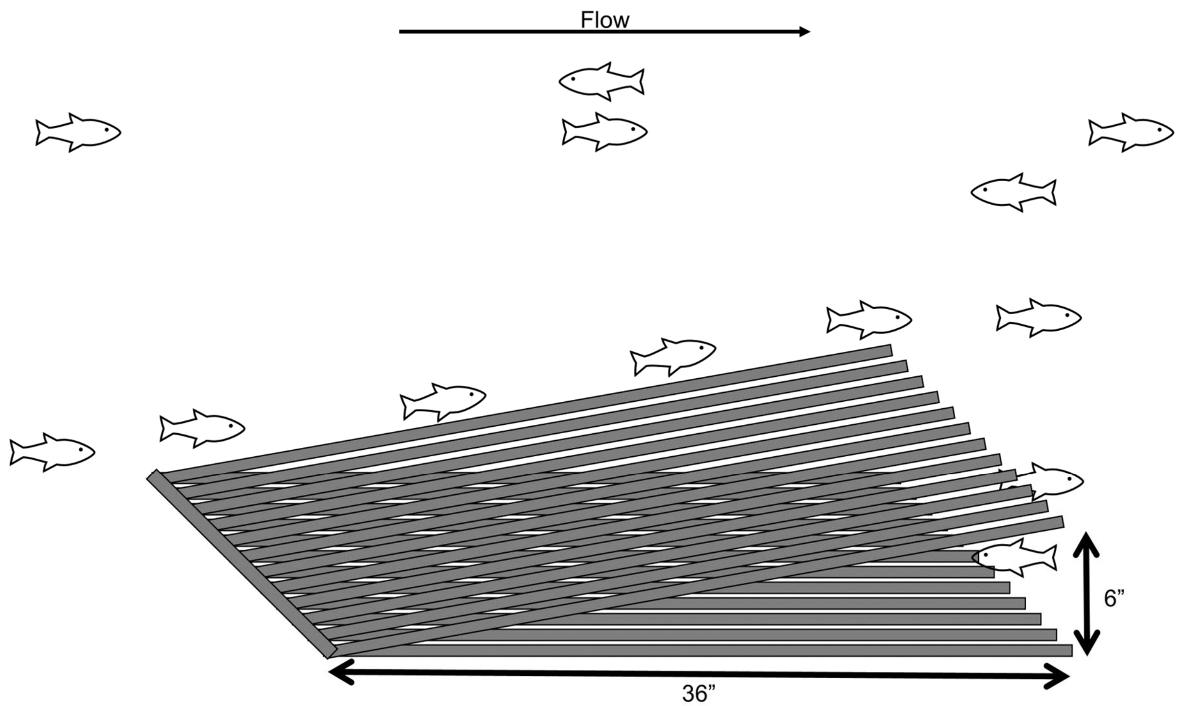
[2] Despite these adjustments, the overall pattern of relatively faster and slower areas noted in Figure 4 has remained consistent since facility design and construction (Chris Karchesky, personal communication, November 16, 2021).



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). “Channel” terminology corresponds with “screen collection channel” within this report.

Figure 4. Mapped and interpolated water velocities within the Swift floating surface collector collection channel in 2013.

In 2022, PacifiCorp installed a low profile, horizontal V-trap along the bottom of the secondary collection channel, to increase retention (Figure 5). This V-trap was installed within the “capture velocity area” of the channel (between lines 6 and 7 in Figure 4), which exhibits among the highest water velocities and is designed to reduce or prevent fish from swimming back upstream. The V-trap was approximately 3 feet long and 6 inches tall, with tines spaced to prevent fish passing between them. Surface-oriented and mid-column juvenile fish moving downstream (towards collection) were unimpeded. Fish approaching along the bottom of the collection channel were guided by the device toward the surface, where they could pass. Fish attempting to swim back upstream (away from collection) were forced to pass over the device, into the high-velocity water near the center of the channel, because passage along the bottom was blocked by the tines that were oriented obliquely downstream. It was hypothesized that this device would increase retention of juvenile fish that had entered the collection channel, inducing them to ultimately pass into the Swift FSC fish collection and sorting facility, thereby improving fish collection efficiency.



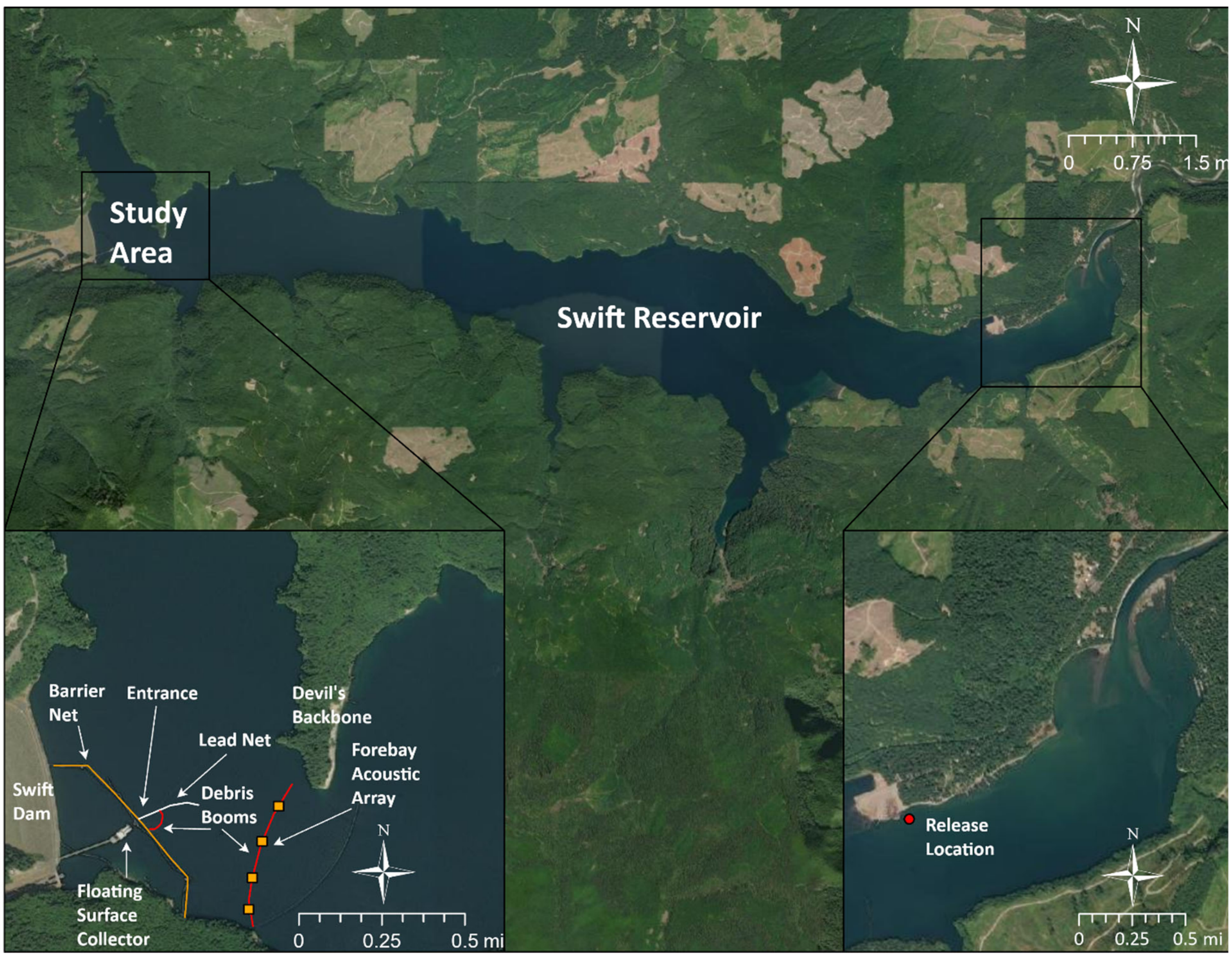
Note: Figure not to scale. Note callouts for approximate height and length of V-trap.

Figure 5. Schematic diagram of a low profile horizontal V-trap similar to the one installed within the Swift floating surface collector collection channel in 2022.

2 Methods

2.1 Study Location and Timing

The 2022 Study focused on evaluating behaviors of fish that were captured at the Swift FSC, dual PIT- and acoustic-tagged (dual-tagged), and released near the head of Swift Reservoir. After release, these dual-tagged study fish were then tracked to describe their behaviors in front of and within the Swift FSC. Fish are guided to the Swift FSC by attraction flows created using pumps within the barge and by the barrier and lead nets (Figure 6, inset). A series of booms extending into the forebay help shield the Swift FSC from large logs and debris. Additionally, a group of PIT-only fish was evaluated to determine recapture rates and run dynamics, which were then compared with results from the dual-tagged study fish.



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

Fish enter the Swift FSC via the NTS, a rigid structure affixed to the Swift 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 sorted by size into life-stage groups (i.e., fry/parr, juvenile, and adult), before being routed to holding tanks. Most fish are then transported and released downstream of Merwin Dam.

Figure 7 provides a timeline of key milestones during the 2022 Study. On eight occasions between April 20 and June 1, 2022, a total of 421 study fish were selected from the run-at-large collected at the Swift FSC, dual tagged, transported to the upstream end of the reservoir, and released (tagging methods are described in more detail in Section 2.2.1). These dual-tagged fish were then monitored using acoustic receivers deployed in the forebay, ZOI, and Swift FSC. Over the course of this tagging program, an additional 672 fish (478 Coho Salmon and 194 steelhead) were tagged with PIT tags only. These PIT-only fish were monitored to determine their recapture rates and timing only.

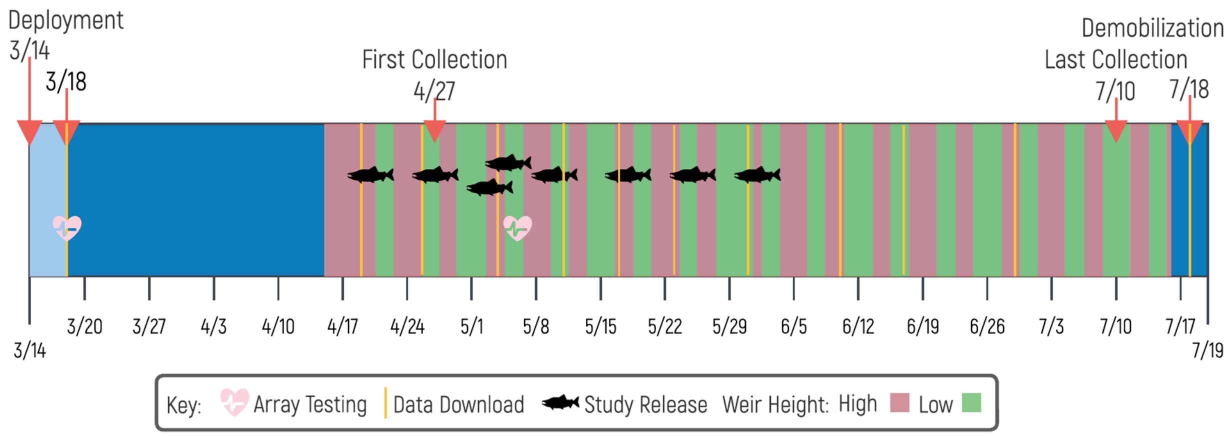


Figure 7. 2022 Swift floating surface collector passage evaluation timeline of key milestones and pumping rates.

On one occasion during the study, from 18:00 on June 7 through 07:00 on June 8, the Swift FSC was shut down to clear debris that had accumulated in the collection channel and perform necessary repairs. Unless otherwise noted, all receiver data collected during this 13-hour period when the Swift FSC was shut down were omitted from analyses and visualizations. On July 18, 2022, PacifiCorp shut down the Swift FSC for summer maintenance (following guidelines described in PacifiCorp 2015). The 2022 Study period thus spans from April 20, when the first study fish were released, to July 18, when the Swift FSC was shut down. The last dual-tagged study fish was collected on July 10, 2022, and the last PIT-only tagged fish was collected on July 12, 2022. The receivers were removed from the water on July 18, 2022, at which point four dual-tagged study fish were still being detected on the array, entirely in the forebay and ZOI.

2.2 Biotelemetry

2.2.1 Fish Tagging and Release

On the eight occasions described in Section 2.1, PacifiCorp staff selected and dual-tagged juvenile fish with fork lengths greater than 100 mm from the run-at-large captured by the Swift FSC (Appendix A). This collection strategy is consistent with that employed during the 2017, 2019, 2020, and 2021 studies.

Target sample sizes for dual-tagged study fish in 2022 were developed to provide a 6% margin of error within a 90% confidence interval for computations of performance metrics, presuming 80% of fish survive their transition through the reservoir to the forebay and then 98% of those fish in the forebay reach the ZOI (as in prior years). The targets were based on counts of juvenile fish collected at the Swift FSC in 2021 (Table 2). The target sample sizes for Coho Salmon and steelhead were consistent with 2020 and 2021 studies. Juvenile Chinook Salmon were not tagged in 2022, because they were not expected to be present in sufficient numbers to obtain a large enough sample size for the study.

Table 2. Recommended, adjusted, and actual sample sizes for 2022.

Species	Juveniles Collected at Swift FSC in 2021	Target Margins of Error	Target Confidence Interval	Target Sample Size in ZOI	Recommended No. Fish to Tag (*)	Actual No. Fish Tagged	Actual Margins of Error (†)
Coho	70,672	6%	90%	188	240	231	6.07%
Steelhead	5,788	6%	90%	183	233	182	7.43%

Notes:
(*) Recommended number of fish to tag to determine P_{CE} at target precision was determined by expanding the target sample size in the ZOI as follows. Target sample size was divided by 0.98 to account for fish that reached the forebay but did not transition to the ZOI. The resulting value was then divided by 0.80 to account for fish that were released at the head of the reservoir but did not transition to the forebay.
(†) Actual margins of error for the 2022 Study were computed using the actual number of each species of study fish that were detected in the ZOI, as presented below in Section 3.3.1. Actual confidence intervals for passage metrics are presented below with results.

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 truck to the Swift Forest Camp release site at the eastern end of Swift Reservoir (Figure 6) where they were subsequently released. Study fish that were tagged and released during a weekly session were considered to be part of a single "release group."

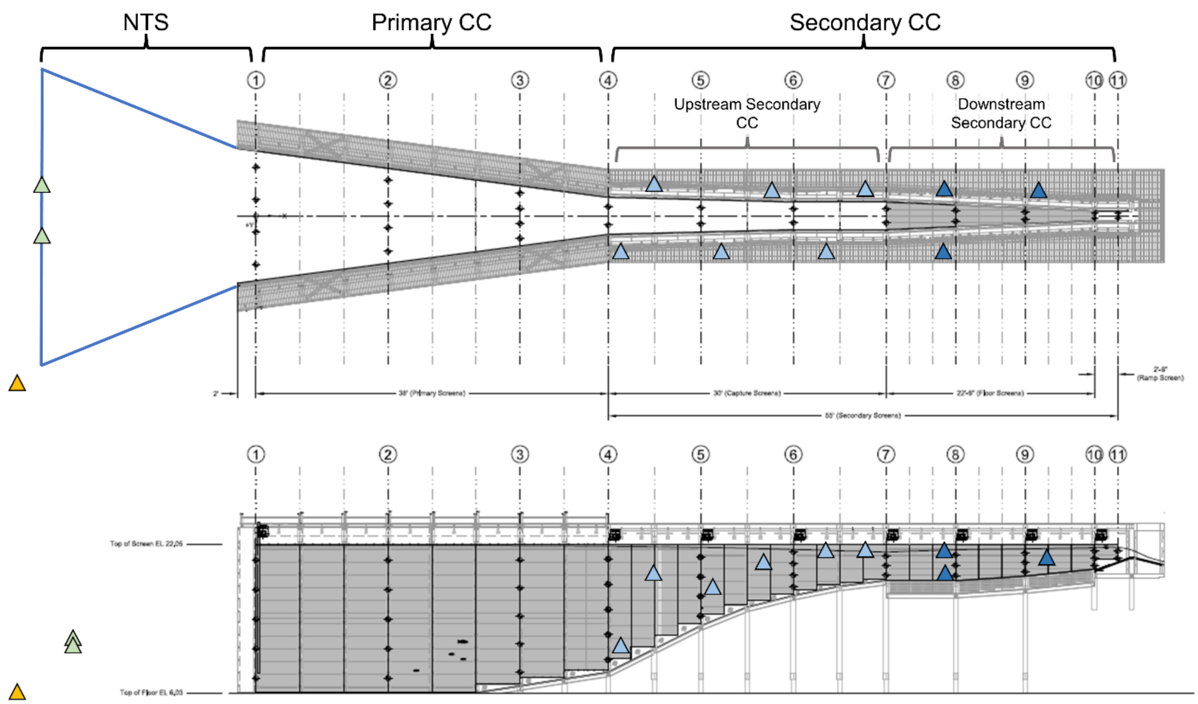
PIT tags were scanned using an HPR Plus reader prior to implantation, and data were uploaded to PTAGIS using P4 software with associated information on species, length, and paired acoustic tag code. Acoustic tag activation, implantation, and functionality after implantation were confirmed using a hydrophone 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 2022 Swift floating surface collector passage evaluation.

Parameter	Value
Length	15.0 mm
Diameter	3.3 mm
Mass	210 mg
Ping Rate	3 seconds
Nominal Tag Life	48 days
Minimum Acceptable Fish Size for Tags (fork length)	95 mm

2.2.2 *Fish Detection and Recapture*

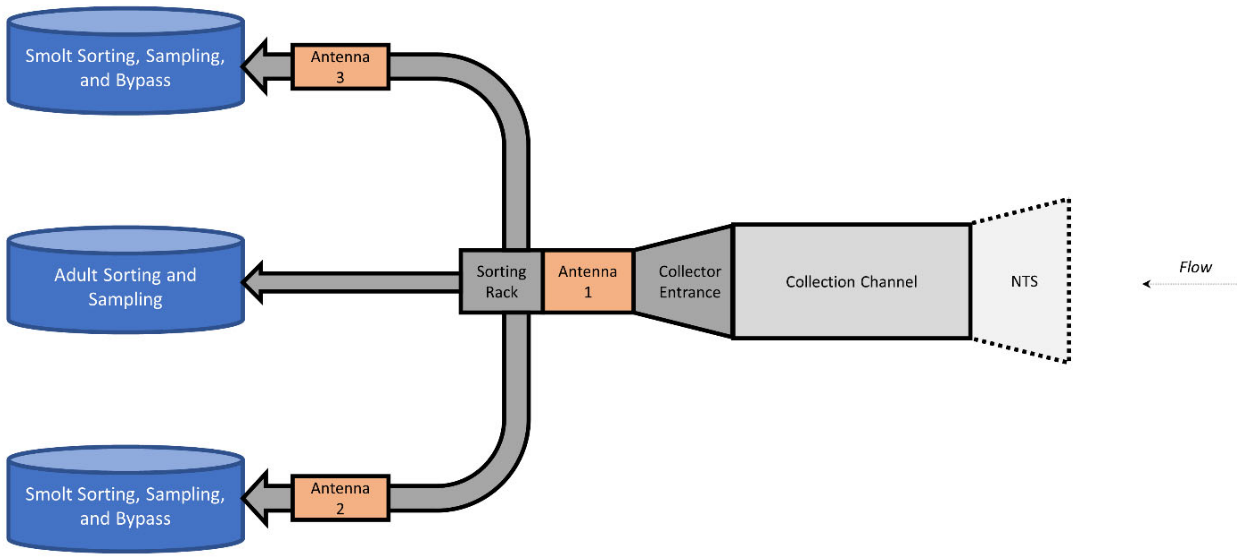
Tagged fish were tracked as they approached and interacted with the Swift FSC by using a combination of PIT and acoustic technology. The acoustic monitoring encompassed an array comprising 19 hydrophones and associated acoustic telemetry receivers deployed in the forebay and Swift FSC. Receivers were concentrated within the secondary collection channel, and also placed in the primary collection channel, NTS, and ZOI (array locations are described in more detail in Section 2.2.3). The primary collection channel extends downstream from the downstream end of the NTS, to a point where the collection channel rapidly becomes shallow (Figure 8). The secondary collection channel then extends downstream from that point where the collection channel becomes shallow to the entrance of the Swift FSC fish collection and sorting facility. The secondary collection channel is divided into upstream and downstream secondary collection channels, based on differences in channel geometry and dewatering screen design. The adjustable weir is located approximately at vertical line number 11 in Figure 8. The horizontal V-trap was installed between vertical line number 6 and vertical line number 7 in Figure 8.



Notes: Top panel shows plan view and bottom panel shows longitudinal cross-section of the collection channel. The net transition structure is shown with blue lines in the top plan view. The primary collection channel (primary CC) extends from the NTS downstream to the vertical line number 4. The secondary collection channel (secondary CC) extends between vertical lines 4 and 11. The secondary collection channel is further divided into the upstream secondary collection channel (vertical lines 4-7) and the downstream secondary collection channel (vertical lines 7-11). The approximate locations of hydrophones are shown as triangles, colors of which correspond to zones listed in the legend in Figure 9.

Figure 8. Swift floating surface collector schematic diagram.

This array detected fish as they entered the forebay, approached the Swift FSC, entered the Swift FSC through the NTS, and transited the primary and secondary collection channels as they approached the entrance to the Swift FSC fish collection and sorting facility. Collection in the Swift FSC was confirmed with a series of PIT antennas on the sorting and collection flumes inside the Swift FSC (Figure 9).



Source: Redrawn, after https://www.ptagis.org/sites/interrogation-site-metadata?IntSiteCode=SHP

Figure 9. Swift hydroelectric project passive integrated transponder interrogation site antenna configuration inside the Swift floating surface collector.

2.2.3 Acoustic Telemetry Array

From March 14 through 17, 2022, Four Peaks staff installed the acoustic telemetry receivers on the Swift FSC, within the NTS, and in the Swift Dam forebay (Figure 10), plus a remote receiver within the recovery tank for confirming tag activation. The array consisted of a combination of shore-based receivers that were time-synchronized frequently using GPS clocks (model ATS SR3017) and autonomous, unsynchronized receivers (model ATS SR3001), plus the remote receiver in the recovery tank (a modified model ATS SR3000). The 19 receivers covered four zones that were defined in terms of 2D areas: forebay (FBY), ZOI, entrance (ENT), and collection channel (CCH).

As in previous years, the forebay zone was delineated by the debris boom extending from the south side of Swift Reservoir, immediately across from the Devil's Backbone feature, and the ZOI was delineated as the area within the forebay immediately upstream of the Swift FSC. In 2022, the entrance zone was newly defined as the combined area of the NTS and the primary collection channel, two zones that had been considered separately in previous studies. Receivers placed at the front of the NTS were directed inwards at the collection channel and used to detect fish through the entire entrance area (Figures 8 and 10). As in previous years, the secondary collection channel was defined as a distinct zone, based on the parameters outlined in Section 2.2.2. For the purposes of fine-scale behavioral analyses, the secondary collection channel was further divided into the upstream secondary collection channel and the downstream secondary collection channel subzones. Each zone or subzone was monitored using a dedicated subarray of telemetry receivers (Table 4).

Spatial Reference: GCS WGS 1984; Aerial imagery source: Google. Additional cartography data sources: ESRI. Map conceived and drawn using ArcGIS Pro. Squares depict SR3001 autonomous receivers while triangles depict SR3017 cabled receivers.

Figure 10. Overview of acoustic telemetry receiver array locations within the Swift floating surface collector and forebay.

Table 4. Locations of telemetry receivers by zone

Zone/Subzone	Receiver Count	Receiver Type	Receiver ID
Forebay	4	Un-synchronized	FBY-01 to FBY-04
ZOI	3	Un-synchronized	ZOI-01 to ZOI-03
ZOI	1	Time-synchronized	ZOI-04
NTS	2	Time-synchronized	ENT-01 to ENT-02
Upstream secondary collection channel	6	Time-synchronized	CCH-01 to CCH-06
Downstream secondary collection channel	3	Time-synchronized	CCH-07 to CCH-09

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 makes it difficult to detect tags in the channel. To address these challenges, a dense array of hydrophones was deployed behind the dewatering screens (Figure 8). Each hydrophone was installed within a cone-shaped baffle, with the tip of the hydrophone pointed towards the dewatering screen, perpendicular to the direction of flow. 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. The dense deployment increases the chance of tag detection within the array.

2.2.4 Telemetry Array Testing and Validation

Field testing of the acoustic telemetry equipment was conducted during and after deployment (Figure 7). 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 recorded by observers during the tests, and the detection data recorded 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, ENT, 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 7). 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.

Detection data were downloaded from the receivers on an approximately bi-weekly schedule (Figure 7) and backed-up to secure cloud-based storage. Forebay and autonomous ZOI 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. The 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 entrance and the collection channels. Data collected by the receivers in this area do not require this filter because (1) they are time-synchronized (Table 4), which enables verification of a single tag “ping” across multiple receivers, and (2) faster-flowing water and relatively rapid fish behaviors in these areas (some fish enter and exit the Swift FSC quickly) limit the number of tag detection opportunities on a single receiver. 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).

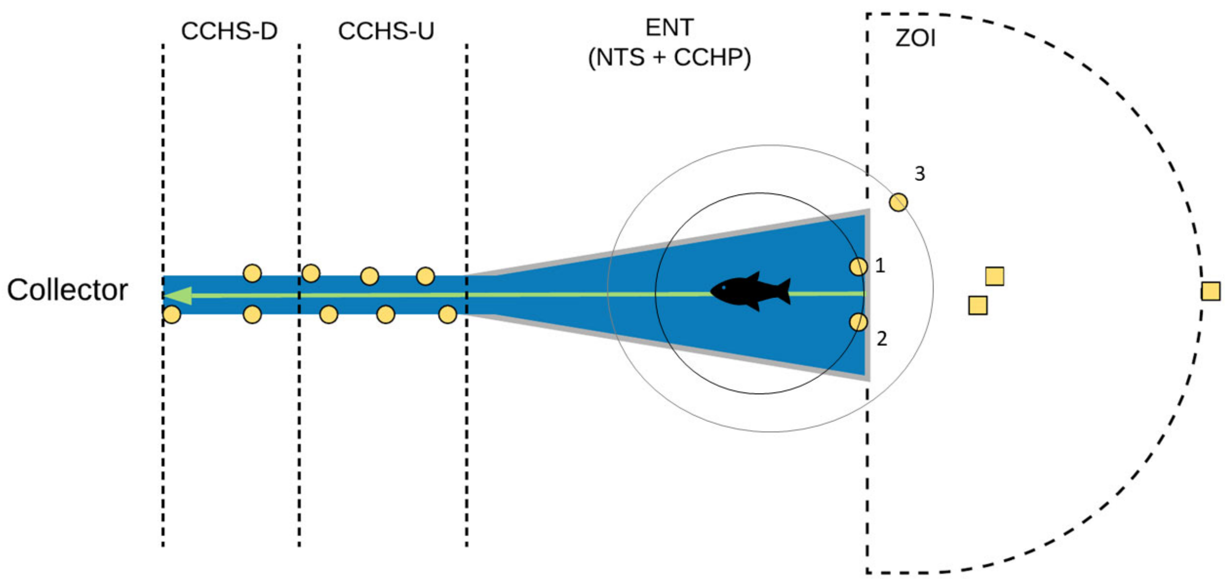
Automated diagnostic processing scripts were applied to the acoustic data after each download to check data quality. These diagnostics enabled the team to quickly verify that receivers were functioning correctly and that corrupt records were removed. Furthermore, these diagnostics provided insight into ambient noise conditions at the Swift 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, ENT, or CCH) 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 2022 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 quasi-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 11 provides a visual depiction of this process, in which a single ping is detected by receivers in the entrance 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.



Note: The numbers depict the order in which each receiver picks up the tag signal; in this case, the signal is heard first on ENT-02, then on ENT-01, and finally on ZOI-04. Based on time-of-arrival difference values across these receivers, the tag would be positioned within the entrance.

Figure 11. Visual depiction of an acoustic signal being emitted from a tag within a fish and being detected in the net transition structure of the entrance and the zone of influence.

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 the ZPTS, which in turn enabled construction of mark-recapture models and analysis of fine-scale behaviors.

2.3 Performance Metrics

Key performance metrics for the 2022 Study included P_{PASS}, P_{ENC}, P_{ENT}, P_{CE}, P_{RET}, $P_{SECCHAN}$, and P_{CAP} (Table 5). 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 5 and Appendix A.

Table 5. Performance metrics.

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

After zone presence was established for all individuals (Section 2.2.6), the corresponding presence-absence matrix was computed. The presence-absence matrix summarizes the detection history for each study fish (Appendix C). The presence-absence matrix was used to fit Cormack-Jolly-Seber mark-recapture models to estimate zonal survival and detection probabilities (White and Burnham 1999).

These parameter estimates were used to estimate 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 pooled seasonal estimates of survival and detection through the upstream and downstream secondary collection channel. This enabled estimation of transition probabilities for each of these reaches individually, 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 Swift 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 (Section 3.4), the study period encompasses a majority of the spring-summer phase of outmigration for each study species within Swift Reservoir (Section 3.2), providing adequate representativeness of the overall population from which the sample of study fish are drawn. To test for seasonal variation in collection efficiency, the P_{CE} metric was computed independently for each release group of study fish, and these release group-specific collection efficiencies then were statistically tested for differences. Collection efficiency was also computed independently for groups of study fish released in each of the months of tagging (April, May, and June), and these monthly collection efficiencies were also statistically tested for differences. As an additional test of the representativeness of dual-tagged study fish, recapture rates of PIT-only fish of each species also were computed, and these recapture rates of PIT-only fish were statistically tested for differences from recapture rates of dual-tagged study fish.

2.4 Passage Attempt Behavioral Analysis

To develop insights about specific locations of Swift FSC rejection and about factors hypothesized to affect recapture, behaviors of study fish that entered the Swift FSC 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). Because the 2022 Study was focused on the secondary collection channel, the receiver array did not include any receivers in the primary collection channel. Therefore, a passage attempt was defined in terms of a study fish's transition into the secondary collection channel. As described above in Section 2.1, attempts that occurred during the 13-hour outage in early June (18:00 June 7, 2022 – 7:00 June 8, 2022) were omitted.

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 Swift FSC 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 weir height within the Swift 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 Swift FSC throughout the study period (Section 2.4.2).

2.4.1 Weir Height Study

Results from the 2021 Study indicated that 48% of Coho Salmon and 40% of steelhead that entered the collection channel rejected collection. For both Coho Salmon and steelhead, this rejection occurred within the downstream secondary collection channel, a location characterized by lower water velocity. To test whether adjustments to Swift FSC operation could reduce this velocity drop and improve collection rates, PacifiCorp staff experimentally manipulated the height of the weir at the entrance to the collection facility. In previous years, the weir height was changed based on flow and debris loading to stay within bounds for generalized flow target inside the Swift FSC fish collection and sorting facility. For the 2022 Study, PacifiCorp staff systematically varied weir height between a high setting that resulted in lower flow into the Swift FSC and low setting that increased flow. Presumably, this manipulation of flow affected water velocity within the channel, reducing the low-velocity pocket of water at the downstream end of the secondary collection channel when the weir was set at the low position. This experiment was run over for 88 days, from April 18 through July 14, following a 2d-2d-3d pattern in duration of each block, with changes generally occurring every Monday, Wednesday, and Friday (Figure 12).

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

Note: 2d-2d-3d pattern was generally adhered to except over the holiday weekends of May 28-30 and July 2-4, when the respective 3d blocks were extended by 1 day before resuming the schedule.

Figure 12. Weir height study design calendar schematic.

2.4.2 Environmental and Operational Monitoring

Environmental and operational monitoring data were collected during the 2022 study period and used to analyze how conditions influence fish interactions with the Swift FSC and, ultimately, Swift FSC 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 Swift 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 Swift FSC deck at 5, 10, 15, and 20 feet below the water surface. The temperature logger deployed at the 10-foot depth failed in May 2022, and data were not collected from that logger from June onward. Light levels on the Swift 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).

2.4.2.2 Operational Sound Monitoring

After conclusion of the fish telemetry component of the 2022 Study, Swift FSC operational noise data were sampled when the Swift FSC was being prepared to come back online after summer maintenance. Data were collected over three periods on October 17, 2022: prior to equipment being turned on, while pumps and other equipment were being turned on, and again after the Swift FSC was fully operational. Measurements were collected: 1) alongside the Swift FSC; 2) outside of the dewatering channel for reference; and 3) at fixed locations from upstream of the NTS to the knife gate at the lower end of the dewatering channel. Additional noise data were recorded near the sorting area flow pumps at the stern of the Swift FSC. To record and analyze these sound data, two calibrated Cetacean Research CR1A hydrophones were interfaced with a SpectraDAQ-200 and connected to an acquisition computer via USB. Data recording was controlled and monitored with SpectraPLUS spectral analysis software.

2.4.3 Initial Data Processing to Identify Passage Attempts

The ZPTS (Section 2.2.6 and Appendix A) for fish that entered the Swift FSC 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 secondary collection channel until the time when it exited. "Exits" include fish moving downstream to collection within the Swift FSC and fish moving back upstream and exiting the secondary collection channel via its upstream end. 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. These plots were then evaluated to remove detection sequences that did not 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 21 attempts (range 1 to 66). 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 retained 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 (Appendix A) informed statistical analyses and modeling described in the following section.

2.4.5.2 Statistical Analysis and Modeling

Three 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 operational, biological, and environmental factors interact to affect juvenile fish passage at the Swift FSC. These model sets included the following:

1. A set of models to evaluate the effects of weir height 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). Each model included a subset of the variables shown in Table 6 (Appendix A).

Table 6. 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
Weir height	Height of weir into the Swift FSC at the time of passage
Species	The species of the fish: Coho Salmon or 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

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 2022 Study indicated that the acoustic telemetry array performed as designed and that algorithms developed to process detection data were capable of accurately positioning acoustic tags within each zone. Detailed array performance results are provided in Appendix A.

3.2 Tagging Operations

421 dual-tagged study fish and 672 PIT-only fish were released from April 20 through June 1. During the early stages of tagging, steelhead were the focus, due to their earlier run timing and to ensure the tagging goal was met. This focus on tagging steelhead early was also a strategy to reduce mortality from handling and tagging as the season progressed, as was observed in previous years. This increased mortality was likely due to rising water temperature and pre-existing (i.e., before capture) physiological stress associated with smoltification and was most prevalent in the larger juvenile steelhead (reasons for which are discussed in Section 4.3.2), so only steelhead less than or equal to 220 mm were tagged.

Peak tagging occurred on May 3 for steelhead and May 10 for Coho. Steelhead tagging ceased following the May 18 release due to increasing mortality rates during pre-tagging holding (i.e., after collection but before tagging). Coho tagging ceased after the June 1 release. Of the 421 fish released, 8 were associated with data entry errors that prevented inclusion in the study, so 182 steelhead and 231 Coho Salmon were included in the study (Table 7).

Table 7. Summary of the number and fork length (mm) of salmonids dual-tagged with passive integrated transponder and acoustic tags during the 2022 Swift floating surface collector passage evaluation.

Release Date	Coho Salmon			Steelhead		
	No. Tagged	FL Mean (SD) (mm)	FL Median (Range) (mm)	No. Tagged	FL Mean (SD) (mm)	FL Median (Range) (mm)
4/20/2022	10	160 (25.0)	167 (111 – 184)	9	189 (14.6)	189 (170 – 214)
4/27/2022	3	155 (15.0)	146 (146 – 172)	42	186 (26.8)	198 (104 – 220)
5/3/2022	26	172 (16.1)	171 (124 – 207)	53	184 (17.0)	184 (151 – 219)
5/5/2022	-	-	-	23	188 (15.6)	184 (164 – 219)
5/10/2022	63	145 (29.0)	138 (100 – 202)	45	186 (20.8)	187 (109 – 220)
5/18/2022	58	153 (32.3)	154 (100 – 202)	10	176 (25.6)	179 (117 – 209)
5/25/2022	39	154 (29.6)	150 (103 – 202)	-	-	-
6/1/2022	32	120 (9.0)	121 (99 – 136)	-	-	-
Total	**231**	**149 (29.7)**	**146 (99 – 207)**	**182**	**185 (20.7)**	**185 (104 – 220)**

Release proportions of dual-tagged study fish generally paralleled, but were slightly earlier than, the run-at-large for both species (Figure 13). This reflects an intentional strategy to limit handling mortality in steelhead and to provide Coho Salmon adequate time to migrate through the reservoir before water temperatures warmed and salmonids stopped their migration attempts. To check that the sample of dual-tagged study fish was representative of the expected peak migration period for each transport species (as stipulated in the M&E Plan), collection efficiency was computed by species for the following groupings: (1) for each release group; (2) by month; and (3) pooled across the study.

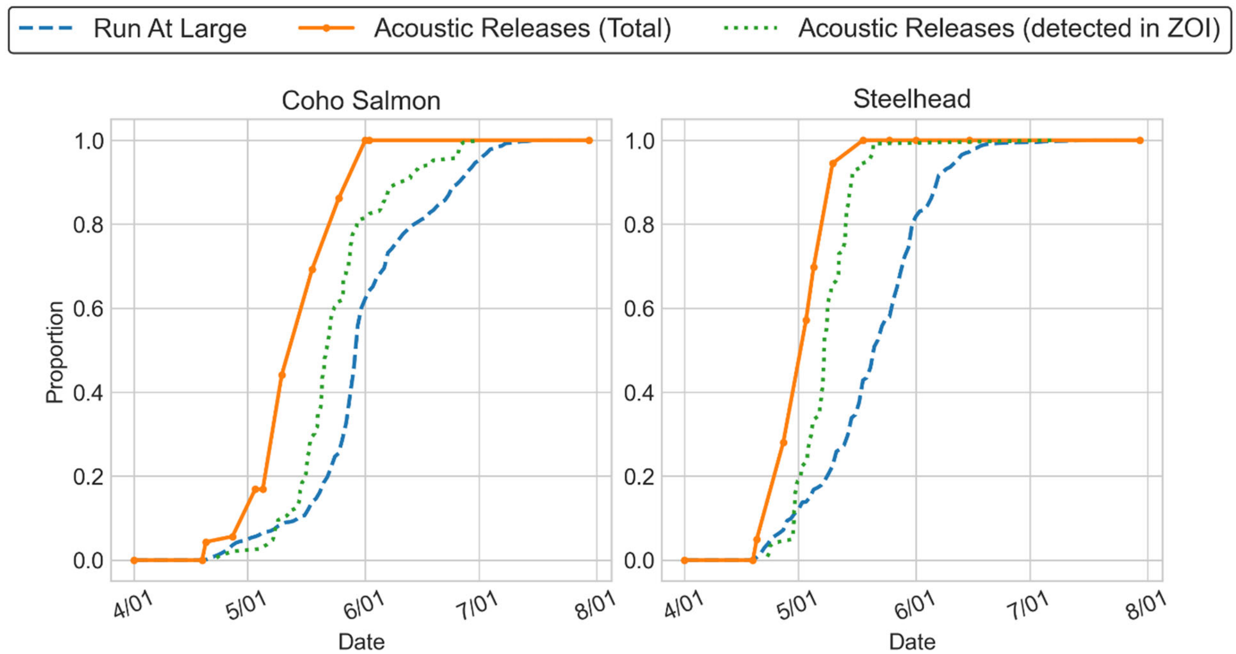
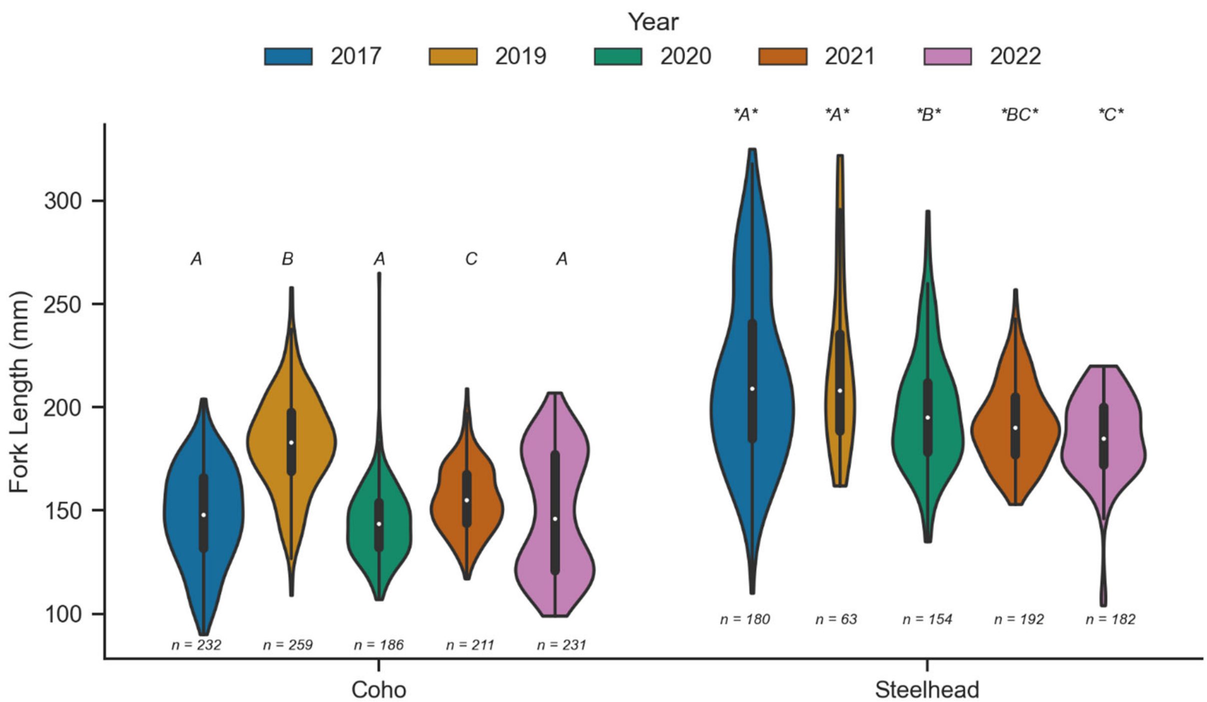


Figure 13. Cumulative distribution functions for each species in 2022, showing cumulative proportions of the total study fish that were acoustically-tagged and released, study fish that appeared in the zone of influence, and the background run-at-large collected at the Swift floating surface collector for transport and release downstream.

During the course of the study, five fish were collected with active PIT tags but were not adequately detected on the acoustic array to perform zone positioning. An analysis of the release information and limited detection sequences of these five tags indicated that the acoustic tags were either shed from these individuals after release or had failed prior to collection due to limited battery life. Consequently, 408 individuals were used for the computation of collection metrics and subsequent passage attempt analyses.

Dual-tagged steelhead in 2022 were similar in length to dual-tagged steelhead in 2021, but smaller than steelhead tagged in 2017, 2019, and 2020 (Figure 14). Coho Salmon were significantly smaller (6.7 mm on average) in 2022 than Coho Salmon tagged in 2019 and 2021 but were similar in size to Coho Salmon tagged in 2017 and 2020. The differences in mean fish length among years varied across species but were generally small to moderate (2-38 mm for Coho Salmon, 4-34 mm for steelhead). Lengths shown in Figure 14 were significantly different among years that do not share the same letter above their respective violin (Tukey's HSD, $p \leq 0.004$).



Note: 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. Violins extend to encompass the range of observations within the data. 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.

Figure 14. Fork length of dual-tagged study fish during years spanning 2017 to 2022.

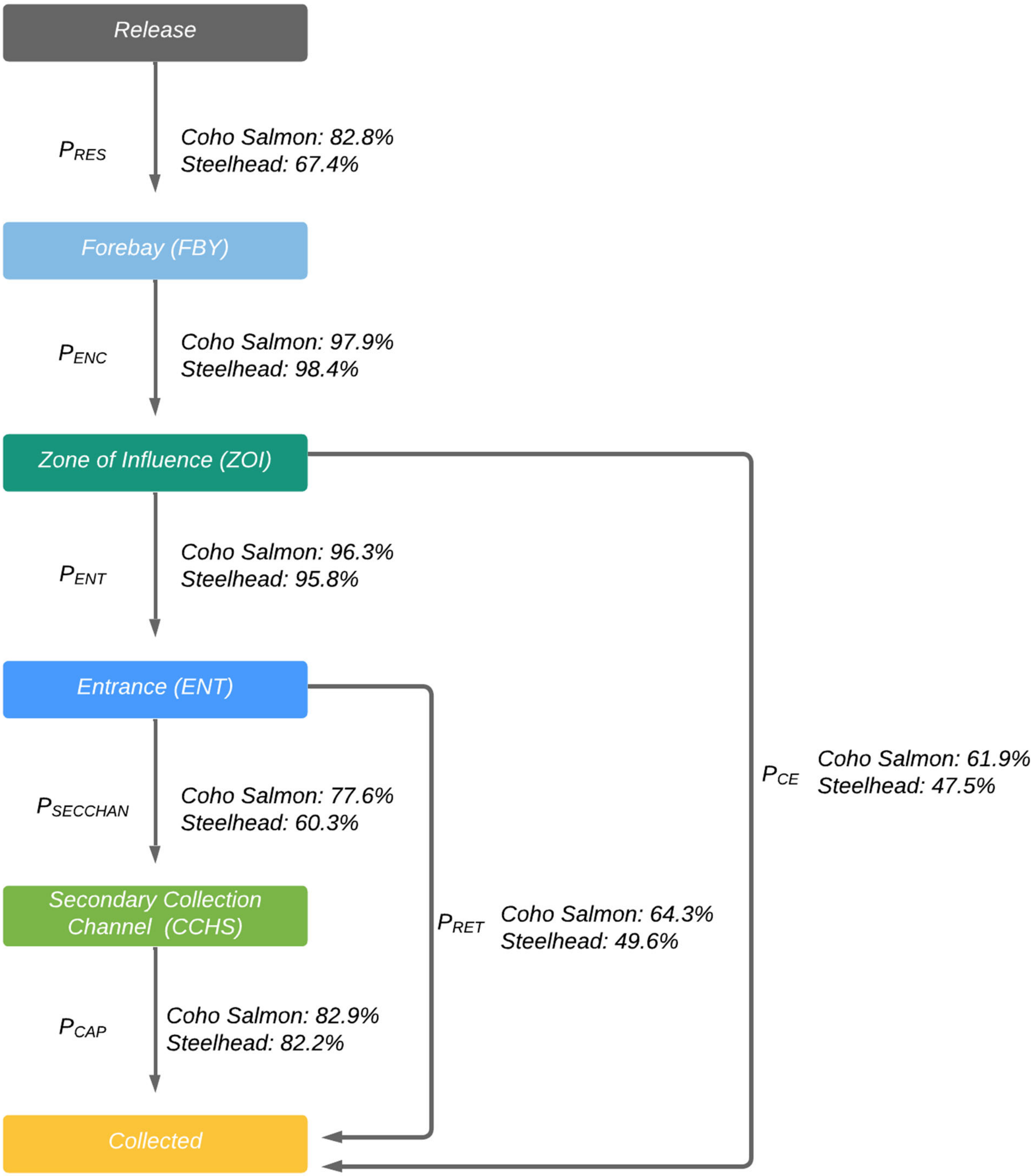
3.3 Swift Floating Surface Collector Performance Metrics

3.3.1 Collection Efficiency Metrics

Swift FSC performance metrics calculated for this study are summarized in Figure 15 and Table 8. Note that 90% confidence intervals are reported for these metrics, as specified in the M&E Plan (PacifiCorp and Cowlitz County PUD 2022).

- Reservoir transition (P_{PASS}), the proportion of dual-tagged study fish that are detected within the forebay, was 83% for Coho Salmon and 67% for steelhead.
- The Swift FSC encounter rate (P_{ENC}), which is the proportion of dual-tagged fish in the forebay that transitioned into the ZOI, was 98% for both species.
- Entrance efficiency (P_{ENT}), the proportion of dual-tagged fish in the ZOI that transitioned into the NTS, was 96% for both species.
- After dual-tagged fish reached the NTS, 78% of Coho Salmon and 60% of steelhead transitioned into the secondary collection channel ($P_{SECCHAN}$).
- Once in the secondary collection channel, 83% of Coho Salmon and 82% of steelhead were successfully collected (P_{CAP}).

- Retention efficiency (P_{RET}), the proportion of dual-tagged fish detected in the entrance zone that were subsequently collected, was 64% for Coho Salmon and 50% for steelhead.
- Collection efficiency (P_{CE}), the proportion of dual-tagged study fish available for collection that are actually collected, was 62% for Coho Salmon, and 48% for steelhead.



Note: P_{CAP} here represents the proportion of individuals that were positioned in the collection channel that made it to collection. P_{ZOI} reported in previous years is presented here as its constituent transition probabilities P_{RES} and P_{ENC}.

Figure 15. Flow chart summarizing 2022 performance metrics.

Table 8. 2022 Performance metric summary.

Species	Released [1]	POS_{FBY} [2]	POS_{ZOI}	POS_{ENT}	POS_{SECCHA} [3]	POS_{COL}	$\hat{P}_{PASS}$ (90% CI)[4]	$\hat{P}_{ENC}$ (90% CI)	$\hat{P}_{ENT}$ (90% CI)	$\hat{P}_{SECCHAN}$ (90% CI)	$\hat{P}_{CAP}$ (90% CI)	$\hat{P}_{CE}$ (90% CI)	$\hat{P}_{RET}$ (90% CI)
Coho Salmon	227	186	183	176	133	114	83% (*79%, 87%*)	98% (*96%, 100%*)	96% (*93%, 99%*)	78% (*72%, 83%*)	83% (*78%, 88%*)	62% (*56%, 68%*)	64% (*59%, 70%*)
Steelhead	181	122	120	115	66	57	67% (*62%, 73%*)	98% (*97%, 100%*)	96% (*93%, 99%*)	60% (*53%, 68%*)	82% (*75%, 90%*)	48% (*40%, 55%*)	50% (*42%, 57%*)

Notes:
1. This excludes five fish whose tags were assumed to have been shed or inactive at time of collection.
2. "POS" metrics refer to numbers of fish positioned within each zone, using ZPC developed for each. Actual detection counts may be higher if detections did not meet ZPC, but those detections are associated with lower confidence.
3. Counts of fish in the secondary collection channel are presented as the union of counts in either subzone.
4. 90% Wald's confidence intervals (CI) are reported for each collection metric.
5. MARK estimated confidence intervals for parameter estimates near the boundaries (0% and 100%) are unstable and thus not reported.

3.3.2 Positioning Efficiency

To accurately estimate collection efficiency metrics and quantify the precision associated with these estimates, mark-recapture models were used to estimate positioning efficiencies for each zone (Table 9). Positioning efficiency is estimated by determining the number of individuals confidently positioned in each zone that were not positioned in the previous (upstream) zone. Positioning efficiency associated with collection (which is determined by PIT detection) is not estimated, but rather assumed to be 100% for the purpose of these computations.

Positioning efficiencies were high across each zone and for each species (Table 9). One fish was missed in the ZOI, and one in the entrance, two zones that are critical for computation of the performance metrics P_{CE} and P_{RET}, respectively. High positioning efficiency in these zones imparts high confidence in these key performance metrics.

Table 9. Zone positioning efficiency by species.

Species	POS_{ZOI} (95% CI)[1]	No. of Fish Missed in ZOI	POS_{ENT} (95% CI)	No. of Fish Missed in ENT	POS_{CCHS} (95% CI)	No. of Fish Missed in Secondary Collection Channel
Coho Salmon	99% (*98%, 100%*)	1	99% (*98%, 100%*)	1	96% (*93%, 100%*)	4
Steelhead	100% (--)	0	100% (--)	0	95% (*89%, 100%*)	3

Notes:
1. 95% Wald's confidence intervals (CI) are reported for each positioning efficiency metric.
2. MARK estimates near the boundary of 0 and 1 are unstable and thus not reported.
3. Positioning efficiency at the Swift FSC is assumed to be 1.0 to provide tangible positioning 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 the subzones within the collection channel (Table 10) and positioning efficiencies within each of the array zones downstream of the ZOI (Table 11). Once in the secondary collection channel, 100% of dual-tagged fish transition from the upstream to the downstream portion. Because all fish make this transition, the subsequent transition from the downstream secondary collection channel into the collection facility is identical in value to P_{CAP} reported in Section 3.3.1, i.e., 83% for Coho Salmon and 82% for steelhead (Table 10).

Table 10. Transition probabilities between channel subzones.

Species	Upstream to Downstream Secondary Collection Channel (*90% CI)*	Downstream Secondary Collection Channel to Collection (*90% CI)*
Coho Salmon	100% (--)[2]	83% *(77%, 89%)*
Steelhead	100% (--)[2]	82% (*75%, 90%)*

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 11. Subzone positioning efficiency, by species.

Species	POS_{ZOI}	Missed in ZOI	POS_{ENT}	Missed in Upstream ENT	POS_{CCHS_U}	Missed in Upstream Secondary Collection Channel	POS_{CCHS_D}	Missed in Downstream Secondary Collection Channel
Coho Salmon	99% (--)	1	99% (--)	1	92% (*87%, 96%*)	11	73% (*65%, 81%*)	31
Steelhead	100% (--)	0	100% (--)	0	91% (*84%, 98%*)	6	68% (*57%, 79%*)	20

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 Swift FSC is assumed to be 1.0, to provide tangible detection efficiency estimation for previous zones in the mark-recapture model.

Zone positioning efficiencies for the primary and secondary collection channel subarrays were calculated in the same manner as for the collection channel as a whole (Section 2.2.6) and were similar between species for each subzone (Table 11). Partitioning the transitions between channel subzones increases uncertainty associated with these subzone detection efficiency estimates. This increase uncertainty is a result of reduced sample size within each subzone. Efficiency in positioning fish in the upstream secondary collection channel was around 90% (Table 11). The downstream secondary collection channel had a lower positioning efficiency of 73% for Coho Salmon and 68% for steelhead (Table 11), with a total of 51 fish missed in this zone. Further precision levels for these zones are discussed in Appendix A.

3.3.4 Identifying Passage Bottlenecks

The transition probabilities from the refined mark-recapture model were applied to counts of study fish within each subzone to visualize bottlenecks that prevent fish from moving downstream and to develop model estimated counts of fish reaching each subzone (Figure 16).

- After release, 83% of Coho Salmon and 67% of steelhead transitioned to the forebay within the study period (Table 8, Figure 15, Figure 16).
- Once in the forebay, 98% of both Coho Salmon and steelhead transitioned to and were positioned within the ZOI.
- Once in the ZOI, 96% of both species entered the NTS and were positioned in the ENT.
- Once in the ENT, 77% of Coho Salmon and 60% of steelhead transitioned to the secondary collection channel. Represented differently, 23% of Coho Salmon and 40% of steelhead that had entered the Swift FSC rejected before the secondary collection channel.
- Once in the secondary collection channel, 17% of Coho and 17% of steelhead rejected before passing over the control weir and into the Swift FSC fish collection and sorting facility.

It is important to note that all dual-tagged study fish that entered the secondary collection channel transitioned through the upstream secondary collection channel subzone and were positioned in the downstream secondary collection channel subzone. This rejection rate at the downstream end of the secondary collection channel in 2022 was less than half the rate observed during the 2021 study, which was the only other study year with an array capable of positioning fish within the downstream secondary screen channel. Possible reasons for this improvement are discussed in Section 4.2.

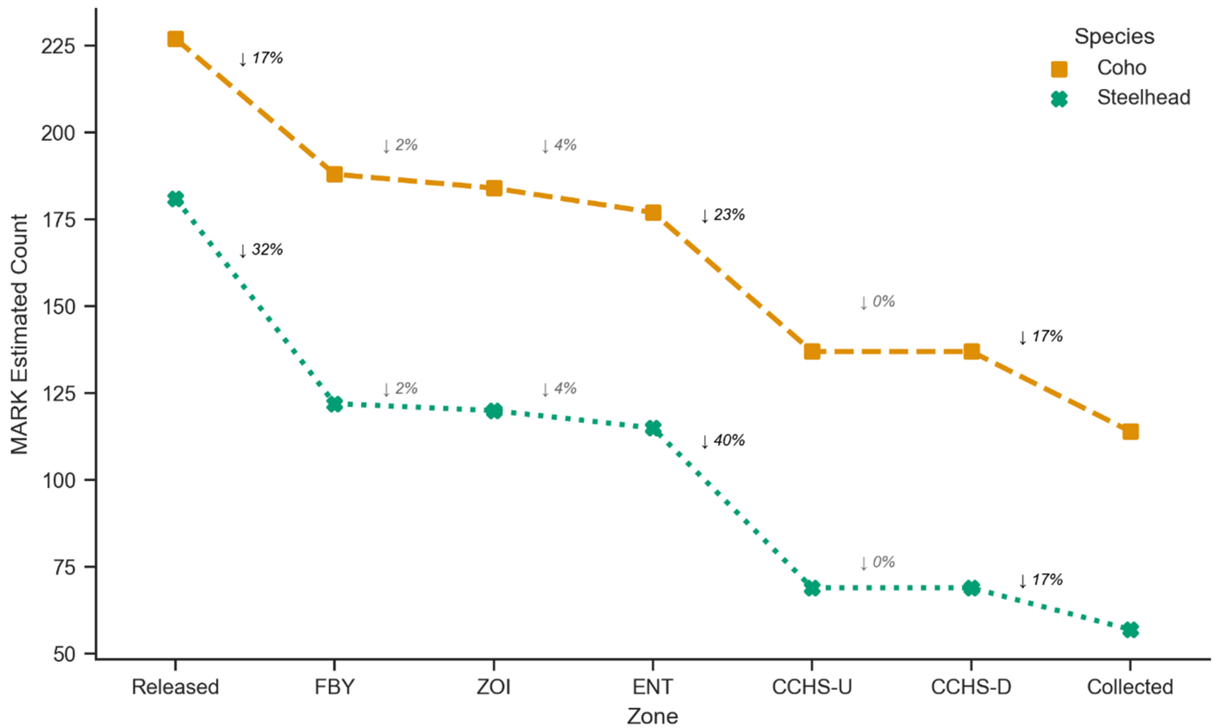
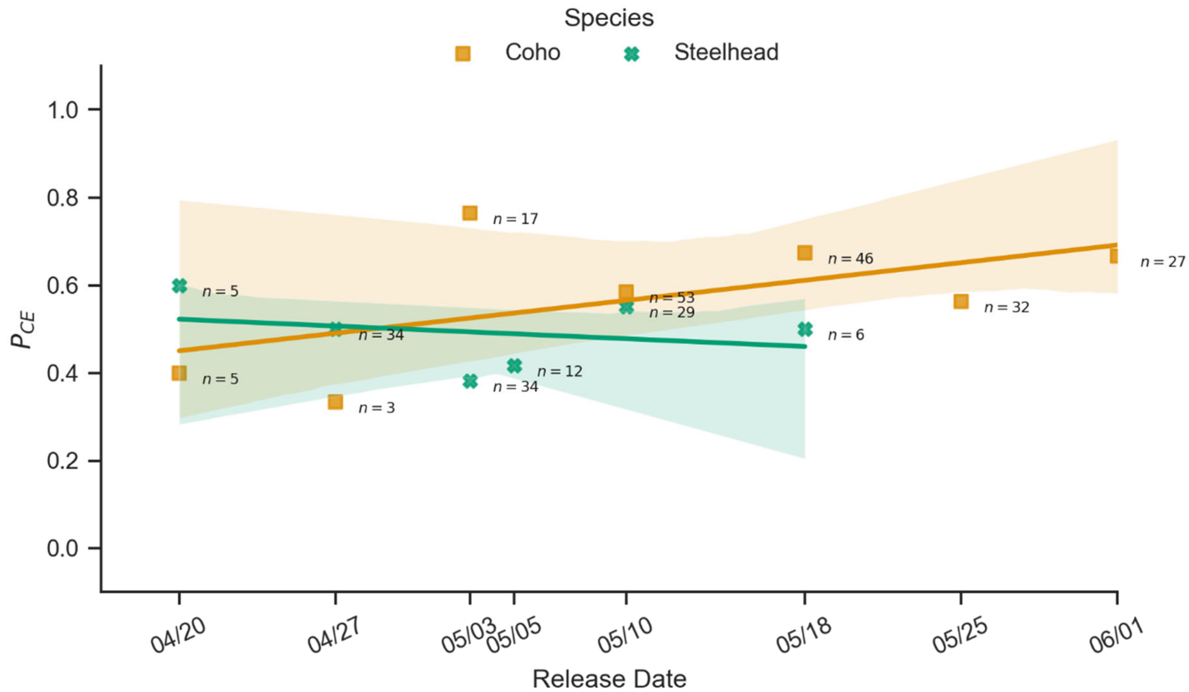


Figure 16. Counts of study fish detected within each zone of the Swift floating surface collector array. Annotation indicates magnitude of species-averaged rejection rates associated with each transition.

3.3.5 Seasonal Trends in Collection Efficiency

Recapture rates were variable among weekly release groups with a slight trend of increasing collection efficiency for Coho Salmon release groups over the season and decreasing collection efficiency for steelhead release groups (Figure 17). However, these trends over time were not significant for either Coho Salmon ($t = 1.46$, $p = 0.19$) or steelhead ($t = 0.54$, $p = 0.61$). Moreover, there was no significant difference in collection efficiency among Coho Salmon release groups (global test for equality of proportions: $\chi^2 = 5.14$, $p = 0.53$) or steelhead release groups ($\chi^2 = 2.43$, $p = 0.79$) (Table 12). Similarly, there was no significant difference in collection efficiency for monthly groups of Coho Salmon ($\chi^2 = 2.33$, $p = 0.31$) or steelhead ($\chi^2 = 0.14$, $p = 0.70$) (Table 13).



Notes: Lines show linear regressions between Julian day and release group P_{CE} for each species. Counts of the number of individuals that transitioned into the ZOI at any point of the study for each release group are illustrated next to each point. Shaded areas indicate 95% confidence interval. Based on a Wald's t-test on the slope parameter, the rate of change in P_{CE} across release groups was not significant for Coho Salmon (b_1=0.0057, p = 0.19) or steelhead (b_1=0.0022, p = 0.61).

Figure 17. Values of P_{CE} by release groups of Coho Salmon and steelhead.

Table 12. Values of P_{CE} for each species by release group.

Species	Release Date	Released[1]	POS_{ZOI}	POS_{COL}	$\hat{P}_{CE}$
Coho Salmon	April 20	10	5	2	0.40
	April 27	3	3	1	0.33
	May 3	26	17	13	0.76
	May 10	62	53	31	0.58
	May 18	56	46	31	0.67
	May 25	39	32	18	0.56
	June 1	31	27	18	0.67
Steelhead	April 20	9	5	3	0.60
	April 27	42	34	17	0.50
	May 3	52	34	13	0.38
	May 5	23	12	5	0.42
	May 10	45	29	16	0.55
	May 18	10	6	3	0.50

Notes:
1. This excludes five fish whose tags were assumed to have been shed or inactive at time of collection.
2. "POS" metrics refer to numbers of fish positioned within each zone, using ZPC developed for each. Actual detection counts may be higher if detections did not meet ZPC, but those detections are associated with lower confidence.

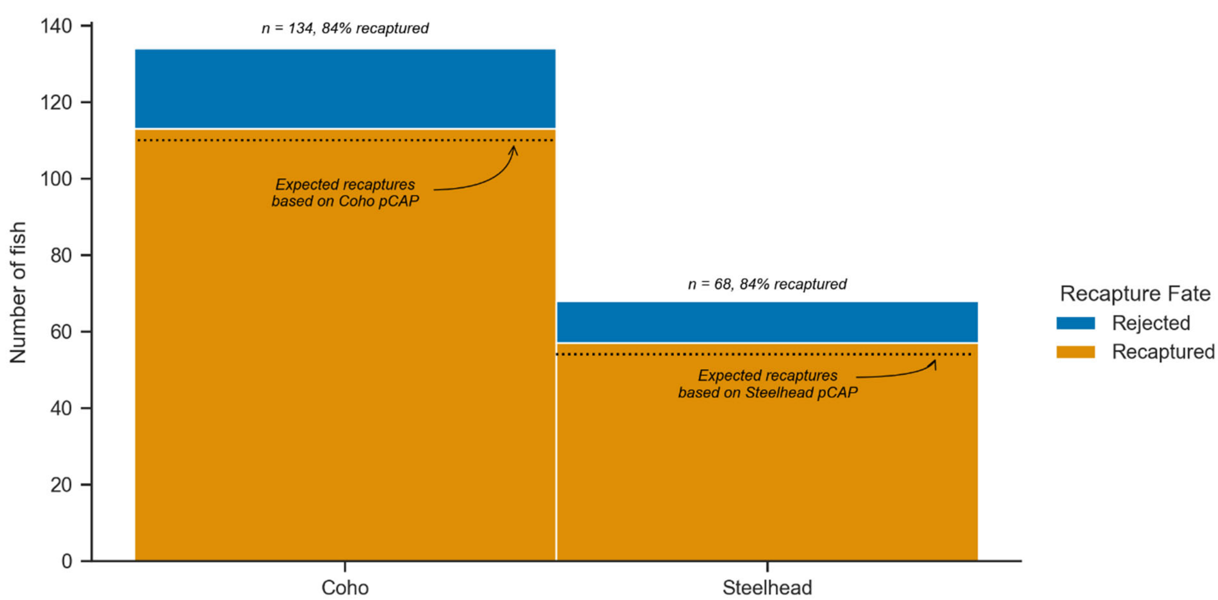
Table 13. Values of P_{CE} for each species by month.

Species	Month of Release	Released[1]	POS_{ZOI}	POS_{COL}	$\hat{P}_{CE}$
Coho Salmon	April	13	8	3	0.38
	May	183	148	93	0.63
	June	31	27	18	0.67
Steelhead	April	51	39	20	0.51
	May	130	81	37	0.46

Notes:
1. This excludes five fish whose tags were assumed to have been shed or inactive at time of collection.
2. "POS" metrics refer to numbers of fish positioned within each zone, using ZPC developed for each. Actual detection counts may be higher if detections did not meet ZPC, but those detections are associated with lower confidence.

3.4 Passage Attempt Behavioral Analysis

Behavioral analyses focused on all passage attempts for individual dual-tagged fish, with each attempt defined in Section 2.4. The set of passage attempts included 1,025 attempts made by 134 Coho Salmon and 68 steelhead. Since these fish included in the behavioral analyses had already entered the secondary collection 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 both species of study fish. For each, the two quantities were nearly identical (Figure 18), indicating that the group of fish included in the behavioral analyses is representative of the overall study group.



Note: 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 ($p > 0.5$).

Figure 18. 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.

No passage attempts were detected during the brief period when the Swift FSC was off from June 7, 18:00 to June 8, 7:00. In the set of 202 fish making 1,025 attempts, 74 fish (37%) made only 1 attempt, and half (50%) attempted 2 times or fewer (Figure 19). Only 10% of fish attempted more than 12 times, and 5% attempted more than 23 times. Three Coho Salmon attempted 50 or more times, with the maximum number of attempts being 66 by one Coho Salmon. The number of passage attempts per individual was similar between rejected and recaptured Coho Salmon and steelhead (Welch's t-test, $p > 0.05$). Unlike in 2020 and 2021, fish that were ultimately recaptured made many more attempts in aggregate (Coho Salmon = 609, steelhead = 189) compared to fish that rejected (Coho Salmon = 169, steelhead = 58). While this could be driven by a change in behavior, it is more likely due to an artifact of the study design. In 2021, a passage attempt was defined as beginning at the entrance to the primary collection channel (Four Peaks 2022), whereas in 2022 it is defined as beginning at the entrance to the secondary collection channel. Thus, the two are not directly comparable.

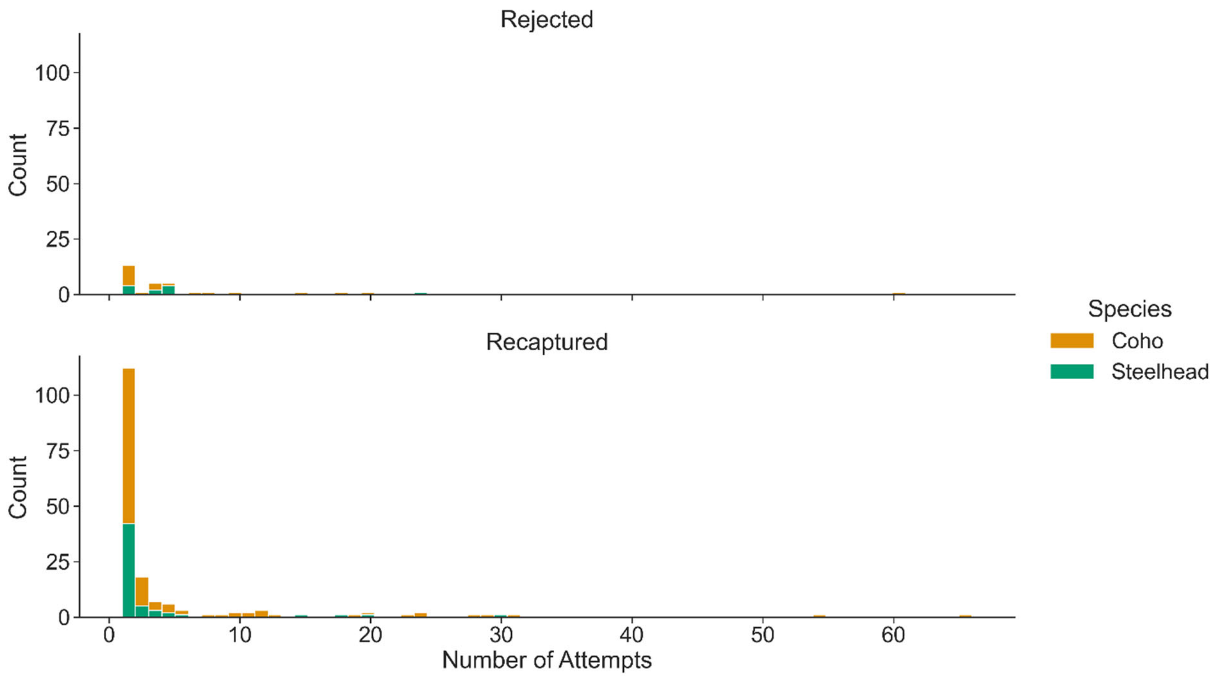


Figure 19. Distribution of the number of Swift floating surface collector passage attempts made by recaptured study fish and study fish that rejected collection during 2022.

Coho Salmon and steelhead outmigration timings were staggered: 50% of the steelhead run-at-large had passed the Swift FSC by May 21, and 50% of the Coho Salmon run had passed by May 30 (Figure 13). The daily counts of dual-tagged study fish attempting passage at the Swift FSC (i.e., counting each fish once per day) indicate distinct but overlapping modes for each species (Figure 20), which generally track the seasonal trend in daily counts of study fish collected at the Swift FSC (Figure 21), and Swift FSC collections of the runs-at-large for each species (Figure 22), indicating that study fish outmigration dynamics roughly paralleled the run-at-large. Steelhead outmigration began in early May and exhibited small peaks through May to early June, before tapering off to low levels that persisted throughout the rest of the season. Coho Salmon outmigration also began in early May and exhibited large pulses in the number of fish attempting per day, especially between May 27 and May 31, when collections peaked for both dual-tagged fish and the run-at-large.

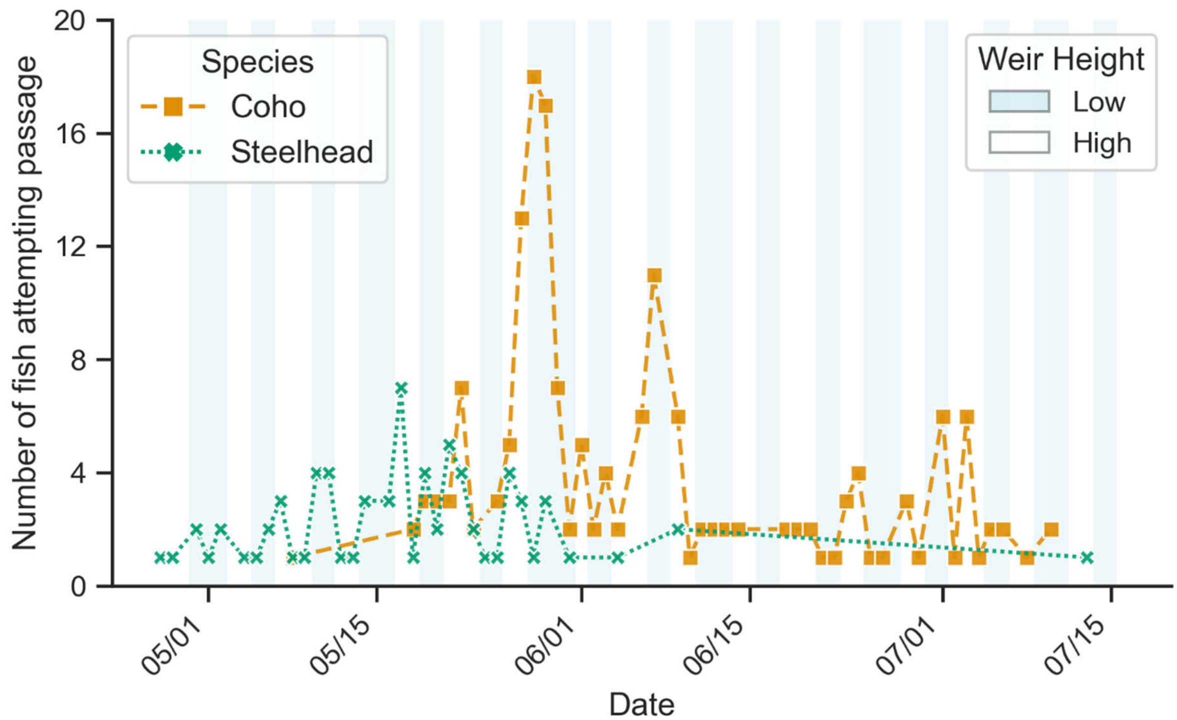


Figure 20. Daily counts of number of study fish attempting passage at the Swift floating surface collector during the 2022 season.

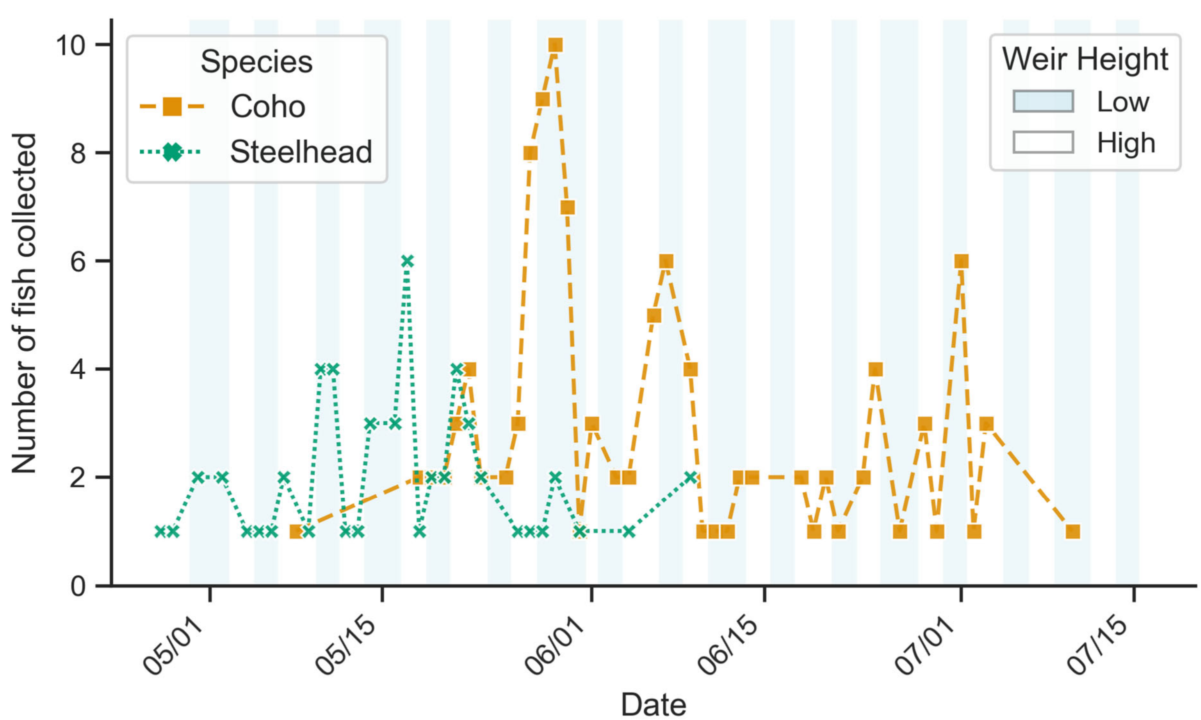


Figure 21. Daily counts of number of study fish recaptured at the Swift floating surface collector during the 2022 season.

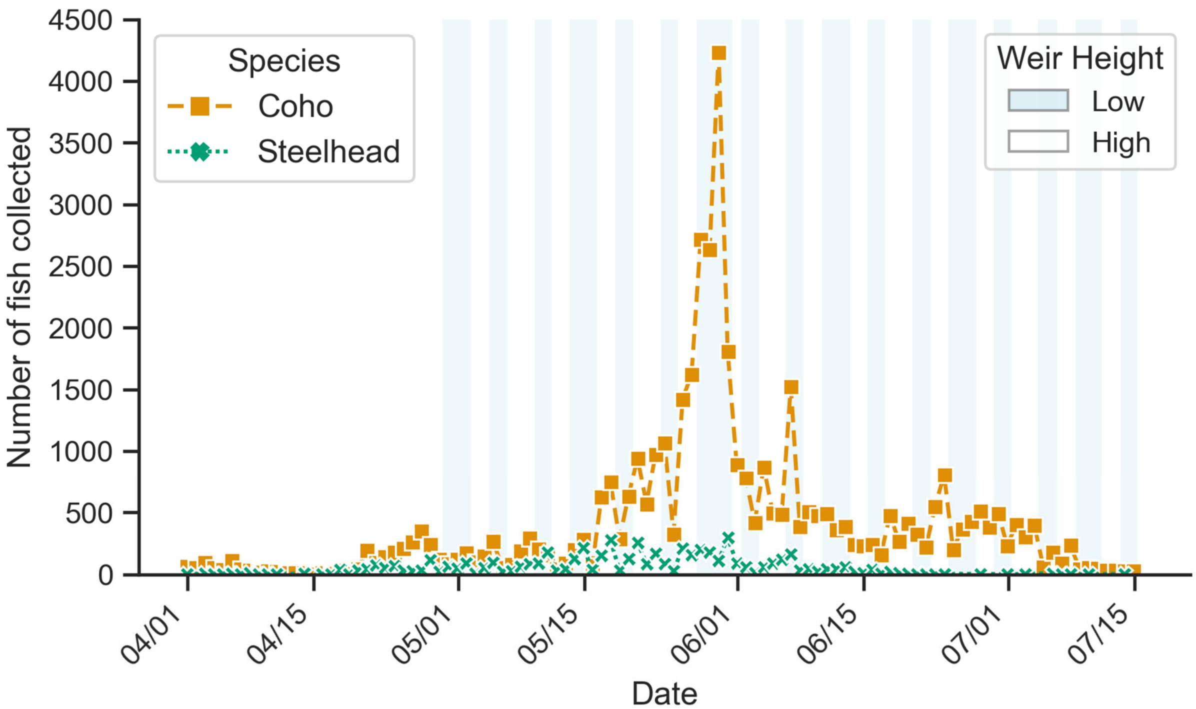
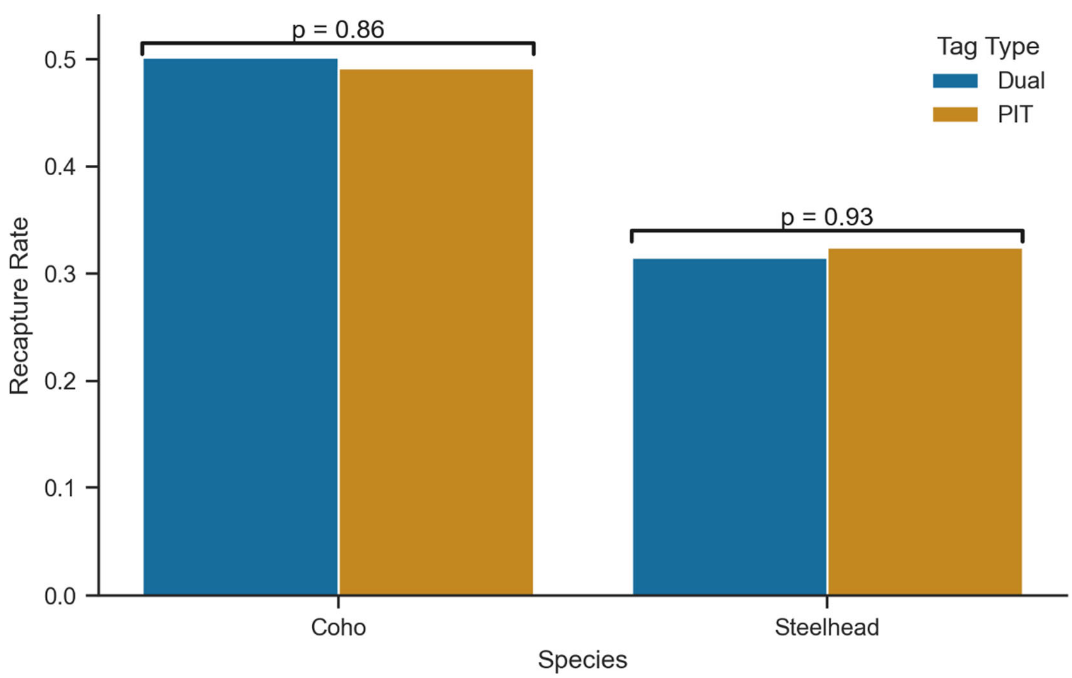


Figure 22. Daily counts of numbers of run-at-large fish collected at the Swift floating surface collector in 2022.

Recapture rates of dual-tagged study fish and PIT-only fish were similar for each species (Figure 23).



Note: p-value annotated above each pair of bars indicates results of chi-squared test of equal proportions. Values greater than 0.05 indicate no significant difference.

Figure 23. Comparison of recapture rates for dual-tagged (study fish) and PIT-only fish of each species.

The peak acoustic sound detected while the Swift FSC was in operation was at about 22 Hz, consistent with observational "spot checks" since 2018 (data unreported) and formal sound testing in 2021 (Four Peaks 2022). This signal was the peak noise detected above the background flow noise at all fixed locations monitored within the collection channel and near the sorting area flow pumps at the stern of the Swift FSC and was the only frequency that was pronounced in the spectral analysis (Figure 24). Prior to 2018, the peak signal detected was 23 Hz and was determined to be from the sorting area flow pumps. The 22 Hz signal was likely present at this time but was masked by the much higher amplitude 23 Hz signal produced by the sorting area flow pumps.

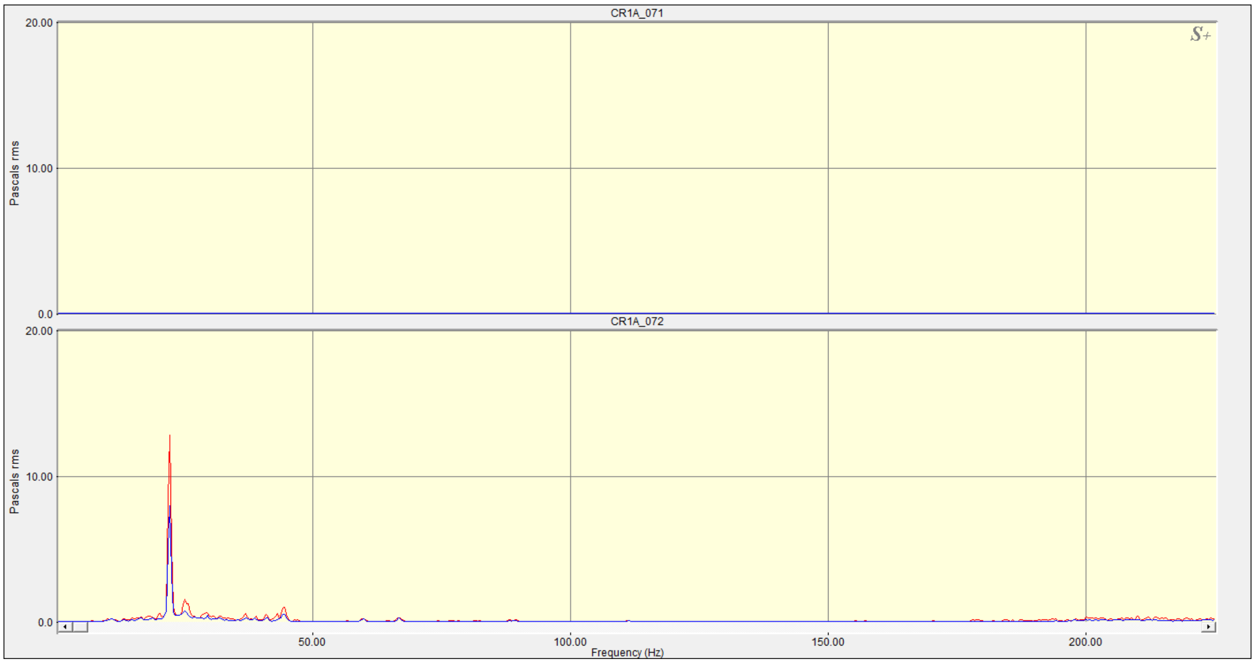


Figure 24. Spectrogram collected with pumps running outside of the dewatering channel (top figure) and within the dewatering channel, showing strong pressure signal at 22 Hz in the channel.

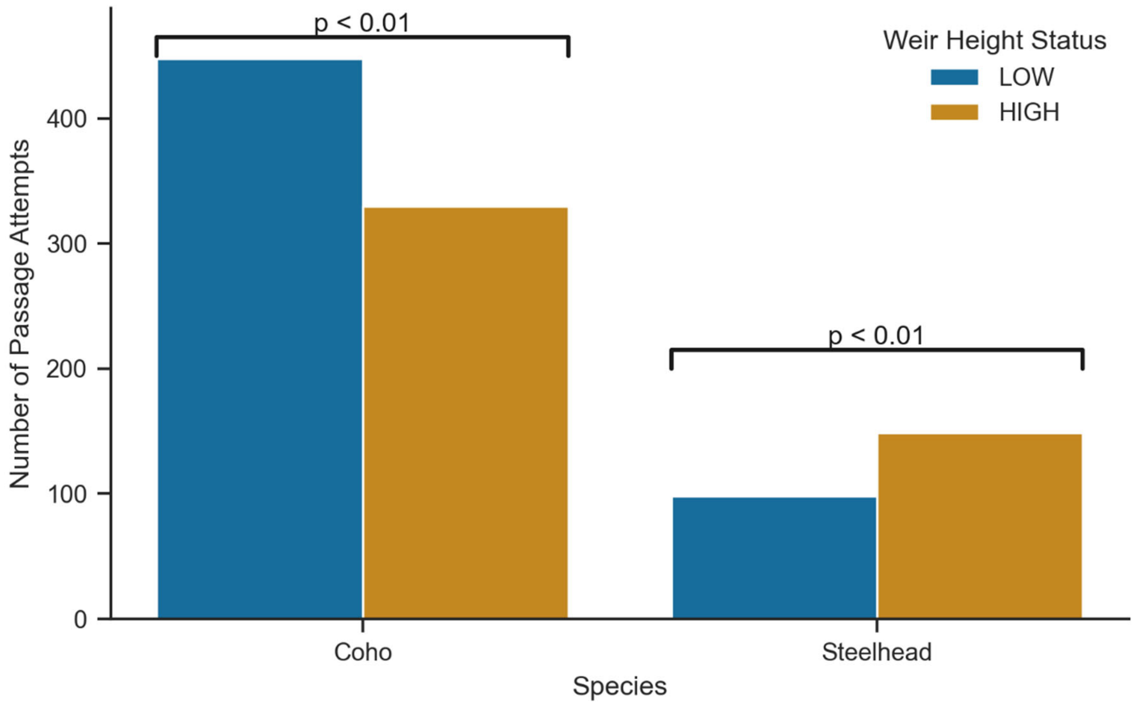
3.5 Analyses of Factors Hypothesized to Affect Collection

Results from a series of statistical analyses and models are summarized in the following subsections. Detailed analytical and modeling methods are provided in Appendix A.

3.5.1 Results of Experimental Weir Height Manipulation

3.5.1.1 Weir Height Seasonal Summary

The total number of passage attempts across the entire season was significantly greater when the weir was at the low setting for Coho Salmon (χ^2 = 17.9, $p < 0.01$) and at the high setting for steelhead (χ^2 = 10.5, $p < 0.01$) (Figure 25). Information presented in Section 3.5.1.2 indicates that this apparent effect may be an artifact of the strong and narrow peaks in outmigration observed for both species in 2022, in particular Coho Salmon (Figure 20, Figure 21, Figure 22), which resulted in unbalanced representation within treatment blocks for both species.

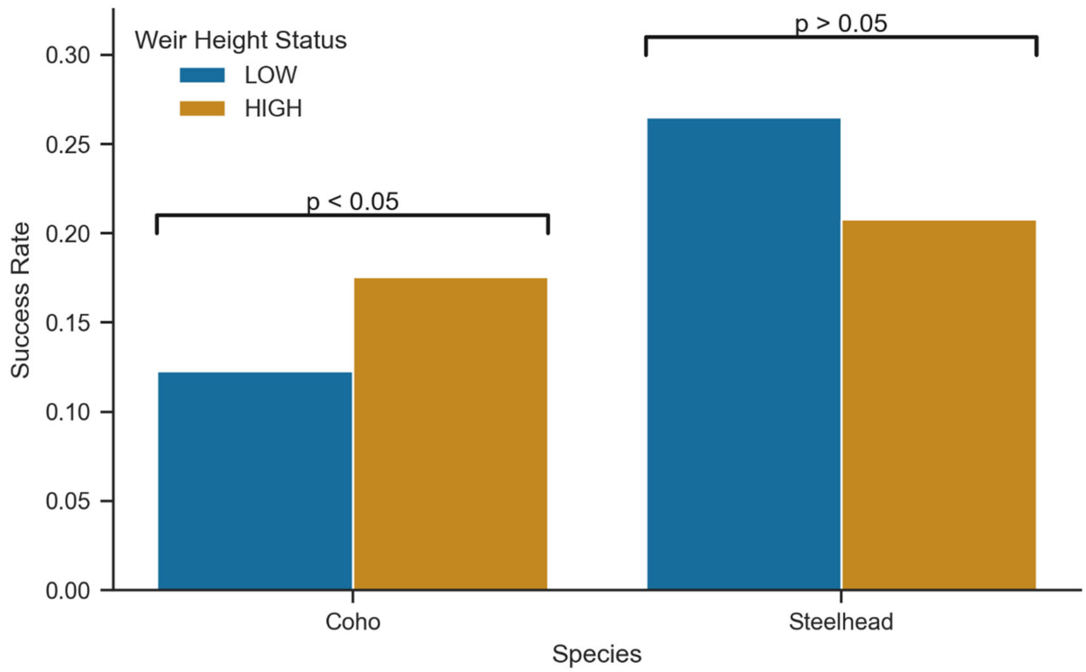


Note: P-values depict significance of a chi-squared test of homogeneity between number of attempts at both weir heights across the entire study period.

Figure 25. Total number passage attempts at both weir heights during the study season for each species.

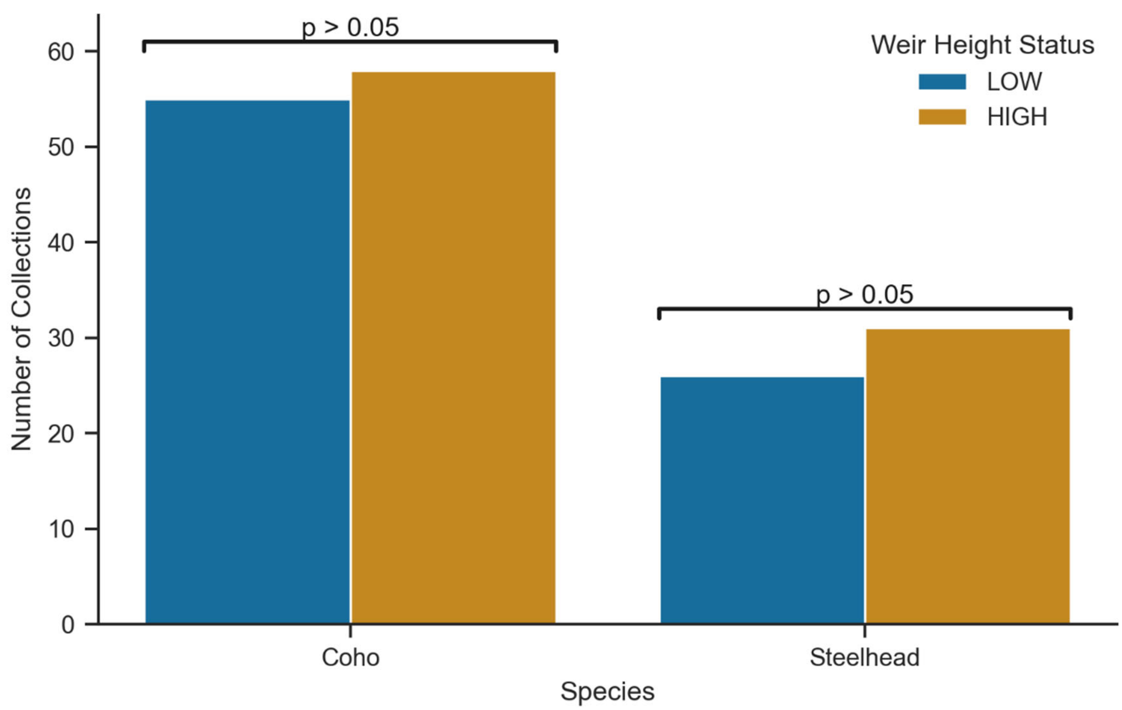
The rate of successful passage attempts across the entire season showed an opposite effect, although the difference was statistically significant only for Coho Salmon (Figure 26). Attempts by Coho Salmon were more successful when the weir was at the high setting ($p = 0.04$); attempts by steelhead were slightly but not significantly more successful ($p = 0.30$) at the low setting. Again, information presented in Section 3.5.1.2 indicates that this apparent effect of weir height on success rate may simply be an artifact of outmigration dynamics (Figure 20).

Overall, the number of fish collected throughout the season did not differ significantly between periods when the weir was operated at the different heights, for either species (Coho: $\chi^2 = 0.1$, $p > 0.05$; steelhead: $\chi^2 = 0.44$, $p > 0.05$; Figure 27). This suggests that weir height and flow volume entering the Swift FSC fish collection and sorting facility did not affect passage success for either species.



Note: P-values depict significance of a z-test for equality between success rate proportions under both weir heights across the entire study period.

Figure 26. Collection success rate at both weir heights for each species.



Note: P-values depict significance of a chi-squared test of homogeneity between number of fish collected at both weir heights across the entire study period.

Figure 27. Total number of fish collected at both weir heights during the study season for each species.

3.5.1.2 Weir Height Blocked Modeling

Results from the ANOVA model testing the effect of weir height on the success of passage attempts further supported that weir height did not have an effect on fish collection (Table 14). Applying this model controlled for unmeasured effects that varied across blocks and provided a more refined analysis of weir height effects. Results from this effort clarified that weir height did not affect the proportion of successful passage attempts within each treatment block, despite an apparent effect of weir height when simply comparing collection rates under the differing weir heights (Figure 26). Results presented in Figure 26 may be an artifact of the strong pulses in outmigration presented above (Figure 20, Figure 21, Figure 22) that resulted in imbalanced representation between the two treatment blocks for both species.

The model results indicate that collection rates varied more among individual blocks (i.e., over time) than between weir height conditions (Table 14). This means that some other, unmeasured, factor(s), which also varied across time, determined collection success more strongly than weir height did.

Table 14. Test statistics and corresponding p-values from ANOVA results on the proportion of successful passage attempts in each block of the weir height study.

Model Term	Coho Salmon		Steelhead		All	
	F Statistic	*P*-value	F Statistic	*P*-value	F Statistic	*P*-value
Weir Height	2.39	0.12	0.24	0.62	0.49	0.49
Block	14.62	< 0.01	11.98	< 0.01	28.68	< 0.01
Weir Height x Block Interaction	3.81	0.28	1.84	0.40	3.93	0.42

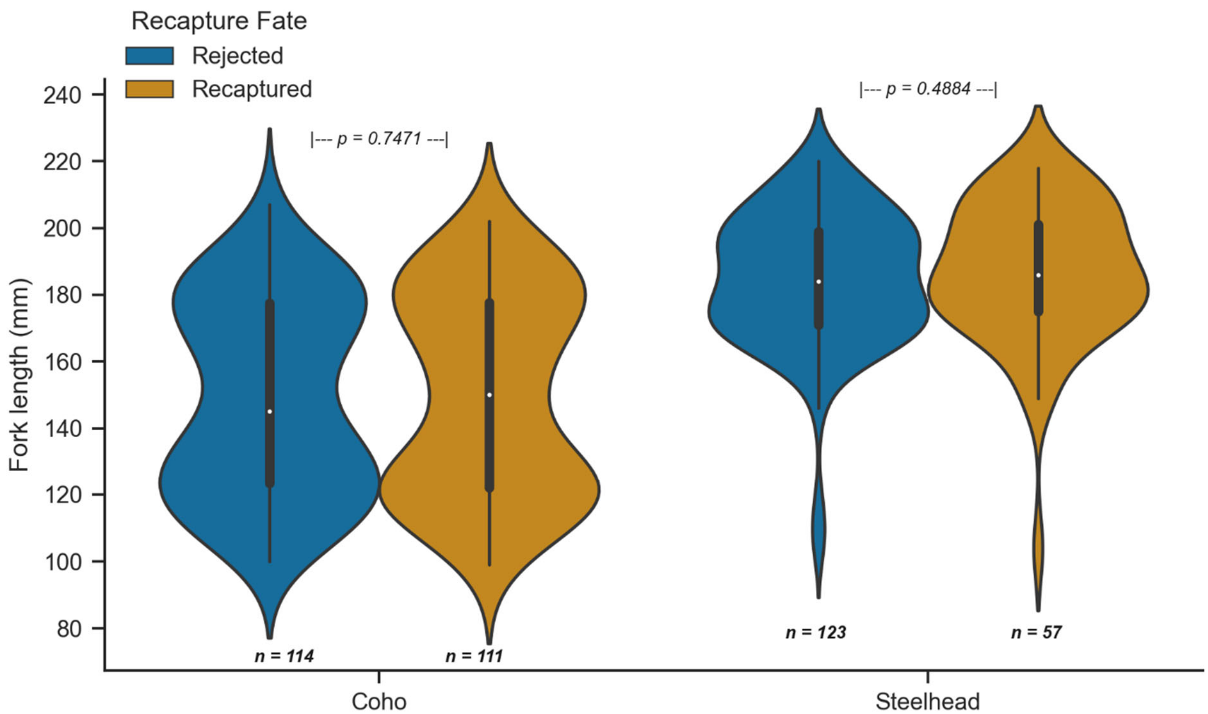
3.5.2 Factors that Affect the Passage Success of Individual Fish

Statistical models provide moderate support that length may have been a factor that contributed to the probability of successful recapture for Coho Salmon but not for steelhead. Models suggested that shorter Coho Salmon were slightly more likely to be successfully recaptured (Table 15). However, the difference in length between Coho Salmon that were collected and those that were not collected was very small and not statistically significant (*t*-test, $p > 0.05$, Figure 28). A similar model for steelhead indicated that length was not an important factor predicting successful recapture (Table 15), and steelhead did not differ in length between individuals that were collected and those that were not (Figure 28). This result is different than previous years where larger steelhead were significantly more likely to reject collection. This difference may have resulted from not tagging steelhead larger than 220 mm in 2022.

Table 15. Estimated effect influence (Sign) and variable importance (Importance) from models of factors affecting passage success of individual fish.

	Coho		Steelhead	
	Sign	Importance	Sign	Importance
Intercept	-	1.00	-	1.00
Length	-	0.55	-	0.42
Release day	✓	0.03	✓	0.01
Length x Release day	✓	> 0.01	✓	> 0.01

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.



Note: See Figure 14 note 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.

Figure 28. Comparison of fork length between study fish that were recaptured and those that rejected the Swift floating surface collector during 2022, grouped by species. All study fish are included in this plot.

3.5.3 Factors that Affect the Success of Individual Passage Attempts

A series of models evaluating factors associated with the success of individual attempts (as opposed to individual fish in Section 3.5.2) found that species, weir height, and both time and date of attempt initiation were all strong predictors of probability of individual passage attempt success (Table 16). Environmental conditions like temperature, east wind events, light levels, and barometric pressure did not appear to affect individual passage success.

For Coho Salmon but not steelhead, fish length appears to be an important predictor of the success of individual attempts (Table 16). This may be caused by longer Coho Salmon making more passage attempts than shorter Coho Salmon (Figure 29). The length of attempting Coho Salmon was significantly and positively correlated with the number of attempts (Pearson's correlation coefficient $r = 29.6\%$, $p < 0.01$) whereas it was only slightly negative and insignificant for steelhead ($r = -6.0\%$, $p = 0.63$). Since collection rates were similar across the range of Coho Salmon length (Figure 28), the greater number of attempts made by longer individuals simultaneously over-represents those fish within the group of attempts while also driving down the apparent success rate of each attempt. For steelhead, length not being a predictive factor in collection may be a result of cutting off the tagging length at 220 mm.

Table 16. 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	-	1.00	-	0.40
Species	✓	0.99				
Weir height	✓	0.89	✓	0.87	✓	0.29
Day of year	-	0.74	-	0.61	-	0.70
Temperature	-	0.48	+	0.57	-	0.48
East wind	-	0.39	-	0.28	+	0.27
Light	+	0.38	+	0.37	+	0.34
Barometric Pressure	+	0.28	-	0.32	+	0.32

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.

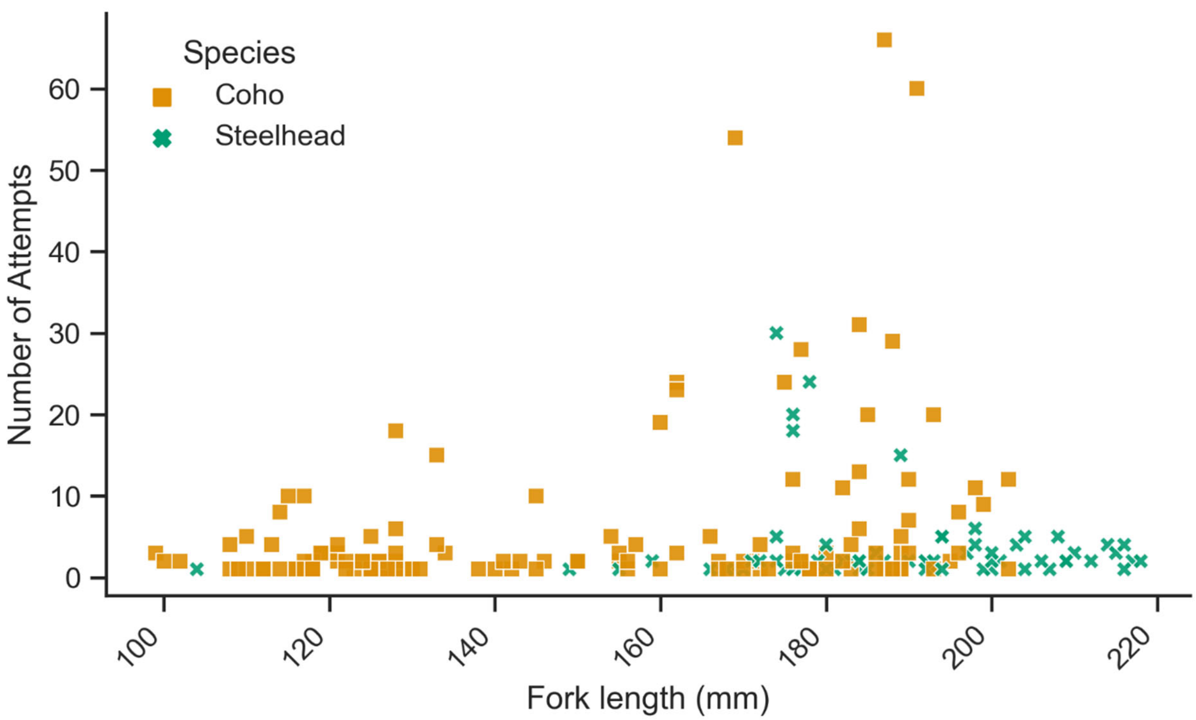
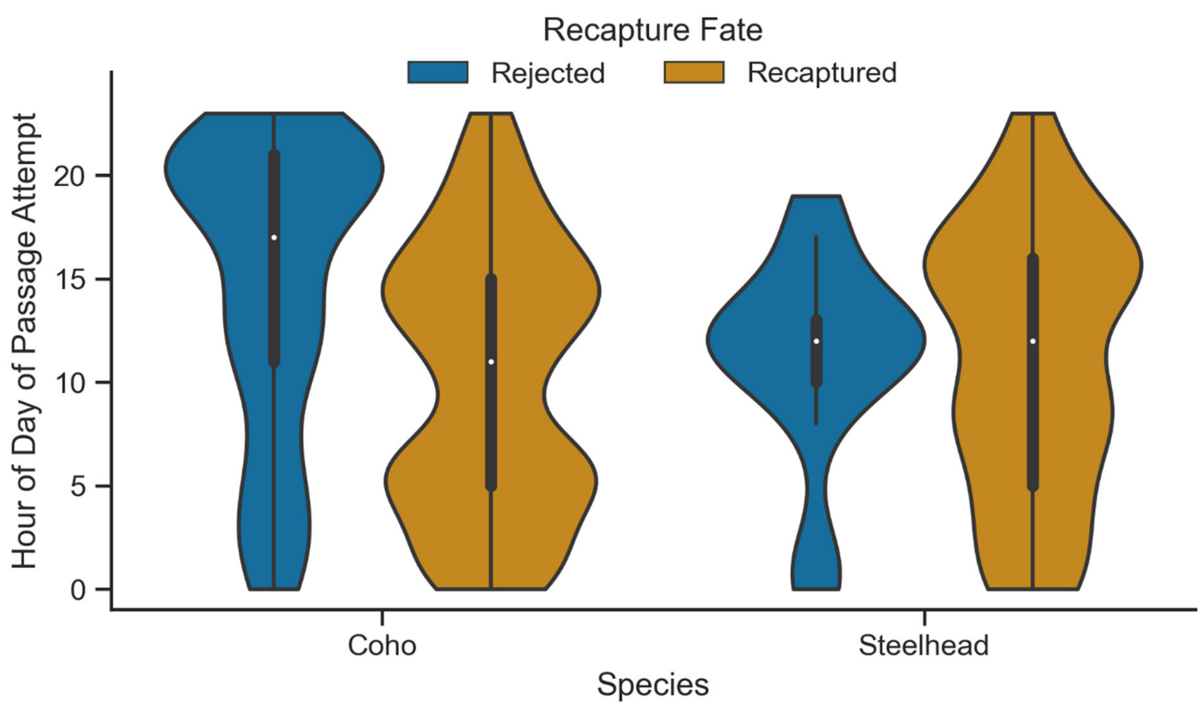


Figure 29. The number of passage attempts made by Coho Salmon and steelhead study fish across their range of observed lengths.

This model indicated that weir height at the time of an attempt was a factor in determining whether that attempt was successful for Coho Salmon but not for steelhead (Table 16). These model results appear to suggest that Coho Salmon made more successful passage attempts when the weir was at the high setting. As presented in Section 3.5.1.2, this result may be an artifact of run dynamics and varying representation of individual fish. Coho Salmon made more passage attempts when the weir was at the low setting, but these attempts were less successful. Thus, while similar numbers of Coho Salmon were collected under the different conditions, the success of each attempt differed. However, results from the blocked ANOVA model indicate that other, unmeasured factors that varied over time are more likely the causative factor underlying this apparent effect.

The date that individual fish attempted passage was a strong predictor of success for attempts made by both Coho Salmon and steelhead (Table 16). Attempts occurring later in the year had a lower probability of collection relative to those occurring earlier in the year. The time of day that fish initiated a passage attempt also strongly predicted the success of an attempt for both steelhead and Coho Salmon (Table 16). Both species initiated attempts throughout the day, but attempts initiated by steelhead during late afternoon and early evening hours were more successful than those initiated by steelhead near midday. Coho Salmon attempts initiated during early morning and mid-afternoon were more successful than those initiated during nighttime (Figure 30).



Note: See Figure 14 note for explanation of violin symbology.

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

4.1 Study Background, Goals, Objectives

Annual performance evaluation studies have been conducted at the Swift FSC since its deployment in 2012. Initial studies showed that most fish could not locate the Swift FSC. These early studies informed the following modifications in the forebay to help fish locate and enter the Swift FSC:

- 2016: Installing the lead net
- 2018: Reprogramming the sorting area flow pumps to reduce noise
- 2019: Installing a “false floor” in the NTS, adjusting primary screen baffles, operating additional attraction pumps within primary collection channel to increase attraction flow
- 2022: Discontinuing backwash screen-cleaning cycles, installing horizontal V-trap within secondary collection channel

In each Swift FSC Performance Evaluation Study conducted since 2019, at least 95% of study fish that were detected in the ZOI entered the Swift FSC (P_{ENT}), but collection efficiency (P_{CE}) has remained below the target of 95%. This is because rejection within the Swift FSC limits its collection efficiency. To identify the precise location of this rejection, studies conducted in 2020 and 2021 began focusing on the area of the Swift FSC between the entrance and the collection channel. The results of these studies indicated that many of the fish rejecting collection did so within the downstream portion of the secondary collection channel. This finding informed two adjustments made to the infrastructure and operations within the secondary collection channel, prior to the 2022 Study:

1) A periodic backwash cycle previously occurring within the secondary portion of the collection channel was eliminated.
   - This backwash had been implemented previously to clean the fish separation system located within the Swift FSC fish collection and sorting facility (Figure 1).
   - However, it was suspected of disrupting the area of capture velocity within the channel, allowing fish to escape the secondary collection channel.
   - Following improvements in debris management within the fish sorting and collection area of the Swift FSC, the backwash cycle was no longer needed.
2) A low-profile horizontal V-trap (Figure 5) was installed on the floor of the secondary collection channel.
   - The purpose of this V-trap was to stop fish from using the lower velocity water at the channel floor to swim back upstream and out of the downstream secondary collection channel.
   - PacifiCorp staff hypothesized that this V-trap would improve retention within this zone of the Swift FSC.

The 2022 Study focused on the secondary collection channel to evaluate the effect that these adjustments had on fish retention in that zone. Additionally, the 2022 Study evaluated the effects of experimentally varying the height of an adjustable control weir located at the downstream end of the secondary collection channel. This weir controls flow into the Swift FSC fish collection and sorting facility and thus velocity within the collection channel. As part of the 2022 Study, effects of environmental factors on fish behavior and collection efficiency also were evaluated, and sound measurements were collected to identify the source of a low-frequency sound suspected of influencing collection efficiency.

4.2 Core Metrics and Key Results

Both species exhibited very high (96%) Swift FSC entrance efficiency (P_{ENT}) in 2022. This is consistent with past studies that have occurred since 2019 and shows that the adjustments and modifications made to the Swift FSC and forebay environment to increase entrance efficiency continue to be effective. If all fish that entered the Swift FSC were retained, the collection efficiency target of 95% would be achieved.

After entering the Swift FSC, about two-thirds (64%) of Coho Salmon were retained (P_{RET}) in 2022, resulting in a collection efficiency (P_{CE}) of 62% for this species. This was a large improvement in retention compared to 2021, in which only 41% of Coho Salmon were retained and collection efficiency was 40%. It was also among the highest on record for this species: Coho Salmon retention and collection efficiency in 2022 was exceeded only nominally in 2019 when retention was 65% and collection efficiency was 64%. Retention and collection of steelhead in 2022 were 50% and 48%, respectively, which is identical to values observed in 2021. Although not markedly improved compared to 2021, steelhead collection efficiency in 2022 was still among the highest observed across all study years. Both species thus exhibited relatively high (among study years) collection efficiency in 2022, a result of Swift FSC retention that was among the highest observed.

The relatively high Swift FSC retention and collection in 2022 was largely a product of increased retention in the downstream secondary collection channel. Retention within this zone improved from 60% for Coho Salmon and 69% for steelhead in 2021 (the only prior study year to evaluate behaviors within this subzone) to 83% for both species in 2022. Three possible explanations have been considered for this increased retention/reduced rejection within the downstream secondary collection channel: cessation of the backwash cycle, installation of the V-trap, and experimental weir height operation.

Among these three factors, elimination of the backwash cycle appears to have the greatest support as the primary factor contributing to increased retention/reduced rejection within the downstream secondary collection channel. This inference is supported in part by process of elimination. Observations and analyses do not support the effectiveness of either the V-trap or the weir height manipulation in improving Swift FSC retention.

First, the V-trap appears not to have been entirely effective at preventing fish from escaping the secondary collection channel. PacifiCorp staff reported observing many fish moving back upstream over the V-trap (Chris Karchesky, personal communication, December 30, 2022). The apparent ineffectiveness of the V-trap may be a result of design. To ensure the trap could withstand the hydraulic forces present within the channel without interfering with downstream movement or introducing turbulence within the collection channel, the trap was intentionally designed to have a low profile (it is only 6 inches off the channel flooring at the highest point). This may have resulted in the fish not being forced to move high enough into the water column to experience the maximum velocities. A V-trap with more of a slope or longer tines may be needed to reduce upstream movement. This may not be possible. A larger V-trap would have more influence on the currents within the collection channel and would be more subject to hydraulic forces that may cause failure.

Second, results from the blocked weir height study indicated that periods when the weir was operated at different heights were associated with similar seasonal fish collection rates. Neither species exhibited significant differences in total collections between periods of differing weir height.

In contrast, there is evidence that eliminating the backwash cycle improved retention. This evidence comes in part from the historical record provided by previous years of evaluation. Debris loading was low during the 2019 study, which resulted in limited use of the backwash cycle. Conversely, debris loading was high during both the 2020 and 2021 studies, resulting in frequent operation of the periodic backwash cycle. Paralleling these differences in backwash operations, retention efficiency (P_{RET}) for Coho Salmon in 2019 was nearly identical to that measured in 2022 (Figure 3, Table 1). This suggests that the periodic backwash cycle may negatively affect retention rates in the downstream secondary collection channel and therefore overall collection rates. Steelhead retention in the downstream secondary collection channel also improved from 69% in 2021 to 83% in 2022.

This apparent effect of the backwash cycle is further supported by a plausible mechanism of action. The cleaning process associated with this backwash disrupts high-velocity capture flows within the downstream secondary collection channel. This disruption creates a temporary low-velocity pocket in the secondary collection channel that may allow fish to escape back upstream. Without this flow disruption (i.e., by eliminating this cleaning cycle), fish may have had fewer opportunities to escape the downstream secondary collection channel in 2022.

The most significant bottleneck to retention now appears to occur somewhere between the Swift FSC entrance and the upper end of the secondary collection channel. Due to the focus in 2022 on monitoring behaviors in the downstream secondary collection channel, it is unclear precisely where fish reject collection within this zone from the NTS through the primary collection channel. Information gained in the 2021 study identified the downstream NTS and primary collection channel as other possible bottlenecks, and this area warrants additional, focused monitoring in future studies (as discussed further in Section 4.3.2).

4.3 Additional Context, Caveats, Considerations, and Recommendations

4.3.1 Other Factors Contributing to Passage Success

Previous Swift FSC evaluations identified length as a factor that influenced whether individual fish were successfully recaptured, but this was not the case in 2022. The change is possibly a result of selectively tagging smaller fish in 2022 than in previous years. In 2022, tagging length was truncated at 220 mm. This was in response to observations of high mortality rates of larger steelhead during collection and tagging (potential reasons for which are discussed further in Section 4.3.2). This is evident in the length distribution comparisons (Figure 14) that show that steelhead study fish length distribution differed from previous study years. This was less evident in the distributions for Coho Salmon, but these fish are typically smaller than steelhead and thus their collection rates are less impacted by size.

Similar to the 2021 study (which was the only other study year in which environmental factors were monitored), environmental factors such as east wind, barometric pressure, and water temperature did not affect the success rate of individual passage attempts in 2022.

Noise monitoring conducted in 2021 detected a 22 Hz noise (which is in the range known to be detectable to salmonids) at the entrance of the Swift FSC, and this signal was still present during testing in 2022. This noise could not be isolated to a single location or piece of equipment in the dewatering channel and is likely an effect of the primary and secondary screen pumps' blade pass frequency (BPF). Noise generated by rotation of a pump impeller is produced at a frequency proportional to the BPF, as shown below in Eq. 1 (Lobanoff et al. 1992).

$$BPF = \frac{n \times t}{60} \quad \text{(Eq. 1)}$$

Where:

n = pump rotational velocity (rotations per minute [rpm])
t = number of impeller blades
60 = seconds per min

The Swift primary and secondary screen pumps are powered by a motor that spins three 30-inch blades at 435 rpm, producing a BPF of approximately 22 Hz.[3] Without specific behavioral testing, the degree to which this noise impacts fish passage at the Swift FSC is unknown. However, the 22 Hz noise is detectable at the entrance of the Swift FSC, and most fish that are detected in the ZOI enter the Swift FSC, indicating this noise does not elicit avoidance of the entrance zone. Still, their attempts may be delayed by the noise, or the noise may cause fish to hold station immediately within the entrance (e.g., in the NTS) without moving further into the collection channel. To adjust the frequency of the emergent noise, fans within these pumps could be replaced with alternatives that have more blades. The feasibility of this retrofit has not been explored.

4.3.2 Methodology

The receiver array employed in 2022 focused efforts within the secondary collection channel, prioritizing high spatial precision of detections in this zone over the areas between the entrance to the Swift FSC and the downstream secondary collection channel. After the 2021 study, it was determined that fish were turning around at three locations within the channel: (1) between the NTS and the primary collection channel; (2) between the primary and the secondary collection channels, and (3) within the downstream secondary collection channel, immediately before collection. The third of these locations, within the downstream secondary collection channel, was the location of the greatest rejection. Because of this, the 2022 Study focused on the downstream secondary collection channel and did not partition fish positions between the NTS and the primary collection channel. Instead, this upstream region of the Swift FSC was treated as a single zone (the entrance, ENT). While this design allowed for focus on the downstream secondary collection channel, it constrained comparisons of the other passage bottlenecks identified in 2021 with results from 2022. It is recommended that future studies allocate adequate receiver coverage to ensure these areas are monitored with as much precision as possible, at the expense of precision within the secondary collection channel if necessary.

The approach for computing core metrics in the 2022 Study was identical to approaches employed in past studies. Time series of inferred positions were compiled for each fish and then summarized across the study season to provide a comprehensive (seasonally pooled) estimate of collection efficiency (P_{CE}) within a mark-recapture framework. Pooling fish positions over time for seasonal estimation is supported by the fact that the study period encompasses the peak outmigration period for each study

[3] $\frac{435 \times 3}{60} = 21.75$

species within the Swift Reservoir. This accords with the M&E Plan, which states, “Collection efficiency [P_{CE}] will be quantified during the expected peak migration period(s) for each transport species. Historically this period occurs from March through June annually for all transport species” (PacifiCorp and Cowlitz County PUD 2022).

The 2022 Study also presents a stratified series of collection efficiency (P_{CE}) estimates by release group and by month. The purpose of presenting these stratified estimates is to address concerns regarding the pooled estimator that has been relied upon previously, and which constitutes the foundation of the core performance metrics provided in this report. The M&E Plan states that this pooled estimator may be biased high, and thus, “A stratified estimator will also be used to calculate [P_{CE}] *when the estimate’s upper confidence interval approaches the performance goal* [emphasis added], to give further confidence that the performance goal is actually being attained” (PacifiCorp and Cowlitz County PUD 2022). All Swift FSC Passage Evaluation Studies to date have reported collection efficiency values with confidence intervals that do not approach the 95% target. Nonetheless, stratified estimate series have been developed for 2022. These series indicate limited change over time in collection efficiency and are closely aligned with full season estimates.

Although the tagging approach used in 2022 was generally consistent with previous years, two differences should be noted between the methodology employed in 2022 and those in previous years. First, juvenile Chinook Salmon were not tagged during 2022, because numbers of out-migrating juvenile Chinook Salmon were predicted to be low, as occurred during 2021, which resulted in low confidence in the results for Chinook Salmon in that year. Second, only steelhead that were shorter than 220 mm or smaller were tagged in 2022, due to high mortality rates of larger steelhead observed during pre-tag holding. Higher mortality rates may have been a result of those larger fish exceeding the optimum size window for physiological adaptations associated with smoltification (reviewed in Wedemeyer et al. 1980) and, thus, experiencing proportionally greater stress from capture. This second methodological change means that analyses including an evaluation of the effect of size on steelhead passage from 2022 may not be directly comparable to results from previous years.

4.3.3 Precision of Estimates

Confidence in the collection metrics reported above is high. This high confidence is the combined effect of appropriate sample sizes to provide margins of error that were close to the target of 6% and accurate positioning algorithms. These positioning algorithms provided efficient positioning within zones that are critical for computing core metrics. Consequently, very few fish were missed within the ZOI and entrance zones. This means that metrics summarizing Swift FSC performance in terms of entrance efficiency (P_{ENT}) and collection efficiency (P_{CE}) are estimated with a high degree of precision, as they do not rely on substantial “expansions” of actual counts of detected fish.

4.4 Conclusions

- Almost all Coho Salmon and steelhead detected in the ZOI enter the Swift FSC (96% for each).
- Retention and collection efficiency of both Coho Salmon and steelhead in 2022 were among the highest observed during all previous studies.
- Improved collection efficiency was the result of reduced rejection in the downstream secondary collection channel.
- The most significant bottleneck to retention now appears to occur between the Swift FSC entrance and the upstream secondary collection channel.

- Weir height did not affect retention or collection for either species but may have affected passage attempt rate differentially for each.
- Noise monitoring indicated that the 22 Hz signal remains and is likely an artifact of the number of blades and operating speed of the primary and secondary screen pumps.

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APPENDIX A Detailed Study Methods

A.1 Acoustic Telemetry Array

Overview

From March 14 to 18, 2022, Four Peaks Environmental Science & Data Solutions (Four Peaks) staff installed an acoustic telemetry array comprising 19 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 (2022 Swift Reservoir Floating Surface Collector Passage Evaluation [2022 Study] Figure 10). The 19 receivers covered four zones: the forebay (FBY), the zone of influence (ZOI), the entrance (ENT), consisting of the net transition structure and the primary channel, and the secondary collection channel (CCHS), with the secondary channel further divided into upstream (CCHS-U) and downstream (CCHS-D) sections. Each of these zones was monitored with a subarray of receivers: four autonomous receivers in the FBY, three autonomous and one cabled receiver in the ZOI, two cabled receivers in the ENT, six 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	Autonomous SR3001	30
ZOI	ZOI-02	Autonomous SR3001	30
ZOI	ZOI-03	Autonomous SR3001	30
ZOI	ZOI-04	Cabled SR3017	10
ENT	ENT-01	Cabled SR3017	6
ENT	ENT-02	Cabled SR3017	6
Secondary Channel (Upstream)	CCH-01	Cabled SR3017	7
Secondary Channel (Upstream)	CCH-02	Cabled SR3017	4
Secondary Channel (Upstream)	CCH-03	Cabled SR3017	5
Secondary Channel (Upstream)	CCH-04	Cabled SR3017	3.75
Secondary Channel (Upstream)	CCH-05	Cabled SR3017	2
Secondary Channel (Upstream)	CCH-06	Cabled SR3017	2
Secondary Channel (Downstream)	CCH-07	Cabled SR3017	2
Secondary Channel (Downstream)	CCH-08	Cabled SR3017	2

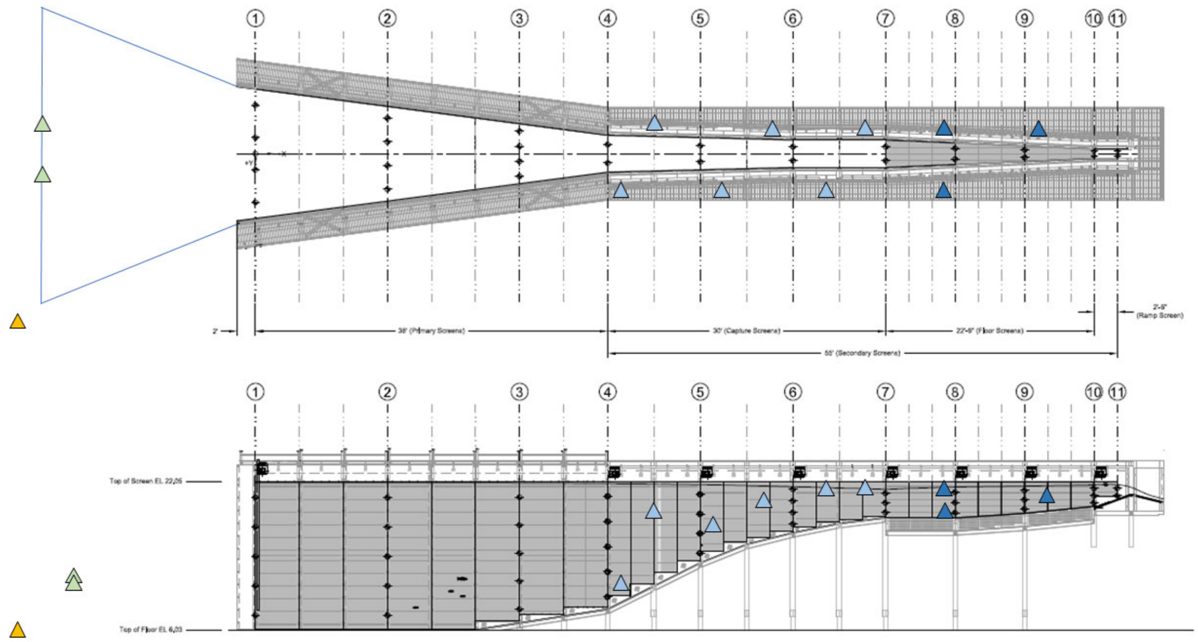
Zone	Receiver ID	Receiver Model	Approximate Hydrophone Depth (ft)
Secondary Channel (Downstream)	CCH-09	Cabled SR3017	2
Recovery Tank	FSC Transfer Tank	Modified Mobile SR3000	*Not Applicable*

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, and results during the 2021 study identified the transition from the secondary channel to collection as having the largest proportion of rejected individuals (Four Peaks 2022). Consequently, the acoustic array for the 2022 Study was designed to maintain focus on the secondary channel while accommodating a lower number of acoustic receivers distributed in the NTS and the primary channel. This allowed for an analysis that used a consistent array design for the area of interest, while providing coarser spatial resolution in the NTS and primary channel.

Secondary Collection Channel Subarrays

An array of 11 shore-based hydrophones cabled directly to acoustic receivers (Advanced Telemetry Systems [ATS] SR3017 Trident) was designed to provide comprehensive coverage of the entrance and channel with minimal exposure to noise and minimal prominence within the channel (Appendix Figure A.1). The collection channel array was designed to concentrate the highest detection efficiency in the secondary collection channel, while providing a coarser positioning of fish in the NTS and the primary channel (collectively, the "entrance") that indicated presence or absence. The design for the receivers in the secondary collection channel was identical to the design for the 2021 Study (Four Peaks 2022), and as such provided consistency which could be used to improve positioning algorithms initially developed in that study. Six receivers were deployed in the upstream secondary channel at depths ranging from 2 to 7 feet, while three receivers were deployed in the downstream secondary channel at 2 feet depth (Appendix Table A.1).



The net transition structure is shown with blue lines in the top plan view, and approximate locations of hydrophones are shown as triangles. Receiver positions are indicated with triangles, with colors corresponding to zones listed in Figure 10 of 2022 Study.

Appendix Figure A.1. Swift floating surface collector schematic diagram, showing plan view (top) and longitudinal cross-section (bottom) of the collection channel.

Deployment of hydrophones in the high-velocity, acoustically challenging aquatic environment of the secondary collection channel required careful consideration to achieve acceptable detection efficiency while minimizing the impact of equipment on fish passage and operations. Deploying hydrophones and their mounts directly within the channel would reduce the detection ranges for these receivers and could affect fish movement or otherwise negatively influence retention and collection efficiency. To avoid these issues, hydrophones were placed on the sides of the channel, behind the dewatering screens (Appendix Figure A.1). 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.

Appendix Figure A.2. Deployment of a collection channel hydrophone and mount showing the location behind the dewatering screens on the collection channel platform where hydrophones were placed. Photo is from 2021 deployment.

Specifically, 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 secondary channel were designed to meet the narrow gap tolerance between the wedge wire dewatering screens and the perforated plates along the walls of the 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 (Appendix Figure A.3). The hydrophone cable was then routed to deck level and attached in position to avoid contact with the screen cleaning assembly.

Entrance and Zone of Influence

To detect tagged fish as they transition from the ZOI into the collection channel by way of the NTS and primary channel, two additional SR3017 Trident receivers were deployed towards the front of the NTS (one port, one starboard). 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. These mounts oriented the receivers downstream towards the collector, in order to detect individuals as they transitioned from the ZOI into the entrance.

Appendix Figure A.3. Cabled hydrophone and pipe mount. Photo is from 2021 deployment.

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 with one cabled (SR3017 Trident receivers) and one autonomous (SR3001 Trident receivers). 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 each autonomous and 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. Photo is from 2021 deployment.

Appendix Figure A.5. ATS reference beacons attached to steel pipe for array deployments. Photo is from 2021 deployment.

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 at 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.6**,** 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	G727DAA4E	30	On receiver
FBY-03	G721F3EF5	30	On receiver
FBY-04	G721F27F4	30	On receiver
ZOI-01	G727DA9AC	30	On receiver
ZOI-02	G727DADCD	30	On receiver
ZOI-03	G721F2077	30	On receiver
ZOI-04	G727DB1F3	10	On receiver
ENT-01	G721F1BE9	6	On receiver
ENT-02	G721F14A8	6	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 entrance and 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 secondary channel.

Appendix Table A.3. Receiver array testing schedule.

Zone	Type	Dates	Notes
ENT and CCHS	Static	3/17/22	Conducted during array deployment.
FBY and ZOI	Static/Drag	3/17/22	Conducted during array deployment.
ENT and CCHS	Drag	3/18/22	Conducted during array deployment.
ENT and CCHS	Drag	5/6/22	Conducted during array deployment.

Appendix Figure A.6. Bottom portion of test tag stringer, showing two tags, stringer cord, and weight. Photo is from 2021 deployment.

Drags and Holds

Field testing included a series of tag drags, floats, and holds, using four 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

Appendix Figure A.7. Deploying test stringer by hand within the floating surface collector collection channel. Photos are from 2021 deployment.

of all receivers and test for detection efficiency and deployment positioning effectiveness.

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, entrance, and secondary 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; 2022 Study Table 3) 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 for each receiver using a series of automated diagnostics that were performed immediately after each receiver download (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 number 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

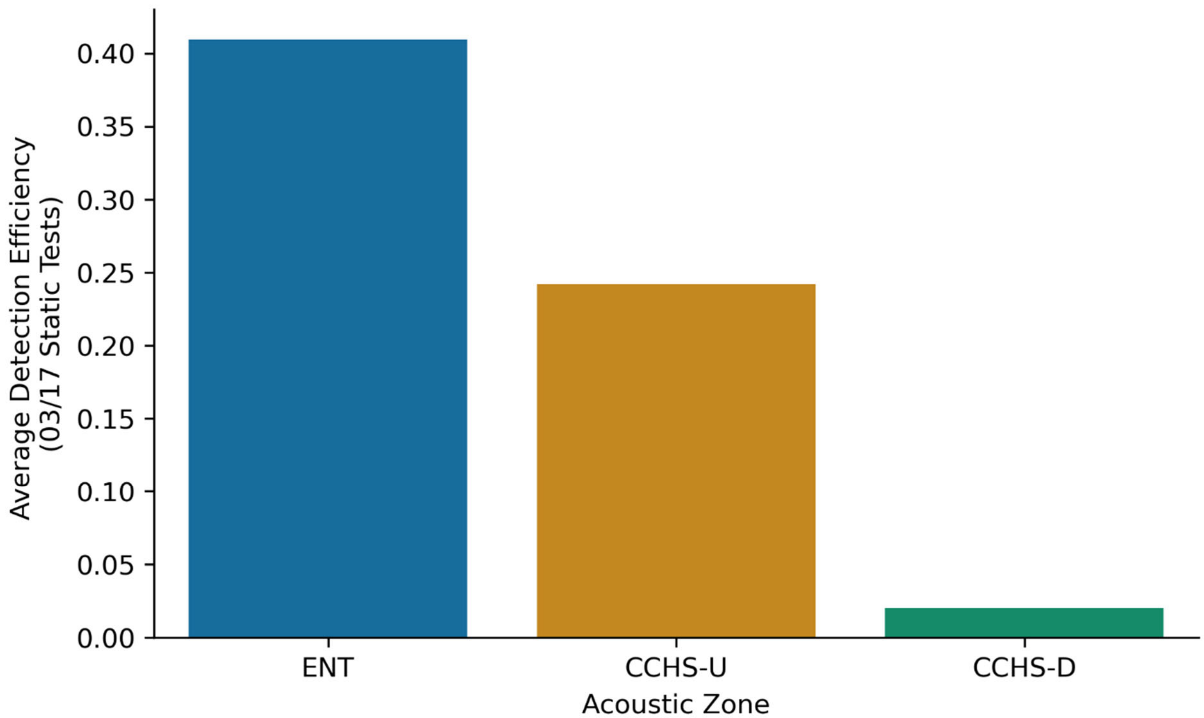
Pre-season array testing confirmed that the receivers were functioning properly and were detecting tags at acceptable ranges, providing ample detection ability for each zone. Results for the forebay, ZOI, entrance, and secondary collection channel subarrays are discussed in the following subsections.

Forebay and Zone of Influence

On March 17, 2022, a series of tests were conducted that involved a stringer of test tags at various depths (approximately 1-5 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 sufficient 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.

Entrance and Secondary Collection Channel

Test results in the entrance and secondary collection channel suggested that the receivers within each zone were able to effectively detect individual tags moving through the entrance and secondary channel. Appendix Figure A.8 depicts average detection efficiency during one static test on March 17, 2022, in the entrance and collection channel. Average detection efficiency for a single static test within the channel across a range of tags at different depths is shown in Appendix Figure A.8. Depths ranged from 1 to 5 feet, and tests lasted a little under 1 minute in each zone. Detection efficiency on the individual test scale ranged from 41% in the entrance to 2% in the downstream (Appendix Figure A.8). Similar to 2021, detection efficiency in the downstream secondary channel was compromised by high flows and operational noise, relative to other locations in the channel. However, 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 March 17, 2022. 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 on the acoustic receivers as detections of random tag codes (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 entrance 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 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 analyzed to position fish within a given zone along the approach to collection (i.e., to determine “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 entrance 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 during the 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, 2022 Study Table 3), and then ordering them chronologically to provide an understanding of where an individual is in the array. The sequence in which a single ping is detected allows estimation of the position of an individual within the acoustic array.

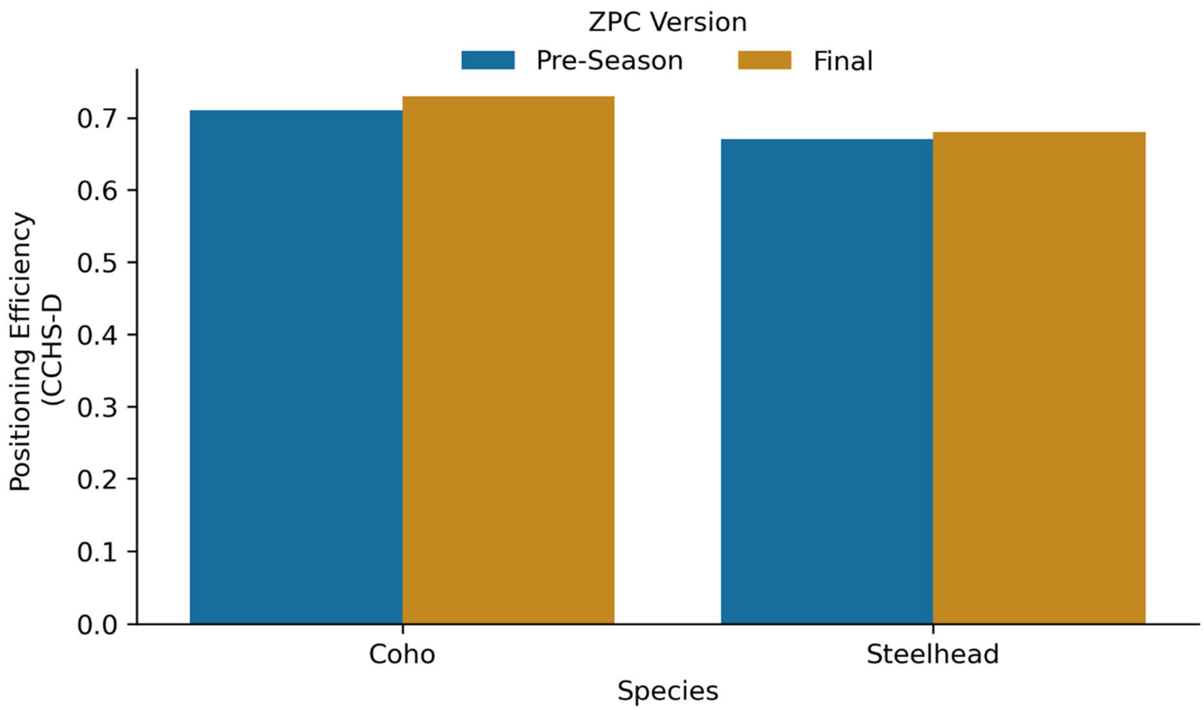
TOAD analyses for each tag were used in conjunction with other criteria to construct a presence-absence matrix across the entire array and throughout the study period. The final set of criteria included TOAD comparisons between each zone to independently position fish within five zones: the forebay,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

ZPC were initially constructed by optimizing the balance of 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:
  - First detected on either ZOI-01, ZOI-02, ZOI-03, or ZOI-04

- An individual was considered within the entrance if there was at least one ping satisfying one of the following criteria:
  - Detected on at least two receivers from the set ENT-01, ENT-02 and ZOI-04 with previous and subsequent detections 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-01, CCH-02, CCH-03, CCH-04, CCH-05 or CCH-06 with an amplitude of 210 or greater
- An individual was considered within the downstream secondary channel if there was at least one ping satisfying one of the following criteria:
  - Detected on either CCH-06, CCH-07, CCH-08, or CCH-09 with an amplitude of 183 or greater with subsequent detections on any other receiver

Initial ZPC for the secondary downstream channel established during array testing struggled to position fish in-season (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, similar to conditions experienced in this zone during the 2021 Study. 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 73% of all collected Coho and 68% of all collected steelhead (2022 Study Table 11; Appendix Figure A.9).



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

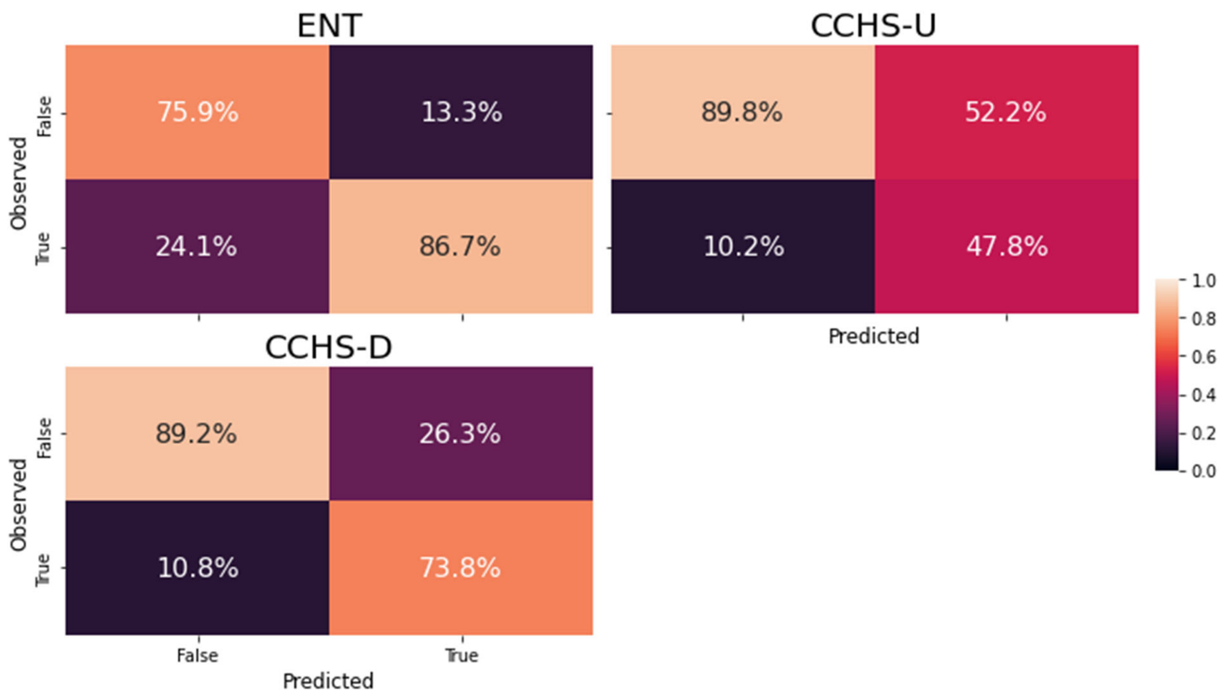
Within the secondary collection channel, ZPC were not mutually exclusive. Consequently, there were instances where individual pings could be assigned to both the upstream and downstream secondary channel.[4] In these instances, pings were resolved to the upstream secondary channel, and were only resolved to the downstream secondary channel when that was the only zone that met the ZPC. For all zones outside the secondary channel, 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, entrance, and secondary 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

[4] A ping that was first detected on CCH-06 with an amplitude of 210 or greater, then subsequently detected on either CCH-06, CCH-07, CCH-08, or CCH-09 would meet the ZPC criteria for both the upstream and downstream secondary collection channel.

the zone (lower right quadrant, true positives). Updates to ZPC were focused on optimizing the balance between false negatives and false positives by maximizing the true positive rate (sensitivity) while maintaining a true negative rate (specificity) that was still as high as possible without negatively affecting the true positive rate. Refinement and evaluation of ZPC on a select subset of pre-season drag tests in the entrance and secondary collection channel allowed for a set of ZPC that had 75-90% specificity rates for all subzones, but lower sensitivity rates ranging from 48% in the upstream secondary channel to 87% in the entrance (Appendix Figure A.10). Initial sensitivity rates for the secondary channel (based on pre-season testing) were lower relative to those in the 2021 Study. However, in-season comparisons between counts of fish positioned in each zone and counts of study fish confirmed to have been collected indicated that the corresponding ZPC were actually under-positioning fish in the secondary collection channel (i.e., specificity was too high).



Appendix Figure A.10. Sets of confusion matrices for pre-season zone presence criteria developed from March 18, 2022, drag testing. Zones depicted are the entrance (ENT), upstream secondary channel (CCHS-U), and downstream secondary channel (CCHS-D). Colors indicate the rate depicted in each quadrant, with the quadrant meanings explained in the section above. Only a single drag is represented here, and thus plots are not representative of season-side zone positioning accuracy rates.

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

After initial receiver deployment during the week of March 16, 2022, data were downloaded from all receivers, generally following a bi-weekly schedule (Appendix Table A.4). This schedule was partly dependent on weather, boat availability, and unanticipated receiver maintenance requirements. During deployment, four receivers experienced equipment issues which prevented them from immediately recording acoustic detections: ZOI-01, ZOI-04, CCH-02, and CCH-03. ZOI-01 had faulty cabling attaching the battery to the processing unit, causing the receiver to lose power. ZOI-04 had was deployed without a battery cable due to a lack of cables being supplied during the initial deployment. Both cables were replaced on April 19. CCH-02 and CCH-03 experienced firmware errors upon initial configuration and were determined to be unfit for deployment. Both receiver units were replaced on April 20. These adjustments to the receiver array occurred prior to the first release of acoustic tags on April 20, and as such did not impact detection efficiency of the array during the study (Appendix Table A.4).

After deployment, acoustic data loss occurred on four instances. The first occurred on April 26, when the firmware on receiver NTS-01 caused the receiver clock to drift substantially and corrupt a portion of the detection data between April 19 and April 26 that were omitted from the analysis. The hydrophone for this receiver was replaced on April 26, and the receiver processor was power-cycled to correct the issue. On May 4, the SD card holder on FBY-03 appeared to have prematurely ejected the SD card, and thus fail to record detections from the processing unit. As such, there was no data from this receiver between April 19 and May 4. The SD card was replaced during servicing. On May 23, the SD card on CCH-08 appeared to be corrupted. The data were attempted to be recovered using an HXD cable to download directly off the receiver, but this procedure was not successful, and data were lost on this unit between April 17 and April 23. A new SD card was deployed on April 23. Finally, on June 17, the SD card holder on receiver CCH-01 snapped, which caused the SD card to be prematurely ejected, and thus fail to record detections from the processing unit. As such, there was no data from this receiver between June 10 and June 17. Due to this issue occurring well into the passage season, there was no opportunity to return this receiver to the manufacturer for repair. However, the field team was able to patch the SD card reader to be secure and this fix was functional for the remainder of the season. The SD card was also corrupted on receivers CCH-02 and CCH-06 during the June 17 download, and on CCH-08 during the July 29 download, but the data were fully recovered during these instances using the HXD cable to download directly from the 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
03/18	Deployment, Array Testing, and Receiver Download	Deployment took place from 03/14 to 03/18.
04/19	Array Adjustment; Receiver Download	Receiver download prior to first study fish release for diagnostics. Forebay receivers downloaded. Cables on ZOI-01 and ZOI-04 replaced.
04/20	Array Adjustment; Study Fish Release	Array adjustment occurred prior to study fish release. Receivers CCH-02 and CCH-03 replaced.
04/26	Receiver Download	Clock drift on NTS-01; hydrophone replaced and receiver serviced.
04/27	Study Fish Release	
05/03	Study Fish Release	
05/04	Receiver Download	Forebay receivers downloaded. SD card failure on FBY-03, data absent.
05/05	Study Fish Release	
05/06	Array Testing	
05/10	Study Fish Release	
05/11	Receiver Download	
05/17	Receiver Download	
05/18	Study Fish Release	

Date	Event	Notes
05/23	Receiver Download	SD card failure on CCH-08, data absent.
05/25	Study Fish Release	
05/31	Receiver Download	Forebay receivers downloaded.
06/01	Study Fish Release	
06/10	Receiver Download	
06/17	Receiver Download	SD card failure on CCH-01, data absent.
06/29	Receiver Download	Forebay receivers downloaded.
07/18	Receiver Download; Demobilization	Forebay receivers downloaded.

A.7 Performance Metrics Computation

Survival and detection probabilities were estimated concurrently within a multinomial mark-recapture framework. In this framework, 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:

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

We note that assumption (1) is required 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:

10. Between the release location and the forebay (p_{PASS})
11. Between forebay and the ZOI (p_{ENC})
12. Between the ZOI and the entrance (p_{ENT})
13. Between the entrance and the secondary collection channel ($p_{SECCHAN}$)
14. Between the secondary collection channel and the collector (p_{CAP})

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 (2022 Study Table 5). For the secondary channel, presence in the subzones was used to indicate presence in the entire zone; that is, an individual was considered present in the secondary channel if it was present in either the upstream or downstream secondary channel. The presence-absence matrix was used to inform mark-recapture models across all seven zones, including release and collection, is provided in APPENDIX B.

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

$$p_{CE} = p_{ENT} \cdot p_{SECCHAN} \cdot p_{CAP}$$

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

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

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

$$p_{RET} = p_{SECCHAN} \cdot p_{CAP}$$

with the associated variance term:

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

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.

A.8 Environmental and Operational Monitoring

Weather Station

On March 17, 2022, 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. The temperature logger deployed at the 10-foot depth failed during May 2022, and data were not collected from that logger from June onward.

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.

A.9 Statistical Modeling and Analysis Methods

Weir Height Analysis

Data collected during the weir height study were analyzed using a systematic block design (Myers et al. 2010). Periods of each treatment (i.e., LOW treatment or HIGH treatment) were paired sequentially to produce nineteen 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.

Two different responses were considered for the experiment: proportion of fish successfully collected and proportion of successful 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. Unlike in 2021, the number of total attempts was not analyzed, as the impact of the weir height setting was presumed to be confined to the collection channel and thus not affect the rate at which fish in the ZOI attempted to pass.

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 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. 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 (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 Salmon 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 2022 Study Table 66. 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 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:

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

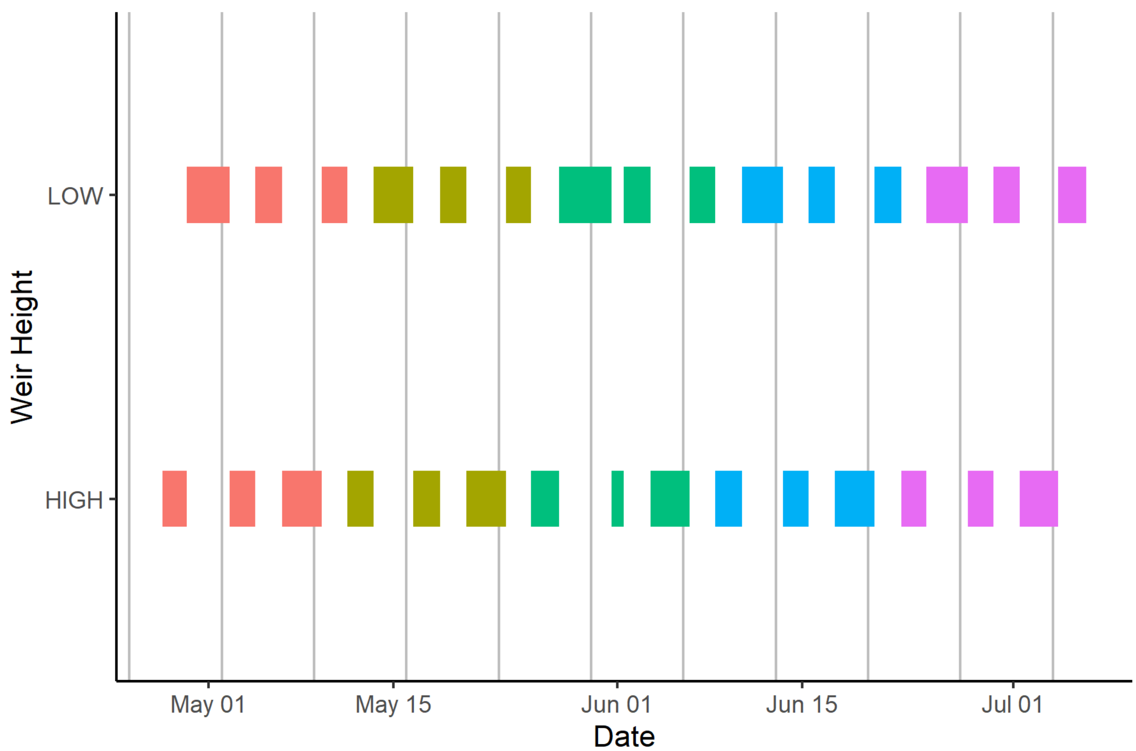
where Δ_i is the difference in AICc value from model i and the model with the lowest AICc value, and R is the total number of models in the set. To evaluate the importance of covariates, relative variable importance was calculated by summing the w_i of all models where the covariate was included. Fitted 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).

A.10 Statistical Modeling and Analysis Results

Weir Height Analysis

To ensure there were no issues of quasi-separation in the data for successful collections, blocks were aggregated over time to allow for instances of success and failures in each of the groups analyzed. This ensured that a single block of data that didn't have collections wasn't used to conflate an effect of weir height. Separation of the data can cause infinite estimates of regression coefficients and lead to artificially significant results (Ali Mansournia et al. 2018). As such, blocks were aggregated into five groups containing six blocking periods each, three for each treatment group, for the full period of analysis (

Appendix Figure A.11). This made an effective sample size of n = 5 blocks of fairly equal sample size to create a more balanced design across the study period.



Appendix Figure A.11. Groups of weir height treatment by date for the weir height study. Individual treatment blocks (see Figure 12 of main 2022 Report) were aggregated into five groups of six individual blocks, with the five groups shown in different colors above. Three replicates within each treatment were present in each group.

Tests of the proportion of fish successfully collected found no significant effect of block for either species (Coho Salmon: $X_3^2 = 0.2, p = 0.97$; steelhead: $X_3^2 = 5.6, p = 0.13$). Similarly, the effect of treatment was not significant for either species (Coho Salmon: $X_1^2 = 2.0, p = 0.16$; steelhead: $X_1^2 = 0.0, p = 0.95$). The interaction between block and treatment was also insignificant for both species. Tests of the proportion of successful attempts indicated that the effect of block was significant for both species (Coho Salmon: $X_3^2 = 14.6, p = 0.002$; steelhead: $X_3^2 = 12.0, p = 0.007$). At the passage attempt level, there was no significant effect of weir height treatment on passage success for either species (Coho Salmon: $X_1^2 = 2.39, p = 0.12$; steelhead: $X_1^2 = 0.24, p = 0.62$), and there was no significant interaction with weir height with the periodic blocking variable (Coho Salmon: $X_3^2 = 3.81, p = 0.28$; steelhead: $X_3^2 = 1.84, p = 0.40$).

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 Coho Salmon.

					Intercept		Length	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**
1	2	117.97	0.00	0.54	1.73	0.25	-0.38	0.25
2	1	118.39	0.43	0.44	1.68	0.24		

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

					Intercept		Length	
Rank	***K***	**AICc**	**Δ**	***w***	**Estimate**	**SE**	**Estimate**	**SE**
1	1	62.25	0.00	0.57	1.65	0.33		
2	2	62.93	0.68	0.41	1.71	0.35	-0.45	0.40

Passage Attempts Models

Appendix Table A.7. Estimated coefficients for top logistic regression models of the probability that an attempt was successful for Coho Salmon.

					Intercept		Attempt DOY		Attempt Time (cos)		Attempt Time (sin)		Length		Weir Height (LOW)	Temperature		Light		Pressure		Wind	
Rank	*K*	AICc	Δ	*w*	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Sign	Est.	SE	Est.	SE	Est.	SE	Est.	SE
1	6	555.5	0.00	0.22	-2.38	0.17	-0.07	0.11	1.08	0.18	0.27	0.16	-0.64	0.11	+								
2	6	555.8	0.32	0.19	-2.38	0.18			1.09	0.18	0.27	0.16	-0.63	0.11	+	-0.02	0.12						
3	7	556.6	1.07	0.13	-2.38	0.18	-0.05	0.12	1.31	0.30	0.32	0.17	-0.64	0.11	+			0.22	0.23				
4	7	556.7	1.22	0.12	-2.38	0.18			1.33	0.30	0.32	0.17	-0.63	0.11	+	-0.01	0.12	0.24	0.22				
5	7	557.3	1.73	0.09	-2.36	0.18	-0.06	0.11	1.08	0.18	0.27	0.16	-0.65	0.11	+					-0.07	0.12		
6	7	557.4	1.85	0.09	-2.38	0.18	-0.13	0.18	1.08	0.18	0.28	0.16	-0.64	0.11	+	0.08	0.19						
7	7	557.4	1.91	0.08	-2.36	0.18			1.08	0.18	0.27	0.16	-0.65	0.11	+	-0.04	0.12			-0.08	0.12		
8	7	557.5	1.95	0.08	-2.39	0.18	-0.08	0.12	1.08	0.18	0.27	0.16	-0.65	0.11	+							-0.03	0.11

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

					Intercept		Attempt DOY		Attempt Time (cos)		Attempt Time (sin)		Length		Weir Height (LOW)	Temperature		Light		Pressure		Wind	
Rank	*K*	AICc	Δ	*w*	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Sign	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
1	4	243.39	0.00	0.25	-1.15	0.17	-0.44	0.20	0.99	0.24	0.21	0.24											
2	5	244.13	0.74	0.17	-1.16	0.17	-0.51	0.22	1.03	0.24	0.20	0.24	-0.19	0.16									
3	4	244.39	1.01	0.15	-1.12	0.16			1.13	0.23	0.16	0.23				-0.36	0.18						
4	5	244.70	1.31	0.13	-1.10	0.18	-0.45	0.20	1.25	0.39	0.26	0.24						0.25	0.28				
5	5	244.90	1.51	0.12	-1.16	0.17	-0.43	0.20	1.03	0.24	0.18	0.24								0.12	0.15		
6	5	245.22	1.83	0.10	-1.26	0.27	-0.46	0.21	1.00	0.24	0.24	0.25			+								
7	5	245.38	1.99	0.09	-1.12	0.16			1.19	0.24	0.15	0.23	-0.17	0.16		-0.40	0.19						

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APPENDIX B Zonal Presence-Absence Matrix Zonal Presence-Absence Matrix

The following table provides a presence-absence matrix of the 408 acoustically-tagged individuals used to inform collection efficiency metrics 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 B.1. Presence-absence matrix of all study tags released in the 2022 Swift Reservoir Floating Surface Collector Passage Evaluation.

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	00F7	3DD.003E218315	04/27/2022 12:00	0	0	0	0	0	0	
Steelhead	013A	3DD.003E218311	04/20/2022 12:00	1	1	1	1	0	1	04/27/2022 04:52
Coho	027B	3DD.003E21831C	04/20/2022 12:00	0	0	0	0	0	0	
Coho	029D	3DD.003E21830C	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	03F4	3DD.003E2182FD	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	040D	3DD.003E218255	05/03/2022 12:00	1	1	1	1	1	1	05/06/2022 19:40
Steelhead	041D	3DD.003E21812C	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	04D7	3DD.003E2182C6	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	05FE	3DD.003E218304	04/27/2022 12:00	1	1	1	1	1	1	05/21/2022 04:19
Steelhead	080E	3DD.003E2182F6	04/27/2022 12:00	0	0	0	0	0	0	
Coho	08F9	3DD.003E21812F	05/10/2022 11:00	1	1	1	1	0	0	
Steelhead	0A65	3DD.003E218216	05/03/2022 12:00	1	1	1	0	0	0	
Coho	0AE5	3DD.003E218253	05/03/2022 12:00	1	1	1	1	1	1	05/08/2022 00:52
Steelhead	0AEA	3DD.003E218209	05/03/2022 12:00	1	1	1	1	1	1	05/17/2022 10:35
Steelhead	0B0E	3DD.003E2181BE	05/05/2022 10:30	1	1	1	0	0	0	
Steelhead	0B37	3DD.003E218224	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	0CA9	3DD.003E21812B	05/10/2022 11:00	0	0	0	0	0	0	
Coho	0D30	3DD.003E2182CE	04/20/2022 12:00	1	1	1	1	0	1	05/30/2022 05:36
Coho	0D49	3DD.003E2180F5	05/10/2022 11:00	0	0	0	0	0	0	
Coho	0D55	3DD.003E218132	05/10/2022 11:00	1	1	1	1	0	1	05/22/2022 14:34
Coho	0E7A	3DD.003E218244	05/03/2022 12:00	0	0	0	0	0	0	
Coho	0F20	3DD.003E21823B	05/03/2022 12:00	1	1	1	1	0	1	05/28/2022 02:04
Steelhead	0F4A	3DD.003E218227	05/03/2022 12:00	1	1	1	0	0	0	
Coho	0F8E	3DD.003E21831D	05/03/2022 12:00	1	1	0	0	0	0	
Coho	0FE2	3DD.003E2182EC	04/20/2022 12:00	1	0	0	0	0	0	
Coho	1060	3DD.003E2180F1	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 05:19
Steelhead	10B1	3DD.003E2181D5	05/03/2022 12:00	1	1	1	1	1	1	05/26/2022 01:48

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	10FC	3DD.003E218317	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	1255	3DD.003E2182F0	04/27/2022 12:00	0	0	0	0	0	0	
Coho	126D	3DD.003E2181A7	05/10/2022 11:00	1	1	1	1	0	1	05/29/2022 03:32
Steelhead	1389	3DD.003E218327	04/20/2022 12:00	1	1	1	1	1	1	05/10/2022 08:02
Steelhead	13C6	3DD.003E218228	05/03/2022 12:00	1	1	1	0	0	0	
Coho	144F	3DD.003E218112	05/10/2022 11:00	1	1	1	1	1	1	06/06/2022 19:10
Coho	1506	3DD.003E2180E6	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	1550	3DD.003E218207	05/03/2022 12:00	1	1	1	1	1	0	
Steelhead	166E	3DD.003E2181E5	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	16AB	3DD.003E21824A	05/03/2022 12:00	1	1	0	0	0	0	
Steelhead	16AD	3DD.003E21822E	05/03/2022 12:00	1	1	1	0	0	1	06/09/2022 02:56
Steelhead	16F9	3DD.003E21823C	05/03/2022 12:00	1	1	0	0	0	0	
Coho	189D	3DD.003E218312	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	1990	3DD.003E21819B	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	1997	3DD.003E2181C7	05/05/2022 10:30	0	0	0	0	0	0	
Coho	1A06	3DD.003E2180FC	05/10/2022 11:00	1	1	0	0	0	0	
Coho	1A92	3DD.003E218234	05/03/2022 12:00	1	1	1	1	1	1	05/18/2022 02:21
Steelhead	1AC9	3DD.003E2182D7	04/27/2022 12:00	1	1	1	1	1	1	05/11/2022 07:21
Steelhead	1C4B	3DD.003E218303	04/27/2022 12:00	1	1	1	1	1	1	05/17/2022 11:16
Coho	1C7A	3DD.003E2180EB	05/10/2022 11:00	1	1	1	1	1	1	06/07/2022 05:21
Coho	1CED	3DD.003E2182EB	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	1EC8	3DD.003E21821A	05/05/2022 10:30	1	1	1	0	0	0	
Steelhead	2065	3DD.003E2181EA	05/05/2022 10:30	1	1	1	1	1	1	05/14/2022 00:44
Steelhead	20B8	3DD.003E21824F	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	22B3	3DD.003E2182FB	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	230E	3DD.003E2181CF	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	2323	3DD.003E2181C4	05/05/2022 10:30	1	1	1	1	1	1	05/16/2022 18:26
Steelhead	23C1	3DD.003E218254	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	23DA	3DD.003E21810D	05/10/2022 11:00	1	1	1	1	0	1	05/22/2022 00:49
Coho	24B1	3DD.003E218104	05/10/2022 11:00	1	1	1	1	1	1	05/30/2022 01:02
Steelhead	25AD	3DD.003E21825E	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	25B7	3DD.003E218222	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	262F	3DD.003E21820F	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	2687	3DD.003E21810F	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	2717	3DD.003E218116	05/10/2022 11:00	1	1	1	1	1	1	05/21/2022 18:46
Coho	2730	3DD.003E218247	05/03/2022 12:00	1	1	1	1	1	1	05/21/2022 16:32
Steelhead	2766	3DD.003E218322	04/20/2022 12:00	0	0	0	0	0	0	
Coho	27A0	3DD.003E218121	05/10/2022 11:00	1	1	1	1	1	1	06/01/2022 11:32
Coho	27CB	3DD.003E218126	05/10/2022 11:00	1	1	1	1	1	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	2829	3DD.003E2182D8	04/20/2022 12:00	1	1	1	1	0	1	05/29/2022 04:51
Steelhead	28CA	3DD.003E218251	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	28D2	3DD.003E2182FF	04/27/2022 12:00	1	1	1	1	0	1	05/02/2022 00:30
Coho	2A1D	3DD.003E218259	05/03/2022 12:00	1	1	1	1	1	1	05/08/2022 17:03
Steelhead	2A8B	3DD.003E2182F9	04/27/2022 12:00	1	1	1	1	0	1	04/30/2022 00:23
Steelhead	2A8E	3DD.003E218301	04/27/2022 12:00	0	0	0	0	0	0	
Steelhead	2AD4	3DD.003E218326	04/27/2022 12:00	1	1	1	0	0	0	
Coho	2B2D	3DD.003E21811C	05/10/2022 11:00	0	0	0	0	0	0	
Coho	2B30	3DD.003E21812A	05/10/2022 11:00	1	1	1	1	0	0	
Steelhead	2B6E	3DD.003E218308	04/27/2022 12:00	1	1	1	1	0	1	05/07/2022 00:45
Steelhead	2B78	3DD.003E218306	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	2B9A	3DD.003E2180F9	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	2F6C	3DD.003E2182C7	04/27/2022 12:00	1	1	1	1	1	0	
Steelhead	301E	3DD.003E2182D9	04/20/2022 12:00	0	0	0	0	0	0	
Coho	30C3	3DD.003E218232	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	3179	3DD.003E218215	05/03/2022 12:00	1	1	0	0	0	0	
Steelhead	319A	3DD.003E218210	05/03/2022 12:00	1	1	1	1	1	1	05/11/2022 02:49
Coho	31DF	3DD.003E21822B	05/03/2022 12:00	1	1	1	1	1	1	05/25/2022 16:57
Steelhead	3200	3DD.003E2182D2	04/27/2022 12:00	1	1	1	1	1	1	04/30/2022 00:18
Coho	326E	3DD.003E218252	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	329F	3DD.003E218320	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	32C0	3DD.003E2180D8	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 23:45
Coho	333E	3DD.003E2182F2	05/03/2022 12:00	1	1	1	1	1	1	05/31/2022 08:06
Coho	333F	3DD.003E2180DD	05/10/2022 11:00	1	1	1	1	1	1	05/22/2022 20:26
Steelhead	3423	3DD.003E218256	05/03/2022 12:00	1	1	0	0	0	0	
Steelhead	3596	3DD.003E21823E	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	3602	3DD.003E2180D2	05/10/2022 11:00	1	1	1	0	0	1	06/04/2022 21:36
Steelhead	3676	3DD.003E21824E	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	368A	3DD.003E218130	05/10/2022 11:00	1	1	1	1	1	1	05/21/2022 03:48
Steelhead	3751	3DD.003E2182F5	04/27/2022 12:00	1	1	1	1	1	0	
Coho	3756	3DD.003E2182D1	04/27/2022 12:00	1	1	1	1	1	1	06/07/2022 06:29
Steelhead	3776	3DD.003E2182F8	04/27/2022 12:00	1	1	1	1	1	1	05/05/2022 01:06
Steelhead	382E	3DD.003E2182CD	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	382F	3DD.003E2182EF	04/27/2022 12:00	0	0	0	0	0	0	
Coho	38B7	3DD.003E2181CC	05/10/2022 11:00	1	1	1	0	0	0	
Coho	3912	3DD.003E2180F7	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	391B	3DD.003E2180DF	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	392C	3DD.003E2182E3	05/03/2022 12:00	1	1	1	1	0	1	05/09/2022 23:54
Steelhead	3AAD	3DD.003E21810B	05/10/2022 11:00	1	1	1	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	3B3B	3DD.003E218220	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	3BD3	3DD.003E218233	05/03/2022 12:00	1	1	1	1	1	1	05/14/2022 22:46
Steelhead	3C3E	3DD.003E2182D6	04/20/2022 12:00	0	0	0	0	0	0	
Steelhead	3C7B	3DD.003E21830F	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	3D96	3DD.003E2182E9	04/27/2022 12:00	1	1	1	0	0	0	
Coho	3D9C	3DD.003E218206	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	3DC5	3DD.003E21825A	05/03/2022 12:00	1	1	1	0	0	0	
Coho	3DD0	3DD.003E218110	05/10/2022 11:00	1	1	1	1	1	1	07/03/2022 17:40
Steelhead	3DF8	3DD.003E21825F	05/03/2022 12:00	1	1	1	1	1	0	
Steelhead	3EC4	3DD.003E218261	05/03/2022 12:00	1	1	1	0	0	0	
Coho	3F60	3DD.003E218133	05/10/2022 11:00	1	1	1	1	1	1	06/29/2022 15:24
Steelhead	40B3	3DD.003E218211	05/03/2022 12:00	0	0	0	0	0	0	
Coho	4160	3DD.003E2182F3	04/20/2022 12:00	0	0	0	0	0	0	
Steelhead	4196	3DD.003E2182F1	04/27/2022 12:00	1	1	1	0	0	0	
Coho	4254	3DD.003E2181C0	05/10/2022 11:00	1	1	1	1	0	1	05/29/2022 00:03
Steelhead	4272	3DD.003E218218	05/03/2022 12:00	1	1	1	1	0	1	05/16/2022 13:34
Coho	4273	3DD.003E2180C8	05/18/2022 11:00	0	0	0	0	0	0	
Coho	42AA	3DD.003E21810A	05/10/2022 11:00	1	1	1	1	1	1	05/27/2022 00:04
Steelhead	439A	3DD.003E2181D8	05/05/2022 10:30	1	1	1	1	0	0	
Steelhead	449B	3DD.003E218258	05/03/2022 12:00	1	1	1	0	0	0	
Steelhead	45BA	3DD.003E218235	05/03/2022 12:00	1	1	1	1	1	1	06/09/2022 04:52
Steelhead	45DB	3DD.003E2182ED	04/27/2022 12:00	1	1	1	1	1	1	05/14/2022 12:34
Steelhead	4636	3DD.003E2182E2	04/27/2022 12:00	1	1	1	1	0	1	05/02/2022 03:13
Coho	46CE	3DD.003E2180FD	05/10/2022 11:00	1	1	1	1	1	1	05/26/2022 00:27
Steelhead	46DB	3DD.003E218314	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	4766	3DD.003E218245	05/03/2022 12:00	1	1	1	0	0	0	
Coho	47A9	3DD.003E218309	04/20/2022 12:00	1	1	1	0	0	0	
Steelhead	47D9	3DD.003E21821B	05/03/2022 12:00	1	1	1	1	0	1	05/07/2022 18:25
Coho	482B	3DD.003E218127	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	483F	3DD.003E2182F7	04/27/2022 12:00	1	1	1	0	0	0	
Coho	4881	3DD.003E21810C	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	4927	3DD.003E21821C	05/03/2022 12:00	1	0	0	0	0	0	
Steelhead	495D	3DD.003E21822D	05/03/2022 12:00	0	0	0	0	0	0	
Coho	4C35	3DD.003E218249	05/03/2022 12:00	0	0	0	0	0	0	
Coho	4C61	3DD.003E218250	05/03/2022 12:00	0	0	0	0	0	0	
Coho	4CA7	3DD.003E218204	05/03/2022 12:00	1	1	1	1	1	0	
Steelhead	4D03	3DD.003E21821E	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	4D9D	3DD.003E218205	05/03/2022 12:00	1	0	0	0	0	0	
Coho	4E4F	3DD.003E218128	05/10/2022 11:00	1	1	1	1	1	1	05/18/2022 00:13

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	4E7E	3DD.003E218134	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	4FAC	3DD.003E2181F4	05/05/2022 10:30	1	1	1	1	0	1	05/13/2022 12:22
Coho	4FD0	3DD.003E2180BA	05/18/2022 11:00	1	1	1	1	1	1	06/26/2022 19:50
Steelhead	5005	3DD.003E2181DD	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	512D	3DD.003E2182CF	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	51DE	3DD.003E21819D	05/05/2022 10:30	1	1	1	1	1	1	05/18/2022 18:26
Coho	5314	3DD.003E2180D7	05/10/2022 11:00	1	1	1	1	1	1	07/01/2022 21:54
Steelhead	5410	3DD.003E2180FE	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	5439	3DD.003E2182E4	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	5472	3DD.003E2182DF	04/27/2022 12:00	1	1	1	1	1	1	05/23/2022 21:59
Coho	5484	3DD.003E218111	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	55A2	3DD.003E21820A	05/03/2022 12:00	1	1	1	0	0	0	
Coho	55A5	3DD.003E2180E5	05/10/2022 11:00	1	1	1	1	1	1	05/19/2022 00:05
Steelhead	56B3	3DD.003E218321	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	56B7	3DD.003E2182DE	04/27/2022 12:00	1	1	1	1	1	1	05/17/2022 05:02
Steelhead	56BD	3DD.003E218201	05/03/2022 12:00	1	1	1	1	1	1	05/10/2022 11:19
Steelhead	570E	3DD.003E218325	04/20/2022 12:00	1	1	1	0	0	0	
Steelhead	57EF	3DD.003E21820C	05/03/2022 12:00	1	1	0	0	0	0	
Steelhead	588D	3DD.003E2181A9	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	58D3	3DD.003E21819E	05/05/2022 10:30	1	1	1	0	0	0	
Steelhead	58EB	3DD.003E218319	04/27/2022 12:00	1	1	1	1	0	1	05/11/2022 15:28
Steelhead	5939	3DD.003E2181A1	05/05/2022 10:30	1	1	1	1	0	1	05/23/2022 16:09
Coho	5945	3DD.003E218242	05/10/2022 11:00	1	1	1	1	1	1	05/20/2022 01:00
Steelhead	5971	3DD.003E21823A	05/03/2022 12:00	0	0	0	0	0	0	
Coho	5A7C	3DD.003E2182CC	04/20/2022 12:00	1	1	1	0	0	0	
Coho	5A85	3DD.003E21822C	05/03/2022 12:00	1	1	1	1	0	1	05/27/2022 03:26
Coho	5A87	3DD.003E21812E	05/10/2022 11:00	1	1	1	1	0	1	06/24/2022 22:57
Coho	5AF2	3DD.003E2182D3	04/20/2022 12:00	1	1	1	1	0	0	
Steelhead	5B2D	3DD.003E218229	05/03/2022 12:00	0	0	0	0	0	0	
Coho	5B4F	3DD.003E218119	05/10/2022 11:00	1	1	1	1	0	1	05/28/2022 00:55
Steelhead	5BF0	3DD.003E2182C9	05/05/2022 10:30	0	0	0	0	0	0	
Steelhead	5C79	3DD.003E218106	05/10/2022 11:00	1	1	1	1	1	1	05/16/2022 20:44
Steelhead	5C7E	3DD.003E2182CB	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	5CC5	3DD.003E218300	04/27/2022 12:00	1	1	1	0	0	0	
Coho	5D54	3DD.003E218248	05/03/2022 12:00	0	0	0	0	0	0	
Coho	5D78	3DD.003E218257	05/03/2022 12:00	1	0	0	0	0	0	
Coho	5D90	3DD.003E2180B4	05/18/2022 11:00	0	0	0	0	0	0	
Coho	5D93	3DD.003E21817E	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	5EDD	3DD.003E218094	05/18/2022 11:00	1	1	1	1	1	1	05/29/2022 03:10

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	5F23	3DD.003E21835F	06/01/2022 10:15	1	1	1	1	1	1	06/13/2022 23:14
Coho	5F82	3DD.003E2180C0	05/18/2022 11:00	1	1	1	1	0	1	05/21/2022 02:38
Steelhead	601B	3DD.003E218310	04/20/2022 12:00	1	1	1	1	1	1	04/28/2022 02:33
Coho	608A	3DD.003E218359	06/01/2022 10:15	1	1	1	1	1	1	06/07/2022 01:59
Coho	60F2	3DD.003E2184B5	05/25/2022 11:00	1	1	1	1	0	1	06/11/2022 01:32
Coho	6115	3DD.003E218377	06/01/2022 10:15	1	1	1	0	0	0	
Coho	613C	3DD.003E218092	05/18/2022 11:00	1	1	1	1	1	1	05/30/2022 01:49
Coho	61BE	3DD.003E218360	06/01/2022 10:15	1	1	1	1	1	1	06/07/2022 09:24
Coho	6323	3DD.003E218466	05/25/2022 11:00	0	0	0	0	0	0	
Coho	6338	3DD.003E2180A9	05/18/2022 11:00	0	0	0	0	0	0	
Steelhead	636B	3DD.003E218125	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	63C2	3DD.003E218156	05/10/2022 11:00	1	1	1	1	0	1	05/20/2022 22:05
Steelhead	63D7	3DD.003E2180FA	05/10/2022 11:00	1	1	1	0	0	0	
Coho	68D2	3DD.003E218172	05/10/2022 11:00	1	1	1	0	0	0	
Coho	694C	3DD.003E21809C	05/18/2022 11:00	0	0	0	0	0	0	
Coho	69F1	3DD.003E2180EA	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	6A1F	3DD.003E21818D	05/10/2022 11:00	1	1	1	1	1	1	05/20/2022 14:13
Steelhead	6A52	3DD.003E21823F	05/03/2022 12:00	1	1	1	1	1	1	05/10/2022 21:05
Coho	6ACD	3DD.003E2180D1	05/18/2022 11:00	0	0	0	0	0	0	
Coho	6CCF	3DD.003E218470	05/25/2022 11:00	0	0	0	0	0	0	
Steelhead	6D88	3DD.003E218079	05/18/2022 11:00	1	1	1	0	0	0	
Coho	6D97	3DD.003E218187	05/10/2022 11:00	1	1	1	0	0	1	06/18/2022 02:04
Steelhead	6DD2	3DD.003E218302	04/27/2022 12:00	1	1	1	1	1	1	05/11/2022 00:58
Coho	6DE0	3DD.003E2180F6	05/10/2022 11:00	1	1	0	0	0	0	
Coho	6F50	3DD.003E2180B1	05/18/2022 11:00	1	1	1	1	1	1	06/06/2022 20:20
Coho	70D2	3DD.003E218356	06/01/2022 10:15	1	1	1	0	1	1	07/01/2022 10:49
Coho	70EF	3DD.003E2180A8	05/18/2022 11:00	1	1	1	1	1	1	06/06/2022 22:59
Coho	7291	3DD.003E21849B	05/25/2022 11:00	1	1	1	0	1	0	
Coho	730B	3DD.003E218169	05/10/2022 11:00	1	1	1	1	1	1	05/30/2022 05:06
Coho	732A	3DD.003E218370	06/01/2022 10:15	1	1	1	1	1	1	07/02/2022 10:05
Steelhead	735F	3DD.003E21816D	05/10/2022 11:00	0	0	0	0	0	0	
Coho	73B9	3DD.003E218364	06/01/2022 10:15	0	1	1	1	1	1	06/06/2022 22:09
Steelhead	74C4	3DD.003E2180D6	05/10/2022 11:00	1	1	1	1	0	1	05/27/2022 04:29
Coho	7543	3DD.003E21807A	05/18/2022 11:00	1	1	1	1	1	1	06/18/2022 01:12
Coho	75B0	3DD.003E218099	05/18/2022 11:00	1	1	1	1	0	1	05/23/2022 04:21
Coho	7716	3DD.003E218155	05/10/2022 11:00	1	1	1	0	0	0	
Coho	7828	3DD.003E21838B	06/01/2022 10:15	1	1	1	1	1	1	07/10/2022 16:12
Coho	796D	3DD.003E21838C	06/01/2022 10:15	1	1	1	1	1	1	06/19/2022 06:43
Coho	7A64	3DD.003E2180BE	05/18/2022 11:00	1	1	1	1	1	1	05/19/2022 23:40

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	7A67	3DD.003E21809B	05/18/2022 11:00	1	1	1	1	0	1	05/25/2022 23:43
Coho	7A68	3DD.003E218114	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	7AA3	3DD.003E2180CC	05/18/2022 11:00	1	1	1	0	1	0	
Coho	7AC8	3DD.003E21833C	06/01/2022 10:15	1	1	1	1	1	1	07/01/2022 19:02
Coho	7AE5	3DD.003E2180A3	05/18/2022 11:00	0	0	0	0	0	0	
Steelhead	7B18	3DD.003E218217	05/03/2022 12:00	1	1	1	0	1	0	
Coho	7B43	3DD.003E218080	05/18/2022 11:00	1	1	1	1	1	1	06/14/2022 00:31
Coho	7B64	3DD.003E218373	06/01/2022 10:15	1	1	0	0	0	0	
Coho	7BCD	3DD.003E2184A3	05/25/2022 11:00	1	1	1	0	0	0	
Coho	7C17	3DD.003E21847F	05/25/2022 11:00	1	1	1	0	0	0	
Coho	7F0D	3DD.003E2180F0	05/10/2022 11:00	1	1	1	0	0	0	
Coho	7F4E	3DD.003E218087	05/18/2022 11:00	1	1	1	0	0	0	
Steelhead	802B	3DD.003E218213	05/05/2022 10:30	0	0	0	0	0	0	
Coho	8038	3DD.003E21822F	05/03/2022 12:00	0	0	0	0	0	0	
Coho	8066	3DD.003E2184A1	05/25/2022 11:00	1	1	1	1	1	1	06/07/2022 05:26
Coho	80A3	3DD.003E218188	05/10/2022 11:00	1	1	1	0	0	0	
Coho	80FD	3DD.003E218344	06/01/2022 10:15	0	0	0	0	0	0	
Coho	8157	3DD.003E218376	06/01/2022 10:15	1	1	1	0	0	1	07/01/2022 18:59
Coho	8161	3DD.003E218493	05/25/2022 11:00	1	1	1	1	1	1	05/28/2022 22:57
Coho	82B3	3DD.003E21832F	06/01/2022 10:15	1	1	1	0	0	0	
Coho	832A	3DD.003E21809E	05/18/2022 11:00	1	1	1	1	0	1	06/06/2022 17:12
Coho	8385	3DD.003E218096	05/18/2022 11:00	1	1	1	1	0	1	05/26/2022 09:05
Coho	8386	3DD.003E2184A7	05/25/2022 11:00	1	1	1	0	0	0	
Coho	849F	3DD.003E218105	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	84AD	3DD.003E218173	05/10/2022 11:00	0	0	0	0	0	0	
Coho	8505	3DD.003E2180A2	05/18/2022 11:00	1	1	1	0	0	0	
Coho	8525	3DD.003E21808D	05/18/2022 11:00	1	1	1	1	1	1	05/23/2022 22:18
Steelhead	857A	3DD.003E218109	05/10/2022 11:00	1	1	1	1	1	1	05/21/2022 00:13
Steelhead	85A6	3DD.003E2180E2	05/10/2022 11:00	1	1	1	1	0	0	
Steelhead	885C	3DD.003E2181B9	05/03/2022 12:00	1	1	1	1	1	1	05/17/2022 15:50
Steelhead	8947	3DD.003E218214	05/03/2022 12:00	0	0	0	0	0	0	
Coho	89A2	3DD.003E218016	05/18/2022 11:00	1	1	1	1	1	1	06/04/2022 03:12
Steelhead	89A4	3DD.003E2181F1	05/05/2022 10:30	1	1	1	1	1	0	
Coho	89BF	3DD.003E21847E	05/25/2022 11:00	1	1	1	0	0	0	
Coho	89EB	3DD.003E21816C	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	8B08	3DD.003E218239	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	8B34	3DD.003E2182D5	04/27/2022 12:00	1	1	1	1	0	1	05/12/2022 14:25
Steelhead	8B3C	3DD.003E218221	05/03/2022 12:00	1	1	1	0	0	0	
Coho	8B59	3DD.003E218198	05/10/2022 11:00	1	0	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	8B8B	3DD.003E2180A6	05/18/2022 11:00	0	0	0	0	0	0	
Coho	8BEA	3DD.003E218074	05/18/2022 11:00	1	1	1	1	1	1	05/30/2022 01:26
Coho	8C2E	3DD.003E218140	05/10/2022 11:00	1	1	1	0	0	0	
Coho	8C7B	3DD.003E218158	05/10/2022 11:00	1	1	1	1	0	1	05/27/2022 15:27
Coho	8C84	3DD.003E218456	05/25/2022 11:00	1	1	1	1	1	0	
Coho	8CC6	3DD.003E21833B	06/01/2022 10:15	1	1	1	0	0	0	
Coho	8D2F	3DD.003E218484	05/25/2022 11:00	1	1	1	0	0	0	
Coho	8E0A	3DD.003E2180AF	05/18/2022 11:00	1	1	0	0	0	0	
Coho	8EB1	3DD.003E2184AD	05/25/2022 11:00	1	1	1	1	1	0	
Steelhead	8F02	3DD.003E21815C	05/10/2022 11:00	1	1	1	1	1	1	05/17/2022 16:01
Coho	8F3A	3DD.003E218496	05/25/2022 11:00	1	1	1	1	1	1	05/29/2022 15:41
Steelhead	8FA8	3DD.003E2180EC	05/10/2022 11:00	0	0	0	0	0	0	
Coho	8FB9	3DD.003E21848A	05/25/2022 11:00	1	1	1	1	0	1	06/28/2022 11:01
Steelhead	8FF4	3DD.003E2180E7	05/10/2022 11:00	1	1	1	0	0	1	05/22/2022 11:10
Coho	9027	3DD.003E218029	05/18/2022 11:00	1	1	1	1	1	1	05/29/2022 22:50
Coho	90D2	3DD.003E2180B3	05/18/2022 11:00	1	1	1	0	1	1	06/09/2022 02:38
Coho	919A	3DD.003E21807F	05/18/2022 11:00	1	1	1	0	0	1	06/12/2022 03:08
Steelhead	91C1	3DD.003E2181C2	05/05/2022 10:30	1	1	1	0	0	0	
Steelhead	91D9	3DD.003E218174	05/10/2022 11:00	1	1	1	0	0	0	
Steelhead	92DF	3DD.003E218056	05/18/2022 11:00	0	0	0	0	0	0	
Coho	9335	3DD.003E21836F	06/01/2022 10:15	1	1	1	1	1	1	06/13/2022 00:08
Coho	9371	3DD.003E218372	06/01/2022 10:15	1	1	1	1	0	1	06/23/2022 11:41
Coho	94CA	3DD.003E2180AE	05/18/2022 11:00	1	1	1	1	1	1	06/03/2022 06:07
Coho	9524	3DD.003E218260	05/03/2022 12:00	1	1	1	1	0	1	05/20/2022 16:56
Coho	9616	3DD.003E218097	05/18/2022 11:00	1	1	1	0	1	1	05/27/2022 04:13
Coho	9637	3DD.003E21835D	06/01/2022 10:15	0	0	0	0	0	0	
Coho	9667	3DD.003E2180C9	05/18/2022 11:00	0	0	0	0	0	0	
Coho	96D0	3DD.003E2180C2	05/18/2022 11:00	1	1	0	0	0	0	
Coho	973C	3DD.003E218475	05/25/2022 11:00	0	0	0	0	0	0	
Coho	9749	3DD.003E21824D	05/03/2022 12:00	1	1	1	1	0	1	05/28/2022 02:16
Coho	9878	3DD.003E21848B	05/25/2022 11:00	1	1	1	1	0	1	06/21/2022 17:21
Coho	98D3	3DD.003E2180CA	05/18/2022 11:00	1	1	1	1	1	1	05/27/2022 11:30
Coho	98F5	3DD.003E21808B	05/18/2022 11:00	1	1	1	0	0	0	
Coho	9977	3DD.003E218184	05/10/2022 11:00	1	1	1	1	1	1	07/03/2022 17:22
Coho	99DC	3DD.003E2180B2	05/18/2022 11:00	1	1	1	0	0	0	
Coho	99F2	3DD.003E2184A8	05/25/2022 11:00	1	1	1	0	0	0	
Steelhead	9A0F	3DD.003E21802A	05/18/2022 11:00	1	1	1	1	1	1	05/22/2022 15:38
Steelhead	9A3F	3DD.003E2180E0	05/10/2022 11:00	1	1	1	1	1	1	05/17/2022 10:05
Steelhead	9D3E	3DD.003E2180B7	05/18/2022 11:00	1	1	1	0	1	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	9D4A	3DD.003E21809A	05/18/2022 11:00	1	1	1	1	1	1	06/24/2022 22:55
Coho	9DAD	3DD.003E2180F3	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 04:25
Steelhead	9DC7	3DD.003E2180AD	05/18/2022 11:00	1	1	1	1	1	1	05/29/2022 00:58
Coho	9EB1	3DD.003E218194	05/10/2022 11:00	0	0	0	0	0	0	
Coho	9ECD	3DD.003E218369	06/01/2022 10:15	1	1	1	1	1	1	06/09/2022 21:29
Coho	9F80	3DD.003E218095	05/18/2022 11:00	1	1	1	1	0	1	05/22/2022 14:34
Coho	9FF7	3DD.003E21831E	04/20/2022 12:00	0	0	0	0	0	0	
Coho	A03C	3DD.003E2180BF	05/18/2022 11:00	1	1	1	0	1	1	06/14/2022 02:57
Steelhead	A09E	3DD.003E218101	05/10/2022 11:00	0	0	0	0	0	0	
Coho	A0EC	3DD.003E218375	06/01/2022 10:15	1	1	1	0	0	0	
Coho	A10B	3DD.003E2180ED	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 03:48
Steelhead	A160	3DD.003E218307	04/27/2022 12:00	1	1	1	1	1	1	05/10/2022 20:27
Steelhead	A161	3DD.003E2180D5	05/10/2022 11:00	1	1	1	0	0	0	
Coho	A1A0	3DD.003E218349	06/01/2022 10:15	1	1	1	1	1	1	06/09/2022 02:04
Steelhead	A230	3DD.003E21815F	05/10/2022 11:00	1	1	1	0	0	0	
Coho	A2B2	3DD.003E218103	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	A2BC	3DD.003E218165	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	A360	3DD.003E2180E8	05/10/2022 11:00	0	0	0	0	0	0	
Coho	A44D	3DD.003E2180AC	05/18/2022 11:00	1	1	1	1	0	0	
Steelhead	A481	3DD.003E218190	05/10/2022 11:00	1	1	1	0	0	0	
Coho	A4F5	3DD.003E2184A0	05/25/2022 11:00	0	0	0	0	0	0	
Coho	A556	3DD.003E218071	05/18/2022 11:00	1	1	1	1	1	1	06/23/2022 16:42
Steelhead	A57C	3DD.003E218115	05/10/2022 11:00	0	0	0	0	0	0	
Coho	A5A9	3DD.003E21815D	05/10/2022 11:00	0	0	0	0	0	0	
Coho	A5B9	3DD.003E218460	05/25/2022 11:00	1	1	1	1	1	1	05/26/2022 02:21
Coho	A5F3	3DD.003E21848C	05/25/2022 11:00	1	1	1	1	1	1	07/01/2022 18:59
Coho	A610	3DD.003E218241	05/03/2022 12:00	1	1	1	1	1	1	06/10/2022 05:20
Coho	A654	3DD.003E21845E	05/25/2022 11:00	1	1	1	1	1	1	05/29/2022 01:43
Coho	A6E6	3DD.003E2182CA	04/20/2022 12:00	0	0	0	0	1	0	
Steelhead	A84C	3DD.003E2181AB	05/05/2022 10:30	0	0	0	0	0	0	
Coho	A8CF	3DD.003E2181DE	05/10/2022 11:00	1	1	1	1	1	1	06/24/2022 05:15
Steelhead	A8E9	3DD.003E2182E5	04/20/2022 12:00	1	1	1	1	1	0	
Steelhead	A963	3DD.003E2182FE	04/27/2022 12:00	0	0	0	0	0	0	
Steelhead	A98D	3DD.003E21813B	05/10/2022 11:00	1	1	1	1	1	1	05/31/2022 08:47
Coho	A9E0	3DD.003E21836B	06/01/2022 10:15	1	1	1	0	0	0	
Coho	AAF0	3DD.003E218157	05/10/2022 11:00	1	1	1	1	1	1	05/27/2022 06:37
Coho	AB01	3DD.003E218363	06/01/2022 10:15	1	1	1	1	1	0	
Coho	ABCF	3DD.003E2184A6	05/25/2022 11:00	1	1	1	1	0	1	06/04/2022 02:41
Coho	ABFB	3DD.003E218478	05/25/2022 11:00	1	1	1	1	1	1	05/28/2022 00:59

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Coho	ACC0	3DD.003E2180A5	05/18/2022 11:00	1	1	1	0	0	0	
Coho	ACD2	3DD.003E2180CB	05/18/2022 11:00	1	1	1	1	0	0	
Coho	ACE3	3DD.003E2180B0	05/18/2022 11:00	1	1	1	0	0	0	
Steelhead	ADF2	3DD.003E2180E3	05/10/2022 11:00	0	0	0	0	0	0	
Steelhead	AE0D	3DD.003E218107	05/10/2022 11:00	1	1	1	1	0	1	05/19/2022 19:25
Coho	AE14	3DD.003E21834D	06/01/2022 10:15	1	1	1	1	1	0	
Coho	AE19	3DD.003E218219	05/03/2022 12:00	1	1	1	1	1	1	05/29/2022 02:00
Coho	AE39	3DD.003E218388	06/01/2022 10:15	0	0	0	0	0	0	
Steelhead	AE64	3DD.003E2180EE	05/10/2022 11:00	0	0	0	0	0	0	
Coho	AF05	3DD.003E21807E	05/18/2022 11:00	1	1	1	0	0	0	
Steelhead	AFE6	3DD.003E218318	04/27/2022 12:00	0	0	0	0	0	0	
Coho	AFE9	3DD.003E218086	05/18/2022 11:00	1	1	1	1	0	1	05/29/2022 01:43
Coho	B011	3DD.003E2180BB	05/18/2022 11:00	0	0	0	0	0	0	
Coho	B069	3DD.003E2180D0	05/18/2022 11:00	1	1	1	1	1	1	06/20/2022 05:18
Coho	B0A8	3DD.003E218492	05/25/2022 11:00	1	1	1	1	1	0	
Coho	B0B7	3DD.003E218387	06/01/2022 10:15	1	1	1	1	1	1	06/07/2022 02:30
Coho	B161	3DD.003E218489	05/25/2022 11:00	1	1	1	1	1	1	05/29/2022 01:35
Coho	B175	3DD.003E21825B	05/03/2022 12:00	1	0	0	0	0	0	
Coho	B187	3DD.003E218089	05/18/2022 11:00	1	1	1	1	0	1	05/30/2022 03:01
Coho	B1E7	3DD.003E2180FB	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	B22E	3DD.003E21830A	04/27/2022 12:00	1	1	1	0	0	0	
Coho	B26A	3DD.003E2180C7	05/18/2022 11:00	0	0	0	0	0	0	
Coho	B2DA	3DD.003E2184A4	05/25/2022 11:00	1	1	1	1	1	1	06/20/2022 03:02
Coho	B31A	3DD.003E21849A	05/25/2022 11:00	0	0	0	0	0	0	
Steelhead	B347	3DD.003E218075	05/18/2022 11:00	0	0	0	0	0	0	
Steelhead	B394	3DD.003E21823D	05/03/2022 12:00	0	0	0	0	0	0	
Coho	B3A1	3DD.003E218471	05/25/2022 11:00	1	1	1	0	0	0	
Coho	B3AC	3DD.003E2180CD	05/18/2022 11:00	1	1	1	1	1	1	06/03/2022 04:25
Coho	B3E7	3DD.003E21846F	05/25/2022 11:00	1	1	1	1	1	1	05/27/2022 02:26
Coho	B400	3DD.003E218113	05/10/2022 11:00	0	0	0	0	0	0	
Coho	B50A	3DD.003E218078	05/18/2022 11:00	1	1	1	0	0	0	
Steelhead	B539	3DD.003E2180F4	05/10/2022 11:00	1	1	1	1	1	1	05/19/2022 15:41
Steelhead	B551	3DD.003E218102	05/10/2022 11:00	0	0	0	0	0	0	
Coho	B5B9	3DD.003E21835E	06/01/2022 10:15	1	1	1	1	1	1	06/28/2022 15:41
Coho	B5ED	3DD.003E218463	05/25/2022 11:00	1	1	1	1	1	1	07/03/2022 18:40
Coho	B60B	3DD.003E2184B9	05/25/2022 11:00	1	1	1	1	1	1	05/29/2022 02:51
Coho	B61F	3DD.003E2180C5	05/18/2022 11:00	1	1	1	0	0	0	
Steelhead	B73C	3DD.003E218328	04/27/2022 12:00	1	1	1	0	0	0	
Coho	B774	3DD.003E218076	05/18/2022 11:00	1	1	0	0	0	0	

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	B787	3DD.003E218139	05/10/2022 11:00	1	1	1	0	0	0	
Coho	B793	3DD.003E218459	05/25/2022 11:00	1	1	1	1	1	0	
Coho	B7D1	3DD.003E21814D	05/10/2022 11:00	1	1	1	1	1	1	06/24/2022 07:15
Steelhead	B830	3DD.003E2181B7	05/05/2022 10:30	1	1	1	0	0	0	
Coho	B870	3DD.003E218185	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 03:03
Coho	B973	3DD.003E218202	05/03/2022 12:00	1	1	1	1	0	1	05/22/2022 00:46
Steelhead	BA1D	3DD.003E2180C3	05/18/2022 11:00	0	0	0	0	0	0	
Coho	BA42	3DD.003E218183	05/10/2022 11:00	1	1	1	1	1	1	05/30/2022 03:00
Coho	BA5C	3DD.003E218091	05/18/2022 11:00	1	1	1	1	1	1	05/21/2022 00:33
Coho	BA8E	3DD.003E218093	05/18/2022 11:00	1	1	1	1	1	0	
Coho	BC13	3DD.003E218382	06/01/2022 10:15	1	1	1	1	0	1	07/01/2022 18:59
Steelhead	BC35	3DD.003E2180D3	05/10/2022 11:00	0	0	0	0	0	0	
Coho	BC7B	3DD.003E218378	06/01/2022 10:15	0	0	0	0	0	0	
Steelhead	BC98	3DD.003E21831F	04/27/2022 12:00	1	1	1	1	0	1	05/04/2022 05:15
Steelhead	BD16	3DD.003E2182E8	04/20/2022 12:00	0	0	0	0	0	0	
Steelhead	BDCF	3DD.003E21816F	05/10/2022 11:00	0	0	0	0	0	0	
Coho	BE88	3DD.003E218385	06/01/2022 10:15	1	1	1	1	1	1	06/28/2022 05:07
Coho	BEAF	3DD.003E218469	05/25/2022 11:00	1	1	1	1	1	0	
Coho	BF49	3DD.003E218473	05/25/2022 11:00	1	1	1	1	0	0	
Steelhead	BF4A	3DD.003E21820B	05/05/2022 10:30	0	0	0	0	0	0	
Coho	BFDF	3DD.003E218336	06/01/2022 10:15	1	1	1	0	1	0	
Steelhead	C088	3DD.003E2180D4	05/10/2022 11:00	0	0	0	0	0	0	
Coho	C0E6	3DD.003E2180BC	05/18/2022 11:00	1	1	1	1	1	1	06/01/2022 11:20
Coho	C0FE	3DD.003E218488	05/25/2022 11:00	0	0	0	0	0	0	
Coho	C330	3DD.003E21815B	05/10/2022 11:00	1	1	1	1	1	1	06/09/2022 23:48
Coho	C3B8	3DD.003E218491	05/25/2022 11:00	1	1	1	0	0	1	06/01/2022 02:34
Coho	C418	3DD.003E2184B8	05/25/2022 11:00	0	0	0	0	0	0	
Coho	C511	3DD.003E218085	05/18/2022 11:00	0	0	0	0	0	0	
Coho	C562	3DD.003E218499	05/25/2022 11:00	1	1	1	1	1	1	05/27/2022 05:49
Steelhead	C679	3DD.003E2182C8	04/27/2022 12:00	0	0	0	0	0	0	
Steelhead	00F7	3DD.003E218315	04/27/2022 12:00	0	0	0	0	0	0	
Steelhead	013A	3DD.003E218311	04/20/2022 12:00	1	1	1	1	0	1	04/27/2022 04:52
Coho	027B	3DD.003E21831C	04/20/2022 12:00	0	0	0	0	0	0	
Coho	029D	3DD.003E21830C	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	03F4	3DD.003E2182FD	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	040D	3DD.003E218255	05/03/2022 12:00	1	1	1	1	1	1	05/06/2022 19:40
Steelhead	041D	3DD.003E21812C	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	04D7	3DD.003E2182C6	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	05FE	3DD.003E218304	04/27/2022 12:00	1	1	1	1	1	1	05/21/2022 04:19

Species	Acoustic Tag	PIT Tag	Release Date-Time	FBY	ZOI	ENT	CCHS-U	CCHS-D	Collected	Collection Date-Time
Steelhead	080E	3DD.003E2182F6	04/27/2022 12:00	0	0	0	0	0	0	
Coho	08F9	3DD.003E21812F	05/10/2022 11:00	1	1	1	1	0	0	
Steelhead	0A65	3DD.003E218216	05/03/2022 12:00	1	1	1	0	0	0	
Coho	0AE5	3DD.003E218253	05/03/2022 12:00	1	1	1	1	1	1	05/08/2022 00:52
Steelhead	0AEA	3DD.003E218209	05/03/2022 12:00	1	1	1	1	1	1	05/17/2022 10:35
Steelhead	0B0E	3DD.003E2181BE	05/05/2022 10:30	1	1	1	0	0	0	
Steelhead	0B37	3DD.003E218224	05/03/2022 12:00	0	0	0	0	0	0	
Steelhead	0CA9	3DD.003E21812B	05/10/2022 11:00	0	0	0	0	0	0	
Coho	0D30	3DD.003E2182CE	04/20/2022 12:00	1	1	1	1	0	1	05/30/2022 05:36
Coho	0D49	3DD.003E2180F5	05/10/2022 11:00	0	0	0	0	0	0	
Coho	0D55	3DD.003E218132	05/10/2022 11:00	1	1	1	1	0	1	05/22/2022 14:34
Coho	0E7A	3DD.003E218244	05/03/2022 12:00	0	0	0	0	0	0	
Coho	0F20	3DD.003E21823B	05/03/2022 12:00	1	1	1	1	0	1	05/28/2022 02:04
Steelhead	0F4A	3DD.003E218227	05/03/2022 12:00	1	1	1	0	0	0	
Coho	0F8E	3DD.003E21831D	05/03/2022 12:00	1	1	0	0	0	0	
Coho	0FE2	3DD.003E2182EC	04/20/2022 12:00	1	0	0	0	0	0	
Coho	1060	3DD.003E2180F1	05/10/2022 11:00	1	1	1	1	1	1	05/28/2022 05:19
Steelhead	10B1	3DD.003E2181D5	05/03/2022 12:00	1	1	1	1	1	1	05/26/2022 01:48
Coho	10FC	3DD.003E218317	04/27/2022 12:00	1	1	1	0	0	0	
Steelhead	1255	3DD.003E2182F0	04/27/2022 12:00	0	0	0	0	0	0	
Coho	126D	3DD.003E2181A7	05/10/2022 11:00	1	1	1	1	0	1	05/29/2022 03:32
Steelhead	1389	3DD.003E218327	04/20/2022 12:00	1	1	1	1	1	1	05/10/2022 08:02
Steelhead	13C6	3DD.003E218228	05/03/2022 12:00	1	1	1	0	0	0	
Coho	144F	3DD.003E218112	05/10/2022 11:00	1	1	1	1	1	1	06/06/2022 19:10
Coho	1506	3DD.003E2180E6	05/10/2022 11:00	1	1	1	1	1	0	
Steelhead	1550	3DD.003E218207	05/03/2022 12:00	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), the collector entrance (ENT), 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 E

SPAWN TIMING, DISTRIBUTION AND ABUNDANCE OF TRANSPORTED FISHES – 2022 FINAL REPORT

Memorandum

To: Erik Lesko, PacifiCorp, Chris Karchesky, PacifiCorp

From: Jason Shappart (Fisheries Scientist) and Tyler McClure (Fish and Wildlife Biologist)

Date: May 30, 2023

Re: 2022 Salmon Spawning Survey Results Upstream of Swift Dam

Introduction

Chinook Salmon spawning surveys were conducted from August 31 through mid-October, 2022 by Meridian Environmental, Inc. (Meridian) under contract with PacifiCorp. Per Objective 15 of the Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2022), surveys were conducted to provide the basis for estimating spawner abundance, timing, and distribution of transported adult Chinook in the North Fork (NF) Lewis River basin upstream of Swift Dam. In addition, surveys were conducted from September 2022 through January 2023 to quantify the proportion of Chinook and Coho that spawned in the drawdown zone (DDZ) of Swift Reservoir per Objective 15 of the Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2022),

Methods

Spring Chinook Methods

In 2021, the Lewis River Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2017) underwent a 5-year review and revision in consultation with the Lewis River Aquatics Coordination Committee – Aquatic Technical Subgroup (ATS). The decision was made that Chinook spawning surveys should continue to estimate spawn timing, distribution, and abundance due the relatively few number of years that spring Chinook have been transported upstream of Swift Dam since the fish passage program began in 2012.

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. Approximately 33% of all available reaches were drawn into three randomly-stratified yearly survey panels. From 2012 through 2020, in years when spring Chinook were transported upstream, this was used as the sample design for conducting spawning surveys to estimate total redds and the proportion of female Chinook that spawned. Beginning in 2021, census surveys were conducted of all reaches potentially accessible for spring Chinook spawning. Surveys conducted through 2021 showed that spring Chinook spawned within the upper mainstem NF Lewis River and Little Creek, the Muddy River watershed, and Drift Creek (when sufficient flows were present) from late August to early October (Figure 2.15.1). Spawning may also occur in Swift Creek due to adequate upstream passage flows that are typically present in September. However, sufficient stream flow is generally lacking to allow adult Chinook access to all other independent Swift Reservoir tributaries. These include several

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small tributaries to the reservoir outside of the upper NF Lewis River watershed upstream of Eagle Cliff (such as S15, S20, Diamond, Range creeks, etc.).

No spring Chinook were previously documented spawning in the Pine or Rush Creek watersheds. However, two potential adult Chinook spawners were observed in lower Pine Creek by WDFW spawning survey staff in 2013, but were not associated with a redd. Although no Chinook spawning was previously documented in these two streams, they were surveyed weekly in September and October for Bull Trout spawning, and any potential spring Chinook spawning activity was also documented.

Field survey methods followed those described in PacifiCorp and Cowlitz PUD (2022). The goal was to conduct a census survey comprised of three spawning survey passes of the streams listed in Table 1 during the Chinook spawning season (September to mid-October), which were thought to compromise all potential spring Chinook spawning habitat. For consistency, the same spatially discrete 0.3 mile reach segments defined and surveyed since 2012 were referenced during the spawning stream census surveys so that future redd counts can easily be compared in a spatially explicit way to prior year results. All surveys were conducted on foot, except NF Lewis River mainstem and Muddy River mainstem surveys were conducted by kayak[1]. Spawning surveys of the Swift Reservoir DDZ were also conducted for spring Chinook as described below for Coho.

Note that in 2022, all surveys were conducted by the same Meridian biologists who have been conducting these surveys since 2016. During each reach survey, the number of live Chinook were enumerated. Chinook 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 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.

Table 1. Length of habitat accessible to spring Chinook in streams selected for Chinook spawning surveys.

Stream Name	Accessible to Anadromous Fish Length (miles)	Surveyable[1] Length (miles)
Mainstem NF Lewis River	12.9	12.9
Little Creek	0.3	0.3
Mainstem Muddy River	9.3	9.2
Clear Creek	11.1	7.5
Clearwater Creek	5.8	3.3
Smith Creek	5.7	5.0
Swift Creek	0.3	0.3
Drift Creek	1.5	1.5
Total Miles	**46.9**	**40.0**

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

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

Analysis methods followed those described by Starcevich (2023), and are summarized below. The detection probability range of 0.80 to 0.90 was applied in a bootstrap application to calculate an estimate of the number of redds that accounted for imperfect detection and to obtain 95% confidence intervals based on the bootstrap. Each bootstrapped sample was obtained by bootstrapping clusters within each stratum then combining the samples across strata and calculating the estimated number of redds with the ratio estimator. Then a detection probability was selected from a uniform distribution within each detection probability range, and the estimated number of redds was inflated by this factor. For a set of 1,000 bootstrap estimates, the 2.5% and 97.5% percentiles were used within and across strata to obtain bootstrapped 95% confidence intervals.

The proportion of spawning females was calculated as the estimated number of redds (after accounting for imperfect redd detection) divided by the total number of transported females, and confidence intervals were constructed from the variance obtained from the ratio estimator. This calculation was based on an assumption that each redd represented a single spawning female, which has been empirically demonstrated for spring Chinook (Murdoch et al. 2009). Given this assumption, the known number of transported Chinook represents the known total number of females in the population upstream of Swift Dam. Therefore, the estimated number of redds is equivalent to the estimated number of spawning females. The Chinook redd counts from 2017, 2018, and 2021 were also re-analyzed with the updated detection probability and sampling frame so that estimates of Chinook redds and the proportion of transported females estimated to have spawned would be more accurate and comparable among years.

Coho Methods

Coho spawning surveys conducted upstream of Swift Dam from 2012 to 2021 generally showed that as fall rains start and transition into winter snow, poor survey conditions limit the ability to conduct spawning surveys from November through January, which can encompass the majority of the Coho spawning season. In 2022, spawning surveys focused on quantifying the number of Coho that may spawn in the Swift Reservoir DDZ (PacifiCorp and Cowlitz PUD 2022). The number of female Coho estimated to spawn in the Swift Reservoir DDZ was estimated through a census redd survey of the DDZ stream channels conducted once every two weeks during the Coho spawning season (i.e., late September through January). Redd counts followed the methods as outlined above for spring Chinook.

Survey Conditions

The USGS NF Lewis River above Muddy River gauge 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 at historical median flows in late August, but dropped well below historical median daily flows through October. During the spring Chinook spawning season, small tributary streams were either totally dry or too low to allow upstream migration of spawning salmon. However, all of the streams listed in Table 1 contained sufficient flow for upstream migration and potential Chinook spawning throughout the survey period. Low flows and the lack of precipitation allowed for excellent survey conditions throughout the Chinook spawning survey period in all survey streams.

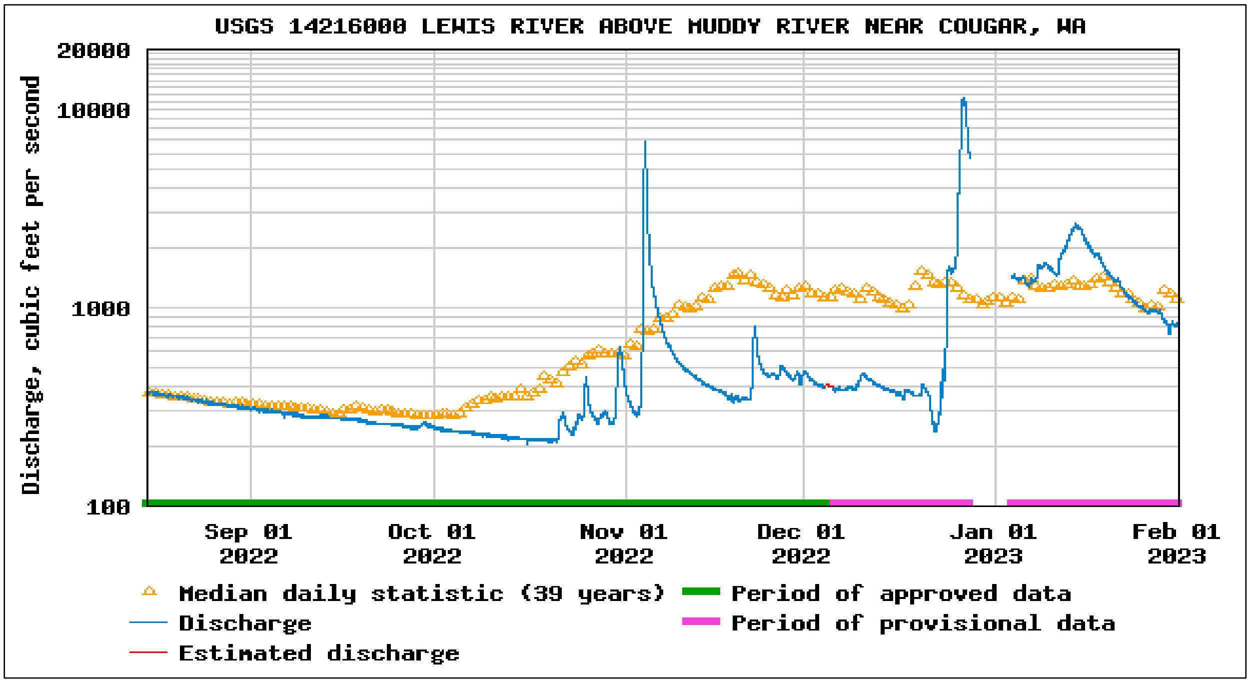

Figure 1. USGS NF Lewis R. above Muddy R. flows (Aug 15, 2022 to Jan 31, 2023).

The Swift Reservoir water surface elevation was near full pool (approximately 999 feet-msl) at the beginning of September, but steadily declined to about 956 feet-msl by mid-December (Figure 2). From mid-November to mid-December, reservoir water surface level restricted access to the Swift boat ramp, so only tributaries accessible by foot were surveyed during that time. Intense preciptiation resulted in the reservoir pool rapidly increasing to 982 feet-msl by January 1, 2023, but the reseroir declined by about 20 feet to about 962 ft-msl by the end of January 2023 (Figure 2).

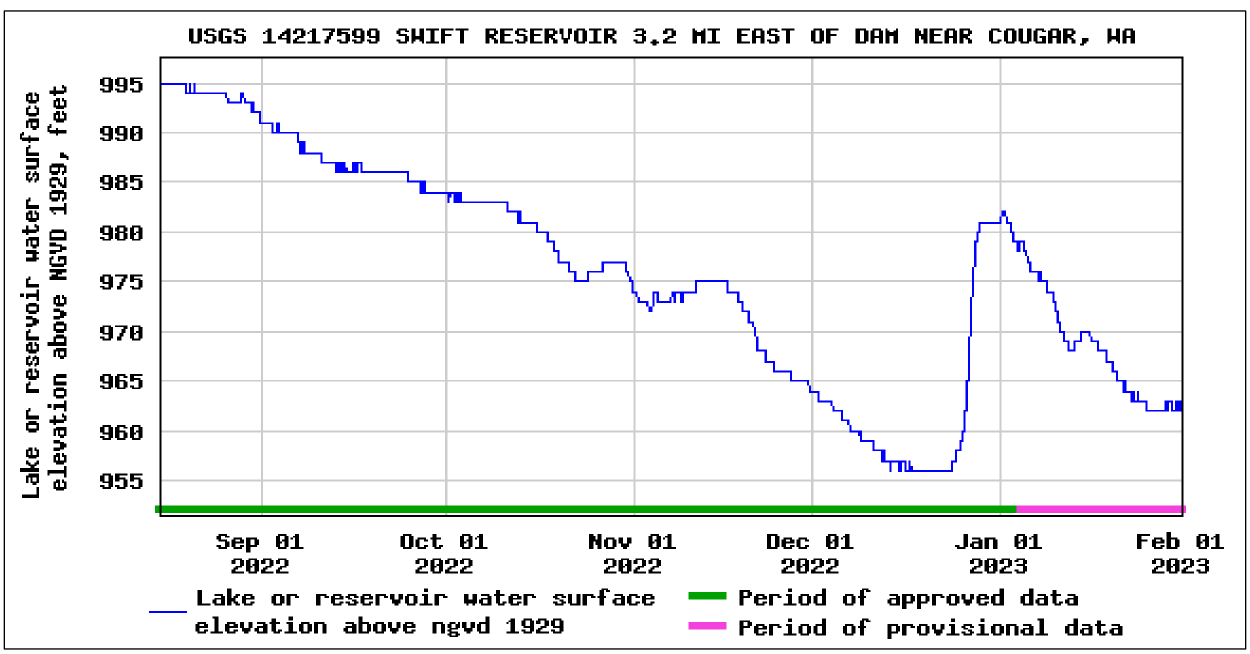

Figure 2. USGS Swift Reservoir water surface elevation (Aug 15, 2022 to Jan 31, 2023).

Results

Spring Chinook Results

A total of 1,428 female and 1,886 male adult Chinook were transported upstream of Swift Dam to spawn in 2022. In addition, 286 Chinook jacks were transported upstream (defined as any returning Chinook <24 inches in length). By the time spawning surveys began on August 31, 97% of the Chinook females had already been transported upstream (Figure 3). The remaining (3%) were transported upstream by September 25, 2022. Nearly all accessible habitat was surveyed at least twice during the Chinook spawning period from September to early October (Table 1). Due to low stream flows and excellent visibility throughout the majority of streams during the spring Chinook spawning period and measured redd visibility over time, we estimate that Chinook redd detection probability ranged between 0.80 to 0.90 during the Chinook spawning season. A few reaches were not surveyed due to accessibility issues, such as upper Clear Creek, which cannot be accessed by surveyors due to steep impassable canyon walls.

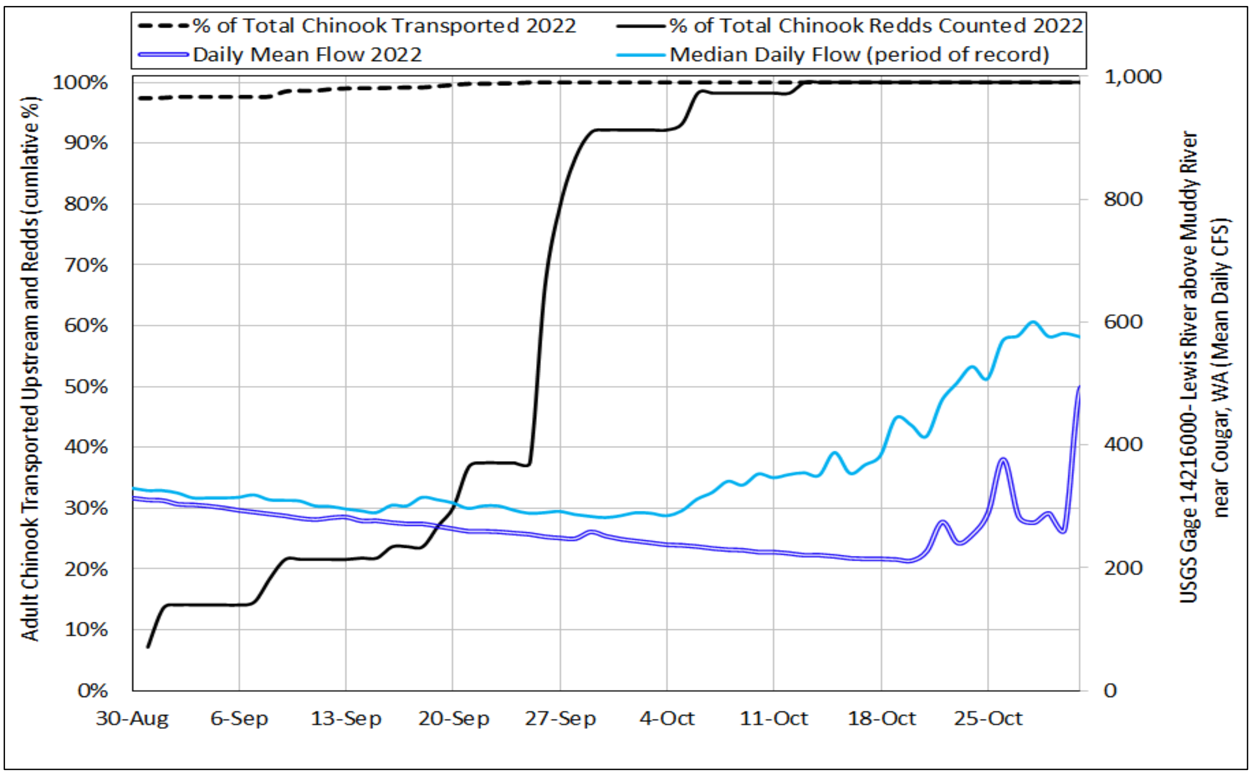

Figure 3. Chinook cumulative % redd count vs. cumulative % adult Chinook transported upstream vs flow (September to October 2022).

A total of 908 Chinook redds were counted in 2022. A total of 56% of redds were counted in the mainstem NF Lewis River, 33% were counted throughout the Muddy River watershed, and 4% were counted in the Pine Creek watershed (Table 2). The remaining redds were distributed in smaller tributaries with enough water for spring Chinook to access, such as Drift, Swift, Little, and Rush Creeks. The spatial distribution of Chinook redds was more extensive in 2022 than in all previous years combined (Figure 4). Most notably, spawning was observed for the first time in 2022 in the mainstem of Pine Creek, in the P8 tributary of Pine Creek, and Rush Creek (NF Lewis River tributary). Four actively spawning spring

Chinook adults and three Chinook redds were observed in the recently re-routed stream channel portion of Rush Creek below the Forest Road 90 bridge in September 2023. The Rush Creek channel was re-routed earlier in the summer of 2022 as part of a restoration project completed by the U.S. Forest Service under PacifiCorp's Aquatic Fund. Also of note is that a total of 60 redds (6.6% of total) were counted in Smith Creek, but from 2012-2021, only one Chinook redd total was observed in Smith Creek (Table 2). Swift Creek had a total of 37 redds (4%) in 2022, but only five redds total (1%) from 2012-2021.

Table 2. Length of habitat accessible to spring Chinook in potential spawning streams[2] and observed redd count total: 2022 and 2012-2021 (combined).

Stream Name	Accessible to Anadromous Fish Length (miles) in 2022	Surveyable[1] Length (miles)	% Surveyed of Length Accessible to Anadromous Fish in 2022	Total Observed Chinook (live and dead) 2022	Total Observed (%) Chinook Redd Count 2022	Total (%) Observed Chinook Redd Count 2012-2021
Clear Creek[1]	11.1	7.2	65%	18	51 (5.6%)	10 (2.1%)
Clearwater Creek	5.8	5.8	100%	66	62 (6.8%)	40 (8.6%)
Smith Creek[1]	3.9	3.9	92%	36	60 (6.6%)	1 (0.2%)
Muddy River mainstem	9.3	9.3	100%	37	131 (14.4%)	17 (3.6%)
Muddy River Watershed	30.1	26.2	86%	157	304 (33.4%)	68 (14.6%)
Little Creek	0.3	0.3	100%	37	18 (2.0%)	19 (4.1%)
Rush Creek	0.6	0.6	100%	4	3 (0.3%)	0 (0%)
NF Lewis River mainstem	12.9	12.9	100%	418	505 (55.6%)	372 (79.7%)
NF Lewis River & Tribs.	13.8	13.8	100%	459	526 (57.9%)	391 (83.7%)
Pine Creek mainstem	8	8	100%	33	29 (3.2%)	0 (0%)
P8 Creek	1.5	1.5	60%	4	5 (0.6%)	0 (0%)
Pine Creek Watershed	9.5	9.5	94%	37	34 (3.7%)	0 (0%)
Drift Creek	1.5	1.5	100%	0	7 (0.8%)	3 (0.6%)
Swift Creek	0.3	0.3	100%	43	37 (4.1%)	5 (1.1%)
Swift Reservoir Tribs.	1.8	1.8	100%	43	44 (4.8%)	8 (1.7%)
Grand Total	**55.2**	**51.3**	**92%**	**696**	**908**	**467**

[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.

Chinook redd counts were used to make estimates of total redds by watershed (Starcevich 2023). Total Chinook redds were estimated at 1,117 (bootstrap 95% confidence interval of 796 to 1,405). Based on the expanded total redd estimate, most redds (55%) were estimated in the NF Lewis River strata (NF Lewis River mainstem, and Little and Rush creeks); 36% were estimated in the Muddy River watershed strata (Muddy River mainstem, and Clear, Clearwater, and Smith creeks); 5% were estimated in the Swift Reservoir strata (Swift and Drift creeks); and 4% were estimated in the Pine Creek watershed strata (Pine Creek mainstem and P8 Creek).

Using the adjusted estimate of total redds based on the range of assumed detection probability and assuming one spawning spring Chinook female per redd (Murdoch et al. 2009), yields an estimate of 0.78 (bootstrap 95% confidence interval of 0.56 to 0.98) as the proportion of transported female Chinook that spawned in 2022 (Table 3). The 2022 estimate is based on the largest cohort of Chinook females transported upstream of Swift Dam to spawn, and the confidence interval of the estimate is most precise among the four years. However, the estimated proportion of spawning females is the lowest among all four years. It is also important to note that surveys in 2017 and 2018 followed the subsampling approach described previously, and only about 38% of available Chinook spawning habitat was surveyed and used for inference. However, surveys in 2021 and 2022 attempted to survey all available Chinook spawning habitat (92% surveyed in 2022 and 88% in 2021), which also contributes to the increased precision in the 2021 and 2022 estimates compared to 2017 and 2018.

Table 3. Estimates of total redds and the proportion of spawning female Chinook by year (Starcevich 2023).

Year	Chinook Females Transported above Swift Dam	Total Chinook Redd Estimate (95% CI)	Estimated Proportion of Spawning Chinook Females (95% CI)
2017	430	394 (207, 560)	0.92 (0.48, 1.30)
2018	177	354 (47, 700)	2.00 (0.26, 3.95)
2021	230	289 (173, 396)	1.26 (0.75, 1.72)
2022	1428	1,117 (796, 1405)	0.78 (0.56, 0.98)

Only three Chinook redds were counted within the DDZ of Swift Reservoir, all within the Swift Creek drawdown channel. Two redds were counted on September 19 and one redd was counted on October 13. Redds counted in the Swift Reservoir DDZ are not included in the redd count summary presented above. Three total redds is less than 1% of the total Chinook redds counted upstream of Swift Dam in 2022. Even assuming a very low detection probability of 0.3 yields a total DDZ Chinook redd estimate of about 1% of the total redds counted upstream of Swift Dam in 2022. Assuming one female Chinook per redd, it is likely that the proportion of total Chinook females that spawned in the Swift Reservoir DDZ was well below 1% during the 2022 spawning season.

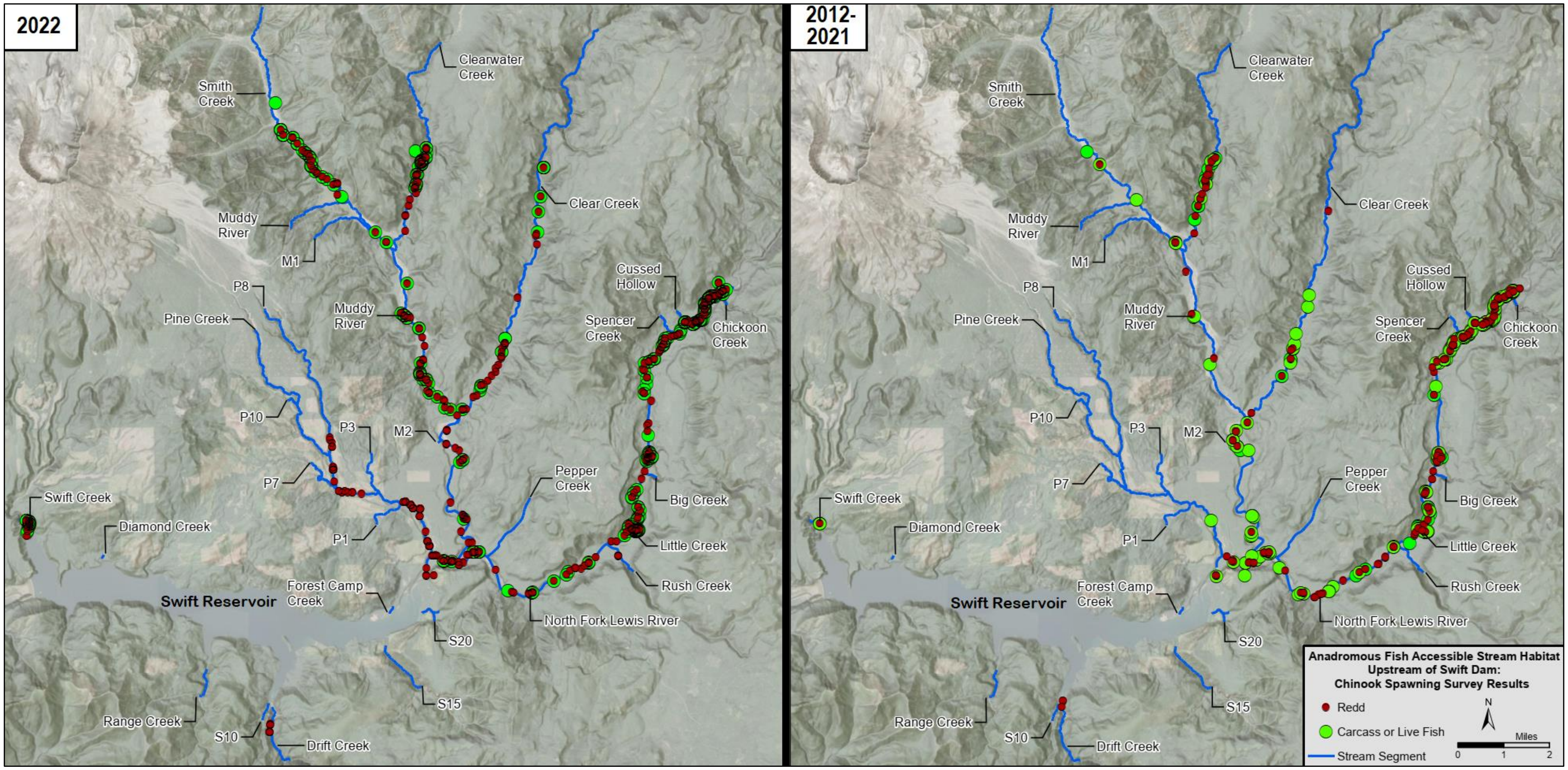

Figure 4. Chinook redd and fish observations made during spawning surveys in 2022 and all Chinook spawning survey observations combined from 2012-2021.

Coho Results

A total of 4,851 female and 4,302 male adult Coho were transported upstream of Swift Dam to spawn in 2022. In addition, 392 Coho jacks were transported upstream (defined as any returning Coho <20 inches in length). About 60% of adult Coho had been transported upstream by the time that DDZ spawning was first observed in late October, and over 95% had been transported upstream by the middle of December (Figure 5). A total of 51 Coho redds were counted in the Swift Reservoir DDZ. The Swift Creek drawdown channel contained the most redds (37%), followed by the NF Lewis River Mainstem (20%). Coho redds were observed in all DDZ channels of all streams previously documented to be used by Coho for spawning except S20 and Forest Camp creeks (Table 4, Figure 6). Very little water from S20 and Forest Camp creeks reached Swift Reservoir due to low flows and percolation into the underlying substrate, which likely limited potential DDZ spawning associated with these streams.

Most Coho DDZ spawning occurred when the reservoir water elevation was below 975 ft-msl. The lowest reservoir water surface elevation occurred between December 13 and 24, and about 35% of all Coho DDZ redds were observed during this time. All of these redds were inundated by the reservoir the following week when the reservoir rose quickly (Figure 5). Note that access for spawning surveys in the DDZ was limited when the reservoir water level was below 970 ft-msl, which precluded use of the Swift boat ramp, so only streams accessible by foot could be surveyed (NF Lewis River, S20, Swift, Forest Camp and Diamond creeks).

The total number of Coho redds in the DDZ was estimated per the methods described in PacifiCorp and Cowlitz PUD (2022). Coho redd detection probabilities were assumed to range between 0.3 and 0.6 in previous years' analyses for spawning surveys conducted upstream of Swift Dam within accessible stream reaches (e.g., Starcevich 2021). Assuming the redd detection probability in the DDZ was actually 0.3, a total of 178 redds were estimated in the Swift Reservoir for the 2022 spawning season (bootstrap 95% confidence interval of 87 to 269). Assuming the upper end of the 95% confidence interval at the lowest assumed detection probability (0.3) results in the highest estimate of potential drawdown zone spawners, 269 Coho females, assuming one spawning Coho female per redd. This represents 5.6% of the total number of females transported upstream of Swift Dam during 2022. Therefore, at most, approximately 5.6% of the female Coho transported upstream of Swift Dam in 2022 spawned in the Swift Reservoir DDZ.

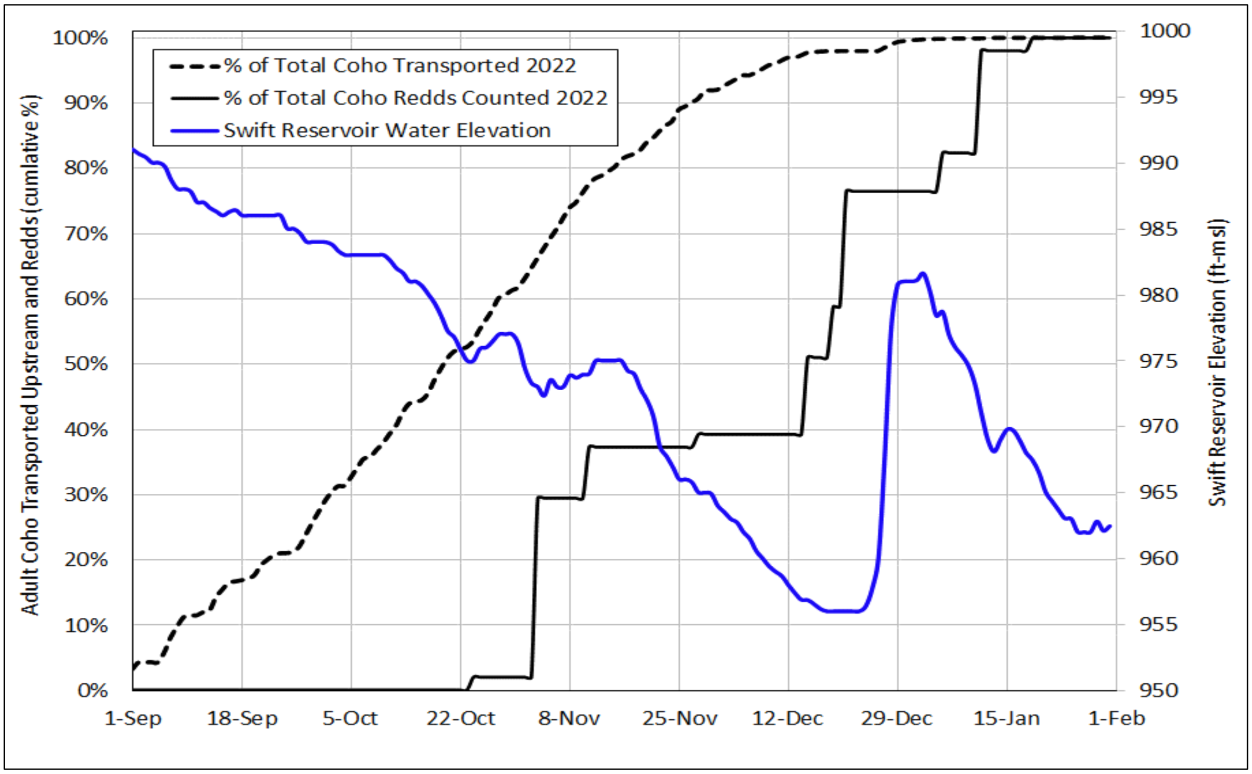

Figure 5. Coho cumulative % redd count vs. cumulative % adult Coho transported upstream vs Swift Reservoir water surface elevation (September 2022 to January 2023).

Table 4. Coho redd counts within drawdown zone channels of tributaries to Swift Reservoir (September 2022 to January 2023).

Stream Name	Total Coho (live and dead) Counted	Total (%) Coho Redds Counted
Diamond Creek DDZ	3	2 (4%)
Diamond Tributary DDZ	12	4 (8%)
Drift Creek DDZ	0	2 (4%)
Range Creek DDZ	5	6 (12%)
S10 Creek DDZ	16	4 (8%)
S15 Creek DDZ	2	4 (8%)
S20 Creek DDZ	0	0 (0%)
Forest Camp Creek DDZ	0	0 (0%)
Swift Creek DDZ	7	19 (37%)
NF Lewis River DDZ	2	10 (20%)
Total	**47**	**51**

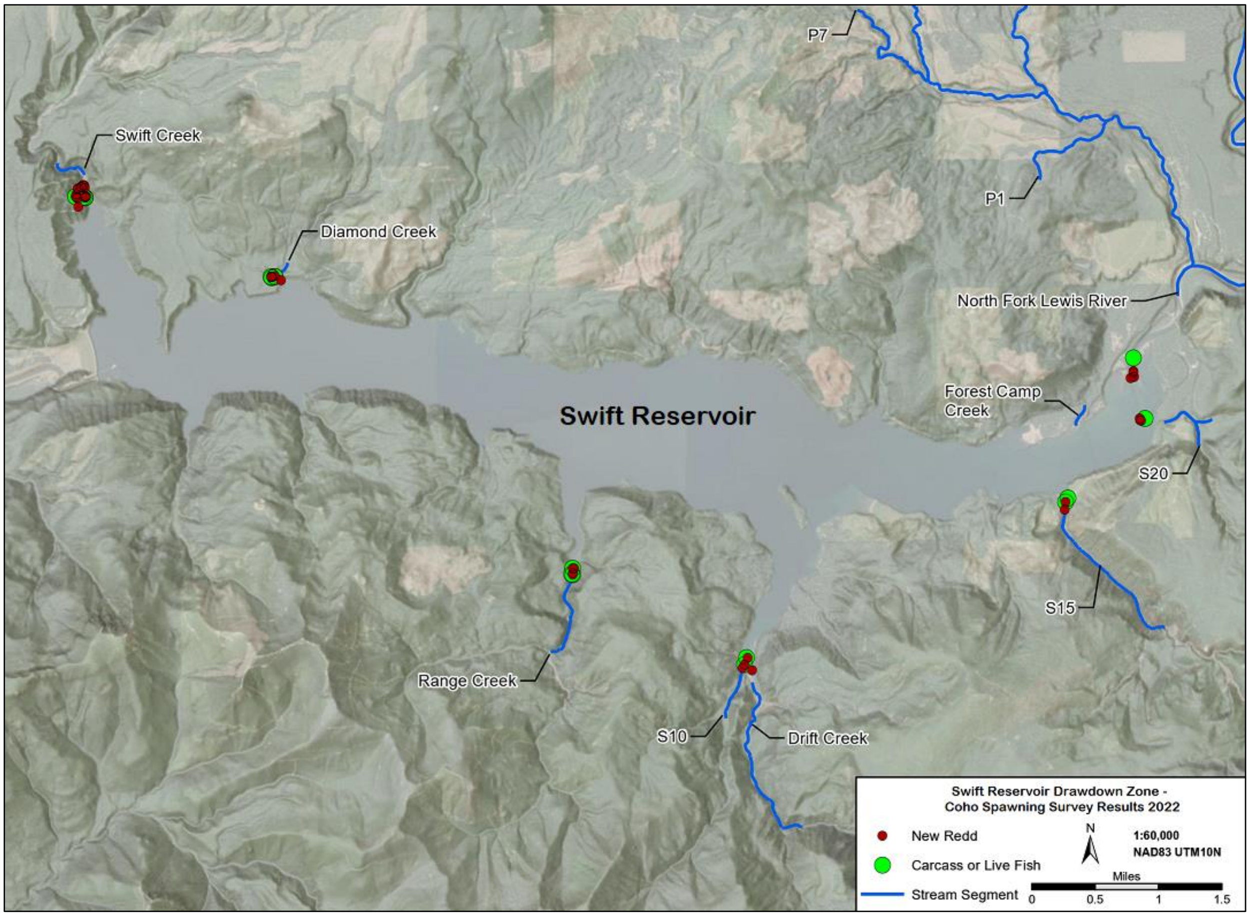

Figure 6. Coho redd and fish observations made during spawning surveys of the Swift Reservoir DDZ (September 2022 to January 2023).

Discussion and Conclusions

The adjusted estimate of total spring Chinook redds, which ranged from 0.78 to 2.00 over the four survey years (Table 3), provided an estimate of spawning females assuming that one spawning female occurs per redd. This assumption is violated if spawning females build redds on top of existing redds (termed redd superimposition), causing the total number of redds to be underestimated, and hence the proportion of spawning females to be underestimated. During 2022, there were many large aggregations of Chinook spawners building multiple redds in clusters and surveyors reported difficulty in precisely counting the number of redds in large clusters. Subsequent resurveys would also have difficulty in assessing redd superimposition if a new group of Chinook spawned in the same location, which would cause an underestimate of total redds.

A planned spill event to test facilities at Swift Dam began on June 11, 2022 and lasted for approximately 52 hours (Figure 7). By June 10, 80.5% of adult spring Chinook had already been transported upstream of Swift Dam. Based on observations of spring Chinook pre-spawn holding behavior, adult Chinook frequently hold in the vicinity of Swift Dam during the summer months. It is likely that some adult Chinook passed downstream during the June spill event, which is evidenced by the observations of several hatchery-origin adult

Chinook spawning in Cougar Creek (Yale Reservoir tributary) in 2022 and Chinook fry in the Cougar Creek screw trap catch in May 2023. If adult Chinook passed downstream via spill in June 2022, then the number of adult female Chinook used in the spawner success estimate is over estimated, which causes the spawner success estimate to be under estimated. For the reason listed above, we believe there is potential that the total Chinook redd count and estimated proportion of females that successfully spawned may be underestimated in 2022.

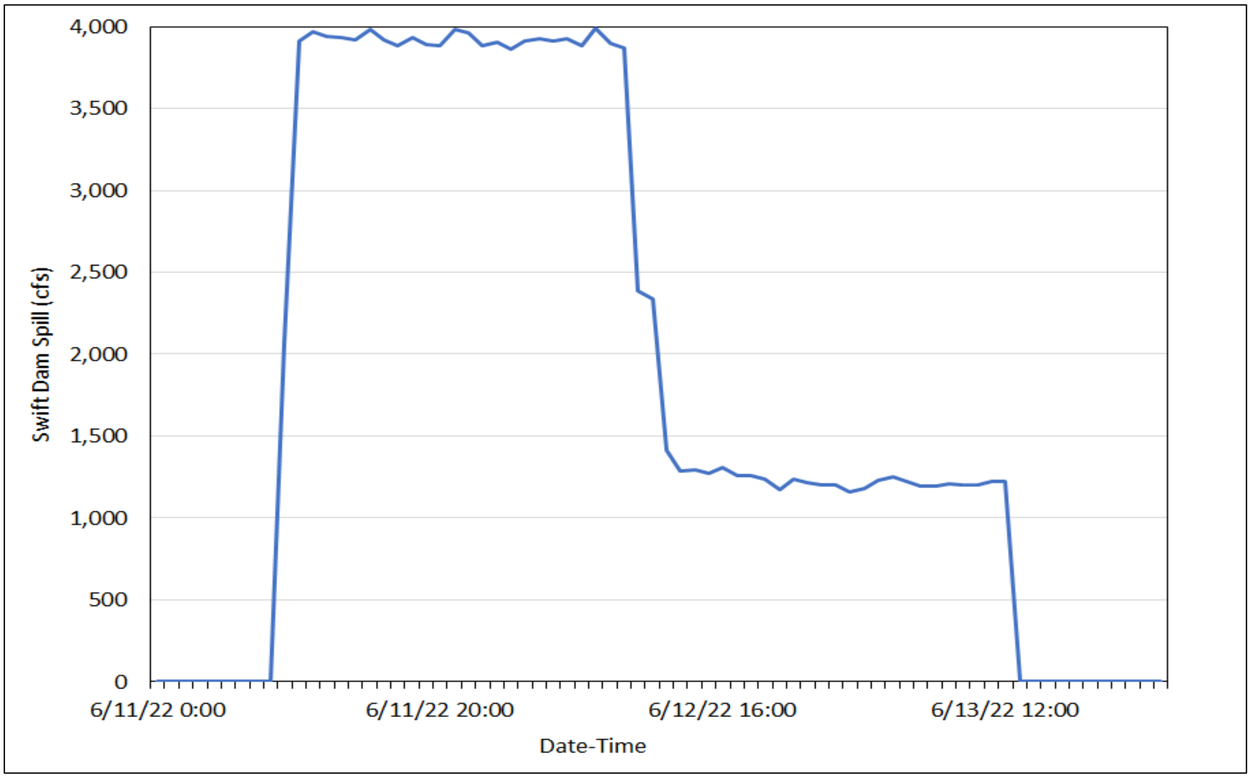

Figure 6. Spill event at Swift Dam during June 2022.

Surveys suggest that very few Chinook and few Coho spawned in the Swift Reservoir DDZ during the 2022 spawning runs. Swift DDZ surveys will continue to be conducted in 2023. Detection probability will continue to be assessed and refined for the Swift DDZ and estimates of Chinook and Coho spawners will be revised as warranted at the end of the five-year DDZ spawning survey study. Objective 15 of the Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2022) also stipulates that pre-spawn mortality will be assumed to fall within the range generally observed within the region by WDFW. The pre-spawn mortality range for Chinook and Coho will be incorporated into the spawning estimates presented in this document once provided by WDFW to further refine the estimate of the total number of successful Chinook and Coho spawners upstream of Swift Dam for the 2022 run.

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Redd Estimates from Surveys Conducted on the Upper North Fork Lewis River: 2022

Analysis Report

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May 1, 2023

CONTENTS

INTRODUCTION

Meridian Environmental, Inc. was contracted by PacifiCorp to conduct spawning surveys for anadromous fish transported upstream of Swift Dam (North Fork Lewis River watershed). Redd surveys were conducted in 2022 to monitor spawning of anadromous fish species (Coho and Chinook salmon). Transported anadromous fish had access to any of four stream networks: the Muddy River, North Fork Lewis River, Pine Creek, and several smaller independent tributaries to Swift Reservoir. Using the data from a survey designed in cooperation with Leigh Ann Starcevich in 2012, Western EcoSystems Technology, Inc. (WEST) was contracted to provide estimates of the total numbers of Chinook redds and the proportions of transported Chinook females that successfully spawned. In this report, we provide estimates for spawning parameters from the 2022 surveys for Chinook salmon.

STUDY DESIGN

In 2012, a stratified random one-stage cluster sampling design was developed. PacifiCorp planned to monitor all accessible habitat upstream of Swift Dam over a three-year period. The sampling frame of all 73.98 miles of potential anadromous fish habitat was identified for the four stream networks. Each year, roughly 25 miles of the stream networks would be surveyed. Each stream network served as a stratum so that network-level inference could be obtained. In 2016, an additional 3.12 miles of stream network in the Muddy River, North Fork Lewis River, and Swift Reservoir tributaries were determined to be part of the target population and were added to the sampling frame. These new streams added to the frame were not originally identified as potentially accessible to transported anadromous fish or became accessible after fish barriers were removed (culverts) after the original 2012 sample design was developed. These reaches were allocated across all three temporal revisit panels and those falling in the 2nd year revisit panel were surveyed in 2016. During the 2019 surveys, a previously unidentified reach was surveyed and determined to be accessible habitat extending from Swift Reservoir to an impassable culvert at the FR-90 crossing. This 0.17-mile reach on Forest Camp Creek was added to the sampling frame in the Swift Reservoir stratum.

Streams vary in length across the target population, ranging from 0.1 to 13.8 miles. An additional stratum was defined to allocate sampling effort across Short reaches (less than 8 miles long) and Long reaches (at least 8 miles long). A stream segment (i.e., reach), the sampling unit of interest for this study, was defined as continuous and non-overlapping length of stream up to 0.3-mile long. Stream segments were combined into clusters consisting of one, two, or three stream segments. Clustering within each stratum allowed for a reduction in travel time among sampling units and an increase in survey efficiency. For each sampled segment, counts of live anadromous fish, redds, and carcasses were collected. The four stream networks in the sampling frame totaled 74.15 miles of stream network after removing reaches identified in 2012 as containing barriers to fish passage and adding additional accessible reaches in 2016 and 2019.

In 2022, 61 reaches had water levels too low for Chinook to access. Low water reaches are considered non-target reaches and are removed from the sample and the frame. A total of 57.6

target stream miles are considered for the analysis. Table 1 indicates the stream length (miles) and number of stream reaches by stratum that are considered annually accessible to spring Chinook during their spawning period from late-August to mid-October.

Table 1. Number of stream reaches by stratum accessible for spring Chinook spawning.

Stratum	Watershed	Length stratum	Number of stream segments	Total length (miles)
1	Muddy River	Long	77	23.10
2	Muddy River	Short	33	9.66
3	NF Lewis River	Long	43	12.90
4	NF Lewis River	Short	3	0.91
5	Pine Creek	Long	26	7.73
6	Pine Creek	Short	5	1.50
7	Swift Reservoir Tributaries	Short	6	1.80
TOTAL				**57.6**

ANALYSIS METHODS

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

N = number of clusters in the population,

n = number of clusters in the sample,

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

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

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

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

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

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

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

Confidence intervals are computed with cluster bootstrapping.

The estimated number of redds was further adjusted for imperfect detection probabilities. In previous analyses for Chinook redds, the detection probability was approximated as 0.8 based on a detailed evaluation of Chinook redd visibility conducted during the 2017 survey season and a range of 0.75 to 0.85 was used to account for some uncertainty in the estimate. During the low water conditions in the 2021 survey, the detection probability was approximated as 0.90 with a range of 0.85 to 0.95 based on professional opinion of the survey crew who reported high-visibility survey conditions present throughout the 2021 survey season. Low water conditions in 2022 resulted in an additional adjustment of the detection probability to 0.85 with a range of 0.80 to 0.90. Additionally, the sampling frame was reduced to only the subset of 57.6 stream miles with adequate flows for Chinook spawning habitat. The Chinook redd counts from 2017, 2018, 2021, and 2022 were analyzed with the updated detection probability and sampling frame so that estimates of Chinook redds would be more accurate and comparable among years.

The detection probability range of 0.80 to 0.90 was applied in a bootstrap application to calculate an estimate of the number of redds that accounted for imperfect detection and to obtain 95%-confidence intervals based on the bootstrap. Each bootstrapped sample was obtained by bootstrapping clusters within each stratum then combining the samples across strata and calculating the estimated number of redds with the ratio estimator. Then a detection probability was selected from a uniform distribution within each detection probability range, and the estimated number of redds was inflated by this factor. For a set of 1000 bootstrap estimates, the 2.5%- and 97.5%-percentiles were used within and across strata to obtain bootstrap confidence intervals.

The proportion of spawning females was calculated as the estimated number of redds (after accounting for imperfect redd detection) divided by the total number of transported females for each species, and confidence intervals were constructed from the variance obtained from the ratio estimator. This calculation was based on an assumption that each redd represented a single spawning female, which has been empirically demonstrated for spring Chinook (Murdoch et al. 2009). Given this assumption, the known number of transported Chinook represents the known total number of females in the population upstream of Swift Dam. Therefore, the estimated number of redds is equivalent to the estimated number of spawning females. Given the total number of transported females (*f*), the proportion of spawning females, $\hat{p}_r$ is calculated as $\hat{p}_r = \frac{\hat{t}_r}{f}$ and confidence intervals are obtained with cluster bootstrapping.

RESULTS

In 2022, 61 reaches had water levels too low for Chinook to access. We considered reaches with low water to be non-target reaches and removed these 61 reaches from the sample and from the frame. Sixteen reaches were inaccessible to surveyors during Chinook surveys (but were not removed from the target population), including 13 reaches in Clear Creek with a steep gorge, two reaches in Pine Creek (P8 tributary) that were not surveyed by PacifiCorp biologists conducting surveys in that tributary, and one reach in Smith Creek that was considered too far to access in a single day. Table 2 summarizes the accessible and inaccessible stream miles by stratum. We treat inaccessible reaches as missing completely at random and extrapolate results from surveyed reaches to unsurveyed reaches to obtain estimates of total redds.

Table 2: Accessible and inaccessible (to surveyors) stream miles by stratum for 2022 Chinook surveys in the analysis.

Stream Network Stratum	Length Stratum	Inaccessible	Accessible and Surveyed
Muddy	L	3.90	19.20
Muddy	S	0.30	9.36
NF Lewis	L	0.00	12.90
NF Lewis	S	0.00	0.91
Pine	L	0.00	7.73
Pine	S	0.60	0.90
Swift	S	0.00	1.80
TOTAL		**4.80**	**52.80**

Estimated Chinook Salmon Redds

Of the 57.6 target survey stream miles assumed to represent the target population of Chinook spawning habitat, 52.8 miles were accessible and surveyed and 4.8 miles were inaccessible to crews and not surveyed . The estimated numbers of Chinook redds by stratum and across strata are provided in Table 3. A total of 908 spring Chinook redds were observed for an unadjusted estimate of 948 total redds (95%-confidence interval: 664, 1196). Adjusting for imperfect detection increased the estimated number of redds to 1,117 (95% bootstrap interval: 796, 1405). The revised estimates by stratum for surveys conducted in 2017, 2018, 2021, and 2022 are provided in Table 4. Total estimated redds ranged from 289 to 1,117 across the four survey years. The large redd counts in 2022 result in much higher estimates of total redds than in the other three years.

Table 3. Unadjusted and adjusted 2022 estimates of total Chinook salmon redds across strata.

Stream Network Stratum	Length Stratum	Total Redds Observed	Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound	Adjusted Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
Muddy	L	182	218.97	134.73	294.18	258.52	166.28	341.57
Muddy	S	122	122.76	75.13	162.61	145.93	88.21	198.46
Muddy	All	304	341.73	251.7	434.36	404.46	296.71	508.6
NF Lewis	L	505	505	266.56	710.52	592.9	317.68	833.01
NF Lewis	S	21	20.65	0	52.84	24.6	0	60.47
NF Lewis	All	526	525.65	285.49	729.76	617.5	339.01	858.85
Pine	L	29	28.74	10.31	44.17	33.73	11.96	53.87
Pine	S	5	8.33	0	15	10.19	0	17.42
Pine	All	34	37.07	17.15	56.53	43.92	20.66	66.09
Swift	S	44	44	4.5	82	51.02	5.16	98.41
All	All	908	948.45	664.13	1195.9	1116.89	796.45	1404.51

Table 4. Adjusted estimates of total Chinook salmon redds by year and across strata assuming a redd detection probability of 0.85 with a range of 0.80 to 0.90.

Stream Network Stratum	Length Stratum	2017		2018		2021		2022	
		Total Redds Observed	Adjusted Total Estimate (Bootstrap CI)	Total Redds Observed	Adjusted Total Estimate (Bootstrap CI)	Total Redds Observed	Adjusted Total Estimate (Bootstrap CI)	Total Redds Observed	Adjusted Total Estimate (Bootstrap CI)
Muddy	L	10	50.98 (0, 93.44)	4	19.41 (0, 41.79)	9	13.91 (2.42, 22.58)	182	258.52 (166.28, 341.57)
Muddy	S	5	23.84 (7.84, 38.28)	0	0 (0, 0)	34	44.66 (12.27, 71.38)	122	145.93 (88.21, 198.46)
Muddy	All	15	74.82 (28.01, 113.98)	4	19.41 (0, 41.79)	43	58.58 (24.28, 88.24)	304	404.46 (296.71, 508.6)
NF Lewis	L	87	297.34 (130.43, 462.09)	93	334.93 (43.76, 686.5)	187	218.61 (110.38, 316.84)	505	592.9 (317.68, 833.01)
NF Lewis	S	9	10.56 (0, 30.03)	0	0 (0, 0)	10	11.52 (0, 34.09)	21	24.6 (0, 60.47)
NF Lewis	All	96	307.9 (141.36, 476.09)	93	334.93 (43.76, 686.5)	197	230.13 (121.64, 330.07)	526	617.5 (339.01, 858.85)
Pine	L	0	0 (0, 0)	0	0 (0, 0)	0	0 (0, 0)	29	33.73 (11.96, 53.87)
Pine	S	0	0 (0, 0)	0	0 (0, 0)	0	0 (0, 0)	5	10.19 (0, 17.42)
Pine	All	0	0 (0, 0)	0	0 (0, 0)	0	0 (0, 0)	34	43.92 (20.66, 66.09)
Swift	S	3	10.98 (0, 22.22)	0	0 (0, 0)	0	0 (0, 0)	44	51.02 (5.16, 98.41)
All	**All**	**114**	**393.7 (207.36, 559.52)**	**97**	**354.34 (46.67, 699.64)**	**240**	**288.71 (172.84, 395.64)**	**908**	**1116.89 (796.45, 1404.51)**

Estimated Proportion of Spawning Females

Using the estimates of total redds, the proportion of spawning females is calculated assuming one spawning female per redd. Dividing the estimated number of redds by the number of transported females per year, the estimated proportions of transported female salmon that spawned are calculated (Table 5). The estimates vary across years and confidence intervals are wide in years when fewer females were transported above the dam. The 2022 unadjusted estimate of the proportion of spawning females for Chinook is 0.66 (95%-CI: 0.47, 0.84), and the detection-adjusted estimate is 0.78 (95%-CI: 0.56, 0.98). The 2022 estimate is based on the largest cohort of transported Chinook females, and the confidence intervals for the adjusted and unadjusted estimates are most precise among all years. However, the adjusted and unadjusted estimated proportions of spawning females are the lowest among all four years. It is also important to note that surveys in 2017 and 2018 followed the subsampling approach described previously, and only about 38% of available Chinook spawning habitat was surveyed and used for inference. However, surveys in 2021 and 2022 attempted to survey all available Chinook spawning habitat (92% surveyed in 2022 and 88% in 2021), which also contributes to the increased precision in the 2021 and 2022 estimates compared to 2017 and 2018.

Table 5. Unadjusted and adjusted estimates of the proportion of spawning female Chinook by year.

Year	Females Trans-ported	Est. Proportion of Spawning Females	95%-CI Lower Bound	95%-CI Upper Bound	Adjusted Est. Proportion of Spawning Females	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
2017	430	0.77	0.41	1.12	0.92	0.48	1.30
2018	177	1.71	0.33	3.42	2.00	0.26	3.95
2021	230	1.07	0.63	1.45	1.26	0.75	1.72
2022	1428	0.66	0.47	0.84	0.78	0.56	0.98

DISCUSSION AND CONCLUSIONS

Design-based estimates of Chinook salmon redds were obtained from a stratified one-stage cluster sample and ratio estimation. Additional uncertainty is introduced when nonsampling errors such as nonresponse and imperfect detection occur. Inaccessible sites were treated as missing completely at random which makes an implicit assumption that the mean redd density in the surveyed reaches is equal to the mean redd density in non-surveyed reaches. Violation of this assumption may result in overestimation or underestimation of the total number of redds depending on the differences between redd counts in the surveyed and unsurveyed reaches. However, there were very few missing (unsurveyable) reaches in 2022; therefore, the potential effect of missing reaches on total redd estimates is expected to be small. However, by nature of the sample design, estimates in 2017 and 2018 are based on inference of a much smaller proportion of surveyed reaches to the total available Chinook spawning habitat; therefore, the potential effect of non-surveyed reaches is much greater.

Chinook redd estimates from data collected during 2017, 2018, 2021, and 2022 surveys were adjusted to account for imperfect detection assuming that redd detection averaged 0.85 and ranged between 0.80 to 0.90. The adjusted estimate of total redds, which ranged from 0.78 to 2.00 over the four survey years, provided an estimate of spawning females assuming that one spawning female occurs per redd. This assumption is violated if spawning females build redds on top of existing redds (termed redd superimposition), causing the total number of redds to be underestimated, and hence the proportion of spawning females is underestimated. During 2022, there were many large aggregations of Chinook spawns building multiple redds in clusters and surveyors reported difficulty in precisely counting the number of redds in a cluster. Subsequent resurveys would also have a difficult time in assessing redd superimposition if a new group of Chinook spawned in the same location, which would cause an under estimate of total redds.

During the upstream passage sorting process, all spring Chinook less than 24 inches in length are categorized as "jacks" (small precocial males). However, some of these fish could potentially be smaller females. There is also likely some error (to an unknown degree) in identifying the sex of adult Chinook greater than 24 inches in length based on physical appearance. If the total number of females is underestimated, then the proportion of spawning females would be overestimated. In addition, female spawners may build more than one redd, causing the estimate of total female spawners to be overestimated. Sources of potential overestimation of Chinook redds include early-run Coho redds misidentified as Chinook redds; overestimation of total Chinook redds would result in total female spawners to be overestimated.

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