Lewis River Fish Passage Program
2015 Annual Report

FERC Project Nos. 935, 2071, 2111, 2213

Eagle Cliff Adult Release Pipe – 2015
Photo by Al Thomas

PacifiCorp
&
Public Utility District No.1 of Cowlitz County

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EXECUTIVE SUMMARY

The purpose of this report is to document results of the field assessments associated with implementation of the fish passage program in the existing Lewis River Aquatic Monitoring and Evaluation Plan[1] (M&E Plan) during 2015. The M&E Plan was developed as part of the Settlement Agreement to evaluate performance measures outlined in the new Licenses. These Licenses were issued to PacifiCorp and Cowlitz PUD for operation of the North Fork Lewis Hydroelectric Project on 26 June 2008. This report summarizes both upstream and downstream fish passage and collection metrics as well as providing an overview of environmental conditions and any key procedural changes that occurred in 2015. The following is a brief summary of relevant performance metrics reported on in this report:

Description	M&E Obj.	Performance Goal	2015 Data	Summary
Number of Juvenile Entering Swift Reservoir	Obj 7.	Monitoring	19,622 coho 3,474 steelhead NA Chinook	Estimates of the total number of juvenile coho and steelhead were made over a 10-week period using screw trap catch information. The trap was located at the head of Swift Reservoir at Eagle Cliff.
Fish Numbers Collected at the Swift Floating Surface Collector (FSC)	Obj. 6	Monitoring	Various	A total 47,832 salmonids were captured by the FSC in 2015. Of these fish, 39,483 were transported and released downstream of Merwin Dam.
Juvenile Migration Timing	Obj. 8	Monitoring	Various	Overall, the run timing in 2015 followed a normal spring time distribution for rivers west of the Cascade Crest. The peak spring out-migration period generally occurred from the first of April through June. Within this time frame, 85% of the coho, 61% of the spring Chinook, 90% of the steelhead and 61% of the cutthroat were collected relative to the total annual catch.
FSC Collection Efficiency (CE)	Obj. 2	Juvenile Collection Efficiency > 95%	Combined 13.2% Coho 11.8% Chinook < 1.0% Steelhead 18.6%	In 2015, CE was evaluated using acoustic telemetry. Of the 200 tagged fish released at the head of Swift Reservoir, 159 were detected in the Zone of Influence and 21 were successfully collected at the FSC for an overall CE estimate of 13.2%.
Swift FSC Injury	Obj. 5	Smolts and Fry < 2%	Fry (0.0%) Smolt (0.6%)	Annual injury rates for all juvenile salmonid species met the required performance standard of 2.0%.
Swift FSC Survival	Obj 4.	Fry > 98.0% Smolt > 99.5%	Fry (99.9%) Smolt (98.7%)	Overall, the combined survival rate for salmonid fry (99.9%) met the performance standard of 98%; however, the combined survival rates for all juvenile salmonid species (98.7%) was slightly lower than the required performance standard of 99.5 percent.

[1] Revisions to the M&E Plan began in 2015, however at the time of this document, they had not been finalized. Methods from the previously approved M&E Plan dated June 2010 were followed.

Description	M&E Obj.	Performance Goal	2015 Estimate	Summary
Overall Downstream Survival (ODS)	Obj. 1	> 80%	Coho 6.5% Chinook < 1.0% Steelhead 12.8%	During the 10-week study period only 382 coho, 37 Chinook, and 117 steelhead were tagged and released at the screw trap located at the head of Swift Reservoir. Of these fish, 10 coho, 0 Chinook, and 3 steelhead were recaptured at the FSC and passed downstream.
Fish Numbers Collected at the Merwin Fish Collection Facility	Obj. 11	Monitoring	Various	A total 15,597 fish were captured at the Merwin Trap in 2015. Of these fish, a total of 1,223 blank wire tag winter steelhead, 319 early coho, 3,435 late coho, and 31 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program.
Adult Passage Survival	Obj. 9	99.50%	Coho 100% Chinook NA Steelhead 99.8% Cutthroat 100%	All coho and cutthroat survived the trapping and transport processes resulting in a UPS of 100 percent. Six blank wire tag winter steelhead mortalities were observed at the Merwin fish sorting facility, resulting in a 99.94 percent UPS for all transported species. No spring Chinook were transported upstream in 2015.
Adult Trap Efficiency (ATE)	Obj. 10	> 98%	Coho 8.6% Chinook 37.5% Steelhead 61.6%	The first year of the ATE evaluation was completed in 2015. Estimates of ATE ranged from 8.6 to 61.6%. The second year of evaluation will be completed in 2016.

1.0 INTRODUCTION

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

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

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

The Lewis River Aquatic Monitoring and Evaluation (M&E) Plan (PacifiCorp and Cowlitz PUD 2010) was developed as part of the Settlement Agreement to evaluate performance measures outlined in the new Licenses. The primary focus of the plan is to provide methods for monitoring and evaluating the fish passage program. In accordance with the Settlement Agreement, the Licensees shall Consult with the Aquatic Coordination Committee (ACC) as necessary, but no less often than every five years, to determine if modifications to the M&E Plan are warranted (SA 9.1). Revisions to the M&E Plan are currently ongoing and are scheduled to be completed by the end of 2016. (This report follows methods outlined in the M&E Plan finalized in June 2010.) 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 2015.

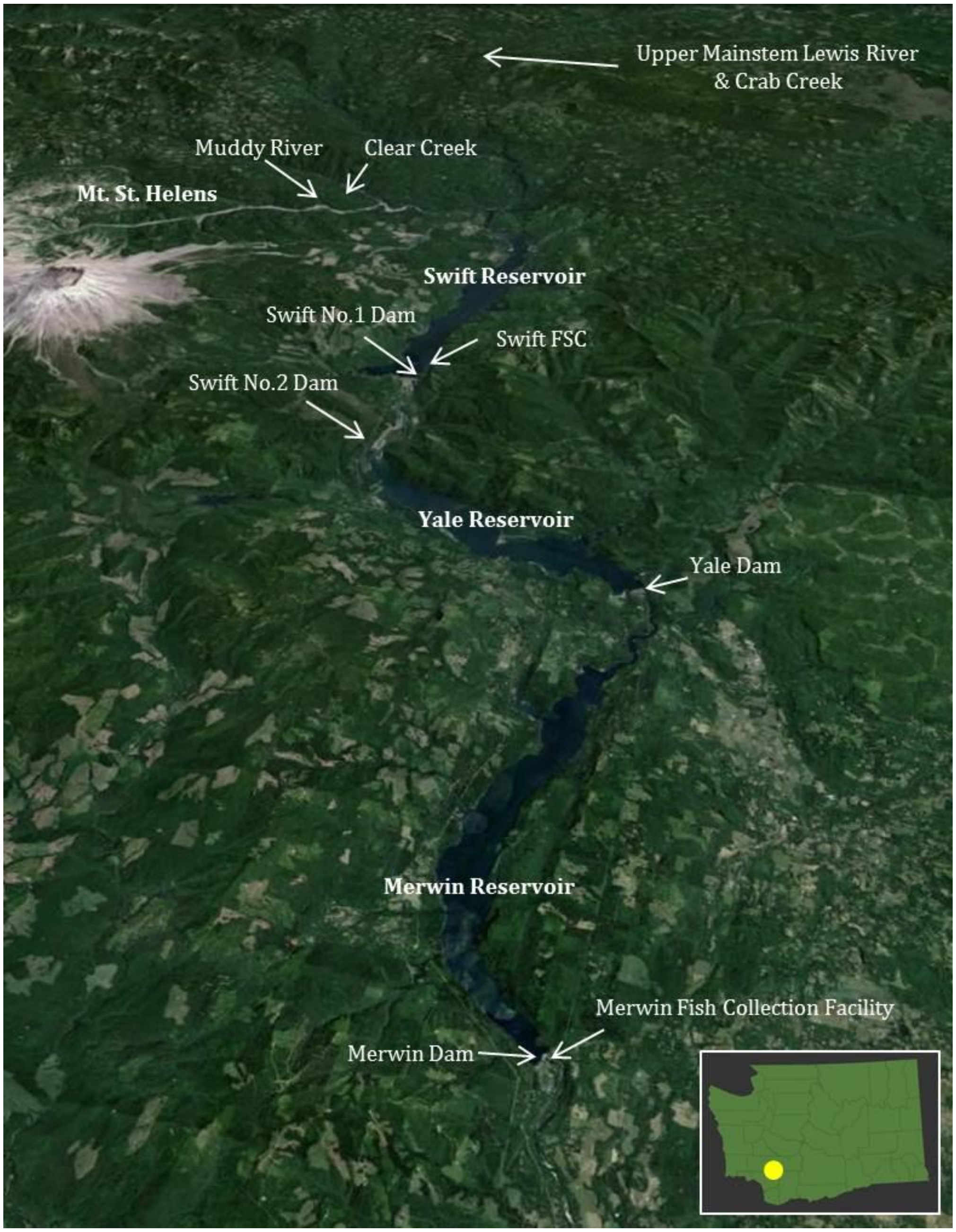


Figure 1.0-1: An overview of key features of the North Fork Lewis River Hydroelectric Project area located in Southwest, Washington.

Some noteworthy environmental conditions and procedural changes occurred in 2015. These items are summarized below:

- *Extreme River Flow Conditions:* In 2015, the Lewis River watershed experienced abnormally low snow packs along with unusually dry conditions throughout the spring and summer. Coupling these two factors resulted in low project inflow and outflows throughout the summer and early fall of 2015 (Figure 1.1-1). To ensure enough project storage would remain for fall Chinook and coho spawning seasons in the lower river, the Flow Coordination Committee (FCC) approved a reduction in minimum flow requirements beginning April 22, 2015 through November 17, 2015 (Table 1.1-1). All minimum flow schedule modifications were agreed upon by the FCC per License Article 415 and the Lewis River Settlement Agreement Section 6.2.4 and 6.2.5.

Table 1.1- 1: FCC minimum flow requirement modifications made in 2015 are shown. Respective License flow requirements during those dates of modifications are also shown.

Date	FCC Approved Flow (cfs)	License Minimum Flow (cfs)
Apr. 22 - June 30	2,300	2,700
July 1 - July 10	1,500	2,300
July 11 - July 20	1,200	1,900
July 21 - July 30	1,200	1,500
July 31 - Oct.15	800	1,200
Oct. 16 - Oct. 31	800	2,500
Nov. 1 - Nov. 3	800	4,200
Nov. 4 - Nov. 9	2,500	4,200
Nov. 10 - Nov. 17	3,300	4,200

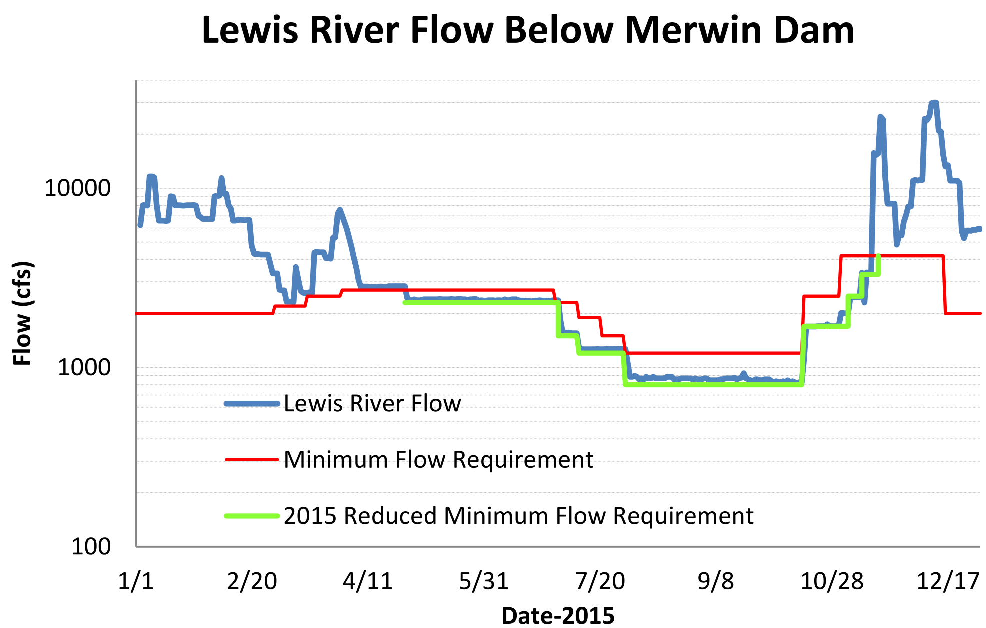


Figure 1.1-1: Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA). Minimum flow requirements and 2015 reduced minimum flow requirements are also shown.

Following record low water conditions in the spring and early fall, extreme high flows occurred during December 2015. In order to maintain minimum reservoir storage requirements, spill occurred at Merwin Dam from December 6, 2015 through December 24, 2015. Maximum total flow below Merwin Dam reached approximately 31,000 cfs. From December 8, 2015 through December 15, 2015 spill also occurred at Yale and Swift Projects.

- *FSC Summer Outage and Maintenance Period:* In March 2015, the ACC accepted operational changes which allowed for the FSC to be turned off during warm reservoir conditions that occur in the summer (Operational Memo March 17, 2015; Appendix A). This was done in support of data that indicated that once reservoir temperatures reach approximately 18 ^{o}C, catch rates of fish declined precipitously. Those fish that were collected also experienced high levels of mortality. Annual maintenance activities will be performed during this summer outage period. It was also decided that while the FSC was offline, operation of the Merwin Trap would be changed from a seven (7) day per week schedule to a five (5) day per week schedule (Operational Memo July 9, 2015; Appendix A). This temporary scheduled allowed for the fish lift and conveyance system to remain operational seven (7) days per week, however daily sorting of fish would only occur Monday through Friday.

- *Modification of the Supplementation Protocols for Adult Coho Transported Upstream of Swift Dam:* In July 2015, the Hatchery and Supplementation (H&S) subgroup met to discuss the protocol for adult coho supplementation upstream of Swift Dam in fall 2015. As part of this discuss, several important modifications were proposed and were ultimately accepted by the ACC during the August 2015 meeting. A detailed description of these modifications are included in Appendix B and briefly described below:

- Reduction in the number of coho supplemented from 9,000 to 7,500 total adults upstream of Swift Dam in 2015;
- The addition of late (Type – N) coho as a supplementation species;
- Extending the upstream transport schedule to include both early (Type – S) and late (Type – N) stocks of adults coho.

- *Releases of Acclimation Fish Changed from Spring Releases to Fall Releases:* During their June 2015 meeting, the ACC agreed that releasing acclimation fish earlier in the fall is a better strategy and more akin to the natural out-migration behavior that has been observed in the upper basin. It was also determined that fish released in the fall would be held a shorter amount of time in the hatchery and thus less susceptible to disease (i.e., Bacterial Kidney Disease – BKD) that has been observed in previous years. Consequently, it was agreed that smolts scheduled to be release in spring 2016 would be instead be released in fall 2015. Fall releases of acclimation fish would be implemented moving forward. It was decided that smolts would be directly released at two locations due to low water conditions and the inability to maintain consistent water levels in the ponds. This decision was made after the acclimation fish already allocated to be released in spring 2015 had been released, therefore two separate release events of spring Chinook in the upper watershed were performed in 2015 (Table 1.1-1):

Table 1.1-2. Summary of acclimation fish released into the Upper Lewis River Basin in 2015..

Spring Chinook Acclimation Releases	Date	Upper Lewis River (Crab Creek Bridge)	Clear Creek (FS 93 Rd Bridge)	Total
March 2015	3/3	37,022	-	109,666
	3/4	-	72,644	
October 2015	10/21	14,739	-	48,000
	10/22	-	33,261	
	Total	**51,761**	**105,905**	
	Overall Total	**157,666**		

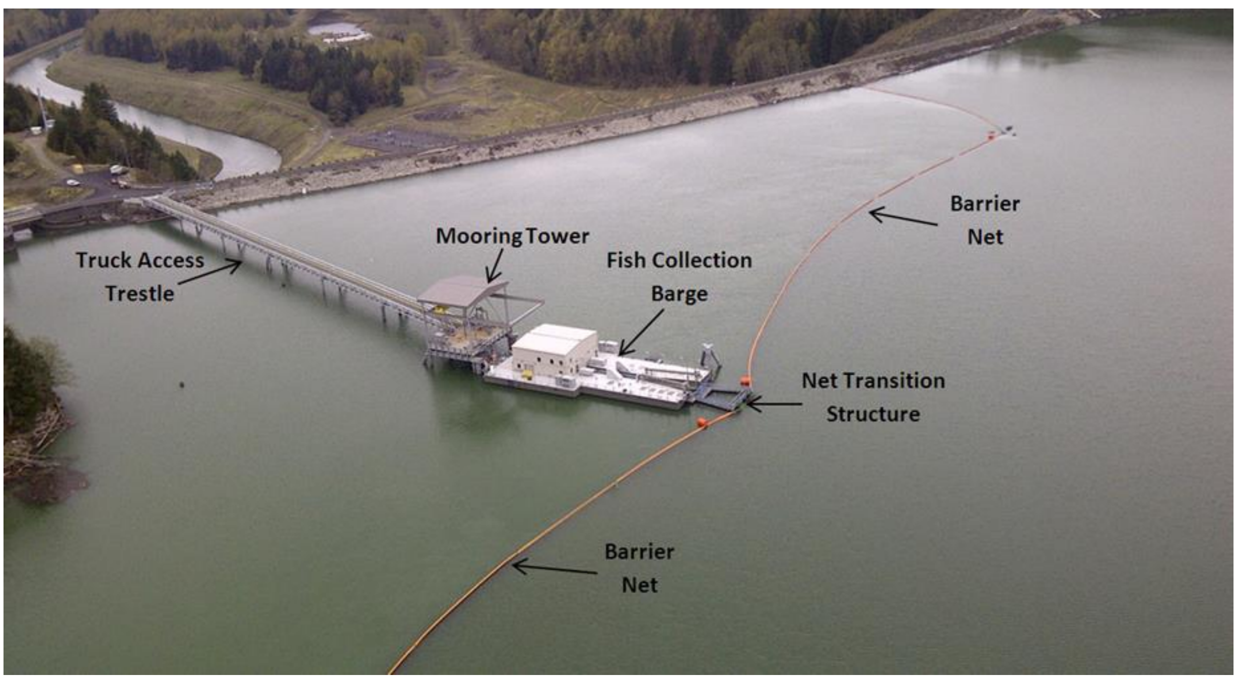
2.0 PASSAGE FACILITIES

2.1 Swift Reservoir Floating Surface Collector

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

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

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



[2] Following transport downstream, smolts are to be transferred into release ponds located near Woodland, WA. Fish are held in these ponds for 24-hours before being allowed to volitionally enter the river. As of December 2015, these ponds have not been constructed. Fish transported downstream in 2015 were released directly in the lower river.

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

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

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

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

The FSC was operated 24-hours a day through 2015 except during periods when it was necessary to shut the facility down due to power outages, facility modification, or scheduled maintenance (Table 2.1-1).

Table 2.1-1. List of FSC outages that occurred in 2015.

Outage Duration	Purpose
July 7th - October 15th	Scheduled summer maintenance period
December 8th - December 15th	Barrier net down for open spillway
December 22nd - December 26th	Heavy debris loading
December 30th - December 31st	Heavy debris loading

[3] The Swift FSC has an operation range of 120 feet in reservoir elevation change.

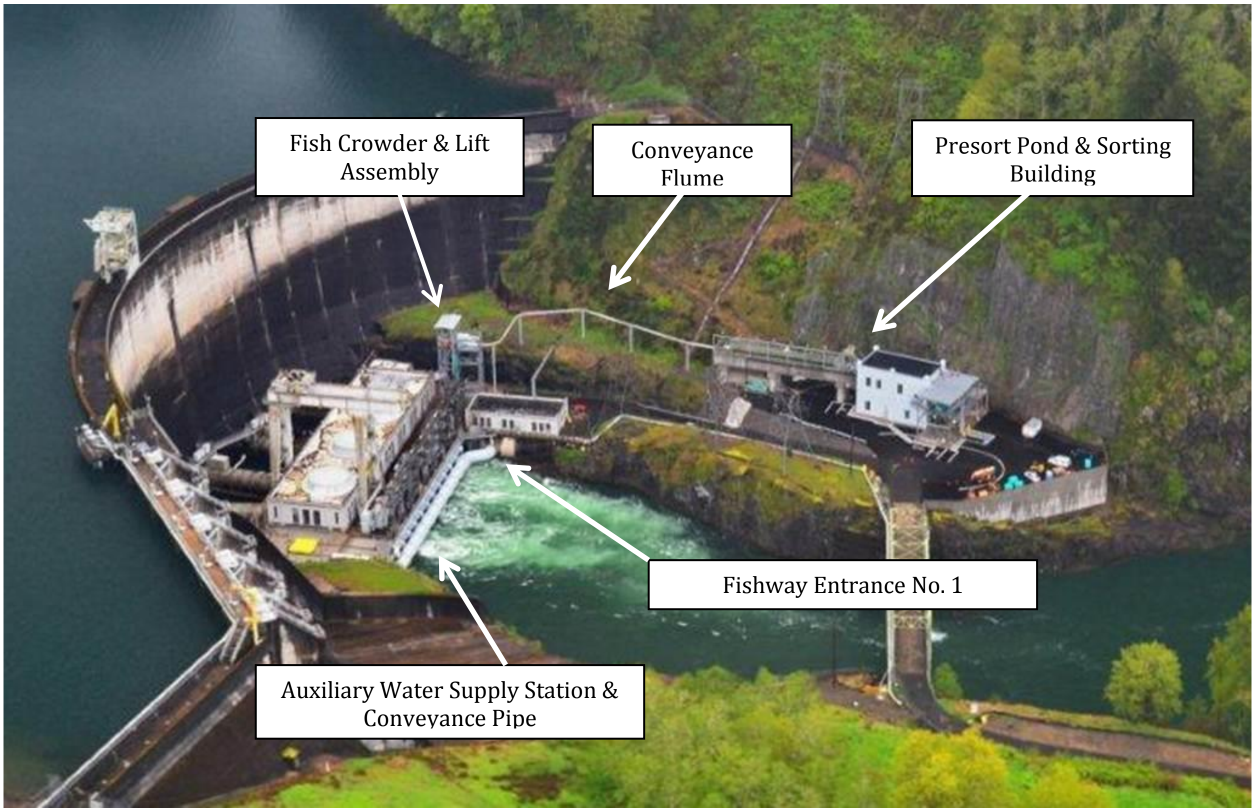


Figure 2.2-1: Merwin Sorting Facility.

2.2 Merwin Upstream Collection Facility

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

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

Phase I represents the initial construction, consisting of four major features:

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

- Sorting Facility

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

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

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

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

The Merwin Fish Collection Facility was operated 24-hours a day through 2015 except during periods when it was necessary to shut the facility down due to facility modifications, scheduled maintenance, or repairs (Table 2.1-1).

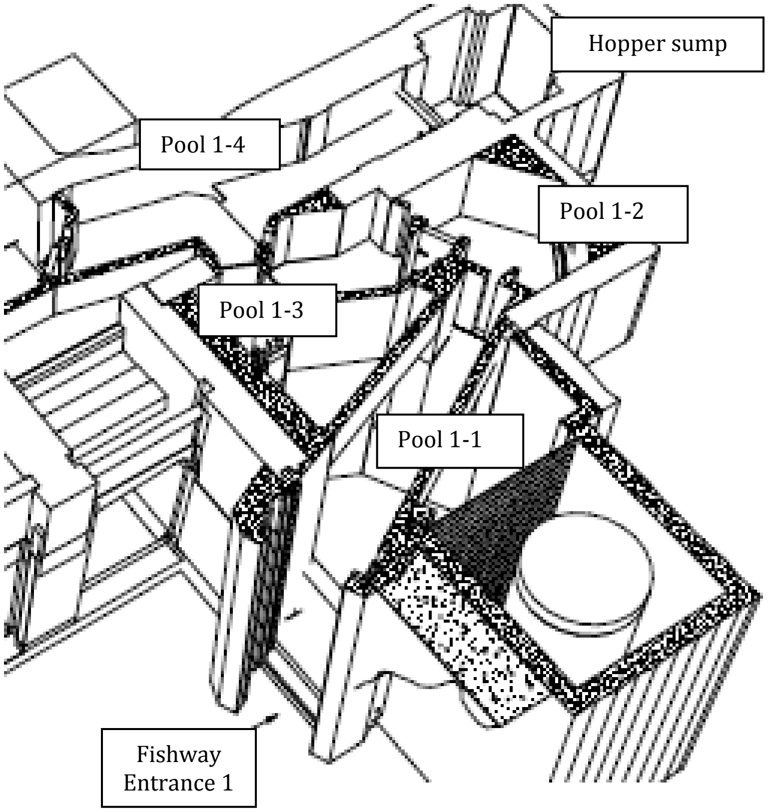


Figure 2.2-2: Merwin Sorting Facility ladder entrance and pool configuration.

Table 2.2-1. A list of scheduled out at the Merwin Fish Sorting Facility in 2015.

Outage Duration	Purpose
January 4th	Repairs - lift and conveyance system
January 18th	Repairs - lift and conveyance system
January 19th	Repairs - lift and conveyance system
[a] February 14th	Repairs – facility air compressor
February 26th - February 27th	Radio telemetry equipment install
April 17th -April 20th	Repairs - lift and conveyance system
May 2nd	Repairs - lift and conveyance system
September 6th - September 14th	Repairs - lift and conveyance system
November 16th - November 19th	High water shut down protocol
November 22nd	High water shut down protocol
December 8th - December 15th	High water shut down protocol
December 17th - December 18th	High water shut down protocol
December 20th	Repairs - lift and conveyance system repairs

[a] The fish crowder, lift assembly and pre-sort pond remained operational - only the sorting facility was not operated.

3.0 DOWNSTREAM COLLECTION AND PASSAGE METRICS

3.1 Number of Juveniles Entering Swift Reservoir

3.1.1 Overview

Developing an annual estimate for total number of juveniles entering Swift Reservoir is required under section 9.2.1(a) of the Settlement and identified as Objective 7 of the M&E Plan. In spring 2015, a single screw trap was installed in the mainstem of the North Fork Lewis River just upstream of the head of Swift Reservoir near the Forest Road 90 Bridge (Eagle Cliff). As outlined in the M&E Plan, subsets of juvenile salmonids collected at the trap daily were marked using Passive Integrated Transponder (PIT) tags. These fish were then either released at the trap to continue their migration downstream into Swift Reservoir, or transported and released upstream of the screw trap to estimate trap efficiency.

Following the M&E Plan, estimates of emigration were to be developed on a weekly basis for juvenile spring Chinook, coho and steelhead over the out-migration period. Estimating the numbers of juveniles entering Swift Reservoir ($\boldsymbol{N_{Ent}}$) was calculated for each species by dividing the total weekly catch by the respective weekly trap efficiency (Equation 3.1-1).

$$\boldsymbol{N_{Ent} = \frac{S_{sp}}{\eta_{sp}}} \qquad \textbf{Equation 3.1-1}$$

$\boldsymbol{N_{Ent}}$ = Total fish of a given species entering Swift Reservoir for the respective week;
$\boldsymbol{S_{sp}}$ = Total number of fish of a given species captured in screw trap for the respective week;
$\boldsymbol{\eta_{sp}}$ = Screw trap efficiency for respective week and species.

Where weekly trap efficiencies ($\boldsymbol{\eta_{sp}}$) were calculated as:

$$\boldsymbol{\eta_{sp} = \frac{R_{sp}}{T_{sp}}} \qquad \textbf{Equation 3.1-2}$$

$\boldsymbol{\eta_{sp}}$ = Screw trap efficiency for respective week and species;
$\boldsymbol{R_{sp}}$ = Total number of recaptured fish for respective week and species;
$\boldsymbol{T_{sp}}$ = Total number of released tag fish for respective week and species.

The key assumptions inherent in the analysis noted in Objective 7 of the M&E Plan are:

1. Juvenile survival rate from small tributaries in the reservoir to the FSC are similar to those for tributaries upstream of Swift Reservoir;
2. Survival rate for tagged fish is the same as for un-tagged fish; and

3. Tagged fish do not show trapping tendency or trap avoidance that differs from untagged fish.

3.1.2 Results/Discussion

In 2015, the screw trap at the upstream end of Swift Reservoir was in operation from March 25th to June 1st. During that 10-week period, a total of 473 coho, 181 juvenile steelhead, and 37 spring Chinook were captured (Table 3.1-1). Of these captured fish, 7% (n = 362) of the coho, 65% (n = 117) of the steelhead, and 100% (n = 37) of the spring Chinook were tagged and transported upstream to estimate trap efficiency.

A reliable estimate of total number of spring Chinook juveniles Swift Reservoir could not be calculated in 2015. This was the result of low migration numbers of species combined with very low recapture rates. It was estimated that 19,622 coho and 3,474 steelhead juveniles emigrated through the head of Swift Reservoir. (No confidence intervals were calculated at this time). During weeks when trap efficiencies could not be calculated the weighted average of efficiencies for the respective species was used for estimating the weekly emigration (Table 3.1-1).

Future estimates of the number of juveniles entering Swift Reservoir is dependent of collecting enough out-migrants to make statistically meaningful estimates. It is expected that as introduction continues, more out-migrants will be available. However, limitations to the current methodology do exist and should be considered in future estimates. The first limitation is that the current methods only focus on out-migrants produced in the upper basin of Swift Reservoir, and do not account for any production in the tributary streams located within the reservoir itself. Based on recent observations made during spawning surveys and from radio tagged fish, these tributaries (e.g., Drift Creek, Swift Creek) do get frequently used for spawning habitat by both adult coho and winter steelhead. The second limitation is that river flow and environmental conditions dictate when the screw trap can be operated at Eagle Cliff. Based on several years of capture data from the Swift Floating Surface Collector, out-migrants are collected throughout the late-fall, winter and spring periods. It is possible that a large proportion of fish enters the reservoir during the periods when the screw trap is not in operation due to operational constraints (e.g., high flows) and is therefore not included in the estimate. These limitations should be considered if the existing approach for estimating the number of out-migrants entering Swift Reservoir is implemented in the future.

Table 3.1-1: Estimated number of smolts entering Swift Reservoir during spring 2015 migration season. 'Tagged' refers to the total amount of fish that received a PIT tag and were released upstream of the screw trap to evaluate screw trap efficiency. Efficiencies that could not be calculated for a given week were assigned as the weighted average of other calculated weekly efficiencies; these are signified by an asterisk.

Week	Coho					Spring Chinook					Winter Steelhead				
	Captured	Tagged	Recap	Efficiency	Estimate	Captured	Tagged	Recap	Efficiency	Estimate	Captured	Tagged	Recap	Efficiency	Estimate
1	80	36	1	*2.8*	***2857***	20	20	1	*5.0*	***400***	18	12	1	*8.3*	***217***
2	32	19	1	*5.3*	***608***	5	5	0	*N/A*	*N/A*	5	0	0	*5.8**	***86***
3	28	14	1	*7.1*	***392***	3	3	0	*N/A*	*N/A*	15	7	0	*5.8**	***259***
4	28	22	0	*2.9**	***966***	0	0	0	*N/A*	*N/A*	15	8	1	*12.5*	***120***
5	23	21	1	*4.8*	***483***	0	0	0	*N/A*	*N/A*	21	15	1	*6.7*	***313***
6	32	28	0	*2.9**	***1103***	0	0	0	*N/A*	*N/A*	40	26	1	*3.8*	***1053***
7	61	57	0	*2.9**	***2103***	5	5	1	*20.0*	***25***	35	25	1	*4*	***875***
8	94	85	1	*1.2*	***7833***	3	3	0	*N/A*	*N/A*	20	17	0	*5.8**	***345***
9	78	65	0	*2.9**	***2690***	1	1	0	*N/A*	*N/A*	9	6	0	*5.8**	***155***
10	17	15	0	*2.9**	***586***	0	0	0	*N/A*	*N/A*	3	1	0	*5.8**	***52***
Total	***473***	***362***	***5***	***2.9% Avg***	***19,622***	***37***	***37***	***2***	*N/A*	*N/A*	***181***	***117***	***5***	***5.8% Avg.***	***3,474***

3.2 Fish Numbers Collected at the FSC

3.2.1 Overview

Section 9.2.1(j) of the Settlement requires PacifiCorp to enumerate the number of salmonids collected at FSC (FSC_{COL}) by species and life-stage. This requirement is identified as Objective 6 in the M&E Plan. The M&E Plan originally stated that the number of juvenile fish entering the FSC would be calculated through both subsampling and by automatic fish counters. During development of the M&E Plan the accuracy of the automatic fish counters were unknown, thus conducting both methods of enumeration was recommended initially. However, during the operating years' 2013-2014, 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 done through subsampling counts as described in section 2.6.1 of the M&E Plan; the key assumption inherent in the methodology is that the subsampled fish are representative of the general population.

SUBSAMPLING COUNTS

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

$$\boldsymbol{FSC_{COL} = \frac{N_{SUB}}{S_{DIV}}} \qquad \textbf{Equation 3.2-1}$$

$\boldsymbol{FSC_{COL}}$ = Number of fish by species collected each day by the FSC;
$\boldsymbol{N_{SUB}}$ = Number of fish by species subsampled each day;
$\boldsymbol{S_{DIV}}$ = Diversion gate sampling rate for respective day.

However, because daily fish collection numbers remained manageable throughout most of 2015, sample rates were continuously set to 100%. Only from May 14th through June 22nd was the diversion gate in operation and subsampling occurred. During this period, a simple linear expansion method as described above was used to derive the total number of fish collected on a given day based on the proportion of fish sampled that day. On a daily basis, fish in the subsample tanks were anesthetized, identified to species and life-stage, and enumerated. All sampled fish were measured for fork length (mm) one day per week.

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

Month	Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Rainbow Trout	Total Trapped
	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Kelt	Fry	< 13 in.	> 13 In.			
January	1	638	157	0	0	9	492	0	0	1	5	0	0	0	45	0	7	35	1,390
February	2,549	3,112	256	0	0	96	458	0	0	7	1	0	0	0	94	4	2	112	6,691
March	3,228	247	169	0	0	53	535	0	0	3	22	4	0	0	36	0	0	319	4,616
April	40	15	684	0	0	5	530	0	0	2	141	9	1	0	60	3	2	272	1,764
May	5	34	14,873	0	0	4	1,934	0	0	7	880	3	23	0	295	38	3	541	18,640
June	1	193	6,998	0	0	22	278	0	0	2	150	0	7	1	64	3	1	569	8,289
July	0	1	41	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	43
August																			
September																			
October	1	14	100	3	0	11	80	0	0	2	5	0	0	0	0	0	2	0	218
November	23	1630	1,339	5	0	7	378	0	3	12	51	0	0	3	90	0	2	4	3,547
December	12	845	938	27	0	23	619	0	2	11	27	0	0	13	92	0	1	24	2,634
Annual Total	***5,860***	***6,729***	***25,555***	***35***	***0***	***230***	***5,305***	***0***	***5***	***47***	***1,282***	***16***	***31***	***17***	***776***	***48***	***20***	***1,876***	***47,832***

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

Coho				Chinook				Steelhead					Cutthroat			Bull Trout	Rainbow Trout	Target Species Downstream
Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Fry	Parr	Smolt	Adult	Kelt	Fry	< 13 in.	> 13 In.			
0	6,478	25,441	0	0	227	5,174	0	0	47	1,277	0	28	0	763	48	0	290	39,483

3.2.2 Results/Discussion

A total 47,832 salmonids were captured by the FSC in 2015 (Table 3.2-1). Of these fish, 39,483 were transported and released downstream of Merwin Dam (Table 3.2-2). Juvenile coho accounted for the highest proportion of the overall catch (81%), followed by spring Chinook (14%), steelhead (3%) and coastal cutthroat trout (2%). A total 1,586 hatchery rainbow trout and 20 bull trout were collected in 2015 and returned to the reservoir. Approximately 290 hatchery rainbow trout were passed downstream of Merwin Dam during subsample collection (May-June).

3.3 Juvenile Migration Timing

3.3.1 Overview

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

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

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

3.3.2 Results/Discussion

Overall, the run timing in 2015 followed a normal spring time distribution for rivers west of the Cascade Crest. The peak spring out-migration period generally occurred from the first of April through June. Within this time frame, 85% of the coho, 61% of the spring Chinook, 90% of the steelhead and 61% of the cutthroat were collected relative to the total annual catch (Figures 3.3-1 through 3.3-12). In addition to the spring out-migration period, a large number of spring Chinook were also collected in the fall and early winter. This out-migration period accounted for approximately 39% of the total annual number of Chinook collected in 2015. This trend in Chinook smolts out-migrating in the fall was also observed in 2013 and especially in 2014. Coastal cutthroat followed a similar out-migration trends a coho with the majority of fish passing in April and May along with a smaller component of fish out-migrating in the fall.

COHO SIZE DISTRIBUTIONS

A bimodal size distribution was observed for juvenile coho collected at the FSC throughout the year, however the mean length of each mode varied by season. Early in the year (January – March), coho fry and parr dominated the catch followed by a much smaller component of larger smolts (240 – 290 mm). In the spring (April – June), coho out-migrants were consistently between 121 mm to 230 mm in length (Figure 3.1-11); coho fry and parr or smolts greater than 230 mm were rarely observed the spring. Later in the year (October – December), a wide range of coho sizes were collected with fish ranging in size from 60 to 300 mm although the majority of fish ranged from 90 to 150 mm (Figure 3.1-11).

SPRING CHINOOK SIZE DISTRIBUTIONS

Review of spring Chinook data captured at the FSC in 2015 reveals size class distribution patterns that positively correlate with hatchery smolt releases. This suggests the majority of spring Chinook collected by the FSC in 2015 originated from the acclimation plants. Acclimation fish were released during both the spring (March) and fall (October) in 2015. However, smaller spring Chinook (less than 120 mm) were also observed predominately in early spring, suggesting that some natural production is occurring. No adult spring Chinook have been introduced since 2013, which indicates that natural populations of spring Chinook residing in the reservoir are successfully reproducing in the upper tributaries.

STEELHEAD SIZE DISTRIBUTIONS

In the spring (April – June), the median steelhead fork length was approximately 240 mm (Figure 3.1-15). The few steelhead that were captured during the remainder of the year displayed a variety of sizes (Figure 3.1-15).

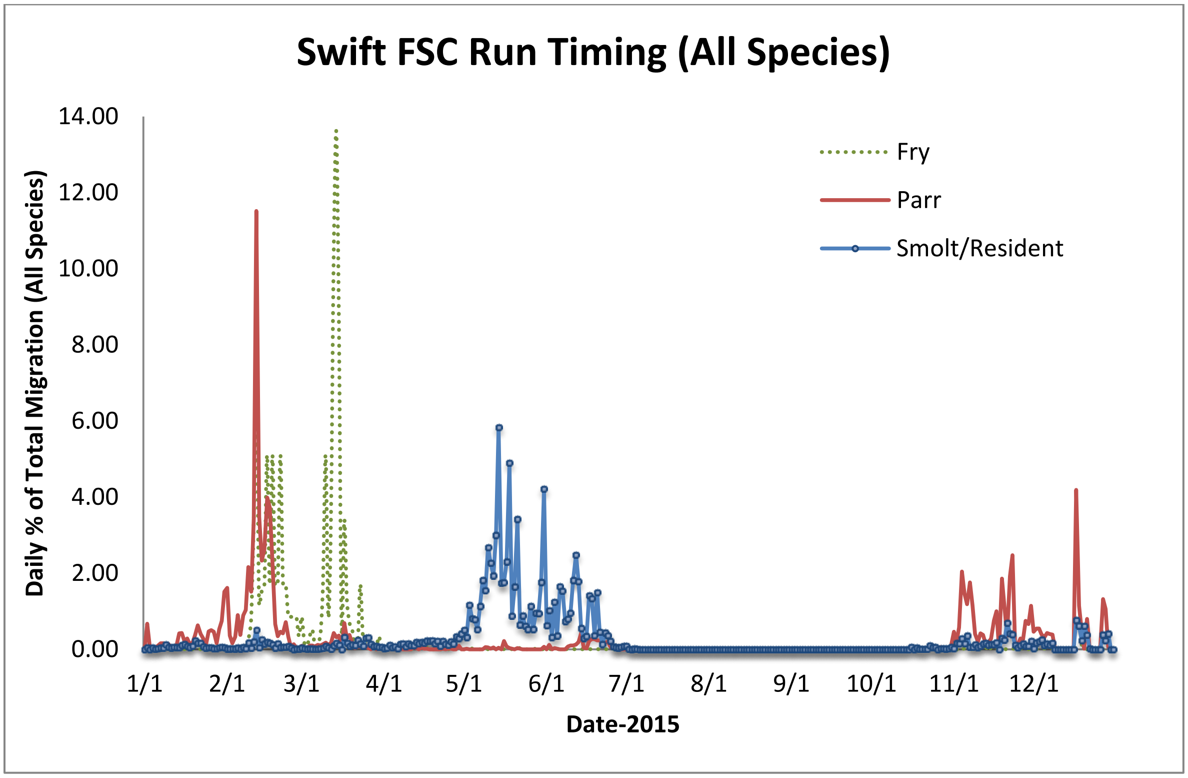


Figure 3.1-1: Estimated daily percent of total migration among all species captured at the FSC.

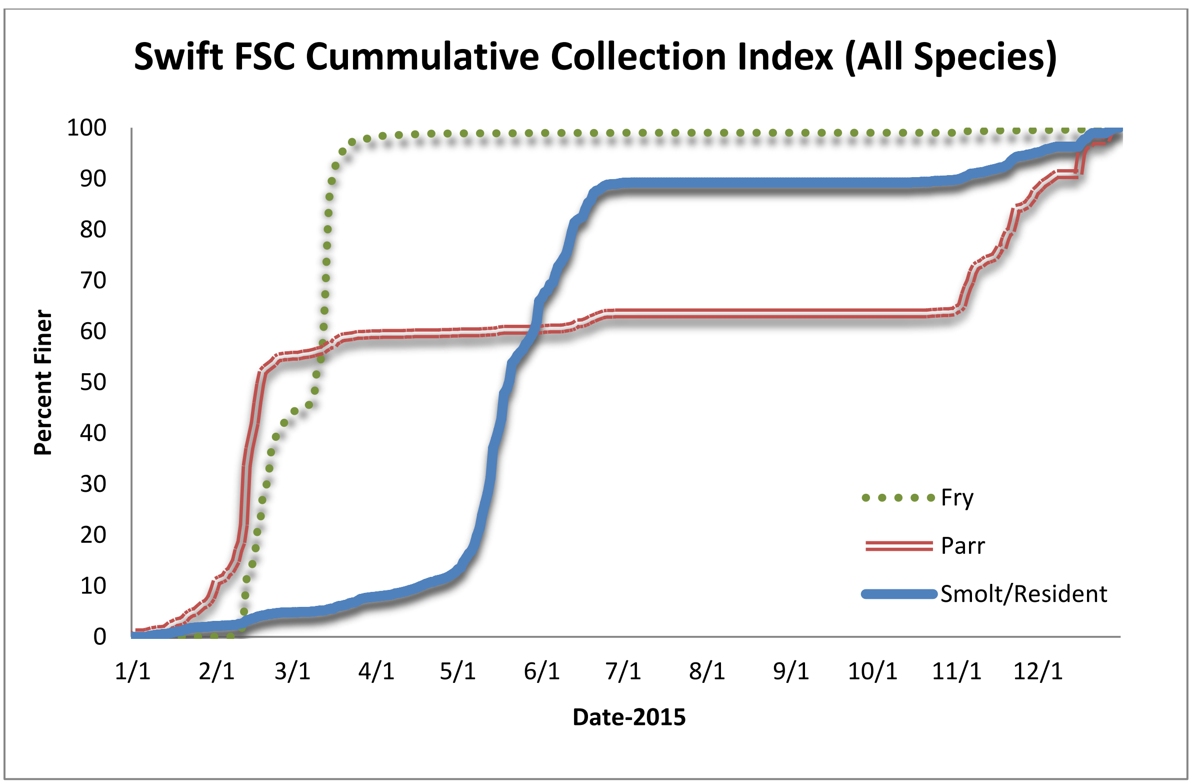


Figure 3.1-2: Cumulative migration timing among all species of fish.

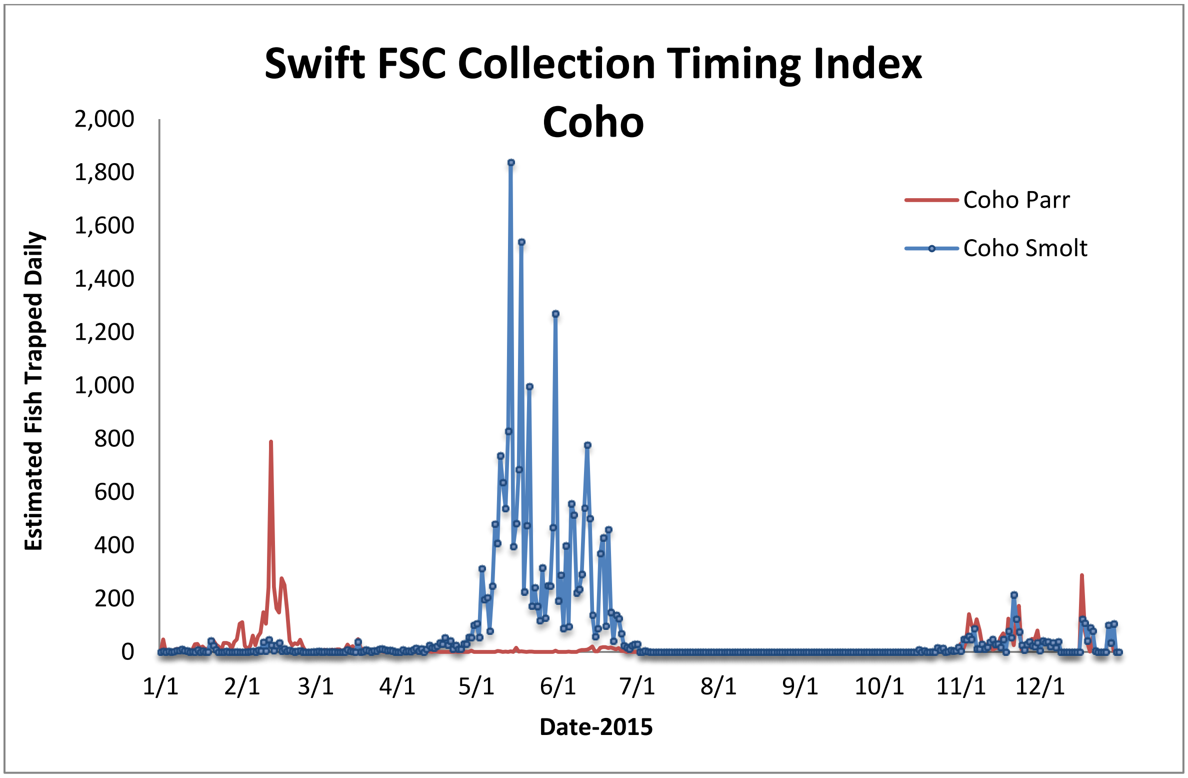


Figure 3.1-3: Estimated daily counts of juvenile coho captured at the FSC.

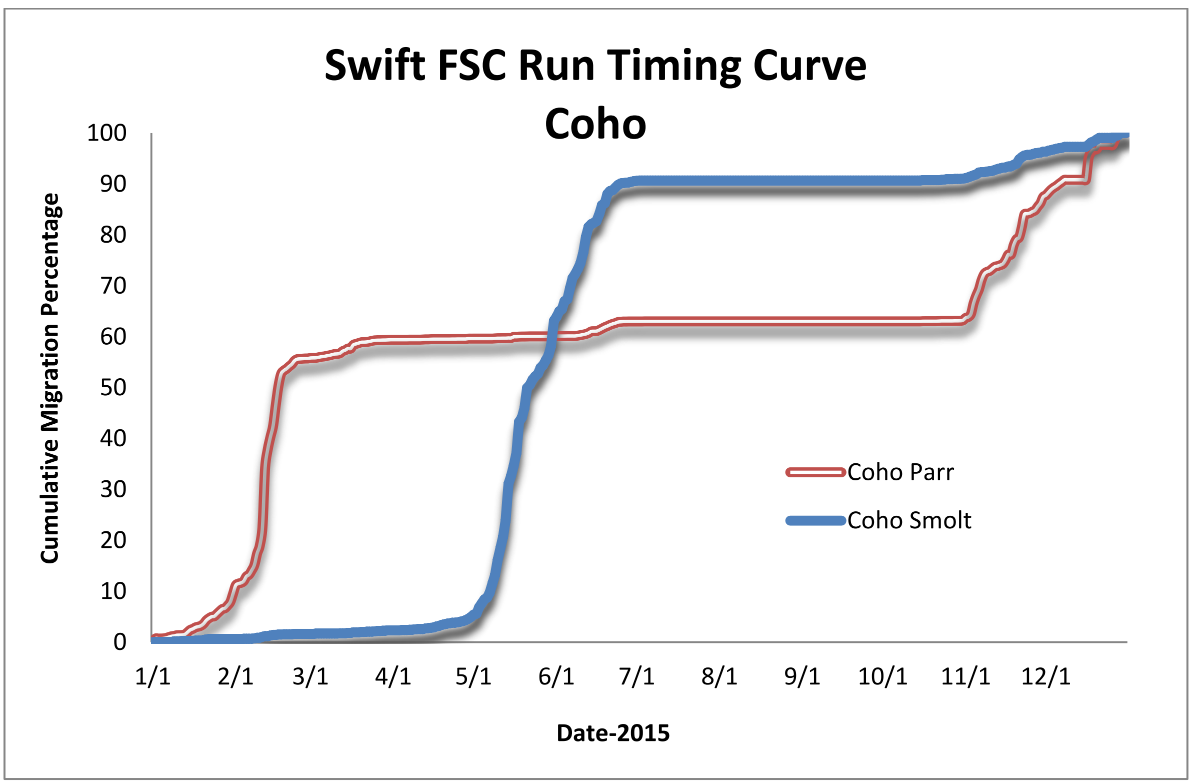


Figure 3.1-4: Cumulative coho migration timing.

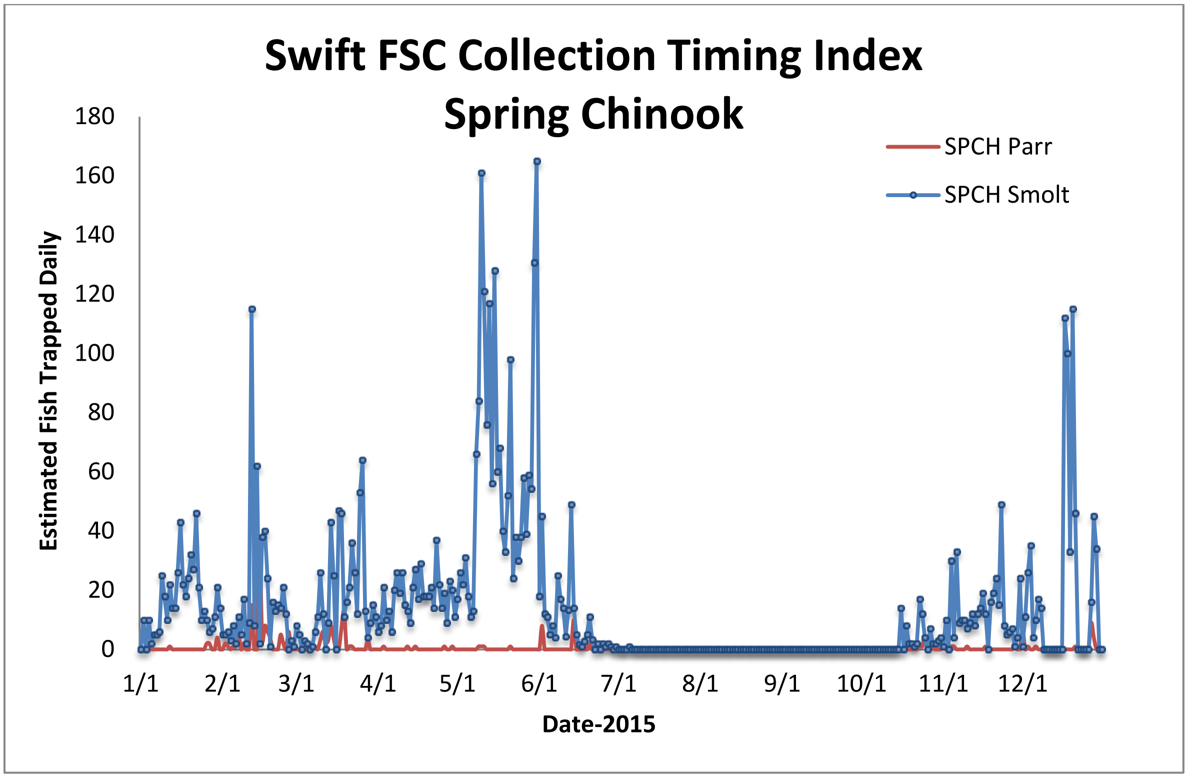


Figure 3.1-5: Estimated daily counts of juvenile spring Chinook captured at the FSC.

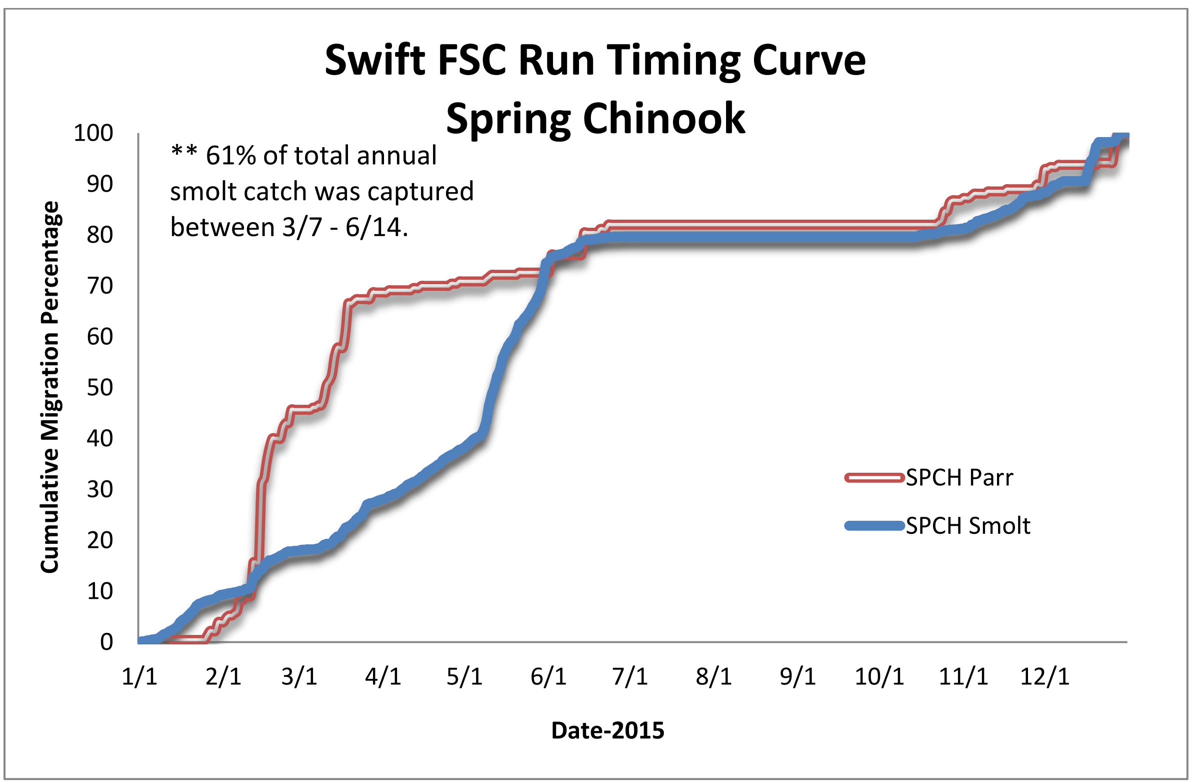


Figure 3.1-6: Cumulative spring Chinook migration timing.

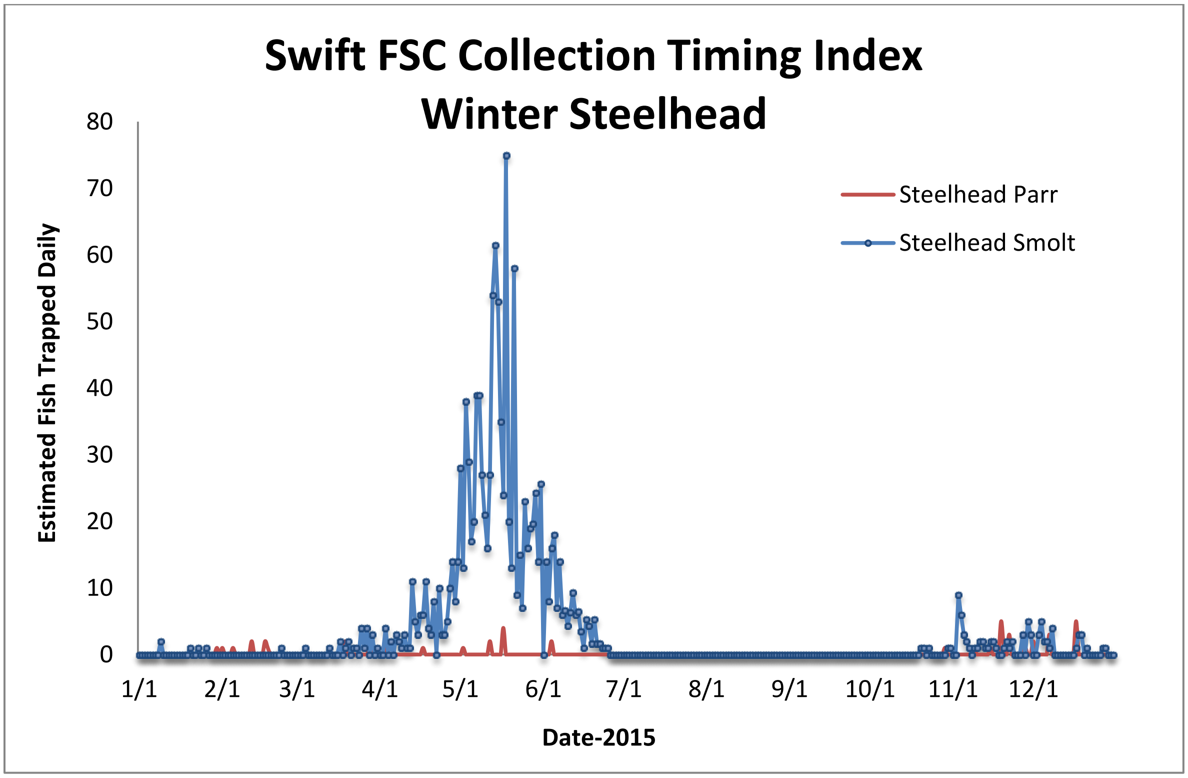


Figure 3.1-7: Estimated daily counts of juvenile steelhead captured at the FSC.

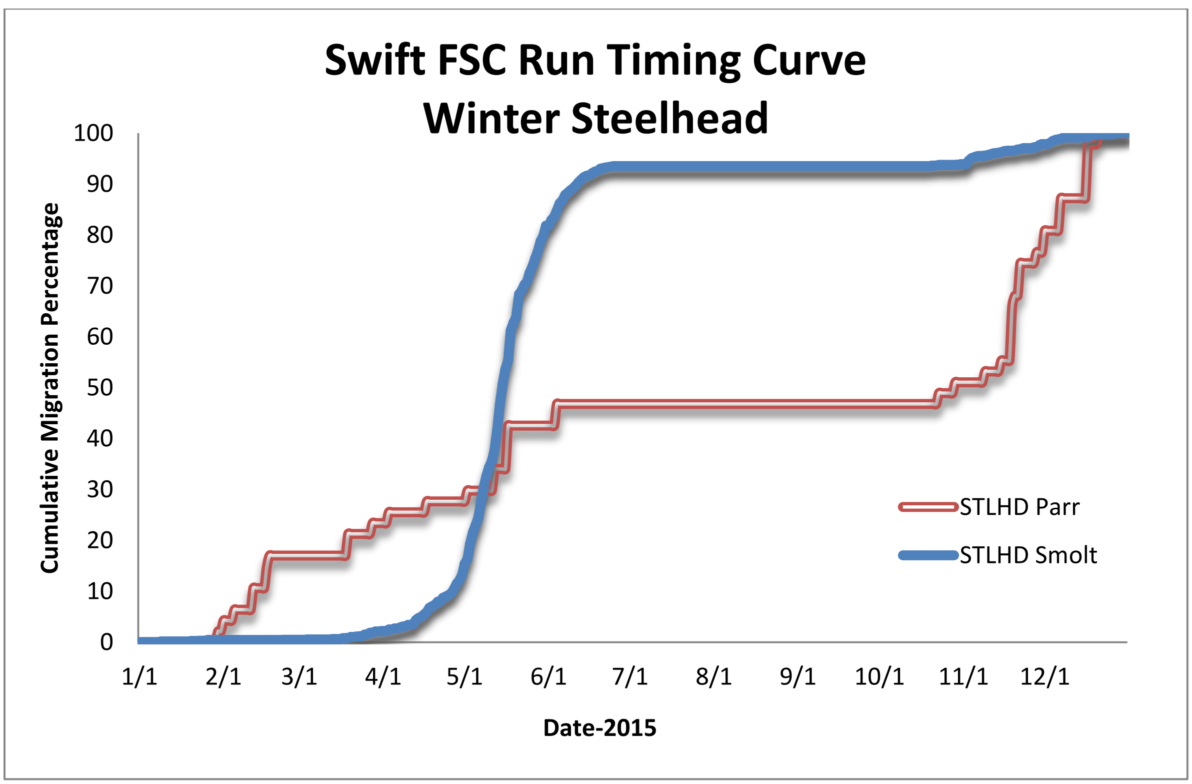


Figure 3.1-8: Cumulative steelhead migration timing.

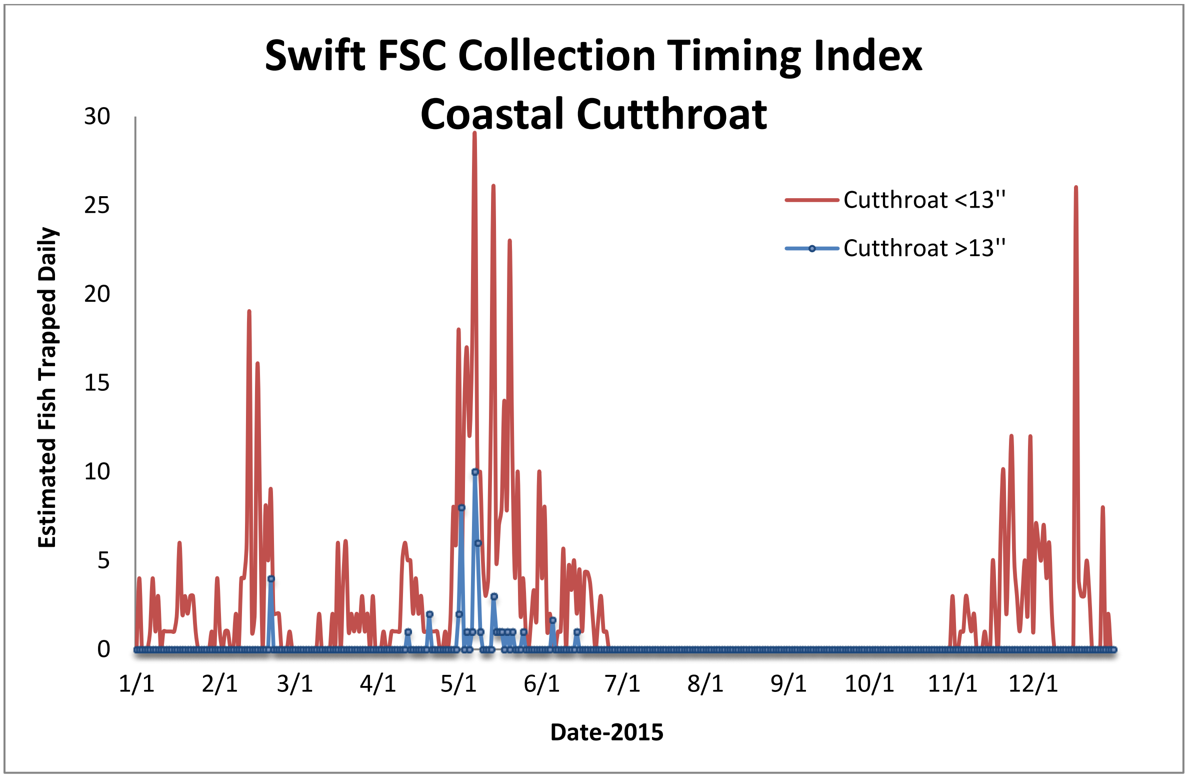


Figure 3.1-9: Estimated daily counts of cutthroat captured at the FSC.

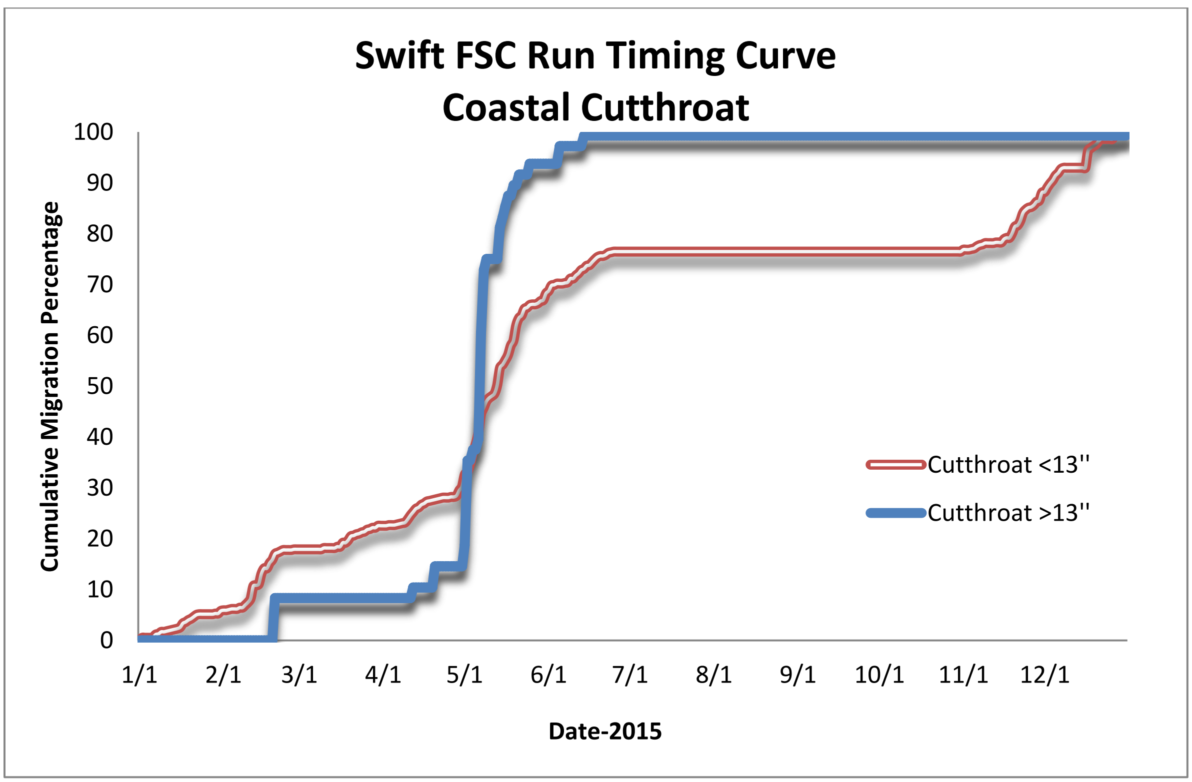


Figure 3.1-10: Cumulative cutthroat migration timing.

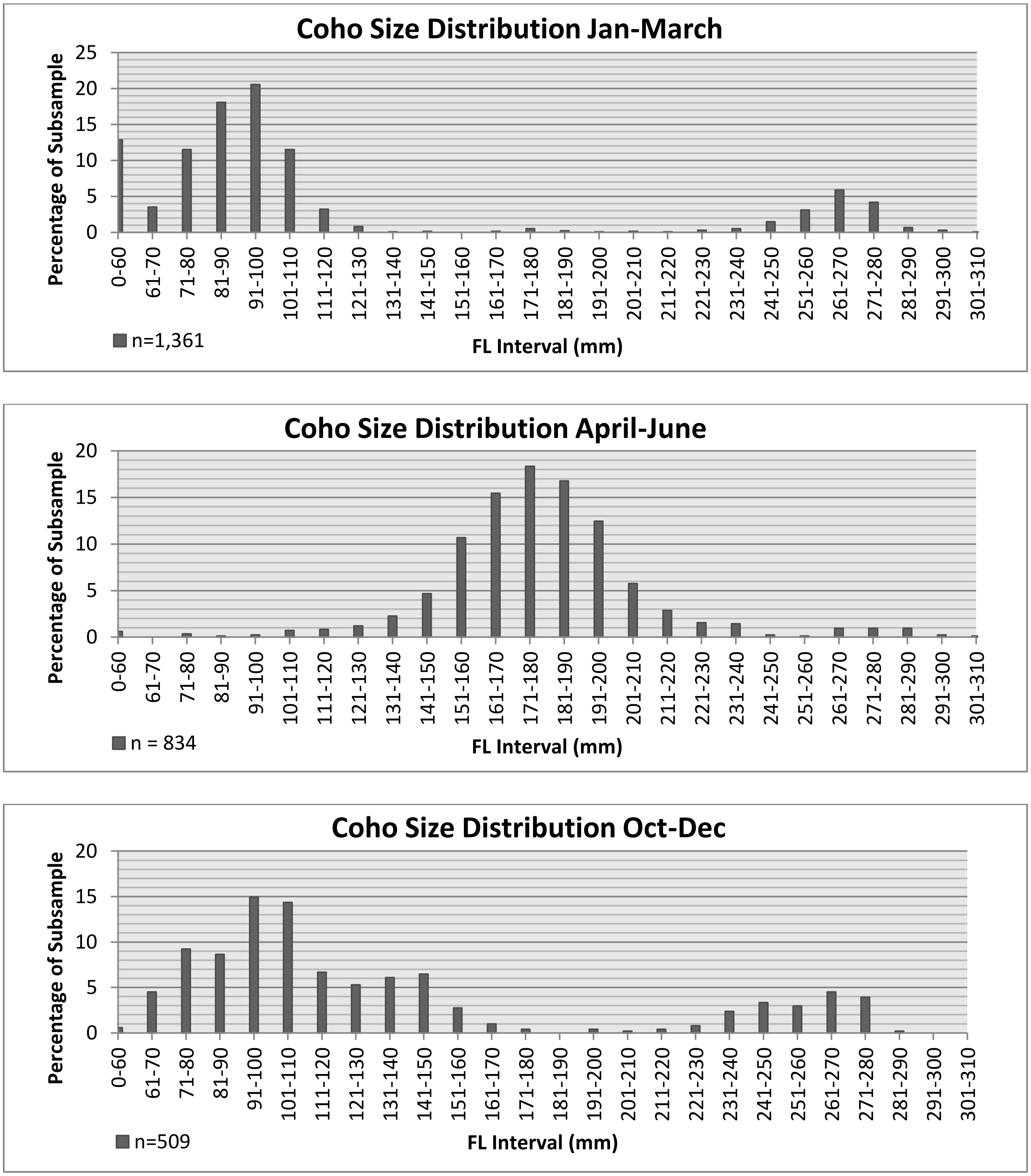
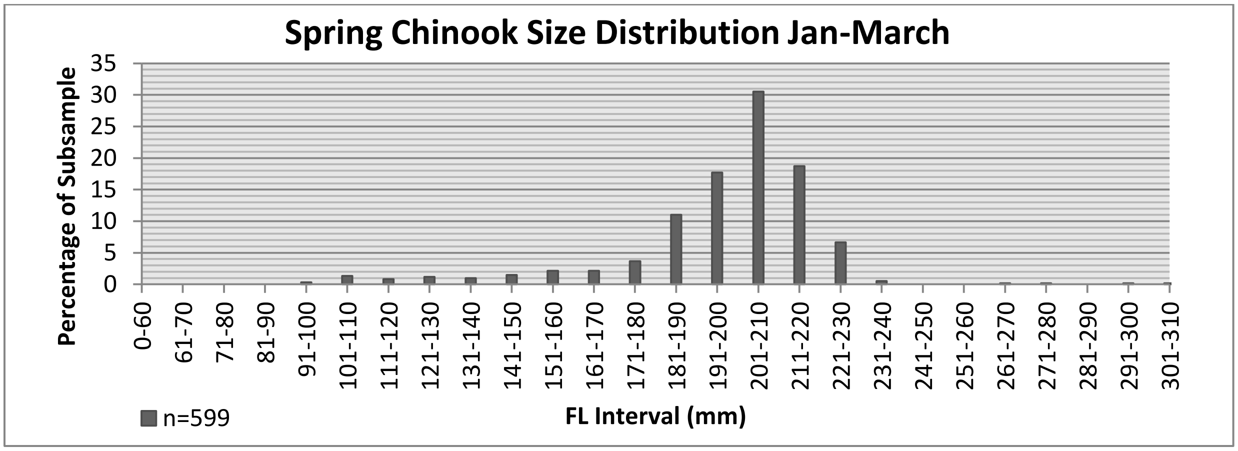
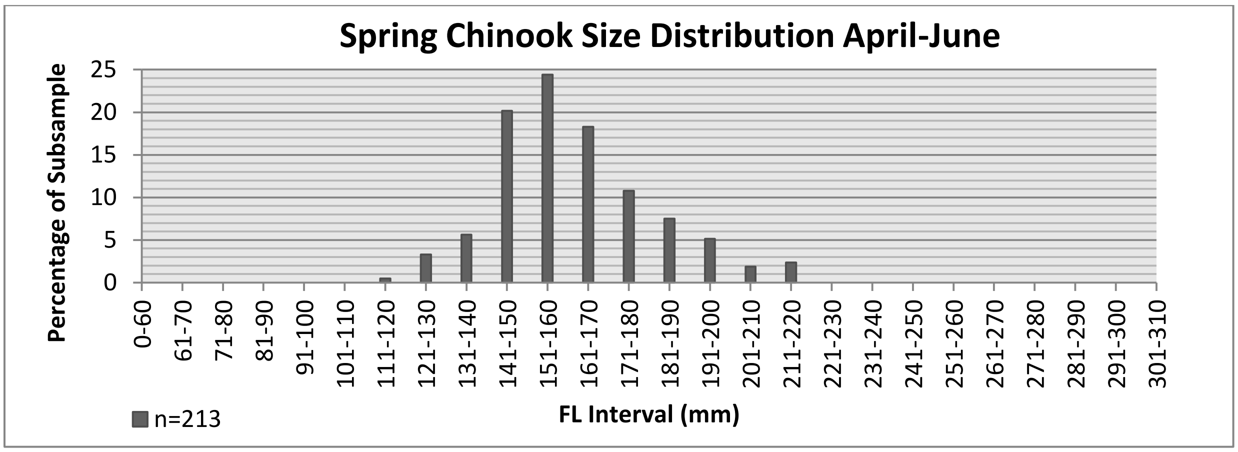


Figure 3.1-11: Size distribution for juvenile coho captured in 2015.





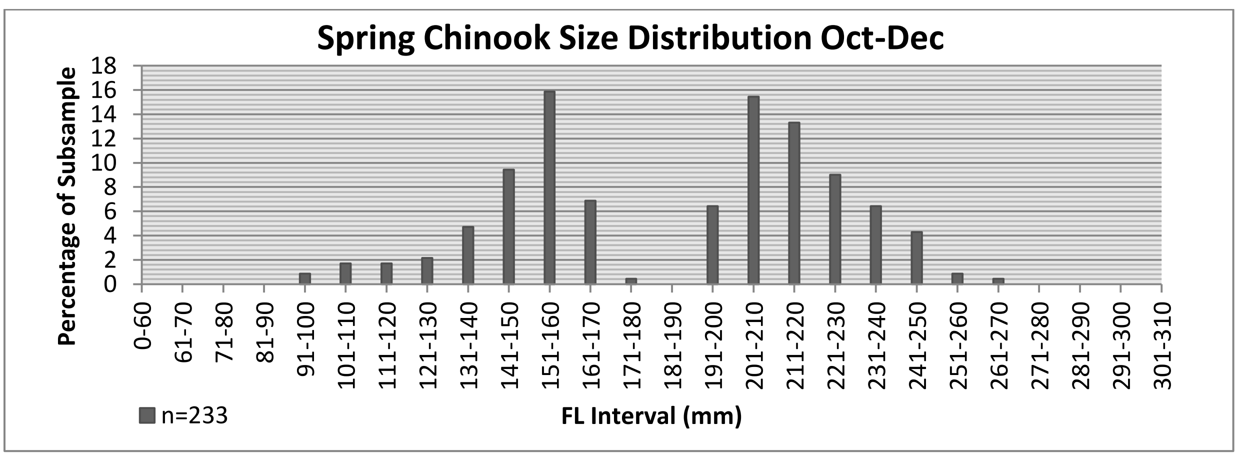


Figure 3.1-12: Size distribution for juvenile spring Chinook captured in 2015.

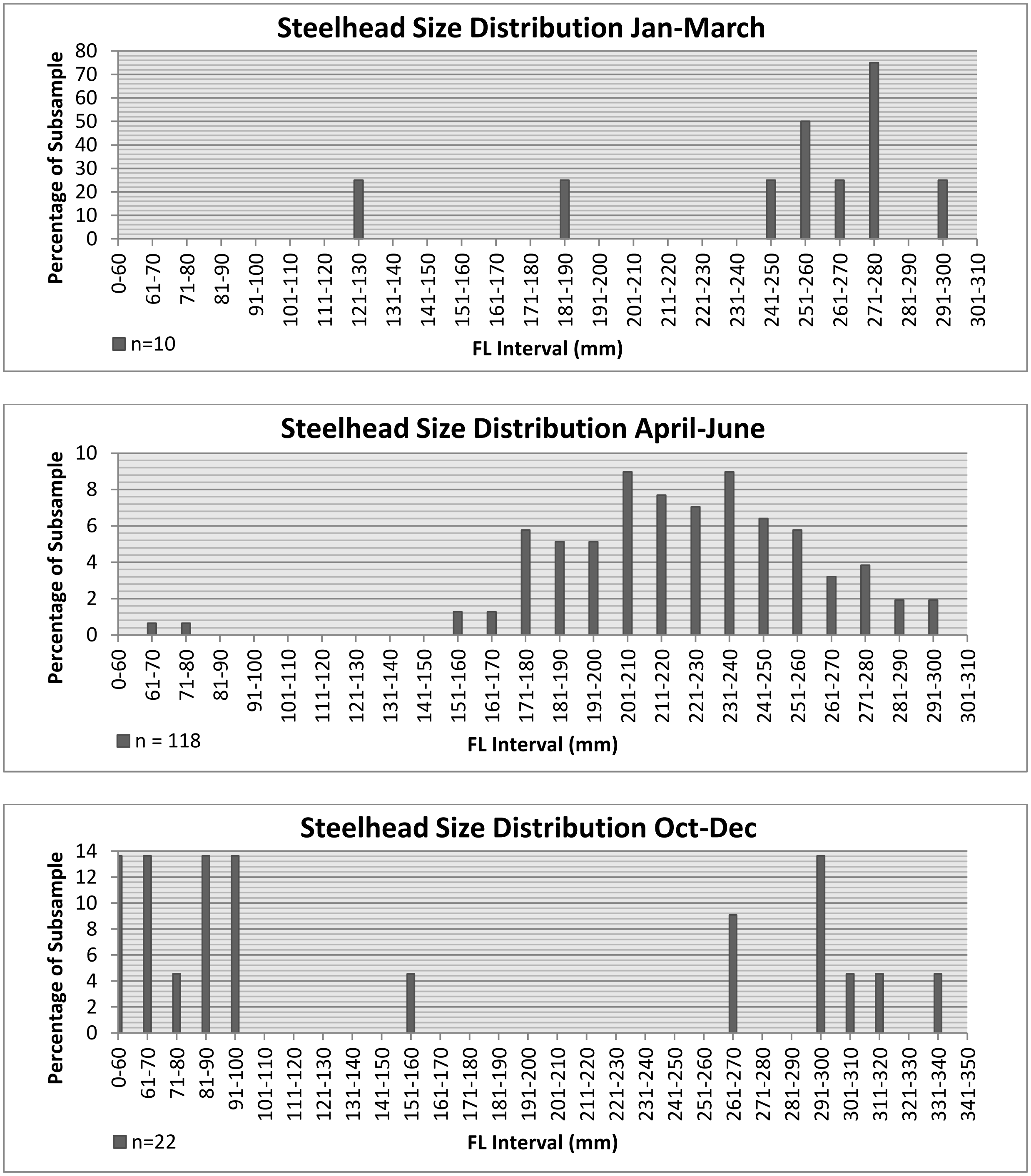


Figure 3.1-13: Size distribution for juvenile steelhead captured in 2015.

3.4 FSC Collection Efficiency

3.4.1 Overview

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

In 2015, acoustic telemetry was used rather than radio telemetry. Test fish were also collected, tagged, and released at the head of Swift Reservoir rather than collected from the FSC which were previously transported and released only 2 miles upstream of the FSC. Autonomous acoustic receivers were deployed around the FSC to detect smolt attraction and passage rates, and were used to describe behavioral mechanisms driving P_{CE}. In addition to providing estimates of P_{CE}, this study also described the preferred approach behaviors of smolts and potential thermal effects on passage success rates.

3.4.2. Results/Discussion

A detailed report describing the methods and results of the 2015 effort can be found in Appendix C. A brief summary of this report is provided below.

In total, 200 smolts were dual tagged with an acoustic transmitter and PIT tag and then released at the head of Swift Reservoir. Of these fish, 159 were detected near the entrance of the FSC at the ZOI and 21 were successfully collected for an overall collection efficiency of 13.2% (21 of 159; Table 3.4.1). While most smolts (>75%) were observed to pass at water temperatures less than 15^{o}C, there was not a significant effect of temperature on collection efficiency. First entrances to the forebay were spread approximately evenly between southern and northern shorelines. However, once in the forebay, most fish approach the FSC from the south even those that initially enter along the north shoreline. In general, smolt transitioned from south to north shorelines and passed the entranced of the FSC along their trajectory. All species had peak rates of first passage within 450 feet of the FSC entrance and approximately 90% of the fish made their first pass within 650 feet of the FSC entrance.

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

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

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	139	14	47	200
Detected in the Forebay	126	9	43	178
P_{RES}	90.6%	64.3%	91.5%	89.0%
Detected at ZOI	110	6	43	159
P_{ZOI}	79.1%	42.9%	91.5%	79.5%
Captured at FSC	13	0	8	21
Collection Efficacy (P_{CE})	11.8%	0.0%	18.6%	13.2%

3.5 Swift FSC Injury and Survival

3.5.1 Overview

Injury and survival of captured juvenile salmonids, cutthroat, bull trout, and steelhead kelts were monitored daily on the FSC during 2015 in accordance with Objectives 4 and 5 of the M&E Plan and Section 9.2.1(d) of the Settlement Agreement.

As outlined in the M&E Plan, smolt injury and survival was evaluated based on fish collected in the subsample tanks. The methods outlined in the M&E Plan assume that rates of fish injury and mortality found in subsampled fish would be representative of the general population. Survival and injury standards that PacifiCorp is required to achieve are displayed in Table 3.5-1.

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

Table 3.5-1 Specified injury and survival standards.

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

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

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

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

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

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

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

$$CS = \frac{M_{SS}}{SS_{Total}}$$ **Equation 3.5-2**

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

3.5.2 Results/Discussion

INJURY RATE

Annual injury rates were combined for parr and smolt as no discernable difference was found between the two life-stages among each species. In the future, a statistical comparison between these two life-stages will need to be completed. Combined annual injury rates for each target species ranged from 0 to 2.0 percent (Table 3.5-3). Juvenile Chinook (parr and smolt) had the highest overall injury rate (2.0%), followed by juvenile steelhead (0.6%), coho (0.3%) and cutthroat (0.2%). Descaling accounted for the greatest proportion of the injuries observed (greater than 80%) in all species, followed by eye hemorrhaging (8.1%) and bruising (5.4%; Figure 3.5-2). No injuries were observed among coho fry (n=5,860), cutthroat fry (n=17), and steelhead fry (n=5). Similarly, injuries were not observed on any of the adult steelhead or bull trout collected.

Overall, annual injury rates for all juvenile salmonid species (smolt and parr) and adult fish appeared to meet the required performance standard of 2.0%. Only juvenile Chinook were found to have an injury rate greater than 0.5%. However, these fish were almost exclusively comprised of fish from the acclimation program and were susceptible to descaling due to the prevalence of Bacterial Kidney Disease (BKD).

PacifiCorp will continue to address the causes of injury in the future. Debris loading on the fry and smolt separator bars continues to be an source for fish injury. As a temporary solution to this problem, PacifiCorp staffed the FSC around the clock to clear debris from the separator bars during peak migration periods.

Table 3.5-3 Annual injury rates for target species collected at the FSC. [1] Mortalities with injuries are not assigned as injured fish; they are assigned to mortality totals. [2] The number sampled for injury rate calculations does not include mortalities

Species	No. Injured[1]	No. Sampled[2]	Injury Rate (%)
Coho (Fry)	0	5,860	0.0
Chinook (Fry)	0	0	0.0
Steelhead (Fry)	0	5	0.0
Cutthroat (Fry)	0	17	0.0
Combined (Fry)	**0**	**5,882**	**0.0**
Coho (Parr & Smolt)	101	32,284	0.3
Chinook (Parr & Smolt)	110	5,535	2.0
Steelhead (Parr & Smolt)	8	1,329	0.6
Cutthroat (Parr & Smolt)	2	824	0.2
Combined (Parr & Smolt)	**221**	**39,972**	**0.6**
Steelhead Adults	0	16	0.0
Steelhead Kelts	0	31	0.0
Bull Trout	0	20	0.0

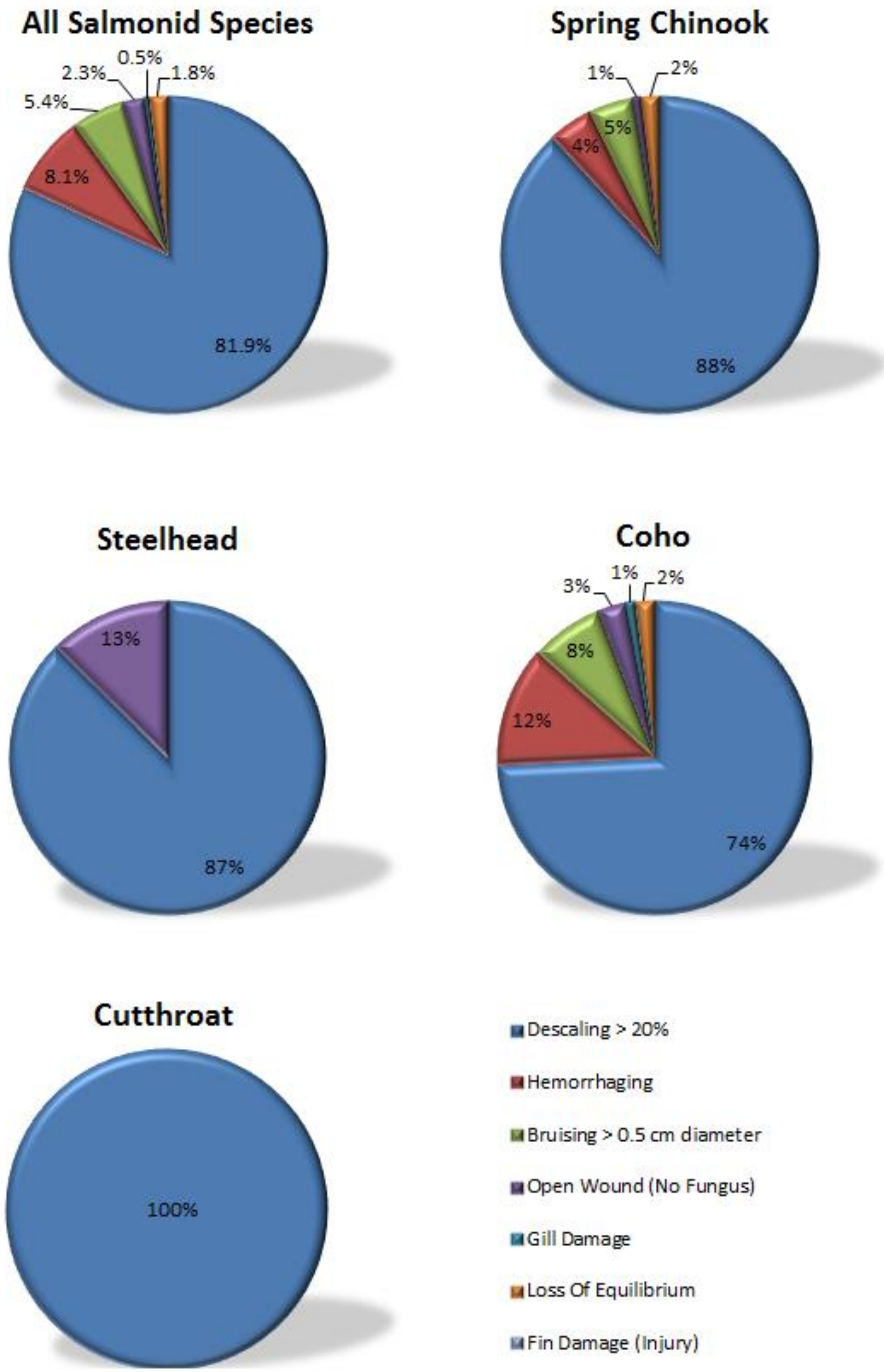


Figure 3.5-2: Composition of injury type occurrences by species. Percentages reflect parr and smolts numbers collected that are referenced in Table 3.5-3.

SURVIVAL RATE

In the absence of juvenile Release Ponds, annual survival rates were based solely on collection survival (S_{COL}) because the Release Ponds were not yet constructed in 2015. Transported fish were directly released into the Lewis River below Merwin Dam and consequently, a true estimate of transport survival (S_{TRAN}) was not possible.

Annual survival rates among all target species and life-stages passing through the FSC ranged from 89.4 to 99.6 percent (Table 3.5-4). Juvenile steelhead had the highest survival rate (99.6%), followed by coho (98.9%), cutthroat (98.7%), spring Chinook (97.6%), bull trout (95.0%), and adult steelhead (89.4). No mortalities were observed among coho fry (n=5,860) and steelhead fry (n=5), however two cutthroat fry were reported dead.

Overall, the survival rates (S_{COL}) for juvenile salmonids appear to be generally high, although more rigorous statistical evaluation is needed in the future. Nearly all mortality observed was associated with debris accumulation on the fish sorting bars and in the holding tanks. This is a particular problem during high run-off periods in the winter and early-spring when sub-yearly out-migrants (parr) are prevalent. Modifications to the sorting areas and tanks are being considered by PacifiCorp to help manage debris accumulation and further reduce mortality.

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

Species	No. of Mortalities	No. Sampled	Survival% (CS)	Combined Survival% (CS)
Coho Parr	251	6,729	96.3	98.9
Coho Smolts	114	25,555	99.6	
Chinook Parr	3	230	98.7	97.6
Chinook Smolts	131	5,305	97.5	
Steelhead Parr	0	47	100	99.6
Steelhead Smolts	5	1,282	99.6	
Cutthroat(> 13 inches)	0	48	100	98.7
Cutthroat (< 13 inches)	11	776	98.5	
			Overall:	**98.7**
Steelhead Adults	2	16	87.5	89.4
Steelhead Kelts	3	31	90.3	
Bull Trout	1	20	95.0	95.0

Table 3.5-5 Annual survival rates for salmonid fry.

Species	No. of Mortalities	No. Sampled	Survival% (CS)
Coho Fry	0	5,860	100
Chinook Fry	0	0	NA
Steelhead Fry	0	5	100
Cutthroat Fry	2	17	88.2
		Overall:	**99.9**

3.6 Swift Powerhouse Entrainment Evaluation

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

3.7 Overall Downstream Survival (ODS)

3.7.1 Overview

An estimate of overall downstream survival (ODS) is required under section 9.2.1 of the Settlement Agreement and is identified as Object 1 of the M&E Plan. An ODS rate of greater than or equal to 80 percent[5] is required given the described assumptions. ODS is defined in Section 4.1.4 of the Settlement Agreement as:

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

That is, ODS is the percentage of the fish entering the Project that migrate, or are transported to the lower Lewis River (i.e., downstream of Merwin Dam) and released successfully (i.e., alive).

Initially, pending the development of passage facilities for Merwin and Yale projects, ODS is defined as the survival of anadromous fish from the head of Swift Reservoir to the Lewis River below Merwin Dam immediately at the exit of the Release Ponds. Estimates of ODS are to be initially developed for out-migrating juvenile coho, spring Chinook, and steelhead. An estimate of ODS will also be developed for sea-run cutthroat trout if data indicate that this cutthroat life history is present in the upper Lewis River basin and the number of juveniles produced and collected at the FSC is sufficient for a meaningful estimate.

The current plan states that fish will be PIT tagged and released at the head of Swift Reservoir to collect ODS data. The Plan also states that these PIT tagged fish can be collected from screw trap operations or, if needed, from fish collected at the FSC. However, it was suggested that fish already collected at the FSC may have a higher propensity to avoid the FSC if used for ODS data, possibly biasing results. In 2015 only fish collected at the screw trap were PIT tagged for the ODS determination.

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[5] An ODS of greater than or equal to 80 percent is required until such time as the Yale Downstream Facility is built or the Yale In Lieu Fund becomes available to the Services, after which ODS shall be greater than or equal to 75 percent.

PIT-tag detectors are located on the FSC and, eventually, the exit of the Release Ponds will be used to monitor passage of tagged fish to estimate ODS. Dead tagged fish found in the FSC and Release Ponds would be assigned to collection loss (S_{COL}) and transport loss (S_{TRAN}), respectively. Because the Release Ponds were not yet constructed in 2015, transported fish were directly released into the Lewis River below Merwin Dam. Consequently, a true estimate of S_{TRAN} was not possible.

The M&E Plan also calls for 50 dead PIT-tagged fish being released into the FSC over the course of the season as a check on the ability of the biologists to detect and recover dead fish at the Release Ponds. (These actions were also not conducted in 2015). Ultimately, if tag recoveries are less than 100%, estimates of ODS will be adjusted based on the calculated error rate.

ODS estimates are to be developed on a weekly basis during the migration season and then expanded to an annual estimate. These estimates will be based on pooling release–recapture data over the season. Because a proportion of tagged fish are likely to overwinter in the reservoir, any fish captured in subsequent years will be added to the ODS estimate for their release year. The ODS calculation under the intended operations (i.e., after completion of the Release Ponds) is shown in Equation 3.7-1. The ODS calculation used in the 2015 study (absent of S_{TRAN}) is shown in Equation 3.7-2.

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

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

$$\boldsymbol{ODS = S_{RES} * S_{COL}}$$ **Equation 3.7-2 (without release ponds - 2015)**

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

3.7.2 Results/Discussion

Only PIT tag interrogations at the FSC recorded on or before December 31st, 2015 were included in the ODS calculations (Table 3.7-1). No dead PIT tagged fish (pertaining to the ODS study) were found in the FSC. Hence, S_{COL} was considered 100 percent for each species during 2015. Since S_{TRAN} was not calculated and assumed to be 100 percent in 2015, thus ODS estimates during the 2015 study were equal to S_{RES}.

The M&E Plan calls for 996 tagged fish per species to be released over a six week period during the particular species respective run-timing in order to achieve the desired statistical power. Because of the lack of adequate numbers of fish to tag, no species received the required 996 tags;

during the 10 week study period, only 382 coho, 37 Chinook, and 117 steelhead were released (Table 3.7-1). The resulting annual ODS estimates are 6.5% for coho, 0% for spring Chinook, and 12.8% for steelhead.

Table 3.7-1: Weekly and annual ODS data for each species (functionally S_{RES}). ODS performance standard for all species is ≥ 80 percent.

Week	Coho			Chinook			Steelhead		
	Released	Recaptured	SRES%	Released	Recaptured	SRES%	Released	Recaptured	SRES%
1	43	4	***9.3***	20	0	***0***	12	1	***8.3***
2	19	3	***15.8***	5	0	***0***	0	0	***N/A***
3	23	1	***4.3***	3	0	***0***	7	1	***14.3***
4	25	2	***8.0***	0	0	***N/A***	8	1	***12.5***
5	21	3	***14.3***	0	0	***N/A***	15	3	***20.0***
6	28	1	***3.6***	0	0	***N/A***	26	4	***15.4***
7	58	7	***12.1***	5	0	***0***	25	2	***8.0***
8	85	4	***4.7***	3	0	***0***	17	3	***17.6***
9	65	0	***0.0***	1	0	***0***	6	0	***0.0***
10	15	0	***0.0***	0	0	***N/A***	1	0	***0.0***
Annual	382	25	***6.5***	37	0	***0***	117	15	***12.8***

SUGGESTED STUDY DESIGN CHANGES FOR ODS IN 2016

With few smolts being captured by the screw trap in 2015 there was little confidence in the calculated ODS values. Only smolts captured by the screw trap were used as ODS test fish. This was done as an attempt to reduce biasing results by using smolts already captured by the FSC as test fish. For 2016, PacifiCorp plans to hold importance of achieving proper sample size (≥ 996 per species in a six week period) over the possibility of biasing results from using FSC captured smolts as test fish. Meaning, if needed, PacifiCorp will PIT tag smolts captured in the FSC and release them back at the head of Swift Reservoir to achieve the desired sample size, despite the possibility of biasing results. This practice will continue until there are adequate numbers of out-migrants produced in the upper watershed.

The M&E Plan states that screw trap operations would continue into the summer or fall if the *2013* pilot study indicates that juvenile run-timings extend into such seasons. The pilot study data indicated that juvenile run-timing for all species appears to come to an end during the latter part of June. Therefore, screw trap operations are expected to run from April 1st to June 30th in the coming years (In 2015, due to very low water conditions, screw trap operations were halted on June 1st).

4.0 UPSTREAM COLLECTION AND PASSAGE METRICS

4.1 Summary

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

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

A total 15,597 fish were captured (recaptured fish counts include 2,109 hatchery summer steelhead, 89 blank wire tag winter steelhead, nine hatchery spring Chinook, eight wild fall Chinook, two wild sockeye, two hatchery early run coho, and one hatchery late run coho) at the Merwin Trap in 2015 (Table 4.1-1). Among the species collected, summer steelhead accounted for the majority of fish captured (n=6,256) followed by winter steelhead (n=4,184), late run coho (n=2,293), early run coho (n=1,144), fall Chinook (n=811), spring Chinook (n=766), various resident fishes (n=108), sockeye (n=34), and pink salmon (n=1).

A total of 2,740 hatchery summer steelhead were captured at Merwin Trap and marked with a caudal clip. These fish were transported and released back into the lower Lewis River as part of the Washington Department of Fish and Wildlife Fish Recycle Program. A total 2,109 summer steelhead were recaptured at Merwin Trap, which produced a 77 percent recapture efficiency in 2015.

A total of 1,223 blank wire tag winter steelhead[6], 319 early coho, 3,435 late coho, and 31 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2015 (Table 4.1-2). Of the 1,223 winter steelhead, 1,196 were captured at Merwin Trap, 27 winter steelhead were captured via tangle net in the lower river as part of the Hatchery and Supplementation Plan monitoring. Of the 319 early coho that were transported upstream, 112 were collected at Merwin Trap, and 207 were collected at Lewis River Hatchery. Of the 3,435 late coho that were transported upstream, 1,383 were collected at Merwin Trap, and 2,052 were collected at Lewis River Hatchery. All 31 cutthroat transported upstream were collected from Merwin Trap.

[6] To distinguish the complete 2013-2014 winter steelhead run, counts include only winter steelhead transported above Swift Dam in that run year.

Table 4.1-1: Total fish collected at Merwin Trap during 2015. 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[7]	366	327	30				14	15	5						6	3		**766**	5
Fall Chinook	239	286	6				102	139	31	6	2							**811**	5
Early Coho	123	147	544	74	103	76	24	34	17						2			**1,144**	7
Late Coho	933	771	256	142	115	24	21	14	16						1			**2,293**	15
Summer Steelhead	1471	2651					7	18							681	1428		**6,256**	40
Winter Steelhead	1522	1249					41	31					748	504	51	38		**4,184**	27
Sockeye Salmon	1						14	17		1	1							**34**	0
Chum Salmon																		**0**	0
Pink Salmon	1																	**1**	0
Cutthroat (>13 inches)																	31	**31**	0
Cutthroat (< 13 inches)																	2	**2**	0
Rainbow (< 20 inches)																	75	**75**	0
Bull Trout (> 13 inches)																		**0**	0
Bull Trout (< 13 inches)																		**0**	0
															Total			**15,597**	100

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

Table 4.1-2: Total fish transported above Swift Dam in 2015 (205 early run coho and 2,052 late run coho were captured at Lewis River Fish Hatchery and 27 blank wire tag (BWT) winter steelhead were captured via tangle net in the lower river as part of the Hatchery and Supplementation Plan monitoring).

Species	Male	Female	Jack	Not sexed	Female:Male Ratio	Jack:Adult Ratio	Total
Spring Chinook	-	-	-	-	-	-	***0***
Early Coho	211	89	19	-	0.4	6.0	***319***
Late Coho	1,819	1,605	11	-	0.9	0.3	***3,435***
Winter Steelhead	746	477	-	-	0.6	-	***1,223***
Cutthroat >13"	-	-	-	31	-	-	***31***
Bull Trout >13"	-	-	-	-	-	-	***0***
						Total	***5,008***

4.2 Adult Passage Survival

4.2.1 Overview

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

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

N = Number of total adults collected
$\mathbf{AD_{TRAP}}$ = Number of dead adults in trap
$\mathbf{AD_{REL}}$ = Number of dead adults at release site

4.2.2 Results/Discussion

A total 5,008 adult salmonids (319 early coho, 3,435 late coho, 1,223 winter steelhead, and 31 cutthroat) were transported upstream throughout the migration period in 2015. All coho and cutthroat survived the trapping and transport processes resulting in a UPS of 100 percent. Six blank wire tag winter steelhead mortalities were observed at the Merwin fish sorting facility, resulting in a 99.94 percent UPS for all transported species. No spring Chinook were transported upstream in 2015.

4.3 Adult Trap Efficiency

4.3.1 Overview

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

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

Based on the methods outlined in Objective 10 of the M&E Plan, the first year of study began in spring 2015. Adults from each target species (i.e., spring Chinook, coho, and winter steelhead) fish were radio tagged and released downstream of Merwin Dam. These fish were monitored at multiple receiver sites as they enter the tailrace and approach the entrance of the new sorting facility.

4.3.1 Results/Discussion

A detailed report of the first year of data collection (2015) is provided in Appendix D.

Overall, 35 coho, 40 spring Chinook, and 148 winter steelhead were radio tagged and released downstream of Merwin Dam in 2015 (Table 4.3.1). Of these fish, all coho and spring Chinook, and 146 (of 148) winter steelhead returned to the tailrace and were used to assess collection efficiency (P_{CE}). Calculated ATE was below target (98%) for all three species studied in 2015 (9%, 38% and 62% for coho, spring Chinook and winter steelhead respectively). However, fish located and entered the trap at much higher rates than the rates at which they were ultimately captured (23%, 90% and 86% for coho, spring Chinook and, winter steelhead respectively). The second year of evaluation will be completed in 2016.

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

Metric	Coho Salmon	Spring Chinook	Steelhead
Total tagged (n)	35	40	148
Entered the Tailrace	35	40	146
Entered the Trap	8	36	126
Trap Entrance Efficiency (P_{EE})	22.9%	90.0%	86.3%
Captured	3	15	90
Collection Efficacy (P_{CE})	8.6%	37.5%	61.6%

4.4 Spawn Timing, Distribution, and Abundance of Transported Fishes

4.4.1 Overview

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

Two methodologies for determining spawn timing, distribution, and abundance of transported fishes were developed. For adult coho salmon, comprehensive spawning ground surveys were conducted in the potentially accessible river and stream reaches upstream of Swift Dam in 2015. No adult spring Chinook were transported upstream in 2015. Due to limited access and anticipated heavy snow accumulations during the spawning season for winter steelhead, a combination of aerial radio telemetry surveys, fixed-station radio antennas, aerial red counts, and single pass electrofishing surveys for young-of-the-year steelhead (during the following summer) were conducted. A detailed description of each method is outlined in Objective 15 of the M&E Plan.

In addition to evaluating spawn timing, distribution, and abundance of transported species, PacifiCorp also implemented and evaluated an extensive seed plant program in 2015. This program was developed based on results of earlier observations (PacifiCorp 2014) which indicated that adult fish released at the head of Swift Reservoir (i.e., Eagle Cliff Adult Release site) remained near the release site or traveled downstream and entered the reservoir. Three additional releases sites were established in the upper watershed of Swift Reservoir in 2015. These released sites included the Muddy River Bridge, the Clear Creek Bridge, and the upper Lewis River Bridge near Crab Creek. A proportion of fish transported upstream were released at these remote locations (Table 4.4.1.). Radio Telemetry combined with a number of aerial surveys were used to evaluate fish behavior and movement.

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

	Eagle Cliff	Upper Watershed				Combined Total
Winter Steelhead		Muddy River Bridge	Clear Creek Bridge	Upper Lewis (Crab Creek)	Total	
Untagged	1,047	28	31	34	93	1,140
Radio Tagged	44	12	12	15	39	83
Total	1,091	40	43	49	132	1,223
Coho Salmon						
Untagged	3,249	124	146	106	376	3,625
Radio Tagged	49	30	18	32	80	129
Total	3,298	154	164	138	456	3,754

4.4.2 Results/Discussion

Data collection on the spawn timing, distribution, and abundance of transported fishes was completed in mid-November, 2015. At the time of this initial review draft, PacifiCorp has not received the results of this 2015 effort. When complete, the results will be attached as Appendix E to this report.

Monitoring of radio tagged winter steelhead and coho salmon transported to upper basin sites and released revealed that fish remained and were assumed to have spawned in these general areas. Based on detection of radio tagged fish, the overall distribution into the upper basin of both species appeared to be greater following seed plant efforts compared to releasing all fish at the head of the reservoir (as done in 2014). It is suggested that future fish releases during the recolonization phase of reintroduction should continue to incorporate seed plants strategies. A comprehensive summary of the upper basin seed plant program completed in 2015 is provided in Appendix F.

5.0 OCEAN RECRUIT ANALYSIS

5.1 Overview

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

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

For this analysis, the average number of ocean recruits over a five-year period will be evaluated. That is, five consecutive brood years. These data will be evaluated to determine if and when hatchery production levels should be altered. A detailed description of the methodology for this analysis is outlined in Objective 12 of the M&E Plan.

5.2 Results/Discussion

Ocean recruit analysis was initiated in fall of 2013 and continued through the rest of the year. Half-way through the process of determining a methodology, investigators realized that the use of coded-wire tags (CWT) and the Regional Mark Information System (RMIS) does not account for CWT detection in fish that still have their adipose fin. It was recommended that PacifiCorp come up with an alternative method to determine Ocean Recruits. PacifiCorp is in the process of updating the methodology as part of the M&E Plan revision. That work will continue into 2016 and will be completed by December 31, 2016 with the new version of the M&E Plan.

6.0 PREFORMANCE MEASURES FOR INDEX STOCKS

6.1 Overview

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

6.2 Results/Discussion

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

7.0 REINTRODUCED AND RESIDENT FISH INTERACTIONS

7.1 Overview

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

7.2 Results/Discussion

In order to provide a meaningful estimate of resident/anadromous interactions, the USGS/UW groups are assessing interactions through stable isotope analysis and analysis of diet from samples within the basin reservoirs and tributaries plus observable interactions on the spawning grounds. A great deal of data collection and sample analyses has occurred along these lines and a final report is due in December 2016.

8.0 LITERATURE CITED

Courter, I, T. Garrison and Forrest Carpenter. 2013. Swift Reservoir Floating Surface Collector Juvenile Salmon Collection Efficiency Pilot Study: 2013 Annual Report. Prepared for PacifiCorp.

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APPENDIX

APPENDIX A

SWIFT RESERVOIR FLOATING SURFACE COLLECTOR OUTAGE PERIOD MEMO

MEMO

Operational Guidelines in Consideration of Suspending Summer Operations at the Swift Floating Surface Collector (FSC)

Prepared by PacifiCorp

Reviewed and Accepted by the Aquatic Coordination Committee

Final: March 17, 2015

Background

As stipulated in the new operating License for the Lewis River Fish Passage Program (Phase I), PacifiCorp is required to operate the Swift Floating Surface Collector (FSC) daily on an annual basis for the duration of the License. This decision to operate the FSC continuously was originally made in large part given the limited amount of information at the time regarding anadromous fish run timing in the upper Lewis River Basin and how run timing may be affected by seasonal reservoir conditions. However, as more information becomes available, it is important to periodically evaluate the operational procedures of the FSC in order to ensure the facility is being operated in a manner beneficial to the capture and safe passage of out-migrating fishes.

After two years of operation, it has been shown that warm surface water temperature in Swift Reservoir correlates to both a reduction in the rate of target species collected by the FSC and an increase in mortality rates. This correlation has been observed from early-July when the spring out-migration period is coming to a close and remains prevalent through September. During this period, surface water temperatures in the reservoir exceed 18^0C and the reservoir becomes thermally stratified. Fish numbers collected at the FSC throughout the summer and early fall remain almost non-existent due to these prevailing warm conditions, however those fish that are collected experience a high rate of mortality. By mid-October reservoir surface water temperatures begin to cool and shortly after fish collection numbers at the FSC begin to increase.

During the December 2014 monthly coordination meeting, PacifiCorp presented these finding to the Aquatic Coordination Committee (ACC). Included in the meeting was discussion on the need for turning the FSC off during this critical time period, particularly when surface water temperatures increase beyond what is thermally tolerated by anadromous salmonids. (The visual references used during this discussion are included at the end of this document). It was also discussed that this outage period would allow PacifiCorp to complete annual maintenance activities on the FSC and prepare the facility for winter operation. The following section is a summary of the protocols agreed upon by the ACC that would be used to guide operational decisions for turning the FSC off in the summer and back on in the fall.

New Operational Protocols

It was agreed that an adaptive management type approach would be best mode of operation for determining when to turn the FSC off each year. The reason for this is that conditions can change from year to year, and that full reintroduction has not yet been established. PacifiCorp will notify the ACC prior to the maintenance outage for the FSC that coincides with warm surface water.

- Key criteria and assumptions that will be considered for suspending daily operations of the FSC in the Summer:
    - Maximum daily water temperature recorded in the FSC surpasses 18^0C;
    - Daily catch rates in the FSC have decreased by 25 percent or more daily over the course of a weeks' time;
    - Daily rates recorded for collection mortality (S_{COL}) or transport mortality (S_{TRANS}) exceed the standard of 0.5 percent for three consecutive days.

- Returning the FSC to daily operation in the fall:
    - The FSC will be returned to service after scheduled maintenance activities are completed and will occur no later than the fifteenth day of October (In the future, this date may need to be adjusted earlier if it is shown that fish begin out-migrating earlier once full reintroduction has been established.) ;
    - Maximum daily water temperature recorded in the FSC remains below 18^0C for three consecutive days;

Visual references provided during the December 2014 ACC meeting:

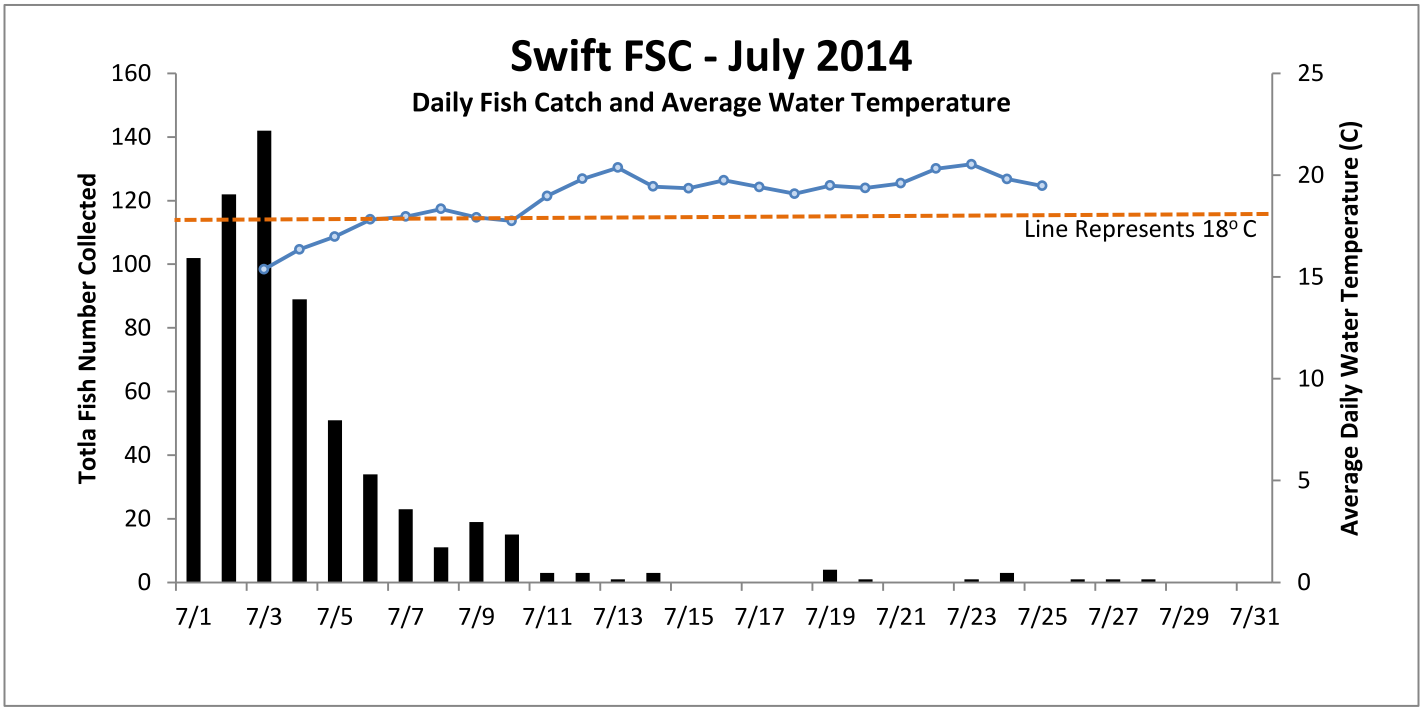
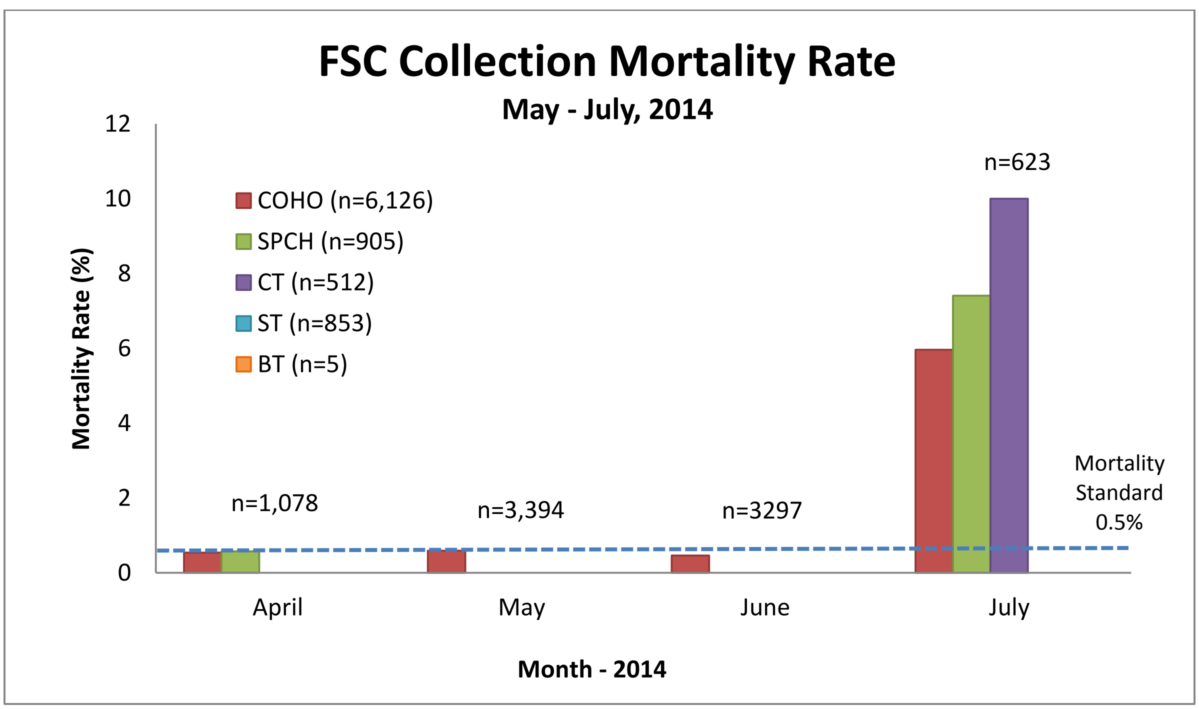


Figure 1. Daily total catch of smolts at the Swift FSC in July 2014.



Firgure 2. Monthly mortality rates recorded for all target species at the Swift FSC during spring 2014. The dotted line represents the mortality standard of 0.5%.

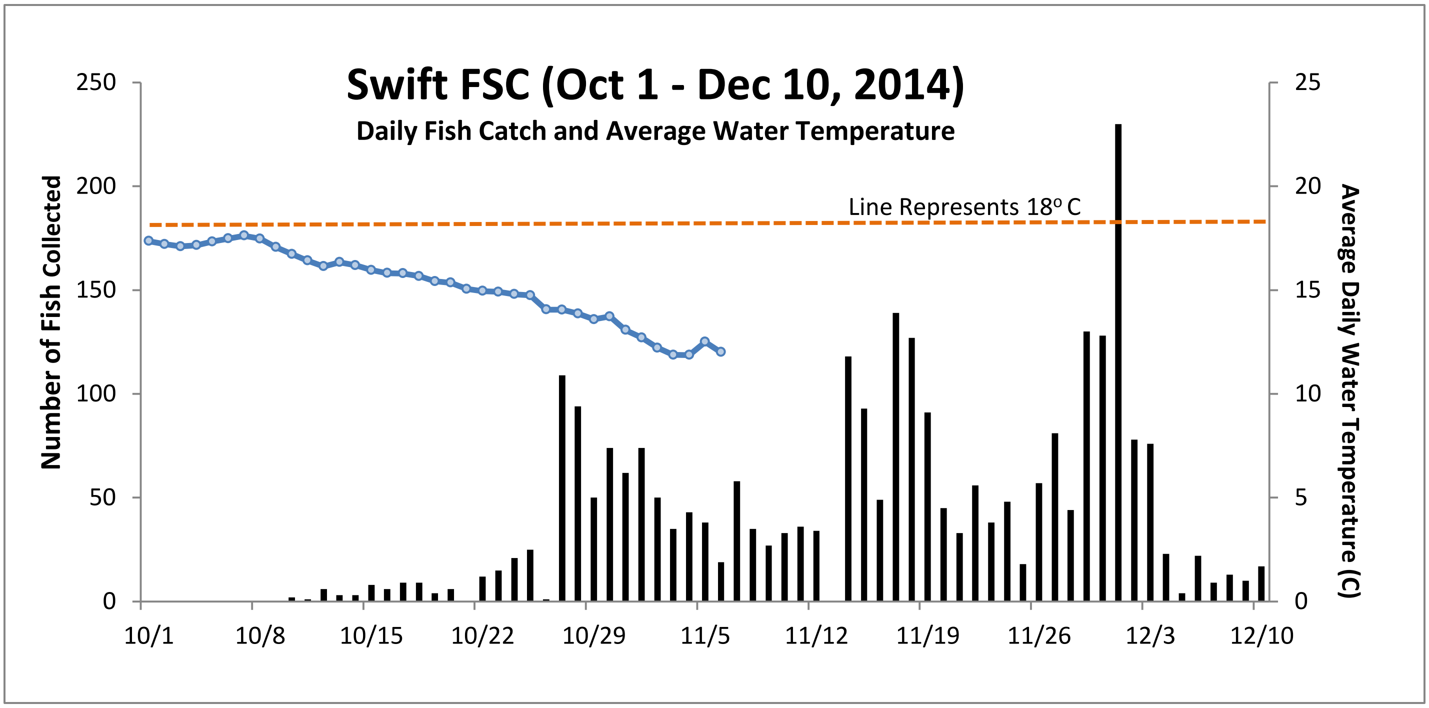


Figure 3. Daily total catch of smolts at the Swift FSC during October through early December, 2014.

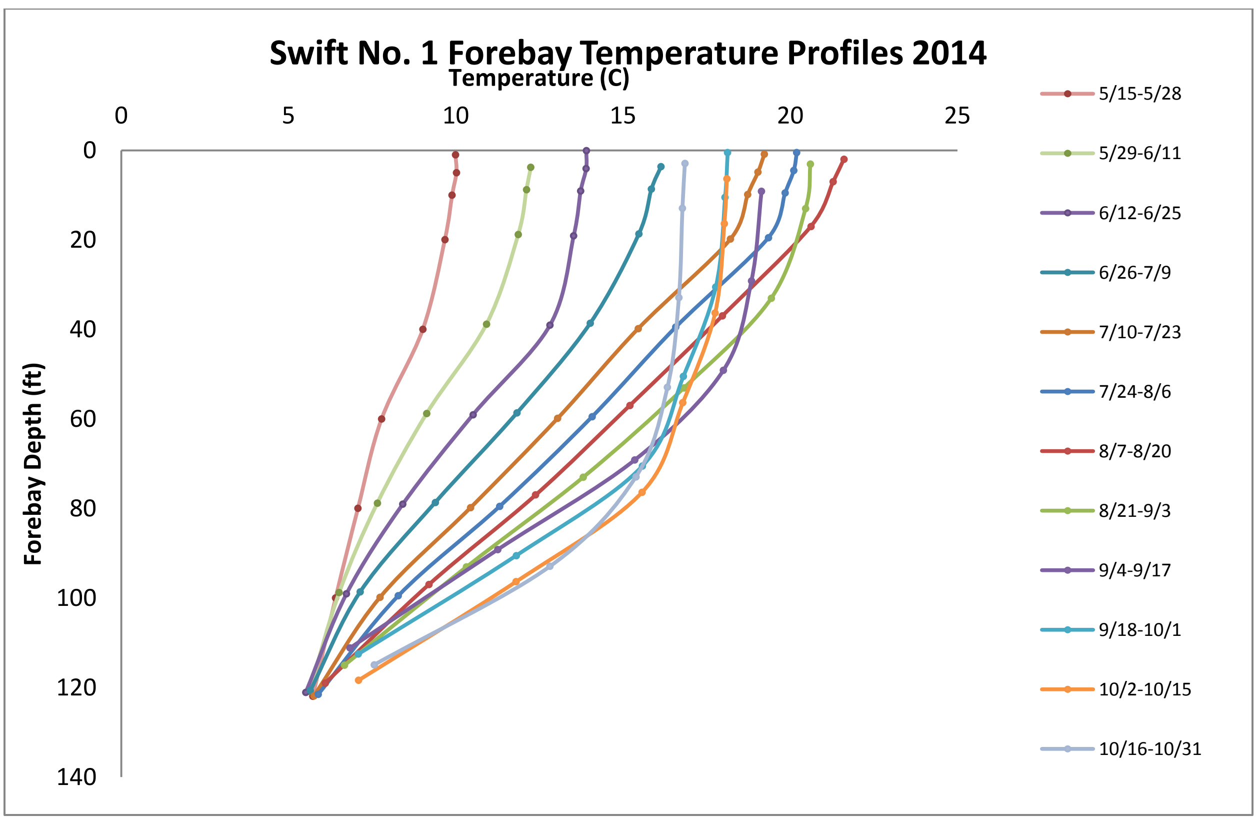


Figure 4. Swift Reservoir forebay temperature profiles (May – Oct, 2014).

MEMO

Operational Guidelines in Consideration of a 5-Day Summer Work Schedule at the Merwin Fish Collection Facility

Prepared by PacifiCorp

Reviewed and Accepted by the Aquatic Coordination Committee

Final: July 9, 2015

Background

During the June 2015 monthly Aquatic Coordination Committee (ACC) meeting, PacifiCorp requested that operations of the Merwin Fish Collection Facility (MFCF) be modified to a five (5) day per week work schedule during the summer months of July and August. Currently the facility operates seven (7) days a week. Rational for this request is that during this timeframe, catch at the facility consists almost exclusively of adult hatchery summer steelhead. These fish are either transported back downstream as part of the WDFW angler recycling program or are taken directly to a hatchery; summer steelhead are not transported upstream. PacifiCorp's proposal is to go to a schedule in which the fish lift and conveyance system remains operational seven (7) days per week, however daily sorting of fish would only occur Monday through Friday. Fish collected on Saturday and Sunday would be held in the presort pond and then processed the following Monday. The following section provides a summary of the protocols that would be used to guide operational decisions for the MFCF during the summer and returning to a seven (7) day per week schedule in the fall.

Proposed Operational Protocols

An adaptive management type approach will be used for determining if/when the abbreviated summer work schedule is implemented each year. The reason for this is that conditions can change from year to year, and full fish reintroduction has not yet been established. Currently, all spring Chinook are being transported to the hatchery as part of brood stock collection. While the majority of these fish arrive at the MFCF in May and June, some of these fish are also collected in July and August. Once full reintroduction has been established, transport of these adults into the upper basin will need to be considered. PacifiCorp will consult with the ACC prior to implementing the five (5) day per week summer operations schedule each year.

PacifiCorp will resume a seven (7) day per week sorting and transport schedule when early-run coho begin to arrive at the MFCF and no later than the first day of September. Returning to an extended schedule prior to September would occur when a combined total of five (5) early run coho are collected over the preceding five (5) day work period or conditions are forecasted that would stimulate fish to pass (i.e., increased flows at Merwin Dam). Coho counts downstream at Lewis River Hatchery will be used to guide this decision.

APPENDIX B

2015 COHO SALMON UPSTREAM RELEASES STRATEGY MEMO

2015 Coho Revised Tagging, Release and Tracking Plan
Prepared by PacifiCorp
August 28, 2015

Background

The Hatchery and Supplementation (H&S) subgroup met on July 21, 2015 to discuss the protocol for adult coho supplementation upstream of Swift Dam this fall. Some important modifications were proposed at this meeting and were accepted by the ACC during the August 13, 2015 meeting. These modifications include:

1. Reduction in the number of coho supplemented from 9,000 to 7,500 total adults upstream of Swift Dam in 2015

Original target numbers for adult supplementation of coho (9,000) were based on initial Ecosystem Diagnosis and Treatment (EDT) modeling that relied largely on opinion from local biologists and U.S. Forest Service staff. Recent distribution studies suggest that (1) most coho are not distributing successfully and (2) EDT estimates may have overestimated the carrying capacity. In addition, there is concern that large numbers of coho may lower spawner success of bull trout (e.g., redd superimposition). Lastly, while the low flow situation can change quickly, the expectation is that flows will be substantially below normal in the fall 2015. Lower flows reduce available habitat especially for side channel and tributary spawners such as coho. For these reasons, the target value was reduced to 7,500 (about 20 percent) until revised EDT estimates are available.

2. The addition of late (Type-n) coho as a supplementation species

The H&S Plan and Lewis River Settlement Agreement identify only early coho as the reintroduction species (as opposed to late coho). However, the H&S subgroup agreed that early and late coho should be combined as one group for supplementation purposes. This change aligns the coho supplementation program with regional recovery planning efforts that do not differentiate between early and late coho (e.g., Lower Columbia River ESA Recovery Plan). PacifiCorp believes it makes more sense to consider the two runs of coho as one stock to be consistent with the Recovery Plan than to continue on a path that differs from the Plan. By incorporating late coho into the supplementation program, the supplementation period will be expanded from two months (September – October) to four months (September – December). This expansion will also extend the spawn timing of coho in the upper basin. Natural factors such as water temperature, water flow and turbidity will influence spawning success, and therefore (over time), naturally influence future run timing for natural origin coho. Other benefits include (1) a more flexible transportation schedule that can adapt better to actual run sizes and (2) more potential for coho to distribute into the upper basin due to the extended transportation window and variable flow conditions in the fall.

3. Revised transport schedule for coho supplementation in 2015

A revised transport schedule for coho was created that includes both early and late coho with a supplementation goal of 7,500. The schedule is based simply on actual trap counts of only natural origin coho over a period of years (Figure 1) and applying those proportions over the course of the run (Table 2).

Ideally, the collection schedule would include only natural origin recruit (NOR) coho, however, there are currently not enough NOR coho to achieve the target. Therefore, all available NOR coho would be transported upstream and hatchery origin recruit (HOR) coho would make up the remaining number for each two week period.

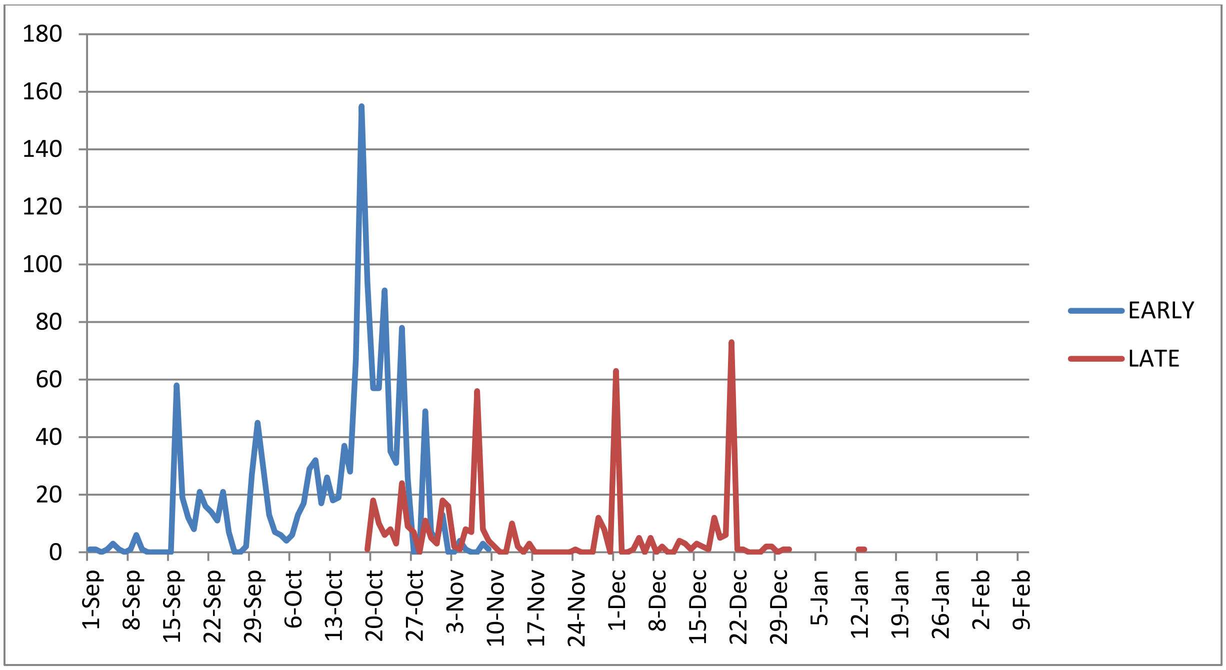


Figure 1. Average daily counts for both early and late NOR coho at Merwin Dam (2010 – 2014) and the Lewis River ladder (2004 – 2010).

Table 1. Proposed collection rate of coho indicating relative and cumulative proportion by two-week period over the collection and transport window.

Period	Number of Coho*	Relative Proportion	Cumulative Proportion
Sep 1-15	300	*0.04*	*0.04*
Sep 16-30	1,200	*0.16*	*0.20*
Oct 1-15	1,300	*0.17*	*0.37*
Oct 16-31	2,000	*0.27*	*0.64*
Nov 1-15	600	*0.08*	*0.72*
Nov 16-30	800	*0.11*	*0.83*
Dec 1-15	700	*0.09*	*0.92*
Dec 16-31	600	*0.08*	*1.00*

** Values based on supplementation goal of 7,500 adults*

Upstream Release Locations and Strategy

Four upper basin release sites will be utilized in 2015. These locations include: 1) Eagle Cliff Adult Release Site; 2) Clear Creek Bridge; 3) Muddy River Bridge; and 4) Upper Lewis River Bridge at Crab Creek. Only the Eagle Cliff Adult Release Site is accessible to the large capacity release truck; smaller capacity trucks will be used to transport and release fish at the other sites.

In order to get a better distribution of fish throughout the upper basin this year, emphasis will be placed on releasing fish at the higher drainage sites as opposed to the lower Eagle Cliff site. The smaller capacity trucks will be operated seven (7) days per week and will transport approximately 60 fish per day (approximately 900 per release period; Table 2). Fish will be distributed evenly among the three (3) higher drainage sites. All remaining fish for each two-week period will be released at Eagle Cliff. However, attempts will be made to minimize consecutive release days at Eagle Cliff to hopefully reduce large numbers of fish holding in the area as seen in 2014. For instance, large loads of fish transported to Eagle Cliff would occur every third or fourth day as opposed to every day.

Table 2. Proposed seed plant release schedule for Type-S and Type-N coho during 2015.

Period	Eagle Cliff	Clear Creek	Muddy River	Upper Lewis	**Total**
Sep 1-15		100	100	100	**300**
Sep 16-30	300	300	300	300	**1,200**
Oct 1-15	400	300	300	300	**1,300**
Oct 16-31*	1,100	300	300	300	**2,000**
Nov 1-15*	150	150	150	150	**600**
Nov 16-30*	200	200	200	200	**800**
Dec 1-15*	175	175	175	175	**700**
Dec 16-31*	150	150	150	150	**600**
Total	**2,475**	***1,675***	***1,675***	***1,675***	***7,500***

***** *Release numbers contingent on weather conditions and site accessibility.*

During each release period, emphasis will be placed on only transporting hatchery coho collected from the Merwin Fish Collection Facility; hatchery coho collected at Lewis River Hatchery will only be transported upstream in the event that the bi-weekly allocation will not appear to be obtained from fish recruiting to the Merwin Trap. No coho containing code wire tags (CWT) will be transported upstream, instead all CWT fish will be surplused at Lewis River Hatchery. All NOR coho will be transported upstream regardless of capture location (i.e., Merwin Trap or Lewis River Hatchery; except for those NOR late-coho that will be used for hatchery brood stock).

Revised Radio Tagging Schedule

The ongoing Adult Trap Efficiency (ATE) evaluation for the Merwin Fish Collection Facility will be modified for coho releases this fall. The original study plan for the ATE evaluation called for 150 Type-S (early run) coho to be radio tagged and released immediately downstream of Merwin Dam. Given the revised release schedule that now incorporates Type-N (late run) coho as part of the upstream transport plan, it is important to include these fish as part of the study design and ongoing evaluation. In addition, efforts will be made in 2015 to transport a number of radio tagged adult coho directly into the upper basin which will be released in various locations to further monitor movement and spawning distribution. These efforts will be done in concert with the ongoing redd and carcass surveys already scheduled to occur in the upper basin for adult coho. The following sections provide details as to the revised allocations for radio tagging and revised upstream release schedule.

Revised Tagging Schedule for ATE Evaluation

The 150 radio tags currently allocated for the ATE study will now be evenly distributed across both the Type-S and Type-N coho migration seasons. Approximately 75 adult coho from each stock will be radio tagged as well as implanted with a half-duplex PIT tag. All fish will be of hatchery origin and collected at the Merwin Fish Collection Facility. In general, tags will be distributed proportional to the run timing although slightly more fish will be tagged earlier during the respective runs to ensure that fish in good physical condition are being tagged (Table 3). In-season adjustments may be made depending on actual running timing curves (low flow conditions are expected which may affect run timing in 2015). All tagged coho recaptured at the Merwin Fish Collection Facility will be transported upstream and released at various locations in the upper basin (following a proportion curve similar to Table 2) for continued monitoring.

Table 3. Proposed ATE tagging schedule for Type-S and Type-N coho during 2015.

Period	Number Type-S	Proportion Type-S	Number Type-N	Proportion Type-N
Sep 1-15	15	*0.20*	0	*0.00*
Sep 16-30	26	*0.35*	0	*0.00*
Oct 1-15	23	*0.30*	0	*0.00*
Oct 16-31	11	*0.15*	15	*0.20*
Nov 1-15	0	*0.00*	19	*0.25*
Nov 16-30	0	*0.00*	19	*0.25*
Dec 1-15	0	*0.00*	15	*0.20*
Dec 16-31	0	*0.00*	7	*0.10*
Total	**75**		**75**	

Revised Tagging Schedule for Direct Upstream Releases

Approximately 130 surplus tags are available in 2015. These tags will be gastrically implanted into adult coho and directly transported upstream and released at various locations in the upper basin. Similar to the ATE study, these tags will be evenly distributed across both the Type-S and Type-N coho migration seasons. However, an emphasis will be placed on tagging exclusively natural origin (NOR) fish. Also similar to the ATE study, tags will be distributed proportional to the run timing although slightly more fish will be tagged earlier during the respective runs to ensure that fish in good physical condition are being tagged (Table 4). In-season adjustments may be made depending on actual running timing curves (low flow conditions are expected which may affect run timing in 2015). All radio tagged fish will also be implanted with a half-duplex PIT tag. An additional 500 adult NOR coho will also receive a half-duplex PIT tag. These fish will comprise most of Type-S coho and will be monitored at various PIT antenna sites located in the upper basin (these sites are typically operated through October).

Table 4. Proposed ATE tagging schedule for Type-S and Type-N coho during 2015.

Period	Number Type-S	Proportion Type-S	Number Type-N	Proportion Type-N
Sep 1-15	9	*0.15*	0	*0.00*
Sep 16-30	23	*0.35*	0	*0.00*
Oct 1-15	20	*0.30*	0	*0.00*
Oct 16-31	13	*0.20*	13	*0.20*
Nov 1-15	0	*0.00*	16	*0.25*
Nov 16-30	0	*0.00*	16	*0.25*
Dec 1-15	0	*0.00*	13	*0.20*
Dec 16-31	0	*0.00*	7	*0.10*
Total	**65**		**65**	

Manual and Aerial Tracking

PacifiCorp plans to use a combination of both aerial, fixed station and on-the-ground manual tacking of radio tagged coho in the upper Lewis. Redd surveys will already be taking place throughout the spawning period (weather permitting) to evaluate spawning success and distribution. The purpose of this task is to further evaluate movement and distribution patterns, both spatially and temporally, of radio tagged coho released in differing locations throughout the basin. The main objective of this task is to determine whether seed planting encourages a better distribution of coho across available habitat and drainages. This information will also be used to complement (validate) distribution information obtained from ongoing redd and carcass surveys occurring in the upper basin.

Tracking Schedule and Strategy

PacifiCorp has at least two aerial flights reserved and available for scheduling during the 2015 coho spawning period. Exact dates for the flights will be adaptively scheduled based on the number of fish released upstream, number of radio tagged fish released upstream, and what information is gathered from on the ground redd and manual tracking surveys. With only two confirmed aerial surveys available, PacifiCorp wants to strategically schedule such that the most information is gathered.

PacifiCorp staff has capacity to designate two days per week towards manual tracking radio tags on the ground. The surveyors will be equipped with a Lotek SRX 800 receiver with GPS locating capability. The GPS locator automatically records the tag ID, GPS location of the tag, and a timestamp of the record. This technology enables the surveyor more time to effectively survey the reaches. The upper Lewis River basin is vast; surveying the entirety of available habitat on foot is not feasible. Index reaches were designated and chosen based on: 1) ability to physically reach the site; 2) ability to adequately survey the reach; 3) likelihood of there being coho present, and 4) general vicinity to the seed plant release sites. Preliminary designations of index reaches to be surveyed are described below:

> *Upper Muddy and Clearwater Rivers to FR 25:* This index will begin on the Muddy River just upstream from the confluence of Smith Creek. The reach will then extend downstream to FR 25 Bridge. The lower Clearwater River will also be surveyed from the confluence with the Muddy River upstream 1 mile. Total length of the survey reach is approximately 5.5 miles. The starting point is reachable at the end of the FR 8322 road. Surveyors will use a combination of surveying from floatable kayaks (for the Muddy River portion) and by foot (for the Clearwater River portion). Due to low water, this index reach may not be floatable earlier in the coho spawning season.
>
> *Lower Clear Creek and Muddy River:* This index will begin on Clear Creek at the FR 93 Bridge and continue downstream to the confluence with the Muddy River, a distance of 1.5 miles. Upon reaching the Muddy River the survey will continue on the mainstem of Muddy River downstream for 1 mile, giving the index a total distance of 2.5 miles.
>
> *Mainstem Lewis River:* The Lewis River Trail #31 will be utilized for surveying the Upper Lewis River. This index will consist of an upper and lower segment. The Upper segment will be surveyed while walking trail #31 and will represent waters from Lower Falls to a point approximately 1 mile downstream of Crab Creek. The lower segment

will also be surveyed while walking trail #31 and will represent waters from the Curly Creek Bridge to a point approximately 2 miles upstream.

Swift Reservoir Tributaries: This survey will consist of multiple streams in which each streams lower 0.5 miles will be surveyed. The tributaries will be reached by boat and walked upstream. The tributaries to be surveyed are S15, Drift, Range, and Swift Creeks. The radio tags being used sendoff powerful signals; consequently, other smaller tributaries may be driven up to by boat and quickly scanned for activity. If a particular smaller tributary is found to have substantial activity, surveyors can then walk the stream to better identify tags.

Each index will be surveyed once every two weeks beginning as soon as approximately 35 tagged fish have been transported upstream and continuing until most of the released radio tagged fish are believed to have spawned and died (~December 31st, 2015). Other sites (particularly the Pine Creek drainage and the lower section of the Lewis River from Curley Creek to Eagle Cliff) will also be surveyed. These reaches will be surveyed as time allows.

Because aerial surveys can cover nearly all the available habitat in a single day, these surveys may be used to compliment and validate (if done concurrently) results obtained from on the ground surveys.

Two (2) fixed receiver stations will be used to continuously monitor the head of Swift Reservoir (immediately downstream of Eagle Cliff) and at Swift Dam near the floating surface Collector. Fixed receivers will be downloaded weekly.

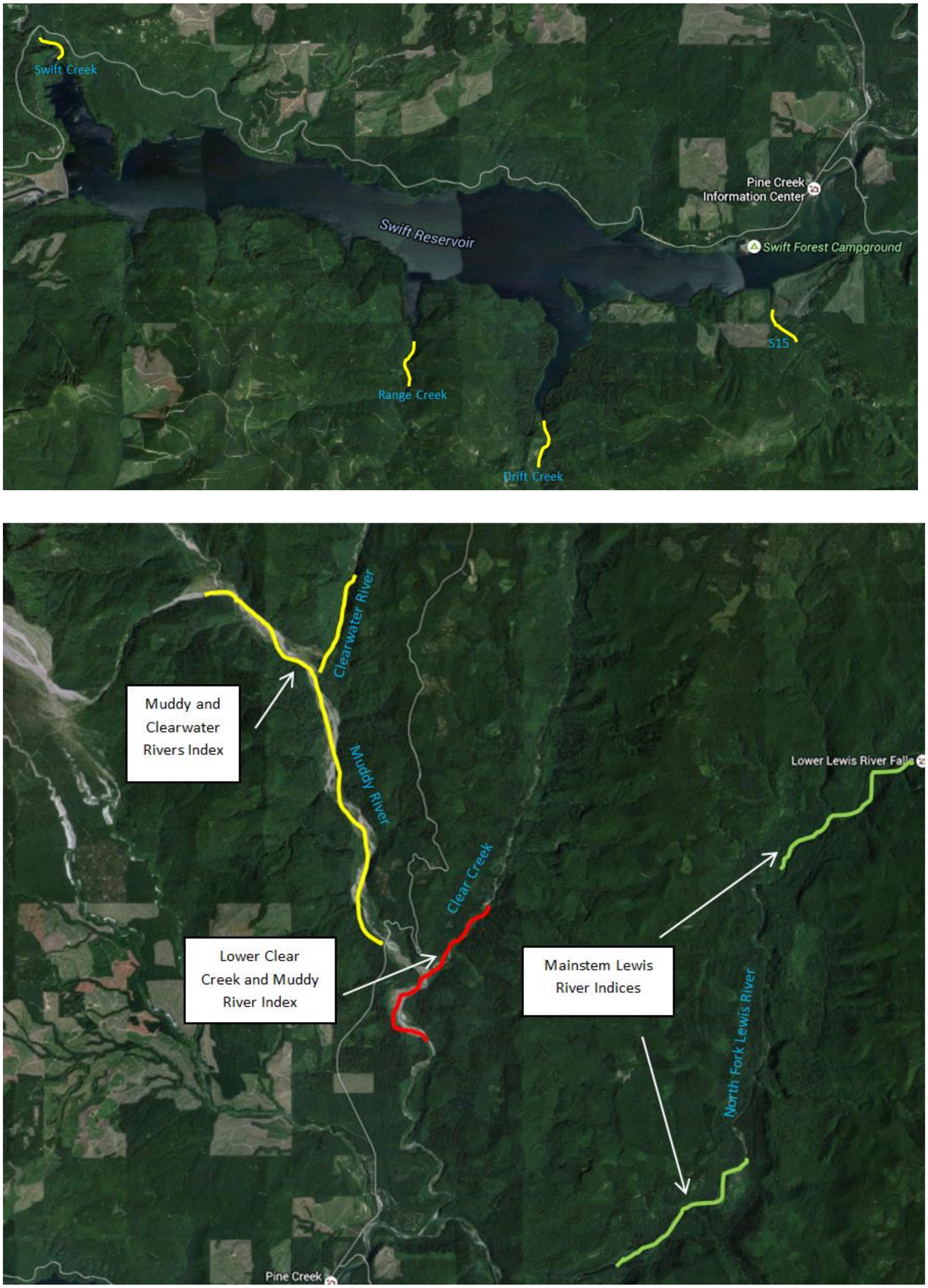


Figure 1: Index reaches for manual tracking radio tagged coho are shown.

APPENDIX C

SWIFT RESERVOIR FLOATING SURFACE COLLECTOR SMOLT COLLECTION EFFICIENCY EVALUATION

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SWIFT RESERVOIR FLOATING SURFACE COLLECTOR JUVENILE SALMON COLLECTION EFFICIENCY

2015 Annual Report Memo

Prepared for:

PACIFIC POWER
A DIVISION OF PACIFICORP

Prepared by: Emily Reynolds, Lindsey Belcher and Peter Stevens - Cramer Fish Sciences

December 2015

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EXECUTIVE SUMMARY

PacifiCorp and Cramer Fish Sciences jointly completed the third year of a study designed to quantify the collection efficiency (P_{CE}) of a new state-of-the-art floating surface collector (FSC) designed to collect out-migrating juvenile salmonids from Swift Reservoir on the North Fork of the Lewis River, Washington. The Lewis River is a major tributary of the Columbia River, roughly 133 km upstream from the mouth, and it supports anadromous populations of fall Chinook, spring Chinook, Coho, and chum salmon, as well as summer and winter steelhead and sea-run cutthroat trout. In 2011, PacifiCorp began releasing adult stocks of winter steelhead, spring Chinook, and Coho into Swift Reservoir with the goal of re-establishing natural runs of these species in the upper Lewis River Basin. The FSC began operation in December 2012.

This report summarizes the results from year three of a telemetry study designed to address the needs of Section 2.2. of the Lewis River Aquatic Monitoring and Evaluation Plan (hereafter "M&E Plan"; PacifiCorp and Cowlitz PUD 2010). The M&E Plan describes the need to quantify P_{CE} of the FSC with a goal of 95% for those juvenile salmonids that are available for collection. Following methods outlined in Section 2.2. and recommendations made from the 2014 study (Stroud et al. 2014), all Coho, spring Chinook and steelhead smolts were initially captured from the screw trap located at Eagle Cliff or angled from the upper reservoir. These fish were then dual tagged with acoustic and passive integrated transponder (PIT) tags, released at the head of Swift Reservoir near the south shoreline and opposite of Swift Forest Camp boat launch, and then monitored using an autonomous acoustic telemetry array designed to detect fish as they made their way back downstream towards the FSC. Autonomous acoustic receivers were deployed around the FSC to detect smolt attraction and passage rates, and were used to describe behavioral mechanisms driving P_{CE}. We report on: 1) the attraction and calculated P_{CE} of Coho, spring Chinook, and steelhead smolts at the FSC; 2) preferred approach behaviors of smolts; and 3) potential thermal effects on passage success rates.

In total, 200 smolts were dual tagged and released. Of these fish, 159 were detected near the entrance of the FSC at the zone of hydraulic influence (ZOI) and 21 successfully passed for an overall P_{CE} of 13.2% (21 of 159). While most smolts (>75%) were observed to pass at water temperatures less than 15^{o}C, there was not a significant effect of temperature on collection efficiency. First entrances to the forebay were spread approximately evenly between southern and northern shorelines. However, once in the forebay, most fish approach the FSC from the south even those that initially enter along the north shoreline. In general, smolt transitioned from south to north shorelines and passed the entranced of the FSC along their trajectory. All species had peak rates of first passage within 450 feet of the FSC entrance and approximately 90% of the fish made their first pass within 650 feet of the FSC entrance.

INTRODUCTION

The FSC is a floating barge (164 x 66 x 26 feet) that has been equipped for collection, handling, and transport of juvenile and adult fish. The FSC is located at the south end of the Swift Dam near the turbine intake. Attached to the front of the barge is an independently floating structure called a Net Transition Structure (NTS), with barrier nets that extend to either shoreline to prevent fish from going past the FSC and entering the turbine intakes. The barge captures fish through an artificial stream channel created by pumps that create a maximum velocity of about 7 feet per second with approximately 600 cubic feet per second (cfs) of flow during normal operations (80% of full capacity). The channel then guides fish from the NTS into the FSC for safe transport downstream. The Zone of Influence (ZOI) is defined as a roughly 150 feet radius section of water in front of the structure which is influenced by positive flow, designed to be attractive for emigrating fish (PacifiCorp and Cowlitz PUD 2010).

In 2013, a pilot study validated the proposed study design demonstrating that radio telemetry was feasible for implementation. While P_{CE} could not be calculated that year due to failure of the exclusion net allowing large numbers of smolts to access the area behind the FSC, a number of valuable insights were gained leading to: 1) the removal of the mooring tower receiver station, 2) the addition of receiver stations at the north and south shoreline at the entrance to the forebay, and 3) reduction the radio tag burst rate from 7 seconds to 5 seconds.

In 2014, P_{CE} was calculated at 26.3% but tagging effects and fish stress may have been factors in collection efficiency rates (Stroud et al. 2014). We determined that capture at the FSC and release mid-reservoir was likely impeding normal smolt out-migration behaviors due to fish stress and non-naive fish. An opportunistic experiment revealed that 88% (7 of 8) of fish released at the rotary screw trap (RST) located at the head of the reservoir at Eagle Cliff were subsequently detected in the forebay. This was a substantially higher P_{RES} (88% for Eagle Cliff release v. 19.7% for all other fish) than that observed for fish collected from the FSC and released only 1km upstream. For 2015, we determined that fish would be collected from the RST at Eagle Cliff and released at the head of the reservoir on the south shoreline opposite Swift Forest Camp to take advantage of prevailing downstream current while bypassing the zone of most active bull trout predation.

For the first two years of the study (2013 and 2014), a radio telemetry array comprised of five fixed-site stations equipped with Lotek SRX-400 receivers were used to monitor P_{CE}. However, in 2015 an array of autonomous acoustic receivers was deployed in order to give insight into the behavioral mechanisms driving FSC collection numbers. Using the acoustic array, we were still able to determine the proportion of tagged fish that enter the ZOI that were later collected by the FSC in addition to capturing finer-scale movement information on the factors driving P_{CE}.

METHODS

An array of ten (10) autonomous acoustic hydrophones was deployed within the forebay (Figure 1). A single hydrophone was deployed about 100m off the north shore peninsula (known as "Devil's Backbone"), while another was deployed approximately 100m from the south shore. These opposing hydrophones were used to determine how fish approached the forebay and eventually transitioned to the FSC. Another single hydrophone was deployed near the south turning point of the barrier net where it connects to the south shore to assess whether fish were delayed in this area. A seven (7) hydrophone array was also deployed directly in front of the FSC. This array was arranged in a "double-diamond" configuration with the long axis running perpendicular to the face of the barrier net. Each hydrophone was paired with a beacon tag. Two moorings were deployed at the center of each "diamond" in the FSC array on individual moorings. This format was designed to provide the highest likelihood of resolving travel paths for fish past the entrance to the FSC. The single receiver deployed at the entrance to the FSC served to define the ZOI. Any single hydrophone had a maximum detection range of approximately 100m under ideal conditions but functional ranges were approximately 30-50m when tested. A fixed PIT tag antenna was used to detect fish after they entered the sorting building on the FSC and were successfully collected.

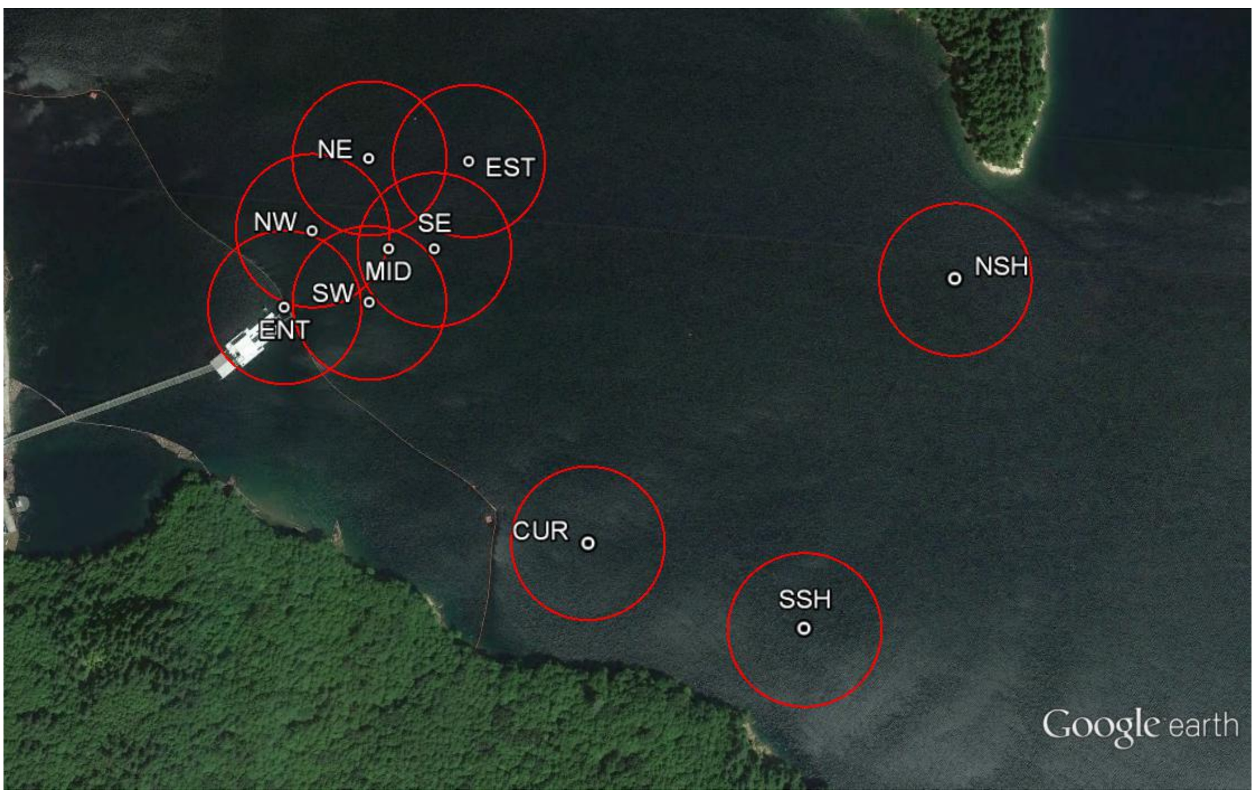

Figure 1. Diagram of the study area depicting the 10 receiver stations within the forebay, comprising the Swift Reservoir floating surface collector telemetry array. Average detection ranges based on range testing are indicated in red.

Only healthy fish free of injury or parasites and displaying smoltification were tagged. The majority (75%, n=150) of smolts were collected and tagged at the head of Swift Reservoir using the screw trap installed at Eagle Cliff. A small number of test fish (14%, n=27) were also collected using hook and line sampling in the vicinity of Eagle Cliff. Twenty three smolts (11%) were collected directly from the holding tanks inside the FSC. All test fish were released at the head of the reservoir.

To reduce varying effects of multiple taggers, all fish had tags surgically implanted by the same designated PacifiCorp staff member. All equipment used in the surgery process (i.e., scalpels, sutures, forceps, scissors, acoustic and PIT tags, and gloves) were sterilized in a Nolvasan bath before use on each fish. Fish were anesthetized in an 80 mg/L MS-222 bath buffered with a 1:1 sodium bicarbonate ratio by weight. Fish remained in the anesthesia bath for approximately 2.5 minutes until full muscle paralysis was observed. Fish were then placed in a minicell foam form to support fish position during surgery. Throughout the surgery fish were exposed to maintenance anesthesia of 40 mg/L of MS-222 buffered 1:1 with sodium bicarbonate by weight. A single incision, approximately 7mm in length, was made just anterior of the pelvic girdle and on center with the ventral line. To reduce the risk of injuring organs a 3mm restricted depth scalpel was used. Both the PIT and acoustic tags were inserted into the body cavity via the incision. Once tags were inside the cavity the incision was closed with a single monofilament suture. The surgery process took approximately 2 minutes on average; therefore fish were under anesthesia exposure for approximately 4.5 minutes. Following surgery, fish were placed in freshwater and allowed a minimum of 2 hours to recover prior to release in the reservoir.

Following recovery, all tagged fish were released near the south shore of Swift Reservoir opposite of Swift Forest Camp (Figure 2). This release location was chosen because prevalent downstream currents often exist here (reminiscent of Lewis River momentum entering Swift Reservoir) and that smolts will bypass staging bull trout that congregate within riverine environments near Eagle Cliff.

Prior to the study, the surgical methods outlined above were tested on hatchery steelhead smolts obtained from Merwin Hatchery. Five steelhead smolts were anesthetized, tagged, sutured, and allowed to recover in the same manner as was intended for the study. Following surgery, tagged steelhead smolts were placed in a 250 gallon tank with constant water supply for two weeks. An additional 5 untagged and non-anesthetized steelhead smolts were held in the same tank over the course of the trial as a control. At the end of the two week holding period all fish, tagged and control, were alive and displayed similar healthy movement patterns. Tagged fish were then culled and underwent further inspection. All incisions were reattached and firmly healed with no apparent skin or tissue abnormalities. The body cavities of tagged fish were then reopened and inspected for injury. There were no signs of organ damage resultant of incision or suture needle puncturing.

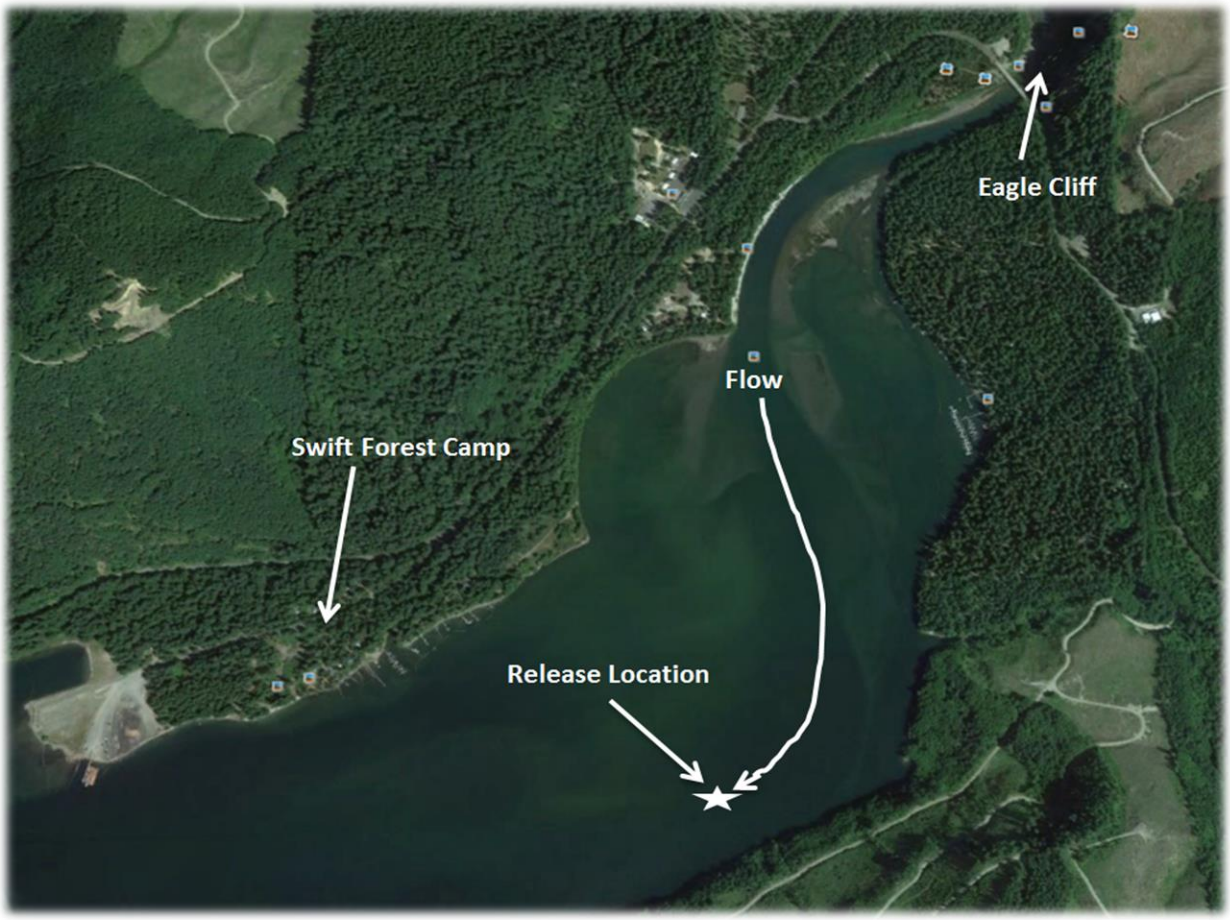

Figure 2. Map of the release location for all tagged fish in the study.

Transfer tanks used to move tagged fish were filled with water pulled directly from the reservoir's surface, thus the temperature was representative of the surface conditions. Care was taken to ensure that transport tanks remained within 2°C of the holding tanks at all times to reduce thermal stress. Water-to-water transfers were the preferred technique when moving fish.

Due to the remoteness of the tagging and release site, there were no appropriate facilities as outlined in Section 2.2 of the M&E Plan (i.e., small circular raceways with adequate long-term holding environment) to perform a paired holding study. Therefore the acoustic telemetry study did not specifically quantify tag failure, tag loss, decay rate or determine post-release mortality. Instead all fish were PIT tagged in addition to receiving an acoustic tag. The FSC has highly efficient PIT tag arrays that detect smolts captured by the FSC. To address tag failure, tag loss and decay rate, PIT tag records at the FSC were compared to acoustic tag records within the forebay and FSC entrance. Thus, if a PIT tag was recorded as captured in the FSC but no records were observed in the acoustic records then the acoustic tag could be assumed to have failed, lost from the body cavity or the battery power had decayed. In addition to PIT tagging, PacifiCorp completed several manual tracking exercises within Swift Reservoir to help address post-release mortality and predation. Surveys were done by deploying an acoustic antenna behind a boat and driving designated routes. During each survey, the entire forebay and head of the reservoir were monitored along with six reservoir cross sections of equal distance apart, and each tributary cove. Manual tracking data was then analyzed for tag codes remaining in the same position over several survey periods (signifying a possible post-release mortality) or tag codes remaining around the Eagle Cliff area (signifying predation by bull trout). These two methods (PIT tagging and manual tracking) were done to generally inform or alert CFS and/or PacifiCorp personnel to any underlying problems associated with tag failure, tag loss, decay rate, post release mortality or predation. Exact quantities were not calculated. Rather, if data suggests an underlying problem with tag failure, predation etc. exists then future studies will need to include fish holding capabilities to perform a paired holding study.

Water Quality Conditions

As reservoir levels fluctuated across the study, we calculated daily average depth of each temperature logger based on its fixed height against the daily reservoir height. We then averaged the temperatures of loggers at each day that were exposed to depths between 2 and 11 feet to represent the reservoir conditions experienced by fish detected in this study. Reservoir temperatures captured directly behind the FSC increased across the study. Generally, reservoir temperatures were 1-2 °C cooler than the temperatures recorded in the FSC but the difference was not statistically significant (t-test; p value = 0.7119). The temperatures between 2 and 11 feet depth averaged 14.8°C on 1 June to 23.1°C on 30 June. Reservoir surface temperatures first reached 18°C (average 3 feet depth) on 6 June and 20 °C (average 1 feet depth) on 24 June. These temperatures were reached nearly a full month earlier than in 2014 demonstrating the extraordinarily hot year experience in the region in 2015.

PacifiCorp reported no significant power outages during the course of the study.

Analytical Approach

An automated computer script (ATS Trident SR3000; ATS, Inc.) was used to filter all capture histories for detections both prior to an individual tag's release and for detections after a confirmed capture at the FSC. Detection histories used for further statistical analysis were comprised of first and last detections at each receiver site (i.e., detection bins), plus PIT tag confirmations when fish entered the FSC. All records were manually reviewed for inconsistencies and then quality assurance/quality control checked by a second biologist.

The P_{CE} metric is a component of the entire reservoir survival estimate (S_{RES}), specified in Section 2.2 of the M&E Plan. For this study, P_{CE} was defined as the percentage of juvenile anadromous fish that were available for collection (i.e., detected at the ZOI) that were subsequently detected within the FSC and had successfully passed. A fish was considered detected by the FSC if its' detection history showed a logical, plausible progression through the array (e.g., detected at south shoreline, curtain and ZOI/entrance receivers in sequence over a reasonable period of time) and/or was confirmed by a PIT tag detection within the FSC. As stated in the Lewis River Settlement (PacifiCorp Cowlitz Co. PUD No. 1., 2004), the performance standard for P_{CE} is 95% or greater for smolts. To test the effects of capture location and smolt size on $P_{CE,}$ we conducted logistic regressions with fork length and capture location as independent predictors of P_{CE}. Capture location was treated as a contrast and interactions between capture location and length were tested. To test the effects of reservoir temperature on P_{CE}, we performed a two sided t-test. All analyses were implemented in the R statistical package.

RESULTS

Collection Efficiency (P_{CE}) — In total, 200 radio tagged fish were released at the head of Swift Reservoir. Tagged Coho, spring Chinook and steelhead had average fork lengths of 146 mm (SD: 34 mm; Min: 104; Max: 282 mm), 147 mm (SD: 22 mm; Min: 119 mm; Max: 178 mm) and 195 mm (SD: 24 mm; Min: 160 mm; Max: 280 mm), respectively.

Of all fish released, 159 fish were detected by the ZOI receivers (P_{ZOI}) at the entrance of the FSC (110 Coho, 6 spring Chinook, and 43 steelhead). Of the 159 released that migrated to (and were subsequently detected at) the ZOI, 13 Coho, 8 steelhead, and 0 spring Chinook passed for an overall P_{CE} of 13.2% (21 of the 159 detected in the ZOI) (Table 2). Those smolts that were collected during the spring out-migration period were detected passing between 28 April and 29 May 2015. Six of the 10 moved into the FSC between the hours of 1007 and 1805 and four were collected between 2158 and 2345 hours.

PIT tag detections within the FSC were reviewed through mid-November 2015 for fish that may have passed after the acoustic battery life had expired. Two fish were detected during this period, one Coho from the 27 May release and one steelhead from the 3 June release. The fish were detected passing on 16 November 2015 at 1935 hrs. and 3 December 2015 at 2217 hrs., respectively.

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Table 1. Total number and average length of tagged fish organized by species.

Release	Coho Salmon		Spring Chinook		Steelhead	
	Total released	Avg. FL (mm)	Total released	Avg. FL (mm)	Total released	Ave.FL (mm)
4/1	4	143	0	NA	0	NA
4/20	0	NA	0	NA	3	198
4/23	2	120	1	123	1	194
4/28	7	120	2	144	6	206
4/30	4	144	2	141	4	191
5/5	4	128	1	169	5	190
5/7	1	121	1	131	6	190
5/12	8	123	1	144	10	186
5/18	8	206	1	127	1	241
5/19	14	136	1	142	1	192
5/22	9	134	0	NA	1	170
5/26	18	117	0	NA	1	280
5/27	20	149	3	174	4	190
5/28	16	142	0	NA	2	180
5/29	3	139	1	127	0	NA
6/3	21	179	0	NA	2	220
Total	**139**	**146**	**14**	**147**	**47**	**195**
(Min – Max)		**(104 – 282 mm)**		**(119 -178 mm)**		**(116 – 280 mm)**

Table 2. Summary of passage metrics for tagged fish released at the head of Swift Reservior by species.

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	139	14	47	200
Detected in Forebay	126	9	43	178
P_{RES}	90.6%	64.3%	91.5%	89.0%
Detected at ZOI	110	6	43	159
P_{ZOI}	79.1%	42.9%	91.5%	79.5%
Captured at FSC	13	0	8	21
Collection Efficacy (P_{CE})	11.8%	0.0%	18.6%	13.2%

Single hydrophones at the north shoreline peninsula and opposite on the south shoreline detected the locational preferences for a fish entering the forebay (Figure 3). Nearly half of the detections (44%) occurred at the south shore (SSH; Figure 3), whereas 35% of the fish first approached from the north shore (NSH; Figure 3). There was a brief period (approximately 1 week) when the north shore hydrophone was non-operational. During this time, 20% of fish passing into the forebay were not detected at the south shoreline hydrophone. At times when both the north and south shoreline hydrophone were operational, only 1% of the fish (n = 1) passed through the middle area between the south and north shores. Therefore, we can likely infer that the vast majority of the 20% passed by the north shore hydrophone, resulting in just over half of the all fish entering the forebay at the north shore overall (55%).

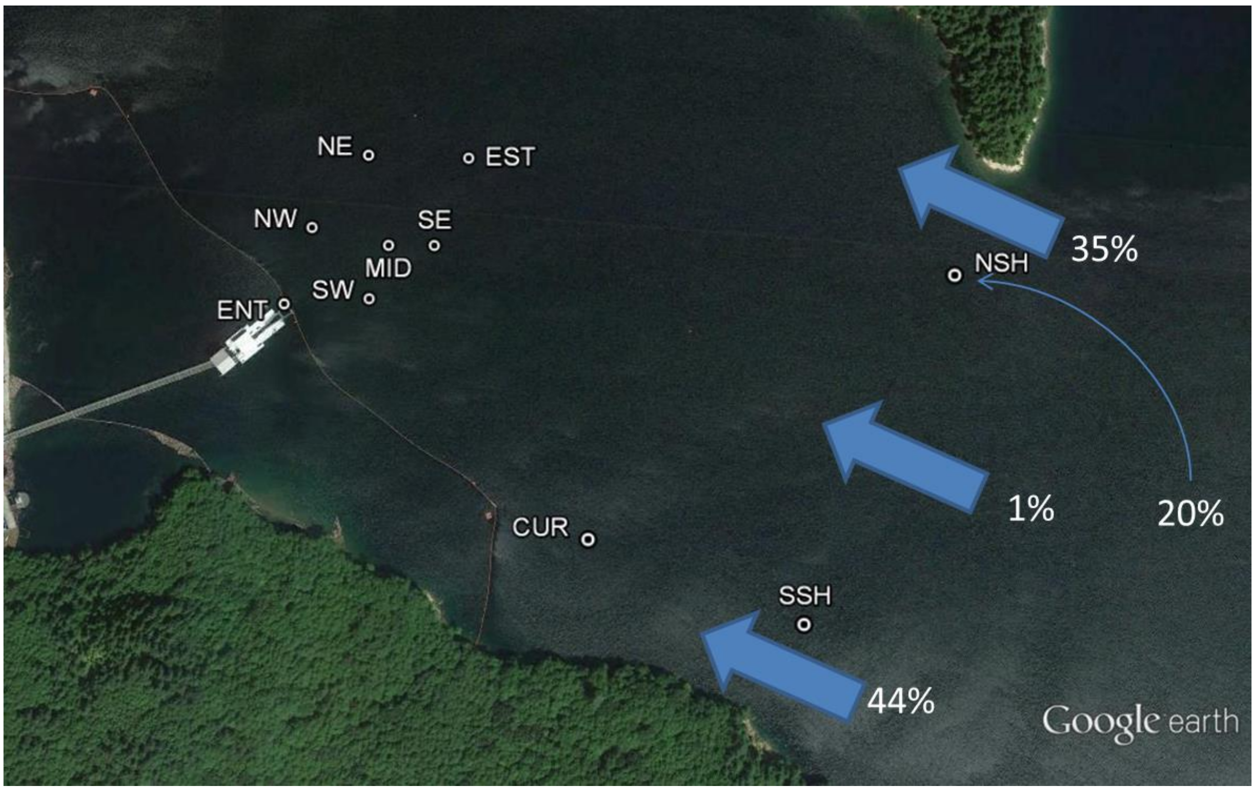

Figure 3. Distribution of the first forebay entrances by area (south shoreline (SSH) or north shoreline peninsula (NSH)), for all species combined.

Once in the forebay, most fish approached the FSC from the south (Figure 4, Table 3). Thirty-four percent (34%) of fish entered the forebay from the north shoreline (NSH; Figure 4) and proceeded directly into the array. However, 23% of fish entered at the north shoreline but then proceed southwest before being detected in the vicinity of the curtain receiver (CUR; Figure 4). These fish joined an additional 43% entering the forebay along the south shoreline (SSH; Figure 4) before being detected in the vicinity of the curtain. Those two groups comprise the 66% total of fish approaching the FSC from the south.

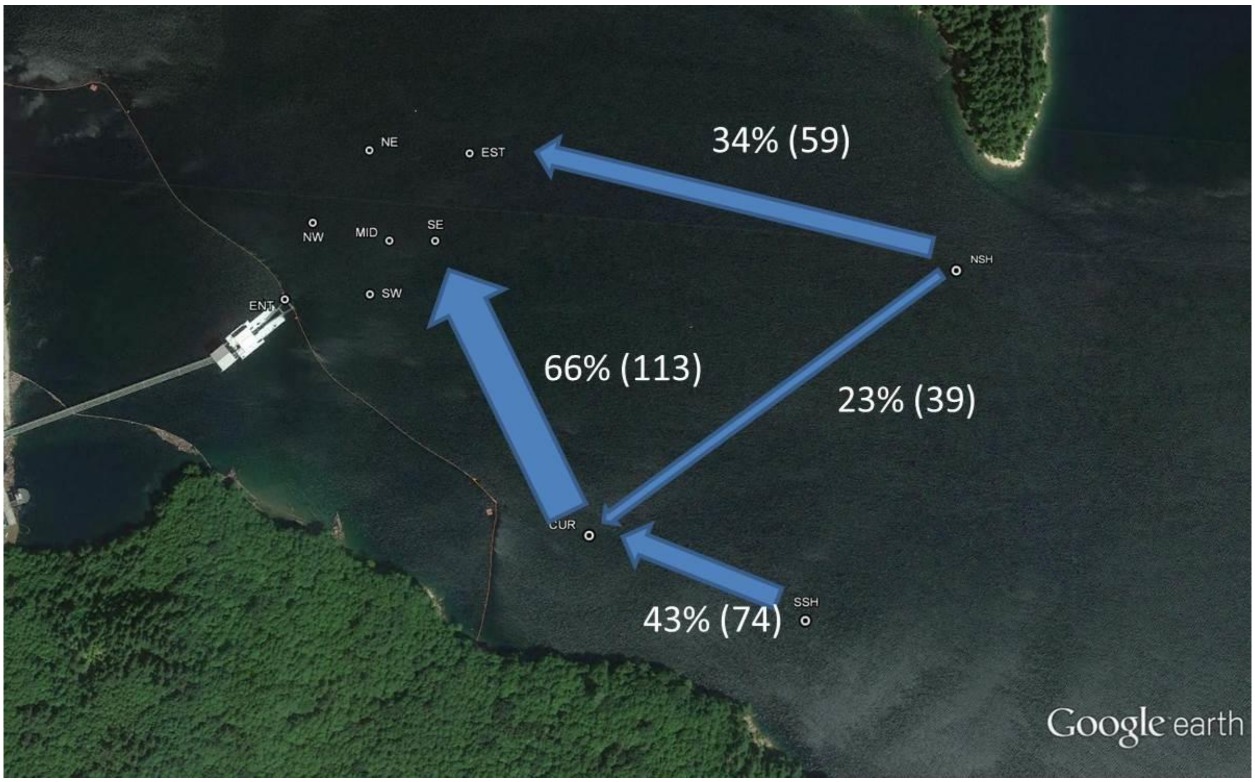

Figure 4. Forebay travel path for all species combined by count (N) and percentage (%). Thickness of arrow denotes relative proportion of fish taking that travel path.

Table 3. Forebay travel path for all species combined by count (N) and percentage (%).

	Location			
	NSH→CUR	SSH→CUR	CUR→ARRAY*	NSH→ARRAY
Count (N)	39	74	113	59
Percentage (%)	23	43	66	34

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* Indicates that CUR→ARRAY counts are a sub-total of the NSH→CUR and SSH→CUR counts combined.

A plurality of fish (43.2%) approached the FSC from the southwest along the curtain with first approaches to the FSC declining in a counter-clockwise direction from southwest to northwest (Figure 5, Table 4).

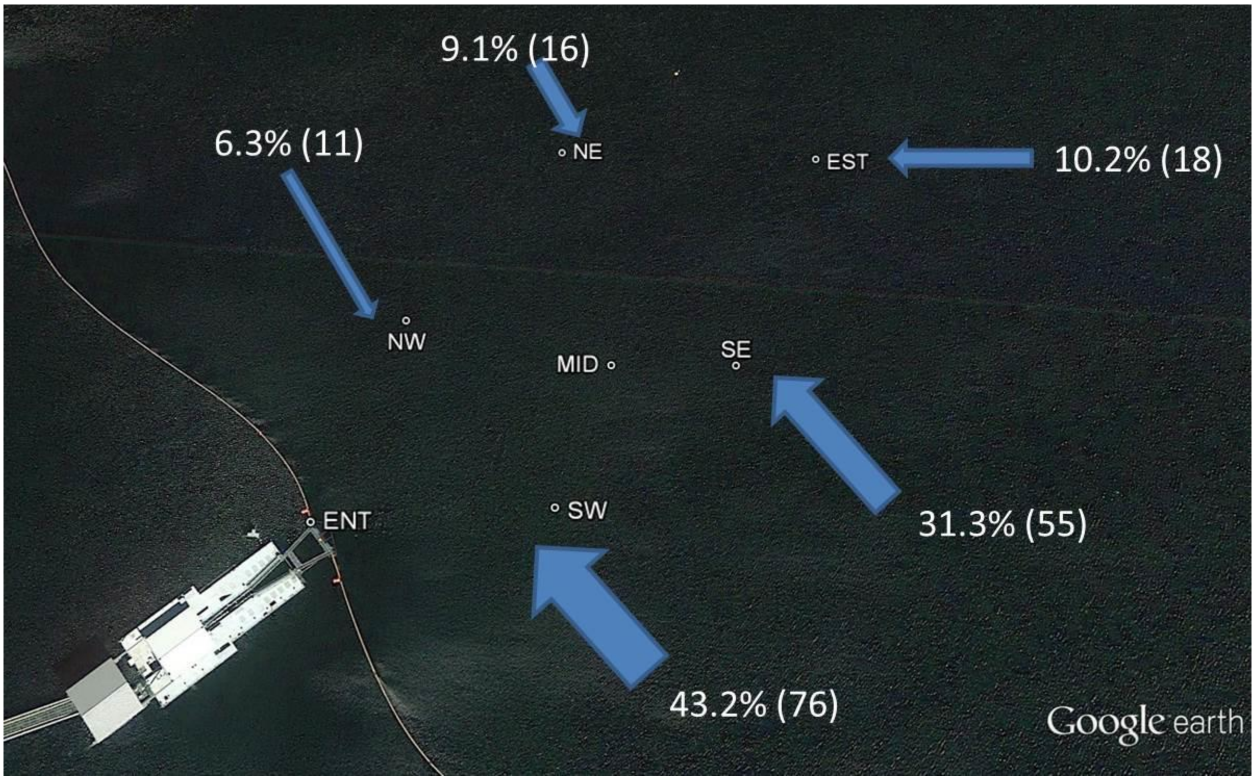

Figure 5. Array detection at various locations for all species combined by count (N) and percentage (%).

Table 4. Array detection at various locations for all species combined by count (N) and percentage (%).

	Location				
	SW	SE	EST	NE	NW
Count (N)	76	55	18	16	11
Percentage (%)	43.2	31.3	10.2	9.1	6.3

The horizontal distribution of tagged fish passing in front of the FSC was relatively consistent among species. The peak distribution of Coho (n=51, 41.1%), spring Chinook (n=4, 50.0%) and steelhead (n=16, 37.2%) were detected passing the array at approximately 200 to 450 feet away from the entrance to the FSC (Figure 6, Table 5); nearly all fish were detected at distances less than 650 feet away from the entrance to the FSC (Figure 7, Table 6).

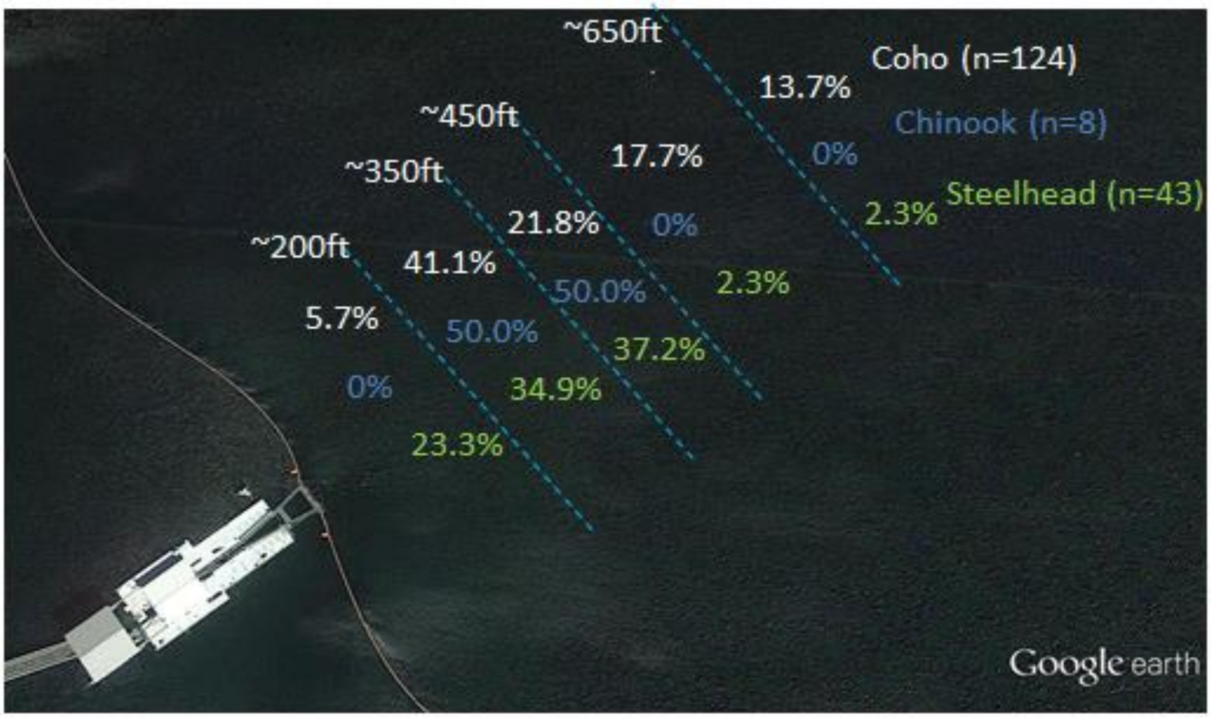

Figure 6. Distribution (%) of array entrances for all species, grouped by various distances from the entrance.

Table 5. The distribution of array entrances for all species, grouped by various distances from the entrance (to the floating surface collector).

	Detected (%) by Distance from Entrance				
	0-200 ft	200-350 ft	350-450 ft	450-650 ft	>650 ft
Coho Salmon (n=124)	5.7	41.1	21.8	17.7	13.7
Spring Chinook (n=8)	0	50.0	50.0	0	0
Steelhead (n=43)	23.3	34.9	37.2	2.3	2.3

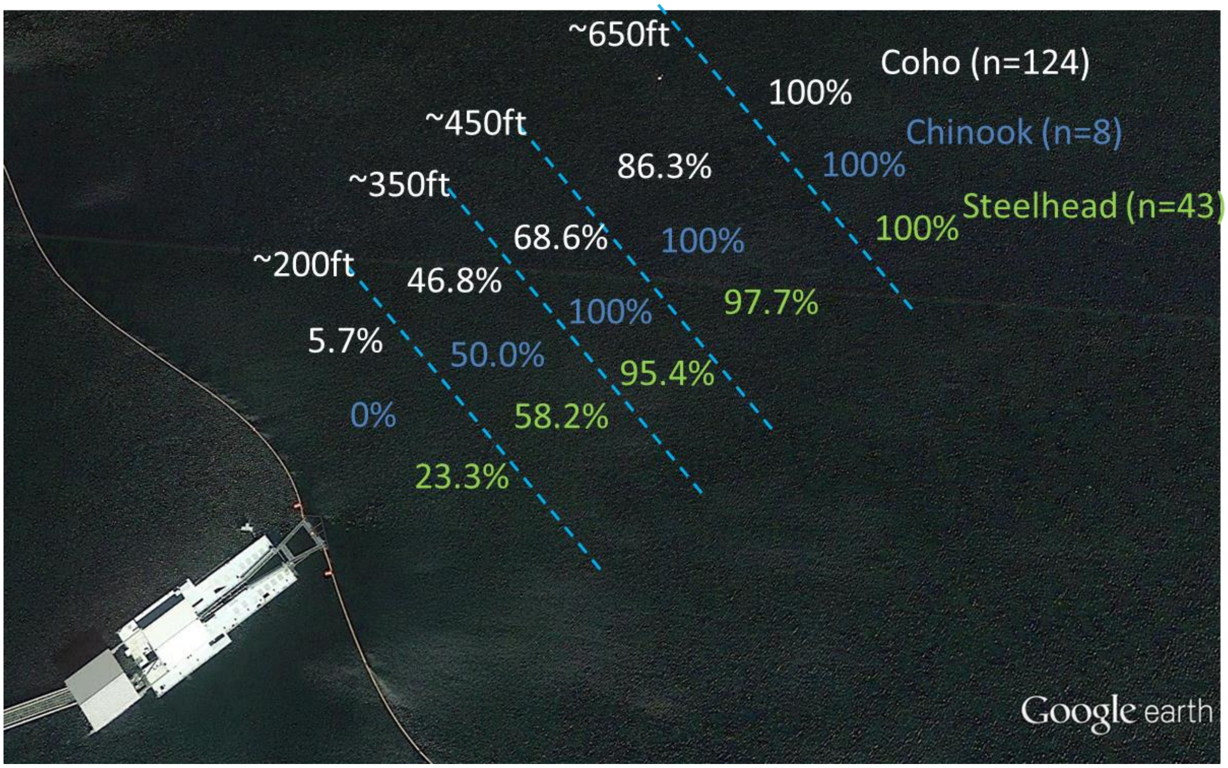

Figure 7. Cumulative distribution (%) of array entrances for all species based on distance from the entrance to the floating surface collector.

Table 6. The cumulative distribution (%) of array entrances for all species, grouped by various distances from the entrance to the floating surface collector.

	Cumulative Detected (%) by Distance from Entrance				
	0-201 ft	200-350 ft	350-450 ft	450-650 ft	>650 ft
Coho Salmon (n=124)	5.7	46.8	68.6	86.3	100
Spring Chinook (n=8)	0	50.0	100	100	100
Steelhead (n=43)	23.3	58.2	95.4	97.7	100

Tag failure, tag loss, decay rate, post-release mortality, predation — All PIT tag records from the FSC were analyzed and compared to recorded acoustic data taken in the forebay and ZOI. There were no records that indicate tag failure, tag loss or decay rate were an issue. That is, all fish that were recorded as being captured in the FSC via PIT tag records were also shown to enter the ZOI via acoustic data records. The only exception being the two fish that entered in fall (November and December) of 2015 after the study had ended for the year.

Review of the acoustic manual tracking data demonstrates there was not an apparent issue with post-release mortality or predation during this study. Of the 200 fish tagged and released at the head of the reservoir, 179 (90%) transitioned through the reservoir at least once and entered the forebay area. Of the 21 fish that did not enter the forebay only one (1) showed (via manual tracking) to not leave the head of the reservoir and was possibly predated upon. An additional 3 of the 21 tagged fish were never recorded after their initial release by any acoustic array, manual tracking, or PIT tag detectors. None of the remaining tags were found to be located in the same spot for multiple surveying dates, indicating post-release mortality is likely not an issue.

The general movement patterns observed during the acoustic manual tracking data were similar to those made previously during the Swift Reservoir smolt behavior studies prior to the construction of the FSC (PacifiCorp 2001; PacifiCorp 2002). Fish appeared to migrate easily to the forebay area and after they did not successfully pass move widely throughout the reservoir. Numerous fish transitioned the length of the reservoir multiple times. Earlier in the season, on survey dates May 14 and May 20, fish appeared spread throughout the reservoir. On the June 12 survey fish specifically seemed to be located in the forebay, the head of the reservoir or in various coves of the reservoir. The June 25 survey showed the majority of fish either in the forebay or at the head of the reservoir. Fish that were not detected in the forebay during these latter surveys of June 12 and June 25 appear to be located in areas of colder waters from tributary inflows. A summary of manual tracking events is provided in Appendix A.

Capture Location – There was no significant difference between collection rates based on capture location for Coho (Logistic Regression w/ Contrasts; RST v. Hook & Line – $p = 0.66$, RST/Hook & Line v. FSC – $p = 0.99$) or steelhead (Logistic Regression w/ Contrasts; RST v. Hook & Line – $p = 0.40$, RST/Hook & Line v. FSC – $p = 0.43$) individually or both species combined (Logistic Regression w/ Contrasts; RST v. Hook & Line – $p = 0.73$, RST/Hook & Line v. FSC – $p = 0.35$). These results may have been confounded by small sample size as relatively few fish of any species were collected. Eleven percent (17 of 147) of fish captured in the rotary screw trap, ten percent (3 of 30) of fish captured by hook-and-line and four percent (1 of 23) of fish captured by the FSC were subsequently collected by the FSC. No comparisons were made with spring Chinook as no spring Chinook were collected.

Length-Dependent Collection – There was no significant effect of fish length on collection for Coho (Logistic Regression; $p = 0.40$) or steelhead (Logistic Regression; $p = 0.67$). Again, no comparisons were made with spring Chinook as no spring Chinook were collected and small sample size may be a confounding factor here as relatively few fish of any species were collected.

Temperatures – Water temperature was monitored in Swift Reservoir just downstream of the FSC at fixed depths of roughly 1, 5, 10, 20, 40, 60, 80, 100, and 122 feet, which were corrected based on reservoir elevation. For the purpose of comparing water temperature to fish passage rates, we assumed that collected fish were primarily active at five feet below the surface. Due to a lack of temperature data for the period of April 28-May 10 (in which 8 fish passed through the FSC), the analysis was performed only for those fish that passed in spring when temperature data was collected (starting May 11th; n=18). Water temperatures within the reservoir were not related to passage success rate (t-test; p=0.897; Figure 6). However, the majority of fish passage occurred when surface temperatures remained below 15 °C (late-May and mid-June). Temperatures were generally warmest within the upper 40 feet (averaging 11°C in May and then increasing to 18 and 19°C by late June). Cooler water (under 10°C) was consistently available at depths of 60-80 feet and below.

Temperature within the FSC holding tanks remained largely similar to reservoir temperatures across the study. FSC temperatures were not significantly warmer than the reservoir surface temperatures (range of difference between reservoir and FSC: -1.7 to 5.1 °C) (t-test; p value = 0.7119).

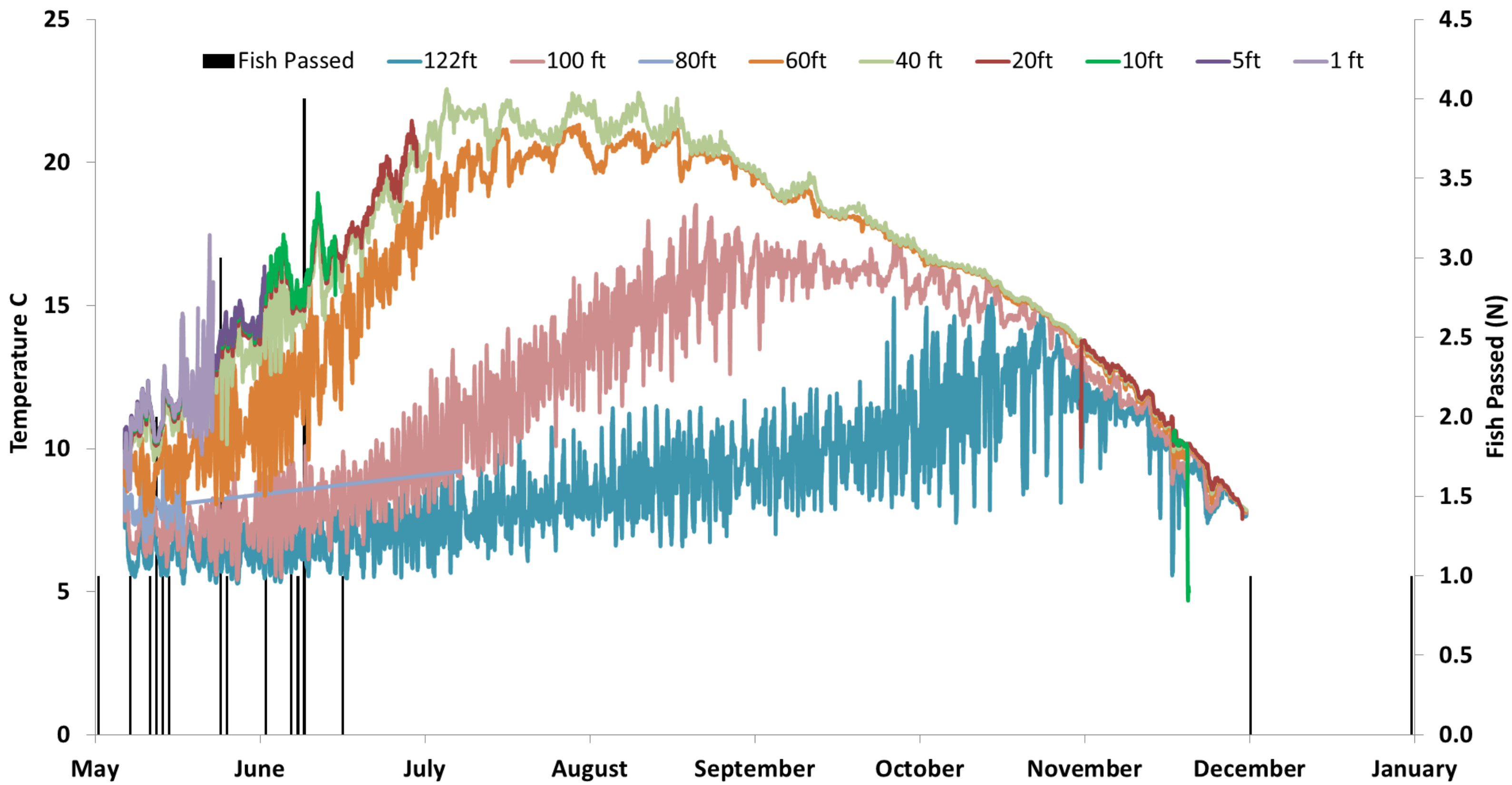

Figure 8. Reservoir water temperature profiles and tagged fish passage frequency at the FSC

CONCLUSIONS

Overall and species specific collection efficiency (P_{CE}) rates measured for this study were lower than the designated performance standard (13.2% v. 95% performance standard). However, the results of this evaluation are consistent with results from 2013 (Courter et al. 2013) and 2014 (Stroud et al. 2014). Neither length by species nor capture location by species or aggregated across species showed any significant correlation with fish collection rates.

Although P_{CE} was below the designated performance standard and lower than previous years (26.3% reported in 2014; Stroud et al. 2015), a higher absolute number of smolts passed through the FSC compared to previous years (n=21 in 2015 v. n= 10 in 2014). This was partially due to substantially higher P_{ZOI} than in 2014 which diluted the effect of higher smolt passage number.

The increased P_{ZOI} was in large part due to an increased capacity to detect fish within a zone of influence (ZOI) that is more consistent with the M&E plan. The M&E plan calls for a ZOI of 150 foot radius which forms a half-circle (overhead view) or a quarter-sphere (3-dimensional) view at the entrance to the FSC. In 2013 and 2014, range testing showed the radio telemetry arrays were likely capturing an ellipsoid in the vertical plane out to 150 foot, but were likely not sampling the periphery of the half-circle in the horizontal plane nor the full depth in the vertical plane (Figure 9). Acoustic hydrophone technology allowed us to position the hydrophone at the FSC entrance to sample the full 150 foot radius in both the vertical and horizontal plane leading to an increased capability to detect fish within the ZOI as defined in the M&E plan.

Two key methodological enhancements were made to the study between the 2014 and this year's study. In 2015, virtually all fish were captured, tagged and released at the head of Swift Reservoir. This was largely motivated by a test documented in Stroud (et al. 2014) where seven of eight (88%) fish capture and released from the rotary screw trap at Eagle Cliff were subsequently detected in the forebay. This rate far surpassed return rates achieved by smolts captured at the FSC and released only a few kilometers upstream. Also, it allowed us to use fish that did not have some of the documented evidence of stress (i.e., – scale loss, lethargy, bruising, parasitism) encountered by Stroud (et al. 2014). Finally, it permitted the use of naïve fish that had never encountered the FSC before and thereby circumvented some of the known challenges with using non-naïve fish in passage studies. Also, the radio-telemetry technology used in 2013 and 2014 (as outlined in Section 2.2 of the M&E plan) was replaced with acoustic telemetry technology. The rationale for this change was that, while both technologies could provide estimates of P_{CE}, acoustic telemetry could also provide behavioral insights on what is driving P_{CE}. This knowledge would allow PacifiCorp to make appropriate operational and structural modifications to enhance P_{CE}.

A number of conclusions can be drawn about fish behavior and movement migrating into the forebay and interacting with the FSC from the current year study. First, forebay entrance by out-migrating smolts seems to be relatively evenly distributed between north (55%) and south

(44%) shorelines. This pattern held at the species level as smolts of all three species entered at approximately equal rates along the north and south shorelines. This is in contrast to previous studies but likely reflects the difference in detectability between acoustic and radio telemetry and smaller sample sizes and differences in fish condition at capture and release in previous years. Second, over two thirds (66%) of the tagged smolts approach the FSC from the south once they entered the forebay. Somewhat counterintuitively, many of the fish that initially enter the forebay from the north shore then swing south and were detected at the south turning point of the barrier net before moving north towards the entrance of the FSC. This is likely due to the effects of the forebay “gyre” (Black and Veatch 2007) which moves in a clockwise direction within the forebay and the effect of fish “leading” along the barrier net towards the FSC. Third, all three species of interest (Coho, spring Chinook and steelhead) all tend to make their first pass of the FSC within 450 feet of the FSC entrance. Finally, approximately 90% of smolts pass within 650 feet of the FSC on their first pass through the forebay. These insights should provide useful information to PacifiCorp as they evaluate operational and structural options for the FSC.

The array for this study was not configured to provide information on fish depth as they passed through the array. The array was configured to maximize the likelihood of acquiring 2D travel paths meaning all receivers were deployed in the same vertical plane (i.e., depth). As a result, there was no expectation of getting reliable depth estimates. While the modeling software attempted to assign depths in some cases, the results were largely non-sensical clustering at or below the maximum reservoir depth or immediately at the surface. In order to resolve reliable, accurate 3D positions, a larger array would be required with receivers deployed at multiple depths.

There were important lessons learned from 2015 which will likely inform study design modifications for 2016. The capture, tagging and release of smolts at Eagle Cliff was an unqualified success with P_{ZOI} rates far surpassing anything seen in previous study years (e.g., - 79.5% in 2015 vs. 19.7% in 2014). This practice should likely be repeated in future studies to ensure naïve fish and the lowest stress-load possible prior to release. The application of acoustic telemetry technology allowed higher-resolution behavioral insights into the factors driving fish movement within the forebay and would likely be the technology of choice going forward. However, some additional hydrophones may be added to attain higher resolution around the entrance to the FSC. Also, array geometry in front of the FSC may be slightly altered to better capture fish movement patterns. Finally, additional receivers may be added or existing receivers moved (e.g., – south barrier net turning point hydrophone) to capture a wider range of high interest habitats (e.g., - cove of Swift Creek to the north of the forebay) in the forebay.

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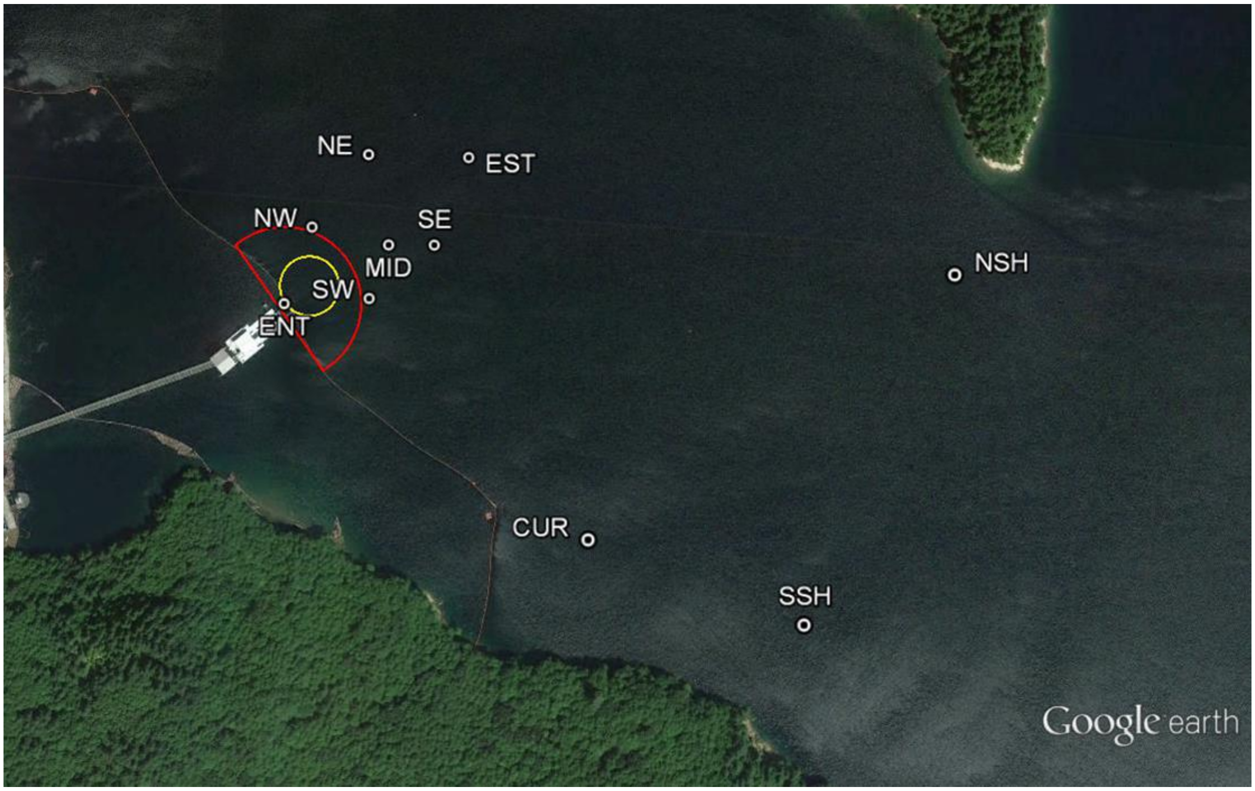

Figure 9. Comparison of zone of influence (ZOI) from radio-telemetry (yellow) and acoustic telemetry (red).

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APPENDIX 1: MOBILE TRACKING FIGURES

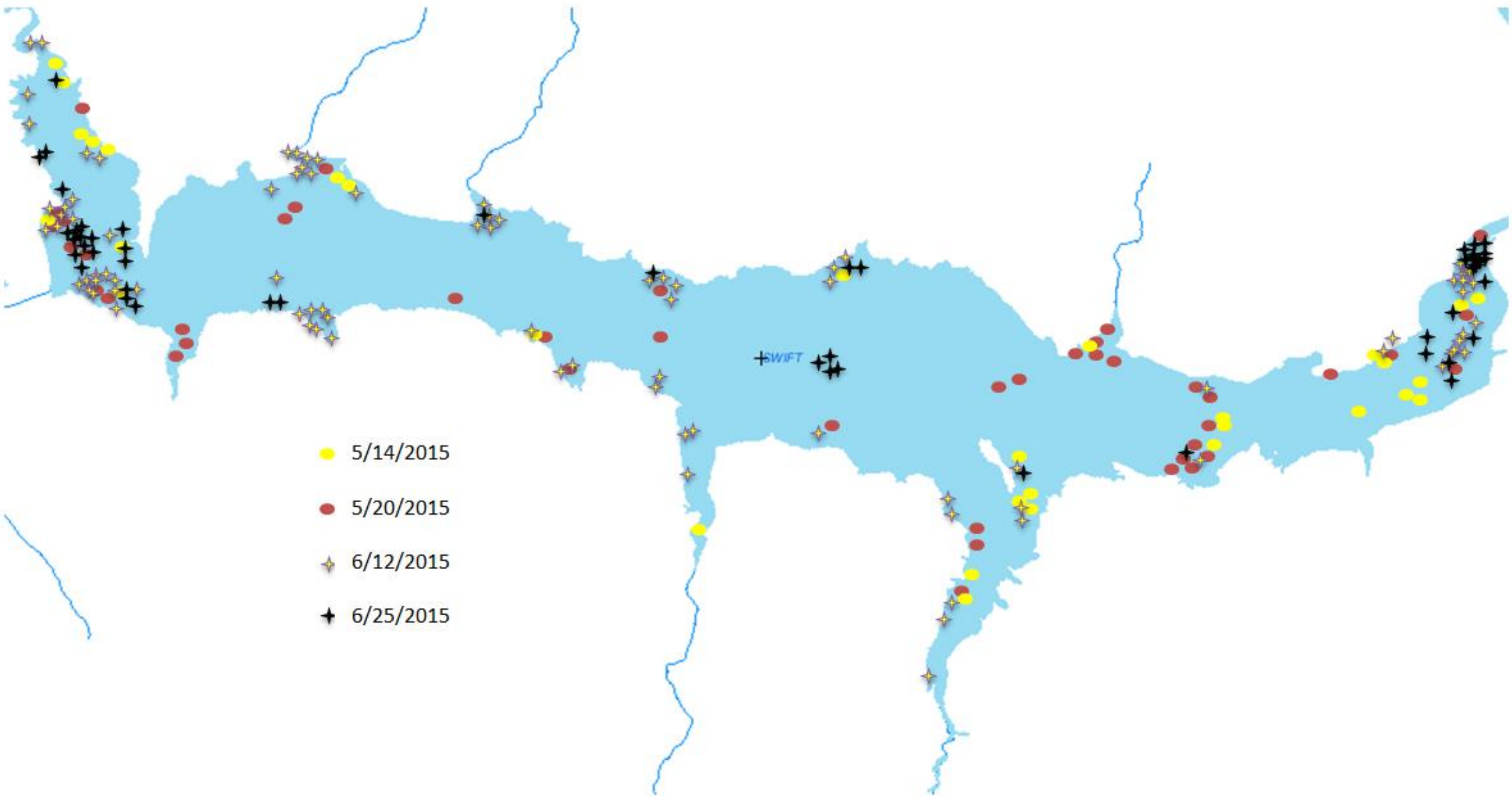

Figure A-1: Detection locations of tagged smolts during mobile tracking runs for Spring 2015.

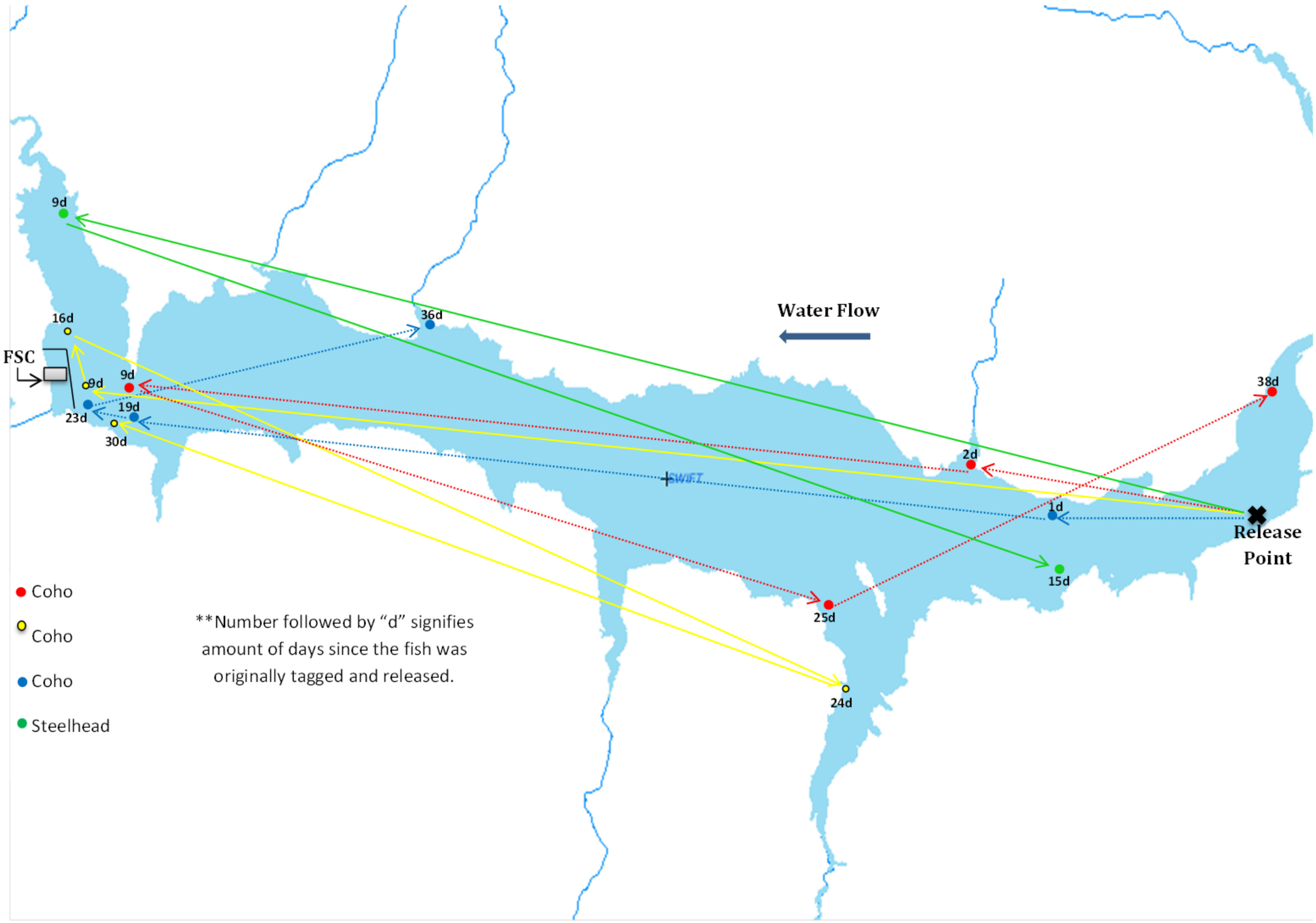

Figure A-2: Representative movements of four tagged smolts detected during multiple mobile tracking events in Spring 2015.

APPENDIX D

MERWIN FISH COLLECTION FACILITY COLLECTION EFFICIENCY EVALUATION

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MERWIN UPSTREAM PASSAGE ADULT TRAP EFFICIENCY

2015 Report

Prepared for:

PacifiCorp
825 NE Multnomah St.
Portland, OR 97232

Prepared by:

Peter Stevens, Mark Morasch, Lindsey Belcher, Forrest Carpenter, and Emily Reynolds

March 14, 2016

Applied Research in Fisheries, Restoration, Ecology, and Aquatic Genetics.

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EXECUTIVE SUMMARY

Cramer Fish Sciences and PacifiCorp jointly completed the first year of a study designed to evaluate upstream adult passage efficiency at the new passage facility at Merwin Dam; PacifiCorp's lower-most hydroelectric project on the North Fork Lewis River in Cowlitz County, Washington. The Lewis River is a major tributary of the Columbia River- roughly 80 miles upstream from the mouth- and it supports anadromous populations of fall and spring Chinook, coho, and chum salmon, as well as summer and late-winter steelhead and sea-run cutthroat trout. Phase I of the Licensing Agreement requires the reintroduction of anadromous salmonids and provision of passage upstream of Merwin Dam and downstream of Swift No.1 Dam; the goal is to achieve genetically viable, self-sustaining, naturally reproducing, and harvestable populations of spring Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and winter steelhead (*Oncorhynchus mykiss*).

This report summarizes the results from the first year of a telemetry study, designed to address the requirements of the Lewis River Aquatic Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2010). The objectives of the study were: 1) determine adult trap efficiency (ATE) for each target species, and compare estimates to the performance standard, 2) determine if the fish show direct movement to the trap entrance and document the behavior patterns in the tailrace, 3) determine if fish in the tailrace spend the majority of their time at the entrance of the trap, 4) determine the total time fish are present in Merwin Dam tailrace and compare to ATE performance standards for safe, timely, and effective passage, 5) describe the movement and behavior of tagged fish that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream, and 6) determine the condition of fish that are captured by the trap.

A radio telemetry array covering the Merwin Dam tailrace, fish ladder, and trap, along with a number of locations downstream of Merwin Dam on the lower Lewis River were installed, monitored, and maintained between February and December 2015. PacifiCorp staff were responsible for the fish collecting and tagging efforts. Late-winter run steelhead were tagged in March 2015, spring Chinook in May 2015, and coho in September 2015 in order to effectively utilize each species' peak migration timing.

Adult trap efficiency was below the 98% performance standard for all three species studied in 2015 (61%, 38% and 9% for steelhead, spring Chinook and coho, respectively). However, fish located and entered the trap at much higher rates than the rates at which they were ultimately captured (86%, 90% and 23% for steelhead, spring Chinook and coho, respectively). ATE performance standards for safe, timely and efficient passage (median tailrace time of less than or equal to 24 hours with less than or equal to 5% of fish taking longer than 168 hours to pass) were not met for some species. Coho spent approximately 15 hours, on average, in the tailrace with only 5.7% of fish spending more than 168 hours in the tailrace. However, neither steelhead nor spring Chinook attained the standard with each spending an average of approximately 49 or 247 hours, respectively, in the tailrace and approximately 14% and 65%, respectively, in residence longer than 168 hours. These longer tailrace residence times may, in part, be an artifact of how the metric was measured. Also, fish appear to be showing increased exploratory behavior along the north shore and also early in their transit of the tailrace. Once fish reach the south shore and the approach/entrance zone they appeared to move in an efficient and directed manner into the trap. Dam operation does appear to influence fish behavior and movement with spill and increased power generation suppressing fish movement. Finally, trap cycling also appears to impact fish retention within the trap as fish appear to exit the upstream most trap pool (pool 4) during crowder and hopper operation.

We recommend, in large part, a continuation of the methods and study design for 2016. We anticipate retaining the current design of the radio telemetry array with the addition of a site within the adult trap positioned at the entrance of the “hopper.” We tested out a preliminary design for this site late last year and it performed to expectations. This will provide higher resolution behavioral and movement data at the terminus of the trap. We expect this will better allow us to determine the movements of fish that enter but are not ultimately captured by the trap. To that end, we recommend considering additional emphasis on documenting and analyzing behavior within the trap including potentially deployment of acoustic imaging and or deployment of proto-type fish retention devices to test their efficacy. Also, we recommend shifting the analytic focus in 2016 to emphasize fish movement and behavior within the adult trap as opposed to the tailrace or downstream. Finally, we recommend considering a shift in analytic focus away from documenting individualistic fish behavior to a greater focus on aggregate response to operational conditions more within PacifiCorp’s control.

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

Metric	Winter Steelhead	Spring Chinook	Coho Salmon
Total tagged (n)	148	40	35
Entered the Tailrace	146	40	35
Entered the Trap	126	36	8
Trap Entrance Efficiency (P_{EE})	86.3%	90.0%	22.9%
Captured	90	15	3
Collection Efficiency (ATE_{Test})	61.6%	37.5%	8.6%

INTRODUCTION

Cramer Fish Sciences and PacifiCorp jointly completed the first year of a study designed to evaluate upstream adult passage efficiency (ATE) at the new passage facility at Merwin Dam; PacifiCorp's lower-most hydroelectric project on the North Fork Lewis River in Cowlitz County, Washington. Located 10 miles east of Woodland, Washington, the North Fork Lewis River hydropower project begins at Merwin Dam and Powerhouse at river mile (RM) 19.5 and extends through three other impoundments, with Swift No.1 being the largest. The study area is located from Merwin Dam (RM 19.5) downstream through the tailrace to the Lewis River Bed & Breakfast (~ RM 7) in Woodland, Washington. The Lewis River is a major tributary of the Columbia River- approximately 80 miles upstream from the mouth- and it supports anadromous populations of fall and spring Chinook, coho, and chum salmon, as well as summer and late-winter steelhead and sea-run cutthroat trout. Phase I of the Licensing Agreement requires the reintroduction of anadromous salmonids and provision of passage upstream of Merwin Dam and downstream of Swift No.1 Dam; the goal is to achieve genetically viable, self-sustaining, naturally reproducing, and harvestable populations of spring Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and winter steelhead (*Oncorhynchus mykiss*).

This report summarizes the results from the first year of a telemetry study, designed to address the requirements of the Lewis River Aquatic Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2010). The plan describes the need for the evaluation of design and adequacy of attraction flow for capturing species of interest. The methods are outlined in detail in Methods: Telemetry Array. A telemetry array of 19 radio receivers were positioned strategically throughout the study area in order to evaluate ATE. The following objectives will be discussed in relation to each target species in this report and are explained in detail in the methods section:

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

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

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

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

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

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

METHODS

Radio telemetry arrays covering the Merwin Dam tailrace, fish ladder, and trap, along with a number of locations downstream of Merwin Dam on the lower Lewis River were installed, monitored, and maintained between February and December 2015. This array was designed to meet the Lewis River M&E plan objectives and similar methods were used in a previous study by R2 Resource Consultants (2007).

Fish Collecting and Tagging

PacifiCorp staff were responsible for the fish collecting and tagging efforts. Late-winter run steelhead were tagged starting in March 2015, spring Chinook starting in April 2015, and coho starting in September 2015 in order to effectively utilize each species' peak migration timing. Given such a large number of fish being released simultaneously in a small study reach, a maximum limit of 25 fish were tagged and released on any given day, for total target of 150 per species, in order to reduce the possibility of tag collisions within the array. By spreading captures out over additional days, better temporal variability in the run was collected. All fish had tags gastrically implanted with a Lotek MCFT-3A digitally coded transmitters. Each tag measured 16 mm in diameter and 46 mm in length and weighed 16 g in air and 6.7 g in water. Tags were programmed with a burst rate of 5 seconds staggered by ½ second intervals within release groups. This, combined with reducing the size of the release groups, substantially mitigated or eliminated the risk of tag collision issues. This allowed for more reliable and complete data to be captured for each fish. Latex tubing was used to reduce tag regurgitation for the gastric implants. All fish were allowed to recover following the tagging procedure and then released via the transport truck directly into the river approximately ¼ mile downstream.

Telemetry Array

A telemetry array which included 19 antennas positioned to cover 14 distinct zones in the study area, using both underwater stripped coaxial cable and aerial antennas (Table 2, Figure 1, and Figure 2) was implemented for the duration of this study period. Fifteen antennas, including 4 underwater and 11 aerial, were located within the tailrace.

Along the powerhouse, aerial antennas were deployed to provide complete coverage of the area (Figure 3). Each powerhouse site (Zones 8 and 9) has an aerial antenna. The gallery behind powerhouse (Zone 10) was monitored using a 3-element aerial antenna mounted on the powerhouse deck facing the gallery behind the powerhouse (Figure 4), and was monitored by a single receiver. The deployment of dipole antennas was considered based on the concern that penstocks may block detection of tagged fish. However, aerial antennas were selected as the gallery area is large and aerial antennas generally perform better under these conditions. The approach and entrance each have either one or two underwater antennas. Each underwater antenna is line combined and amplified to increase sensitivity, if necessary and each has a 10 pound weight attached to minimize movement in turbulent powerhouse flow.

Table 2. Location of detection zones and corresponding antenna arrays.

Location	Site Abbreviation	Type	Antenna	Detection Zone
Downstream: Bed and Breakfast	BBL	Aerial	1	1
Downstream: Lewis River Hatchery	LRH	Aerial	2	2
Downstream: below Merwin boat ramp	BLD	Aerial	3	3
Downstream: Holding Pool	BLU	Aerial	4	4
Tailrace: below bridge	BRG	Aerial	5-7	5
Tailrace: left bank	SS	Aerial	8-9	6
Tailrace: right bank	NS	Aerial	10-11	7
Tailrace: along powerhouse wall	PWS	Aerial	12	8
Tailrace: along powerhouse wall	PWN	Aerial	13	9
Tailrace: gallery behind dam	GAL	Aerial	14	10
Tailrace: downstream of trap	APR	Underwater	15	11
Tailrace: trap entrance	ENT	Underwater	16	12
Trap: upstream in ladder	PL2, PL4	Underwater	17a&17b	13
Trap: processing facility	TRP	Aerial	18	14

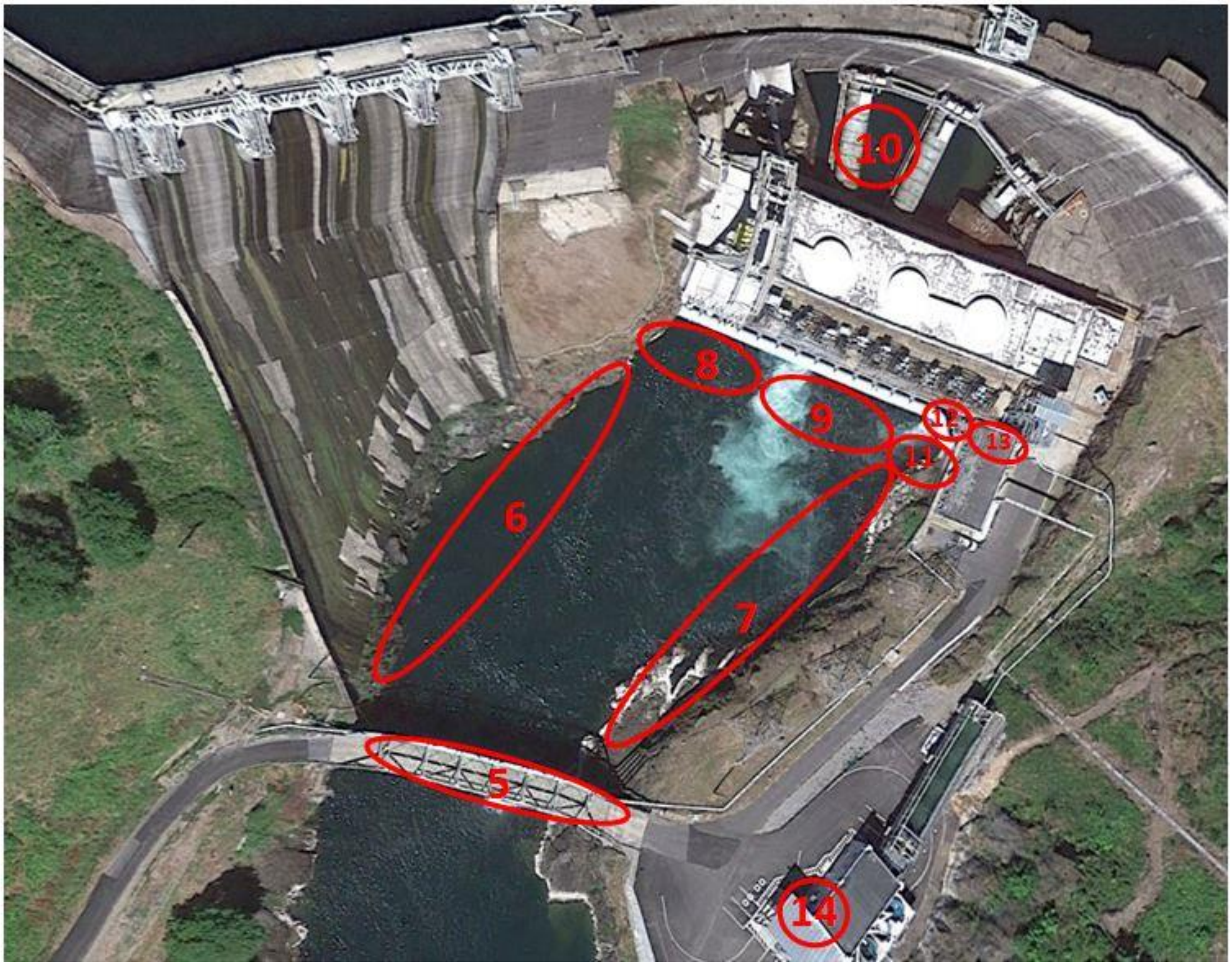

Figure 1. Location of radio antennas within the Merwin Tailrace.

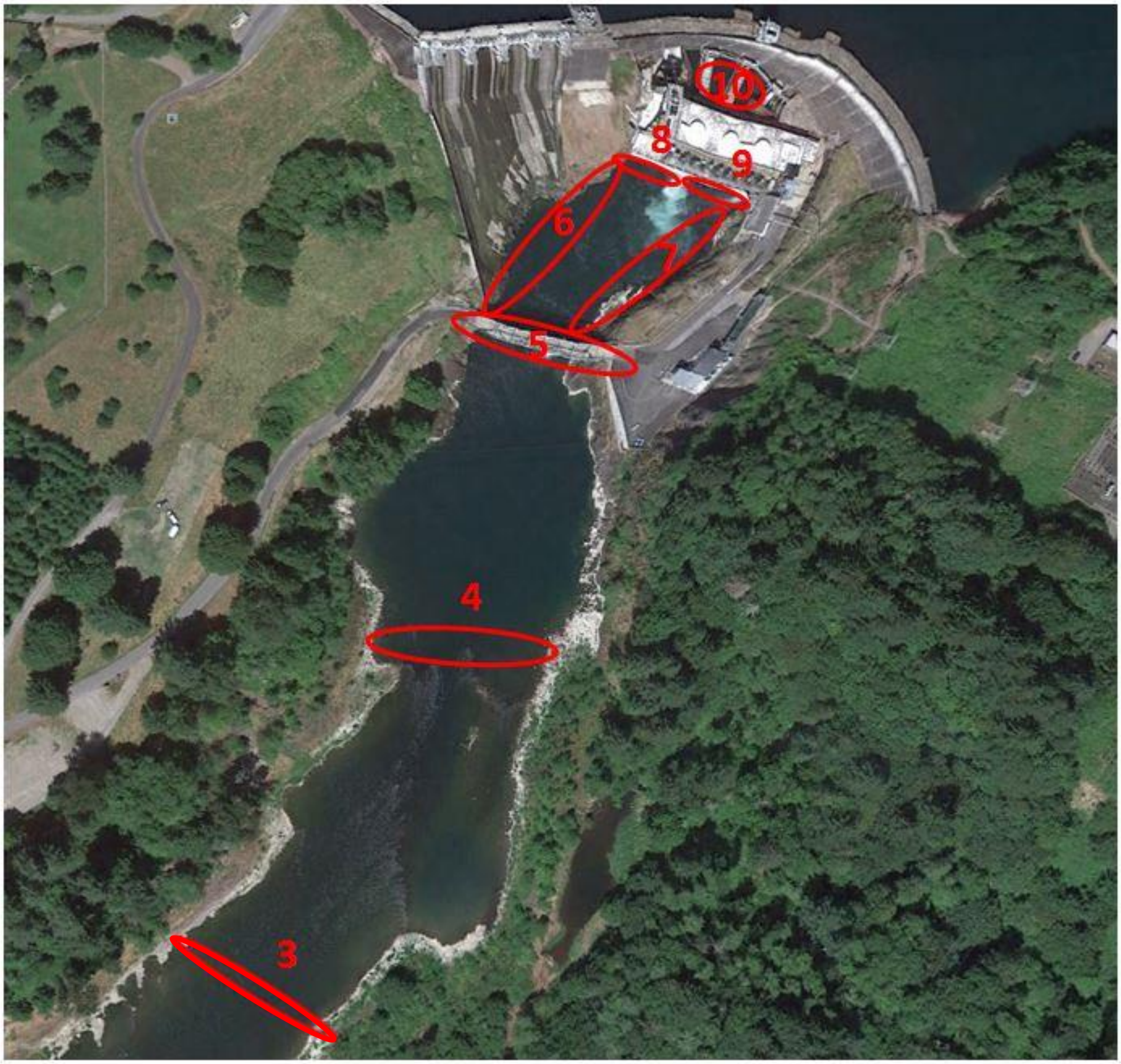

Figure 2. Location of radio antennas within the Merwin Tailrace.

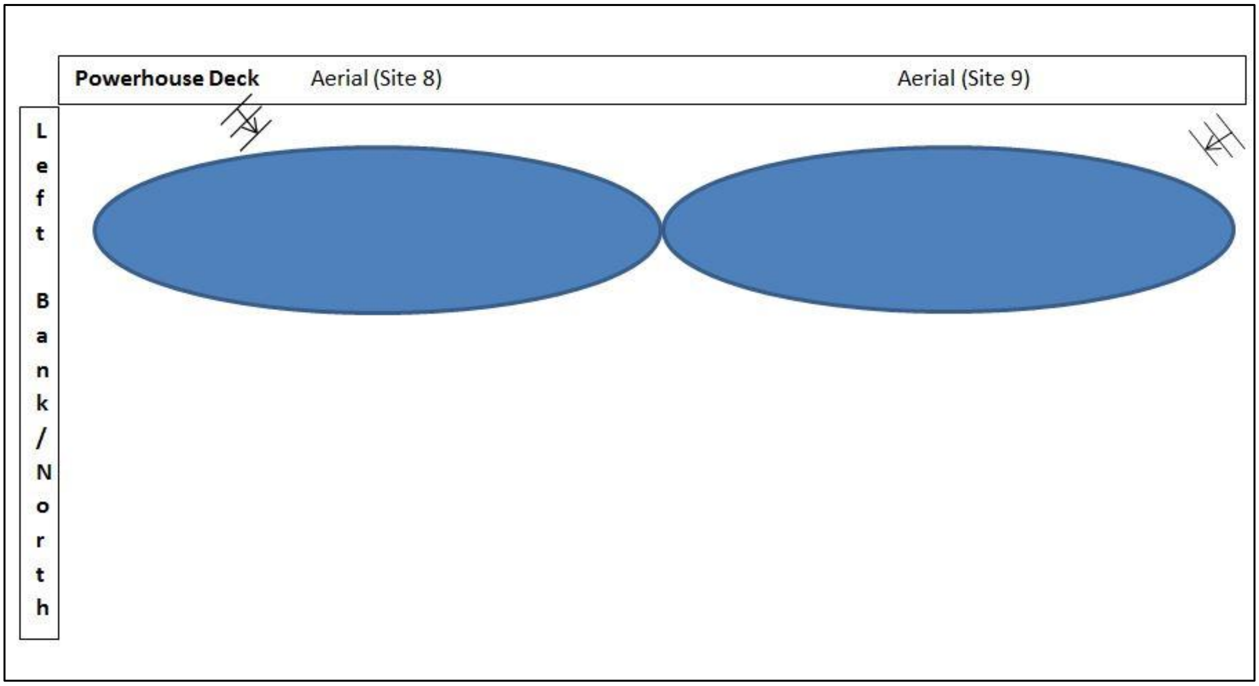

Figure 3. Antenna layout for the powerhouse area (Zones 8 and 9).

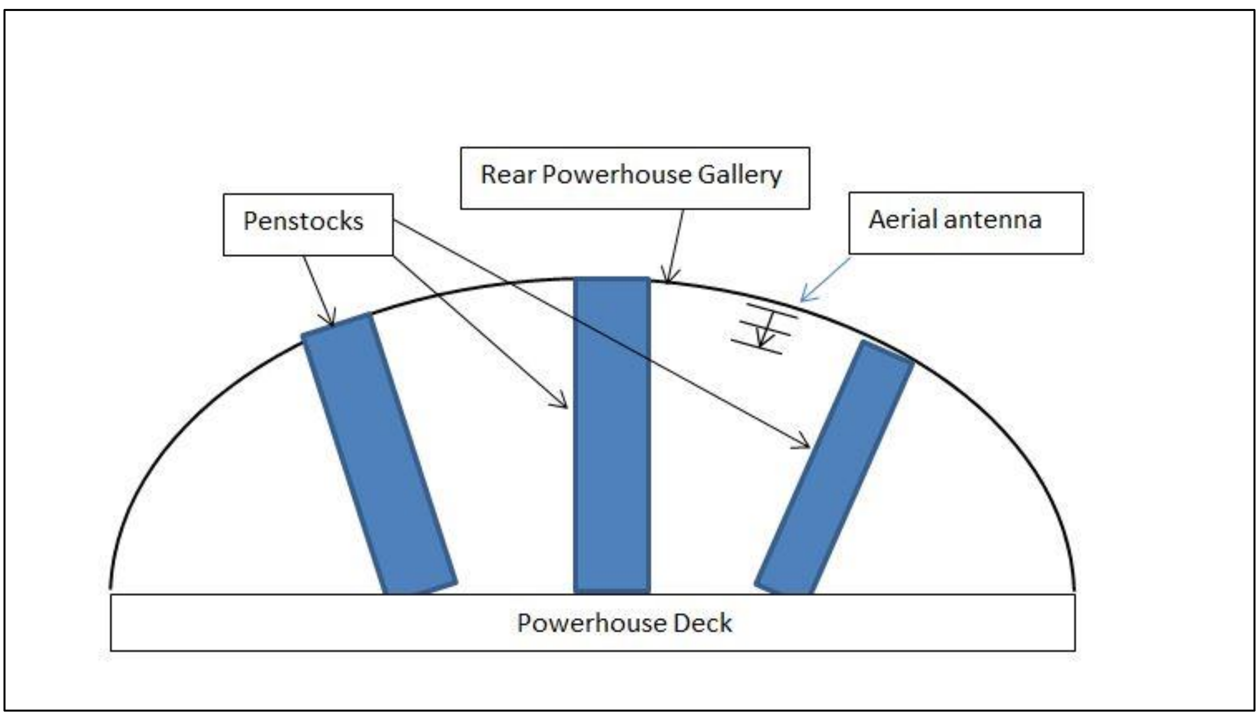

Figure 4. Antenna layout for the rear powerhouse gallery (Zone 10).

To provide adequate coverage for the left and right banks downstream of the powerhouse, a combined 3 element and 5 element aerial antennas were placed on each side of the bridge (Figure 5). The 5 element aerial antenna was pointed towards the powerhouse section of the range giving a narrow, high gain detection region in the far field. The 3 element antenna was used to monitor the area closest to the bridge. This allowed for the most consistent and reliable detection range along either bank.

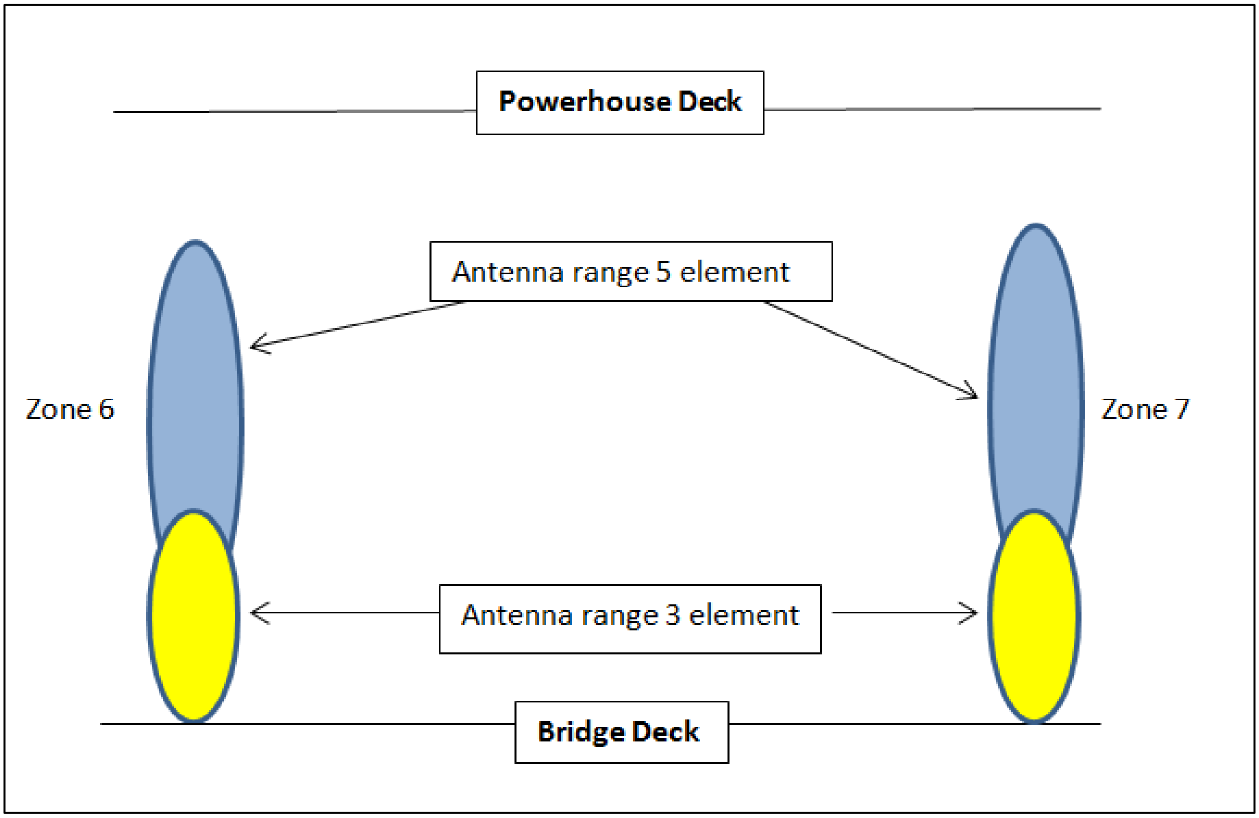

Figure 5. Antenna layout for north and south bank coverage (Zones 6 and 7)

Antennas deployed from the bridge were periodically subject to extreme flow conditions created by high flows from the powerhouse and sideways flows coming over the spillway. Due to heavy flow and high turbulence, underwater antennas at the bridge would likely be damaged or destroyed. Therefore, 3 aerial antennas were attached to a frame made of schedule 90 PVC pipe and suspended from the deck with large cable ties. This allowed for efficient removal and adjusting of the antennas for the maximization of detection efficiency. Also, the PVC insulated the aerial antennas from the steel bridge, preventing ambient noise that could be transferred from the bridge to the aerial antennas, resulting in decreased detection ranges and reliability. Aerial antennas provide far more consistent operation and detection ranges than moving underwater antennas which would have likely become wrapped around each other or damaged by debris. All 3 antennas were combined for one receiver site and amplified.

Although aerial antennas have demonstrated detection depths of up to 40 feet, there was a possibility that fish could be deeper than 40 feet in the bridge zone. To account for this, ten (10) combination re-usable radio/archival tags that logged depth were deployed as part of the study. When the archival tagged fish was re-captured at the trap, the tag was removed and downloaded.

The depth data obtained from the tags was used to estimate detection efficiency at the bridge aerial antennas to determine how many, if any, fish may be traveling deeper than the aerial detection range. These tags also can provide a more complete, three-dimensional understanding of how a representative sample of fish are moving through the tailrace by combining location data from receivers and depth data from tags.

Two underwater dipole antennas were deployed in the fish trap (Zone 13) with one deployed in Pool 2 and another deployed in Pool 4. These antennas were used to determine movement by fish into and out of the trap without being captured. In order to identify successful captures, an additional antenna and receiver (Zone 14) was deployed in the collection facility. This antenna and receiver was able to definitively identify captured fish, since a fish could enter and exit the trap without being brought into the processing facility, creating erroneous capture records.

Four detection zones comprising four antennas were deployed downstream of the Merwin tailrace. Two parallel, fixed aerial antennas were deployed immediately downstream of a holding pool directly below the Merwin tailrace (Zone 4) using a single receiver. The shallow water here allowed for reliable aerial detection and paired antennas provided information on directional movement to determine when a fish entered or left the tailrace. A single antenna (Zone 3) was deployed downstream of the Merwin Boat Launch to monitor downstream movement of fish following release. An aerial antenna was deployed at the Lewis River Hatchery (Zone 2) near the entrance of the fish ladder, to detect fish moving into the hatchery. Lastly, a single serial antenna was deployed at Lewis River Bed and Breakfast (Zone 1) to detect any fish that moved downstream away from the dam, or upstream towards the dam.

Range testing prior to the study was used to define the size and shape of the detection zone for each antenna and to calibrate the antenna array. All receiver settings were tuned to ensure adequate coverage of the tailrace with minimal overlap between adjacent zones. Downstream receivers were tuned to ensure bank-to-bank coverage of the river, creek, or fish ladder, as appropriate.

Arrays were checked at least weekly in order to ensure proper orientation, conduct routine maintenance, and download the data during the study period from February through December 2015.

Data Management and Processing

Detection data was backed up on multiple, redundant servers on the same day as downloads. An automated data proofing and coding program, implemented in R, was used for initial detection coding and processing of the telemetry data. This program combined the records for multiple receivers into a single “master” file and generated a detection history for each fish by assigning movement and action codes to time-stamped detections at a given receiver. An action code included a first and last detection within a given zone, all approaches to the trap entrance numbered sequentially, all trap entrances into trap ladder numbered sequentially, and any passages based on detections within the processing facility. If a fish passed the facility but subsequent passed back downstream over the spillway or through the turbines and was detected in the tailrace or further downstream, the event was considered a fallback and labeled appropriately in the automated program. This process created a preliminary detection file suitable for tentative review and troubleshooting.

Each history was then manually reviewed by a trained technician for invalid detection events, tag collisions or histories that were not logically consistent and supported. This step was completed at the end of the study period (i.e.-run) for a given species and produced a final, QA/QC'ed file which was used for all final analysis and reporting.

Analytical Approach

Objective 1: Determine trap effectiveness based on the ATE metric for each target species, and compare those estimates to the 98 percent performance standard.

The Lewis River Settlement Agreement defines adult trap efficiency (ATE) as the percentage of adults of a given species actively attempting to migrate above Merwin Dam and, therefore, caught in the Merwin fish trap. The Lewis River Monitoring and Evaluation Plan (2010), sets an ATE target of 98% for adult fish migrating upstream towards spawning habitat above the hydro projects. ATE_{test} was calculated as follows:

$$ATE_{test} = C / M$$

where *M* is the number of actively migrating fish that enter Merwin Dam Tailrace and *C* is the number of fish that successfully pass upstream. *C* will include unique detections from Zone 11 (Trap) and any manually collected tags from the collection facility or during fish sorting minus dead or mortally wounded fish or those collected after a specified time period. Unique detections from tailrace zones (1-10) will be used to derive *M.*

A statistical test comparing the measured ATE rate to the target ATE was not feasible since the ATE standard does not have an estimate of variability around it. However, it is possible to calculate a mean sampled ATE and its standard deviation by species using the ATE for each individual release group of a given species as replicates. This allowed us to calculate a normal sampling distribution for the sampled ATE rate by species. The target ATE was then compared to this sampling distribution to determine what percentage of the likely ATE values within the distribution fall above or below the target using a Z-score approach. For example, if the target 98% ATE falls ~2 standard deviations below the mean on the sampling distribution, it would indicate that 95% of the likely true values of the measured ATE are greater than or equal to the target ATE. This would indicate strong support for the target ATE having been met.

We assumed ATE was a normally distributed variable for which we calculated a mean (μ) and standard deviation (σ) using each individual release group of a given species as replicates. This allowed us to define the probability that the true mean ATE (X) is greater than 98% as follows:

$$P(X > 0.98) = P(X - \mu > 0.98 - \mu) = P((X - \mu) / \sigma > (0.98 - \mu) / \sigma)$$

Since

$$Z = (X - \mu) / \sigma$$

Therefore

$$P(X > 0.98) = P(Z > (0.98 - \mu) / \sigma)$$

The Z-score can then be looked up in any standard normal table (e.g. - Sokal and Rohlf 2012) to convert it to the probability that the true mean in greater than 98%.

An Analysis of Variance (ANOVA) was conducted on the ATE_{test} rates based on release group to determine any seasonal trends in passage rates. In this case, ATE_{test} was the dependent variable and release date was the independent variable. Residual and normal probability plots were examined to confirm that data conformed to test assumptions.

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

Network (graph) theory was applied to conceptualize, visualize and analyze fish movements within the tailrace (Wilson 1996). Network theory provides a simple, intuitive method for conceptualizing, visualizing and analyzing fish movement data particularly at it relates to fish passage issues. All detections zones were represented as nodes (vertices) and the movements of individual fish between detection zones were represented as the connections (edges) between nodes. Movement patterns were then analyzed both visually and quantitatively.

Network diagrams representing the study area (e.g. – Figure 7) were created for visual analysis. The size of the nodes representing detection zones was weighted to reflect the degree of connection between that zone and other zones within the study area. Larger circles indicated a higher degree of connectedness (i.e. – a more centralized location for fish to pass through in their movements). Detections zones were also color coded for ease of identification according to whether they were tailrace (red) or downstream or within the adult trap (blue). The thickness of lines representing fish movements were weighted based on the total number of individual movements between a given pair of nodes. Thicker lines mean more individual movements in that direction between two zones. This provides a simple, intuitive way of aggregating, visualizing and analyzing complex fish movements through a system.

Quantitative analysis was performed using four network metrics, number of edges, network diameter, average number of neighbors and edge to diameter ratio. The number of edges is merely the number of connections (e.g. – movements) by a given fish as it transited the study area. This gives an idea of how much a fish moved or how active it was. The network diameter is the farthest distance between any two connected nodes in the network. This measures path length of a fish through the study area. The average number of neighbors is the number of edges for each node divided by the number of nodes. This measures movement between sites for a given fish. Finally, edge to diameter ratio is number of edges in a network divided by the diameter. This provides a good measure of milling or exploratory behavior by fish as they transit the study area. Each of these metrics were calculated for individual fish and then a grouped by fish that either passed (i.e. – entered and were captured in the ATE) or did not pass (i.e. – fish that did not enter and/or were not captured). Distributions for each network metric were plotted by group and a Wilcoxon Rank Sum test (non-parametric) was used to test for significant differences between network metrics for fish that were or were not captured.

The number of tailrace zones used by fish and the frequency and probability at which they transition between them provide important insight into fish attraction to trap entrances and the effectiveness of trap location. We constructed a passage efficiency matrix that could be used to determine which passage routes through the tailrace result in the highest passage success (Keefer et al. 2014). This is a general extension of mark-detection models that use fish passage efficiency estimates between zones in place of traditional survival probabilities. This method allows the calculation of a route specific passage (RSP) efficiency, commonly referred to as a Kaplan-Meier survival estimate (Kaplan and Meier 1958; Pollock et al. 1989). RSP was calculated as the product of tailrace zone efficiencies (ZE):

$$\text{ZE} = (1 - f_{ij} / n_{ij})$$

Where f is the number of fish that failed to pass upstream from a zone and n is the number of fish that entered the zone. The RSP for a given route Z that passes through three zones can then be calculated as:

$$\text{RSP}_Z = (n_Z) \text{ x } (\text{Z}E_{Z1}) \text{ x } (\text{Z}E_{Z2}) \text{ x } (\text{Z}E_{Z3})$$

The RSP estimates can help determine which locations and paths provide the highest passage probabilities.

Table 3. Probable routes through the tailrace to be analyzed for route specific passage (RSP) efficiency.

Route	Route Code
Downriver > BRG > NS > PWN > APR > ENT > ATRP	R1
Downriver > BRG > NS > PWS > APR > ENT > ATRP	R2
Downriver > BRG > SS > PWN > APR > ENT > ATRP	R3
Downriver > BRG > SS > PWS > APR > ENT > ATRP	R4
Downriver > BRG > NS > SS > PWN > APR > ENT > ATRP	R5
Downriver > BRG > NS > SS > PWS > APR > ENT > ATRP	R6
Downriver > BRG > NS > PWN > PWS > APR > ENT > ATRP	R7
Downriver > BRG > SS > PWN > PWS > APR > ENT > ATRP	R8
Downriver > BRG > NS > SS > PWN > PWS > APR > ENT > ATRP	R9
Downriver > BRG > NS > PWN > GAL > APR > ENT > ATRP	R10
Downriver > BRG > NS > PWS > GAL > APR > ENT > ATRP	R11
Downriver > BRG > SS > PWN > GAL > APR > ENT > ATRP	R12
Downriver > BRG > SS > PWS > GAL > APR > ENT > ATRP	R13
Downriver > BRG > NS > SS > PWN > GAL > APR > ENT > ATRP	R14
Downriver > BRG > NS > SS > PWS > GAL > APR > ENT > ATRP	R15
Downriver > BRG > NS > PWN > PWS > GAL > APR > ENT > ATRP	R16
Downriver > BRG > SS > PWN > PWS > GAL > APR > ENT > ATRP	R17
Downriver > BRG > NS > SS > PWN > PWS > GAL > APR > ENT > ATRP	R18

Depth and detectability within the tailrace were measured using archival tags deployed in a random subset of study fish. However, due to logistic and technical complications as well as low recovery rates, the data available is limited to just three steelhead. Nonetheless, it is still possible to glean valuable insight from the data available for these three fish. The data will be analyzed qualitatively below.

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

Time spent in specific tailrace zones provides information on effectiveness of the trap location and fish attraction to the trap entrance area. Moreover, it may predict passage efficiencies and post-passage migration and spawning success depending on prevailing environmental conditions. Fish that are delayed in the tailrace under high, turbulent flows or supra-optimal temperatures may experience post-passage behavioral effects impacting migration and reproductive success (Caudill et al. 2007; Burnett et al. 2014).

Median time within zone for each species was calculated in order to determine if fish were preferentially holding in the approach/entrance zone directly in front or the trap or whether they might be preferentially selecting an alternative location. The median was selected as it is less prone to bias from extremely high or low residency times. Median residence time within the approach/entrance zone was compared to median residence times within the other tailrace zones using the non-parametric Wilcoxon rank-sum test with a Bonferroni correction for multiple comparisons. Non-parametric test such as the Wilcoxon rank-sum do not require assumptions about the normality of the data. As such, they are well suited to comparison of medians as opposed to other measures of central tendency (e.g. – t-test, ANOVA, etc.) which are better suited to comparison of means. The Bonferroni correction was applied to the resulting p-values to account for the decreasing power accompanying multiple pairwise comparisons. Also, percent time in approach/entrance zone as function of total tailrace time was calculated. This provided an alternative measure of whether fish were preferentially holding in from of the trap entrance.

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

The amount of time fish are present in the tailrace was used to assess attraction rates and the potential for fish delay at the Merwin trap. The median and range of total time in tailrace was summarized for comparison with the ATE standard of median tailrace time less than or equal to 24 hours with no more than 5% of fish taking longer than 168 hours to pass. As defined in the M & E plan, total tailrace time could be calculated in one of two ways:

1) as time between initial detection at the bridge (Zone 5), or the first tailrace zone (5-12) where a fish is detected, and time of first detection at ladder (Zone 13) or trap (Zone 14); given the possibility of noise interference, tag collisions, interactions of swimming speed and tag burst rate, it was prudent to account for the possibility that some subset of fish may bypass the bridge site and be detected initially somewhere else in the tailrace; or

2) total time spent in any tailrace zone.

Both definitions of total tailrace time are comparable.

The second method was employed in this study as it was designed to account for fish milling behavior where fish move repeatedly in and out of the tailrace. Preliminary review of the data indicated that this milling behavior was clearly exhibited in our study. Therefore, the aggregate of total time spent in any tailrace zone (i.e. - the second method) was employed for determining compliance with the ATE performance standard.

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

Network (graph) theory (Wilson 1996) was applied to conceptualize, visualize and analyze fish movements downstream of the tailrace. As for Objective 2 above, movement patterns were analyzed both visually and quantitatively. The same network diagrams (e.g. – Figure 7) created for visual analysis under Objective 2 were analyzed and interpreted in the context of downstream movement and behavior. Also, similar quantitative analysis was performed using the four network metrics, number of edges, network diameter, average number of neighbors and edge to diameter ratio, described above. All metrics were calculated and analyzed as described in Objective 2.

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

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

Operational Analyses

Anecdotal observations of fish behavior within the adult trap suggested that operation of the "hopper" within the collection area of the trap may have been impacting fish behavior. A cursory review of a sub-sample of preliminary data also suggested this may be the case. Consequently, we examined fish movements during trap "cycling" to determine if trap operation may have been startling fish into leaving the trap area. We cross-referenced trap cycling times with movements of fish from pool 4 (PL4) to pool 2 (PL2) to determine if fish exited pool 4 during a period of trap operation. Precise start and stop times for the hopper cycling were not available, only records of whether or not the trap was operating within a given 15 minute time window. In order to account for this uncertainty, as well as the possibility of asynchrony between radio telemetry receiver clocks and the systems monitoring trap operation, we applied both a conservative and liberal time criteria. Under the conservative criteria, a fish had to move from pool 4 into pool 2 within the 15 time period of trap cycling to be considered to have reacted to trap operation. Under the liberal criteria, a fish had to move from pool 4 to pool 2 within the 15 minute period of trap cycling or during the period immediately preceding or following. Rates of fish classified as exiting at the same time as trap cycling were then calculated using the total number of pool 4 to pool 2 exits as the denominator. No statistical tests were performed as these metrics are point estimates with no variance around them.

Both spill and power generation operations were analyzed for impacts on fish movement and behavior within the Merwin Dam tailrace. Network (graph) theory was applied to analyze fish movements within the tailrace under different spill or power generation scenarios. As for Objectives 2 and 5 above, movement patterns were analyzed quantitatively. Similar quantitative analysis was performed using the four network metrics, number of edges, network diameter, average number of neighbors and edge to diameter ratio, described above. All metrics were calculated and analyzed as described in Objective 2, except that metrics were separated by spill versus no spill or by which unit or combination of units were generating power. Not all units or combinations of units were generating during the run time for a given species so comparisons were made opportunistically. A Wilcoxon Rank Sum test with a Bonferroni correction for multiple comparisons was performed on all pairs of generation conditions occurring during the late-winter steelhead run. Low numbers of tagged study fish and therefore detections, severely limited sample size under any given generating condition for both Chinook and coho. Therefore, no statistical test for significance could be conducted.

RESULTS

Late winter-run Steelhead

A total of 147 tagged steelhead were detected in the radio telemetry array during the radio-telemetry study. A single tagged steelhead never entered the study area. However, the fish's tag was found at the golf course boat launch and returned indicating a likely tag loss. A total of 126 steelhead entered the adult trap at some point and of those 90 were ultimately captured. A single tagged steelhead (#238) was captured in the trap but never detected by the array. This fish likely had a tag that failed or ran out of battery early as it had tens of thousands of credible detections over a period of 26 days following release but was not detected for 6 days prior to recapture.

Objective 1: Determine trap effectiveness based on the ATE metric for each target species, and compare those estimates to the 98 percent performance standard.

The overall ATE_{test} for steelhead was 61.2% (90/147). This corresponds to only a 7.9% (Mean: 0.612, Std. Dev.: 0.260; Z = 1.41) probability that the true ATE_{Test} value is greater than the 98% performance standard. However, a substantially higher proportion of fish found and entered the adult trap (85.7%; 126/147) than were ultimately captured.

ATE_{test} by release group ranged between 0 and 83% (Table 4). There was a significant effect of release date (Figure 6; $r^2 = 0.28$, $p = 0.01$) with a greater percentage of fish released later in the run ascending than fish released earlier. However, low sample sizes later in the run may have influenced this result.

Table 4. Adult trap efficiency (ATE_{test}) for steelhead by release group, 2015.

Release Date	Number Released	Number Recaptured	ATE_{test} (%)
3/6/2015	3	1	33.3%
3/9/2015	3	1	33.3%
3/10/2015	1	0	0.0%
3/17/2015	8	4	50.0%
3/20/2015	10	7	70.0%
3/24/2015	11	6	54.5%
3/25/2015	2	1	50.0%
3/27/2015	11	7	63.6%
3/30/2015	4	0	0.0%
3/31/2015	11	5	45.5%
4/2/2015	11	7	63.6%
4/8/2015	6	5	83.3%
4/9/2015	6	4	66.7%
4/10/2015	12	6	50.0%
4/15/2015	11	8	72.7%
4/21/2015	15	12	80.0%
4/22/2015	5	5	100.0%
4/27/2015	6	3	50.0%
5/4/2015	5	3	60.0%
5/13/2015	3	3	100.0%
5/21/2015	4	2	50.0%
Total	**147**	**90**	**60.8%**

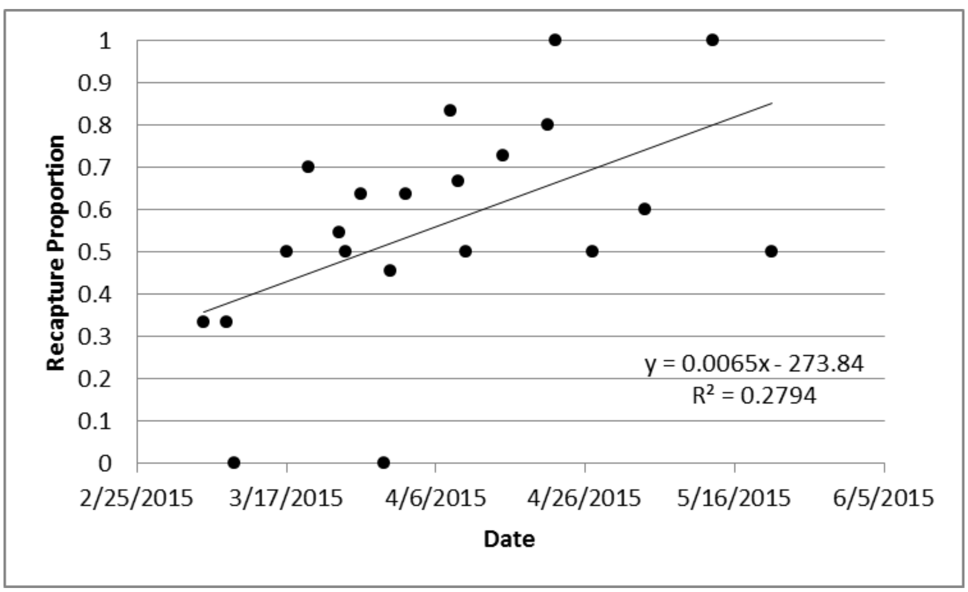

Figure 6. The proportion of steelhead recaptured (ATE_{Test}) plotted as a function of time for Merwin Dam, 2015. A best-fit regression line has been interpolated and the equation of the line as well the r^2 value are displayed.

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

A visual analysis of the network diagram for steelhead movements throughout the study area clearly illustrates the tendency of fish to move widely within the tailrace (Table 8). Movement from the bridge (BRG) seems to be relatively evenly balance between the north (NS) and south (SS) shores as evidenced by the uniform width of lines connecting these points. However, movement seems to concentrate with a lot of milling behavior seen between the south shore, north (PWN) and south shore (PWS) powerhouse and the approach zone (APR). Notably, few fish interact with the gallery zone.

Steelhead that successfully passed the tailrace, entered the adult trap and were passed demonstrated significantly different behavior that fish that did not pass. Fish that entered the adult trap and were captured had significantly higher median number of edges (i.e. – more active), a higher average number of neighbors (i.e. – more movement between sites) and larger edge to diameter ratio (i.e. – less milling and exploring; Figure 8; Table 5). Median diameter (i.e. - furthest distance traveled between sites) was approximately equivalent between the two but biased higher for fish that entered the trap and were captured. This difference was, however, not statistically significant.

Individual zone efficiencies are a good indicator of possible bottlenecks where fish are able to enter but not to progress upstream. For steelhead, zone efficiencies (ZE) on average tended to be higher downstream of the tailrace, moderate within the tailrace zone and lowest within the ATE (Figure 9). Individual ZEs were highest at the downstream boat launch and gallery site (100%) and lowest at the north powerhouse, pool 4 within the adult trap and the approach zone.

Route-specific passage (RSP) efficiencies were highest for fish taking the most direct routes through the tailrace (i.e. – fewest steps between the bridge and entrance zones; Figure 10, Table 6) and lowest for fish taking longer routes. This result is intuitive as a longer, more convoluted route would necessarily be less efficient. Also, paths involving passage along the south shore and past the south shore powerhouse tended to have higher RSP efficiencies and cluster near the top. Paths passing through the north powerhouse tend to have lower efficiencies as a result of the north powerhouse's low zone efficiency.

Note that the stair-step phenomena observed in Figure 10 is a result of 100% passage at the gallery site meaning that adding the additional step of passing through the gallery zone did not impact overall RSP efficiency. This anomaly is a result of an extremely low sample size of gallery fish. All other things being equal a shorter travel path would be more efficient and therefore preferred.

Archival tags used to document depth and detectability were deployed in ten steelhead. Five of these ten tags were recovered. However, two tags were damaged to the point where data was not recoverable and the additional three only had pressure (as opposed to depth) recovered from them. However, as pressure is the raw metric used to calculate depth, it is possible to infer some qualitative depth information from the recovered tags. All three tags demonstrated that steelhead were detectable throughout the tailrace and across a wide variety of pressures (depths). It was evident that fish spent the majority of their time at low pressures (i.e. – near the surface) within the tailrace. However, periods of high pressure (i.e. – deep dives) were observed, including some prolonged periods, particularly in the vicinity of the bridge and north shore. Detection data combined with archival tag pressure data indicates that even during these deep dives, fish were still detectable by receivers in the appropriate zone and no prolonged breaks in detection history were observed coincident with high pressures indicating deep dives.

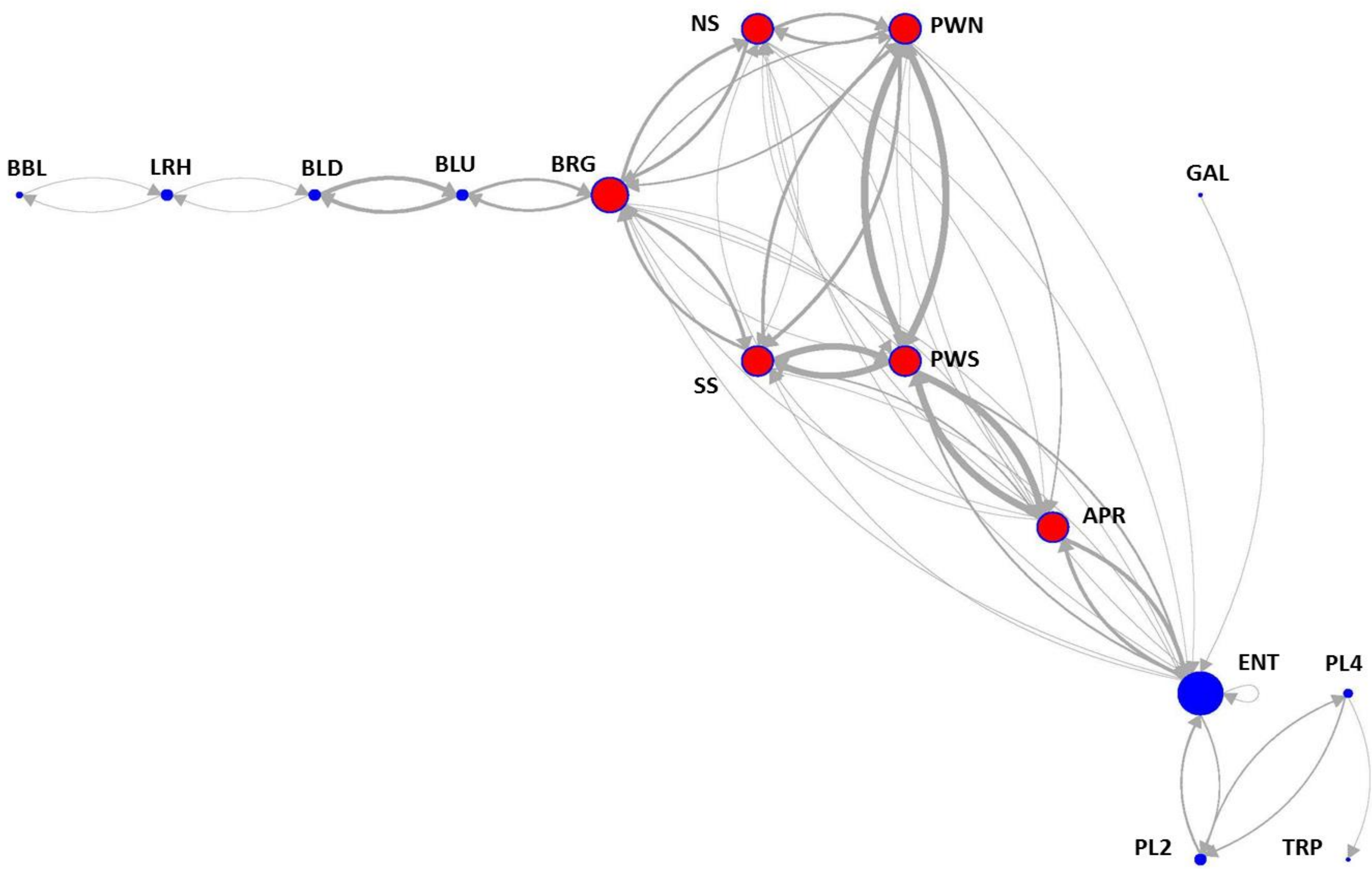

Figure 7. Network diagram of steelhead movements within the study area at Merwin Dam, 2015. Tailrace sites are denoted in red. Node size is scaled by the total number of paths entering the node. Path thickness is scaled based on the total number of individual travel paths between nodes in that direction. BBL = Lewis River Bed & Breakfast, LRH = Lewis River Hatchery, BLD = downstream of Boat Launch, BLU = Holding Pool upstream of Boat Launch, BRG = Bridge, NS = North shore, SS = South shore, PWN = North Powerhouse, PWS = South Powerhouse, GAL = Gallery, APR = Approach, ENT = Trap Entrance, PL2 = Trap Pool 2, PL4 = Trap Pool 4, TRP = Processing Facility.

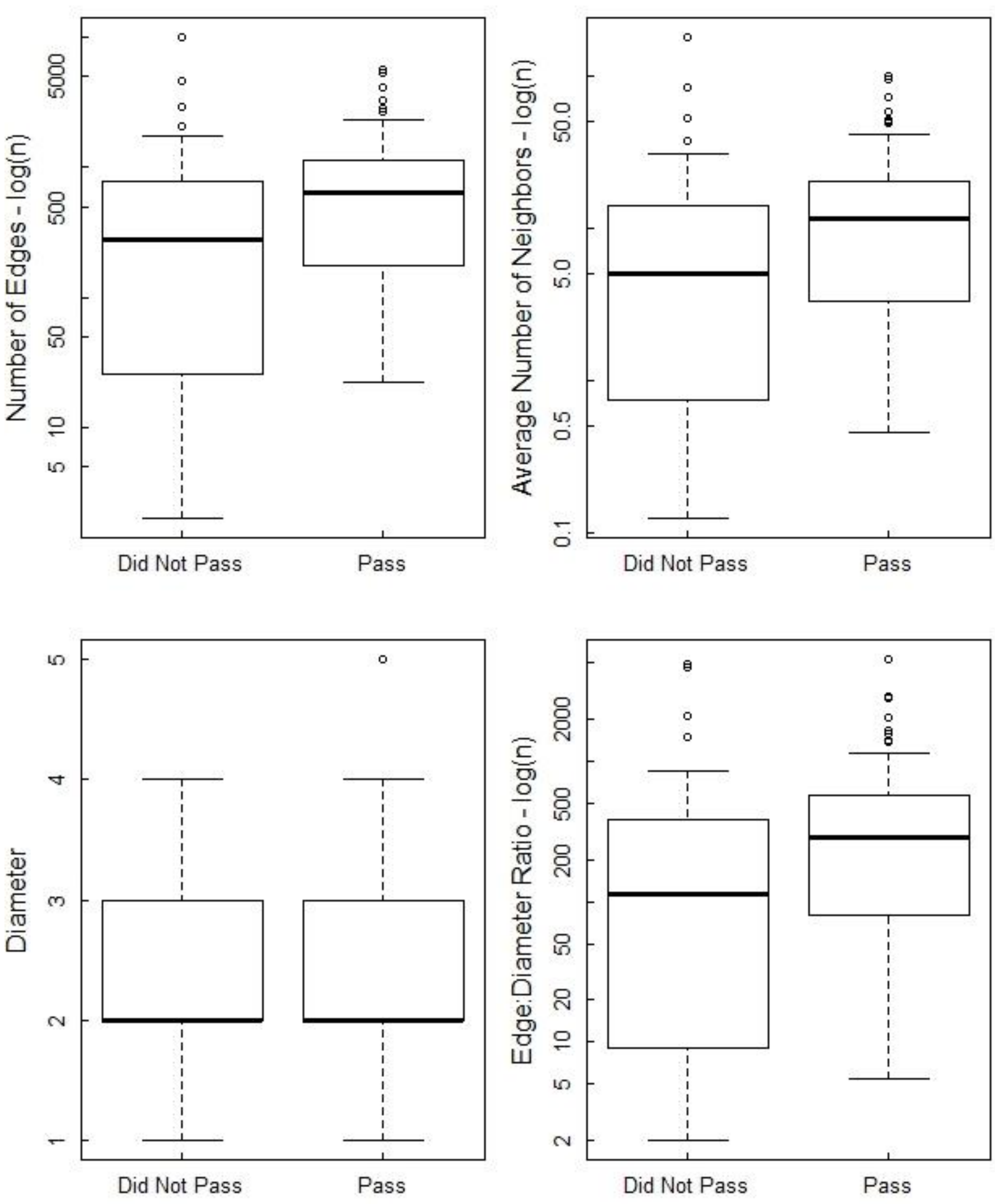

Figure 8. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for steelhead that were captured and passed or did not pass Merwin Dam, 2015.

Table 5. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for steelhead that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for steelhead that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	647	280	0.05*
Diameter	2	2	0.57
Avg. Nearest Neighbor	11.5	5.0	0.05*
Edge:Diameter Ratio	287	114.5	0.04*

* Significant at the α = 0.05 level

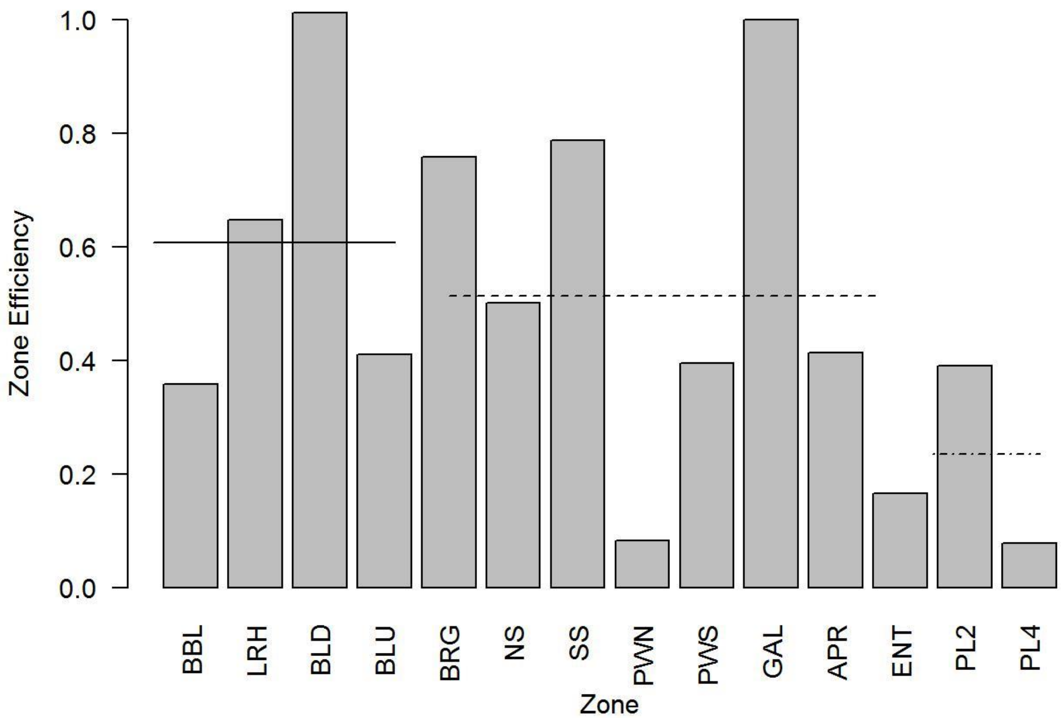

Figure 9. Zone efficiency (ZE) for all zones in the study based on steelhead detection data at Merwin Dam, 2015. The solid, dashed and dot-dashed horizontal lines represents the average ZE for downstream, tailrace and trap sites, respectively.

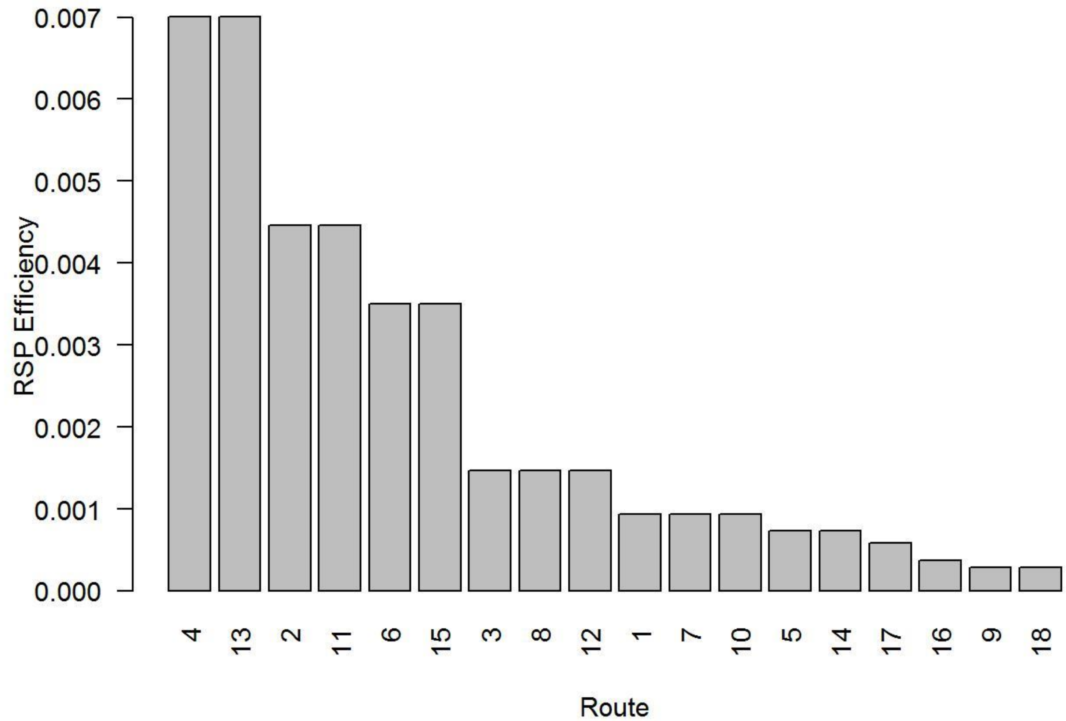

Figure 10. Route Specific Passage (RSP) efficiency ranked from highest to lowest for probable routes through the tailrace for steelhead at Merwin Dam, 2015.

Table 6. Route Specific Passage (RSP) efficiency route names, samples sizes and values ranked from highest to lowest for probable routes through the tailrace for steelhead at Merwin Dam, 2015.

RSP Efficiency	Route	*n*	RSP Efficiency
Downriver > BRG > SS > PWS > APR > ENT > ATRP	R4	148	0.0070
Downriver > BRG > SS > PWS > GAL > APR > ENT > ATRP	R13	148	0.0070
Downriver > BRG > NS > PWS > APR > ENT > ATRP	R2	148	0.0044
Downriver > BRG > NS > PWS > GAL > APR > ENT > ATRP	R11	148	0.0044
Downriver > BRG > NS > SS > PWS > APR > ENT > ATRP	R6	148	0.0035
Downriver > BRG > NS > SS > PWS > GAL > APR > ENT > ATRP	R15	148	0.0035
Downriver > BRG > SS > PWN > APR > ENT > ATRP	R3	148	0.0014
Downriver > BRG > SS > PWN > PWS > APR > ENT > ATRP	R8	148	0.0014
Downriver > BRG > SS > PWN > GAL > APR > ENT > ATRP	R12	148	0.0014
Downriver > BRG > NS > PWN > APR > ENT > ATRP	R1	148	0.0009
Downriver > BRG > NS > PWN > PWS > APR > ENT > ATRP	R7	148	0.0009
Downriver > BRG > NS > PWN > GAL > APR > ENT > ATRP	R10	148	0.0009
Downriver > BRG > NS > SS > PWN > APR > ENT > ATRP	R5	148	0.0007
Downriver > BRG > NS > SS > PWN > GAL > APR > ENT > ATRP	R14	148	0.0007
Downriver > BRG > SS > PWN > PWS > GAL > APR > ENT > ATRP	R17	148	0.0006
Downriver > BRG > NS > PWN > PWS > GAL > APR > ENT > ATRP	R16	148	0.0004
Downriver > BRG > NS > SS > PWN > PWS > APR > ENT > ATRP	R9	148	0.0003
Downriver > BRG > NS > SS > PWN > PWS > GAL > APR > ENT > ATRP	R18	148	0.0003

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

The median tailrace residence time by zone for steelhead showed that fish spend the longest amount of time within the bridge (BRG) zone (Figure 11). They spend the least time in the approach (APR) and entrance (ENT) zones. Steelhead rarely end up in the gallery (GAL) zone and, when they do, spend little time there. Steelhead spend significantly more time in the bridge, southshore (SS) and south powerhouse (PWS) zones (Table 7). The mean percent time spent by steelhead in the approach/entrance zone as a function of total tailrace time was 4.0%.

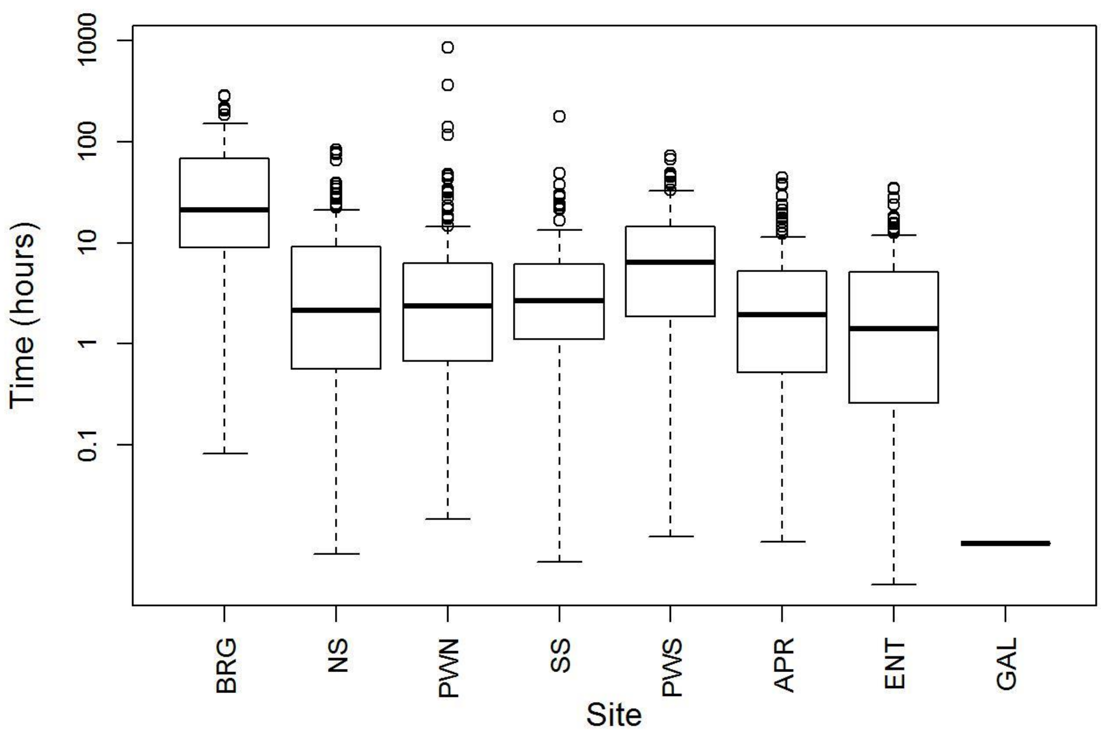

Figure 11. Median residence time for tailrace detection zones for steelhead at Merwin Dam, 2015.

Table 7. Median tailrace residence time for steelhead at entrance zone and comparison zones as well Bonferroni adjusted p-values for a Wilcoxon Rank Sum test of medians for Merwin Dam, 2015.

Comparison	Median Residence Time – ENT	Median Residence Time – Comparison Zone	Bonferroni Corrected p-value
ENT => BRG	1.41	21.1	<0.001*
ENT => NS	1.41	2.16	0.21
ENT => SS	1.41	2.65	0.01*
ENT => PWN	1.41	2.39	0.48
ENT => PWS	1.41	6.44	<0.001*
ENT => APR	1.41	1.93	1.00
ENT => GAL	1.41	0.01	0.94

* Statistically significant at the α = 0.05 level

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

The median tailrace residence time for all steelhead in the Merwin Dam tailrace was 49.4 hrs with a range between 0.08 and 1077.4 hrs (5 minutes to ~45days, respectively; Figure 12). Given fish milling behavior, this may represent total time spent during multiple trips through the tailrace. Approximately 13.5% of steelhead had a tailrace residence time greater than 168 hrs (7 days).

Steelhead that entered the tailrace but never entered or passed the trap had a median tailrace residence time of 22.9 hours with a range of 0.08 hours to 482.0 hours and <1% had a tailrace residence time greater than 168 hrs (7 days). Steelhead that entered the trap but never passed had a median tailrace residence time of 67.6 hours with a range between 8.9 and 408.7 hours and 6.1% had a tailrace residence time greater than 168 hrs (7 days). Steelhead that entered and passed the trap had a residence time of 55.1 hours with a range of 0.80 to 1077.4 hours and 6.8% had a tailrace residence time greater than 168 hrs (7 days).

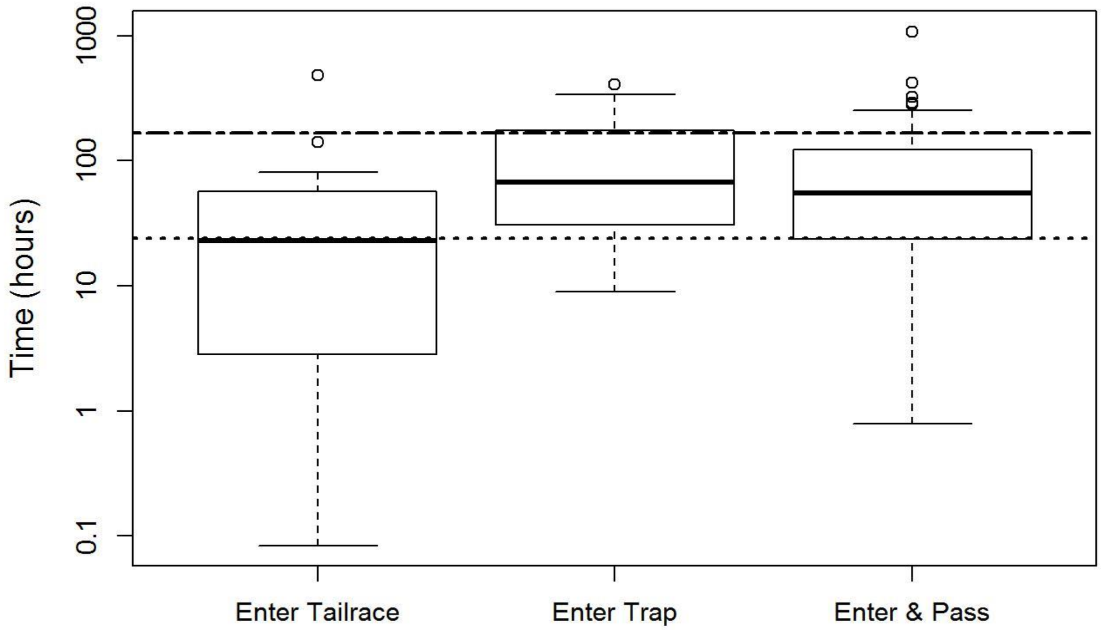

Figure 12. Distribution of median residence time for steelhead that either entered the tailrace, entered the trap or entered the trap and were captured (passed) at Merwin Dam, 2015. The dotted horizontal line represents the 24hr median standard. The dot-dash horizontal line represents the 168 hr standard.

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

A visual analysis of the network diagram for steelhead movements throughout the study area clearly illustrates the tendency of fish to move widely between the area below the boat ramp (BLD) and the "holding pool" (BLU; Figure 7). There is also a substantial amount of movement between the "holding pool" and the bridge site (BRG). There was noticeably less movement between the boat launch and holding pool and the Lewis River Hatchery (LRH) or the downstream-most bed & breakfast (BBL) site. This seems to indicate a tendency by steelhead to congregate in the holding pool and to move short distances up and downstream when below the tailrace area.

Steelhead that successfully entered and were captured in the adult trap did not demonstrate significantly different behavior in downstream sections below the bridge than fish that did not pass. The one exception was path diameter where fish that did not pass had a larger path diameter (i.e. – moved more widely between downstream sites) than fish that passed (Figure 13; Table 8). Median number of edges, average number of neighbors and edge to diameter ratio were all largely similar between fish that were captured compared to those who were not. None of these differences were statistically significant.

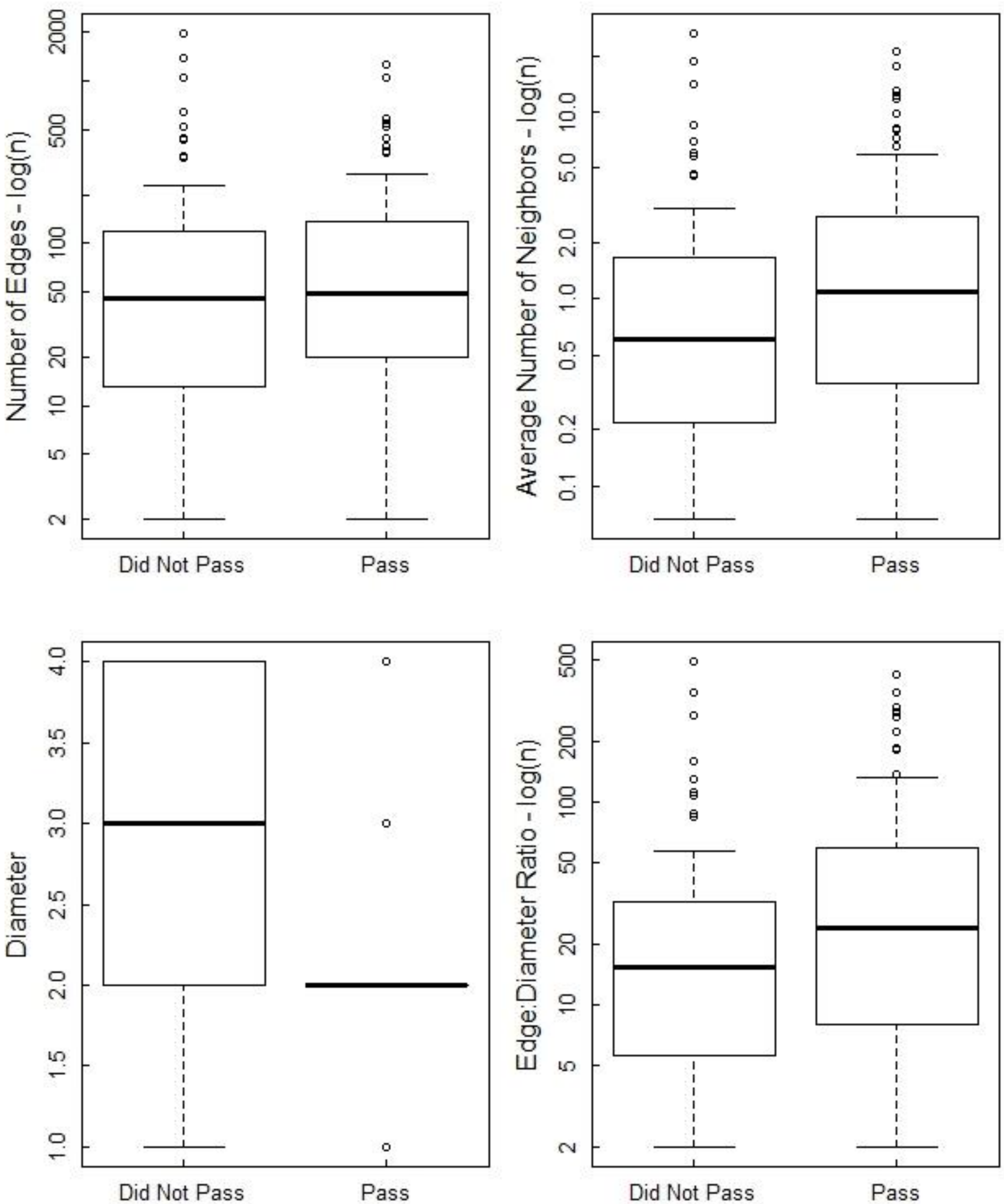

Figure 13. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for steelhead that were captured and passed or did not pass Merwin Dam, 2015.

Table 8. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for steelhead that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for steelhead that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	49	46	1.00
Diameter	2	3	<0.001*
Avg. Nearest Neighbor	3.25	1.84	0.40
Edge:Diameter Ratio	24	15.3	0.34

* Significant at the α = 0.05 level

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

PacifiCorp staff reported only 2 of 90 (2.2%) recaptured steelhead possessed any descaling or injury not originally observed during initial capture. Both fish were observed to have minor abrasions on their snouts. These injuries were not substantial nor were they believed likely to impede survival, spawning or passage success.

Operational Analyses

Steelhead demonstrated significantly different behaviors under different spill conditions. Steelhead had fewer total edges (i.e. – less overall movement), a smaller average number of neighbors (i.e. – less movement between zones) and a lower edge to diameter ratio (i.e. – less milling and exploring) under spill conditions than non-spill conditions (Figure 14). These differences were all statistically significant (Table 9). There was no statistically significant difference between path diameters under differing spill conditions. Also, all steelhead passed under non-spill conditions. However, non-spill conditions occurred for 89% of the study period with most spill occurring late in the year when no steelhead likely remained in the study reach.

Steelhead also demonstrated significantly different behaviors under different power generation conditions. Steelhead had fewer total edges (i.e. – less overall movement), a smaller average number of neighbors (i.e. – less movement between zones) and a lower edge to diameter ratio (i.e. – less milling and exploring) when all units or Units 1 and 3 were generating (Figure 15). These differences were significantly different from the same metrics when Unit 3 or Units 2 and 3 were generating (Table 10; Table 11). Behavior when Unit 2 only was generating was intermediate for these metrics and not significantly different from any other generation conditions. Path diameter (i.e. – total distance travelled through the tailrace) showed no detectable pattern and no differences were significant. Also, the 59.7% and 33.7% of steelhead were captured and passed when Units 2 and 3 or Unit 3 only were generating. However, generation by Units 2 and 3 or Unit 3 only were the second (20.7%) and fourth (11.3%) most common generation condition during the study period.

There were 608 instances where steelhead exited from pool 4 into pool 2 during the study. Of these exits, 103 (16.9%) occurred during the 15 minute period of trap cycling (conservative criteria) and 298 (49.0%) occurred during or immediately adjacent to the 15 minute period of trap cycling (liberal criteria).

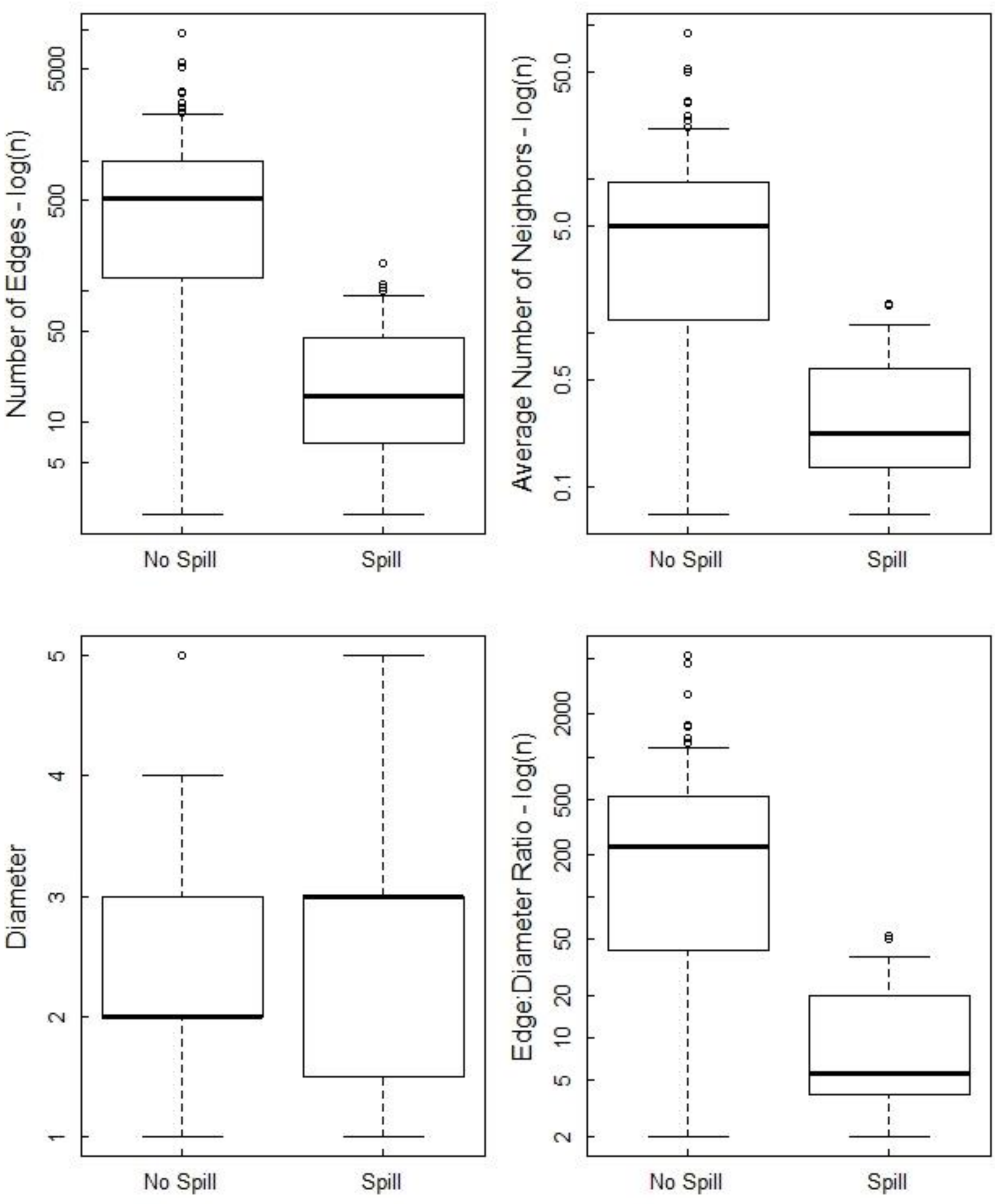

Figure 14. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under spill or no spill conditions for steelhead at Merwin Dam, 2015.

Table 9. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for steelhead under spill or no spill conditions at Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for steelhead that passed versus those that did not are reported.

Network Metric	Median – Spill	Median – No Spill	Bonferroni Adjusted p-value
# Edges	16	510	<0.001*
Diameter	3	2	0.73
Avg. Nearest Neighbor	0.22	4.9	<0.001*
Edge:Diameter Ratio	5.7	227.7	<0.001*

* Significant at the $\alpha = 0.05$ level

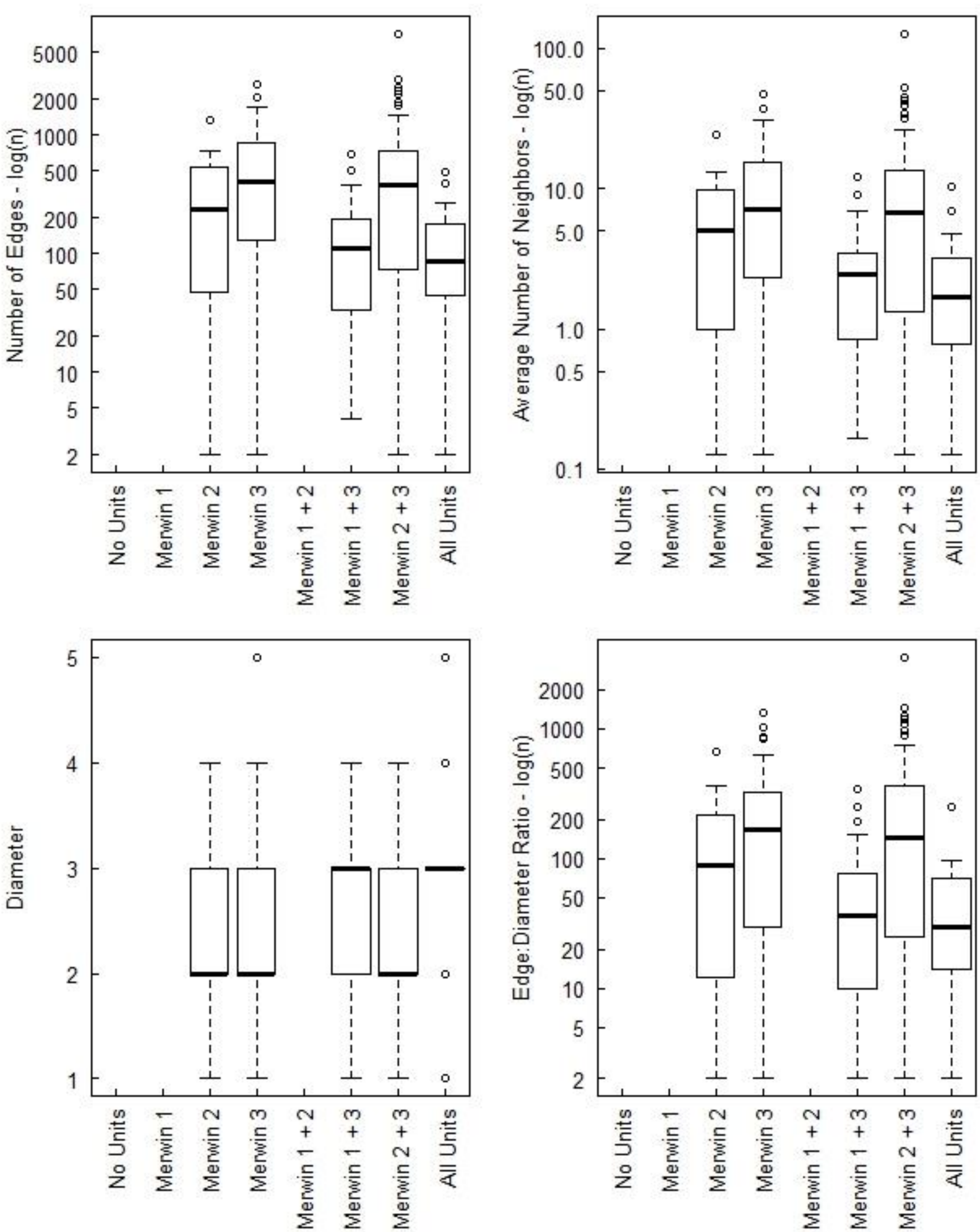

Figure 15. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under multiple power generation conditions for steelhead at Merwin Dam, 2015.

Table 10. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for steelhead under multiple power generation conditions at Merwin Dam, 2015.

	Median				
Network Metric	Merwin 2	Merwin 3	Merwin 1 + 3	Merwin 2 + 3	All Units
# Edges	240	398	110	382	87
Diameter	2	2	3	2	3
Avg. Nearest Neighbor	5	7.1	2.4	6.8	1.7
Edge:Diameter Ratio	88	169	36	146	29.3

* Significant at the α = 0.05 level

Table 11. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for steelhead under multiple power generation conditions at Merwin Dam, 2015.

	Network Metrics			
Bonferroni Adjusted p-Value	# Edges	Diameter	Avg. Nearest Neighbor	Edge:Diameter Ratio
Merwin 2 : 3	1.0	1.0	1.0	1.0
Merwin 2: 1 + 3	1.0	1.0	1.0	1.0
Merwin 2: 2 + 3	1.0	1.0	1.0	1.0
Merwin 2:All Units	1.0	0.13	0.84	0.87
Merwin 3: 1 + 3	0.05*	1.0	0.05*	0.10
Merwin 3: 2 + 3	1.0	1.0	1.0	1.0
Merwin 3: All Units	0.02*	0.11	0.02*	0.03*
Merwin 1 + 3:2 + 3	0.009*	1.0	0.007*	0.01*
Merwin 1 + 3: All Units	1.0	1.0	1.0	1.0
Merwin 2 + 3: All Units	0.005*	0.004*	0.003*	0.002*

* Significant at the α = 0.05 level

Chinook

A total of 40 tagged spring Chinook were detected in the radio telemetry array during the radio-telemetry study. All tagged spring Chinook entered the study area at some point. A total of 36 Chinook entered the adult trap at some point and of those 15 were ultimately captured. All tagged spring Chinook captured in the trap were detected by the array.

Objective 1: Determine trap effectiveness based on the ATE metric for each target species, and compare those estimates to the 98 percent performance standard.

The overall ATE_{test} for spring Chinook was 37.5% (15/40). This corresponds to functionally a 0% (Mean: 0.375, Std. Dev.: 0.138; Z = 4.37) probability that the true ATE_{Test} value is greater than the 98% performance standard. However, as with steelhead, a substantially higher proportion of fish found and entered the adult trap (90.0%; 36/40) than were ultimately captured.

ATE_{test} by release group ranged between 16.7% and 50% (Table 12). There was no significant effect of release date ($p = 0.14$). However, a visual inspection of the plot shows a decline in the percentage of fish passing later in the run (Figure 16; $r^2 = 0.73$). This result is speculative however given the low overall sample size and limited number of releases.

Table 12. Adult trap efficiency (ATE_{test}) for spring Chinook salmon by release group, 2015.

Release Date	Number Released	Number Recaptured	ATE_{test} (%)
4/27/2015	9	4	33.3%
5/4/2015	12	6	50.0%
5/13/2015	13	5	38.5%
5/21/2015	6	1	16.7%
Total	**40**	**15**	**37.5%**

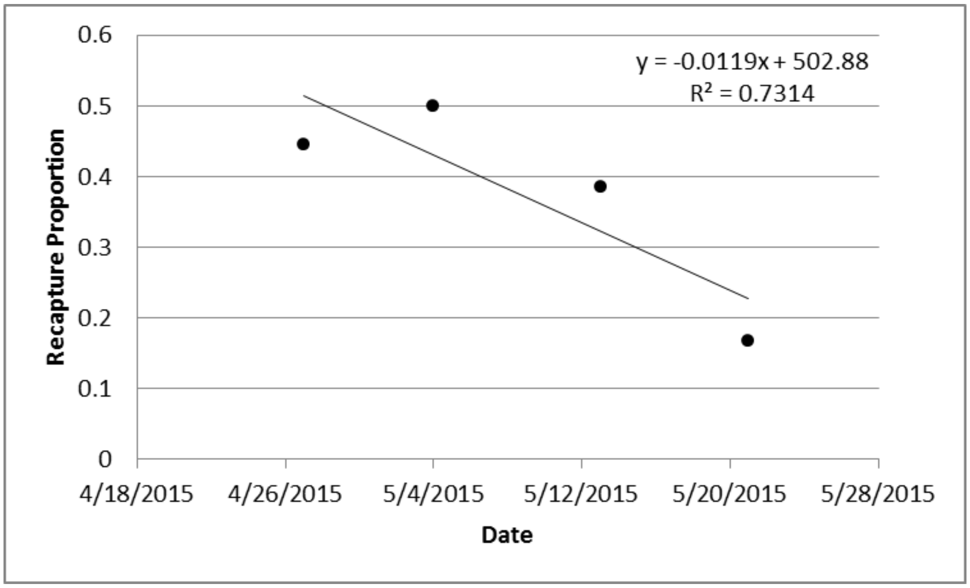

Figure 16. The proportion of spring Chinook recaptured (ATE_{Test}) plotted as a function of time for Merwin Dam, 2015. A best-fit regression line has been interpolated and the equation of the line as well the r^2 value are displayed.

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

A visual analysis of the network diagram for spring Chinook movements throughout the study area illustrates the tendency of fish to move widely throughout the tailrace (Figure 17). Fish seem to preferentially move from the bridge (BRG) site along the north shore (NS) before moving directly across the tailrace to the south powerhouse (PWS) and then on to the approach (APR) zone. A smaller number of fish appear to move from the bridge (BRG) along the south shore (SS) before joining with fish that have moved across from the north shore (NS) and proceeding to the south powerhouse (PWS) and then approach (APR) zone. The greatest amount of movement appear to occur between north shore (NS), south shore (SS) and the south powerhouse (PWS) and the approach. Unlike steelhead, substantial numbers of spring Chinook move between the gallery (GAL) and all other tailrace zones.

Spring Chinook that successfully passed the tailrace and entered the adult trap demonstrated different behavior than fish that did not pass. Fish that entered the adult trap and were captured had lower median number of edges (i.e. – less active), a lower average number of neighbors (i.e. – less movement between sites) and larger edge to diameter ratio (i.e. – less milling and exploring; Figure 18). However, none of these relationships were determined to be statistically significant (Table 12) likely due to very small sample sizes (n =40). Median diameter (i.e. - furthest distance travel between sites) was approximately equivalent between the two groups but biased higher for fish that entered the trap and were captured. Again, this difference was, however, not statistically significant.

Individual zone efficiencies are a good indicator of possible bottlenecks where fish are able to enter but not to progress upstream. As with steelhead, spring Chinook zone efficiencies (ZE) tended to be higher, on average, downstream of the tailrace, intermediate within the tailrace zone and lowest within the ATE (Figure 19). Individual ZEs were highest at the bridge, bed & breakfast, south shore and downstream boat launch and lowest at the north powerhouse, pool 4 within the adult trap and the approach, entrance and gallery zones.

Route-specific passage (RSP) efficiencies were highest for fish taking the most direct routes through the tailrace (i.e. – fewest steps between the bridge and entrance zones; Figure 20, Table 13) and lowest for fish taking longer routes. This result is intuitive as longer, more convoluted routes would necessarily be less efficient. Also, paths involving passage along the south shore and/or past the south powerhouse tended to have higher RSP efficiencies. There is a precipitous drop in RSP efficiency after the first three routes all three of which involve the south shore, south powerhouse or both. Paths passing through the north powerhouse and gallery tend to have lower efficiencies as a result of their low ZE.

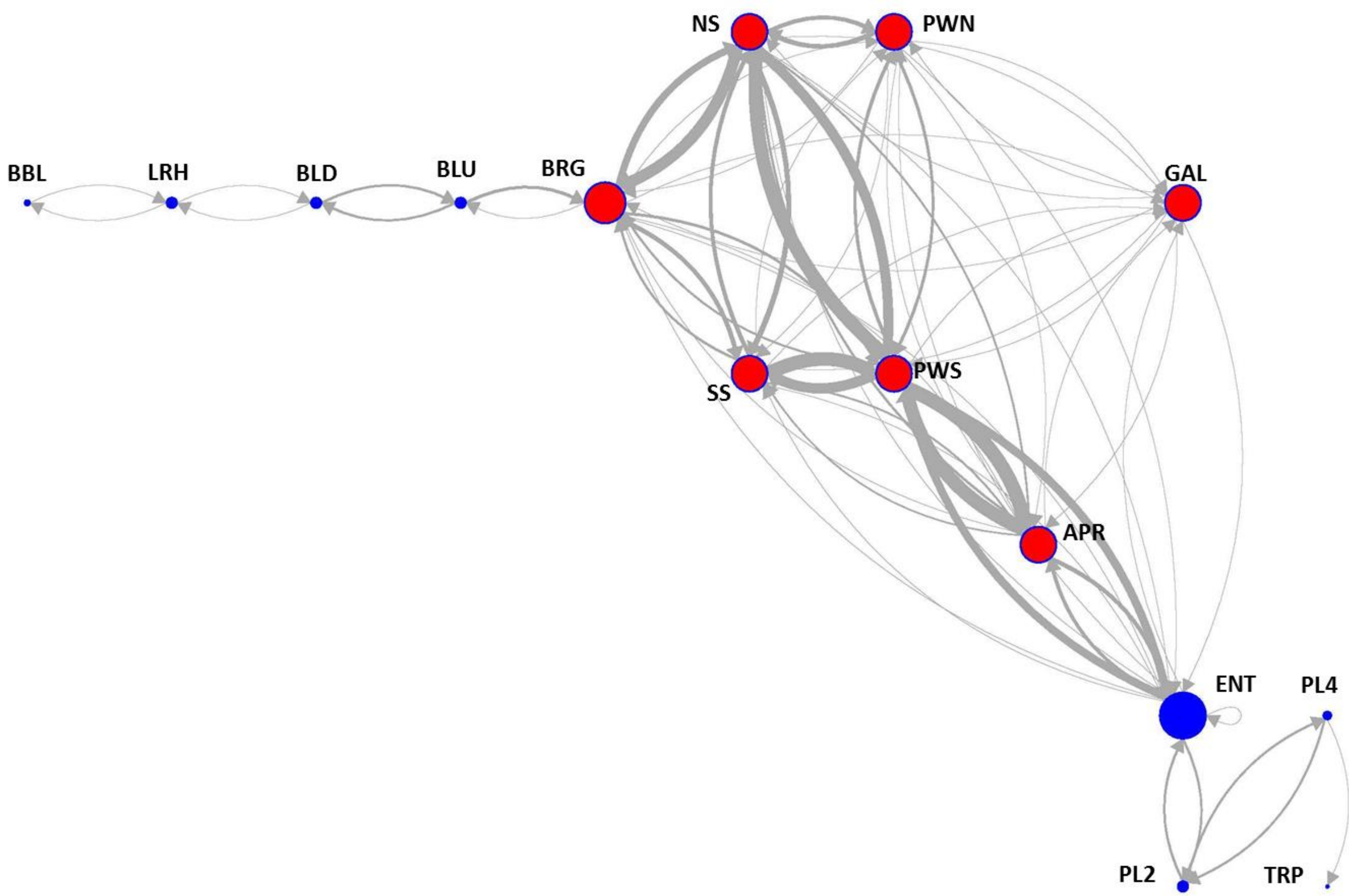

Figure 17. Network diagram of spring Chinook movements within the study area at Merwin Dam, 2015. Tailrace sites are denoted in red. Node size is scaled by the total number of paths entering the node. References for node labels can be found in Table 1. Path thickness is scaled based on the total number of individual travel paths between nodes in that direction. BBL = Lewis River Bed & Breakfast, LRH = Lewis River Hatchery, BLD = downstream of Boat Launch, BLU = Holding Pool upstream of Boat Launch, BRG = Bridge, NS = North shore, SS = South shore, PWN = North Powerhouse, PWS = South Powerhouse, GAL = Gallery, APR = Approach, ENT = Trap Entrance, PL2 = Trap Pool 2, PL4 = Trap Pool 4, TRP = Processing Facility.

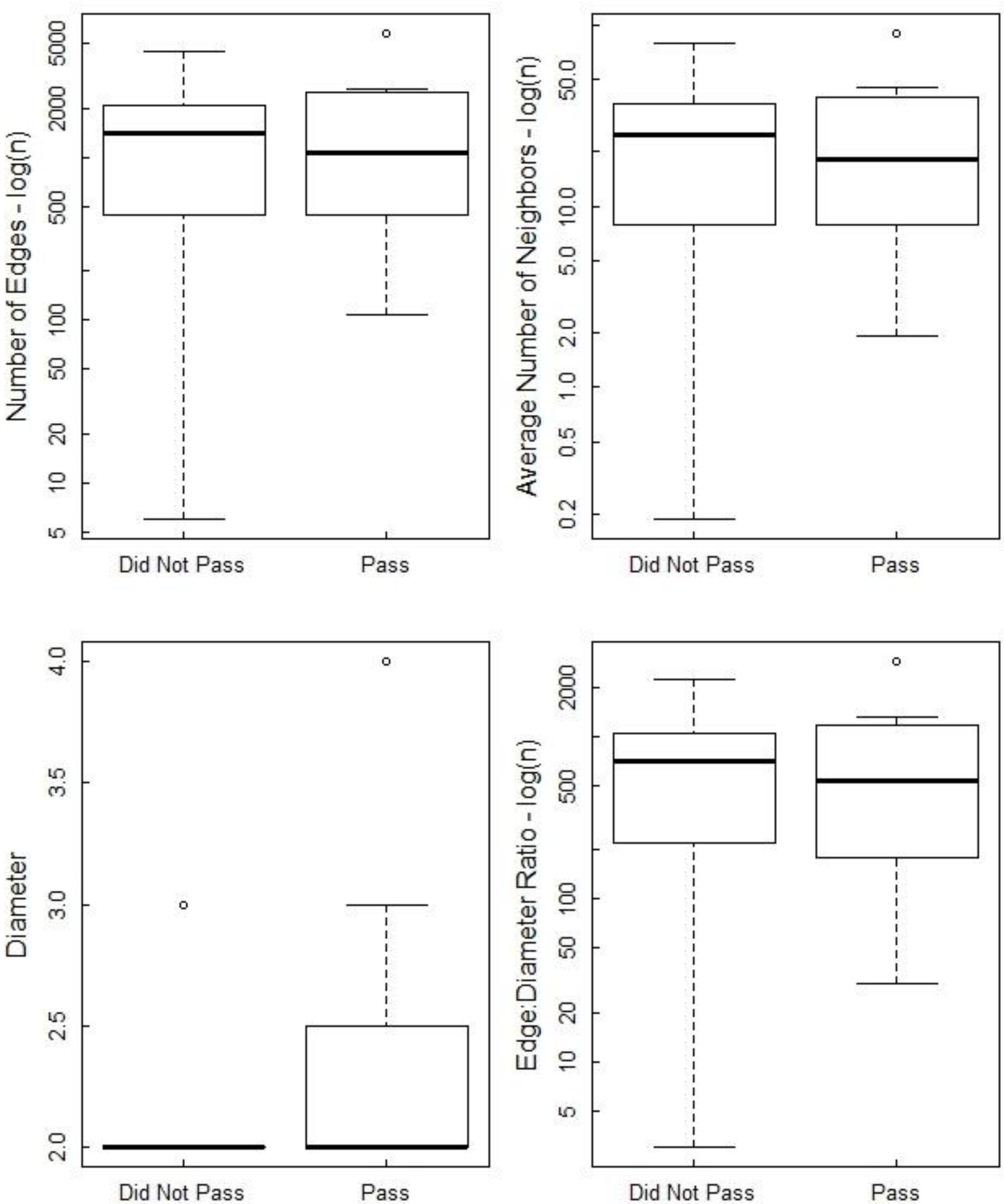

Figure 18. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for spring Chinook that were captured and passed or did not pass Merwin Dam, 2015.

Table 13. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for spring Chinook that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for Chinook that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	1077	1401	1.00
Diameter	2	2	1.00
Avg. Nearest Neighbor	18.0	25.0	1.00
Edge:Diameter Ratio	538.5	700.5	1.00

* Significant at the α = 0.05 level

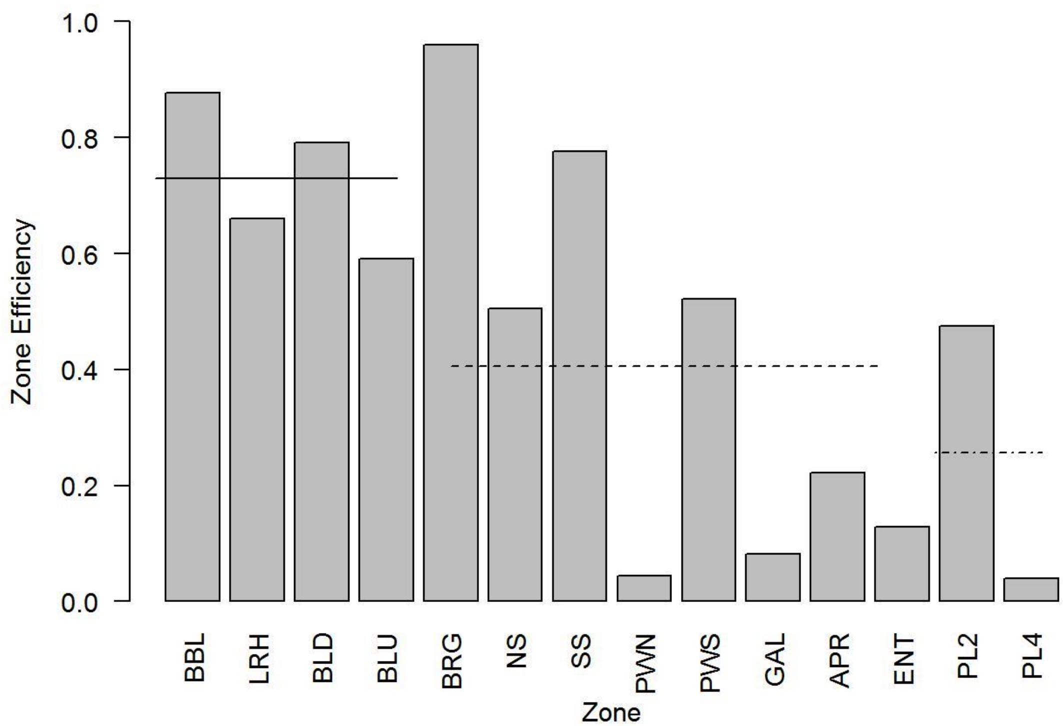

Figure 19. Zone efficiency (ZE) for all zones in the study based on spring Chinook detection data at Merwin Dam, 2015. The solid, dashed and dot-dashed horizontal lines represents the average ZE for downstream, tailrace and trap sites, respectively.

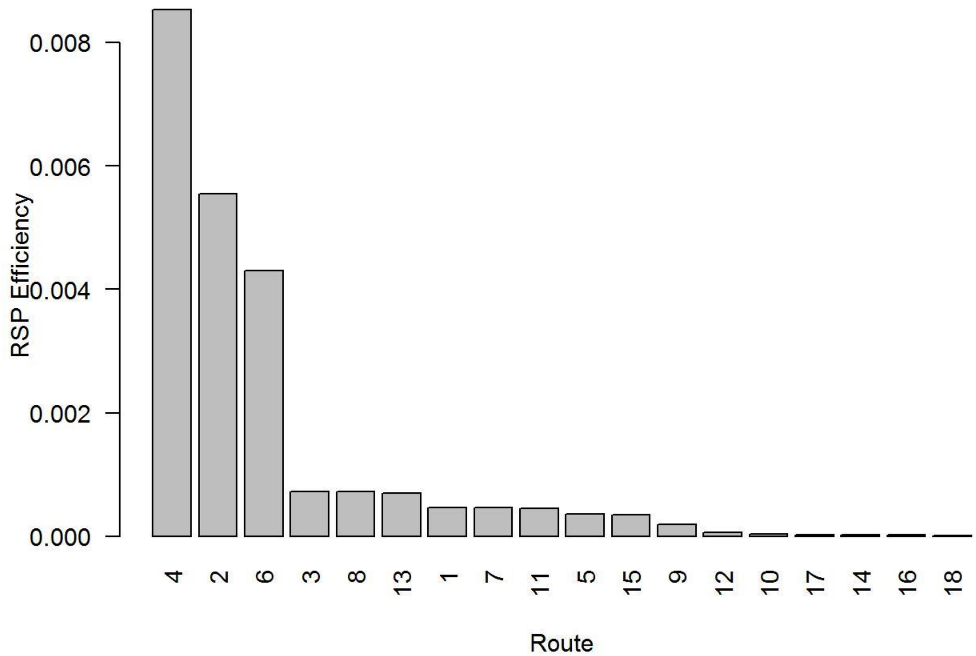

Figure 20. Route Specific Passage (RSP) efficiency ranked from highest to lowest for probable routes through the tailrace for spring Chinook at Merwin Dam, 2015.

Table 14. Route Specific Passage (RSP) efficiency route names, samples sizes and values ranked from highest to lowest for probable routes through the tailrace for spring Chinook at Merwin Dam, 2015.

RSP Efficiency	Route	*n*	RSP Efficiency
Downriver > BRG > SS > PWS > APR > ENT > ATRP	R4	148	0.0085
Downriver > BRG > NS > PWS > APR > ENT > ATRP	R2	148	0.0055
Downriver > BRG > NS > SS > PWS > APR > ENT > ATRP	R6	148	0.0043
Downriver > BRG > SS > PWN > APR > ENT > ATRP	R3	148	0.0007
Downriver > BRG > SS > PWN > PWS > APR > ENT > ATRP	R8	148	0.0007
Downriver > BRG > SS > PWS > GAL > APR > ENT > ATRP	R13	148	0.0007
Downriver > BRG > NS > PWN > APR > ENT > ATRP	R1	148	0.0005
Downriver > BRG > NS > PWN > PWS > APR > ENT > ATRP	R7	148	0.0005
Downriver > BRG > NS > PWS > GAL > APR > ENT > ATRP	R11	148	0.0005
Downriver > BRG > NS > SS > PWN > APR > ENT > ATRP	R5	148	0.0004
Downriver > BRG > NS > SS > PWS > GAL > APR > ENT > ATRP	R15	148	0.0004
Downriver > BRG > NS > SS > PWN > PWS > APR > ENT > ATRP	R9	148	0.0002
Downriver > BRG > SS > PWN > GAL > APR > ENT > ATRP	R12	148	0.00006
Downriver > BRG > NS > PWN > GAL > APR > ENT > ATRP	R10	148	0.00004
Downriver > BRG > SS > PWN > PWS > GAL > APR > ENT > ATRP	R17	148	0.00003
Downriver > BRG > NS > SS > PWN > GAL > APR > ENT > ATRP	R14	148	0.00003
Downriver > BRG > NS > PWN > PWS > GAL > APR > ENT > ATRP	R16	148	0.00002
Downriver > BRG > NS > SS > PWN > PWS > GAL > APR > ENT > ATRP	R18	148	0.00002

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

The median tailrace residence time by zone for spring Chinook showed that fish spent the longest amount of time within the bridge (BRG) zone followed closely by the Northshore (Figure 21). They spent the least amount of time in the approach and entrance zones although the north powerhouse zone also has low residence time. Some spring Chinook end up in the gallery zone and spend a moderate amount of time there. Fish spend significantly more time in the bridge, Northshore and south powerhouse zone as compared to the entrance but spend significantly less time in the approach zone (Table 15). The mean percent time spent by spring Chinook in the approach/entrance zone as a function of total tailrace time was 10.7%.

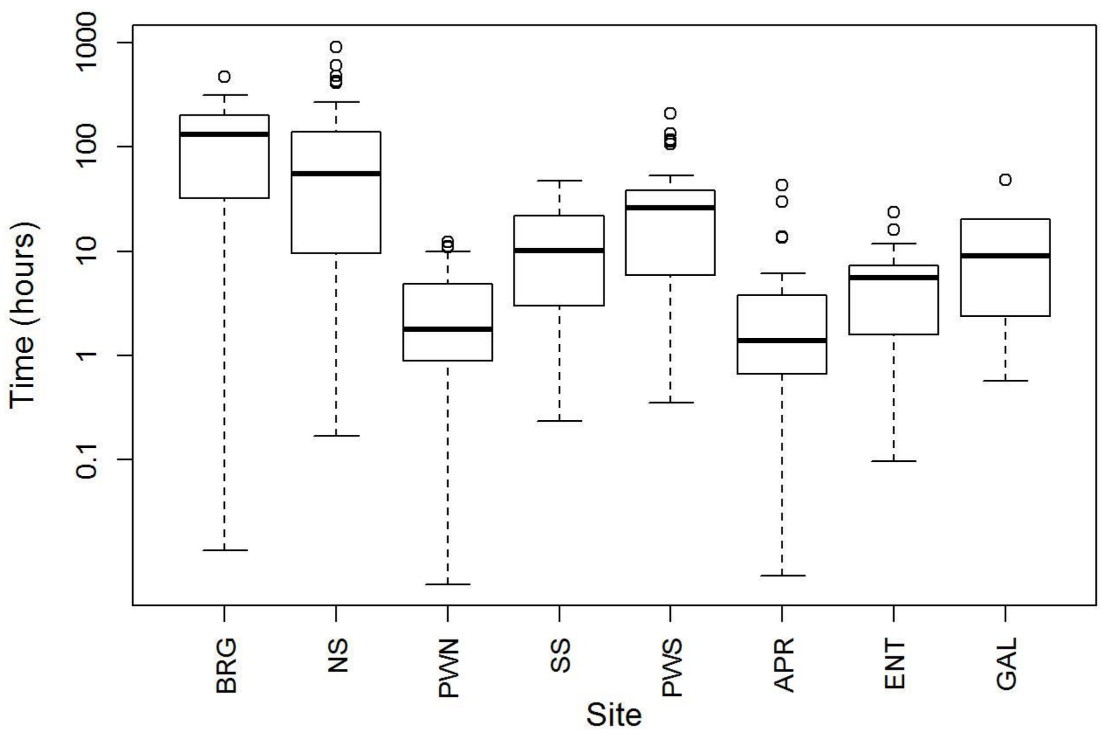

Figure 21. Median residence time for tailrace detection zones for spring Chinook at Merwin Dam, 2015.

Table 15. Median tailrace residence time for spring Chinook at entrance zone and comparison zones as well Bonferroni adjusted p-values for a Wilcoxon Rank Sum test of medians for Merwin Dam, 2015.

Comparison	Median Residence Time (hours) – ENT	Median Residence Time (hours) – Comparison Zone	Bonferroni Corrected p-value
ENT => BRG	5.53	130.8	<0.001*
ENT => NS	5.53	55.4	<0.001*
ENT => SS	5.53	10.1	0.17
ENT => PWN	5.53	1.77	0.14
ENT => PWS	5.53	26.0	<0.001*
ENT => APR	5.53	0.42	0.02*
ENT => GAL	5.53	9.00	1.00

* Statistically significant at the α = 0.05 level

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

The median tailrace residence time for spring Chinook in the Merwin Dam tailrace was 246.5 hours with a range between 0.01 and 1412.4 hours (<1 minutes to ~59days, respectively; Figure 22). Given fish milling behavior, this may represent total time spent during multiple trips through the tailrace. Sixty-five percent (65%) of spring Chinook had a total tailrace residence time greater than 168 hours (7 days).

Spring Chinook that entered the tailrace but never entered or passed the trap had a median tailrace residence time of 0.02 hours with a range of 0.01 hours to 4.6 hours and none had a tailrace residence time greater than 168 hrs (7 days). Spring Chinook that entered the trap but never passed had a median tailrace residence time of 278.0 hours with a range between 28.7 and 941.8 hours and 42.5% had a tailrace residence time greater than 168 hrs (7 days). Spring Chinook that entered and passed the trap had a residence time of 228.4 hours with a range of 7.5 to 11412.4 hours and 22.5% had a tailrace residence time greater than 168 hrs (7 days).

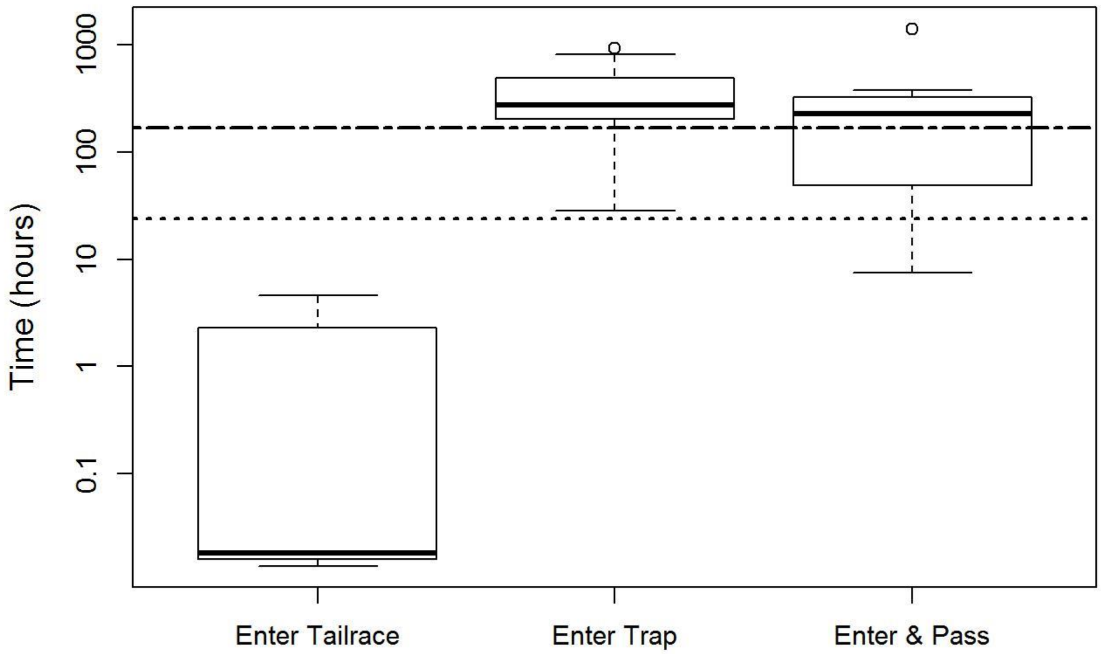

Figure 22. Distribution of median residence time for spring Chinook that either entered the tailrace, entered the trap or entered the trap and were captured (passed) at Merwin Dam, 2015. The dotted horizontal line represents the 24hr median standard. The dot-dash horizontal line represents the 168 hr standard.

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

A visual analysis of the network diagram for spring Chinook movements throughout the study area illustrates the tendency of fish below the tailrace to move frequently between the area below the boat ramp (BLD) and the "holding pool" (BLU; Figure 17). There is also a noticeable amount of upstream movement from the holding pool towards the bridge site (BRG) although less so moving downstream in the opposite direction. As with steelhead, there was noticeably less movement between the boat launch and holding pool and the Lewis River Hatchery (LRH) or the downstream-most bed & breakfast (BBL) site. Observations from opportunistic mobile tracking efforts by PacifiCorp staff during the summer appear to confirm this as spring Chinook were found holding in both the holding pool and a deep hole adjacent to the Lewis River Hatchery. This seems to indicate a tendency by spring Chinook, much like steelhead, to congregate in the holding pool and to move short distances up and downstream when below the tailrace area.

Spring Chinook that successfully entered and were captured in the adult trap demonstrated highly similar behavior in downstream sections below the bridge than fish that did not pass (Figure 23; Table 16). Median number of edges, path diameter, average number of neighbors and edge to diameter ratio were all largely similar, if not identical, between fish that were captured and passed compared to those who were not. In all cases, the only notable difference was that fish which were not captured and passed showed wider variation in the four network metrics than fish which were captured and passed. None of these differences, however, were statistically significant. It is worth noting that sample size overall (n = 40) and for fish that entered the adult trap and were captured (i.e. – passed; n = 15) were both low which may have influenced the results.

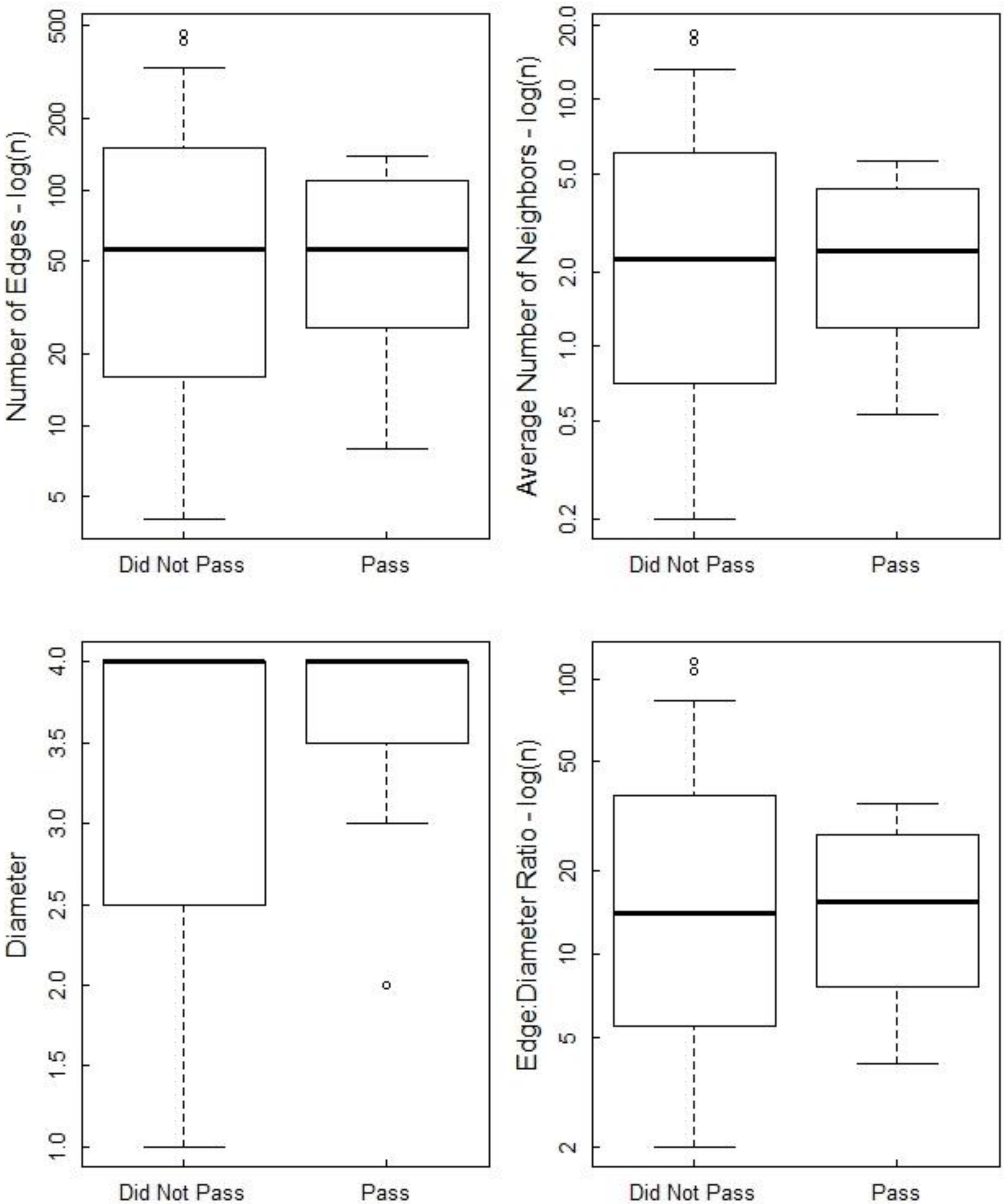

Figure 23. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for spring Chinook that were captured and passed or did not pass Merwin Dam, 2015.

Table 16. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for spring Chinook that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for Chinook that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	56	56	1.00
Diameter	4	4	1.00
Avg. Nearest Neighbor	2,42	2.24	1.00
Edge:Diameter Ratio	15.5	14	1.00

* Significant at the α = 0.05 level

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

PacifiCorp staff reported that none of the 15 (0%) recaptured spring Chinook possessed any descaling or injury not originally observed during initial capture.

Operational Analyses

Spring Chinook demonstrated significantly different behaviors under different spill conditions. Spring Chinook had fewer total edges (i.e. – less overall movement), a smaller average number of neighbors (i.e. – less movement between zones) and a lower edge to diameter ratio (i.e. – less milling and exploring) under spill conditions than non-spill conditions (Figure 24). These differences were all statistically significant (Table 17). Counter-intuitively, spring Chinook appeared to have a larger path diameter (i.e. – maximum distance traveled within the tailrace). However, this difference was neither statistically, nor likely biologically, significant as it totaled only a single additional zone. Also, all spring Chinook passed under non-spill conditions. However, non-spill conditions occurred for 89% of the study period with most spill occurring late in the year when no spring Chinook likely remained in the study reach.

Spring Chinook experienced the complete range of generation conditions with all units operating singly and in combination at some point during their run. However, low numbers of study fish and therefore low numbers of detections combined with the relatively large number of power generating conditions meant that any given combination had few samples and therefore little power for statistical inference. Network metrics are presented visually below but without further interpretation given low sample sizes (Figure 25). Also, while 73.3% of spring Chinook were captured and passed when Units 2 only was generating, this was the most common generating condition (32.8%) during the study period. Therefore, it is not unexpected that most fish would pass under these conditions.

There were 327 instances where spring Chinook exited from pool 4 into pool 2 during the study. Of these exits, 45 (13.8%) occurred during the 15 minute period of trap cycling (conservative criteria) and 116 (35.5%) occurred during or immediately adjacent to the 15 minute period of trap cycling (liberal criteria).

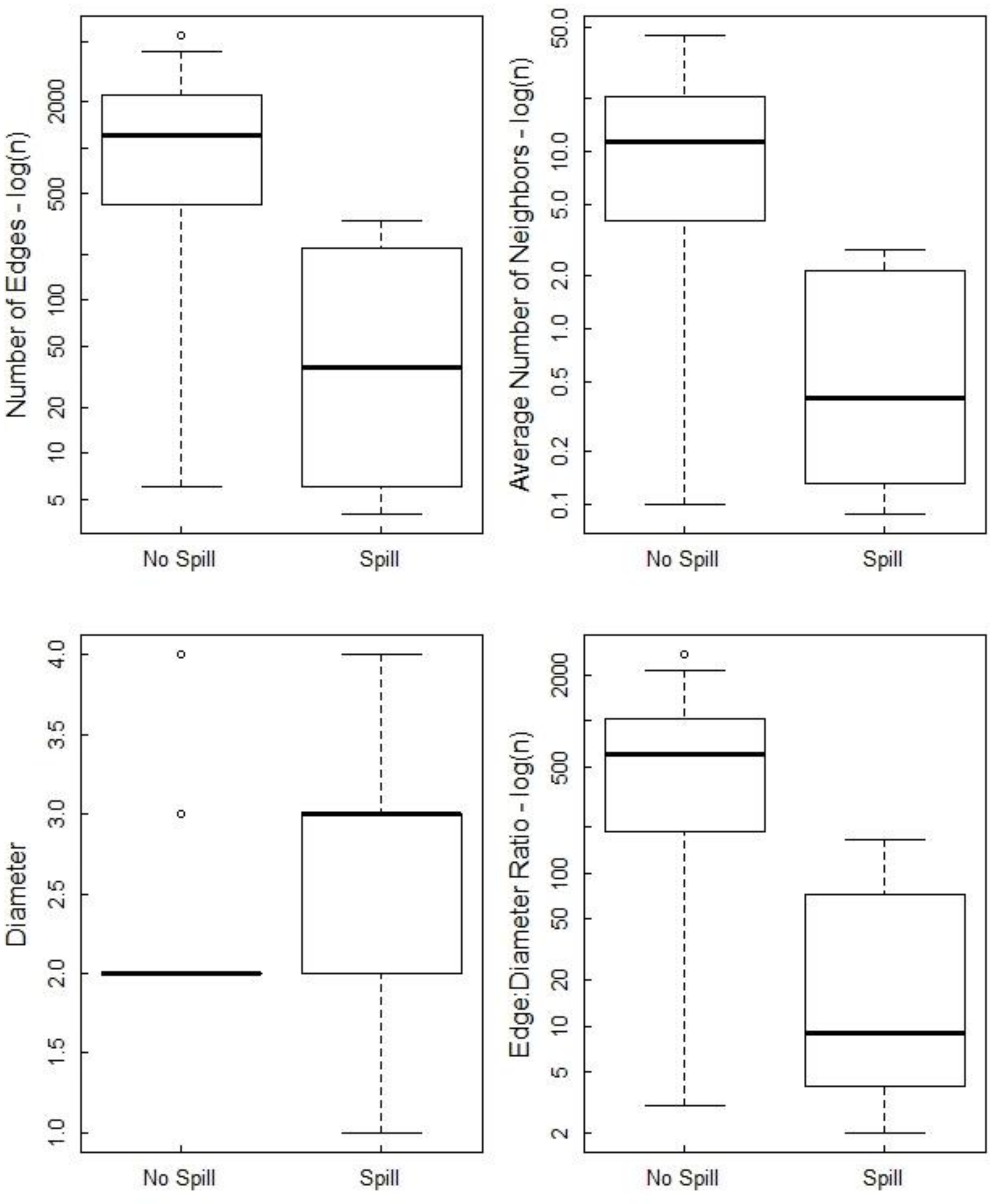

Figure 24. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under spill or no spill conditions for spring Chinook at Merwin Dam, 2015.

Table 17. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for Chinook under spill or no spill conditions at Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for spring Chinook that passed versus those that did not are reported.

Network Metric	Median – Spill	Median – No Spill	Bonferroni Adjusted p-value
# Edges	36	1205	<0.001*
Diameter	3	2	0.48
Avg. Nearest Neighbor	0.4	11.5	<0.001*
Edge:Diameter Ratio	9	603	<0.001*

* Significant at the $\alpha = 0.05$ level

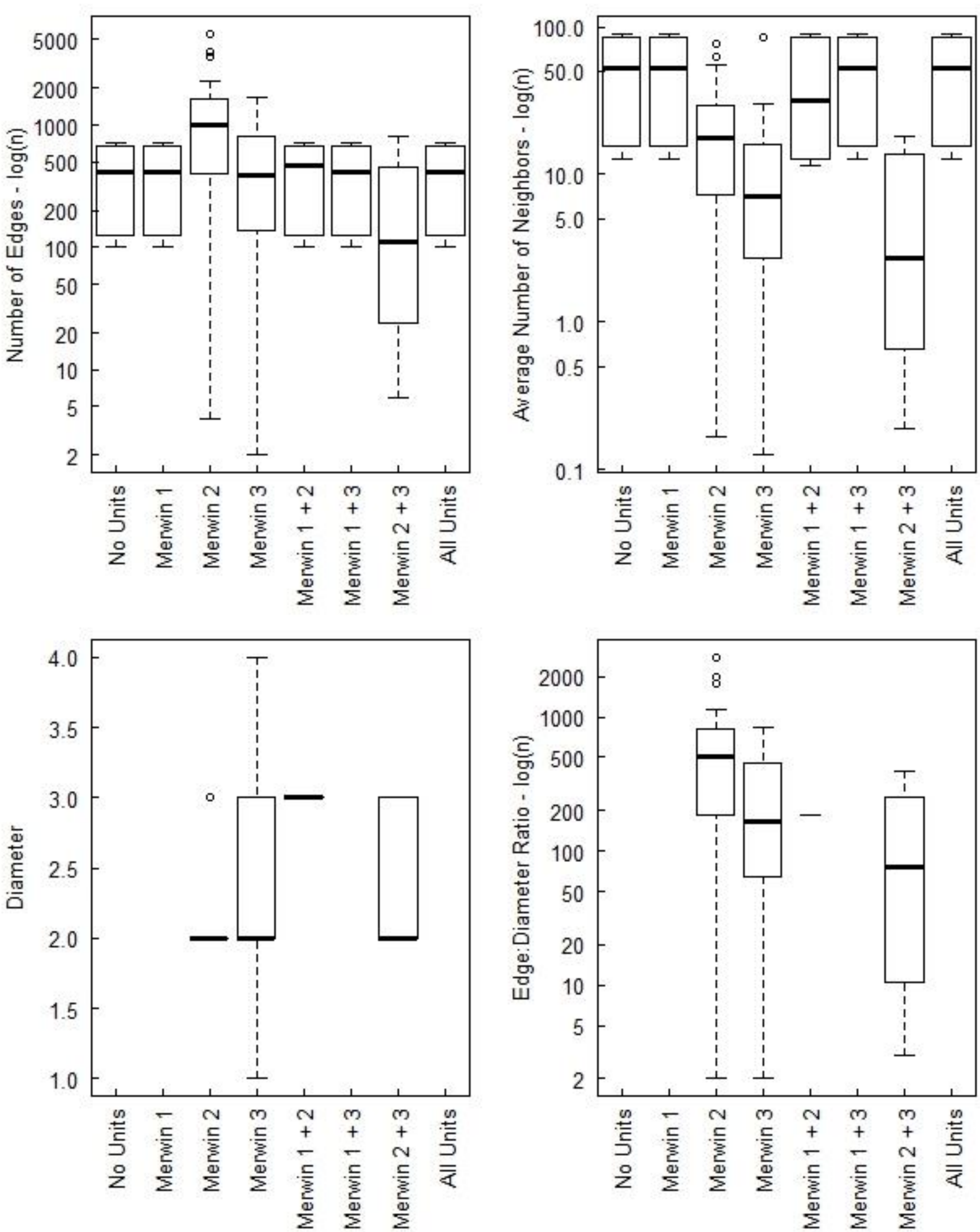

Figure 25. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under multiple power generation conditions for spring Chinook at Merwin Dam, 2015.

Coho

A total of 35 tagged coho were detected in the radio telemetry array during the radio-telemetry study. All of the tagged coho entered the study area at some point. A total of 8 coho entered the adult trap at some point and of those 3 were ultimately captured. All tagged coho captured in the trap were detected by the array.

Objective 1: Determine trap effectiveness based on the ATE metric for each target species, and compare those estimates to the 98 percent performance standard.

The overall ATE_{Test} for coho was 8.6% (3/35). This corresponds to a 0% (Mean: 0.086, Std. Dev.: 0.103; Z = 8.72) probability that the true ATE_{Test} value is greater than the 98% performance standard. However, more than double the number of fish found and entered the adult trap (22.9%; 8/35) than were ultimately captured.

ATE_{Test} by release group ranged between 0 and 25% (Table 18). There was a no effect of release date ($p = 0.71$) and a visual inspection of the plot confirms this result (Figure 26; $r^2 = 0.02$). However, given the low overall sample size and limited number of release groups, there would need to be an extremely strong effect to be statistically detectable. This result should be interpreted with caution as it is likely a result of low statistical power.

Table 18. Adult trap efficiency (ATE_{test}) for coho salmon by release group, 2015.

Release Date	Number Released	Number Recaptured	ATE_{test} (%)
9/4/2015	1	0	0.0%
9/15/2015	15	1	6.7%
10/12/2015	2	0	0.0%
10/14/2015	4	1	25.0%
10/30/2015	2	0	0.0%
11/3/2015	3	0	0.0%
11/5/2015	3	0	0.0%
11/12/2015	5	1	20.0%
Total	**35**	**3**	**8.6%**

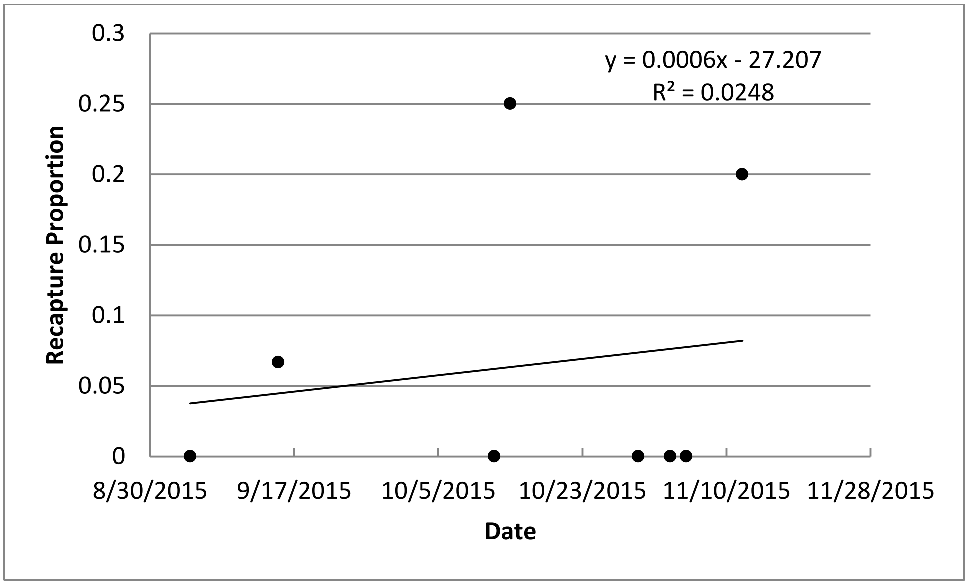

Figure 26. The proportion of coho recaptured (ATE_{Test}) plotted as a function of time for Merwin Dam, 2015. A best-fit regression line has been interpolated and the equation of the line as well the r^2 value are displayed.

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

A visual analysis of the network diagram for coho movements throughout the study area illustrates the tendency of fish to move widely within the tailrace (Figure 27). Coho appear to move most frequently from the bridge (BRG) along the north shore (NS) to the north powerhouse (PWN). However, many fewer of these fish appear to move to the south powerhouse (PWS) or approach zones (APR) from the north powerhouse. Most fish appear to move from the bridge (BRG) or north shore to the south shore (SS) and then to the south powerhouse and approach zone. There appears to be significant movement between the south powerhouse and approach zones. Like steelhead, very few fish pass through the gallery (GAL) zone at any time.

Coho that successfully passed the tailrace and entered the adult trap demonstrated different behavior that fish that did not pass. Fish that entered the adult trap and were captured had a higher median number of edges (i.e. – more active), a higher median diameter (i.e. – longer travel path), a higher average number of neighbors (i.e. – more movement between sites) and larger edge to diameter ratio (i.e. – more milling and exploring; Figure 28). This was essentially consistent with observations of steelhead but contradictory to results for spring Chinook. However, as with spring Chinook, none of these relationships were determined to be statistically significant (Table 19) likely due to small (n = 35) sample sizes.

Unlike steelhead and spring Chinook, coho zone efficiencies (ZE) tended to be equal, on average, both downstream of and within the tailrace zones. However, similar to steelhead and spring Chinook, ZEs were lowest within the adult trap (Figure 29). Similar to steelhead and spring Chinook, individual ZEs were highest at the bridge, downstream boat launch and entrance and lowest at the north powerhouse, pool 4 and the approach zones. Unlike the previous two species, ZEs were also low at the Lewis River Bed & Breakfast and the Lewis River Hatchery zone. It should be noted, however, that these numbers are based on a small sample of fish (n = 35) and therefore may not be fully representative.

Route specific passage (RSP) efficiencies were again highest for fish taking the most direct routes through the tailrace (i.e. – fewest steps between the bridge and entrance zones; Figure 30, Table 20) and lowest for fish taking longer routes. Again, this result is intuitive. Also, paths involving passage along the south shore and/or past the south powerhouse tended to have higher RSP efficiencies. As with, spring Chinook, there is a precipitous drop in RSP efficiency after the first three routes all three of which involve the south shore, south powerhouse or both. Paths passing through the north powerhouse and/or north shore tend to have lower efficiencies as a result of their low ZE. Finally, no coho successfully passed upstream from the gallery site meaning any route including the gallery site received an RSP efficiency of zero. Again, out of an already limited number of coho released an extremely small number passed through the gallery. This extremely small sample is not likely representative of the population as a whole. Upstream passage from the gallery site may be low but it is unlikely to be zero given results from other species.

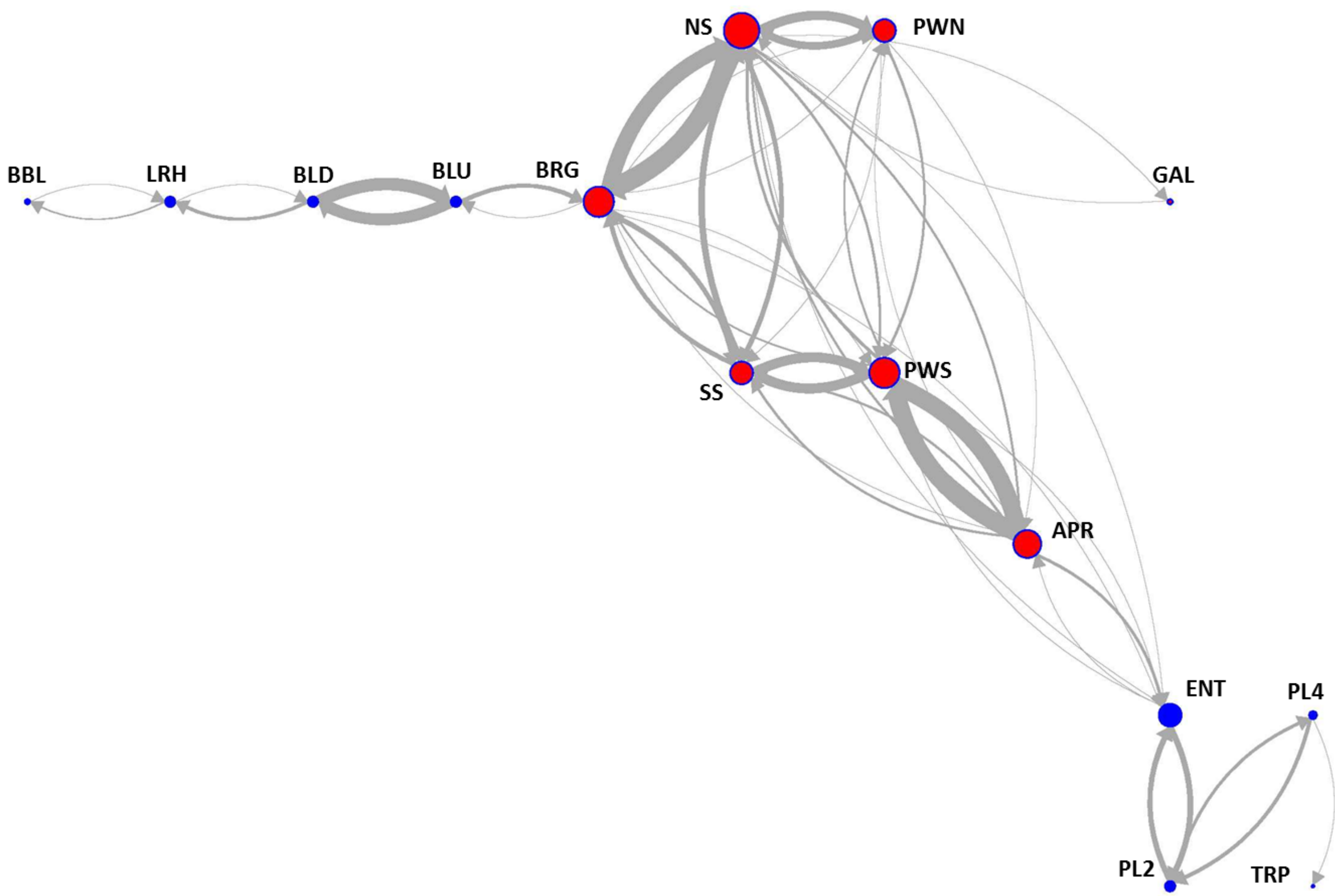

Figure 27. Network diagram of coho movements within the study area at Merwin Dam, 2015. Tailrace sites are denoted in red. Node size is scaled by the total number of paths entering the node. References for node labels can be found in Table 1. Path thickness is scaled based on the total number of individual travel paths between nodes in that direction. BBL = Lewis River Bed & Breakfast, LRH = Lewis River Hatchery, BLD = downstream of Boat Launch, BLU = Holding Pool upstream of Boat Launch, BRG = Bridge, NS = North shore, SS = South shore, PWN = North Powerhouse, PWS = South Powerhouse, GAL = Gallery, APR = Approach, ENT = Trap Entrance, PL2 = Trap Pool 2, PL4 = Trap Pool 4, TRP = Processing Facility.

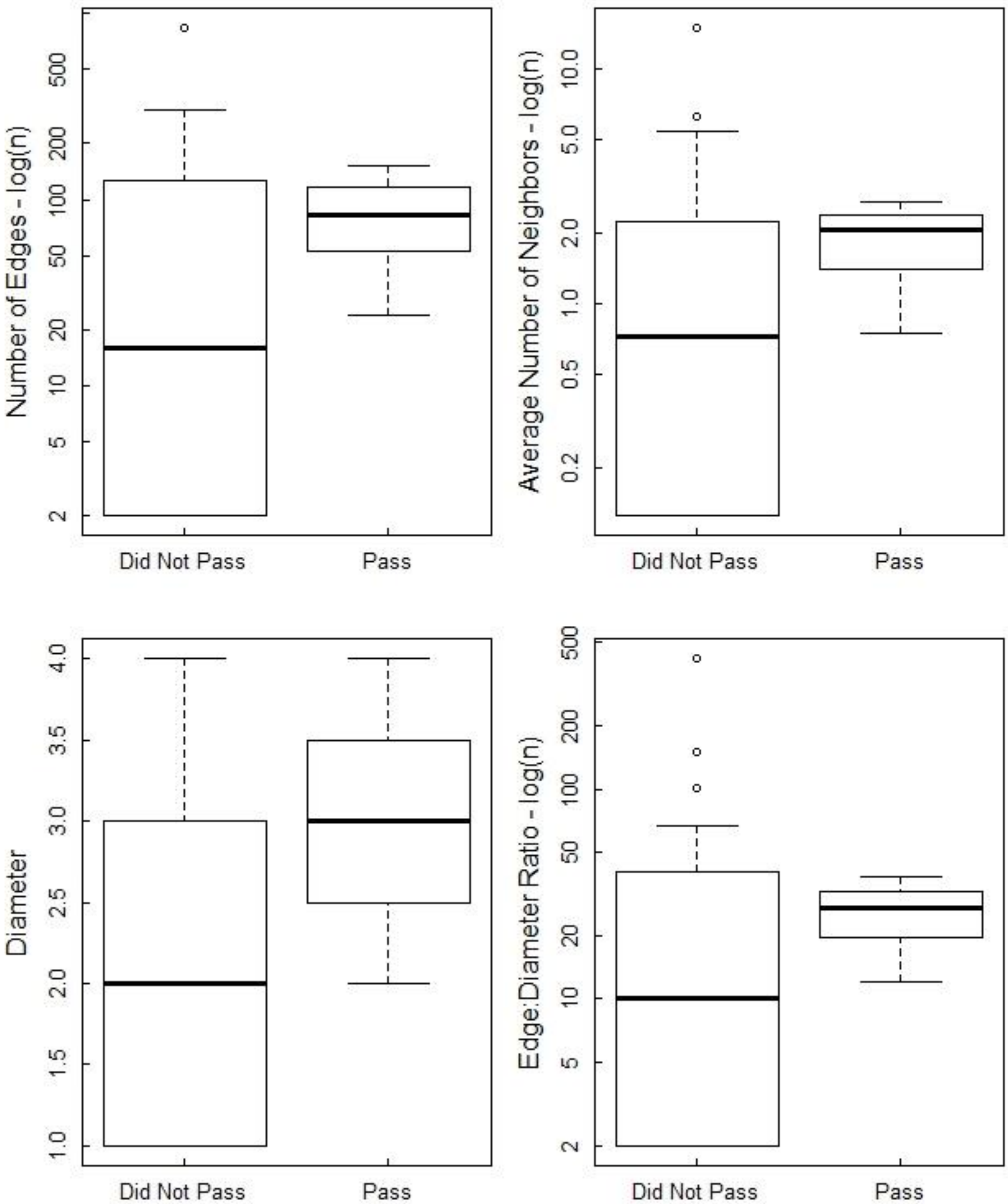

Figure 28. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for coho that were captured and passed or did not pass Merwin Dam, 2015.

Table 19. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for coho that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for coho that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	82	16	1.00
Diameter	3	2	0.51
Avg. Nearest Neighbor	2.05	0.72	1.00
Edge:Diameter Ratio	27.3	10	1.00

* Significant at the α = 0.05 level

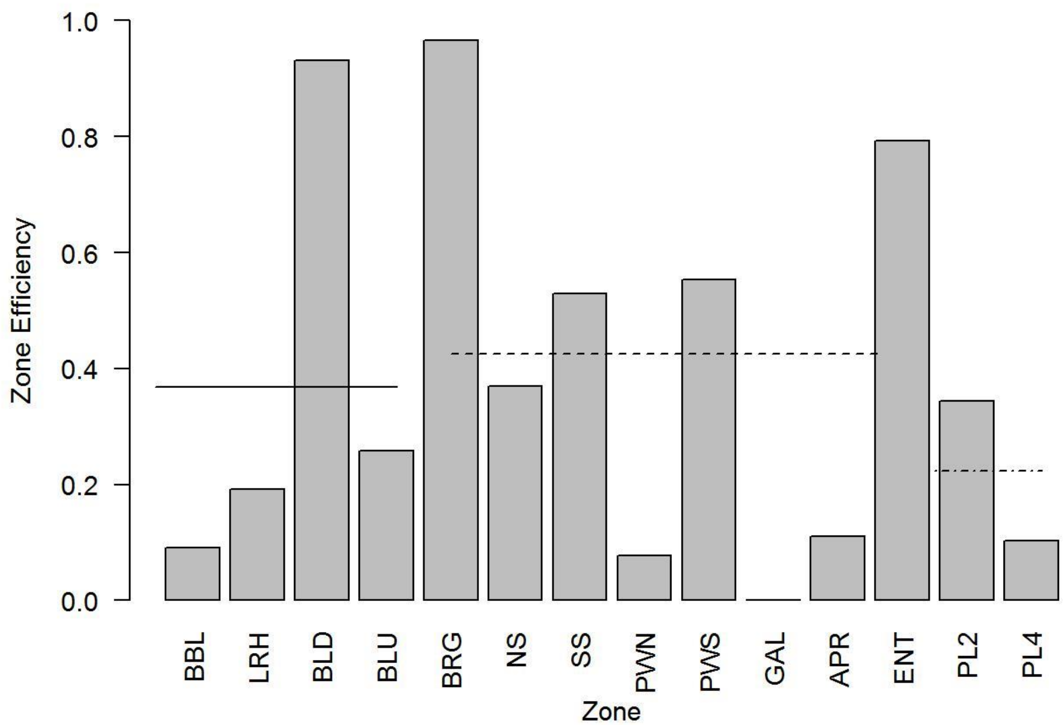

Figure 29. Zone efficiency (ZE) for all zones in the study based on coho detection data at Merwin Dam, 2015. The solid, dashed and dot-dashed horizontal lines represents the average ZE for downstream, tailrace and trap sites, respectively.

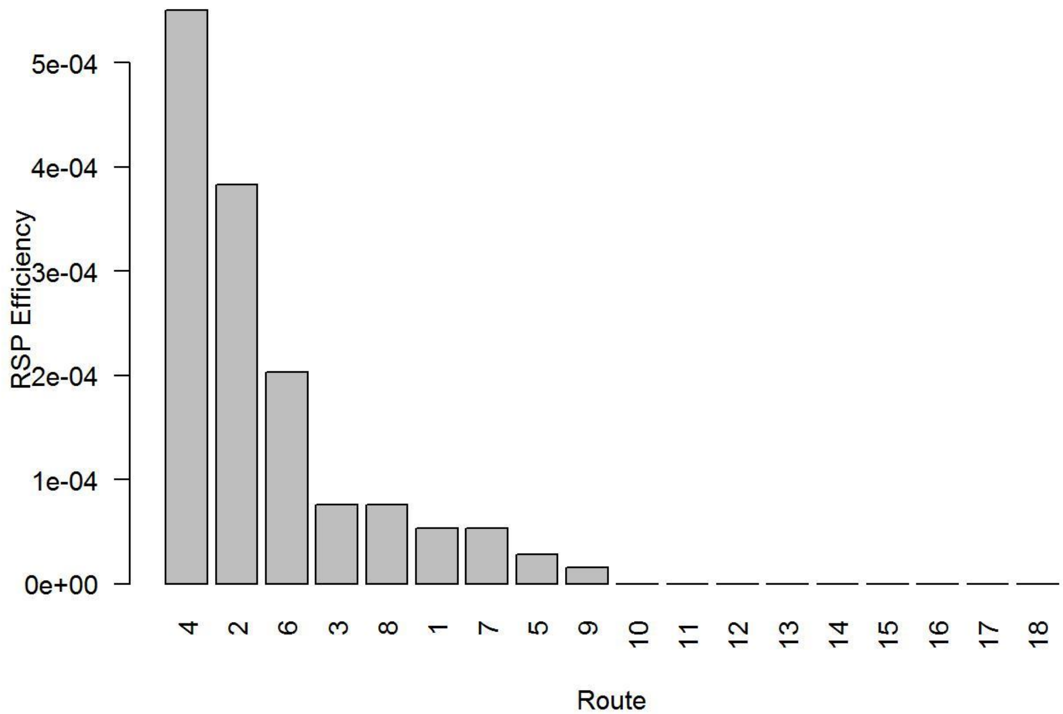

Figure 30. Route Specific Passage (RSP) efficiency ranked from highest to lowest for probable routes through the tailrace for coho at Merwin Dam, 2015.

Table 20. Route Specific Passage (RSP) efficiency route names, samples sizes and values ranked from highest to lowest for probable routes through the tailrace for coho at Merwin Dam, 2015.

RSP Efficiency	Route	*n*	RSP Efficiency
Downriver > BRG > SS > PWS > APR > ENT > ATRP	R4	148	0.00055
Downriver > BRG > NS > PWS > APR > ENT > ATRP	R2	148	0.00038
Downriver > BRG > NS > SS > PWS > APR > ENT > ATRP	R6	148	0.00020
Downriver > BRG > SS > PWN > APR > ENT > ATRP	R3	148	0.00008
Downriver > BRG > SS > PWN > PWS > APR > ENT > ATRP	R8	148	0.00008
Downriver > BRG > NS > PWN > APR > ENT > ATRP	R1	148	0.00005
Downriver > BRG > NS > PWN > PWS > APR > ENT > ATRP	R7	148	0.00005
Downriver > BRG > NS > SS > PWN > APR > ENT > ATRP	R5	148	0.00003
Downriver > BRG > NS > SS > PWN > PWS > APR > ENT > ATRP	R9	148	0.00002
Downriver > BRG > NS > PWN > GAL > APR > ENT > ATRP	R10	148	0.00
Downriver > BRG > NS > PWS > GAL > APR > ENT > ATRP	R11	148	0.00
Downriver > BRG > SS > PWN > GAL > APR > ENT > ATRP	R12	148	0.00
Downriver > BRG > SS > PWS > GAL > APR > ENT > ATRP	R13	148	0.00
Downriver > BRG > NS > SS > PWN > GAL > APR > ENT > ATRP	R14	148	0.00
Downriver > BRG > NS > SS > PWS > GAL > APR > ENT > ATRP	R15	148	0.00
Downriver > BRG > NS > PWN > PWS > GAL > APR > ENT > ATRP	R16	148	0.00
Downriver > BRG > SS > PWN > PWS > GAL > APR > ENT > ATRP	R17	148	0.00
Downriver > BRG > NS > SS > PWN > PWS > GAL > APR > ENT > ATRP	R18	148	0.00

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

The median tailrace residence time by zone for coho showed that fish spend the longest amount of time within the bridge (BRG) zone (Figure 31). They spend the least time in the entrance and southshore zones. Very few coho ended up in the gallery zone but those that did spent a relatively long time there. Fish spend significantly more time in the bridge and northshore zones as compared to the entrance (Table 21). The mean percent time spent by steelhead in the approach/entrance zone as a function of total tailrace time was 13.0%.

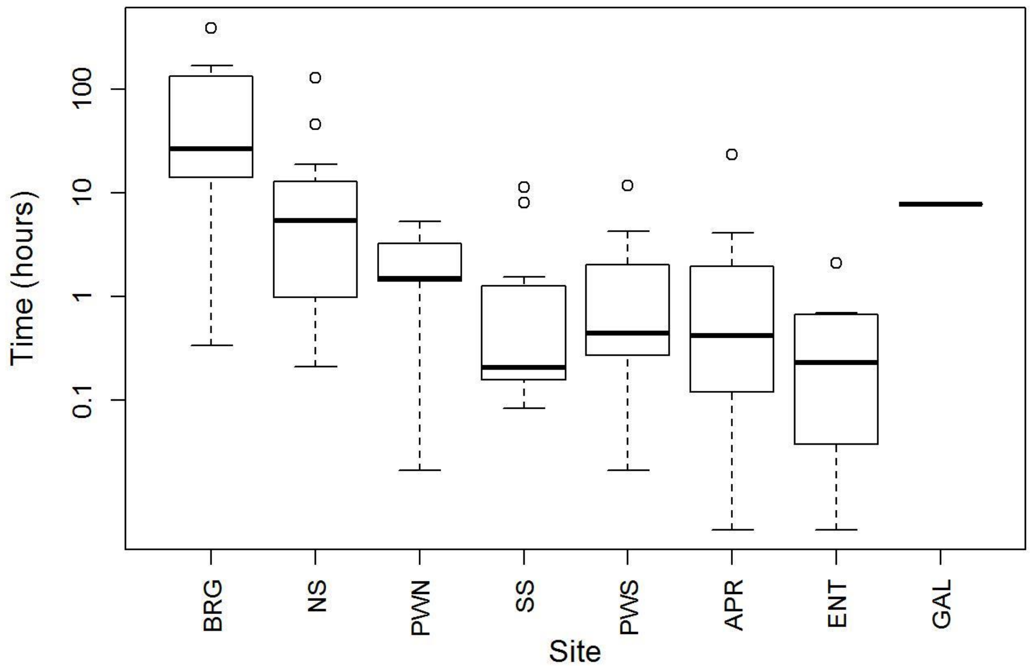

Figure 31. Median residence time for tailrace detection zones for coho at Merwin Dam, 2015.

Table 21. Median tailrace residence time for coho at entrance zone and comparison zones as well Bonferroni adjusted p-values for a Wilcoxon Rank Sum test of medians for Merwin Dam, 2015.

Comparison	Median Residence Time – ENT	Median Residence Time - Comparison	Bonferroni Corrected p-value
ENT => BRG	0.23	25.5	0.009*
ENT => NS	0.23	5.41	0.003*
ENT => SS	0.23	0.21	1.00
ENT => PWN	0.23	1.50	0.16
ENT => PWS	0.23	0.44	1.00
ENT => APR	0.23	0.42	1.00
ENT => GAL	0.23	7.70	1.00

* Statistically significant at the α = 0.05 level

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

The median tailrace residence time for coho in the Merwin Dam tailrace was 15.3 hrs with a range between 0.21 and 395.7 hrs (~13 minutes to ~16 days, respectively; Figure 32). Given fish milling behavior, this may represent total time spent during multiple trips through the tailrace. Approximately 5.7% of coho had a tailrace residence time greater than 168 hrs (7 days).

Coho that entered the tailrace but never entered or passed the trap had a median tailrace residence time of 2.1 hours with a range of 0.2 hours to 23.0 hours and none had a tailrace residence time greater than 168 hrs (7 days). Coho that entered the trap but never passed had a median tailrace residence time of 167.1 hours with a range between 25.5 and 395.7 hours and 5.7% had a tailrace residence time greater than 168 hrs (7 days). Coho that entered and passed the trap had a residence time of 2.3 hours with a range of 0.9 to 26.5 hours and none had a tailrace residence time greater than 168 hrs (7 days).

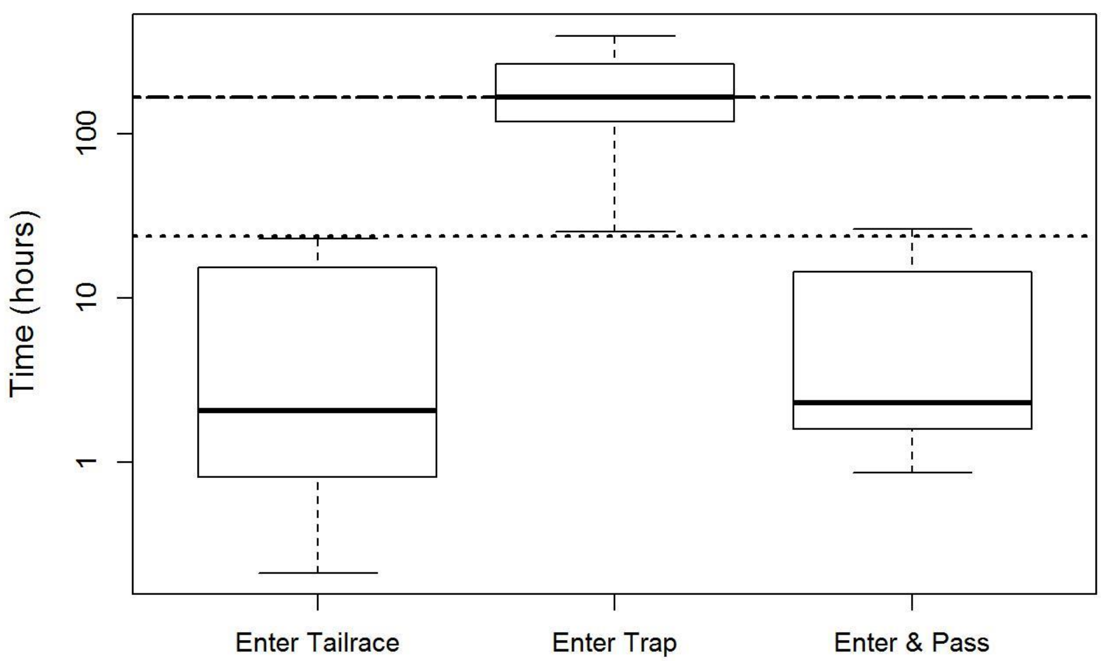

Figure 32. Distribution of median residence time for coho that either entered the tailrace, entered the trap or entered the trap and were captured (passed) at Merwin Dam, 2015. The dotted horizontal line represents the 24hr median standard. The dot-dash horizontal line represents the 168 hr standard.

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

A visual analysis of the network diagram for coho movements throughout the study area illustrates the substantial tendency of fish below the tailrace to move frequently between the area below the boat ramp (BLD) and the "holding pool" (BLU; Figure 27). There is also a notable amount of upstream movement from the holding pool towards the bridge site (BRG) and from below the boat launch to the Lewis River Hatchery (LRH). Both travel paths show less movement in the opposite direction (i.e. – LRH => BLD or BRG => BLU). There was noticeably less movement between the boat launch and holding pool and the downstream-most bed & breakfast (BBL) site. This seems to indicate a tendency by coho, much like steelhead and Chinook, to congregate in the holding pool and to move short distances up and downstream when below the tailrace area.

Coho that successfully entered and were captured in the adult trap demonstrated qualitatively different behavior in downstream sections below the bridge than fish that did not pass (Figure 33; Table 22). The few fish that passed had fewer edges (i.e. – less overall movement below the tailrace), fewer average number of neighbors (i.e. – less movement between sites below the tailrace) and smaller edge to diameter ratio (i.e. – less milling and exploring). There was no difference between the groups in path diameter. However, none of these differences were statistically significant.

Sample size overall (n = 35) and for fish that entered the adult trap and were captured (i.e. – passed; n = 3) were both low which clearly impacted the results. Particularly the lack of variation in network metrics for fish were captured and passed impacted the power and reliability of statistical testing.

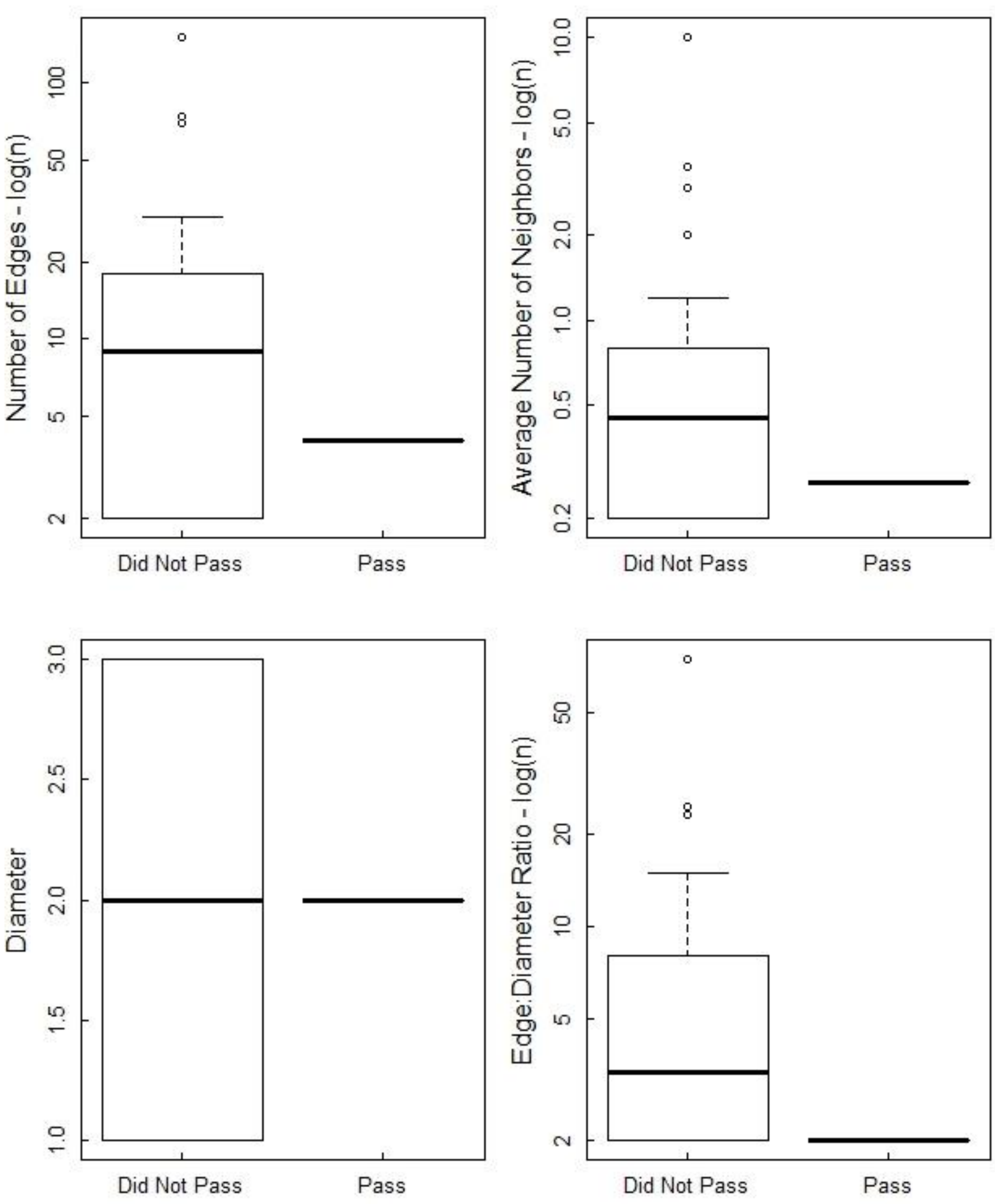

Figure 33. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for coho that were captured and passed or did not pass Merwin Dam, 2015.

Table 22. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in downstream segments for coho that were captured and passed or did not pass Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for coho that passed versus those that did not are reported.

Network Metric	Median – Pass	Median – Did Not Pass	Bonferroni Adjusted p-value
# Edges	4	9	1.00
Diameter	2	2	1.00
Avg. Nearest Neighbor	0.26	0.45	1.00
Edge:Diameter Ratio	2	3.3	0.31

* Significant at the α = 0.05 level

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

PacifiCorp staff reported that none of the three (0%) recaptured coho possessed any descaling or injury not originally observed during initial capture.

Operational Analyses

Coho demonstrated different behaviors under different spill conditions. Coho had more total edges (i.e. – more overall movement), a larger average number of neighbors (i.e. – more movement between zones) and a higher edge to diameter ratio (i.e. – more milling and exploring) under spill conditions than non-spill conditions (Figure 34). However, none of these differences were statistically significant (Table 23). Coho also appeared to have a slightly larger median path diameter (i.e. – maximum distance traveled within the tailrace). However, this difference was neither statistically, nor likely biologically, significant as it totaled a fraction of an additional zone. Also, all coho passed under non-spill conditions. However, non-spill conditions occurred for 89% of the study period with most spill occurring late in the year when few to no coho likely remained in the study reach.

Coho experienced most generation conditions during their run with the exception of only Unit 1 generating (Figure 35). However, low numbers of study fish and therefore low numbers of detections combined with the relatively large number of power generating conditions meant that any given combination had few samples and therefore little power for statistical inference. This is most clearly demonstrated for Unit 1 and 2 and Units 1 and 3 operating in tandem where there were not enough observations to generate a quantile distribution. Therefore, network metrics are presented for reference but without further interpretation.

There were 18 total instances where coho exited from pool 4 into pool 2 during the study. Of these exits, zero (0%) occurred during the 15 minute period of trap cycling (conservative criteria) and 10 (55.6%) occurred during or immediately adjacent to the 15 minute period of trap cycling (liberal criteria).

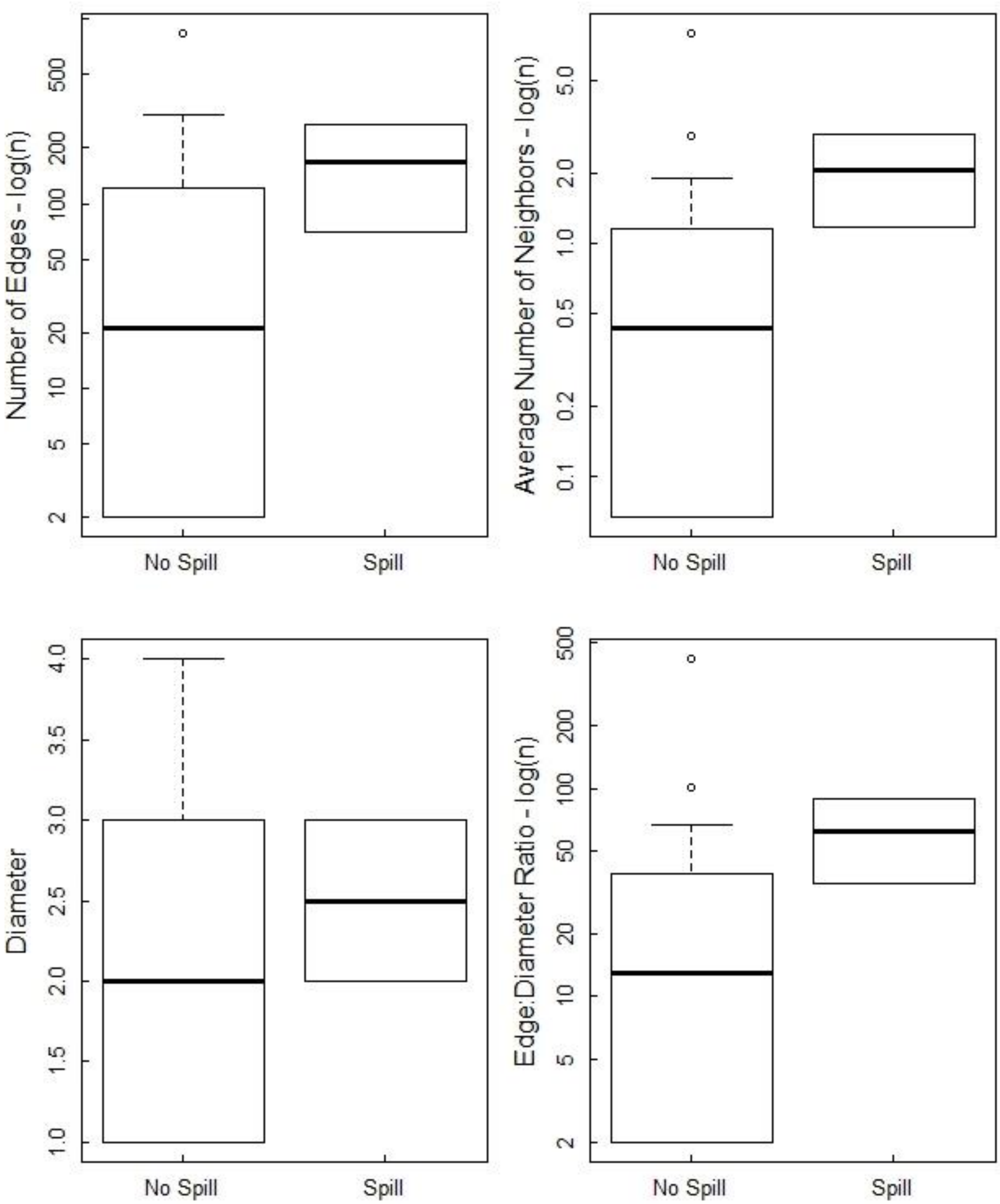

Figure 34. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under spill or no spill conditions for coho at Merwin Dam, 2015.

Table 23. Median number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace for coho under spill or no spill conditions at Merwin Dam, 2015. Bonferroni adjusted p-values for Wilcoxon Rank Sum tests of medians for coho that passed versus those that did not are reported.

Network Metric	Median – Spill	Median – No Spill	Bonferroni Adjusted p-value
# Edges	168	21	1.0
Diameter	2.5	2	1.0
Avg. Nearest Neighbor	2.1	0.43	0.47
Edge:Diameter Ratio	61.8	13	0.73

* Significant at the $\alpha = 0.05$ level

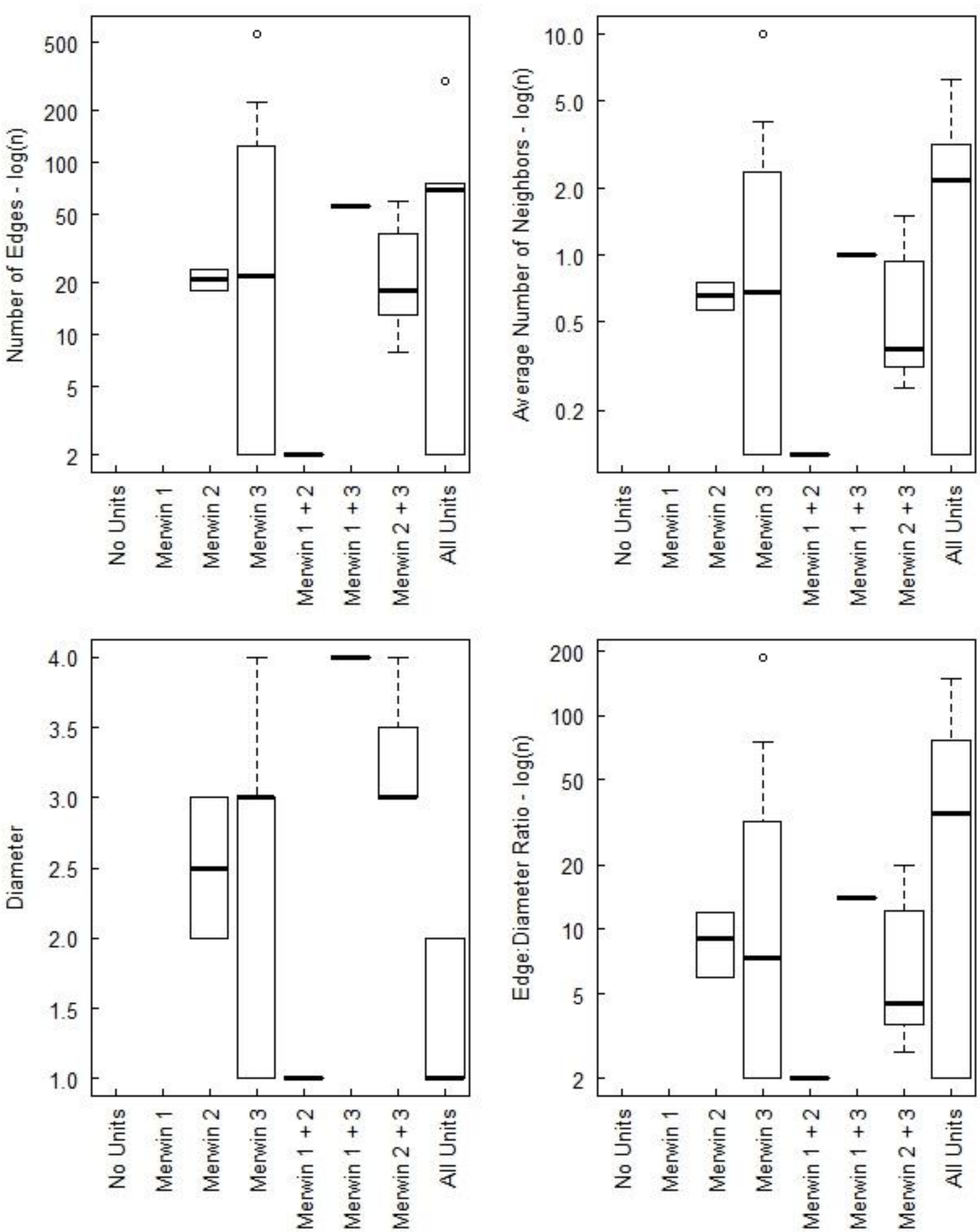

Figure 35. Number of edges, path diameter, average number of nearest neighbors and edge to diameter ratio in the tailrace under multiple power generation conditions for coho at Merwin Dam, 2015.

DISCUSSION

Adult trap efficiency (ATE) was below target for all three species studied in 2015 (61%, 38% and 9% for steelhead, spring Chinook and Coho, respectively). However, fish located and entered the trap at much higher rates than the rates at which they were ultimately captured (86%, 90% and 23% for steelhead, spring Chinook and Coho, respectively). This suggests that fish are locating the attraction flow and entering the trap but that trap operation or the transitioning fish from pool 4 into the “hopper” area may be impeding their progress. Some potential effect of trap operation seems likely given evidence that trap cycling coincided with high rates of all three species exiting pool 4 into pool 2 (0 – 17% under conservative criteria or 36 – 56% under more liberal criteria). This suggests that an engineered or behavioral solution to retain fish within the trap once they have entered has the potential to produce substantial increases in trap efficiency.

Standards for timely passage were only met for coho. Coho spent approximately 15hrs, on average, in the tailrace with only 5.7% of fish spending more than 168 hours in the tailrace. This meets the standard of an average of less than 24hrs tailrace residency and is extremely close to the no more than 5% having a residency longer than 168 hours. However, neither steelhead nor spring Chinook attained the standard with each spending an average of approximately 49 or 247 hours, respectively, in the tailrace and approximately 14% and 65%, respectively, in residence longer than 168 hours. These longer tailrace residence times may, in part, be an artifact of how the metric was calculated. The metric was calculated based on aggregate residency time within any given tailrace zone given the high degree of milling behavior observed. This could artificially inflate the residency metrics as the aggregate time could represent multiple trips within the tailrace.

Within the tailrace, all species spent the most time in the bridge zone closely followed, in most cases, by the north shore zone. The amount of time spent in these two zones was often significantly longer than the time spent in the entrance zone. This seems to suggest that fish were milling around at the entrance of the tailrace and/or were moving up the north shore preferentially but not passing through efficiently. All three fish species spent some of the least time in the approach or entrance zones as compared to other tailrace zones. No species spent more than 15% of their total tailrace time in the approach/entrance zone. However, given the relatively high trap entrance efficiency (P_{EE}) (i.e. – the number of fish finding and entering the trap), this seems to suggest that fish are having to engage in more exploratory behavior as they enter the tailrace but are able to move into the trap relatively quickly and efficiently once they reach the approach and entrance zones.

Both steelhead and coho that entered and were captured in the adult trap tended to show less directed movements with more milling and/or exploratory behavior within the tailrace. Conversely, spring Chinook showed a slight, non-significant tendency towards more directed movement within the tailrace for fish that ultimately entered and were captured. This could be the result of difficulties locating the attraction flow and trap entrance under varying spill and flow conditions, environmental conditions unique to the study season or behavioral tendencies of the fish. Environmental conditions during 2015, discussed in more detail below, likely played a substantial role given the limited spring run-off, low flow and high water temperatures experienced throughout the migration period.

Route Specific Passage (RSP) efficiencies were highest for all species for the most direct routes through the tailrace. This result is intuitive as, all other things being equal, shorter passage routes should be more efficient. For all species, the most efficient route tended to pass along the south shore and past the south powerhouse. However, it is interesting to note that network diagrams show that, particularly for coho and spring Chinook, a substantial amount of movement takes place along the north shore and even as far as the north shore powerhouse. This demonstrates that the route of travel most often used to transit the tailrace may not correspond to the most efficient route.

The Zone Efficiencies (ZE) used to calculate RSP efficiencies demonstrated that for all three species the north powerhouse zone and the pool 4 zone represent the most substantial bottlenecks to fish movement and passage. Network analysis shows substantial numbers of fish moving along the north shore – north powerhouse route. However, both RSP efficiencies and the ZEs they are built on indicate that fish moving along the north shore - north powerhouse route are not moving into the trap along that route. This would be consistent with the disconnect seen in the network diagrams where substantial movement along the north shore does not connect with the approach and/or entrance zones via the north powerhouse. While some of these fish ultimately locate the trap along other routes, time spent milling and exploring along the north shore may impact the safe, timely and effective passage standard.

Depth did not appear to affect detectability in the subset of fish tagged with archival tags. While logistic and technical difficulties precluded a complete analysis, the available data showed fish detected at high pressures (i.e. – deep depths) in the vicinity of both the bridge and north shore. All three fish had detections coincident with some of the highest pressures (i.e. – deepest depths) recorded during their deployment and none showed prolonged gaps in detections history corresponding to periods of high pressure (i.e. – deep dives). We expect to confirm these results in the second year of the study across more fish and all species.

Dam operations also may influence fish movement in the tailrace and therefore the efficiency of the adult trap. Steelhead and spring Chinook both displayed significantly less total movement, less movement between zones and less exploratory behavior within the tailrace under spill conditions. Coho actually displayed more movement, more movement between locations and more exploratory behavior under spill conditions. However, none of the results for coho were significant and low sample sizes likely confounded the analysis. All fish of all species passed under non-spill conditions. However, non-spill conditions occurred for 89% of the study period with most spill occurring late in the year when few, if any, fish were likely actively migrating within the study reach.

Power generation also appeared to affect fish movement in the tailrace and therefore the efficiency of the adult trap although the directionality of the effect is less clear. Both steelhead and spring Chinook passed at higher rates when fewer units were generating (i.e. – only one or two units). Moreover, steelhead showed less overall movement, less movement between zones and less exploratory behavior when two or more units were operational as opposed to single units. The specific unit or combination of units did not appear to exert as noticeable an effect as the total number of units in operation. This is consistent with expectations as multiple units in operation would create increased cavitation and confused flows making it potentially more difficult for fish to transit the tailrace or locate the trap attraction flows.

An important caveat to the analysis of power generation condition on movement and behavior is that generating conditions were not varied uniformly according to an established sampling design. The various generating conditions represent an opportunistic sampling based on conditions encountered. As a result, not all conditions are represented for any given species or even across the study. Also, the duration of time any given generating condition persisted varied with some prevailing for long periods and others persisting only briefly. This likely had an impact on the effects observed.

Limited numbers of spring Chinook and coho were tagged and therefore a much smaller sample of detections may have impacted conclusions drawn for these species. Where possible and appropriate, we attempted to complete a full suite of analyses. However, a complete, rigorous analysis was not always possible. This was particularly true in the case of power generating conditions where up to eight different generating conditions could have occurred during the migration period. Conclusions drawn this year from spring Chinook or coho data must be considered preliminary until additional years with larger sample sizes can be considered.

The current study year was an extreme climactic outlier with little to no spring freshet and abnormally low flows and high water temperatures throughout the duration of nearly all migration periods. Anecdotal observations noted fish staging for long periods in the holding pool below the bridge and making repeated, exploratory trips through the tailrace before returning. These observations appear to be confirmed by network diagrams and metrics which show substantial milling behavior by fish below the tailrace. While fish that were or were not ultimately captured and passed showed effectively no significant differences in network metrics downstream of the tailrace, network diagrams showed substantial movement by all species immediately downstream of the bridge in the vicinity of the holding pool and boat launch. Low flows and high temperatures may have caused fish to delay or abandon migration altogether in favor of holding in the deeper, thermal refuge downstream of the tailrace. This effect may be testable in 2016 provided we have more normal climactic conditions.

In summary, the first year of study seems to indicate that while adult trap efficiencies are below target, substantially more fish are finding and entering the trap than are being retained and captured. If these fish can be retained and captured, capture efficiencies could increase by up to an additional 24.7, 14.3 and 52.5 percentage points for steelhead, spring Chinook and coho, respectively. Also, fish appear to be showing increased exploratory behavior along the northshore and also early in their transit of the tailrace. Once fish reach the south shore and the approach/entrance zone they appear to move in an efficient and directed manner into the trap. Dam operation does appear to influence fish behavior and movement with spill and increased power generation suppressing fish movement. Finally, trap cycling does appear to impact fish retention within the trap as fish appear to exit the upstream most trap pool (pool 4) during hopper operation.

RECOMMENDATIONS FOR 2016

We recommend, in large part, a continuation of the methods and study design for 2016. We anticipate retaining the current design of the radio telemetry array with the addition of a site within the adult trap positioned at the entrance of the "hopper." We tested out a preliminary design for this site late last year and it performed to expectations. This will provide higher resolution behavioral and movement data at the terminus of the trap. We expect this will better allow us to determine the movements of fish that enter but are not ultimately captured by the trap. To that end, we recommend considering additional emphasis on documenting and analyzing behavior within the trap including potentially deployment of acoustic imaging and or deployment of proto-type fish retention devices to test their efficacy. Also, we recommend shifting the analytic focus in 2016 to emphasize fish movement and behavior within the adult trap as opposed to the tailrace or downstream. Finally, we recommend considering a shift in analytic focus away from documenting individualistic fish behavior to a greater focus on aggregate response to operational conditions more within PacifiCorp's control.

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APPENDIX E

SPAWN TIMING, DISTRIBUTION, AND ABUNDANCE OF TRANSPORTED FISHES

Environmental Sciences
Regulatory Planning
Project Management

Memorandum

To: Erik Lesko, PacifiCorp

From: Jason Shappart, Fisheries Scientist

Date: April 15, 2016

Re: NF Lewis River upstream of Swift Dam – coho spawning survey results (late-September 2015 through December 2015)

Introduction

Coho salmon spawning surveys were conducted from late-September through December 2015 by PacifiCorp and WDFW (through contract with PacifiCorp) to provide the basis for estimating the spawning success of transported anadromous fish in the North Fork Lewis River upstream of Swift Dam. This memorandum summarizes coho spawning survey results for the period from September 28 to December 31, 2015.

Survey Conditions

Western Washington experienced a drought during 2015, followed by intense and extended precipitation from late fall to early winter. Flow conditions in the North Fork Lewis River basin were lower than the normal through October, which precluded float surveys of the mainstem North Fork Lewis River. Intense precipitation resulted in high flow and difficult or unsurveyable float and walking survey, and these conditions persisted from early November through December. The North Fork Lewis River above Muddy River gage approximates the general flow patterns relative to median conditions throughout the basin during the survey season.

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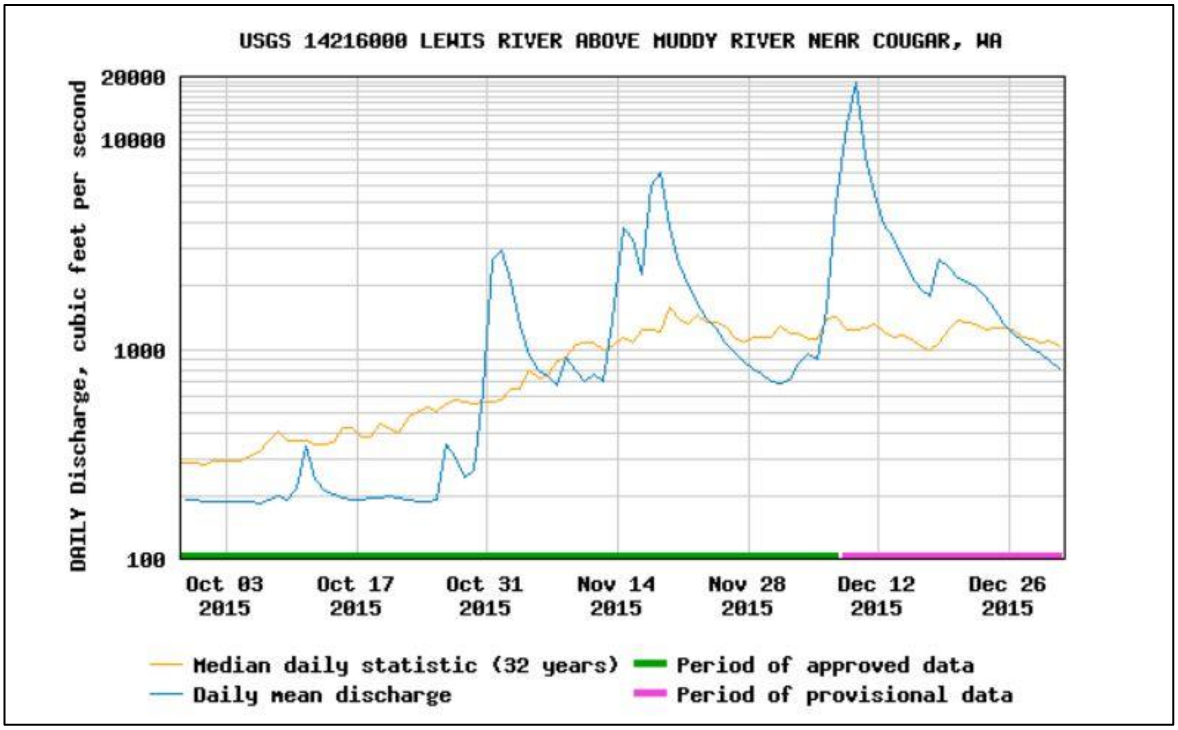

Results

A total of 3,754 adult coho were transported upstream to spawn during 2015. About 80 percent of these fish were transported upstream after high flows and difficult/unsurveyable conditions began the first week in November. Only 21 live coho, 6 redds, and 2 carcasses were observed during the entire survey season.

Discussion

Due to the overall difficult/poor survey conditions, which persisted during the period when the majority of coho were transported upstream, statistical estimates of total redds and spawners success of transported coho adults would likely be spurious due the unknown, but likely large influence of survey conditions on carcass and redd detection probability.

APPENDIX F

UPPER BASIN SEED PLANT PROGRAM – 2015 SUMMARY

Summary of the Adult Fish Seed Planting Program Upstream of Swift Reservoir 2015

Prepared by PacifiCorp

February 24, 2016

Background

PacifiCorp implemented and evaluated an extensive seed plant program in 2015. This program was developed based on results of earlier results (PacifiCorp 2014) which indicated that adult fish released at the head of Swift Reservoir (i.e., Eagle Cliff Adult Release site) remained near the release site or traveled downstream and entered the Swift Reservoir. In an effort to promote a wider distribution and habitat utilization by transported fish, it was agreed to by the Aquatics Coordination Committee (ACC) that a portion of fish would be transported and released much further into the upper basin. This was based on recent work previously done with spring Chinook on the North Fork Cispus River in the Cowlitz River Basin (Nissell 2011). Three additional releases sites were established in the upper watershed above Swift Reservoir in 2015. These released sites included the Muddy River Bridge, the Clear Creek Bridge, and the upper Lewis River Bridge near Crab Creek. A proportion of fish transported upstream were released at these remote locations (Table 1). Radio Telemetry combined with a number of aerial surveys were used to evaluate fish behavior and movement in the upper basin. The following sections provide a summary of observations made for both winter steelhead and coho salmon from the 2015 effort.

Winter Steelhead

In 2015, in an effort to promote a wider distribution of habitat utilization, portions of winter steelhead transported above Swift Dam were released at various ‘seed plant’ locations. Since 2012 all steelhead were released at head of Swift Reservoir either the Eagle Cliff Adult Release site or at the Swift Forest Camp boat launch; radio telemetry data during these years indicated that steelhead were not utilizing the majority of available habitat. Radio telemetry surveys were done during the winter steelhead spawning season to evaluate whether seed plant efforts promoted wider habitat utilization. A total of four surveys were done in 2014 while two surveys were done in 2015.

Of the 1,223 winter steelhead released upstream of Swift Reservoir in 2015, about 10 percent (132 of 1,223 – 10.8%) were released at the three remote sites in the upper basin (Table 1). These fish were released approximately evenly among sites with 40 adults released at the Muddy River site, 43 at the Clear Creek site, and 49 released in the upper Lewis River. Of these fish, about 30 percent of each release group contained radio tags.

A total of 82 and 83 radio tagged blank wire tag winter steelhead were released upstream of Swift Dam in 2014 and 2015, respectively. In 2014 all radio tags were released at either Swift Forest Camp or Eagle Cliff. During 2014 radio tags were released from mid-February through mid-April at even rates. In 2015 a portion radio tagged steelhead were released at seed plant locations on Muddy River (n=12), Clear Creek (n=12), and the Upper Lewis River near Crab Creek (n=15), the remainder were released at the Eagle Cliff site (n=44). During 2015 radio tags were released from mid-March through mid-May with release rates peaking during the third week of April.

A total of four aerial surveys were completed in 2014 (4/1, 4/17, 4/29, and 5/29). From these surveys, radio tagged steelhead utilized limited habitat upstream of Eagle Cliff (Figure 1). Pine, Drift, and Swift Creeks were the only streams having considerable amounts radio tags detected in them. There were limited detections in the lower reaches of Lewis and Muddy Rivers while the majority of tags were detected in Swift Reservoir.

In 2015 radio tags were detected throughout the Muddy River, Clear Creek, and Lewis River while Pine and Drift Creeks saw a decline in usage (Figures 2 and 3). In 2015 the majority of tags were detected in riverine environments rather than Swift Reservoir as observed in 2014. During both years, fish observed in Swift Reservoir tend to congregate at the head of the reservoir, in the forebay of Swift Dam and in Swift Creek Cove. The increase in habitat utilization could in part be due to environmental factors such as hydrologic patterns; however, there appears to be a pronounced increase of radio tagged steelhead distributions following seed planting efforts.

Table 1. Summary of fish releases upstream of Swift Reservior as part of the 2015 seed plany evaluation.

	Eagle Cliff/Swift Forest Camp	Upper Watershed				Combined Total
Winter Steelhead 2014		Muddy River Bridge	Clear Creek Bridge	Upper Lewis (Crab Creek)	Total	
Untagged	951	-	-	-	-	951
Radio Tagged	82	-	-	-	-	82
Total	1,033	-	-	-	-	1,033
Winter Steelhead 2015						
Untagged	1,047	28	31	34	93	1,140
Radio Tagged	44	12	12	15	39	83
Total	1,091	40	43	49	132	1,223

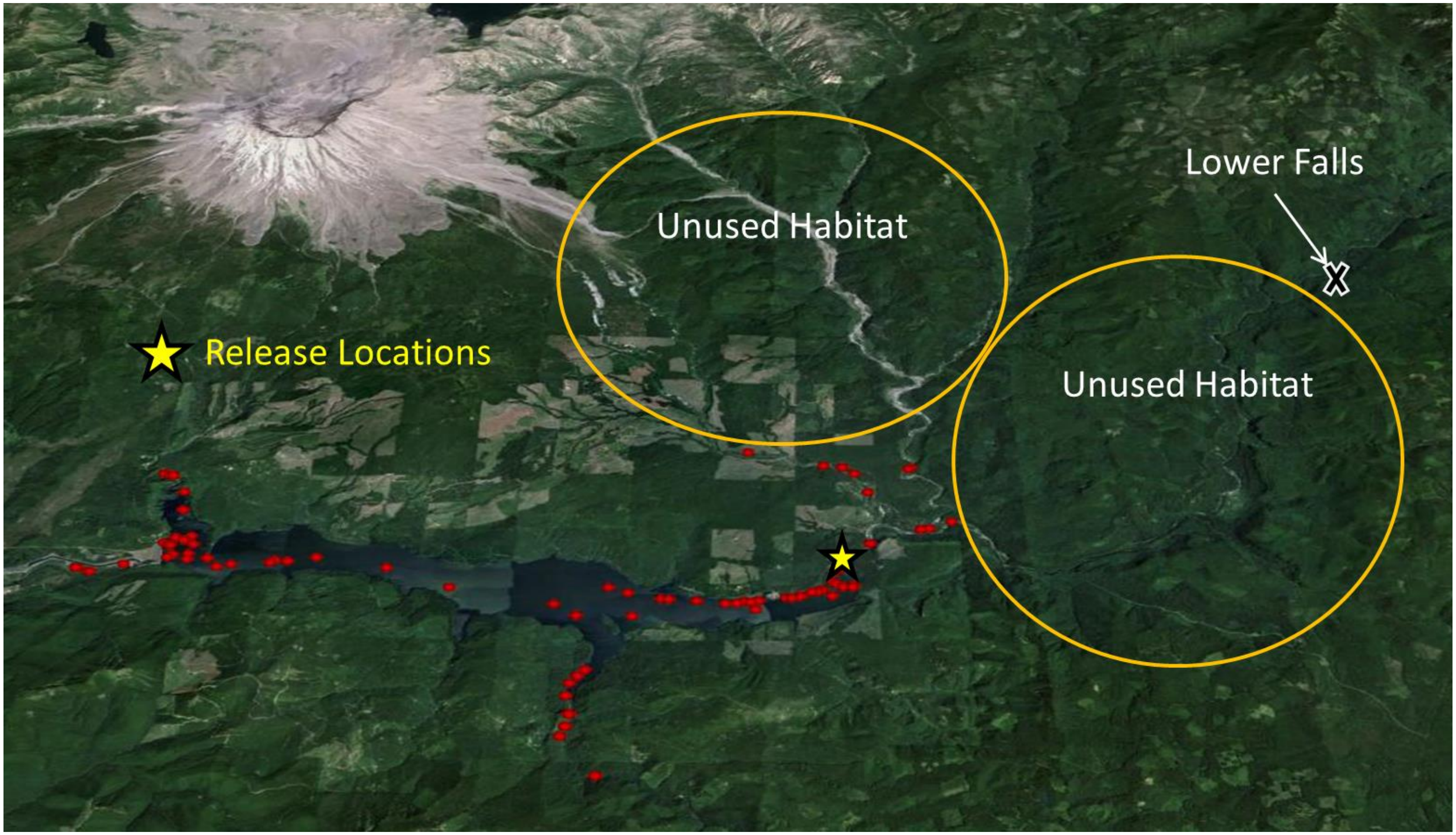

Figure 1. Steelhead detections during the spring of 2014 when all fish were released at either Swift Forest Camp or Eagle Cliff sites. Data combines all four flights.

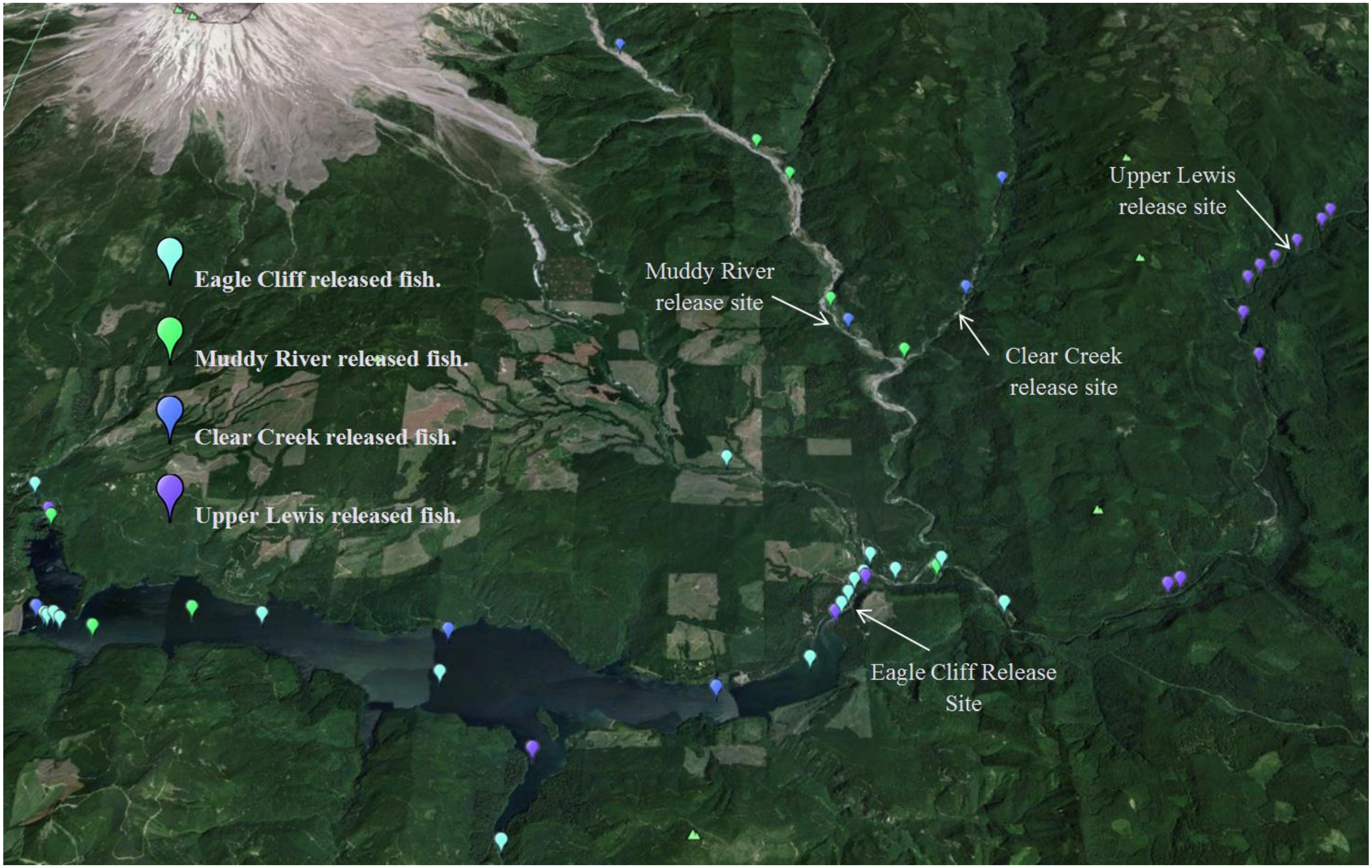

Figure 2. Steelhead detections during the May 1, 2015 flight.

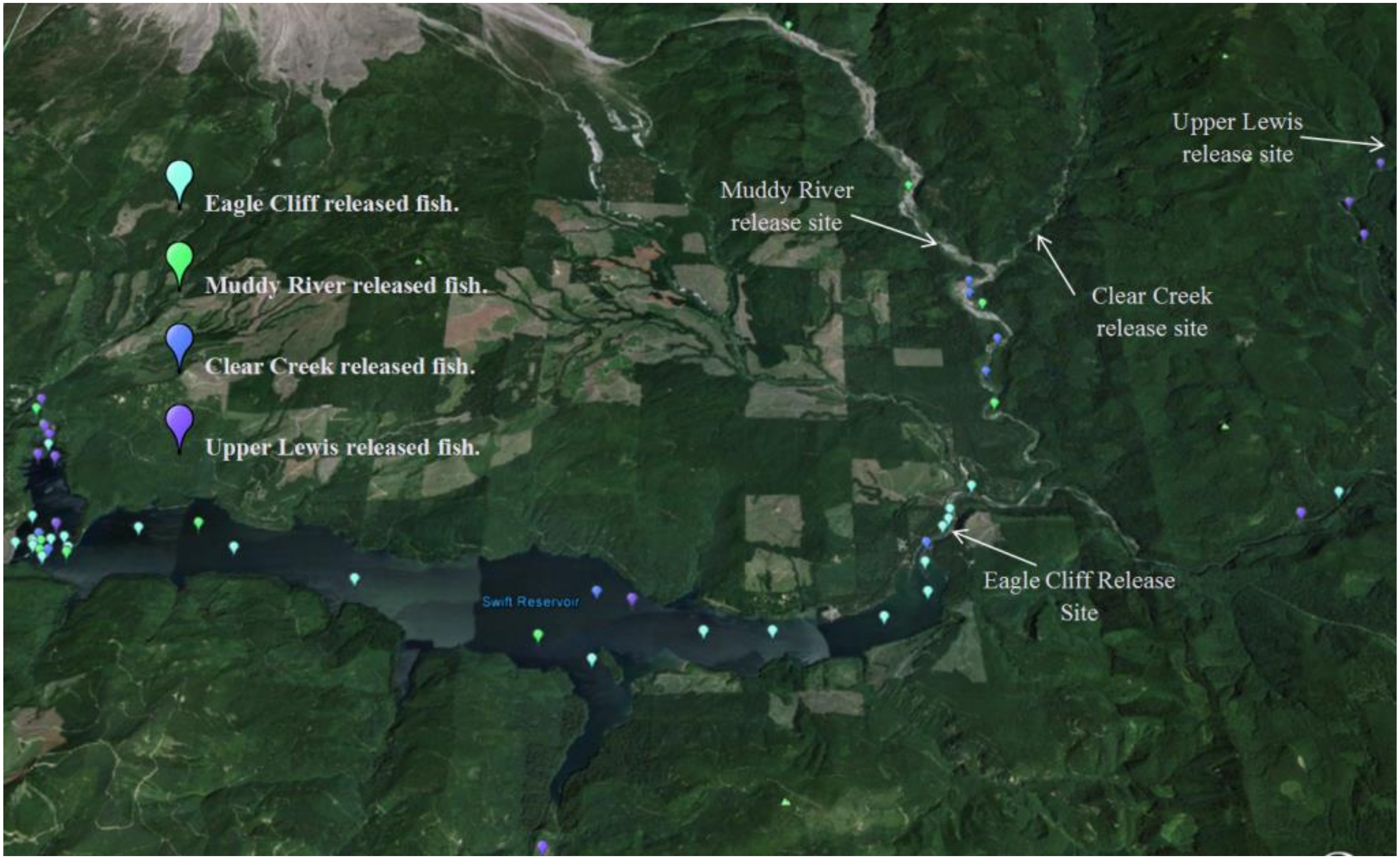

Figure 3. Steelhead detections during the May 28, 2015 flight.

Coho Salmon

Given the results of the seed plant efforts in early 2015 for winter steelhead, PacifiCorp decided to implement a similar program for coho salmon. This was the first year coho released into the upper basin would be radio tagged. Prior to radio tagging events of fall 2015 PacifiCorp developed a radio tagging schedule for seed planted coho. The tagging schedule was intended to proportionally mimic the intensity of a typical run of coho that was historically observed on the Lewis River. In 2015 an abnormally low amount of coho returned to the Lewis River. Consequently, the proposed tagging schedule was difficult to follow as retaining coho for broodstock production was held paramount over seed planting operations. Rather than following the tagging schedule biologist had to adaptively tag fish whenever available, the resulting tagging schedule is shown in Table 2.

Table 2. The proposed and actual radio tagging schedules for both Type-S and Type-N coho.

Period	Number Type-S		Proportion of total Type-S		Number Type-N		Proportion of total Type-N	
	Proposed	**Actual**	*Proposed*	**Actual**	*Proposed*	**Actual**	*Proposed*	**Actual**
Sep 1-15	*9*	**0**	*0.07*	**0**	*0*	**0**	*0*	**0**
Sep 16-30	*23*	**10**	*0.18*	**0.08**	*0*	**0**	*0*	**0**
Oct 1-15	*20*	**8**	*0.15*	**0.06**	*0*	**0**	*0*	**0**
Oct 16-31	*13*	**4**	*0.10*	**0.03**	*13*	**51**	*0.10*	**0.40**
Nov 1-15	*0*	**0**	*0*	**0**	*16*	**25**	*0.12*	**0.19**
Nov 16-30	*0*	**0**	*0*	**0**	*16*	**25**	*0.12*	**0.19**
Dec1-15	*0*	**0**	*0*	**0**	*13*	**6**	*0.1*	**0.05**
Dec 16-31	*0*	**0**	*0*	**0**	*7*	**0**	*0.05*	**0**
Total	*65*	**22**	*0.50*	**0.17**	*65*	**107**	*0.50*	**0.83**

Radio tag tracking surveys were originally intended to be a combination of walking and flight surveys. The walking surveys involved regularly crossing creeks and rivers. Two walking surveys were done in late October with little data gathered. High water events began in November and persisted through December making walking surveys unfeasible. For these reasons radio tag locations were gathered by flight surveys only. Flight surveys were conducted on November 20 and December 30 2015. The November 20 survey was done to evaluate movement patterns occurring dependent of planting location. The December 30th survey was done assuming that a recorded tag location, being late in the spawning season, could be considered as the terminal location of that fish. To assist with this assumption, the majority of tags were put in female coho (97 of 129 or 75%). It is thought that female coho will typically die in close proximity to where they spawned.

November 20 2015 flight data: The data gathered for the November 20 flight is shown in Table 2 and Figure 1. A large portion (43%) of the tagged fish were not detected on the November 20 flight survey. This could be due to signal noise from the helicopter, environmental factors, tag collision, or tagged fish being too deep in the reservoir for detection. The majority of the fish, 38 of 71 that were detected (54%), were generally detected within 1 mile of their release site. Tagged fish released at the Muddy and Upper Lewis River sites appear to display higher degrees of distribution. However, the November 20 flight data should be interpreted with caution as tag release groups at certain sites did not have the same ample time for fish to distribute as other sites. For example, 5 of the 19 fish released at Clear Creek and all (20) of the fish released at Swift Forest Camp were released just two days prior to the November 20 flight survey.

December 30 2015 flight data: The data gathered for the December 30 flight is shown in Table 3 and Figure 2. As with the November 20, a large portion (51%) of the tagged fish were not detected on the December 20 flight survey. Extreme high flow conditions persisted through much of December 2015 and could have washed tagged carcasses into Swift Reservoir to a depth undetectable from a helicopter. Although carcasses may have been washed into Swift Reservoir, the December 30 still shows a wide distribution of tag locations upstream of Swift Reservoir. It appears tags released at seed plant locations (Muddy River, Clear Creek, and Upper Lewis River) had a higher propensity to reside in tributaries above Swift Reservoir than did tags released at normal release locations (Swift Forest Camp and Eagle Cliff). If tags released at seed plant locations are grouped into one set and tags released at normal locations are grouped into a separate set we see that only 18% (9 of 49) of tags released at normal locations resided in tributaries upstream of Swift Reservoir, compared to 54% (43 of 80) of tags released at seed plant locations. No tags on either survey date were detected in the immediate tributaries to Swift Reservoir (e.g. Drift, Swift, and Diamond Creeks).

Similar to winter steelhead, just over 10 percent of the coho released upstream of Swift Reservoir in 2015 were released in the upper basin (456 of 3,754 – 12%); the remained of adults were released at the head of the reservoir at Eagle Cliff (Table 3). These fish were also released evenly among the three sites with 154 adults released at the Muddy River site, 164 at the Clear Creek site, and 138 released in the upper Lewis River. Of these fish, about 20 percent of each release group contained radio tags.

Table 3. Summary of coho salmon releases upstream of Swift Reservior as part of the 2015 seed plant evaluation.

	Eagle Cliff	Upper Watershed				Combined Total
Coho Salmon		Muddy River Bridge	Clear Creek Bridge	Upper Lewis (Crab Creek)	Total	
Untagged	3,249	124	146	106	376	3,625
Radio Tagged	49	30	18	32	80	129
Total	3,298	154	164	138	456	3,754

Table 4. November 20 2015 radio telemetry flight data. Table shows number and percentage of tagged fish locations based on release site.

Observed Location	November 20th 2015 Flight Data — Release Location: Swift Forest Camp		Eagle Cliff		Muddy River		Clear Creek		Upper Lewis	
# Released	**n = 20**		**n = 23**		**n = 30**		**n = 19**		**n = 32**	
Swift Reservoir	6	30%	0	0%	1	3%	0	0%	2	6%
Lower Lewis	3	15%	13	57%	1	3%	0	0%	1	3%
Mid Lewis	0	0%	0	0%	0	0%	0	0%	3	9%
Upper Lewis	0	0%	1	4%	0	0%	0	0%	12	38%
Muddy River	0	0%	0	0%	13	44%	0	0%	0	0%
Clear Creek	0	0%	0	0%	6	20%	9	47%	0	0%
Unaccounted	11	55%	9	39%	9	30%	10	53%	14	44%

Table 5. December 30 2015 radio telemetry flight data. Table shows number and percentage of tagged fish locations based on release site.

Observed Location	December 30th 2015 Flight Data — Release Location: Swift Forest Camp		Eagle Cliff		Muddy River		Clear Creek		Upper Lewis		Total	
# Released	**n = 26**		**n = 23**		**n = 30**		**n = 18**		**n = 32**		**n=129**	
Swift Reservoir	1	4%	2	9%	1	3%	1	6%	2	6%	7	5%
Swift Bypass/Yale	2	8%	1	4%	0	0%	0	0%	1	3%	4	3%
Lower Lewis	0	0%	5	22%	4	13%	1	6%	1	3%	11	9%
Mid Lewis	0	0%	1	4%	0	0%	0	0%	6	19%	7	5%
Upper Lewis	0	0%	0	0%	0	0%	0	0%	7	22%	7	5%
Muddy River	1	4%	1	4%	7	24%	0	0%	1	3%	10	8%
Clear Creek	1	4%	0	0%	6	20%	5	28%	1	3%	13	11%
Clearwater Creek	0	0%	0	0%	4	13%	0	0%	0	0%	4	3%
Unaccounted	21	80%	13	57%	8	27%	11	60%	13	41%	66	51%

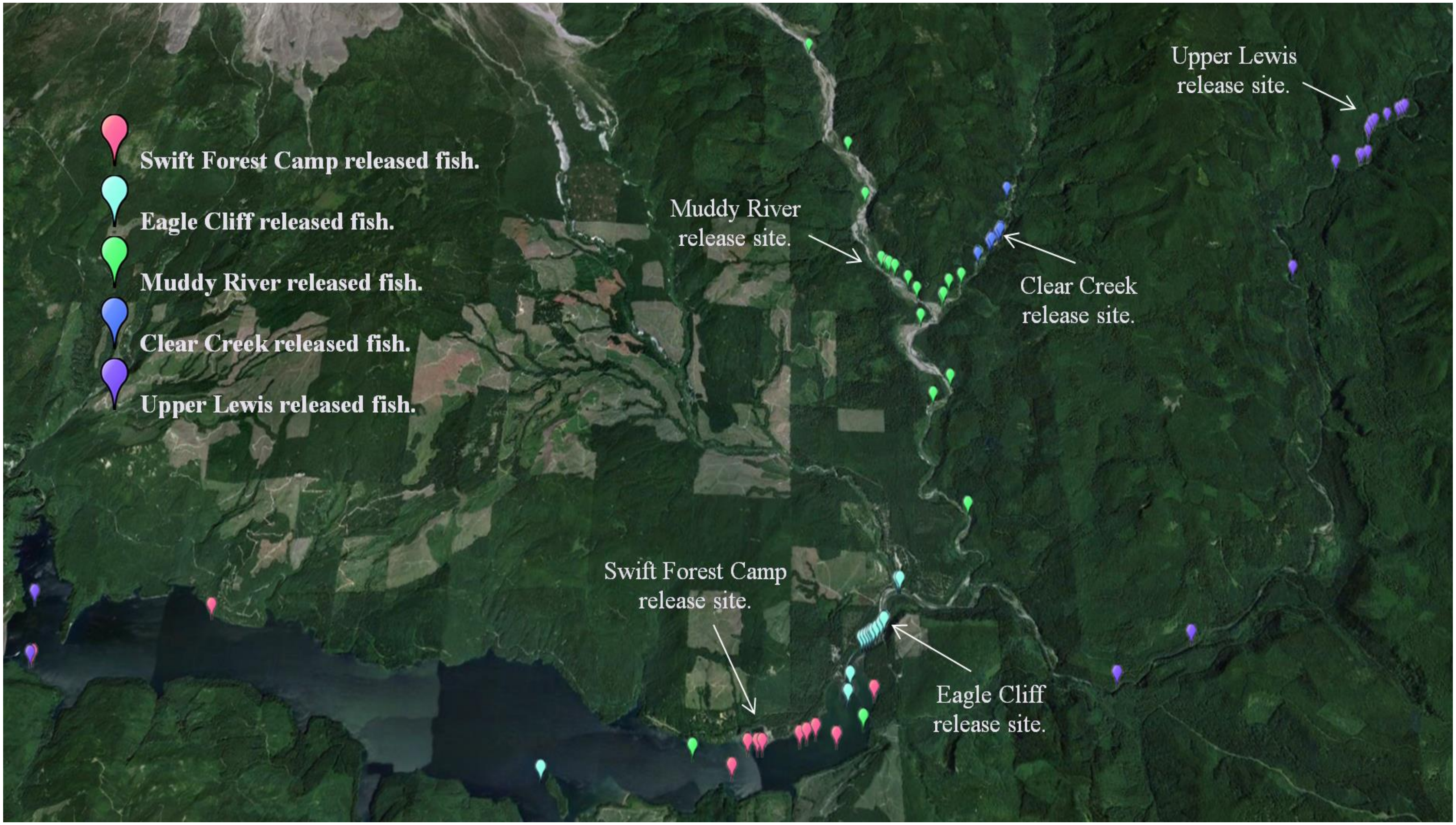

Figure 4. November 20th 2015 flight data. Each icon represents a unique fish.

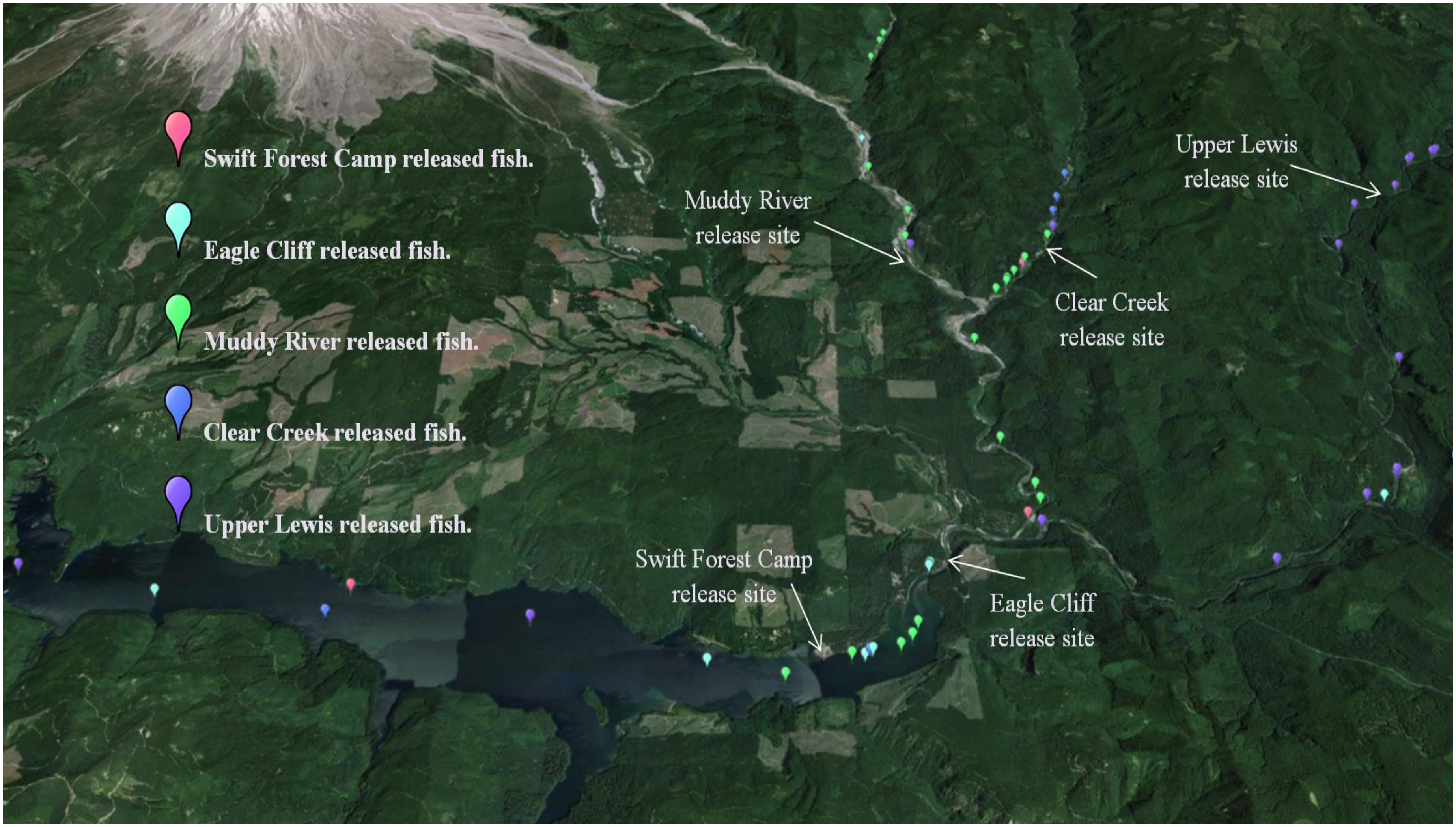

Figure 5. December 30th flight data. Each icon represents a unique fish.

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