Lewis River Bull Trout (*Salvelinus confluentus*)
Annual Operations Report

P8 bull trout - 2019

North Fork Lewis River – 2019

Merwin	*FERC No. 935*
Yale	*FERC No. 2071*
Swift No. 1	*FERC No. 2111*
Swift No. 2	*FERC No. 2213*

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1.0 INTRODUCTION

PacifiCorp and the Public Utility District No. 1 of Cowlitz County, Washington (Cowlitz PUD) (collectively the Utilities) are involved in various bull trout (*Salvelinus confluentus*) and salmonid monitoring programs on the North Fork Lewis River in southwest Washington. These monitoring programs and this Report are designed to meet requirements pursuant to Article 402 in the Utilities' Federal Energy Regulatory Commission (FERC) operating licenses for the Merwin, Yale, Swift No. 1 and Swift No. 2 hydroelectric projects as well as requirements pursuant to sections 4.9, 9.6 and 14.2.6 of the Lewis River Settlement Agreement (SA). This Report and listed monitoring programs also serve to meet requirements contained in the 2006 Biological Opinion issued to PacifiCorp and Cowlitz PUD by the U.S. Fish and Wildlife Service (USFWS).

All activities are developed in consultation with the USFWS. This Report provides results from programs that are either ongoing or have been completed in 2019. For methods and general descriptions of all programs please refer to the Bull Trout Annual Operating Plan for the North Fork Lewis River 2019 that was submitted to the USFWS, members of the Lewis River Aquatic Coordination Committee (ACC) and FERC within the ACC/TCC Annual Report in April 2019.

2.0 STUDY AREA

Bull trout monitoring activities are performed on the North Fork Lewis River and its tributaries upstream of Merwin Dam commencing at river mile (RM) 19.5 and ending at Lower Falls, a complete anadromous and resident fish barrier at RM 72.5. The North Fork Lewis River above Merwin Dam is influenced by three reservoirs created by hydroelectric facilities; 4,000 acre Merwin Reservoir, 3,800 acre Yale Reservoir, and the largest and furthest upstream 4,600 acre Swift Reservoir. From Lower Falls downstream, the North Fork Lewis is free-flowing for approximately 12 miles until the river reaches the head of Swift Reservoir at RM 60. A map of the study area for all programs is shown in Figure 2.0-1.

Bull trout are found in all three reservoirs as well as the Swift No. 2 Power Canal, with the bulk of the population residing in Swift Reservoir. Only three known bull trout spawning streams are found in the study area; Rush and Pine Creeks, tributaries to the North Fork Lewis River upstream of Swift Reservoir, and Cougar Creek a tributary to Yale Reservoir. Recent genetic analysis performed in 2011 identified three distinct local populations residing within the basin; Rush, Pine, and Cougar Creek bull trout (Dehaan and Adams 2011).

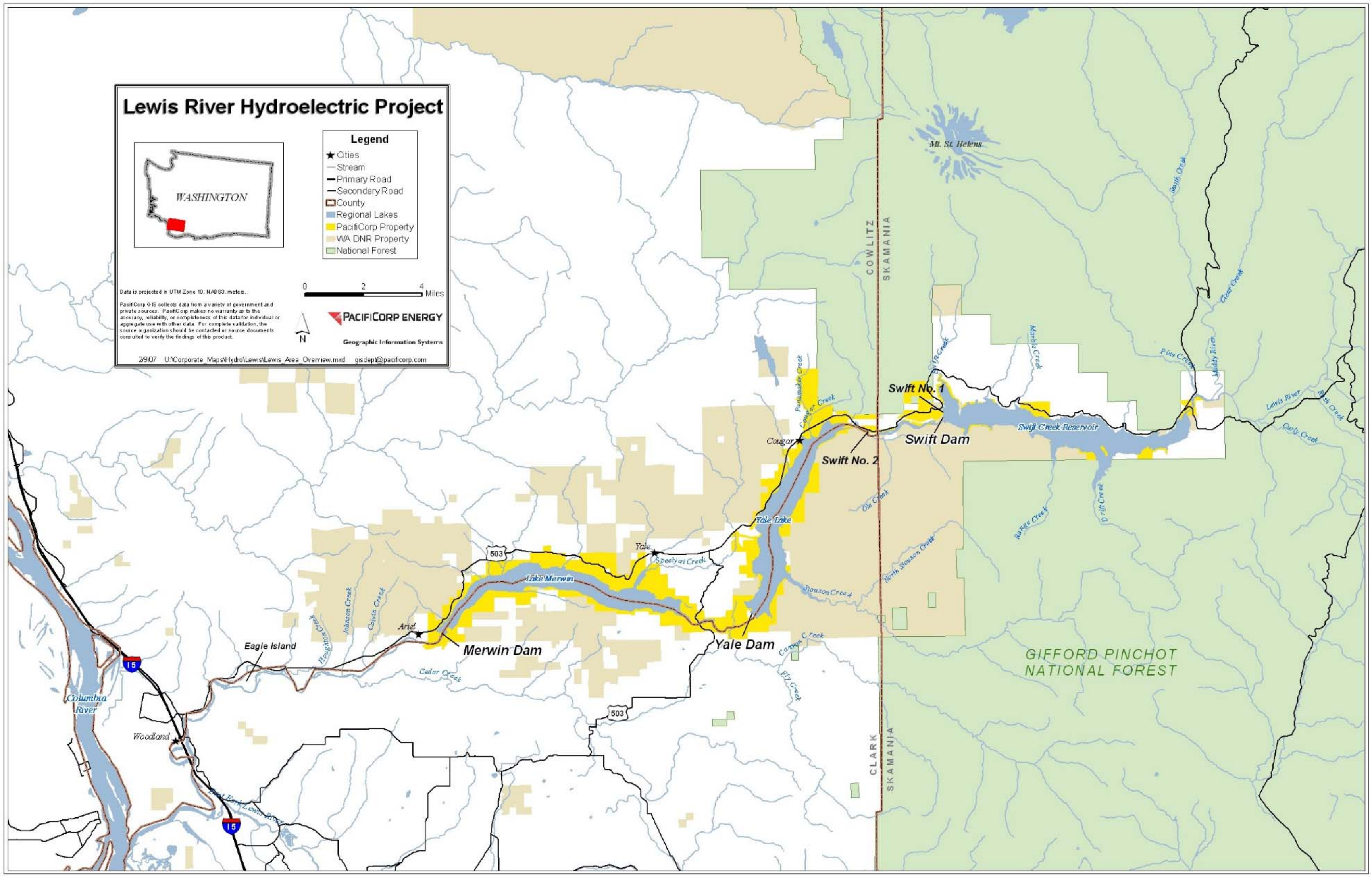

Figure 2.0-1. Map of North Fork Lewis River study area.

3.0 RESULTS FROM 2019 PLANNED ACTIVITIES

During 2019 the Utilities participated in, funded, or initiated six monitoring programs.

1. Swift Reservoir adult migration estimate and ultrasound for sex determination, Survival (S), and juvenile relative abundance surveys
2. Half-duplex Passive Integrated Transponder (PIT) tag antenna arrays in Cougar, Pine, P8, and Rush creeks, as well as Rush Pool.
3. Yale tailrace collection and transport
4. Weir and underwater video camera operation to enumerate bull trout migrants in Cougar Creek
5. Bull trout redd surveys of Cougar, Pine, P8 and Rush creeks with associated observer error study
6. Summer and fall stream temperature monitoring of bull trout pertinent sites upstream of Eagle Cliff

3.1 FERC PROJECT LICENSE ARTICLE 402(B) AND LEWIS RIVER SETTLEMENT AGREEMENT SECTION 9.6 – SWIFT RESERVOIR BULL TROUT POPULATION EVALUATION

3.1.1 ESTIMATE OF THE NUMBER OF STAGING BULL TROUT THAT MIGRATED UP THE NORTH FORK LEWIS RIVER FROM THE HEAD OF SWIFT RESERVOIR

EAGLE CLIFFS BULL TROUT COLLECTION (MARK):

In light of compelling data presented in 2016 that highlighted the numerous handling opportunities that could befall bull trout within Swift and Yale Reservoirs and the negative impact this handling is presumed to have on long-term survival, no capture and marking activities were conducted within Swift Reservoir in 2017 and 2018. The Utilities in Consultation with the USFWS and the Lewis River Bull Trout Recovery Team, which is a group comprised of representatives from the Washington Department of Fish and Wildlife (WDFW), United States Department of Agriculture-Forest Service (USDA-FS), United States Geological Survey (USGS) and USFWS, decided in 2016 to place a two year research handling moratorium on all bull trout monitoring activities in Swift and Yale Reservoirs. 2019 marks the first year since capture and handling activities were completed at Eagle Cliffs since the handling moratorium was put in place in 2016.

Tangle net collection activities at the upper end of Swift Reservoir began on May 10, 2019 and continued through July 10, 2019 (Appendix A). Ten netting days were completed during the period. A total of 105 bull trout were captured in the Eagle Cliffs area of Swift Reservoir. Of these, 76 were tagged with two, three inch Floy® T-bar anchor tags between the last two posterior dorsal fin-rays. Of the remaining 29 captures, 8 did not meet minimum fork length tagging requirements (>450mm), and 21 were current year recaptures (Appendix A).

Of the 84 maiden bull trout captures in 2019, 13 had Floy® or PIT (Passive Integrated Transponder) tags from previous years collection activities, bringing the total capture rate of previously handled fish to 15 percent (13 fish of a total of 84).

New in 2019, double Floy® tagged fish were partitioned into size-classes and tagged accordingly. Each size-class was given a unique colored tag. Researchers wanted to assess if certain sized fish were represented at a greater number on the re-sight grounds than other size-classes. Table 3.1.1-1 gives the size-class breakdown, size-class corresponding unique tag color, and number of fish captured and tagged within each size-class in 2019.

Table 3.1.1-1. Breakdown of size-classes, tag color, and total catch by size-class during Eagle Cliffs bull trout netting in 2019.

Floy color	Total tagged	Percentage of catch
Pink (>650mm)	19	22
Chartreuse (551-650mm)	39	46
White (450-550mm)	18	21
No tag (<450mm)	8	9

To catch Swift Reservoir staging bull trout, tangle nets are typically drifted along the stream bottom by means of a power boat or allowed to passively soak for up to ten minutes in slow-water areas of high bull trout concentration. Tangle nets consist of dyed green 6# monofilament, with depths of approximately 2 meters (m), varying lengths of 25 – 40 m, and varying mesh sizes of 2.5 – 7.5 centimeter (cm) stretch.

Keeping with previously established methods, all Floy® tagged bull trout captures received a second same colored tag (depending on size and correlating size-class color) on the opposite side of the fish. It is anticipated that double-tagging bull trout captures will refine tag-loss estimates and assumptions within the annual migration estimate. Tag retention was evaluated by snorkelers during the recapture surveys performed of the confluence areas of Muddy River and Rush and Pine Creeks. Surveyors paid careful attention to the number of Floy® tags observed in tagged bull trout in order to determine the proportion of bull trout missing a Floy® tag.

All newly captured bull trout received Floy® (if larger than 450mm) and half-duplex (HDX) PIT tags (if greater than 250mm dorsal sinus PIT tag location, if less than 250mm but greater than 120mm, these fish received a full-duplex (FDX) PIT tag, also in the dorsal sinus).

To tag fish with a 23mm HDX tag in the dorsal sinus, a small incision was made with a scalpel just anterior to the dorsal sinus and the tag was then gently pushed toward the caudal peduncle into the sinus (Tranquilli et. al 2003). If a bull trout was recaptured containing a Full Duplex (FDX) PIT tag, these fish were double-tagged with an HDX PIT tag as well. Research conducted by the United States Geological Survey (USGS) in 2007 identified that, when the copper coils of an FDX tag came within 1 centimeter (cm) of the copper coils within an HDX tag, the FDX tag interfered with the HDX tag signal and the HDX tag was not detected by the tag reader (Compton 2007). To alleviate the problem of tag interference between the two tag types in double-tagged bull trout, HDX tags were inserted in the dorsal sinus on the opposite side of the original FDX tagging location. Since 2010, this location has been incorporated with no known interference.

Along with tagging activities, all captured bull trout (minus same year recaptures) were measured to their caudal fork and, when feasible, weighed to the nearest gram. Recording bull trout weights is a data collection activity that was first implemented in 2008 and, along with fork lengths, can be used to assess the condition factor (K-factor) of bull trout residing in Swift Reservoir (Fulton 1902). When available, this biological information will be recorded with each fish captured and individual metrics will be compared with each recapture to evaluate trends in reservoir productivity and how this pertains to bull trout behavior. In order to not skew K-factors, bull trout that had recently fed on large fish (evidenced by a caudal fin protruding from the maw) were not weighed. All true maiden captures were also sampled for genetic material with the intent of genetic analysis being performed at a later date.

Also new in 2019, and when available, Eagle Cliff captured bull trout were scanned with a handheld, portable veterinarian ultrasound machine. The goal of this data collection was to determine the sex ratio of staging pre-spawn bull trout. Additional information, as well as photos and analysis can be found in the memo by Jamie Lamperth of WDFW titled "2019 Eagle Cliff Bull Trout Ultrasound Sampling" located in Appendix B of this Report.

SNORKEL SURVEYS OF THE CONFLUENCE AREAS OF MUDDY RIVER, PINE, AND RUSH CREEKS WITH THE NORTH FORK LEWIS RIVER:

Snorkel surveys of the three confluence areas occurred from July 18 to October 1 for a total of seven surveys (Table 3.1.1-2).

Snorkel surveys of the Muddy, Pine, and Rush confluence areas began upstream of each confluence in the North Fork Lewis and continued downstream until bull trout were no longer observed, usually a distance of approximately 100m. Given the short distance between the mouth of Pine Creek and the Muddy River, this area was also surveyed for bull trout during each confluence survey day (Figure 3.1-1). New in 2019, the Eagle Cliffs area from just above the highway bridge to a quarter mile below it was also snorkeled on six separate occasions during the same confluence areas snorkel survey time-frame (Table 3.1.1-3).

Table 3.1.1-2. 2019 bull trout snorkel survey results for the Muddy River, Rush and Pine Creeks confluence areas of the North Fork Lewis River.*Poor water clarity in Muddy confluence, not surveyed.

				Breakdown of observed marks and fish too small							
Date	**Location**	**Total no. unmarked observed**	**Total no. marked observed**	**<450mm**	**No. white Floy (450-550mm)**	**No. chartreuse Floy (551-650mm)**	**No. pink Floy (>650mm)**	**Total >450mm**	**% of total >450mm with mark**	**Single tags observed**	**Tag loss %**
18-Jul	Pine, Rush, Muddy confluence areas	48	6	5	1	5	0	49	14%	0	0%
29-Jul	Pine, Rush, Muddy confluence areas	50	4	4	1	2	1	50	9%	0	0%
7-Aug	Pine, Rush, Muddy confluence areas	45	7	4	5	2	0	48	17%	0	0%
23-Aug	Pine, Rush, Muddy, confluence areas	32	5	8	3	1	1	31	21%	0	0%
3-Sep	Pine, Rush, Muddy, confluence areas	26	3	4	1	1	1	25	14%	0	0%
23-Sep	Pine, Rush, Muddy* confluence areas	11	2	0	2	0	0	13	15%	0	0%
1-Oct	Pine, Rush, Muddy* confluence areas	19	2	0	0	2	0	21	9%	0	0%
TOTAL	**Pine, Rush, Muddy confluence areas**	**231**	**29**	**25**	**13**	**13**	**3**	**237**	**12%**	**0**	**0%**

*did not survey Muddy due to poor water clarity

Table 3.1.1-2. 2019 bull trout snorkel survey results for the Eagle Cliffs area of the North Fork Lewis River.

				Breakdown of observed marks and fish too small							
Date	Location	Total no. unmarked observed	Total no. marked observed	<450mm	No. white Floy (<450mm)	No. chartreuse Floy (451-650mm)	No. pink Floy (>650mm)	Total >450mm	% of total >450mm with mark	Single tags observed	Tag loss %
18-Jul	Eagle Cliff	2	5	0	2	1	2	7	71%	0	0%
7-Aug	Eagle Cliff	3	5	0	2	1	2	8	62%	1	20%
23-Aug	Eagle Cliff	3	2	0	0	1	1	5	66%	0	0%
3-Sep	Eagle Cliff	5	1	0	1	0	0	6	20%	0	0%
23-Sep	Eagle Cliff	16	4	1	0	2	2	19	21%	0	0%
1-Oct	Eagle Cliff	20	4	0	1	1	2	24	16%	0	0%
TOTAL	**Eagle Cliff**	**49**	**21**	**1**	**6**	**6**	**9**	**69**	**30%**		

Historically, Swift Reservoir bull trout migration data was analyzed and a migration estimate obtained using program NOREMARK®. NOREMARK® computes an estimate of population size for a closed population with a known number of marked animals and one or more re-sighting events (White 1996). Program NOREMARK® utilizes four mark-resight estimators of population abundance; for all four estimators, the marked fish are assumed to have been drawn randomly from the population. That is, the marked fish are a representative sample of the population (White 1996). Given discussions within the LRBTRT concerning known violation of key assumptions within the NOREMARK® estimate for this population, the 2019 NOREMARK® estimate was put on hold at this time. Discussions concerning the future of this methodology are ongoing, and if deemed necessary after completion of said discussions the 2019 estimate can be generated and reported at a later date.

Figure 3.1-1. Snorkel sites (for recapture) associated with the Swift Reservoir bull trout migration estimate

3.1.2 Evaluation of Survival (S) of Swift Bull Trout Populations through the use of PIT tag Detections

Further analysis of Survival (S) of the 2019 Swift Reservoir bull trout population can be found in the Memo: Patterns of bull trout *Salvelinus confluentus* demography, life-history and abundance in the North Fork Lewis River—2019 Annual Report, located in Appendix C of this Report.

3.1.3 Evaluation of the Swift Reservoir Bull Trout Effective Population (Ne)

Estimation of effective population size can provide information on the level of genetic variation within a population and how fast genetic variation may be lost through genetic drift (Luikart et al. 2010). The effective population size represents the size of an ideal population that would have the same rate of loss of genetic variation as the observed population (Wright 1931). Although general guidelines for minimum effective population sizes have been suggested (e.g., the 50/500 rule; Franklin 1980), evaluating temporal trends in estimates of N_e are often more useful than determining whether a population meets some minimum threshold number. For example, a population that shows a large decrease in N_e over the course of one or two generations could be experiencing a genetic bottleneck or decline in abundance. Alternatively, an increase in effective size following implementation of new management actions could be one indication that the population is responding positively (Pers. Comm. Pat DeHaan, USFWS).

To evaluate N_e, genetic tissue from juvenile bull trout from the same cohort (presumably age 0) was attained from utilized spawning tributaries (Rush, Pine, and Cougar Creeks, Figures 3.1.3-1 to 3.1.3-3). In order to get maximum genetic representation, fish captures were spatially balanced as much as practical along the length of usable habitat within each stream. Surveys were timed such to ensure capture of prior year's brood fish, with less than 70 mm fork length the cut-off used to determine age 0 bull trout (Fraley/Shepard 1989).

Activities pursuant to the possible annual assessment of an Effective Population (N_e) size of bull trout within Swift Reservoir were performed in 2019. N_e is performed as part of the bull trout demographic characteristics evaluation objective within Section 17 of the Monitoring and Evaluation Plan. In 2019, per the direction of the LRBTRT, no lab analysis of gathered genetic tissue for genetic estimation of spawner abundance for eventual Effective Population estimation was performed. Though no lab analysis was scheduled for 2019, juvenile surveys were still conducted in order to assess relative abundance of bull trout and reintroduced anadromous juvenile fish species and their associated interaction. Being fish were in hand, tissue samples were also taken of all captured age 0 bull trout for possible future N_e analysis.

Areas within Rush Creek were sampled with a backpack electrofishing unit on July 8 (Figure 3.1.3-1). In all, 34 juvenile bull trout were captured and sampled for genetic tissue. 33 of the captures were less than 70 mm fork length and assumed to be of 2018 brood year origin. The length range of the age 0 bull trout was 36 mm – 50 mm, with an average fork length of 43 mm.

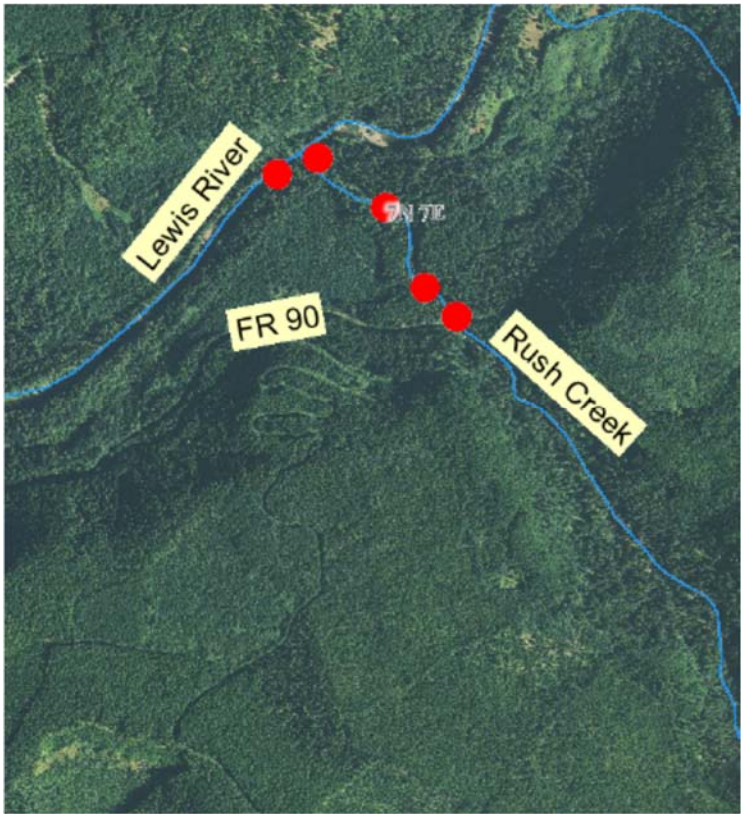

Figure 3.1.3-1. Electrofishing sites within Rush Creek during 2019 juvenile bull trout collection.

Areas within Pine Creek and tributary P8 were sampled for juvenile bull trout with a backpack electrofisher on June 18 and July 2 (Figure 3.1.3-2). In all, 91 juvenile bull trout were captured from within P8 ranging from 39 – 57 mm fork length with an average fork length of 46 mm. 45 juvenile bull trout were captured from within areas of Pine Creek mainstem ranging in size from 51 – 68 mm fork length with an average of 60 mm.

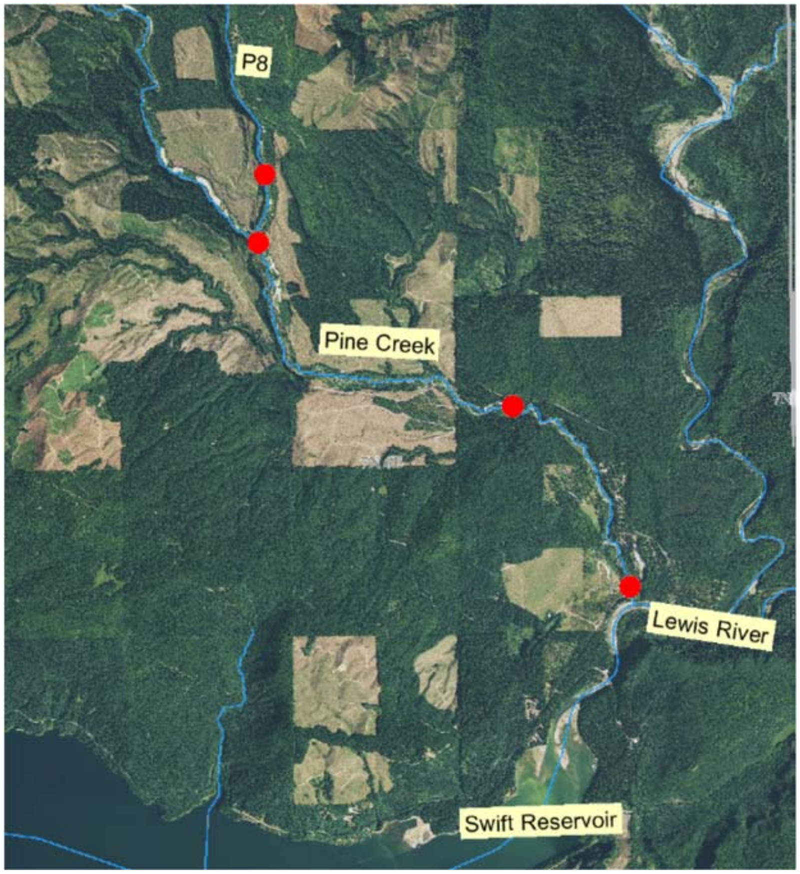

Figure 3.1.3-2. Electrofishing sites within the Pine Creek system during 2019 juvenile bull trout collection.

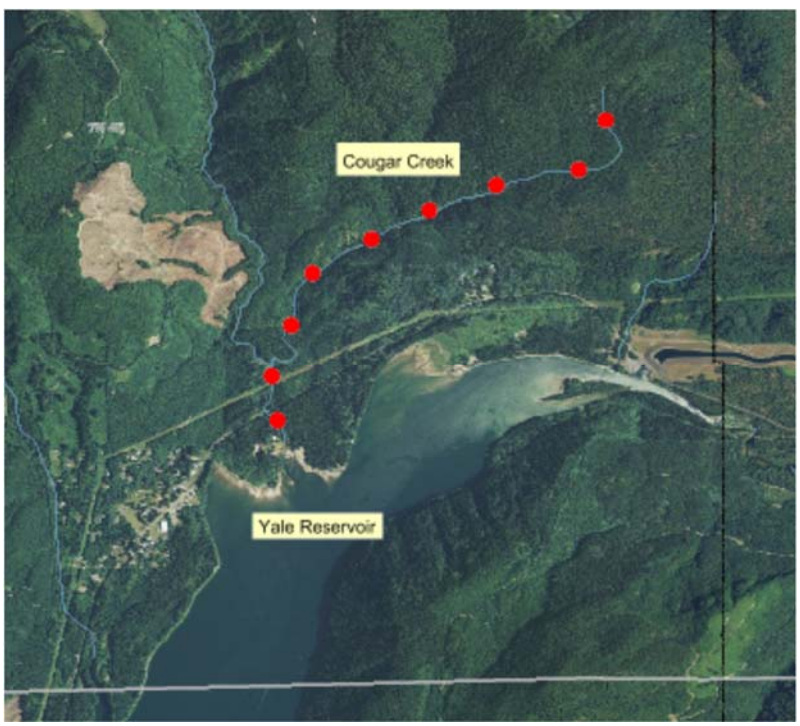

Figure 3.1.3-3. Electrofishing sites within the Cougar Creek system during 2019 juvenile bull trout collection.

Areas within Cougar Creek were sampled with a backpack electrofishing unit on June 19 (Figure 3.1.3-3). In all, 53 juvenile bull trout were captured and sampled for genetic tissue. The length range of captured age 0 bull trout was 37 – 65 mm, with an average fork length of 51 mm (Figure 3.1.3-4).

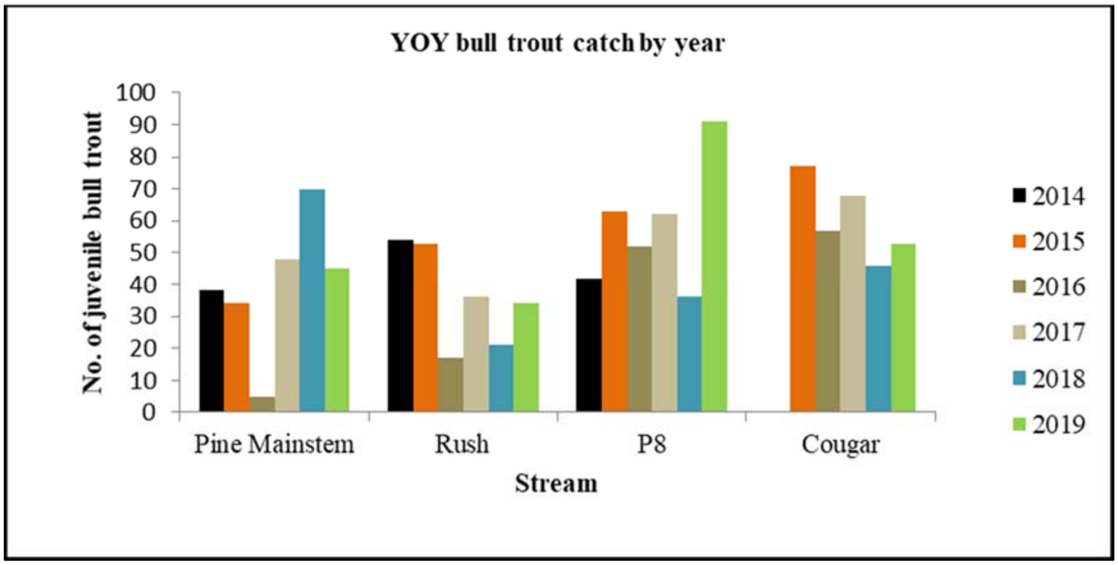

Figure 3.1.3-4. Trend bull trout juvenile catch during stream electrofishing surveys. Cougar Creek was not surveyed in 2014.

As part of monitoring and evaluation of anadromous reintroduction efforts, a rotary cone screw trap was also operated at the head of Swift Reservoir in the area of the Eagle Cliff pool in 2019. This single 2.4 m diameter cone screw trap was operated from March 13 – June 30 in 2019. Emigrating bull trout juveniles were inadvertently captured during screw trap operations, data analysis of bull trout capture data is provided in Table 3.1.3-1.

Table 3.1.3-1. Historical Eagle Cliff screw trap bull trout captures and data analysis.

Year	Location	Trap operation dates	Range of capture dates	Number captured	Length (mm) Median	SD	Mean	Min	Max
2001	Eagle Cliff	5/18-6/28	5/19-6/28	83	155	23	151	125	210
2013	Eagle Cliff	3/28-6/30	3/29-6/21	52	133	24	126	98	220
2014	Eagle Cliff	3/18-7/2	3/26-6/4	16	137	46	121	77	265
2015	Eagle Cliff	3/25-6/1	4/12-5/11	9	131	30	120	103	180
2016	Eagle Cliff	3/24-6/30	4/4-6/16	4	139	18	141	115	157
2017	Eagle Cliff	4/20-7/30	5/10 - 6/27	6	160	26	157	130	200
2018	Eagle Cliff	3/13-6/30	3/20-6/24	19	120	37	106	45	149
2019	Eagle Cliff	3/15-7/19	3/15-7/13	55	125	58	110	25	217

Monitoring and Evaluation Plan Objective 18; juvenile bull trout/coho interactions

Numerous young of the year (YOY) coho were also found to be occupying the same habitat as YOY bull trout in the Rush and Pine creek systems above Swift Reservoir and as such were inadvertently captured during electrofishing surveys. These coho were quantified and measured to their caudal fork as part of activities pursuant to Objective 18 within the M&E Plan, evaluation of resident/anadromous fish interactions. Juvenile coho captured within the Rush and Pine creek drainages were progeny of adults released above Swift Reservoir as part of the ongoing anadromous reintroduction program.

Coho YOY dominated the catch in all areas electrofished within the mainstem of Pine Creek; few coho were encountered within Rush Creek, and no coho were encountered or observed within P8 or Cougar Creek in 2019. Pine Creek mainstem had a total coho catch of 167, and Rush a total coho catch of 12. There was a paucity of other species encountered, with the occasional steelhead (*Oncorhynchus mykiss*) or coastal cutthroat trout (*Oncorhynchus clarkii*). The Pine Creek mainstem coho catch corresponds to a YOY bull trout catch of 45 and a difference in overall collected of 73 percent more YOY coho. Far fewer coho YOY were encountered in Rush Creek, where the coho catch represented only 35 percent of the total (Figure 3.1.3-5).

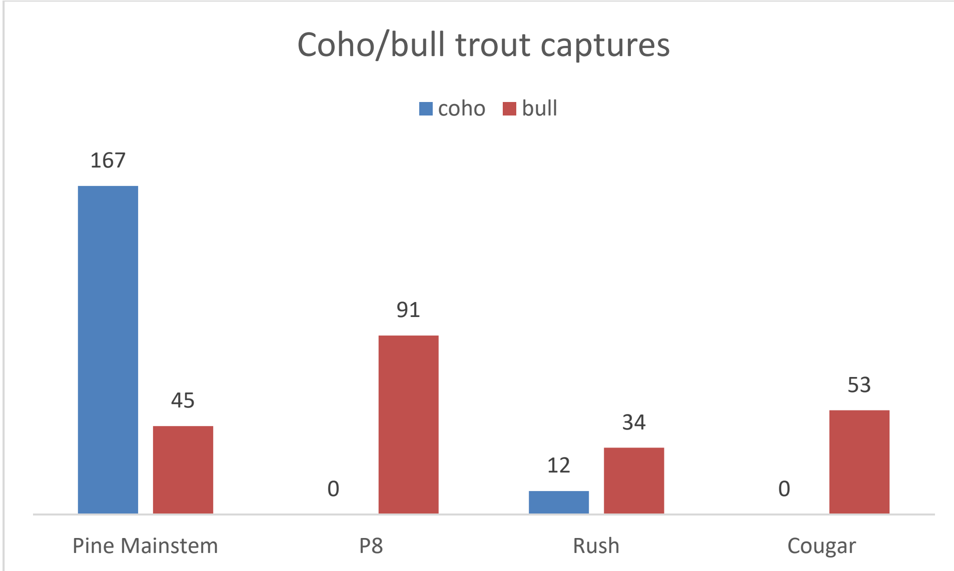

Figure 3.1.3-5. Coho and bull trout juvenile capture numbers by stream of capture in 2019.

Size of coho YOY in terms of average fork length was also assessed and compared to that of YOY bull trout occupying the same habitat within the Pine and Rush creek systems. Bull trout YOY were marginally larger than coho YOY in Pine Creek mainstem, while coho YOY in Rush Creek were slightly larger than encountered bull trout YOY (Figure 3.1.3-6).

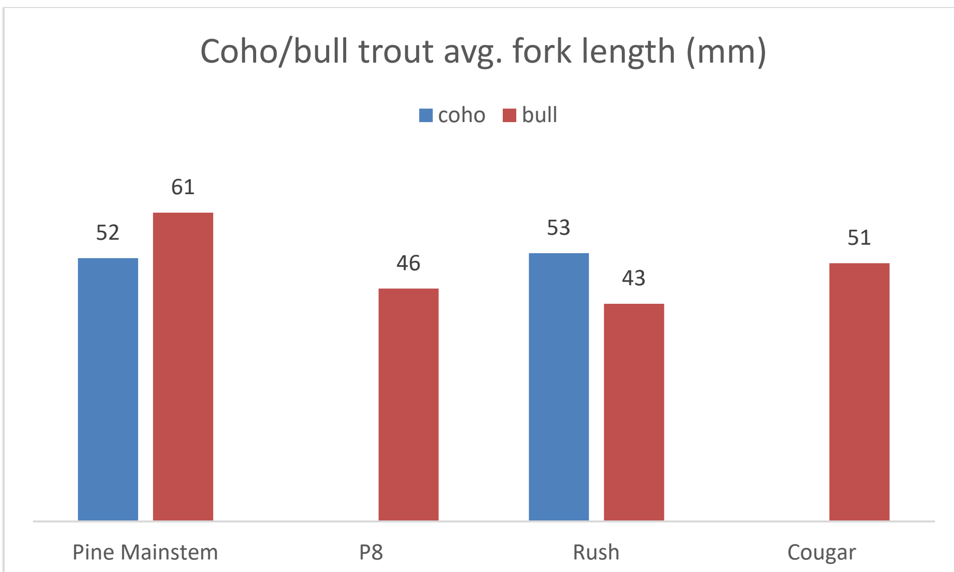

Figure 3.1.3-6. Juvenile coho and bull trout captures average fork length observed in 2019.

3.2 Lewis River Passive Integrated Transponder Tag Antenna Arrays

3.2.1 Evaluation of Swift and Yale Reservoir Bull Trout through the use of Stream-Width Half-Duplex Passive Integrated Transponder Antennas in Rush, P8, Pine and Cougar Creeks

Stream-width half-duplex PIT tag antennas were placed in Pine, P8, Rush, and Cougar creeks in the late summer through fall time period (Figures 3.2.1-1 and 3.2.1-2). The remote PIT antenna array in Pine Creek was stream-spanning and located in a shallow riffle approximately 300 m upstream from the confluence with the North Fork Lewis River. The Rush Creek antenna array was located in a narrow shoot approximately 100 m upstream from the confluence with the North Fork Lewis River. The array in P8 was stream-spanning and located approximately 150 m upstream from the confluence with Pine Creek. The array in Cougar Creek was also stream spanning and located approximately 200 m upstream from its confluence with Yale Reservoir. The antenna located in Rush Creek Pool was a 1.7 meter diameter submersible proximity antenna manufactured by Biomark®. The submersible antenna was anchored to the stream bottom within the thalweg of the Rush Creek Pool area of the North Fork Lewis River.

In 2019, all stream-spanning antennas were a single loop consisting of 10-gauge copper wire looped along the stream bottom starting from one stream bank, spanning the entire wetted-width of the stream along the stream bottom to the opposite bank, and then along the stream surface back to the original starting point creating a large swim thru rectangle shape. Each antenna wire or cable was connected to an Oregon RFID RI-Acc-008B antenna tuner unit. Copper twinax was then run from each tuner unit to an Oregon RFID RI-RFM-008 reader board and data logger. The antenna reader board and data logger were located in secure Joboxes near the stream bank and were powered by two large 12 volt deep-cycle marine batteries run in parallel. Batteries at the Pine Creek site were charged via three 120w solar panels hooked to a charge controller. The submersible antenna within Rush Creek Pool was completely self-contained with no leads or wires connected to the stream bank. The antenna was powered by lithium-ion batteries connected to the antenna itself and allowed for one month of continuous deployment.

Figure 3.2.1-1. Half-duplex stream-width PIT tag antenna locations in the Upper Lewis River Basin – 2019.

Figure 3.2.1-2. Half-duplex stream-width PIT tag antenna locations in the Yale Reservoir Basin – 2019.

In 2019 there were 54 unique PIT tag detections at stationary antennae in tributaries to Yale and Swift Reservoirs. The breakdown of detections by stream, as well as timing and spawning frequency is as follows:

Cougar Creek

The PIT antenna at the mouth of Cougar Creek was in operation from August 2 – October 22, at which time the antenna loop was destroyed by a high water event. This antenna experienced almost constant interference that researchers could not fully resolve during the period of operation. As such, it is unknown how often this antenna while in operation was actually detecting tags. During the operational period three total detections were recorded. Due to the aforementioned logistical problems associated with this antenna at this site, this is considered the minimum number of PIT tagged bull trout available that were interrogated in Cougar Creek in 2019 (Figure 3.2.1-3).

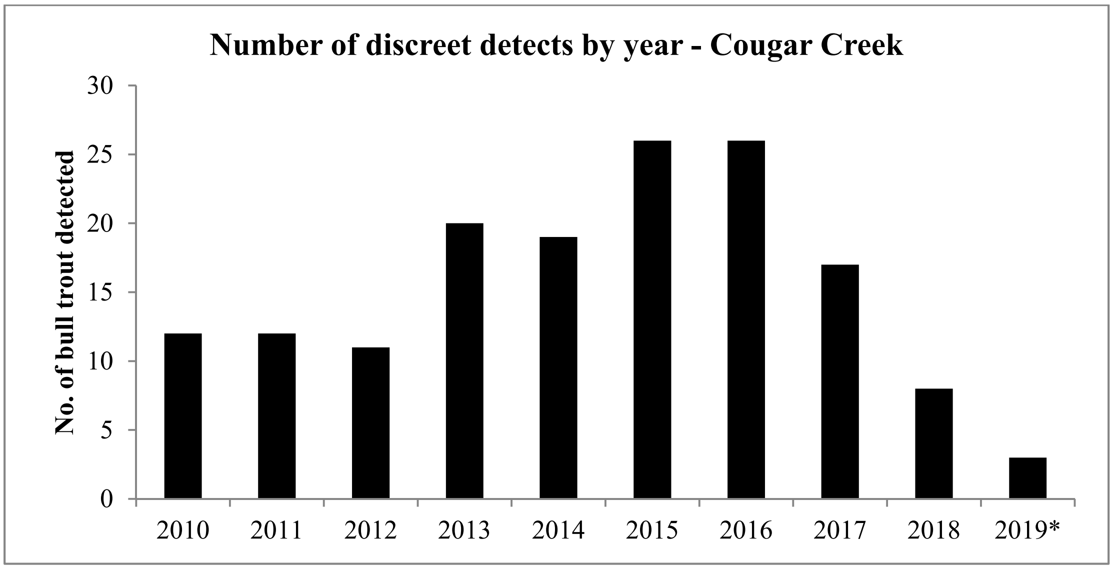

Figure 3.2.1-3. Historical PIT detections by year in Cougar Creek. *antenna experienced technical and or logistical problems, incomplete dataset.

Pine Creek

The PIT antenna at the mouth of Pine Creek was in operation from July 29 to September 7, when the antenna unexpectedly stopped reading tags. Researchers tried to re-tune the antenna to no avail, and the antenna at this location was turned off permanently on September 7. No working antenna was at this site for three weeks, from September 7 – 23. In order to record the back half of the post-spawn migration, researchers decided to pull the submersible antenna from the Rush Pool location and deploy it at the mouth of Pine Creek. The submersible PIT antenna was deployed, powered, and reading tags at the mouth of Pine Creek from September 24 – October 24. The submersible antenna was pulled from the mouth of Pine Creek on October 24. 47 detections were experienced during the two periods of operation resulting in 24 discrete bull trout tags. Given the loss of operation during the middle of the upstream migrational period, no distinct migration pattern was analyzed for this antenna site in 2019.

The number of historical discrete detects at the Pine Creek site is expressed in Figure 3.2.1-4. Due to antenna loss during peak migration, the number recorded in 2019 is considered incomplete and the minimum available for detection. 16 of the 24 bull trout that were detected moving past this antenna in 2019 were correspondingly only detected at this site. The other eight interrogations were also detected upstream of this location at the PIT antenna at the mouth of P8. Of the 16 bull trout that were only detected at the Pine Creek mouht PIT antenna location, 30 percent showed evidence of consecutive year migrations (2, 3, 4, 5 or 6 year consecutive), and 70 percent were maiden detections.

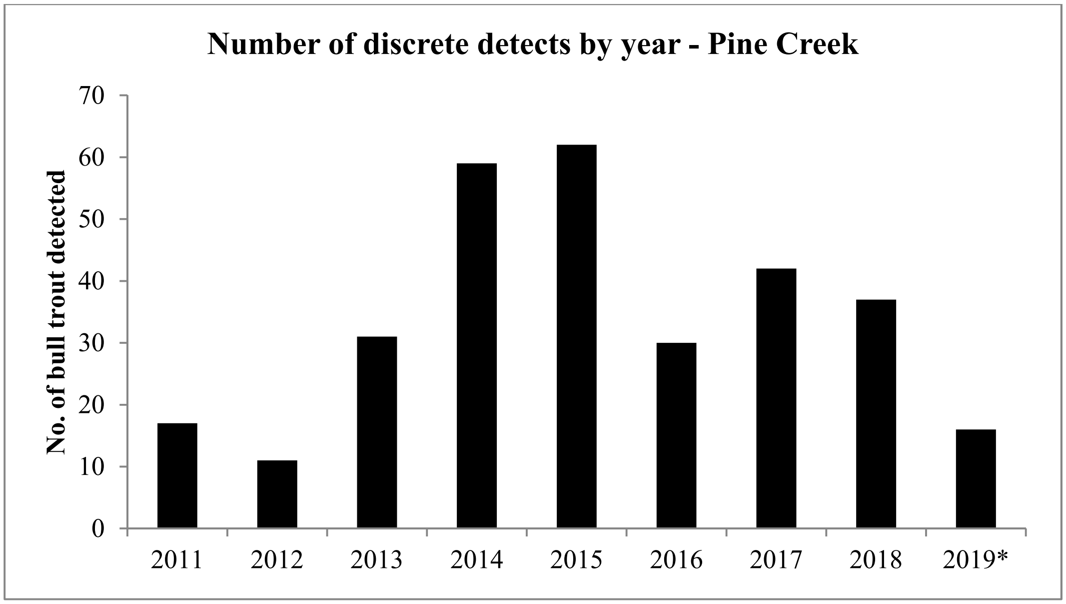

Figure 3.2.1-4. Historical PIT detections observed in Pine Creek by year. *incomplete dataset, minimum number available for detection.

Pine Creek Tributary P8

The PIT antenna at the mouth of Pine Creek tributary P8 was in operation from July 30 to October 21. Power loss was experienced for a total of eight days, August 23-28 and October 3-7, both due to a drained battery. 2586 detections were recorded during the period of operation resulting in 31 discrete bull trout tags. Of these 31 discreet detects, 23 were detected only at the P8 antenna, the other seven discreet detects were detected at both the Pine Creek mouth and P8 antennas. Peak migration was observed on September 21 when ten bull trout volitionally swam past the P8 antenna (Figure 3.2.1-5).

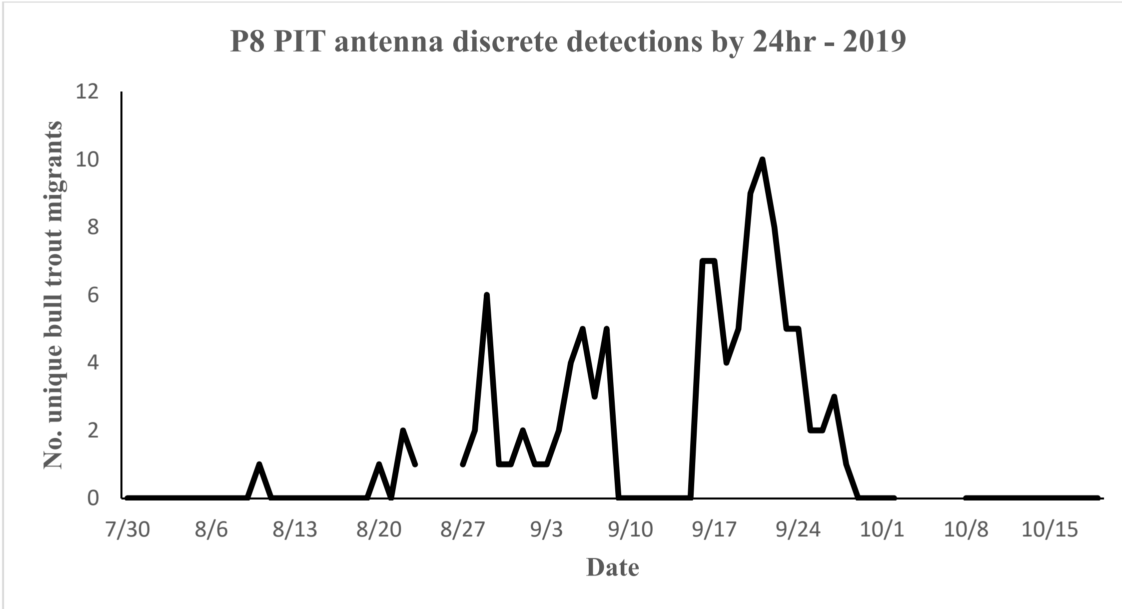

Figure 3.2.1-5. PIT detections by 24 hour period in P8 during 2019.

Historical discrete detections at this site are expressed in Figure 3.2.1-6. Of the 23 bull trout detected only at the P8 antenna in 2019, 36 percent showed evidence of consecutive year migrations to this site, while 64 percent were maiden detections.

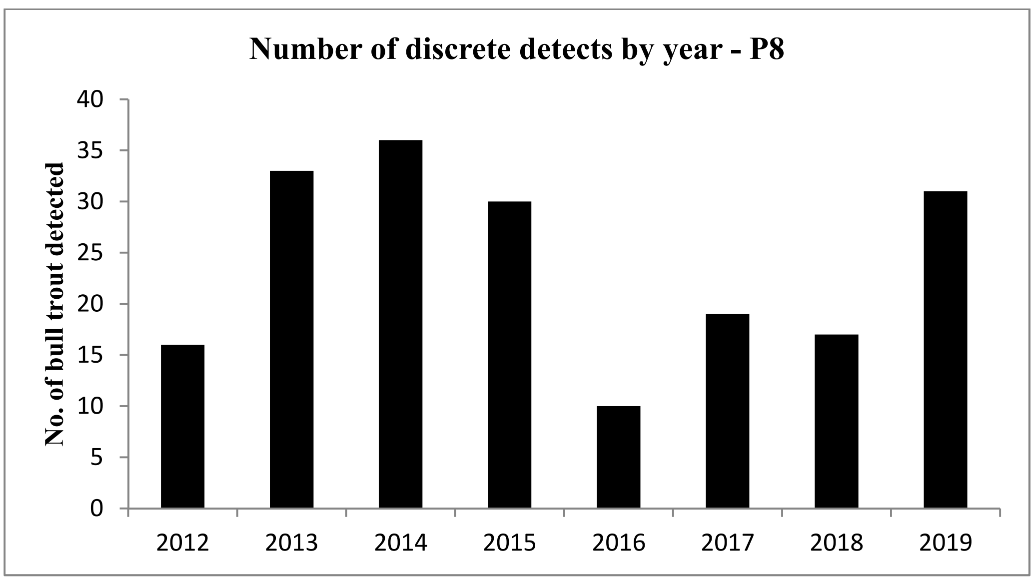

Figure 3.2.1-6. Historical PIT detections by year in P8.

Rush Creek

The PIT antenna near the mouth of Rush Creek was in operation from August 10 - October 28 at which time the antenna was destroyed by a high flow event. Power loss was experienced for three days, from September 20-23, due to a drained battery. 16 detections were recorded during the period of operation resulting in five discrete bull trout tags. Peak migration of two bull trout was observed on August 6 (Figure 3.2.1-7).

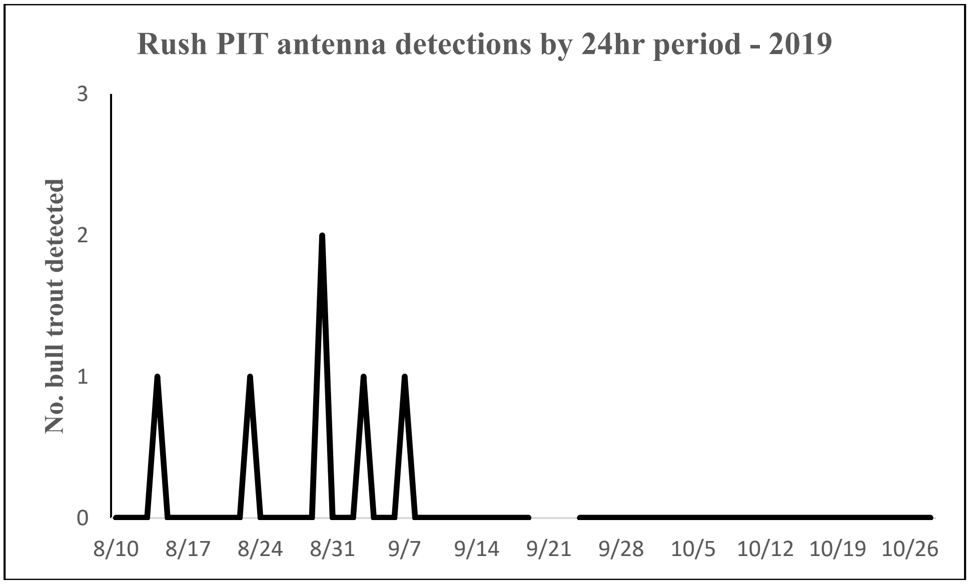

Figure 3.2.1-7. PIT detections by date observed in Rush Creek in 2019.

Historical discrete detections at this site are expressed in Figure 3.2.1-8. Of the five bull trout detected at the Rush Creek antenna location in 2019, 60 percent showed evidence of consecutive year migrations, and 40 percent were maiden detections.

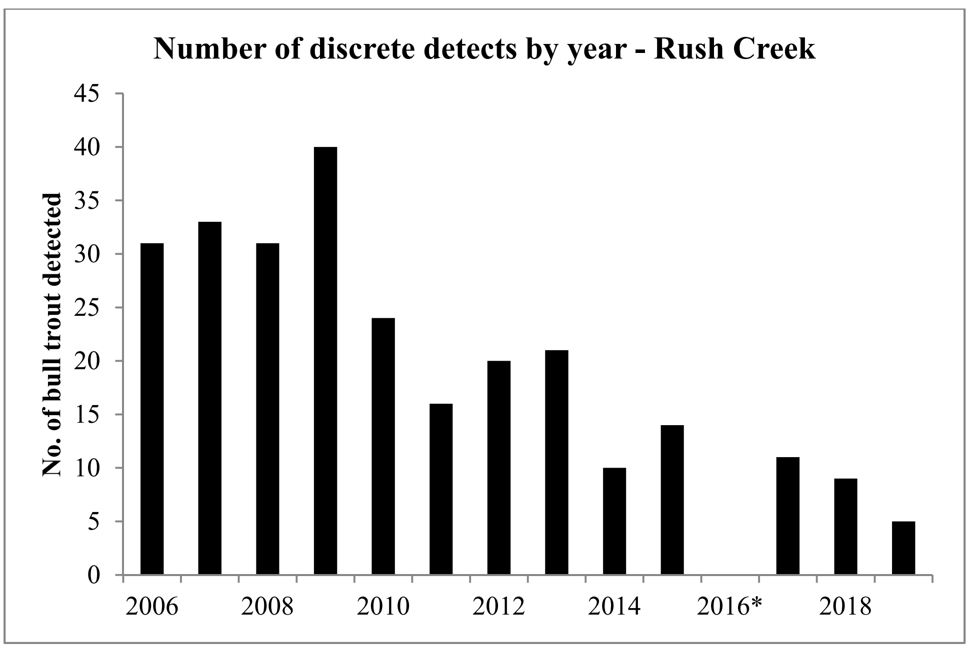

Figure 3.2.1-8. Historical PIT detections by year in Rush Creek. *logistical and technical problems prohibited antenna deployment.

Rush Creek Pool

The antenna located in Rush Creek Pool consisted of a 1.7 meter diameter submersible proximity antenna manufactured by Biomark®. The submersible antenna was anchored to the stream bottom within the thalweg of the Rush Creek Pool area of the North Fork Lewis River on July 23, and ran continuous with no loss of power until it was pulled from the stream on September 24. During the period of operation thousands of detections were recorded on this antenna. Due to the holding behavior of bull trout in the area of deployment, many redundant interrogations were experienced. After analysis of the data, the interrogations were found to be from 13 discreet bull trout PIT tags.

Of the 13 unique bull trout interrogated at the Rush Creek Pool PIT antenna site, five were subsequently later detected moving pass the Rush Creek PIT antenna, the other eight bull trout were not detected at any other PIT antenna station in 2019. Bull trout were detected on 52 of the 62 days that this antenna was deployed at this location. All of the days of no detects occurred after September 7.

All Detection Analysis

Spawning frequency for the last five years from all detections at all streams combined was analyzed and is expressed in Figure 3.2.1-8. It is noted that a shift from maiden detection to multiple year detection is observed from 2015 to 2019, this shift is expected to become more pronounced as additional data is collected and individual fish are followed through their lifecycle.

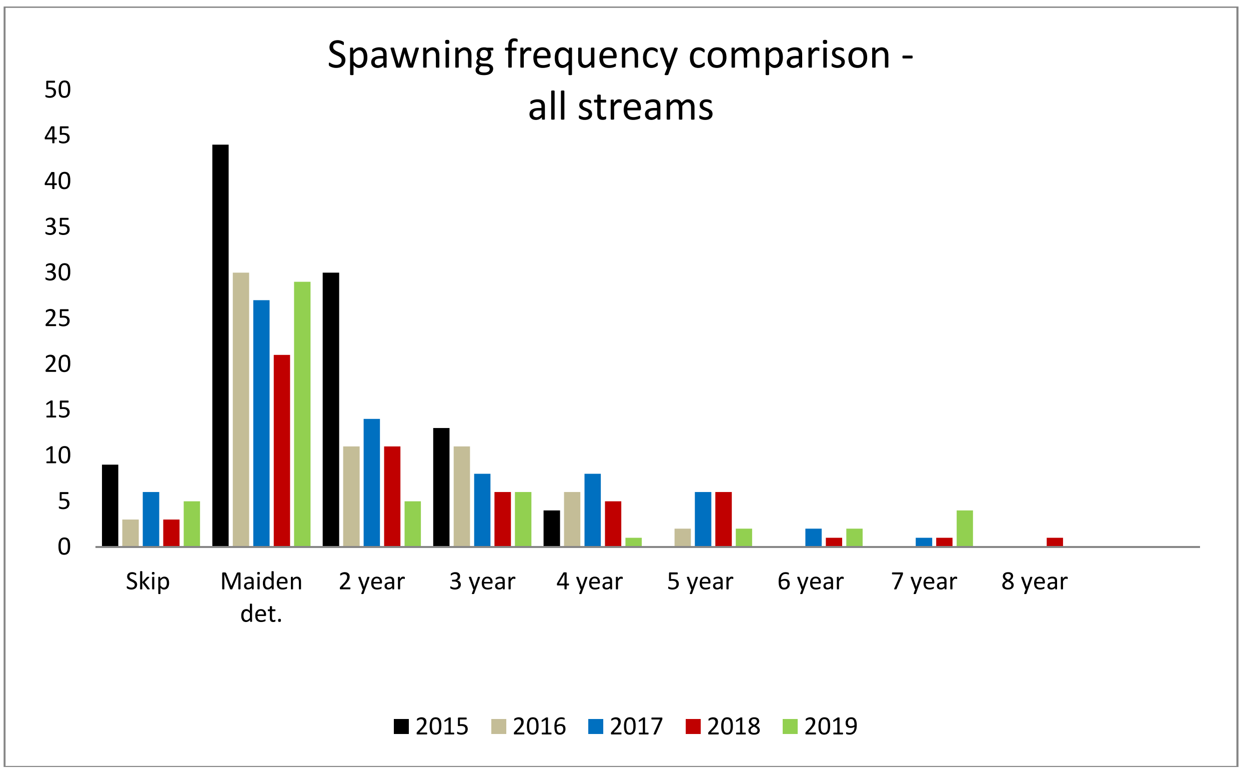

Figure 3.2.1-8. Spawning frequency of all detections for the years 2015-2019.

Figure 3.2.1-9 compares annual detections from all sites for all years on record.

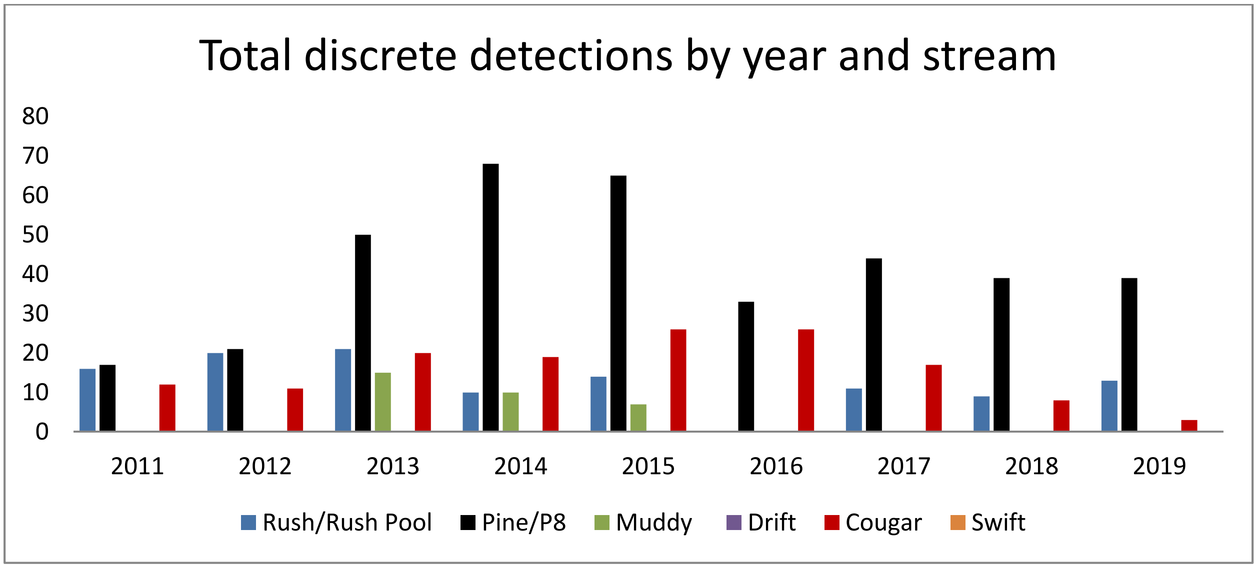

Figure 3.2.1-9. Total detections by year from all sites from years 2011-2019.

2019 Eagle Cliff capture and subsequent PIT antenna interrogation analysis

Of the 84 maiden captures handled during Eagle Cliffs collection activities during 2019, 37 (44%) were later detected moving past an upstream PIT antenna. Table 3.2.1-1 details 2019 size-class representation during capture at Eagle Cliffs, snorkeling of confluence areas during recapture activities, and migration past a fixed PIT antenna station upstream of Eagle Cliffs in either the Pine or Rush creek basins. Of interest is the apparent under-representation of the larger size-class fish (>650mm) during snorkel surveys of the confluence areas, which is then corrected when compared to stream PIT detections. Though the >650mm size-class comprised 22% (19) of the total catch during 2019 Eagle Cliffs collection activities, only three total (10%) were observed during all snorkeling events combined. We know this was a vast under-representation when the snorkel observations of this size-class are compared to empirical PIT antenna detections. Though only three were observed during snorkel activities, eleven were actually detected upstream within or around spawning tributaries. The eleven detections of the >650mm size-class bull trout in 2019 represented the highest proportional detection within size-class of 2019 PIT antenna detections (58%).

Table 3.2.1-1. Breakdown of observations by size-class of 2019 Eagle Cliffs bull trout captures.

Size class	Percent of total capture (n=84)	Percent of marked snorkel observations (n=29)	Percent of total size-class capture detected at PIT antenna (n=37)
>650	22% (19)	10% (3)	58% (11)
550-649	46% (39)	40% (13)	54% (21)
450-549	21% (18)	40% (13)	17% (3)
<450	9% (8)	(25)	25% (2)

3.3 LEWIS RIVER BULL TROUT CAPTURE AND TRANSPORT ACTIVITIES

3.3.1 FERC PROJECT LICENSE ARTICLE 402(A) AND LEWIS RIVER SETTLEMENT AGREEMENT SECTIONS 4.9.1 & 4.9.2 - SWIFT BYPASS REACH CAPTURE AND TRANSPORT ACTIVITIES

The Swift Bypass Reach is the former Lewis River channel between the Swift No. 1 and Swift No. 2 hydroelectric projects. Since 2010, a minimum flow of 65 cubic feet per second (cfs) has flowed in the Bypass Reach through what the SA termed the "Upper Release Point" and the "Canal Drain". The Upper Release Point flows from the Swift No. 2 Power Canal directly upstream from the Swift No. 1 spill plunge pool and provides 51 – 76 cfs of water depending on the time of year. The Canal Drain flows from the Swift No. 2 Power Canal into an approximately 350 m long reach (termed the Constructed Channel) that is relatively unaffected by Swift No. 1 spill events and provides a continual 14 cfs of water flow. This Constructed Channel then joins the main channel Bypass Reach. Along with Ole Creek, these two water release points provide most of the flow into the Bypass Reach.

In 1999, The Utilities began netting the Swift No. 2 powerhouse tailrace as part of requirements contained in amendments to Article 51 of the former Merwin license. The tailrace was not netted from 2001 to 2005 because of the Swift No. 2 canal failure in 2001 and subsequent reconstruction. Capture efforts were then restarted in 2006 pursuant to sections 4.9.1 and 4.9.2 of the Lewis River Settlement Agreement and in 2008 pursuant to Article 402(a) of the new FERC licenses for Swift No. 1 and No. 2.

At the 2007 annual bull trout coordination meeting (attended by USFWS, WDFW, and PacifiCorp), the Utilities proposed to discontinue netting the Swift No. 2 tailrace (since only two fish had been captured since 1999) and move the collection site to an area near the International Paper (IP) Bridge within the Swift Bypass Reach (Figure 3.3.2-1). As noticed in past Swift Bypass Reach snorkel surveys, this area was found to contain adult bull trout between the months of June thru October. The USFWS and those in attendance at the 2007 coordination meeting approved this recommendation.

In light of compelling data presented in 2016 that highlighted the numerous handling opportunities that could befall bull trout within Swift and Yale Reservoirs and the negative impact this handling is presumed to have on long-term survival. The Utilities in Consultation with the USFWS and the Lewis River Bull Trout Action Team, which is a group comprised of representatives from the Washington Department of Fish and Wildlife (WDFW), United States Department of Agriculture-Forest Service (USDA-FS), and USFWS, decided in 2016 to place a two year research handling moratorium on all bull trout activities in Swift and Yale Reservoirs. This moratorium was lifted for 2019 in the Eagle Cliff area of Swift Reservoir, while it was kept in place in Yale Reservoir. The group decided to continue the moratorium within the Swift Bypass Reach of Yale Reservoir for 2019. As such, no capture and handling of bull trout within Yale Reservoir occurred in 2019. Figure 3.3.1-2 and Table 3.3.1-2 illustrate historical total capture and transport numbers.

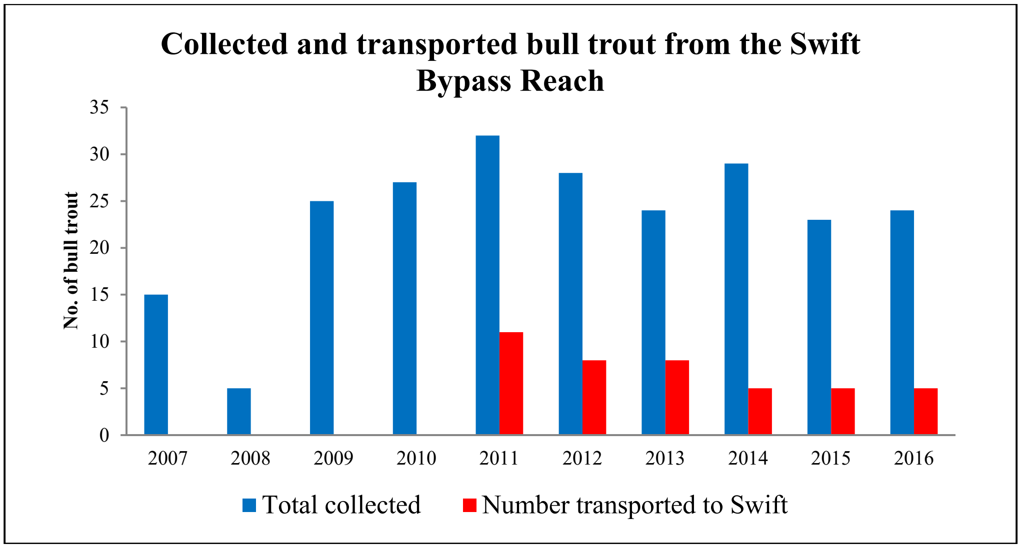

Figure 3.3.1-2. Historical Swift Bypass Reach capture and transport numbers.

Table 3.3.1-2. Number of bull trout collected from the Swift Bypass Reach (Yale Reservoir) and transferred to Swift Reservoir: 2007 – 2016.

YEAR	No. captured at the Swift Bypass Reach	No. transferred to Swift Reservoir	No. released back into Yale Reservoir	MORTALITIES
2007	15	0	15	0
2008	6	0	6	0
2009	25	0	25	0
2010	27	0	27	0
2011	32	15	17	0
2012	29	8	20	1
2013	24	8	16	0
2014	30	5	25	0
2015	21	5	15	1
2016	24	5	17	2
TOTAL	**233**	**46**	**184**	**4**

3.3.2 FERC PROJECT LICENSE ARTICLE 402(A) AND LEWIS RIVER SETTLEMENT AGREEMENT SECTIONS 4.9.1 & 4.9.2 - YALE TAILRACE CAPTURE AND TRANSPORT ACTIVITIES

Per Article 402(a) in the FERC licenses and the Lewis River SA section 4.9.1, PacifiCorp annually captures bull trout from the Yale powerhouse tailrace (upper Merwin Reservoir). All bull trout captures are transported to and held at Merwin Hatchery while rapid response genetic analysis is performed following methods outlined in Section 3.3.2 of this Report. Depending on the outcome of the analysis, bull trout are either transported for release into Yale or Swift reservoirs. A total of 162 bull trout have been captured from the Yale tailrace since the program began in 1995 (Table 3.3.2-1). Figure 3.3.2-1 also illustrates historical catch and associated effort.

To capture bull trout from the Yale Tailwaters, monofilament mesh tangle nets are used (typically 40 m long, 2 m deep, and consisting of 6.5 cm stretch mesh). Depending on catch rates, netting occurs for the most part on a monthly basis beginning in June and ending mid-August. Netting usually occurs between the hours of 0900 and 1200. During this time, the powerhouse generators are taken off-line to facilitate deployment and handling of the nets. Nets are tied to the powerhouse wall and then stretched across the tailrace area using a powerboat. The nets are then allowed to sink to the bottom. Depending on conditions or capture rate, the nets are either held by hand on one end or allowed to fish unattended. The maximum time nets are allowed to fish is 10 minutes.

Upon capture of a bull trout, it is immediately freed of the net (usually by cutting the net material) and placed in a live well. Captured fish are measured to their caudal fork, weighed with a hand-held scale to the nearest gram, and if a maiden capture inserted with a uniquely coded HDX or FDX PIT tag (size dependent). All fish are scanned with a hand-held PIT tag detector to check for previous tags prior to inserting a PIT tag. Along with fork length information, the weights of captured bull trout will be used to assess the condition factor (K-factor) of fish residing in Lake Merwin.

Use of Alternative Capture Methods
PacifiCorp continues to consider more effective and less intrusive methods to collect bull trout from the Yale tailrace. Past alternative methods investigated include; beach seines, purse seines, drifting tangle nets when the powerhouse is online, and angling.

In 2019, tangle nets and angling were the only methods used. To date, tangle nets remain the most effective. PacifiCorp continues research on possible alternative methods of effective capture and transport. However, upon investigation of each concept or pilot test conducted at other Northwestern dams, PacifiCorp has not been successful in finding a better alternative than the current method.

Yale Netting Results
At the Yale powerhouse tailrace in 2019, three capture attempts were completed; June 14, July 19, and August 15 yielding no bull trout captures.

Table 3.3.2-1. Number of bull trout collected from Yale tailrace (Merwin Reservoir) and transferred to the mouth of Cougar Creek (Yale tributary) or Swift Reservoir: 1995 – 2019.

YEAR	No. captured at the Yale tailrace	No. transferred to mouth of Cougar Creek	No. transferred to Swift Reservoir	No. released back into Merwin Reservoir	MORTALITIES
1995	15	9	0	6	0
1996	15	13	0	2	0
1997	10	10	0	0	0
1998	6	6	0	0	0
1999	6	0	0	6	0
2000	7	7	0	0	0
2001	0	0	0	0	0
2002	6	5	0	1	0
2003	19	8	0	1	10^
2004	8	3	0	5	0
2005	5	5	0	0	0
2006	5	5	0	0	0
2007	13	13	0	0	0
2008	15	15	0	0	0
2009	5	5	0	0	0
2010	1	0	0	0	1
2011	6	5	0	0	1
2012	3	3	0	0	0
2013	6	4	2	0	0
2014	0	0	0	0	0
2015	1	0	0	0	1
2016	8	7	0	0	1
2017	3	3	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
TOTAL	**162**	**122**	**2**	**21**	**14**

^Please refer to the 2003 PacifiCorp Threatened and Endangered Species Monitoring Report for a description of mortalities

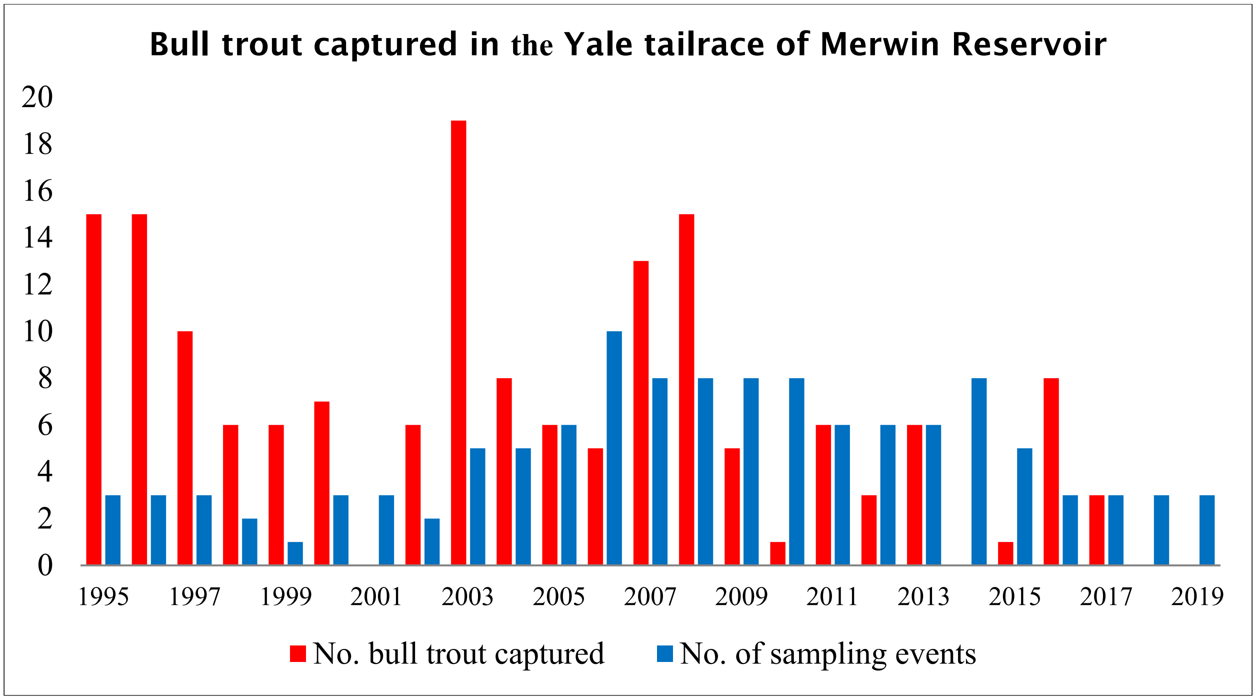

Figure 3.3.2-1. Historical catch and associated effort within the Yale Tailrace (1995-2019).

3.4 UNDERWATER VIDEO CAMERA OPERATION IN COUGAR CREEK

Please see the memo located in Appendix D of this Report for information, data, and analysis from the operation of an underwater video camera by the United States Fish and Wildlife Service within Cougar Creek in 2019.

3.5 LEWIS RIVER BULL TROUT SPAWNING SURVEYS

3.5.1 FERC PROJECT LICENSE ARTICLE 402(B) AND LEWIS RIVER SETTLEMENT AGREEMENT SECTION 9.6 - COUGAR CREEK SPAWNING ESTIMATE

Since 1979, PacifiCorp biologists, along with various state and federal agencies, have conducted annual surveys to estimate spawning escapement of kokanee in Cougar Creek. Along with the kokanee, surveyors also count the number of bull trout and bull trout redds observed within the creek. In 2019, the Utilities conducted five Cougar Creek bull trout redd surveys from September 26 to November 5. Surveys begin at the mouth of the creek and end at the creek's spring source, a distance of approximately 2100 m.

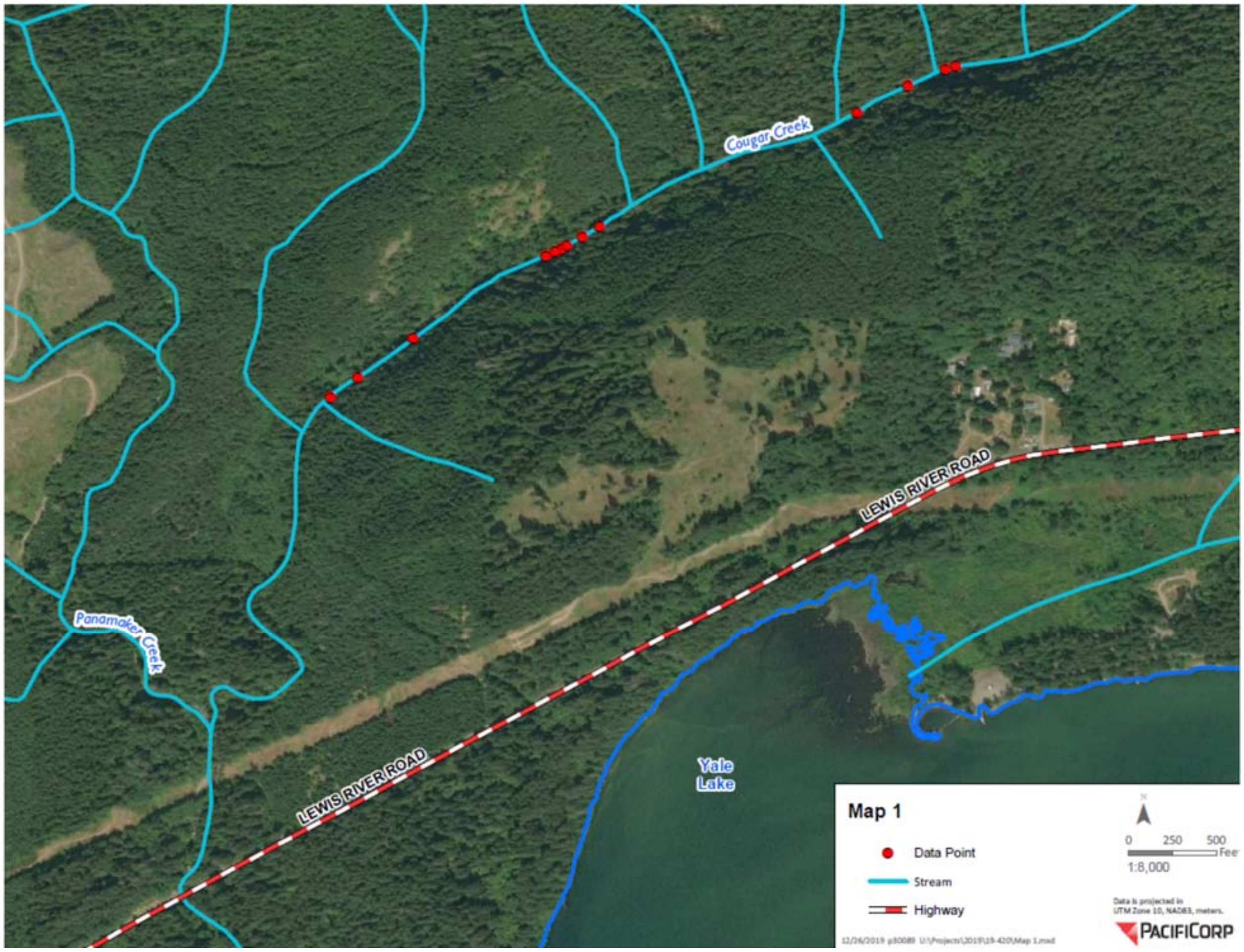

Figure 3.5.1-1. GPS locations of bull trout redds in Cougar Creek in 2019. Each red dot represents an individual bull trout redd (n=19).

Due to the wide range use of redd counts to quantify bull trout spawner abundance, multiple research studies have been performed in an effort to gauge the precision of this methodology and also to question the efficacy of redd counts as a population estimator (Dunham et al. 2001, Muhlfeld et al. 2006). Most often, redd surveys are conducted in large river systems with multiple different observers. The large systems necessitate the need for index areas mainly due to time and logistical constraints. The use of indices has been questioned based on their reliance of fish coming back to the same area at the same time every year to spawn. In addition, the use of multiple observer teams and a variety of observers on the same project, is considered to cause inaccuracies based on the variability between observers' experience with identifying redds.

The redd count methodology employed within Cougar Creek differs from most large-scale redd surveys in that the stream is small enough to feasibly cover the entire length during each survey, and currently is the only known bull trout spawning stream in Yale Reservoir. Cougar Creek also lends itself nicely to these types of surveys in that the water is extremely clear and has stable flow for most of the survey period. Also, redd life, the amount of time a redd remains visible, has an exceptionally long duration. Most, if not all, observed redds remain visible during the entire time-frame of the surveys.

In 2019, biologists walked the entire 2100 m of Cougar Creek during each redd survey. Surveys are completed over an extended period of time to address potential error associated with spawn-timing, and to alleviate inter-observer variability, all surveys in 2019 were performed by the same experienced biologists. Dunham et al. (2001) specified that a sampling effort should not rely on indices and should use the same surveyors as effective ways of improving the reliability of bull trout redd counts.

The real challenge of using bull trout redds to quantify the bull trout spawning population size lies in determining the relationship between redd counts and actual numbers of fish (Budy et al. 2003). Much past and present research has been conducted that attempts to correlate the number of spawning adult bull trout per redd. These numbers range widely by basin (1.2 to 4.3 fish per redd) and it seems the number of bull trout per redd is most likely basin or watershed specific. At this time, given that the exact number of bull trout that ascended Cougar Creek in 2019 to spawn is unknown, there is no reliable way to get an approximate number of fish per redd.

During each 2019 redd survey, new redds were flagged and identified by Global Positioning Satellite (GPS) coordinates. The date, location of redd in relation to the flag, and GPS coordinates were all written on the flagging (Figure 3.5.1-1). Subsequent surveys inspected each redd to see if they were still visible. If a redd was still visible, that information was written on the flagging with the date, until the redd was no longer visible, at which time this was noted on the flagging. Biologists also counted any bull trout observed within the vicinity of each redd.

19 individual bull trout redds were observed in Cougar Creek in 2019 (figure 3.5.1-2). As in past years, all bull trout redds were observed in the upper half of the creek upstream of a log jam that in most years is impassable to kokanee (Figure 3.5.1-1).

A continued concern within Cougar Creek, first observed in 2008, are bull trout redds found to be superimposed over one another. During redd counts in 2019, three bull trout redds were observed superimposed or partially superimposed over a previously excavated bull trout redd.

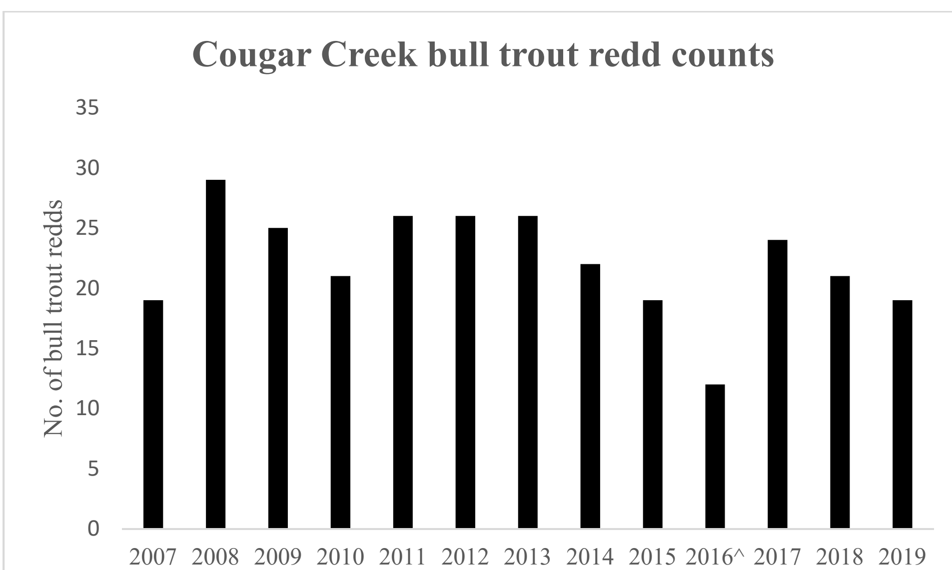

Figure 3.5.1-2. Annual Cougar Creek bull trout cumulative redd counts, 2007-2019. ^truncated survey year.

3.5.2 BULL TROUT REDD SURVEYS OF PINE CREEK, PINE CREEK TRIBUTARY P8, AND RUSH CREEK

P8

Tributaries to Pine Creek are counted from the mouth of Pine Creek upstream. P8 (Figure 3.5.2-1) is the eighth and largest of these tributaries. Based on surveys performed in 1999 and 2000 to document the extent of available anadromous fish habitat within the North Fork Lewis River basin, P8 contains approximately 6400 m of accessible anadromous fish habitat and has relatively low gradient for the first 1600 m. P8 is a relatively small stream, with an average wetted width of 3.5 m, but it contains abundant annual flow and cold water (PacifiCorp and Cowlitz PUD 2004).

Redd surveys (consistent with methodology utilized on Cougar Creek) were performed on Pine Creek tributary P8 six times from September 4 – October 24 during the 2019 bull trout spawning season. In all, GPS coordinates were collected from 51 bull trout redds during the survey period. Redds were observed and counted from the mouth of P8 to 2100 m upstream (Figure 3.5.2-1 and 3.5.2-2). Interspecies redd superimposition was not observed within P8 during the 2019 survey period.

Spawning coho had been observed within P8 during the 2014 and 2015 bull trout spawning season. No coho or coho redds were observed within P8 in 2019.

Pine Creek

Redd surveys on a weekly rotation of all available spawning habitat were performed within Pine Creek mainstem during the months of September and October in 2019 (river mile 0 to river mile 8). In all, eight surveys were completed and 110 redds were recorded and GPS'd (Figures 3.5.2-1 and 3.5.2-2). 4 percent of redds were recorded in the lower quarter of available spawning habitat (5 redds from river mile 0 to river mile 2.1), 49 percent of redds were recorded in the lower middle quarter of available habitat (54 redds from river mile 2.1 to river mile 4.1), 34 percent of bull trout redds were recorded and observed in the upper middle quarter of available habitat (37 redds from river mile 4.1 to river mile 6.1), while 13 percent of observed bull trout redds in Pine Creek in 2019 were observed in the upper quarter of available habitat (14 redds from river mile 6.1 to river mile 8).

Due to low water for the duration of the spawning season that prohibited upstream bull trout migration, no bull trout redds were observed within tributary P10 in 2019 (Figure 3.5.2-1).

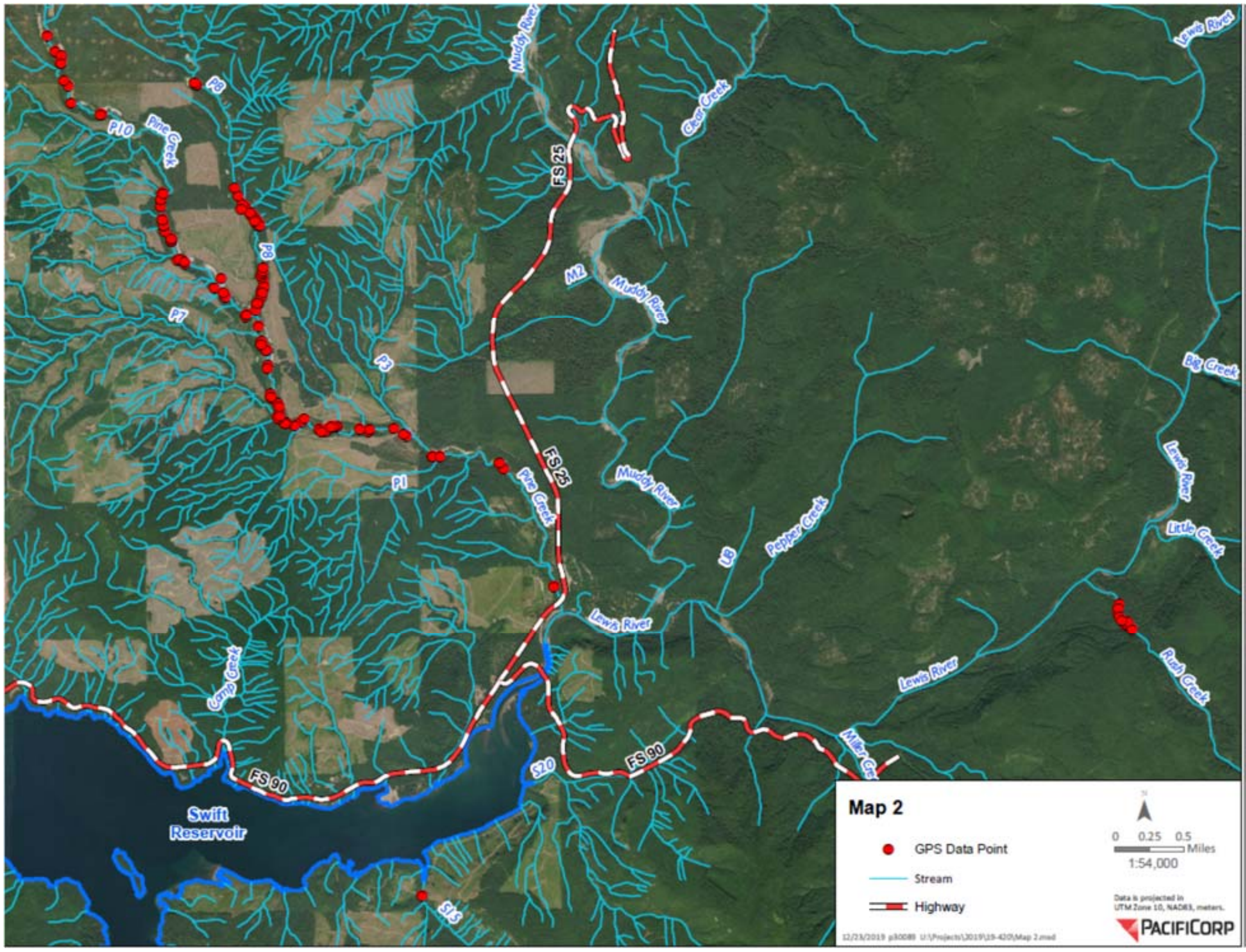

Figure 3.5.2-1. GPS locations of bull trout redds in Pine Creek, Rush Creek and tributary P8 in 2019. Each red dot represents an individual bull trout redd (n=171).

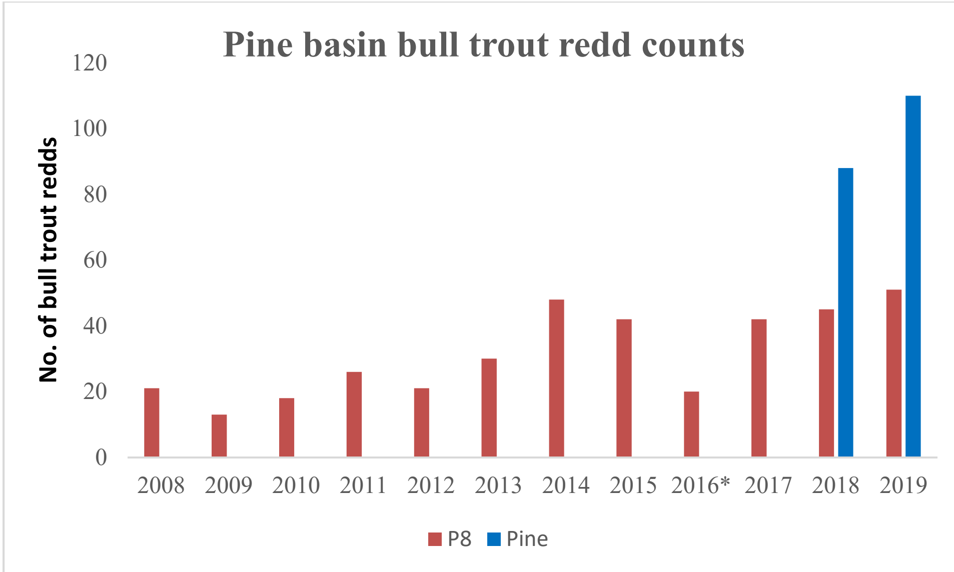

Figure 3.5.2-2. Pine Creek and tributary P8 historical bull trout redd counts (2008 and 2009 data courtesy of WDFW). *truncated survey year due to high flows.

Figure 3.5.2-3 further illustrates the spawn curve within the Pine Creek basin by evaluating by week snorkel observations at the mouth of Pine Creek, P8 fixed PIT antenna detections, and redd counts within Pine Creek and tributary P8.

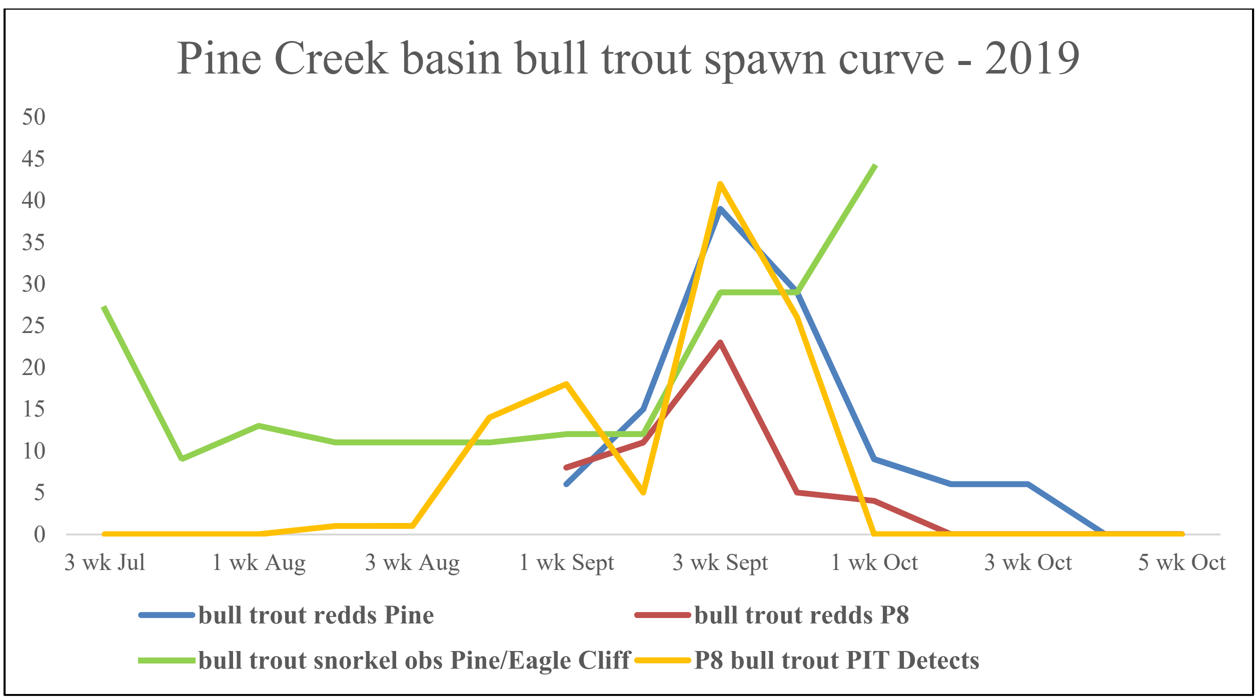

Figure 3.5.2-3. Evaluation of the Pine Creek bull trout spawn migration in 2019.

Rush Creek

Rush Creek was surveyed on five occasions between September 10 and November 4, 2019. Ten redds were observed and marked by flagging and GPS (Figure 3.5.2-1). Redd surveys were completed from the stream mouth upstream to the Forest Road 90 bridge, a distance of approximately 1,600 m. Historical redd counts are expressed in Figure 3.5.2-4.

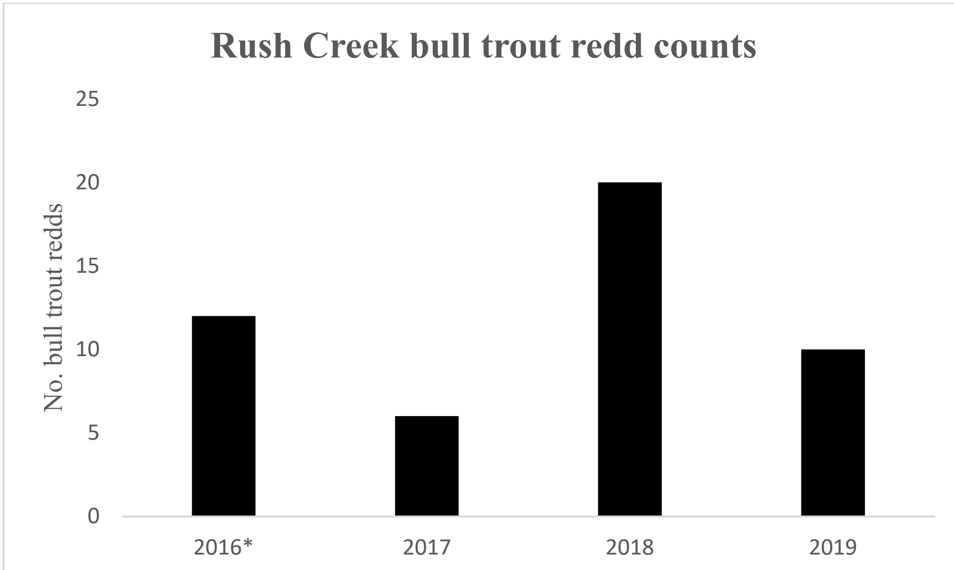

Figure 3.5.2-4. Rush Creek historical bull trout redd counts. *truncated survey year due to high flows.

Observer Error Redd Surveys

In order to evaluate and incorporate the inherent error associated with surveyor subjectivity during stream-type redd surveys, three observer error redd surveys were performed of each bull trout spawning stream in 2019. Analysis of this data can be found in the Memo: Patterns of bull trout *Salvelinus confluentus* demography, life-history and abundance in the North Fork Lewis River—2019 Annual Report, located in Appendix C of this Report.

3.6 Summer and Fall Stream Temperature Monitoring of Bull Trout Pertinent Sites Upstream of Eagle Cliff

In order to better understand bull trout spawn migration timing and how it correlates to stream temperature, Onset Tidbit® temperature data loggers were remotely deployed on June 15 in Pine, P8, P10, and Rush creeks and in the mainstem Lewis River at Eagle Cliffs and just upstream from Rush Creek in 2019. Thermographs were quality assured/quality controlled by the manufacturer prior to deployment and were set to record continuous hourly temperature readings at each identified location. Thermographs operated until October 31 at which time they were recovered and taken out of each stream location. All sites experienced continuous data collection at each location during the stipulated time-frame. The 2019 dataset was added to the 2018 dataset and this data collection will continue to be added to in the future to better assess long-term thermal changes of bull trout spawning streams in the upper Lewis River basin.

4.0 ACKNOWLEDGEMENTS

The Utilities would like to thank Dr. Robert Al-Chokhachy from USGS for his analysis of bull trout PIT tag data and subsequent Survival and abundance estimates, as well as Jamie Lamperth from WDFW for his assistance during Eagle Cliffs marking activities and ultrasound work. The Utilities would also like to thank Marshall Barrows from USFWS for operation of the Cougar Creek weir and video and analysis of video data.

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APPENDIX A
2019 Eagle Cliffs Collection Biological Data

Record #	Floy tagged Capture #	DATE	LENGTH (mm)	FLOY COLOR	FLOY No.	PIT	RECAP COLOR	REMARKS	Genetic Vial #	Capture Method	Ultrasound
2133		5/10/2019	384	too small		AC776C1	detected @Rush pool		3357-043	Angling	yes
2134		5/10/2019	356	too small		AC776C2	detected @Rush pool		3357-044	Angling	yes
2135	1	5/16/2019	677	Pink	151/152	AC776C3	detected @Rush pool	h2o - 7.5	3357-045	Angling	yes
2136	2	5/16/2019	528	White	268/269	AC776C4			3357-046	Angling	yes
2137	3	5/16/2019	680	Pink	153/154	AC776C5	detected at Pine		3357-047	Angling	yes
2138	4	5/16/2019	608	Chartreuse	176/177	AC77682	detected in P8	RECAP, green Floy 59/60, pec fin not healed		Angling	yes
2139	5	5/16/2019	618	Chartreuse	178/179	AC776C6	detected in Pine	RECAP, FDX PIT 3D60015550AD2		Angling	yes
2140	6	5/16/2019	542	Chartreuse	180/181	AC776C7			3357-048	Angling	yes
2141	7	5/16/2019	620	Chartreuse	182/183	AC776C8	detected in P8			Angling	yes
2142	8	5/16/2019	546	Chartreuse	184/185	AC776C9			3357-049	Angling	yes
2143	9	5/16/2019	581	Chartreuse	186/187	AC776CA			337-050	Angling	yes
2144	9	5/16/2019	444	too small		AC776CB			3357-051	Angling	yes
2145	10	5/16/2019	619	Chartreuse	188/189	AC776CC	detected in P8		3357-052	Angling	yes
2146	11	5/23/2019	492	White	270/271	AC776CD		h2o - 10.8	3357-053	Angling	yes
2147	12	5/23/2019	667	Pink	251/252	AC776CE	detected at Pine		3357-054	Angling	yes
2148	13	5/23/2019	640	Chartreuse	190/191	AC776CF			3357-055	Angling	yes
2149	14	5/23/2019	535	White	272/273	AC776D0	detected in P8			Angling	yes
2150	15	5/23/2019	470	White	274/295	AC776D1	detected @Rush pool		3357-056	Angling	yes
2151	16	5/23/2019	503	White	293/294	AC776D2			3357-057	Angling	yes
2152	17	5/23/2019	608	Chartreuse	192/193	AC776D3			3357-058	Angling	yes
2153	18	5/23/2019	602	Chartreuse	194/195	AC776D4	detected at Pine		3357-059	Angling	yes
2154	18	5/30/2019	340					MORT	3357-060	Angling	yes
2155	19	5/30/2019	621	Chartreuse	196/197	AC776D5	detected at Pine		3357-061	Angling	yes
2156	20	5/30/2019	581	Chartreuse	198/199	AC776D6			3357-062	Angling	yes
2157	21	5/30/2019	528	White	280/281	AC776D7			3357-063	Drift net	yes
2158	22	5/30/2019	512	White	282/283	AC776D8			3357-064	Drift net	yes
2159	23	5/30/2019	584	Chartreuse	201/202	AC77693		RECAP		Drift net	yes

2160	24	5/30/2019	521	White	284/285	AC776D9			3357-065	Drift net	yes
2161	25	5/30/2019	590	Chartreuse	203/204	AC776DA	detected in P8		3357-066	Drift net	yes
2162	26	5/30/2019	621	Chartreuse	205/206	AC77677	detected in P8	RECAP, Green Floy 33/34		Drift net	yes
2163	26	5/30/2019	380	too small		AC776DB			3357-067	Angling	yes
2164	26	6/6/2019	327	too small		AC776DC		Ultrasound unavailable. 5 drifts	3357-068	Drift net, EC hole	no
2165	27	6/6/2019	600	Chartreuse	207/208	AC776DD			3357-069	Drift net, EC hole	no
2166	27	6/6/2019						RECAP. This year chartr.205/206		Drift net, EC hole	no
2167	28	6/6/2019	545	White	288/289	AC776DE			3357-070	Drift net, EC hole	no
2168	29	6/6/2019	661	Pink	254/255	944D		**PIT prefix 3843515E0 starts**	3357-071	Drift net, EC hole	no
2169	30	6/6/2019	557	Chartreuse	209/210	AC7767B	detected in Pine	RECAP		Drift net, EC hole	no
2170	31	6/6/2019	538	White		944E			3357-072	Drift net, EC hole	no
2171	32	6/6/2019	591	Chartreuse	211/212	944F			3357-073	Drift net, EC hole	no
2172	33	6/6/2019	570	Chartreuse	213/214	9450			3357-074	Drift net, EC hole	no
2173	34	6/6/2019	627	Chartreuse	215/216	9451			3357-075	Drift net, EC hole	no
2174	35	6/6/2019	601	Chartreuse	217/218	9452	detected in Pine		3357-076	Drift net, EC hole	no
2175	36	6/13/2019	694	Pink	256/257	AC775B0	detected in Pine	RECAP. h2o 13C. 7 drifts EC hole only		H&L	yes
2176	37	6/13/2019	588	Chartreuse	219/220	9453	detected in Pine		3357-077	H&L	yes
2177	38	6/13/2019	513	White	290/291	9454			3357-078	H&L	yes
2178	39	6/13/2019	525	White	3674/3675	9455			3357-079	Drift net, EC hole	yes
2179	40	6/13/2019	645	Chartreuse	224/225	9456	detected in P8		3357-080	Drift net, EC hole	yes
2180	41	6/13/2019	638	Chartreuse	222/223	AC77698		RECAP.		Drift net, EC hole	yes
2181	42	6/13/2019	641	Chartreuse	226/227	9457		Pink worm jig in mouth	3357-081	Drift net, EC hole	yes
2182	43	6/13/2019	540	White	3672/3673	9458	detected at Pine		3357-082	Drift net, EC hole	yes

2183	44	6/13/2019	605	Chartreuse	228/229	9459	detected in P8		3357-083	Drift net, EC hole	yes
2184	45	6/13/2019	681	Pink	258/259	945A	detected in P8		3357-084	Drift net, EC hole	yes
2185	46	6/13/2019	626	Chartreuse	230/231	945B		fishing line coming out gills	3357-085	Drift net, EC hole	yes
2186	46	6/13/2019	429	too small		945C			3357-086	Drift net, EC hole	yes
2187	47	6/13/2019	748	Pink	260/261	945D			3357-087	Drift net, EC hole	yes
2188	47	6/13/2019						RECAP. This year white 295/274		Drift net, EC hole	
2189	47	6/21/2019	412	too small		9464		h2o 10.1. 6 drifts EC hole	3357-088	Drift net, EC hole	yes
2190	47	6/21/2019						RECAP. This year chart 222/223		Drift net, EC hole	
2191	48	6/21/2019	625	Chartreuse	232/233	AC7769B	detected in Pine	RECAP. Green floy 109/110		Drift net, EC hole	yes
2192	49	6/21/2019	695	Pink	262/263	9465	detected in P8		3357-089	Drift net, EC hole	yes
2193	50	6/21/2019	594	Chartreuse	234/235	9466	detected in P8			Drift net, EC hole	yes
2194	51	6/21/2019	632	Chartreuse	236/237	9467				Drift net, EC hole	yes
2195	51	6/21/2019						RECAP. This year white 268/269		Drift net, EC hole	
2196	51	6/21/2019						RECAP. This year white 284/285		Drift net, EC hole	
2197	52	6/21/2019	643	Chartreuse	238/239	9468	detected in P8	Missing left pec.		Drift net, EC hole	yes
2198	53	6/21/2019	667	Pink	264/265	AC7765B	detected at Rush pool	RECAP. Green floy 123		Drift net, EC hole	yes
2199	53	6/21/2019						RECAP. This year chart 205/206		Drift net, EC hole	
2200	53	6/21/2019						RECAP. This year Pink 260/261		Drift net, EC hole	

2201	53	7/1/2019						No boat access, drysuits in EC hole, 4 drifts. Ultrasound unavailable RECAP. This year white 295/274		Drift net, EC hole	no
2202	53	7/1/2019						RECAP. This year chart 230/231		Drift net, EC hole	no
2203	54	7/1/2019	618	Chartreuse	249/250	9469	detected in Pine		3473-071	Drift net, EC hole	no
2204	55	7/1/2019	815	Pink	266/267	A89AF22		RECAP. largest fish on record, pic, Initial cap 2012, never detected at a PIT antenna		Drift net, EC hole	no
2205	56	7/1/2019	541	White	3670/3671	946A			3473-072	Drift net, EC hole	no
2206	57	7/1/2019	660	Pink	268/269	946B			3473-073	Drift net, EC hole	no
2207	58	7/1/2019	675	Pink	270/271	946C	detected Pine		3473-074	Drift net, EC hole	no
2208	59	7/1/2019	695	Pink	272/273	AC776A5		RECAP		Drift net, EC hole	no
2209	59	7/1/2019	405	too small		946D			3473-075	Drift net, EC hole	no
2210	60	7/3/2019	605	Chartreuse	247/248	9470	detected Pine	no boat access, drysuits in EC hole, 3 drifts. Ultrasound unavailable	3473-077	Drift net, EC hole	no
2211	61	7/3/2019	671	Pink	180/181	9471	detected Pine			Drift net, EC hole	no
2212	62	7/3/2019	715	Pink	182/183	9472	detected in P8		3473-078	Drift net, EC hole	no
2213	63	7/3/2019	645	Chartreuse	245/246	9473			3473-079	Drift net, EC hole	no
2214	64	7/3/2019	595	Chartreuse	243/244	9474		large sucker in mouth	3473-080	Drift net, EC hole	no
2215	65	7/3/2019	676	Pink	184/185	AC77656	detected Pine	RECAP. Green floy 115/116		Drift net, EC hole	no
2216	66	7/3/2019	595	Chartreuse	240/241	9475	detected in P8		3473-081	Drift net, EC hole	no

2217	67	7/3/2019	530	White	3667/3668	9476			3473-082	Drift net, EC hole	no
2218	67	7/3/2019						RECAP. This year too small		Drift net, EC hole	no
2219	67	7/3/2019						RECAP. This year white 3669/3671		Drift net, EC hole	no
2220	67	7/3/2019						RECAP. This year pink 246/265		Drift net, EC hole	no
2221	67	7/3/2019						RECAP. This year white 268/269		Drift net, EC hole	no
2222	67	7/3/2019						RECAP. This year pink 268/269		Drift net, EC hole	no
2223	68	7/3/2019	735	Pink	274/275	946E			3473-076	Drift net, EC hole	no
2224	68	7/3/2019						RECAP. This year white 274/295		Drift net, EC hole	no
2225	69	7/3/2019	678	Pink	176/177	946F				Drift net, EC hole	no
2226	70	7/3/2019	679	Pink	178/179	AC77696		RECAP. Green floy 93/94		Drift net, EC hole	no
2227	71	7/10/2019	618	Chartreuse	121/122	947A		Sucker in mouth. no boat access, drysuits in EC hole, 4 drifts.	3473-086	Drift net, EC hole	yes
2228	72	7/10/2019	501	White	3663/3664	947B			3473-087	Drift net, EC hole	yes
2229	73	7/10/2019	485	White	3661/3662	947C			3473-088	Drift net, EC hole	yes
2230	73	7/10/2019						RECAP. This year too small		Drift net, EC hole	yes
2231	73	7/10/2019						RECAP. This year white 286/287		Drift net, EC hole	yes
2232	73	7/10/2019						RECAP. This year white 290/291		Drift net, EC hole	yes
2233	73	7/10/2019						RECAP. This year pink 264/265		Drift net, EC hole	yes
2234	74	7/10/2019	600	Chartreuse	117/118	9477	detected @Rush		3473-083	Drift net, EC hole	yes
2235	75	7/10/2019	485	White	3665/3666	9478			3473-084	Drift net, EC hole	yes

2236	75	7/10/ 2019						RECAP. This year chart 228/229		Drift net, EC hole	yes
2237	76	7/10/ 2019	615	Chartr euse	119/1 20	9479	detected at Pine		3473- 085	Drift net, EC hole	yes

APPENDIX B
MEMO BY JAMIE LAMPERTH, WASHINGTON DEPARTMENT OF FISH AND WILDLIFE: "2019 EAGLE CLIFFS BULL TROUT ULTRASOUND SAMPLING"

ULTRASOUND SAMPLING

We explored the use of ultrasound technology to determine the sex of bull trout. Ultrasonography has been used for applications related to fish reproduction for over two decades (Novelo and Tiersch 2012). We used a Honda HS-1600V diagnostic ultrasound scanner with a HLV-875M 7.5Mhz linear probe (https://www.honda-el.co.jp/en/medical/HS-1600VE.html). The scanner was used in B-Mode (i.e., a single two-dimensional gray-scale image) with acoustic power (A) set to 60% and range (R) set to 60 (unknown units). The gamma curve was set to 4 for easier viewing of the ultrasound images (the images appeared crisper at this setting). We experimented with the gain setting (G) and found a gain of 100% worked best in terms of image clarity. The unit provides the ability to change focal point of the image (focus shallower or deeper); generally we kept the focal point at the mid-point. Ultrasound examinations were conducted as part of the general biological sampling described elsewhere in this document. To conduct the ultrasound examination, fish were turned ventral side up with the head to the left. The probe was placed at the pectoral fins, perpendicular to the ventral surface (, and moved posteriorly until the gonads appeared. Sex calls were made in the field based on best judgement. An image annotated with PIT code and field sex call of the fish were saved for additional evaluation in the office. Occasionally phenotype was recorded based on best judgement.

This was the first time any of the samplers used this technology so we were learning as the season progressed. It took several examinations (~7) before we could positively identify gonads. Once we improved our probing technique to locate gonads, nearly all the gonads we located over the entire sampling season appeared to be ova (i.e., globular, discrete spheres). However, these sex determinations based on ultrasonography were called into question a few times when the fish we were examining morphologically appeared to be male (i.e., spawning coloration and presence of a kype) but the gonads appeared to be ova according to the examiner. During the last day of sampling, we examined the gonad imagery in more detail and noticed that the shapes that made up the lobes of the gonads on some of the images appeared more non-spherical and irregular. At that point, more irregular shapes were interpreted as testes, and discrete spheres were interpreted as ova.

In the office the images were re-examined classifying each as globular, non-spherical, unknown (lobes visible but unable to classify as globular or non-spherical) and not visible (lobes of the gonads not visible, in our inexperience opinion).

We also contacted Carlin McAuly at the NOAA Manchester Lab to help evaluate our images. Mr. McAuly has regularly used ultrasound to determine maturation status of captive broodstock salmon species (e.g. Frost et al. 2014). Mr. McAuly examined nearly all of the images and classified the vast majority as female, generally consistent with the original field calls. Mr. McAuly described testes as being black (non-reflective) masses. This is based on the images of salmon that he and his team work with. Black non-reflective masses are generally absent from the bull trout images. However, in one of the images he identified the testes as what we would call lobes made up of non-spherical shapes.

We examined 57 bull trout between May 10 and July 10, 2019. Of these, gonads were discernable from 32 fish (56% of fish examined). Poor imagery, user inexperience, and fish immaturity (gonads too small to locate) were reasons that we were unable to discern gonads for 44% of the fish we examined.

Based on our initial field calls, there were 28 females and 4 males. Based on our subjective analysis of the shape of the biomass making up the gonadal lobes there were 11 globular (interpreted as female; Figure 1), 18 non-spherical (interpreted as male; Figure 2), and 3 unknown. Figure 3 shows an example of a fish that was initially classified in the field as a female, despite morphologically appearing as a male. Mr. McAuly looked over most of the images (the exact number that he evaluated was not recorded, he looked at as many as he had time for) and classified 5 males, the rest were classified as females (~25-30).

The results of this evaluation suggest that either 1) there is a high proportion of female bull trout congregating at the head of Swift Reservoir or 2) we need to improve our classification of sex using ultrasonography. The probability that the sex ratio is 5-7 females: 1 male is really low. Based on the shape analysis, the sex ratio is approximately 0.61 females: 1 male; likely a bit closer to reality. Because of the unlikely results and inconsistency between methods, we believe the sex determinations from the 2019 ultrasound examinations are generally not reliable. If we are to use this technology in the future, we need to conduct robust validation sampling to hone in our skills at classifying sex of bull trout with ultrasonography. Alternatively, we could explore the use and reliability of endoscopy (e.g. Swenson et al. 2007) for our application.

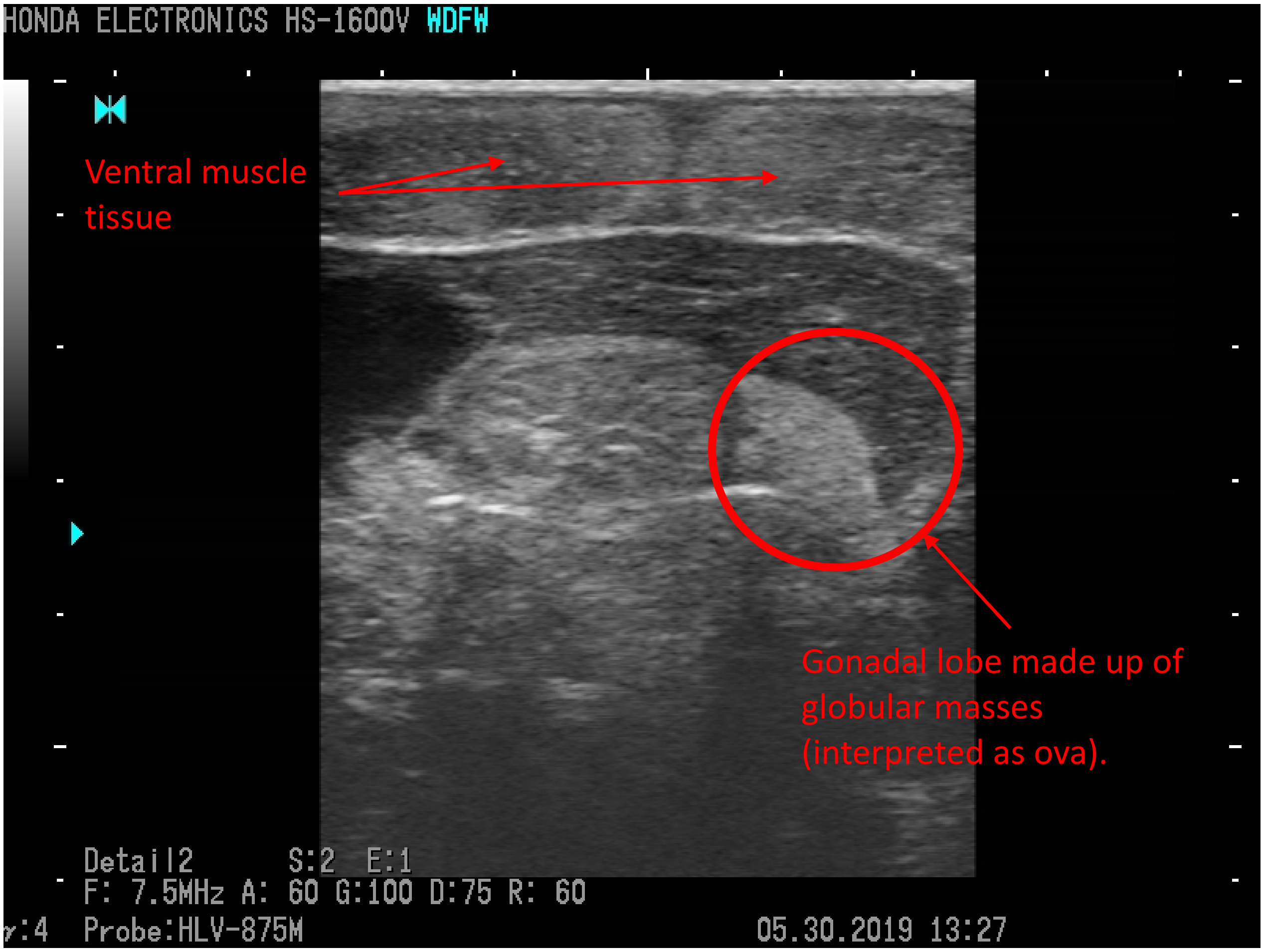

Figure 1. Example of a gonadal lobe made up of globular masses (ova) based on our interpretation of the ultrasound imagery.

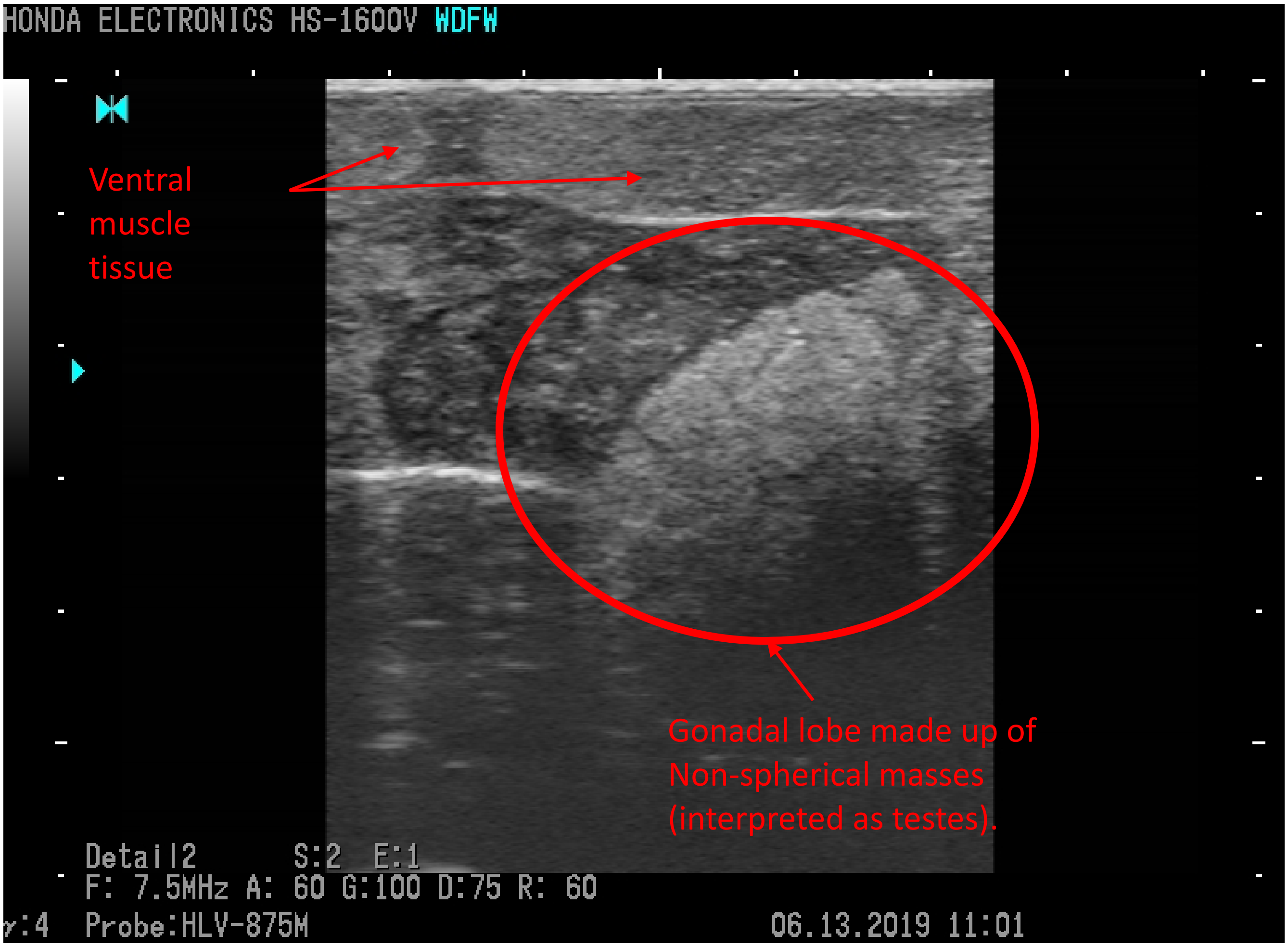

Figure 2. Example of a gonadal lobe made up of non-spherical masses (testes) based on our interpretation of the ultrasound imagery.

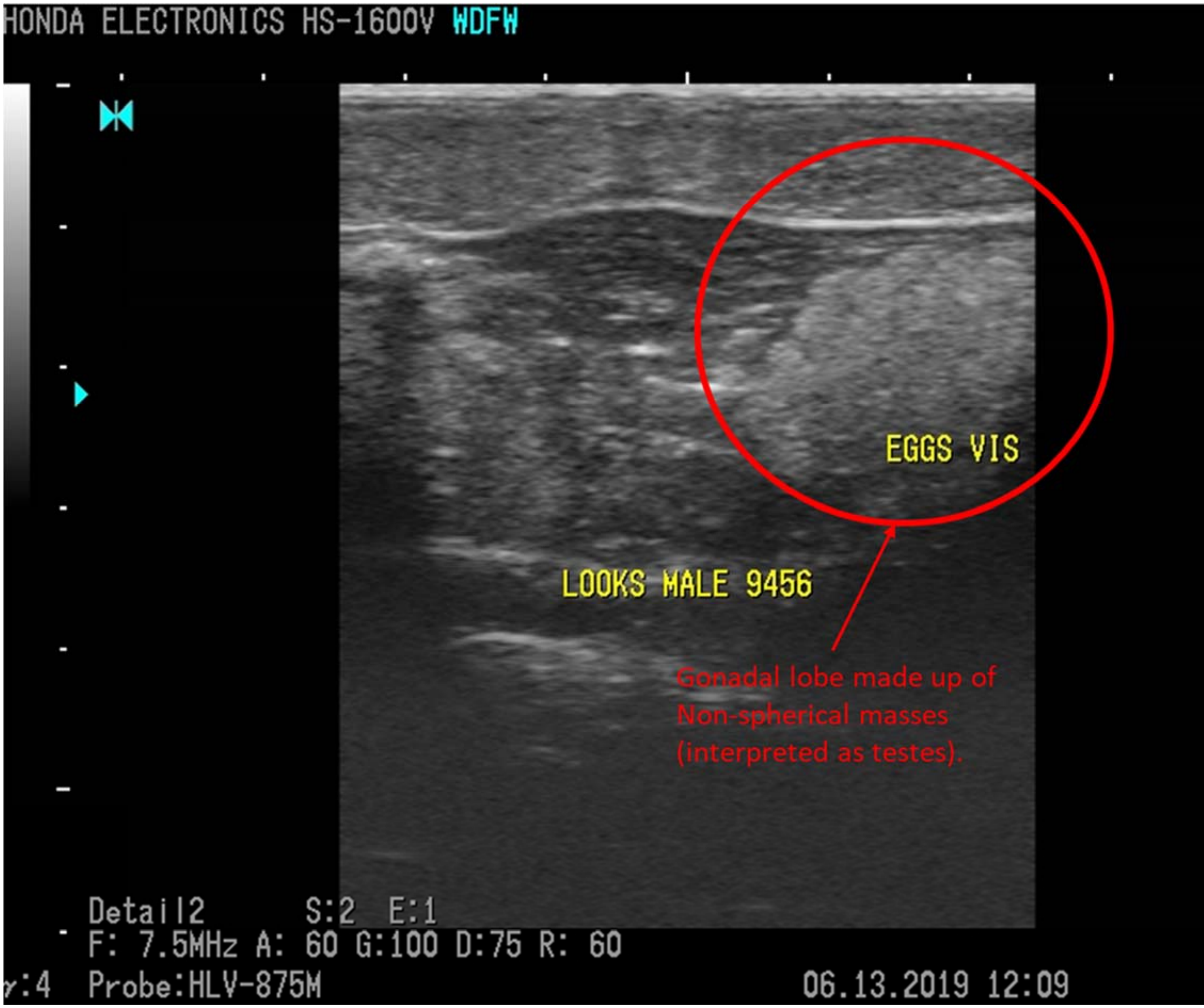

Figure 3. Example of a fish that morphologically appeared to be a male but was thought to be a female based on the appearance of the gonads. The yellow text are field notes. In this example, we initially thought the gonadal lobe contained ova. Now we believe the mass is non-spherical testes. Validation sampling should be conducted to determine if the shape of the mass comprising the gonadal lobe is a characteristic that can be used to classify sex.

References

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APPENDIX C

MEMO BY ROBERT AL-CHOKHACHY, UNITED STATES GEOLOGICAL SERVICE: Patterns of bull trout *Salvelinus confluentus* demography, life-history and abundance in the North Fork Lewis River—2019 Annual Report

Patterns of bull trout *Salvelinus confluentus* demography, life history and abundance in the North Fork Lewis River—2019 Annual Report

By

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Introduction

Declines in the distribution and abundance of bull trout *Salvelinus confluentus* across much of the historic range in the Pacific Northwest region of Canada and the USA have been well documented (Rieman et al. 1997; Post and Johnston 2002). Recent estimates of population trends appear to vary considerably across regions with large numbers of migratory and resident populations exhibiting significant declines in adult abundance (Al-Chokhachy et al. 2016; Kovach et al. 2018), while others remain stable or potentially increasing (Erhardt and Scarnecchia 2014; Meyer et al. 2014). For example, 61% of the core populations in Alberta, Canada are considered declining, while 39% are stable or increasing (Alberta Sustainable Resource Development 2012). The variability in population status and trends highlights the importance of population-specific data.

Much of our understanding of bull trout life history has stemmed from a few, well-studied populations, and continuing to improve our knowledge of the variability in life-history expressions (e.g., Starcevich et al. 2012) is important in directing local and regional conservation efforts (*sensu* Schindler et al. 2010). Here, we consider the life history and demographic patterns for an adfluvial population of bull trout in the North Fork Lewis River Basin in Washington. We synthesize recent monitoring efforts and field studies to refine our understanding of bull trout life-history expressions (i.e., migration patterns) and demographics. In addition, we consider temporal trends in abundance of bull trout using contemporary monitoring data across a variety of field methods. Within this context, we also evaluate how sampling error may affect the ability to detect changes in abundance to better understand patterns from recent monitoring data and inform future monitoring efforts.

Methods

Study area

The majority of this study focuses on bull trout populations in the North Fork Lewis River upstream of Swift Dam, Washington, USA (Figure 1). The climate is typical of the lower elevation Cascade Mountains with relatively mild, wet winters and warm, dry summers. Annual precipitation within the basin commonly exceeds 2 m with higher amounts as elevation increases; precipitation predominantly falls as rain at lower elevations and snow at higher elevations. The vegetation is dominated by maritime species with forests dominated by Douglas-fir and western hemlock. Land ownership in the North Fork Lewis River (upstream of dams) varies including federal ownership (70%), state lands (11%), and the remainder under private ownership. The majority of private ownership is through timber harvest corporations and ongoing timber harvest by public and private landowners occurs within the basin, including the Pine Creek drainage.

For a regional perspective, only 16 local bull trout populations exist within the entire Lower Columbia Recovery Unit for the species (USFWS 2015) and numerous existing threats have been documented to the majority of these populations. The extant bull trout populations in the Lewis River Basin are likely to act as regional strongholds under anticipated trends in climate warming (Mote et al. 2003) given the cold stream temperatures and access to reservoirs that thermally stratify (*sensu* Al-Chokhachy et al. 2018). The major bull trout spawning tributaries in the study area include Pine Creek, a tributary to Pine Creek (P8), and Rush Creek. Rush Creek is a steep, large tributary (bankfull width = 24 m) to the North Fork Lewis River, Pine Creek is a medium-sized tributary (bankfull width = 13.5 m) to the Lewis River, and P8 is considerably smaller (bankfull width = 8.3 m). Although a resident bull trout component is possible within the North Fork Lewis River, the populations are considered primarily migratory (Hudson et al. 2019). Similar to numerous other bull trout populations (e.g., Johnston et al. 2007; Erhardt and Scarnecchia 2014; Ratliff et al. 2015), bull trout in the Lewis River study population occur as an adapted adfluvial life history due to the historic flooding of the Lewis River valley and creation of a reservoir.

Bull trout spawning migrations

As part of a larger abundance, movement, and demographic study, bull trout were captured using predominantly gill nets (varying lengths 25 – 40 m, dyed green 6# monofilament line, varying mesh sizes 2.5 – 7.5 cm, 2 m in depth) drifted down through the pool to entangle fish at Eagle Cliff (Figure 1) during the late spring and summer from 1992 to 2016. Once captured bull trout were anesthetized with Tricaine Methanesulfonate (MS-222), checked for any previous marks, measured in fork length, and marked with an individual-specific tag. All fish during this study were marked with an external anchor tag (Floy) at the base of the dorsal fin for estimates of adult abundance (Hudson et al. 2019). Beginning in 2002, fish were also marked with 12-mm full duplex passive integrated transponder (PIT) tags in the dorsal sinus, a switch to 23-mm half duplex PIT-tags occurred in 2011. Upon full recovery where fish regained equilibrium, individuals were released near the point of capture.

The individual PIT tags were used to provide individual growth, movement, and survival information (Hudson et al. 2019). However, due to recent changes in monitoring strategies, no new marking of bull trout occurred in 2017 or 2018 (new fish will be marked every 3rd year beginning in 2019). As such, no new estimates of growth are presented herein (see Al-Chokhachy et al. 2019). Despite the lack of marking events, we used information from previously marked bull trout and passive instream antennas (PIAs) to evaluate bull trout movement patterns and provide estimates of annual survival (see below). Bull trout migration patterns were quantified using capture information at Eagle Cliff and passive detections at the PIAs. Each year PIAs were installed near the mouth of Pine Creek (since 2011), near the mouth of P8 (since 2012), and the mouth of Rush Creek (since 2012) and operated from mid-summer through mid-autumn. The antennas spanned the individual channel widths and were powered continuously through the spawning season each year, but we acknowledge that some years high discharge altered the exact data of installation as well as when the PIAs were taken out of operation. In addition, in 2019, a submersible PIA was installed in the NF Lewis River pool at the confluence of Rush Creek prior to and during the spawning season.

We used the dates of recaptures at the PIAs, and the layout of the PIAs to interpret the directionality and timing of bull trout movements. We combined the data from 2018 with previous mark-recapture data (Al-Chokhachy et al. 2019) to quantify estimates of the number of spawning events per individual, where we assumed that upstream migrations indicated spawning events. We also quantified the timing and duration of spawning migrations. Here, we used known recaptures at Pine Creek and P8 to quantify the duration of upstream spawning migrations (Pine Creek to P8), the duration of downstream spawning migrations (P8 to Pine Creek), and the overall duration (Pine Creek to Pine Creek). In addition, we quantified the proportion of fish entering Pine Creek that utilized P8 (presumably for spawning activities). For each metric we considered interannual differences and present the results graphically.

Previous research indicated upstream bull trout migration patterns were not correlated with hydrologic regimes (Al-Chokhachy et al. 2019). However, here we evaluated if interannual differences in air temperature (as a surrogate for stream temperature) were correlated with upstream bull trout migrations. We summarized air temperature data from the June Lake Snotel site (Station MRBW1; 46.133, -122.15; http://www.climate.washington.edu/maps/map.php) to quantify average monthly air temperatures from July through September. We then correlated these annual values with the median date of upstream migration using Pearson's correlation coefficient.

Bull trout survival analyses

We conducted two separate survival analyses. First, we used the marking and recapture data using active sampling only (i.e., from netting and angling at Eagle Cliff) to estimate apparent survival of bull trout in Swift Reservoir (1997 – 2019). These data included all fish (>450 mm) marked and recaptured via marking efforts from drift-gill nets at Eagle Cliff (Figure 1) at the head of Swift Reservoir. We estimated survival using a Cormack-Jolly-Seber (CJS) open mark-recapture model in Program MARK (White and Burnham 1999). The assumptions of the CJS model include no tag loss, marked fish are representative of the population, marking and releases occur over relatively short time periods (relative to the intervals between tagging), equal probability of recapture of all marked fish, fates of individuals are independent (i.e., no schooling), and that individuals within groups have similar recapture and survival probability (Pollock et al. 1990). We considered it unlikely that our dataset violated any assumptions of the CJS model as PIT-tag retention is typically high in bull trout mark-recapture studies (~93%; Al-Chokhachy and Budy 2008), bull trout are not known to school outside of spawning season, and we have no inference to suggest unequal capture probabilities or differences in survival within subadults and adults. Furthermore, former analyses of goodness-of-fit of the mark-recapture data from Eagle Cliff (Program RELEASE; Cooch and White 2018) suggested assumptions of the CJS model were met (Al-Chokhachy et al. 2019).

For the second approach, we combined the mark-recapture information from the PIAs in 2019 with previous mark-recapture data (2011 – 2017) to estimate subadult (<450 mm) and adult bull trout (≥450 mm) survival. Given the need to account for complex movement patterns in survival estimates and to avoid bias associated with apparent survival estimates (e.g., Cormack-Jolly-Seber; Bowerman and Budy 2012; Conner et al. 2015), we estimated survival using the Barker model which accounts for emigration and thus provides estimates of "true" survival. The Barker model allows for recapture information from additional sources (e.g., PIA recaptures) that occur between sampling events (e.g., active annual gill-net sampling), which often leads to reduced bias and increased precision in survival estimates (Conner et al. 2015). The Barker model is described in detail elsewhere (Conner et al. 2015) and has been used to estimate survival of salmonids with high precision. Here, we included all PIT-tag recapture information available from PIAs as well as recaptures during any collections associated with the Swift Dam operations. We used an age-structured model where we included all bull trout >300 mm at marking and transitioned all individuals to adults (>450 mm) based on previous growth analyses (Al-Chokhachy et al. 2019). We used multi-model framework to calculate survival (Burnham and Anderson 2002) and considered survival models differing by time and age (sub-adult and adult).

Annual population monitoring

We used two indices of abundance to evaluate temporal trends in the population above Swift Dam each year. Both approaches are commonly used to monitor bull trout populations (Meyer et al. 2014; Kovach et al. 2018).

Snorkel surveys. —Snorkel counts were conducted each summer at known staging areas on the Lewis River proximate to the major spawning tributaries including near the mouth of Pine Creek, Rush Creek, and the Muddy River and the section between the Muddy River and Pine Creek. Each year, snorkel surveys were conducted approximately weekly beginning in mid-summer and continuing through mid-autumn. Based on previous analyses and the timing of bull trout migration (see below), snorkel counts in 2019 began earlier than previous years (year day 199; 18-July) and continued until 1-October. However, we constrained all summaries herein to snorkeling efforts completed prior to 7-September (day of year 250) to focus surveys on fish prior to- and during the spawning migration (see below; Figures 6, 14). During surveys 3 snorkelers floated downstream staying lateral and equidistant to each other and enumerating all bull trout >450 mm in their lanes (Brenkman et al. 2012). Survey data were recorded on underwater slates.

We considered two separate metrics for the snorkel survey data as it remains unclear as to the most robust metric for evaluating trends. First, we evaluated the trend of the maximum total number of bull trout observed across sections on a survey date by year. In addition, we calculated the temporal trends of the median counts across all weekly surveys within a year. We estimated bull trout population growth rates (λ) for each metric using the exponential growth state space model (EGSS) with restricted maximum likelihood (Humbert et al. 2009). The EGSS is a flexible approach that allows for estimating population trends from data that can span short time periods (i.e., <10 years). The confidence intervals in the EGSS models are generally more accurate compared with simple, exponential trend analyses (Humbert et al. 2009; Meyer et al. 2014). State space models have been effective in quantifying trends for bull trout populations in numerous studies (Meyer et al. 2014; Al-Chokhachy et al. 2016). For all analyses we used a conservative significance value (α = 0.10) due to the potential implications of Type II errors for a species such as bull trout, which is listed under the Endangered Species Act (Brosi and Biber 2009).

Redd count surveys. —We also evaluated the temporal trends of the bull trout population using data from annual redd count surveys. Annual redd surveys were conducted using standard approaches for salmonid and bull trout monitoring. Surveys were conducted approximately weekly, depending upon available personnel. During each survey one or two surveyors proceeded upstream enumerating and georeferencing all redds. Newly constructed redds were marked with flagging, making note of previously flagged old redds to assess visibility of redds. If redds were no longer visible, flags were removed.

We focused our analyses on P8 as redd count surveys have been consistently completed in P8 since 2008. Similar to snorkel survey trend estimation, we used the EGSS to estimate bull trout population growth rate (λ) based on the redd data from P8 and an alpha value of 0.10.

Because of the potential difficulties of identifying bull trout redds (Al-Chokhachy et al. 2005) and implications of observer errors in trend analyses (Muhlfeld et al. 2006), we continued the observer error study that was initiated in 2018 during 2019. Here, we used repeat redd surveys in each of the spawning tributaries including P8, Pine Creek from P3 to P8, Rush Creek, and Cougar Creek (Yale Lake). Surveys were conducted by two personnel each visit. The first surveyor proceeded upstream based on standard redd monitoring procedures enumerating all new redds (see above), but this first surveyor did not mark redds with flagging. A second surveyor proceeded a minimum of 30 minutes after the first surveyor to ensure that the first surveyor was not in visual contact. The survey methods for second surveyor were identical to the standard redd survey methods.

Given the hydrologic and geomorphic differences of the streams, we quantified observer error by stream and considered both the coefficient of variation (CV) and signal to noise (Kaufmann et al. 1999). Here we calculated the signal to noise as the ratio of the variance of the average counts (across observers) over all surveys in a stream divided by the variance of the counts across observers and surveys in a stream (Whitacre et al. 2007). In general, higher signal-to-noise values result in greater power to detect change through time in monitoring, and signal-to-noise values <2 indicate low precision to detect change and values approaching 6 and higher indicate noise is unlikely to affect ability to detect change. We then used the CV values to determine the power to detect changes in abundance through time. We integrated the CV values in a power analysis (Gerrodette 1987) to consider the statistical power to detect different changes (% change) over twenty years in each of the streams ($\alpha = 0.10$; two-tailed; Package fishmethods, R CoreTeam 2012).

Results and Discussion

Bull trout spawning migrations

During 2019, 103 bull trout were marked or recaptured during sampling surveys at Eagle Cliff. Of this total, 73 were newly marked individuals, 11 were individuals marked in previous years, and 19 fish were captured multiple times during the sampling season. The median size of bull trout captured was 583 mm, which was the second highest measure since 1997 (Figure 2). Overall, the median sizes of bull trout have varied considerably across years. As expected, the number of newly marked bull trout was high and the number of recaptures across years low, due to the lack of marking and recapture efforts in 2017 and 2018 (Figure 3). Nearly 15% of the fish captured during 2019, were captured multiple times during the sampling season with one fish being captured 4 times.

Of the total number of bull trout marked or recaptured with PIT tags at Eagle Cliff (n = 85) in 2019, 52 (61%) were detected at the PIAs in Pine Creek and P8. When considering P8 only, where the PIA has operated near continuously since 2012 (i.e., during the spawning season), it is apparent that a large portion of bull trout marked or recaptured at Eagle Cliff used Pine Creek and P8 each year (Figure 4).

The date of upstream spawning migration into Pine Creek has varied across years (Figure 5A). In 2019, the median date of upstream migration was 8-August (day of year = 220), which was nearly two weeks earlier than the median across years (day of year = 231). The median date of upstream migration was strongly correlated with average August air temperature ($r = 0.81$), suggesting that during warmer years bull trout migration is later in the season—a pattern generally consistent with recent research indicating that the timing of bull trout spawning is influenced by stream temperature (Austin et al. 2019). The median date of downstream migration was 1-October (Day of year in 2019 = 274; Figure 5B) which again was six days later than the median across years (Day of year = 268). Across all years, the majority of upstream migrations typically occur prior to 7-September (day of year = 250) and all downstream migrations have occurred prior to 1-November (Figure 6).

Using bull trout that spawned in P8 as an indicator of time spent pre- and post-spawning, it is clear that bull trout migrate into Pine Creek likely “stage” well before migrating into P8 and/or spawning (Starcevich et al. 2012). Across years, bull trout used 25 days (median; range = 2 - 54) to migrate from Pine Creek to P8 (Figure 7A). However, downstream migration was considerably more rapid (median = 1 day; range = 0 – 27; Figure 7B), a pattern consistent with large adfluvial bull trout in Idaho (Monnot et al. 2008). The rapid migration pattern is in contrast to spawning migration studies of fluvial bull trout in Washington, where bull trout can remain in streams for months (Nelson 2014). It remains unclear what influences downstream spawning migrations, but may be driven by a combination of biotic and abiotic factors (Barnett and Paige 2013) as well as the ability to recover post spawning.

Merging the migration data from 2019 with previous years, we found very few bull trout spawn multiple times (as suggested from migrations; Figure 8). Since 2011, a large portion (44.5%) of the marked fish have never been detected migrating, while 24.2% only spawned once. Only 15.0% have migrated more than two times, however, we do acknowledge that this estimate may be biased low due to imperfect detection and operation of PIAs.

Understanding the size/age at sexual maturity of bull trout in the North Fork Lewis River is important for assessments of the size of the spawning population. Based on the size at marking at Eagle Cliff and migration data, we find that the proportion of fish spawning (based on migration) increases with size (Figure 9), a pattern consistent with other potadromous salmonids (Downs et al. 1997). Specifically, we found that although bull trout as small as 356 mm make spawning migrations, only 6% of individuals <450 mm made spawning migrations during the year of tagging. Recent analyses indicated the probability of spawning increases substantially near 450 mm (Al-Chokhachy et al. 2019). Our result indicated 45% of fish between 450 mm and 600 mm and 91% of fish >600 mm made spawning migrations during the year of tagging.

Bull trout survival

Analyses including both subadult (≤450 mm) and adult fish resulted in numerous values that were not able to be estimated; as such we proceeded with analyses using adult only data (i.e., fish >450 mm). Estimates from the CJS mark-recapture data from Eagle Cliff (Figure 10) indicated the greatest support for time-varying estimates of survival and a constant estimate of capture probability (p = 0.26; SE = 0.03) for bull trout in the North Fork Lewis River. Our results illustrated high interannual variability since the start of the time series (Figure 10). Apparent survival from 2016 to 2019 was considerably higher than the median estimate of apparent survival (median = 0.45; range = 0.07 to 0.80).

Mark-recapture analyses from the Barker analyses suggested two plausible models (i.e., ∆AICc <4) describing bull trout survival (Table 1). The top model with the most weight (*Wi* = 0.73) indicated survival to vary by year, but no differences in survival between subadults and adults. The next best model (∆AICc = 2.0, *Wi* = 0.27) suggested differences in survival across subadults and adults that varied additively across years. The results from the top model are presented, given it is more parsimonious (Burnham and Anderson 2002). Our results from this analysis are inconsistent with previous analyses (Al-Chokhachy et al. 2019), which suggested differences in survival between subadults and adults. Differences in survival by age class is also suggested in the second most supported model (Table 1), where subadult survival was slightly higher than adults, but confidence intervals overlapped substantially (not shown). The disagreement in survival by groups may be due to inherent differences in the mark-recapture datasets (i.e., active marking and recapture and PIA recapture data) as well as the time series of data, which is considerably shorter here than in Al-Chokhachy et al. (2019). Furthermore, we do acknowledge that our resight estimates at the PIAs for the subadult group was low (R; <0.15), which can limit the accuracy of survival estimates (Conner et al. 2015). The low recapture rates at the PIAs is likely due to the small proportion of this size class making spawning migrations (see above and Figure 9).

As anticipated, the survival estimates from the Barker model were substantially higher than the apparent survival estimates from the CJS analyses (Bowerman and Budy 2012). Similar to the CJS analyses, the survival estimates varied significantly through time with survival during 2013, 2015, 2016, and 2019 significantly lower than 2011, 2012, and 2014 (Figure 11). The high variation in survival is surprising, given the stable reservoir environment (*sensu* Kovach et al. 2016). Across years with reasonable confidence intervals (SE< 0.10; 2011 – 2015), bull trout survival varied from 0.50 to 0.92. Adult survival in Swift Reservoir population is higher than found for fluvial populations (Al-Chokhachy and Budy 2008). Estimates from 2011, 2012, 2014, and 2016 were consistent with estimates of adfluvial bull trout in Canada (Johnston and Post 2009), but survival during all other years was markedly lower. At this point it is unclear what may be causing the observed fluctuations in survival, and further investigations are warranted. Furthermore, it is unknown if temporary emigration is driving the large differences in apparent survival and survival, which also varies by year (Figures 10, 11). As expected, recent survival estimates (2018) demonstrate wide confidence intervals, which will likely improve with additional years of data to extend encounter histories and update capture probabilities.

Annual monitoring

Snorkel surveys. —Results from annual snorkel surveys indicated inconsistent patterns across snorkel locations. Both median counts and maximum counts indicated general declining trends at the confluences of Rush Creek and the Muddy River and the North Fork Lewis River (Figure 12), while no apparent trends were evident at the Pine Creek confluence. Both maximum and median counts were highest in Rush Creek in 2019, a pattern opposite to that from snorkel data in 2018. The highest numbers of bull trout counted near Rush Creek are also in contrast with the contemporary redd count data and PIT-tag movement, which both indicate relatively low numbers of bull trout currently spawning in Rush Creek (not shown).

The median annual counts indicated considerable differences in the interannual variability of snorkel counts. Across sites, the lowest variability was found at the Rush Creek (CV = 32) and Muddy River sites (CV = 34), moderate variability was evident at Pine Creek (CV = 67), and highest variability at the Muddy to Pine site (CV = 93), albeit with low overall numbers each year at the Muddy to Pine site. At least part of the variability in annual counts may be driven by the large differences in the number of bull trout observed during any given survey (Figure 11). Indeed, bull trout movements during the spawning season can be complex (e.g., Barnett and Paige 2013) and it remains unclear how fish move among the different sites to feed or stage for spawning.

Global trends of snorkel surveys from 2011 to 2019 suggested generally consistent patterns (Figure 13). Despite declining numbers from median and maximum counts (both λ estimates were <1), the temporal trends were not significant. We found high variability in the estimates and confidence intervals overlapped one for both the median counts (λ = 0.96; CI = 0.91 – 1.02) and the maximum counts (λ = 0.93; CI = 0.87 – 1.02). Together, these estimates suggest the population has been relatively stable over this period.

Continuing to refine monitoring methods to reduce bias and increase precision is warranted. For example, closer examination of the date of upstream and downstream emigration suggests temporal overlap in pre- and post-spawn bull trout may confound snorkel surveys (Figure 6). Minimizing the potential of double-counting bull trout, which affects median count estimates, would limit the duration of snorkel surveys to where most adults are counted prior to upstream migration and relatively few post-spawning adults are present. Data from PIT-tagged individuals suggest constraining snorkel surveys to dates prior to year day 251 (8-Sepember), which is where 90% of bull trout historically have migrated upstream (Figure 14). Given the plethora of historical data in the Lewis, there is an ample amount of information to improve monitoring approaches.

Redd counts. —In 2019, 51 bull trout redds were documented in P8, the highest documented since surveys were initiated in 2008. We eliminated data from 2016 in our trend analyses where counts were cut short by high discharge and low water clarity. Temporal trend analyses indicated bull trout redd counts have increased significantly since 2008 (λ = 1.11; 95% CI = 1.03 – 1.20; Figure 15). Despite the increasing trends in P8, there is uncertainty regarding the trend in the total number of spawners in the Swift population as long term redd counts are not available in Pine Creek and Rush Creek. During 2019, 110 bull trout redds were counted in Pine Creek, which was markedly higher than 2018 (n = 88) and is consistent with increases in P8. Continued monitoring in each of the spawning tributaries (I.e., P8, Pine Creek, and Rush Creek) will provide more comprehensive estimates of trends at the population level.

Considering the redd count trends in P8 with trends from migration data and snorkel surveys suggest there is uncertainty in the most robust metric for monitoring the overall bull trout population above Swift Dam. For example, the P8 redd data since 2012 were strongly correlated with the number of migrants to P8 (Pearson Correlation, $r = 0.82$). However, we acknowledge that this is based on a relatively small sample size ($n = 5$ years of comparable data) and further analyses are needed. Concomitantly, the snorkel survey trends (Figure 13) also do not align with the increasing trends observed in P8. These differences illuminate the need for continued monitoring of multiple metrics to identify the appropriate monitoring methods (*sensu* Falcy et al. 2016).

Observer error studies for bull trout redd surveys suggest sampling error can be high and differ by stream (Dunham et al. 2001), a pattern consistent with our results. Our results indicated high correlations in redd counts between observers (Pearson Correlation, $r = 0.88$; Figure 16). However, estimates of signal to noise (S:N) suggested relatively low ability to detect changes in abundance using redd counts (S:N range = 0.93 to 1.05) through time. The low S:N values are likely driven by the similarity in counts across surveys (i.e., small signal) and we urge caution in interpreting these results. Estimates of CV also indicated differences in observer error across streams with the highest variation between observers (excluding zero-count surveys) in Rush Creek, moderate inter-observer variation for Pine Creek, and the lowest variation in P8 and Cougar Creek (Figure 17). The differences are likely due to reduced visibility from high turbulence in Rush Creek and Pine Creek as well as the size of the streams, as P8 is considerably smaller.

The differences in observer error by stream suggest the power to detect changes in relative abundance will vary as well. Indeed, analyses suggest the power to detect 25% declines in Cougar Creek and P8 Creek over 20 years would be 0.85 and 0.74, respectively (i.e., there is a 0.15 and 0.26 probability of a type II error, which is the failure to detect a change, when a change has occurred), but would drop to only 0.54 for Pine Creek and 0.17 for Rush Creek (Figure 18). The observer errors in the Lewis were generally lower than observed by Dunham et al. (2001), but together with the high interannual variability found in many bull trout populations (Rieman and Myers 1997; Kovach et al. 2016) suggests detecting even modest changes in Pine Creek and Rush Creek may be difficult. Maintaining consistent, well-trained observers will certainly increase the ability to detect changes through time (Muhlfeld et al. 2006). Continuing to monitor with redd counts is highly recommended as redd surveys are cost-effective, minimally invasive, and have been demonstrated to be instrumental in understanding how intrinsic and extrinsic factors drive bull trout population dynamics and population trends (Kovach et al. 2016; Meyer et al. 2014).

Monitoring Summary

The difference in trends across the metrics illustrates the uncertainty in identifying which metric is the most robust for monitoring and the need for continued corroboration among monitoring methods (i.e., redd counts, abundance monitoring). However, we acknowledge the challenges of cross-walking data types. For example, redd surveys represent the number of known spawning events, whereas snorkel surveys represent potential spawners as not all bull trout may spawn in a given year (Johnston and Post 2009). In the Lewis River, it appears that the proportion of adult bull trout (i.e., >450 mm) that spawns within a given year generally increases with size and age (Al-Chokhachy et al. 2019). This discrepancy may hinder the inferences of cross-walking different monitoring data types and suggests the need for considering multiple metrics.

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Table 1. The results from the mark-recapture analyses (Barker model; 2011 to 2019) including model structure, Akaike Information Criterion scores (corrected for small sample size), model weights (*Wi*), the number of parameters (*K*), and deviance considering the survival of subadult and adult bull trout in the North Fork Lewis River upstream of Swift Dam, Washington. Note: S is survival, *p* is capture probability during field sampling, *R* is the probability that a fish survived and was resighted alive between capture events; *R'* is the probability that a fish died but was resighted alive between capture events before dying, *F* is the probability that an animal at risk of capture at time *i* is at risk of capture at time *i* + 1 (i.e., has not emigrated), and *F'* is the probability that an animal not at risk of capture at time *i* is at risk of capture at time *i* + 1 (e.g., temporary emigration.

Model†	AICc	ΔAICc	W_i	K	Deviance
$S_{(t)}$, $p_{(t)}$, $R_{(g+t)}$, $R'_{(g+t)}$, $f_{(.)}$=$f'_{(.)}$	2,441.6	0	0.73	32	774.9
$S_{(g+t)}$, $p_{(t)}$, $R_{(g+t)}$, $R'_{(g+t)}$, $f_{(t)}$=$f'_{(.)}$	2,443.6	2.0	0.27	33	774.8

† *t* is time (year), *g* is stage (i.e., subadult or adult), *"."* indicates no differences across time or stage.

Figure 1. The study area of the North Fork Lewis River upstream of Swift Reservoir indicating the known major bull trout spawning tributaries Pine Creek, P8, P3, and Rush Creek. Also shown is the location of Eagle Cliff where bull trout are sampled for mark-recapture analyses and the locations of the passive instream antennas (PIAs; grey circles). Black box in the inset illustrates the location of the study area within the Pacific Northwest, USA.

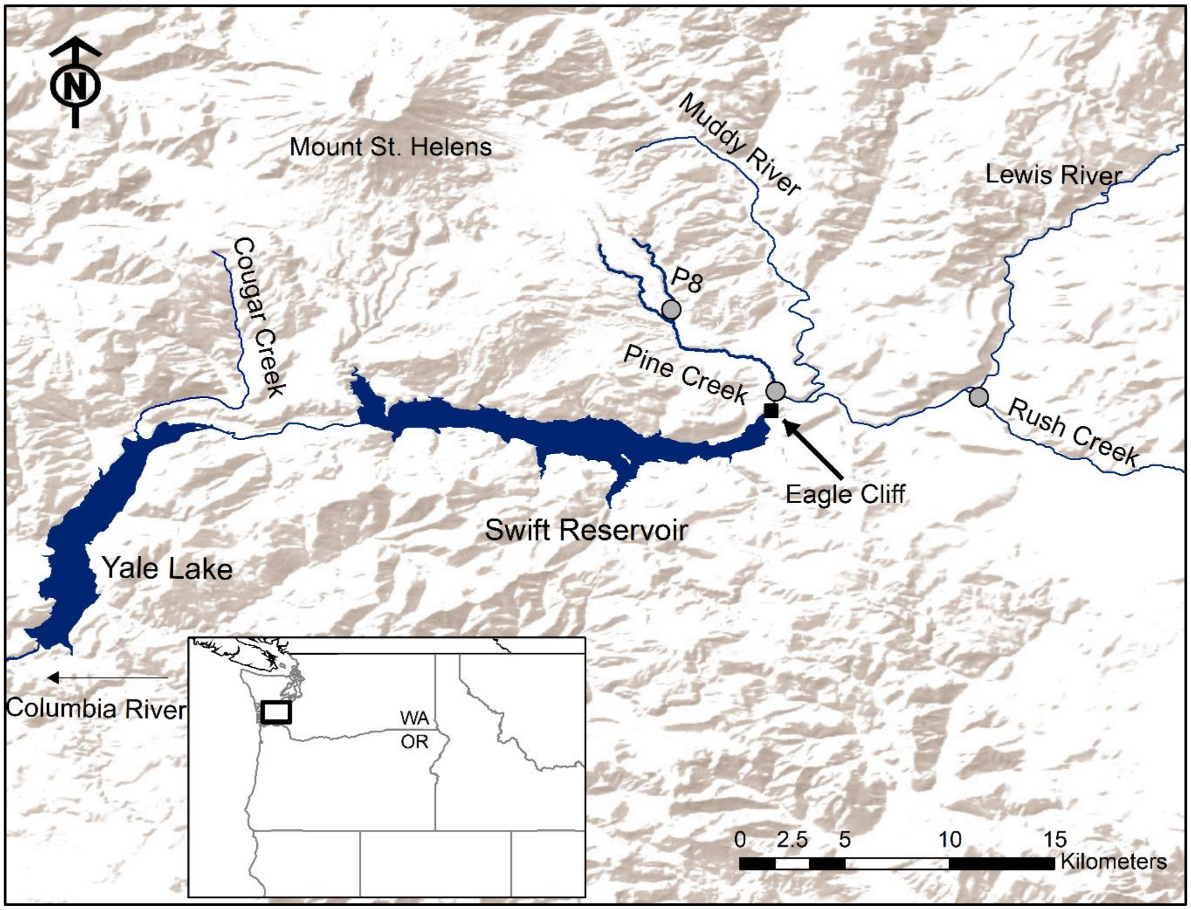


Figure 2. Boxplots of the size (total length) of bull trout captured and newly marked or recaptured from previous surveys at the Eagle Cliff sample site in the North Fork Lewis River, Washington. Boxes represent the 25th and 75th percentiles, the black line is the median, and the lines represent the 5th and 95th percentiles with the points as outliers. Sample sizes for each year are given below.

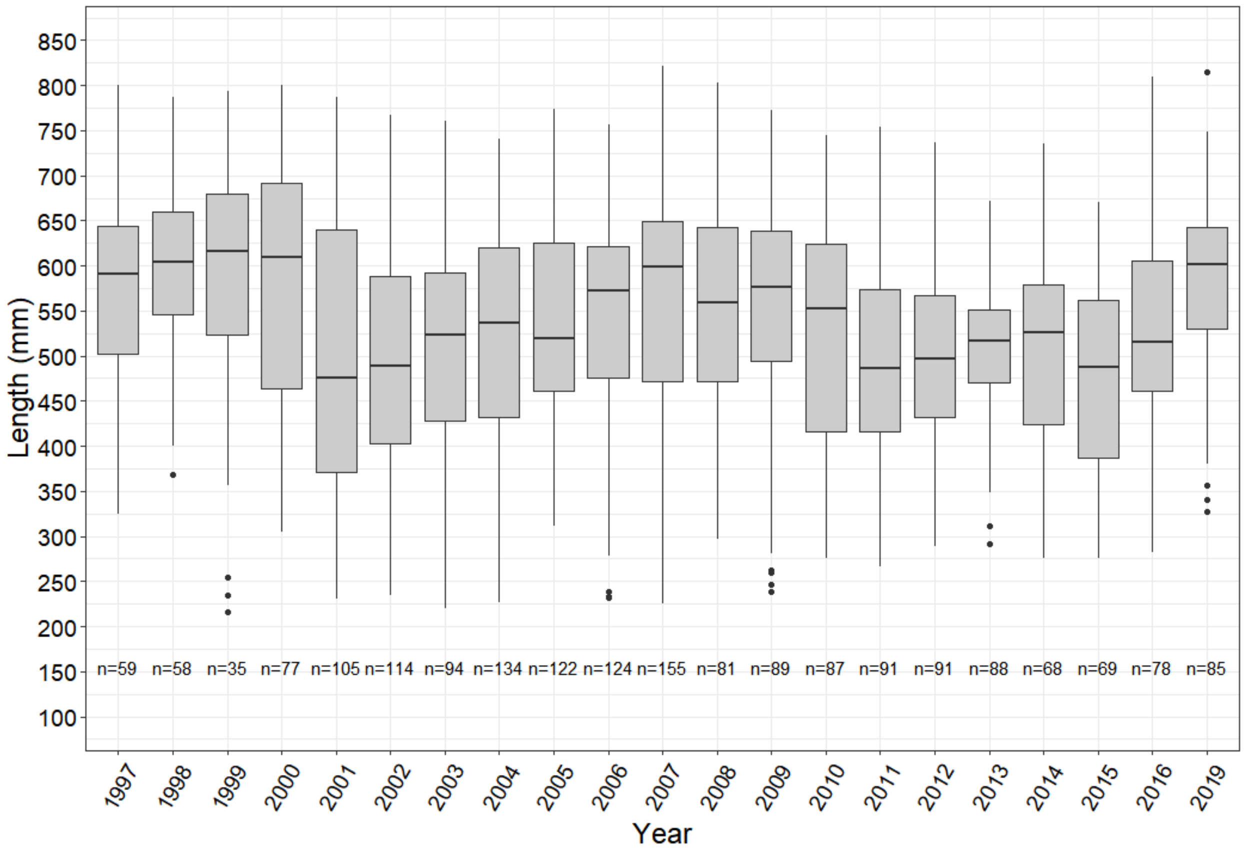


Figure 3. Counts of bull trout from mark-recapture surveys at Eagle Cliff on the North Fork Lewis River, Washington that were newly marked (i.e., not previously marked, “No”; black), recaptured from previous marking events (“Across”; white), and recaptured multiple times within a year (“Within”; red) since 1998. Note: no active sampling occurred in 2017 and 2018.

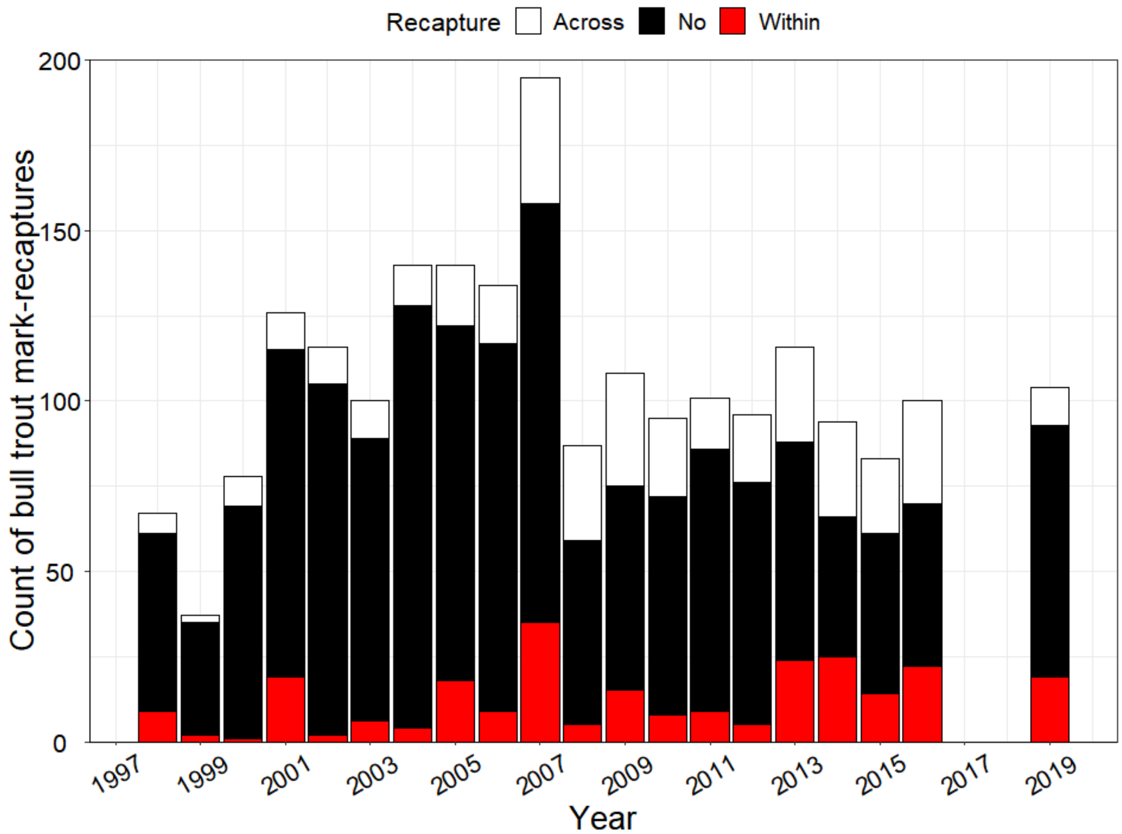


Figure 4. The proportion of bull trout marked or recaptured at Eagle Cliff in the North Fork Lewis River, Washington that were detected at the passive instream antenna (PIA) on P8 since 2012.

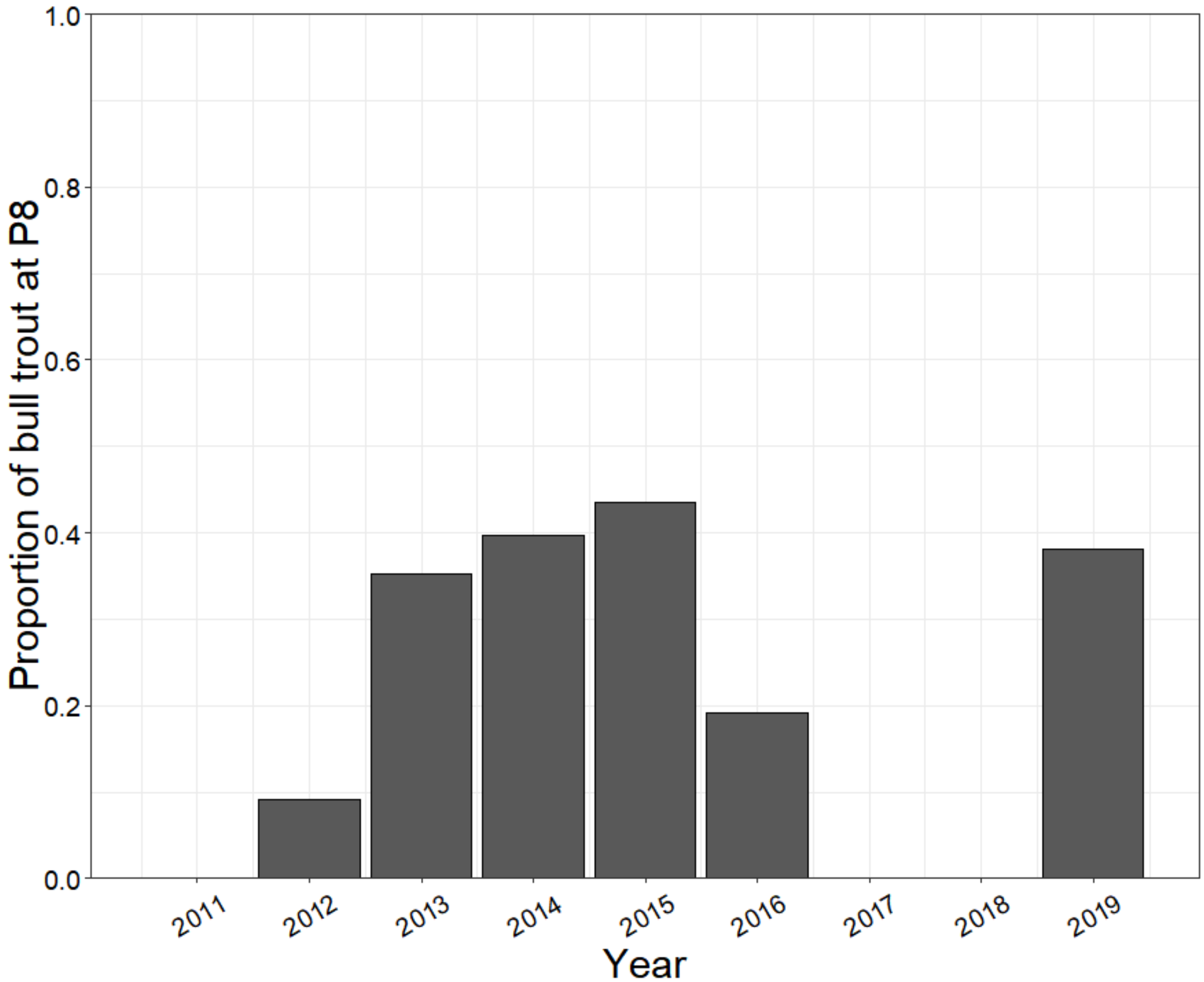


Figure 5. The day of upstream (A) and downstream (B) migration of PIT-tagged bull trout in Pine Creek (2011 – 2019) in the North Fork Lewis River, Washington with the dashed black line indicating the median date across years. For reference 8-August is the 220th day and 7-October is the 280th day of the year. Note: the small sample size in downstream migration in 2012 was due to the criteria used to quantify movement direction, and the few numbers of bull trout detected where downstream direction could clearly be identified by antenna detections.

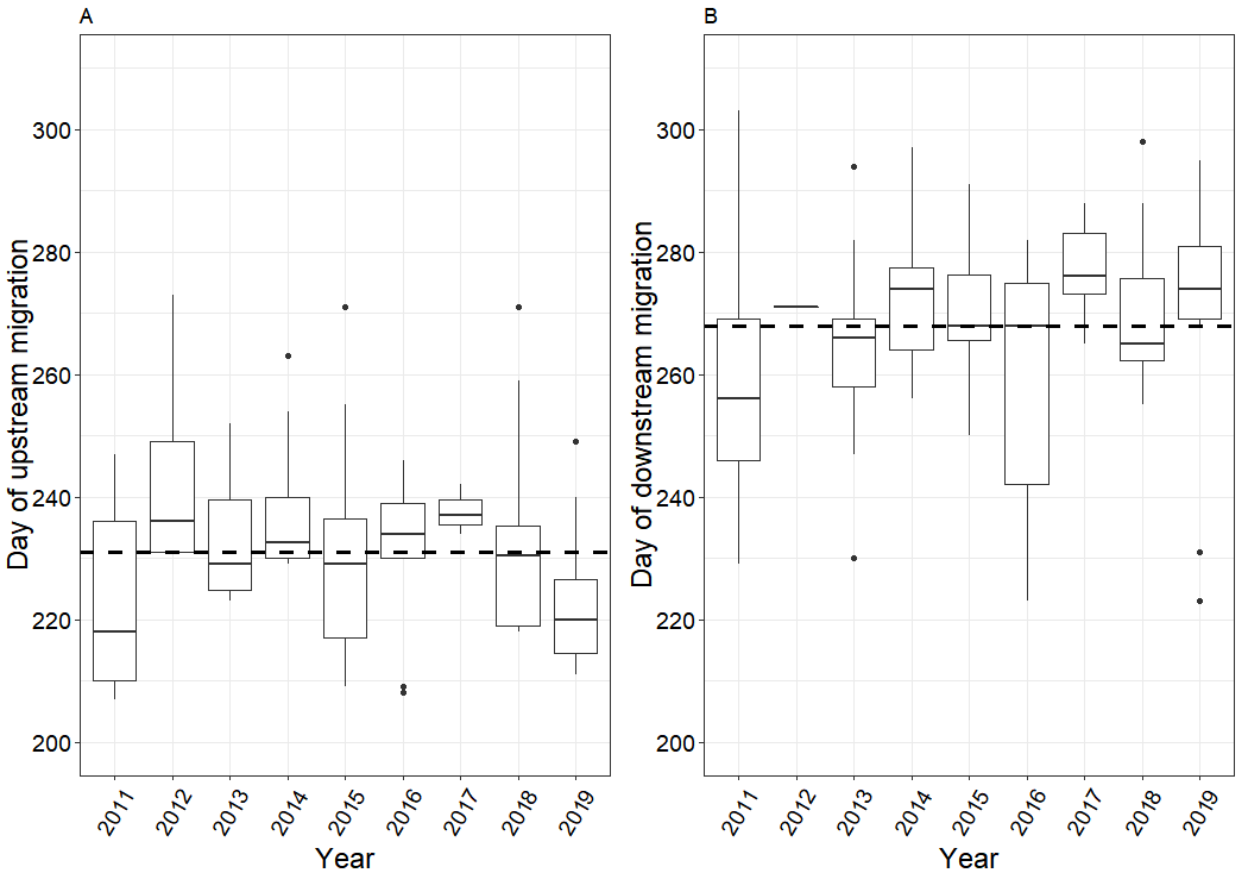


Figure 6. Histograms of the day of year of upstream (green) and downstream (red) migration of bull trout into tributaries based on PIT-tagged individuals detected at passive instream antennas (PIAs) in Pine Creek in the North Fork Lewis River drainage in Washington. For reference, day of year 225, 250, and 275 are 13-August, 7-September, and 2-October, respectively.

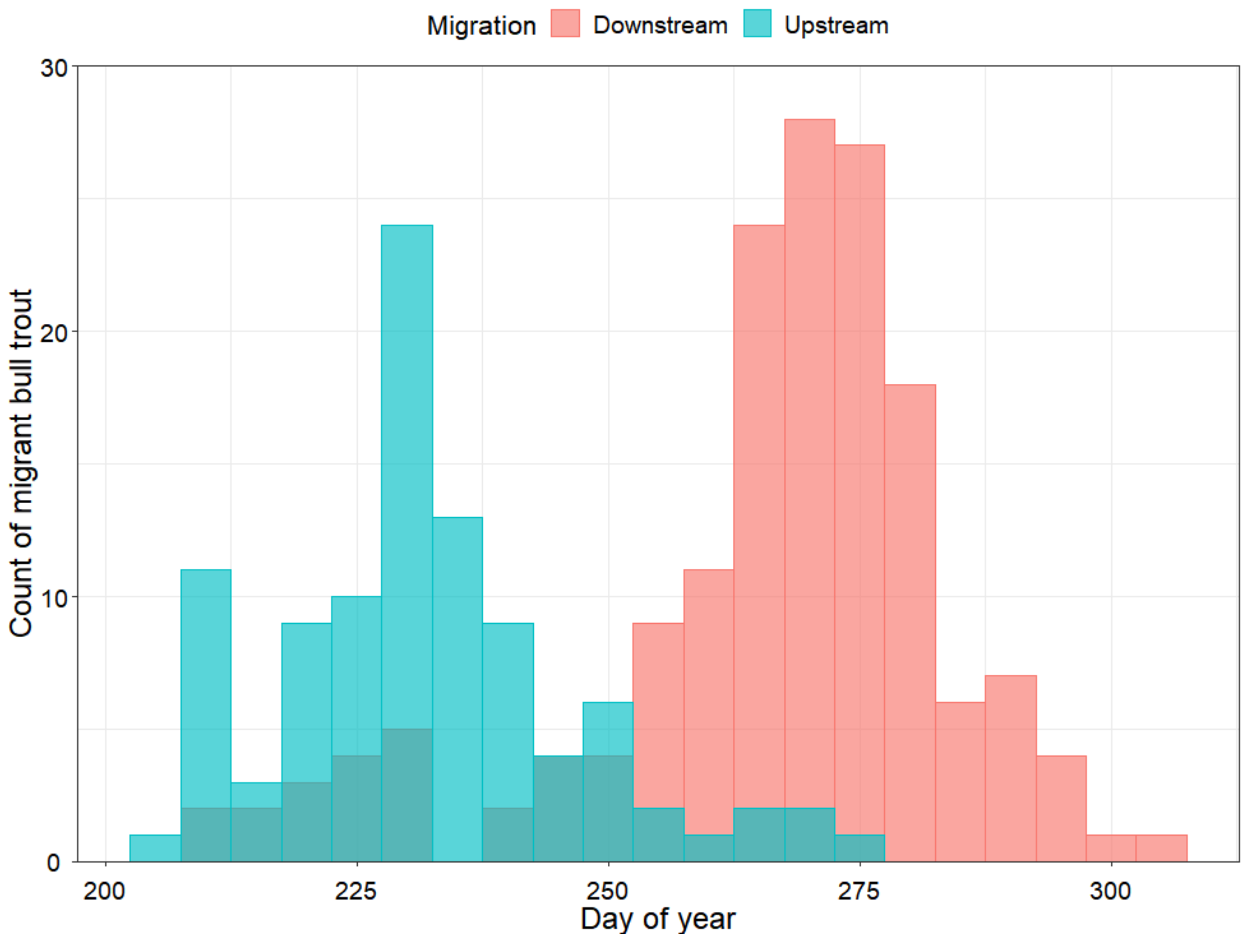


Figure 7. Yearly estimates of the duration of spawning migrations of PIT-tagged bull trout from passive instream antennas (PIAs) on lower Pine Creek upstream to P8 (i.e., pre-spawn migration; A) and from P8 downstream to Pine Creek (i.e., post-spawn migration; B), a tributary to the North Fork Lewis River, Washington.

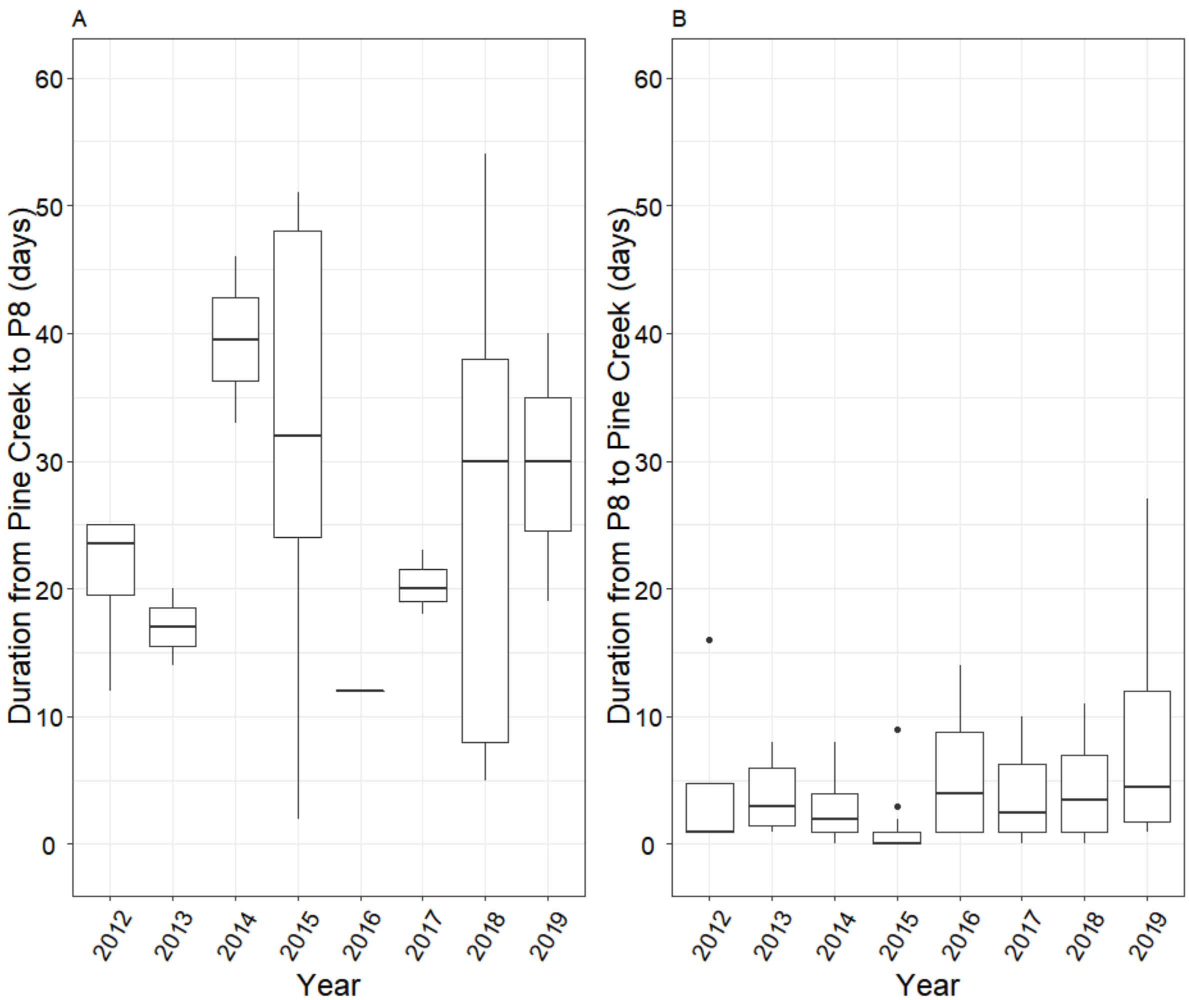


Figure 8. The frequency of the number of spawning migrations of bull trout into Pine Creek or Rush Creek in the North Fork Lewis River from PIT-tagged individuals and passive instream antenna (PIA) recaptures (2011-2018). Note: a zero indicates fish that have never been detecting making a spawning migration.

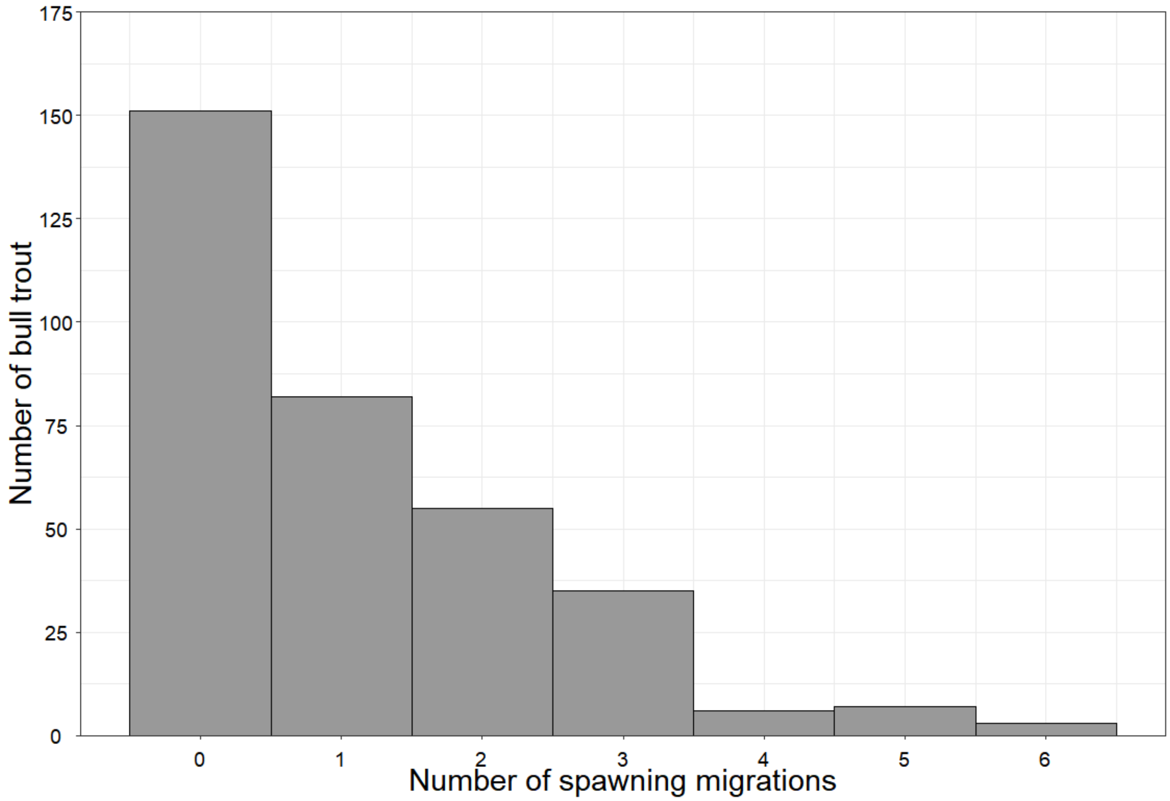


Figure 9. Bull trout that spawned during the year of marking (1; cyan) and did not spawn during the year of marking (0; red) by length in the North Fork Lewis River, Washington. Each dot represents an individual fish.

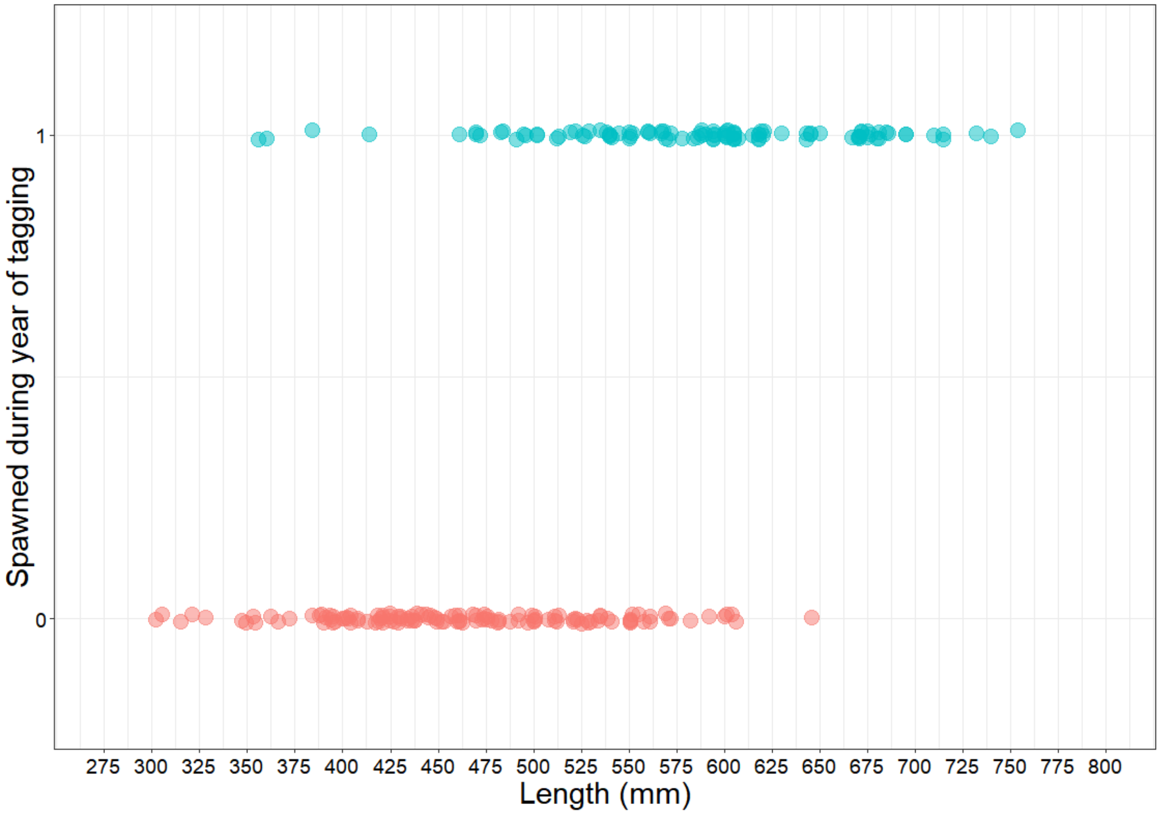


Figure 10. Annual estimates of bull trout apparent survival from marking and recapture data at Eagle Cliff on the North Fork Lewis River, Washington with the horizontal dashed line indicating the average across years (excluding the uninformative estimate in 2016).

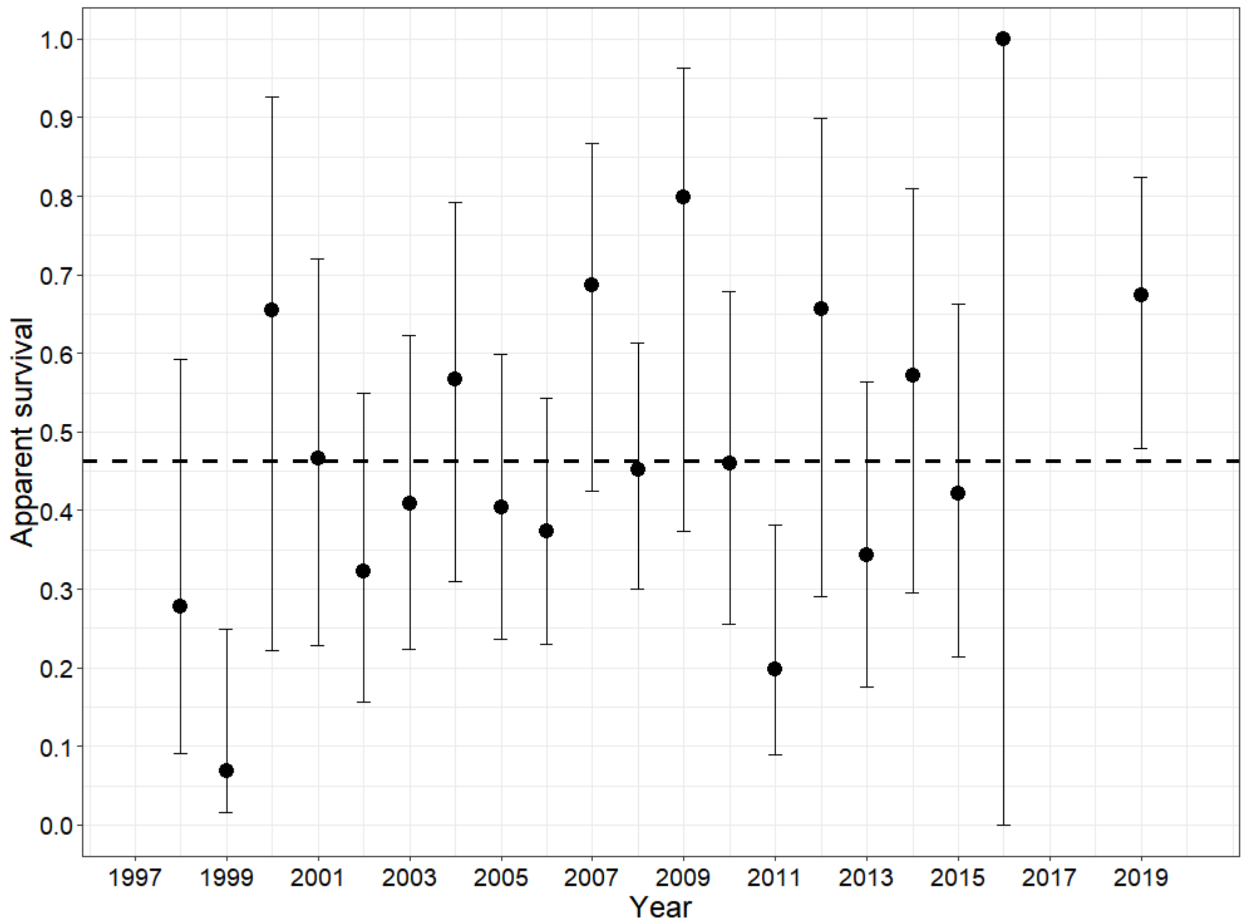


Figure 11. Estimates of annual bull trout survival (Barker model; adults [red] and subadults [green]) from mark-recapture sampling at Eagle Cliff and recapture data from the passive instream antennas (PIAs) within Pine Creek, Rush Creek, and Muddy River within the North Fork Lewis River, Washington.

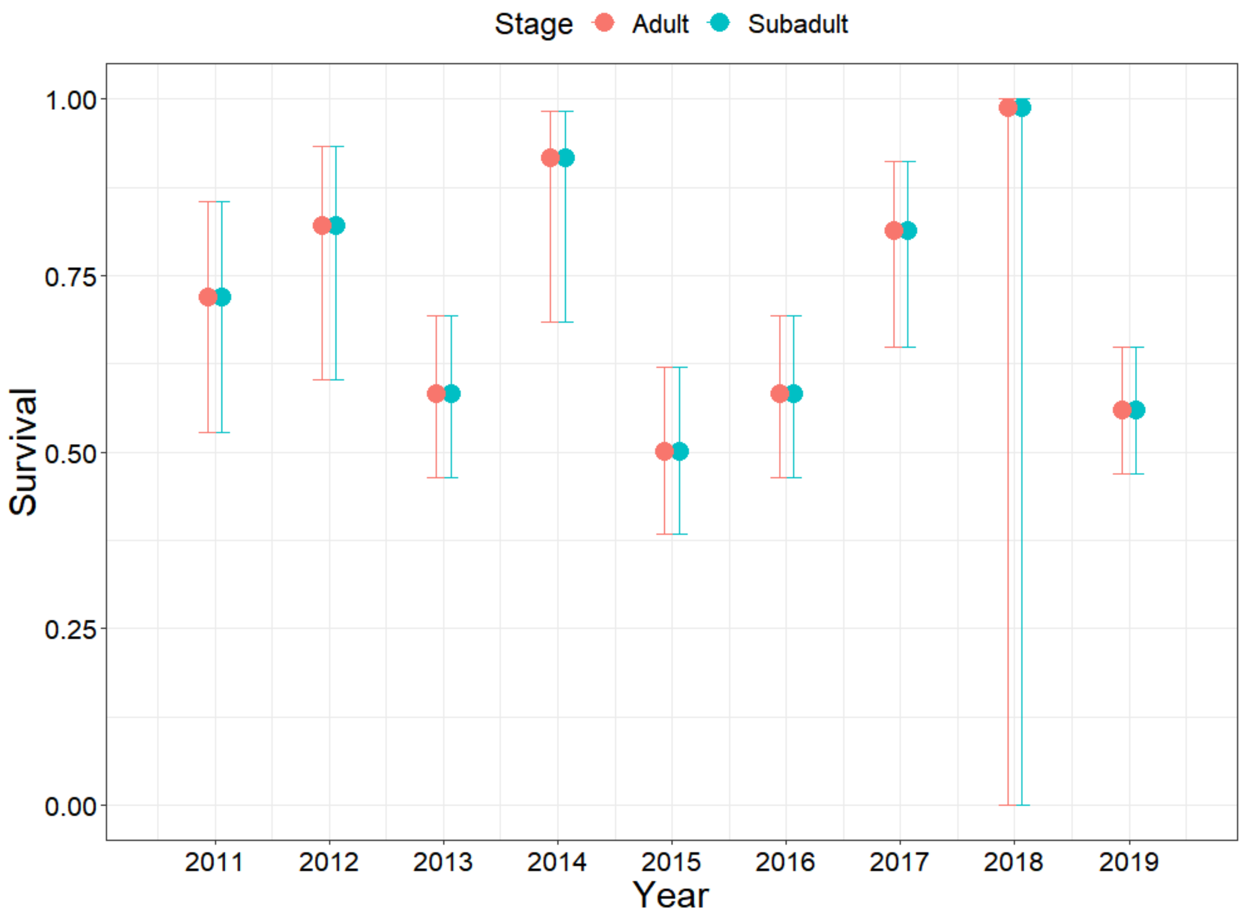


Figure 12. Median (A) and maximum snorkel counts (B) by year of adult bull trout (>450 mm) from the confluence of the North Fork Lewis River and the Muddy River (light grey), the North Fork Lewis River from Muddy River to Pine Creek (black), the confluence of the North Fork Lewis River and Pine Creek (blue), and the confluence of the North Fork Lewis River and Rush Creek (dark grey) in Washington. Note: only includes sampling from dates prior to the 250th day of year (7-September). Also, not difference in scale of y-axis in the figures.

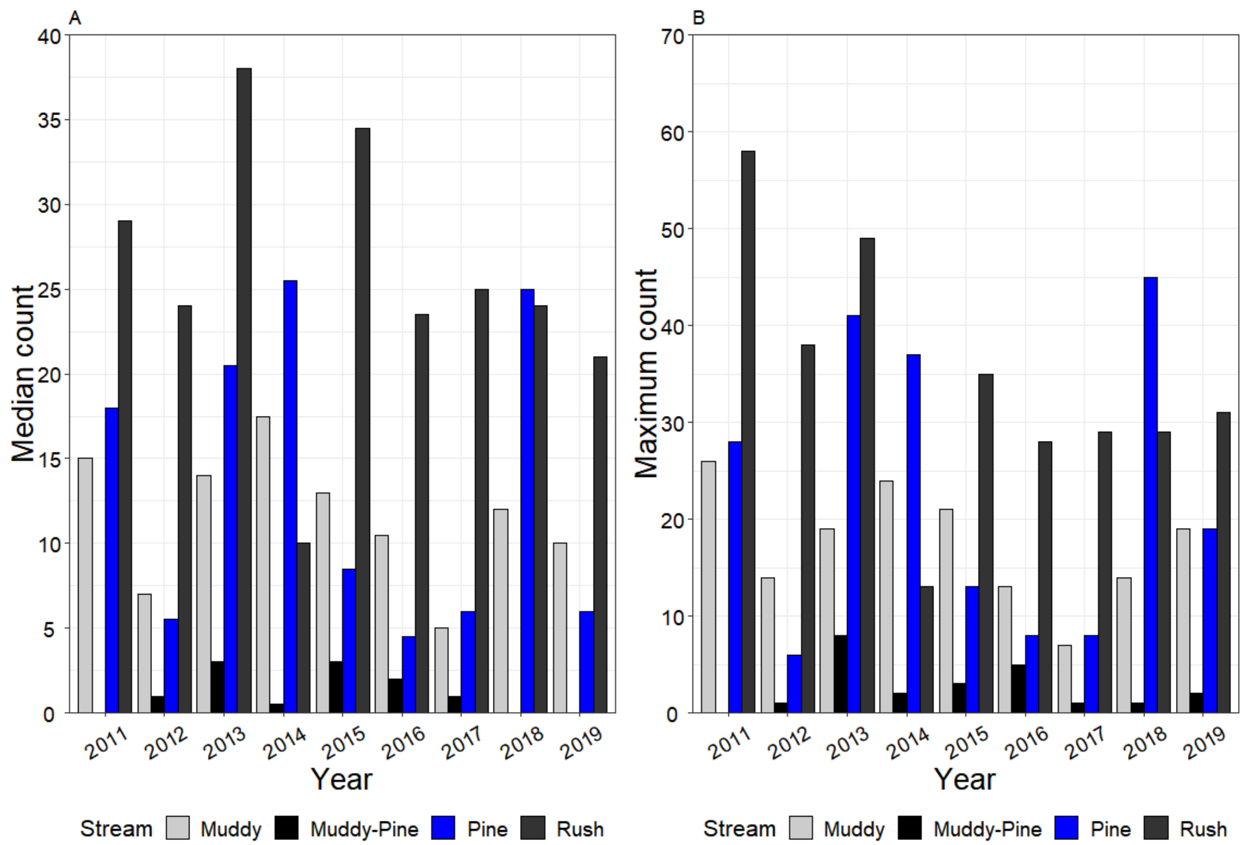


Figure 13. Trends of adult bull trout abundance from median (A) and maximum (B) snorkel counts (totaled across sites for each survey date) from the North Fork Lewis River, Washington from 2011 – 2018. The dashed lines indicate the linear trend and the shaded region indicates the 5th and 95th confidence intervals.

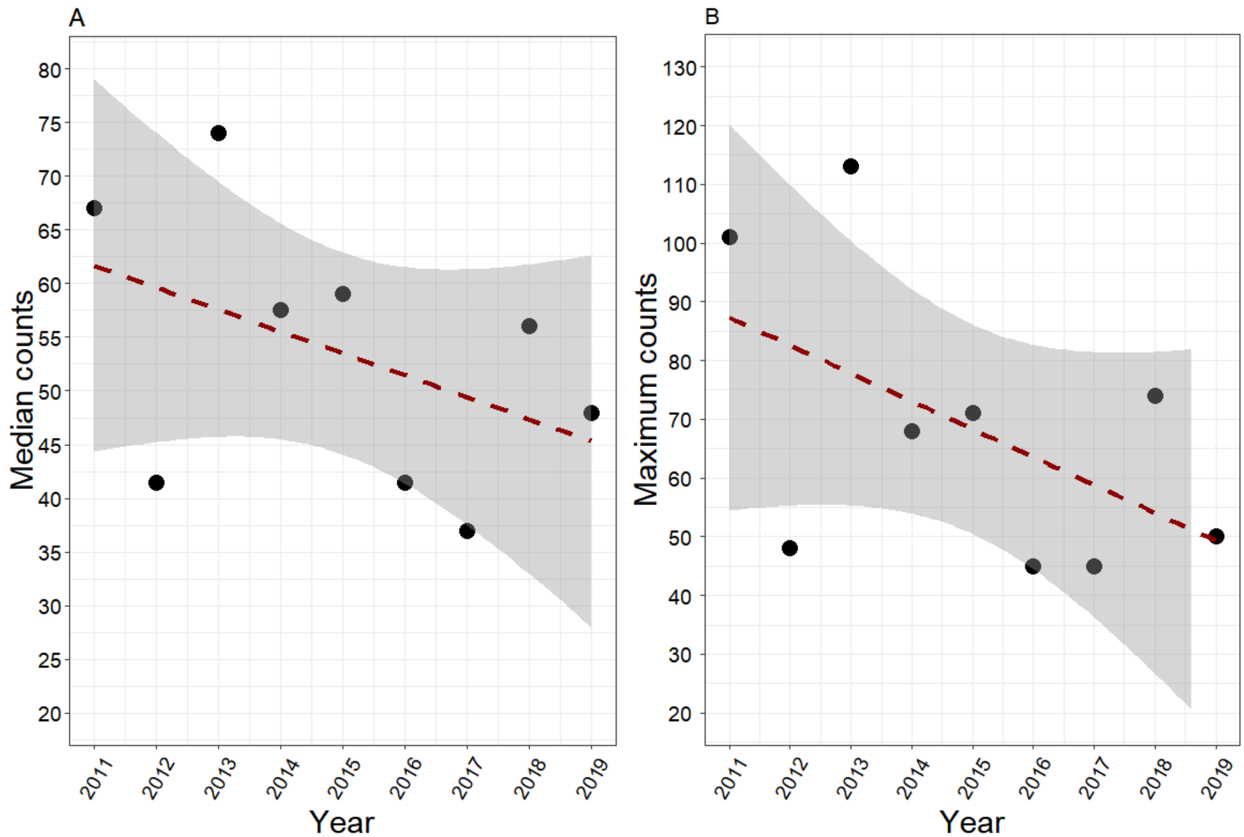


Figure 14. A cumulative frequency plot of the day of year of bull trout upstream migrations from PIT-tagged individuals detected at passive instream antennas (PIAs) on Pine Creek in the North Fork Lewis River in Washington. For reference day of year of upstream migration 220 and 250 are 8-August and 7-September, respectively

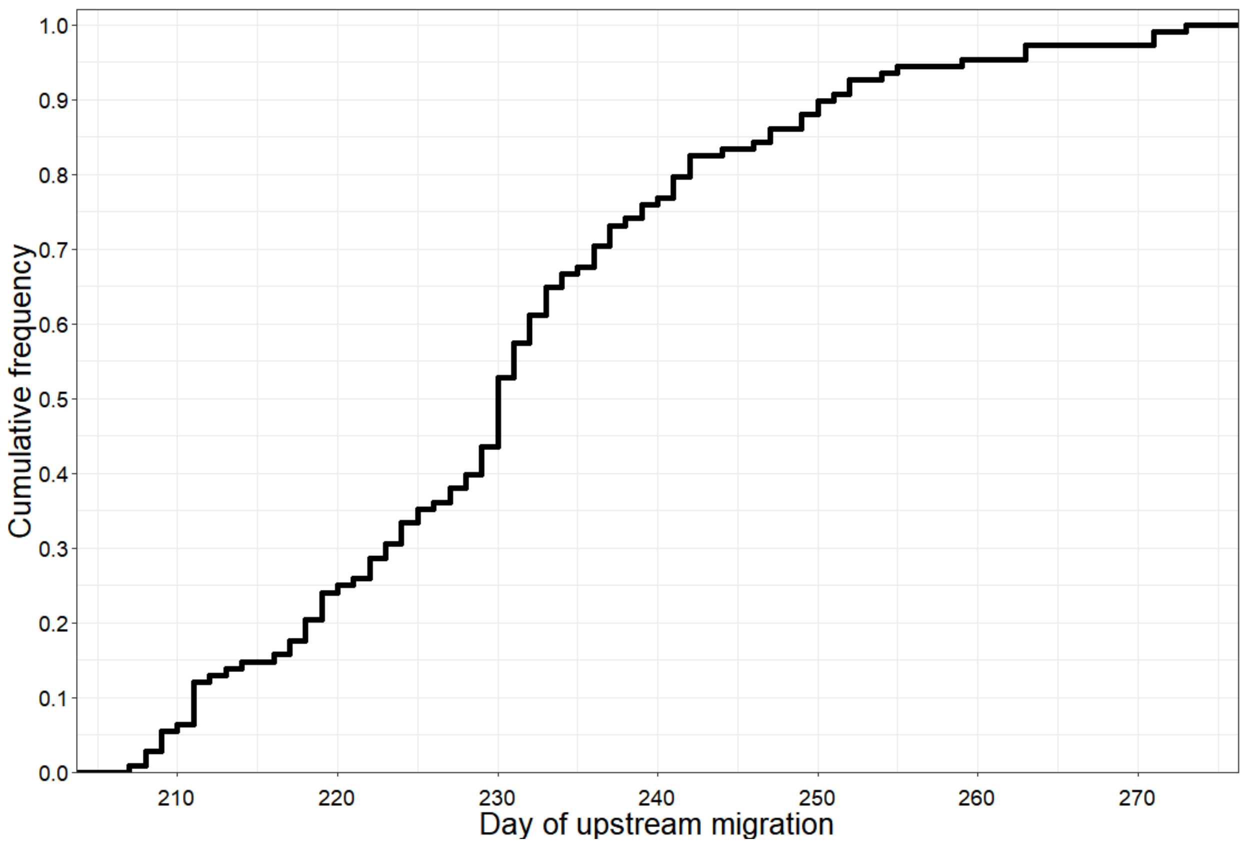


Figure 15. Total bull trout redd counts by year from P8, a tributary to Pine Creek in the North Fork Lewis River basin, Washington.

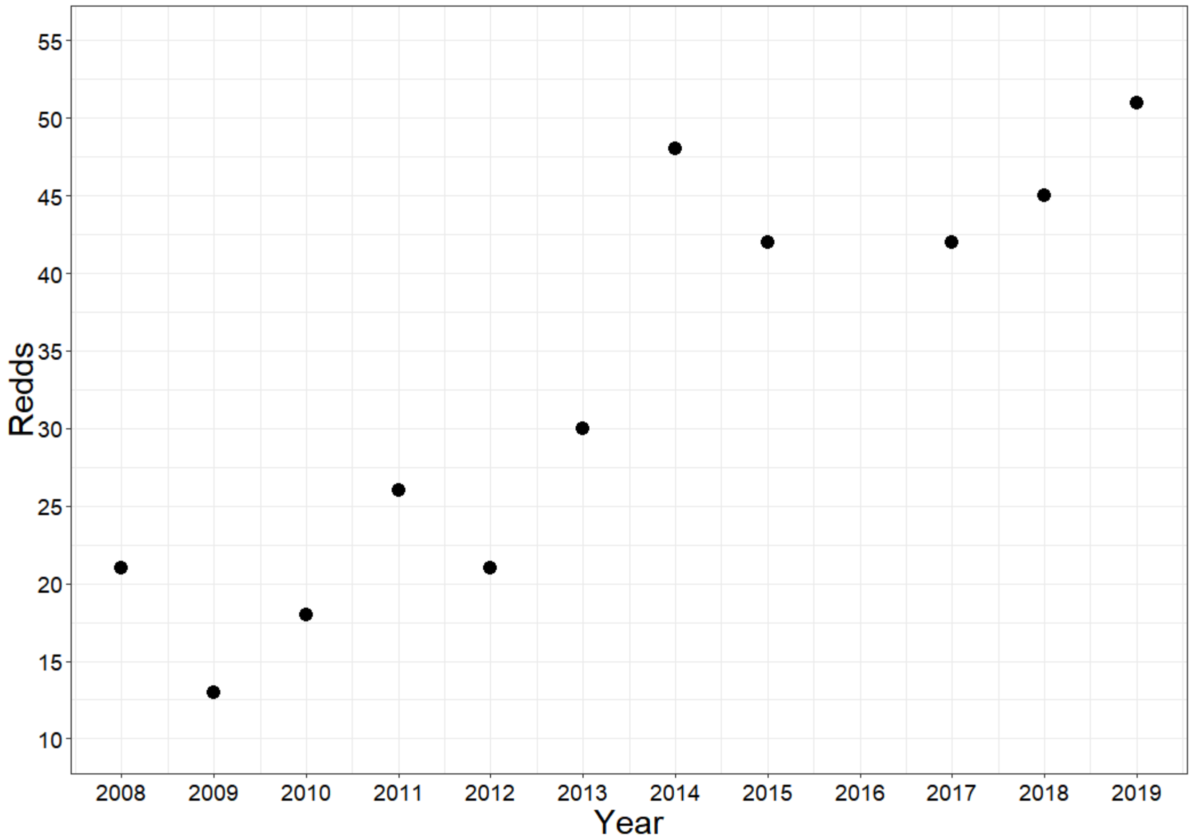


Figure 16. Correlations in bull trout redd counts between observers from repeat surveys from 2018 and 2019 in Cougar Creek (salmon), P8 (green), Pine Creek (blue), and Rush Creek (purple) within the North Fork Lewis River in Washington. The 1:1 line is shown (black).

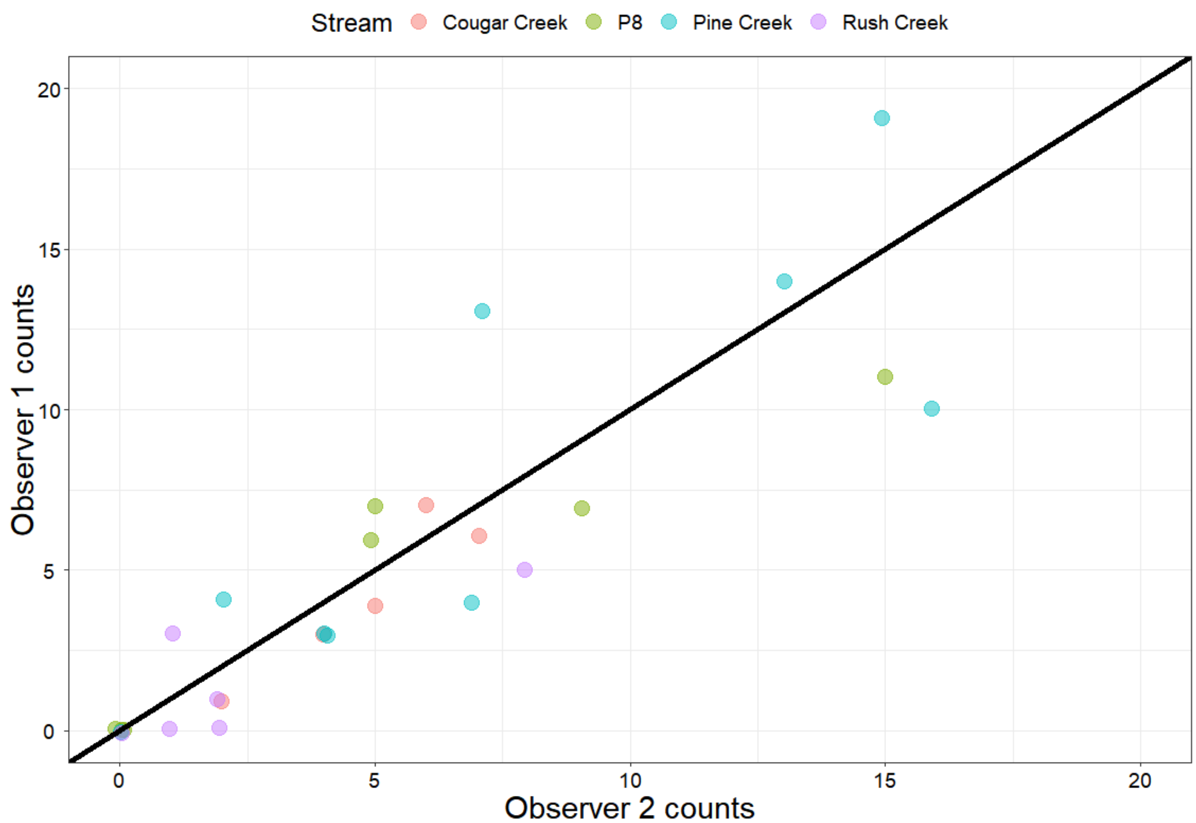


Figure 17. The coefficient of variation (CV) from repeat bull trout redd surveys in 2018 and 2019 to quantify observer error at different mean redd counts in Cougar Creek (salmon), P8 (green), Pine Creek (blue), and Rush Creek (purple)—tributaries to the North Fork Lewis River, Washington.

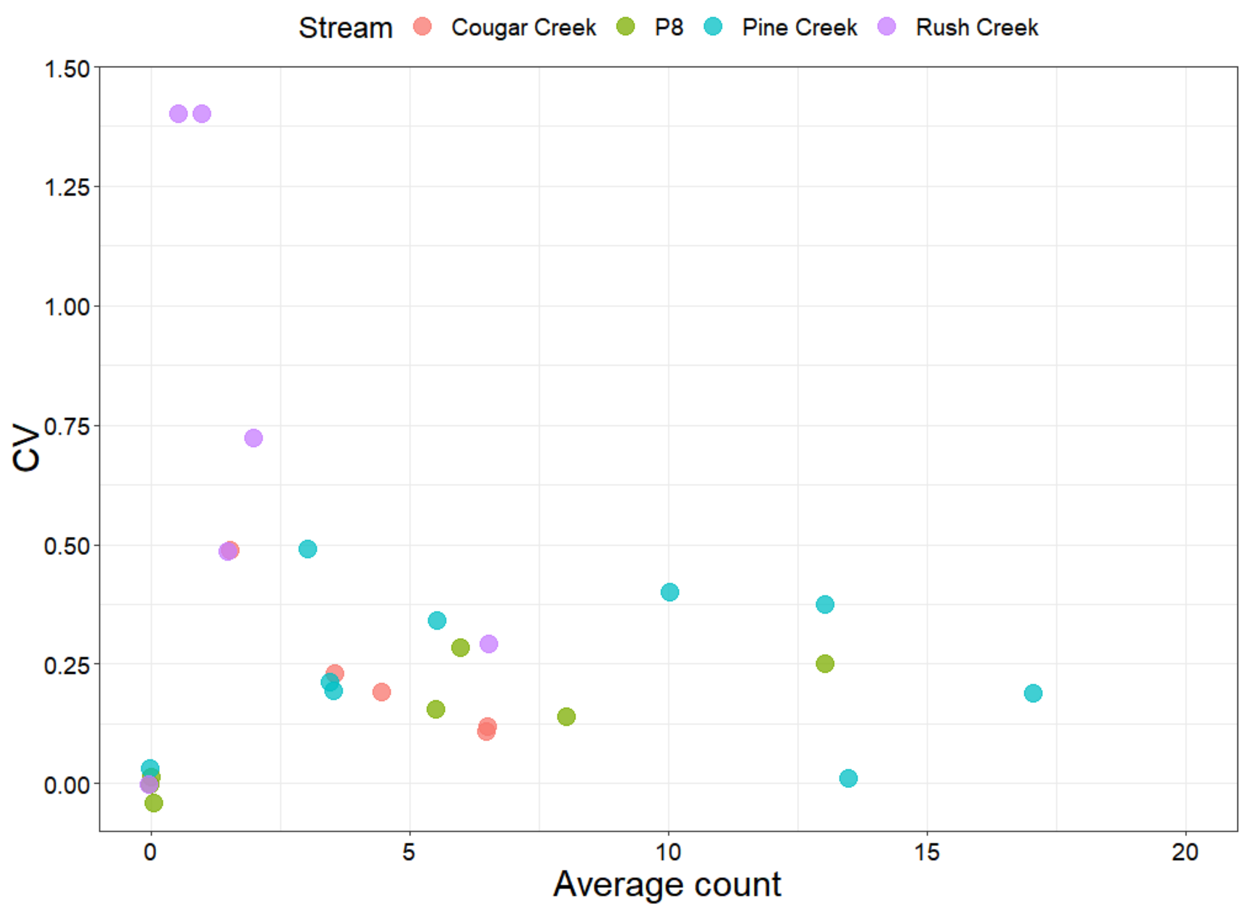
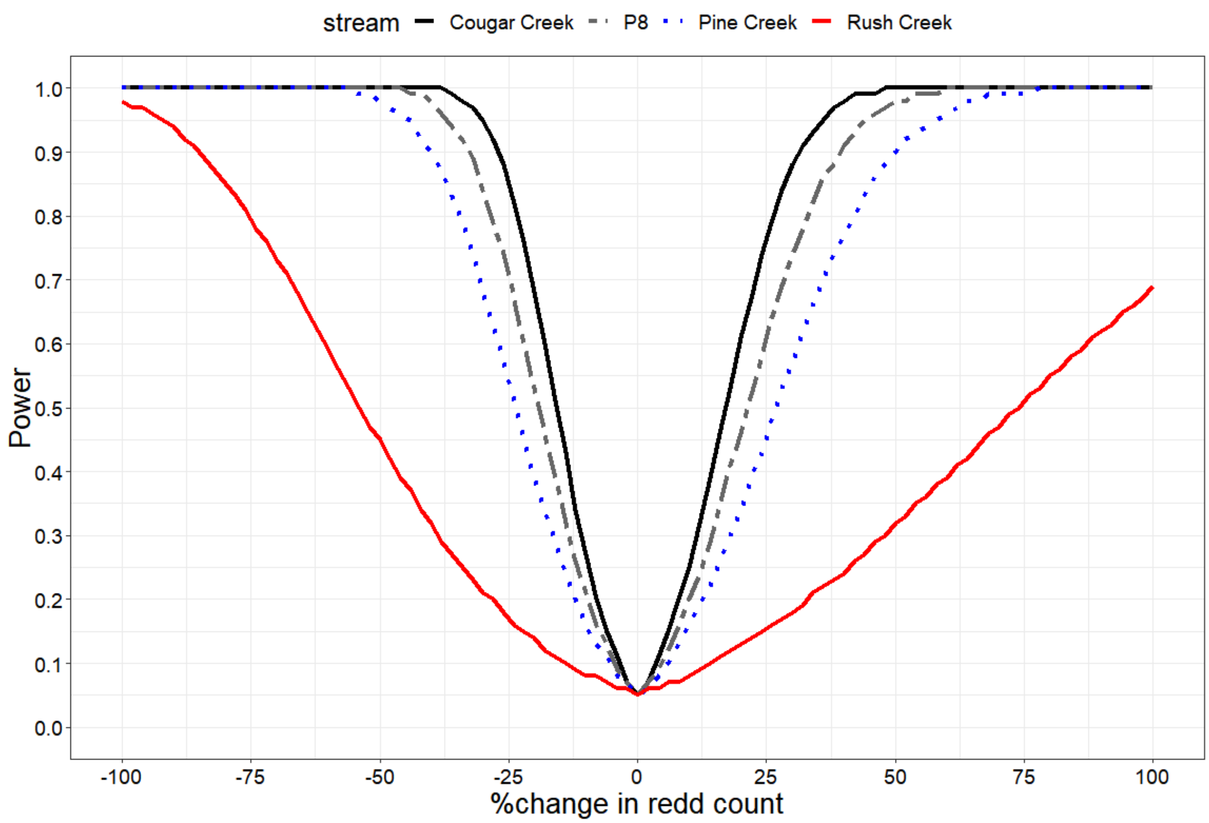


Figure 18. The power to detect different changes in bull trout redd counts over 20 years with CV values from observe error studies for Cougar Creek (CV = 13; black solid), P8 (CV = 18; grey dashed), and Pine Creek and Rush Creek (CV = 40; blue dotted)—tributaries to the North Fork Lewis River, Washington.



APPENDIX D

MEMO BY MARSHALL BARROWS, UNITED STATES FISH AND WILDLIFE SERVICE: Operation of Cougar Creek Weir and Underwater Video, 2019 Report.

*Upon submission of the ACC/TCC Annual Report for Agency review, the above Report was still under internal USFWS review. It will be made available for review as an addendum to this document at a later date.