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

P8 bull trout - 2018

North Fork Lewis River – 2018

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

Jeremiah Doyle, PacifiCorp

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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 2018. For methods and general descriptions of all programs please refer to the Bull Trout Annual Operating Plan for the North Fork Lewis River 2018 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 2018.

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).

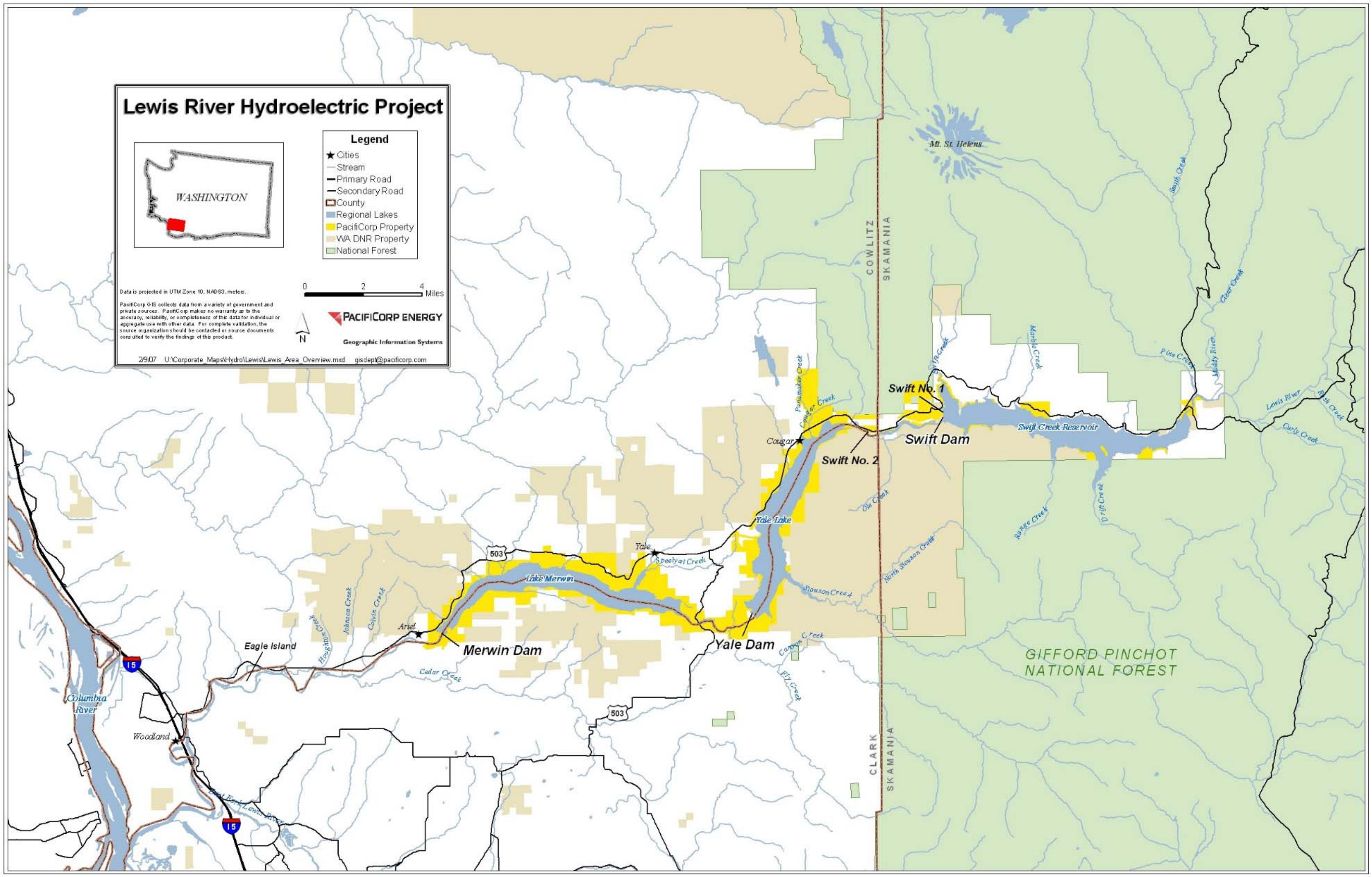

Figure 2.0-1. Map of North Fork Lewis River study area.

3.0 RESULTS FROM 2018 PLANNED ACTIVITIES

During 2018 the Utilities participated in, funded, or initiated six monitoring programs.

1. Swift Reservoir adult migration snorkel surveys, Survival (S), and juvenile relative abundance surveys
2. Half-duplex Passive Integrated Transponder (PIT) tag antenna arrays in Cougar, Pine, P8, and Rush creeks
3. Yale tailrace collection and transport
4. Underwater video camera operation to enumerate bull trout migrants in P8 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 for the second straight year. 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. The next year these activities could commence would be in 2019.

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 20 to October 3 for a total of eight instances (Table 3.1-1).

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 3.1-2).

Table 3.1-1. 2018 bull trout snorkel survey results for the Muddy River, Rush and Pine creeks confluence areas with the North Fork Lewis River.*Poor water clarity in Rush confluence. ^River otters working Muddy confluence, not snorkeled. $^{\vee}$ Most all observed bull trout post-spawn.

Date	Confluence location			Total Observed >450mm
	Pine	Rush	Muddy	
20-Jul	29	26	11	66
31-Jul	46	14	14	74
10-Aug	25	6*	10	41
22-Aug	14	29	13	56
30-Aug	11	24	12	47
10-Sep	8	13	13	34
24-Sep	16	16	n/a^	32
3-Oct	14$^{\vee}$	7$^{\vee}$	16$^{\vee}$	37
TOTAL	**162**	**135**	**89**	**387**

Continued in 2018, due to the lack of newly marked bull trout from the handling moratorium put in place after 2016 activities, no separate tagged group of bull trout were identified during snorkel surveys. All bull trout observed were pooled into one total count by survey date. Thus no NOREMARK® estimate was generated in 2018.

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). With no marking activities occurring in 2018 it was not possible to generate an estimate with this program; instead snorkel information was pooled for each survey and a peak count was established.

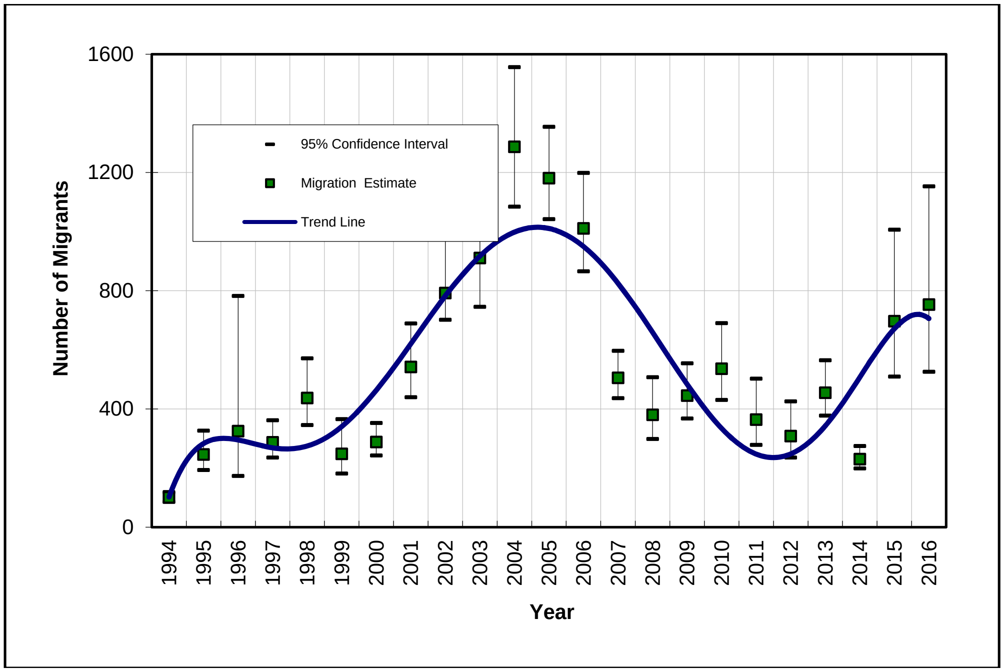

Figure 3.1-1. Estimates of bull trout that migrated from Swift Reservoir up the North Fork Lewis River for the years 1994 through 2016. (1994-2000 Peterson Estimator, 2001- 2016 Program NOREMARK®, Smith 1996)

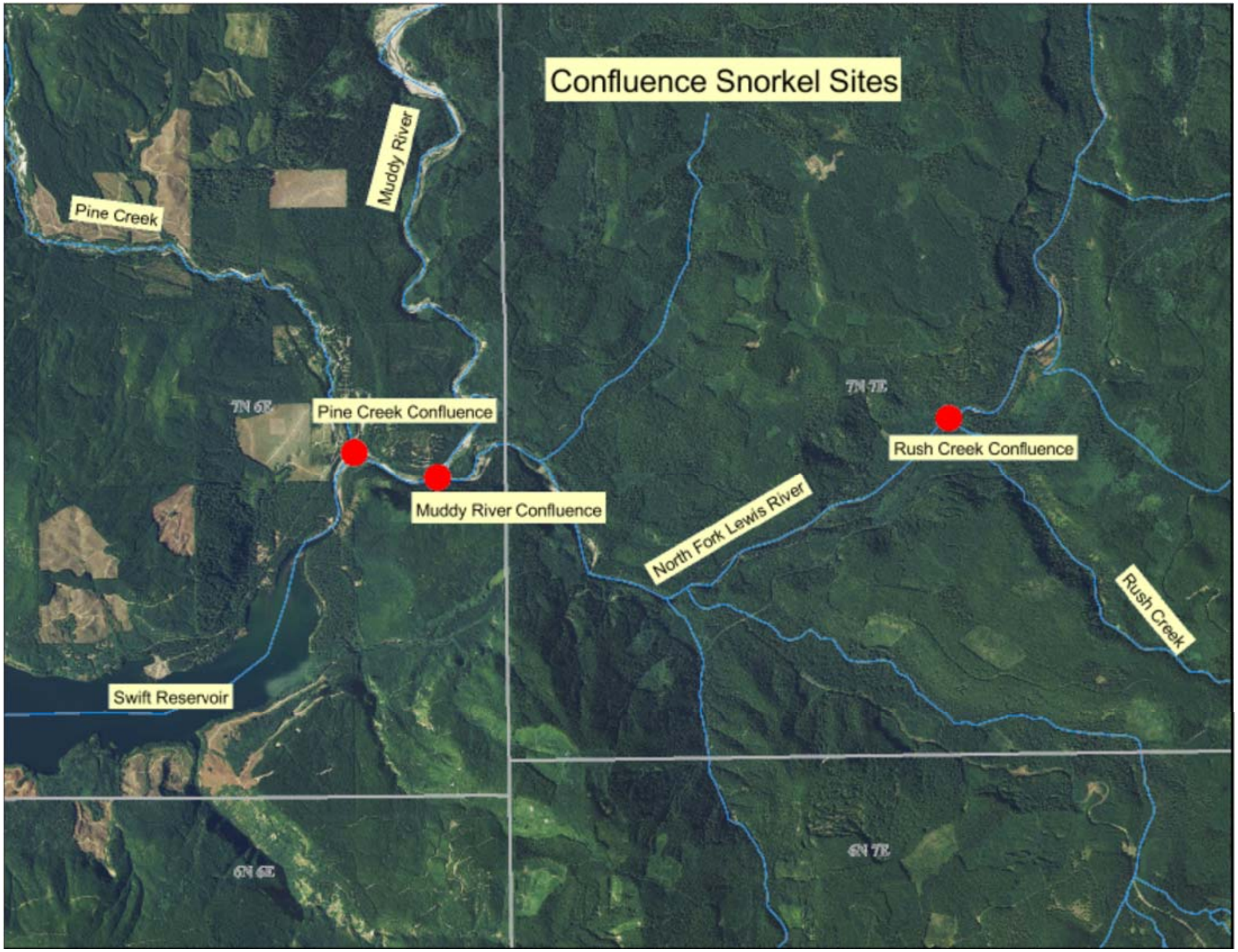

Figure 3.1-2. Snorkel sites (for recapture) associated with the Swift Reservoir bull trout migration estimate

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

Analysis of this data was still pending at the time of submission of this Report. As results and associated memo become available it will be made accessible and included within a later filing of this Report.

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

Activities pursuant to the eventual annual assessment of an Effective Population (N_e) size of bull trout within Swift Reservoir were performed in 2018. N_e is performed as part of the bull trout demographic characteristics evaluation objective within Section 17 of the Monitoring and Evaluation Plan. New in 2018, 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 2018, juvenile surveys were still conducted in order to assess relative abundance of bull trout and reintroduced anadromous juvenile fish species and their associated interaction. Tissue samples were also taken of all captured age 0 bull trout for possible future N_e analysis.

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).

Areas within Rush Creek were sampled with a backpack electrofishing unit on July 9 and July 18 (Figure 3.1.3-1). In all, 21 juvenile bull trout were captured and sampled for genetic tissue. 17 of the captures were less than 70 mm fork length and assumed to be of 2017 brood year origin. The length range of the age 0 bull trout was 39 mm – 55 mm, with an average fork length of 49 mm.

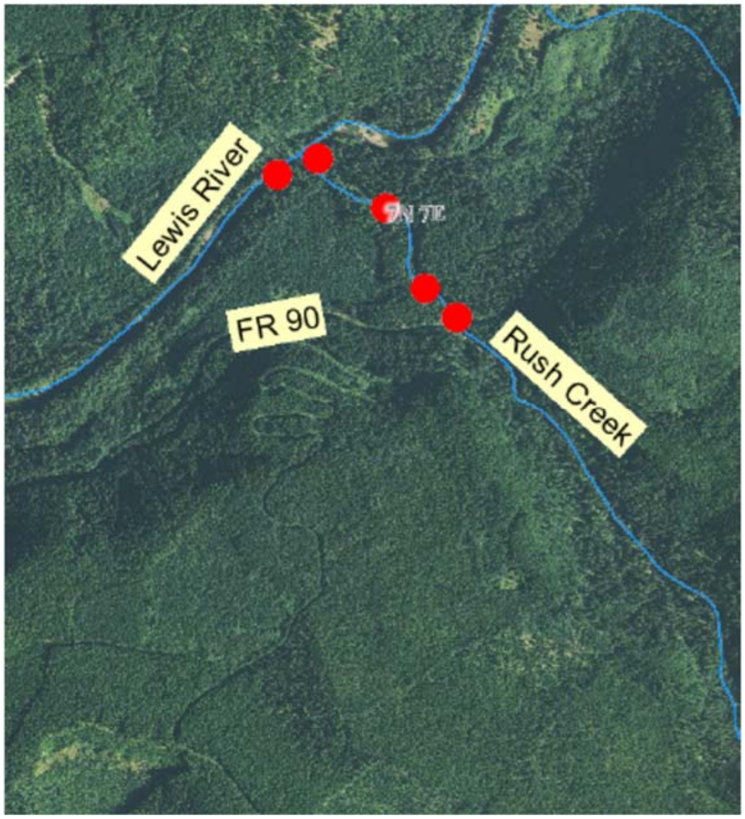

Figure 3.1.3-1. Electrofishing sites within Rush Creek during 2018 juvenile bull trout collection.

Areas within Pine Creek and tributary P8 were sampled for juvenile bull trout with a backpack electrofisher on June 10 and 13, and June 19 (Figure 3.1.3-2). In all, 36 juvenile bull trout were captured from within P8 ranging from 27 – 55 mm fork length with an average fork length of 41 mm. 70 juvenile bull trout were captured from within areas of Pine Creek mainstem ranging in size from 40 – 74 mm fork length with an average of 59 mm.

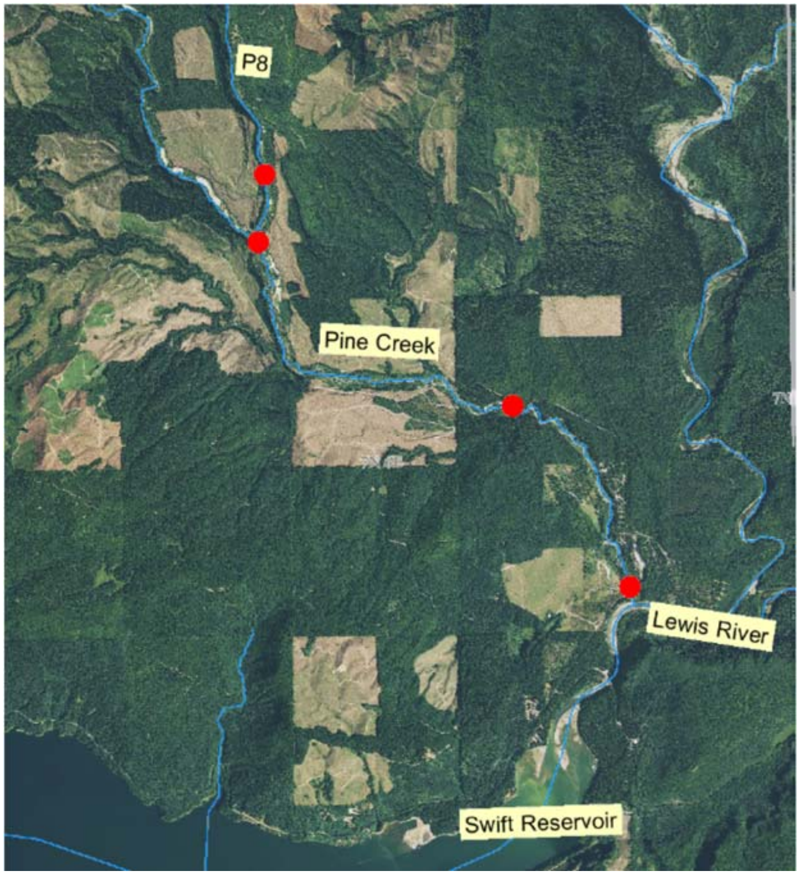

Figure 3.1.3-2. Electrofishing sites within the Pine Creek system during 2018 juvenile bull trout collection.

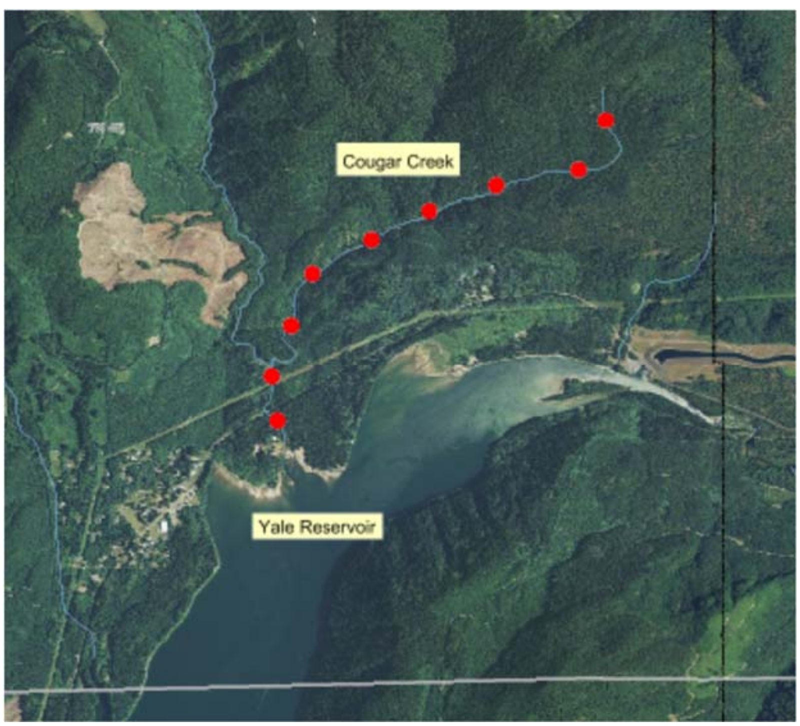

Figure 3.1.3-3. Electrofishing sites within the Cougar Creek system during 2018 juvenile bull trout collection.

Areas within Cougar Creek were sampled with a backpack electrofishing unit on July 5 (Figure 3.1.3-3). In all, 46 juvenile bull trout were captured and sampled for genetic tissue. The length range of captured age 0 bull trout was 43 – 68 mm, with an average fork length of 54 mm (Figure 3.1.3-4).

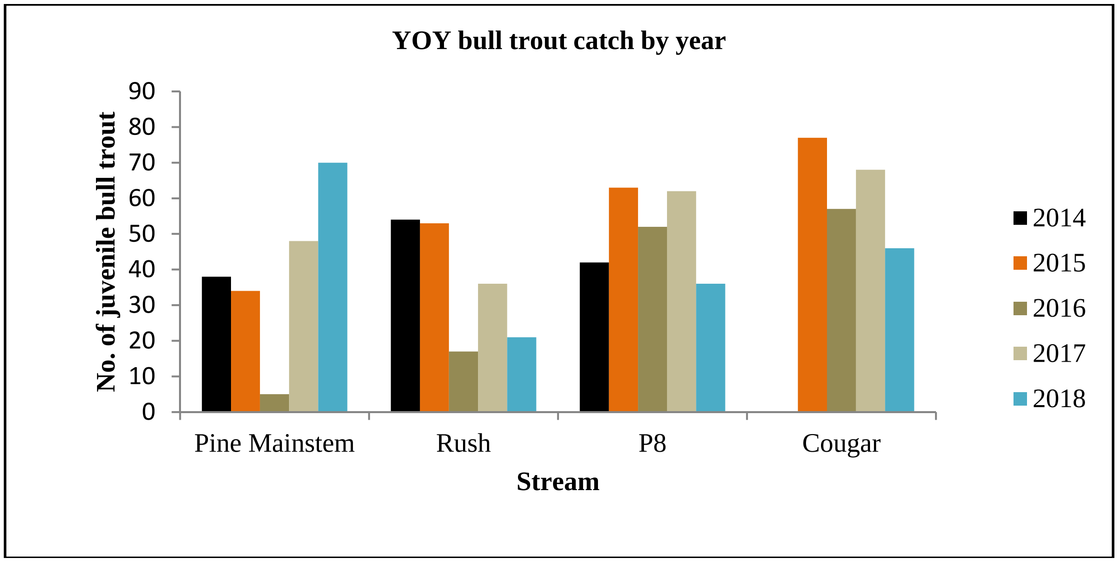

Figure 3.1.3-4. Trend bull trout juvenile catch during stream electrofishing surveys. Cougar Creek was not surveyed in 2014.

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 in 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 upstream of Swift Reservoir; no coho were encountered or observed within Cougar Creek in 2018. Pine Creek mainstem had a total coho catch of 332, P8 a total coho catch of 59 and Rush a total coho catch of 75. There was a paucity of other species encountered, with the occasional steelhead (*Oncorhynchus mykiss*) or coastal cutthroat trout (*Oncorhynchus clarkii*). This coho catch corresponds to a YOY bull trout catch of 70 and a difference in overall collected of 83 percent more YOY coho captures in Pine Creek mainstem. A similar theme was observed in P8 and Rush creeks, where 36 and 21 YOY bull trout were captured with a difference in overall collected of 62 and 78 percent more coho captured in P8 and Rush creeks (Figure 3.1.3-5).

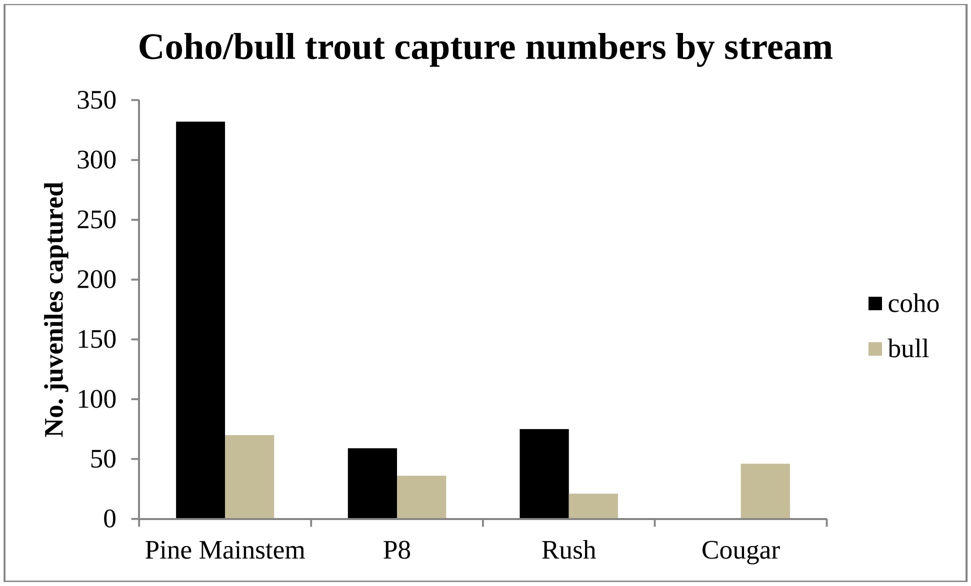

Figure 3.1.3-5. Coho and bull trout juvenile capture numbers by stream of capture in 2018.

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. Across the board bull trout YOY were marginally larger than coho YOY except in P8 Creek (Figure 3.1.3-6).

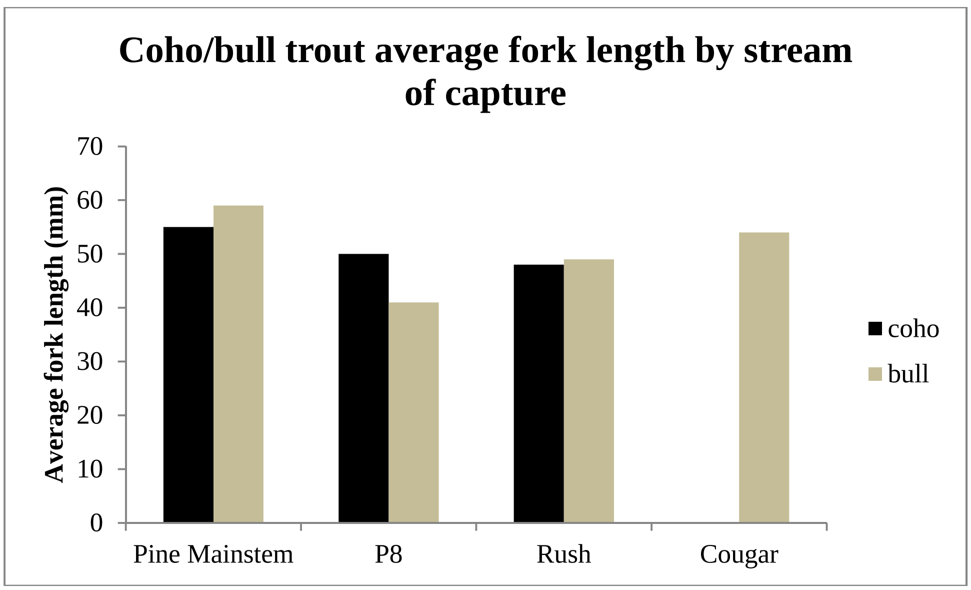

Figure 3.1.3-6. Juvenile coho and bull trout captures average fork length observed in 2018.

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.

Historically each half-duplex antenna site consisted of two antennas (for directionality) that were multiplexed (synchronized) and spaced approximately two meters apart. Continued in 2018 and for the second season in a row in order to conserve power, extend antenna life, and increase tag detection efficiency all antennas at all sites were only a single loop and not multiplexed. Antennas consisted 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 120w solar panels hooked to a charge controller.

Figure 3.2.1-1. Half-duplex stream-width PIT tag antenna locations in the Upper Lewis River Basin – 2018.

Figure 3.2.1-2. Half-duplex stream-width PIT tag antenna locations in the Yale Reservoir Basin – 2018.

In 2018 there were 57 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 8 – October 28, at which time the antenna loop was destroyed by a high water event. Continuous operation was experienced during this sampling timeframe with no loss of power. During the migration period 41 detections occurred at the antenna resulting in 8 unique bull trout. All of the 41 upstream and downstream movement events occurred during the crepuscular period. Peak migration of two bull trout was observed on multiple occasions. In general, no defined migration pattern was observed at this PIT antenna location (Figure 3.2.1-3).

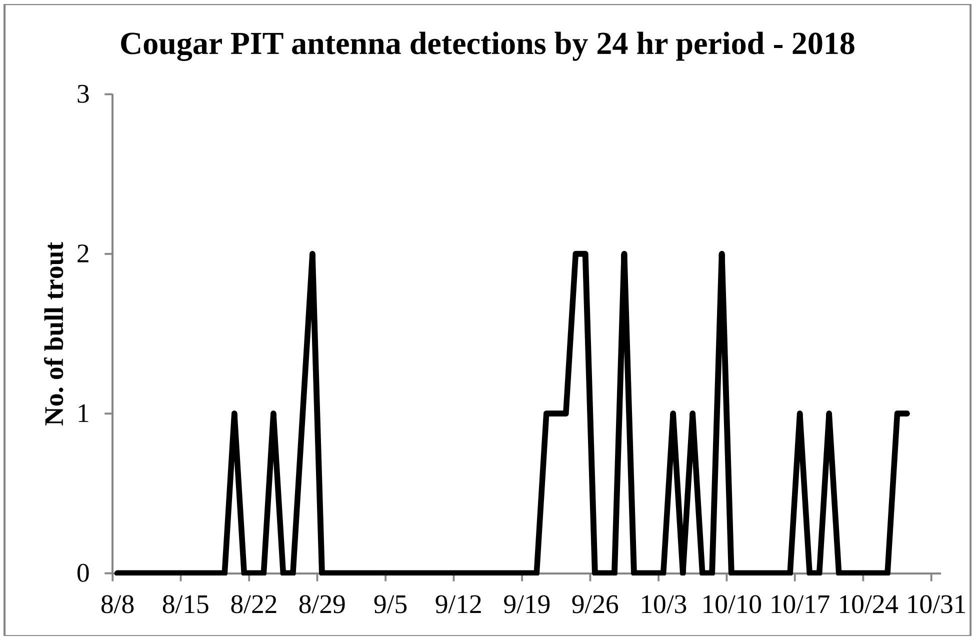

Figure 3.2.1-3. PIT detections by date in Cougar Creek in 2018.

The number of unique bull trout detections in 2018 as compared to historical detections at this site is expressed in Figure 3.2.1-4. 2018 experienced the least amount of detections on record with eight. Of these eight detections, seven (87 percent) were consecutive spawners with one fish being detected for the last seven consecutive years. One bull trout migrant (13 percent) was a maiden detection at Cougar Creek in 2018. Of note, the one maiden detection at this site in 2018 was initially captured within the Swift Bypass Reach of Yale Reservoir in 2016, at which time it was held at Merwin Hatchery while rapid response genetic assignment was conducted. Genetic analysis identified this bull trout as being of Pine Creek ancenstry, and as such this fish was transported upstream and released into Swift Reservoir on June 3, 2016. Three months later it was detected moving upstream past the Pine Creek PIT antenna of Swift Reservoir on September 10, 2016. No more detections of this fish occur until September 28, 2018 at which time it is detected moving upstream past the Cougar PIT antenna located in Yale Reservoir.

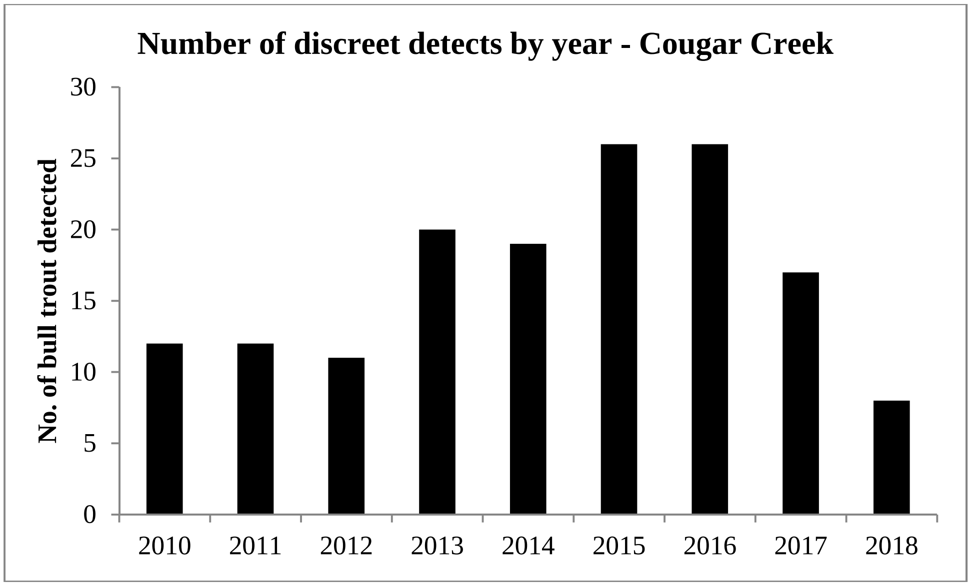

Figure 3.2.1-4. Historical PIT detections by year in Cougar Creek.

Pine Creek

The PIT antenna at the mouth of Pine Creek was in operation from August 1 to October 28. Power loss was experienced for three days during the study period, October 6 – October 8. The antenna loop was destroyed on October 28 due to a high water event. 75 detections were experienced during the period of operation resulting in 37 discrete bull trout tags. Peak migration past this antenna was observed in the ten-day period between September 18 and September 28 when 19 bull trout volitionally swam past (Figure 3.2.1-5).

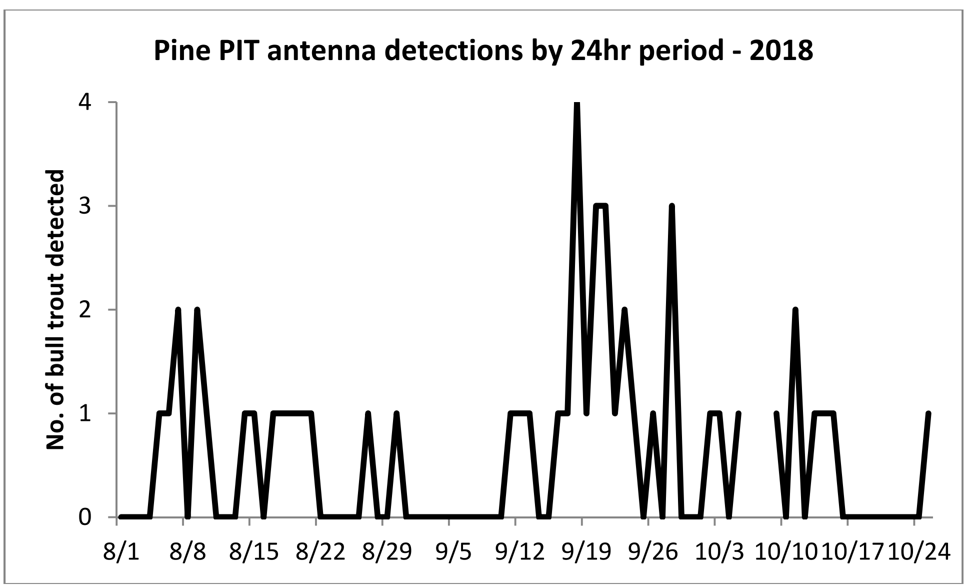

Figure 3.2.1-5. PIT detections by date at the Pine Creek PIT antenna in 2018.

The number of historical discrete detects at the Pine Creek site is expressed in Figure 3.2.1-6. Of the 37 bull trout that migrated upstream past this antenna, 51 percent showed evidence of consecutive year migrations (2, 3, 4 or 5 year consecutive), 43 percent were maiden detections, and 6 percent showed evidence of biennial migrations.

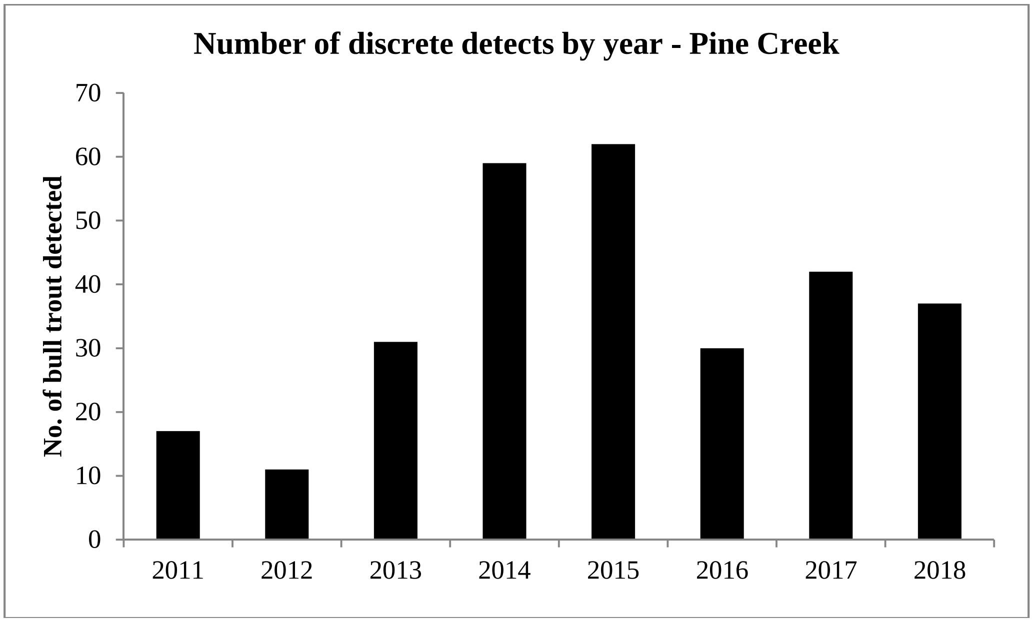

Figure 3.2.1-6. Historical PIT detections observed in Pine Creek by year.

Pine Creek Tributary P8

The PIT antenna at the mouth of Pine Creek tributary P8 was in operation from August 17 to October 8. Power loss was experienced for six days, September 6 – 11, due to a drained battery. Problems with the antenna motherboard and ability to tune the antenna to read a tag at suitable ranges prohibited start-up and contributed to the late date of initial operation. This antenna was taken out of service prematurely by a power surge that wiped the memory from the antenna motherboard and caused an inability to write a tag code to memory. 272 detections were recorded during the period of operation resulting in 17 discrete bull trout tags. Peak migration was observed on September 17 when four bull trout volitionally swam past the antenna (Figure 3.2.1-7).

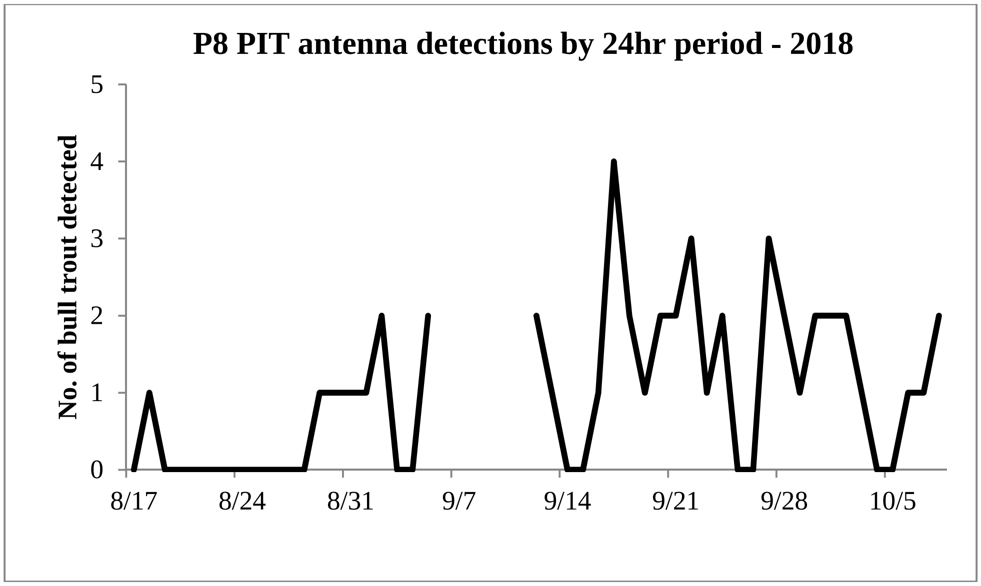

Figure 3.2.1-7. PIT detections by date in P8 during 2018.

Historical discrete detections at this site are expressed in Figure 3.2.1-8. Of the 17 bull trout detected at this antenna in 2018, 30 percent showed evidence of consecutive year migrations to this site, 11 percent evidence of biennial migrations, while 59 percent were maiden detections. 15 of the 17 bull trout detected at the P8 antenna were also detected downstream at the Pine Creek mainstem antenna.

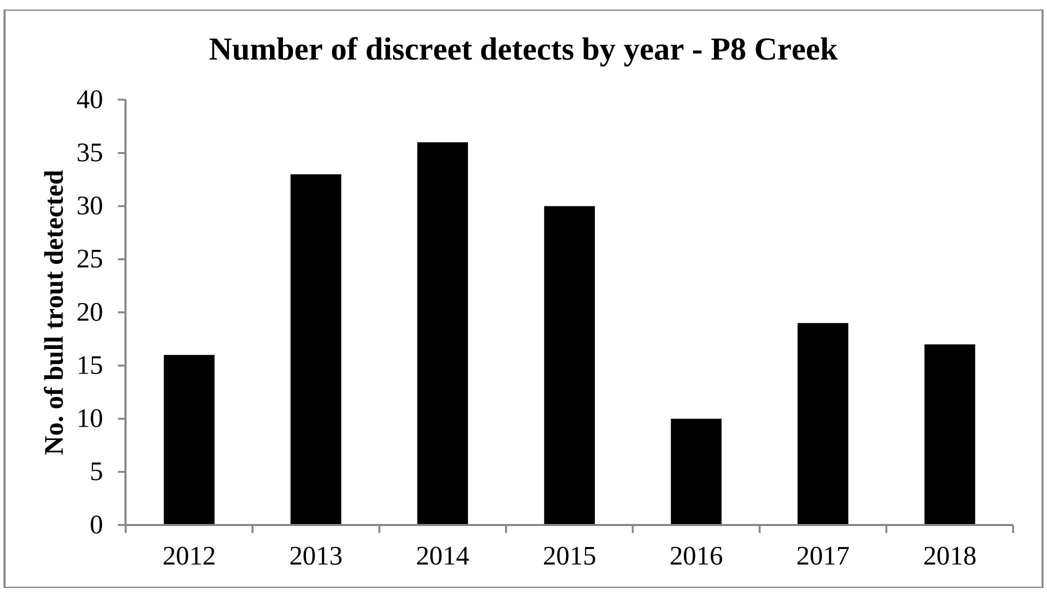

Figure 3.2.1-8. Historical PIT detections by year in P8.

Rush Creek

The PIT antenna near the mouth of Rush Creek was in operation from July 25 to October 22 at which time the antenna was destroyed by a high flow event. Power loss was experienced for six days, from September 27 – October 2, due to a drained battery. 13 detections were recorded during the period of operation resulting in nine discrete bull trout tags. Peak migration of two bull trout was observed on August 6 (Figure 3.2.1-9).

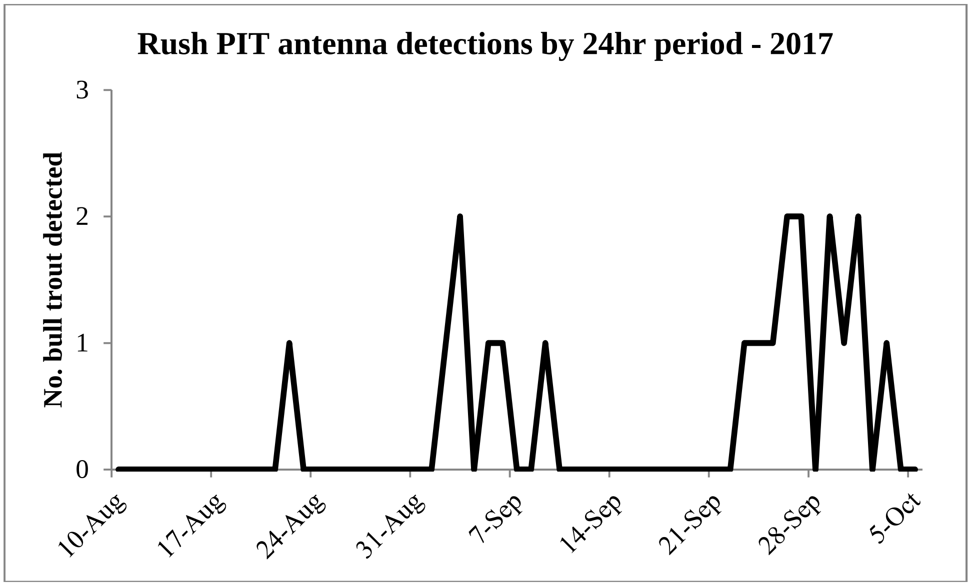

Figure 3.2.1-9. PIT detections by date observed in Rush Creek in 2018.

Historical discrete detections at this site are expressed in Figure 3.2.1-10. Of the nine bull trout detected at this antenna location in 2018, 67 percent showed evidence of consecutive year migrations, 11 percent biennial migration pattern, and 22 percent were maiden detections. For one bull trout, 2018 was the eighth consecutive year it was interrogated within Rush Creek.

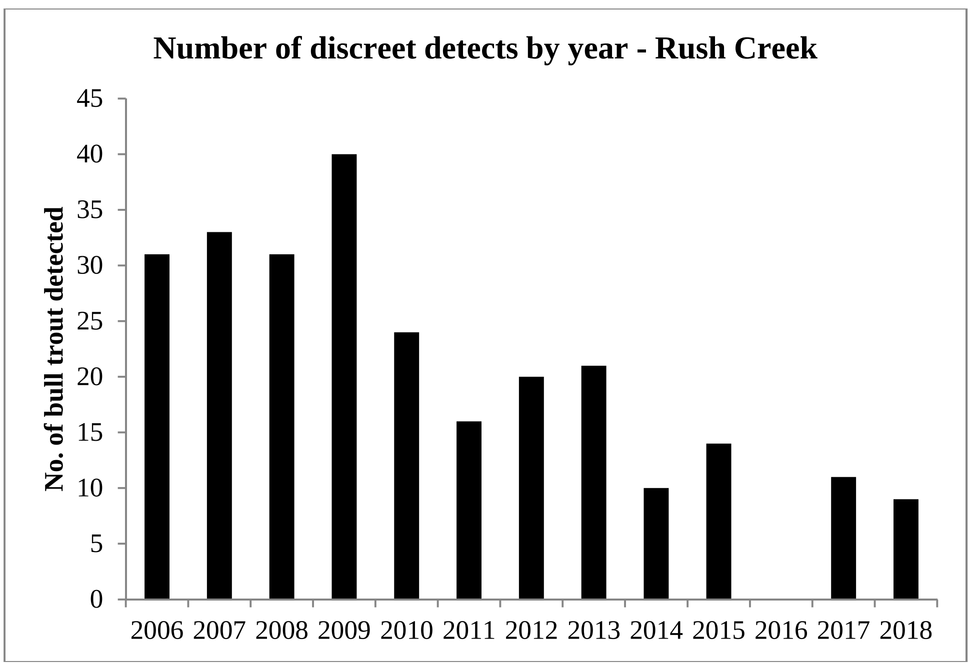

Figure 3.2.1-10. Historical PIT detections by year in Rush Creek.

Rush Creek Pool

A PIT antenna was intended and attempted on multiple occasions within Rush Creek Pool. This antenna was constructed as a hardened loop made from polyvinylchloride pipe with a diameter of two meters. The intent was to secure the antenna loop to the stream bottom in the middle of the pool, a distance of approximately fifteen meters from the ordinary high water mark. Due to the large geographical and fluvial area of the mainstem Lewis River at this site, no stream-spanning antenna was proposed. The idea was to place the small antenna in a conspicuous spot for bull trout holding in the pool to come volitionally into read-range. After the antenna was constructed and secured to the most likely spot within the pool, researchers were unable to get the antenna to read a tag. It was deemed that the antenna was too large and beyond the capabilities of the technology.

All Detection Analysis

Spawning frequency for the last four years from all detections at all streams combined was analyzed and is expressed in Figure 3.2.1-11. It is noted that a shift from maiden detection to multiple year detection is observed from 2015 to 2018, this shift is expected to become more pronounced as additional data is collected and individual fish are followed through their lifecycle. Of note in 2018 was the detection of two separate bull trout at both the Rush Creek and Pine Creek antenna locations. This is the first time during the period of study that a bull trout has been detected in both spawning tributaries within the same spawning season.

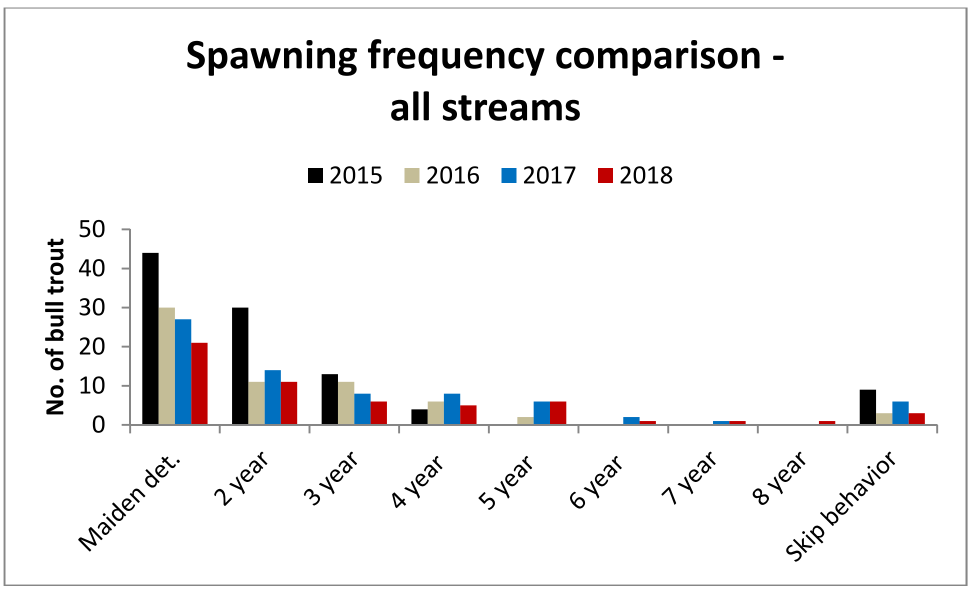

Figure 3.2.1-11. Spawning frequency of all detections for the years 2015-2018.

Figure 3.2.1-12 compares annual detections from all sites for all years on record.

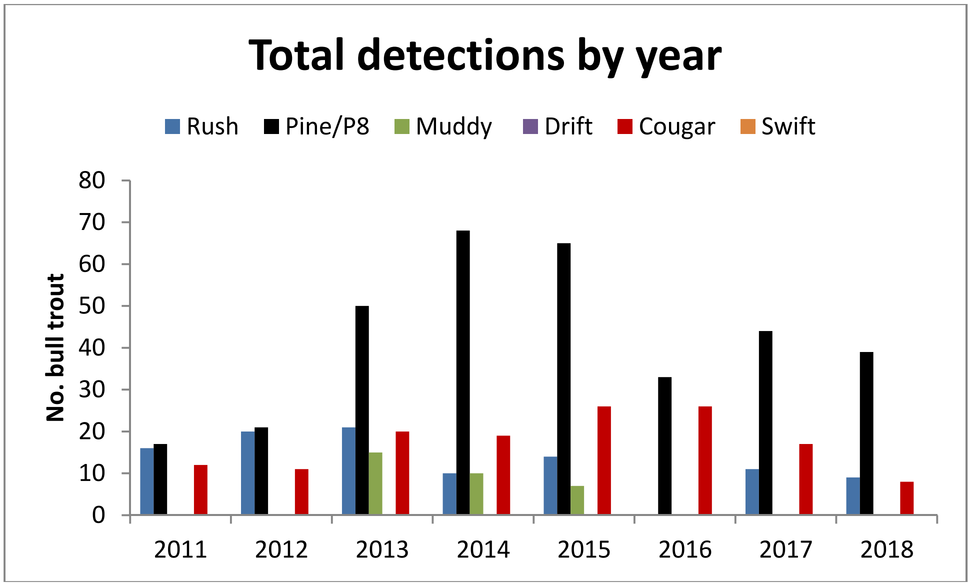

Figure 3.2.1-12. Total detections by year from all sites from years 2011-2018.

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 (see Utilities 2007 Annual Bull Trout Monitoring Plan for meeting notes http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Lewis_River/Annual_Bull_Trout_Monitoring_Plan_2007.pdf).

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 2018. 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. The next year these activities could commence would be in 2019. Figure 3.3.1-2 and Table 3.3.1-2 illustrate historical total capture and transport numbers.

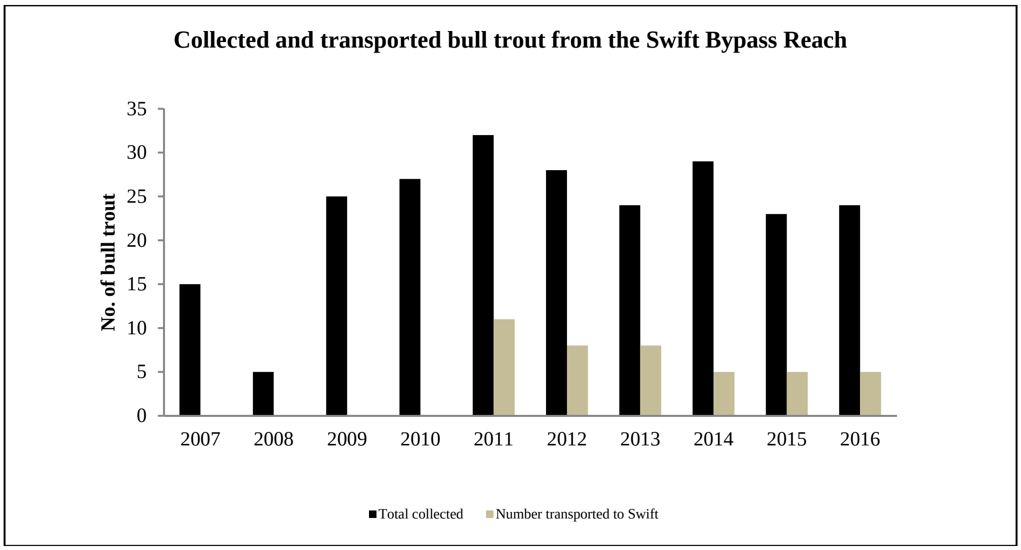

Figure 3.3.1-2. Historical Swift Bypass Reach capture and transport numbers.

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).

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 2018, 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 2018, three capture attempts were completed; June 12, July 23, 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 – 2017.

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
TOTAL	**162**	**122**	**2**	**21**	**14**

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

3.4 UNDERWATER VIDEO CAMERA OPERATION IN PINE CREEK TRIBUTARY P8 – PILOT STUDY

To better correlate numbers of bull trout spawners to each observed bull trout redd, a partial weir with an associated underwater video camera was installed and put into operation within P8 Creek near its confluence with Pine Creek in 2018. The intent of this study was to have the camera operate and record all bull trout migrations during the entire bull trout spawning period, August-October, in order to get a total spawner migration count. This total migration count would then be divided by the total number of redds observed for the year within this stream for an accurate number of fish per redd. It was also anticipated that data pertaining to sex ratios, as well as general size of bull trout migrants, would also be collected from video recordings of migrating fish.

On July 30, 2018 an aluminum fish swim-thru box 38 centimeters (cm) high x 91 cm wide x 71 cm long was installed in the creek immediately adjacent to the stream margin. The swim-thru box housed one color underwater video camera and four light emitting diodes (LED). Fish passage through the aluminum box was kept at a fixed distance of 43 cm from the underwater video camera lens (Figure 3.4-1). The underwater video camera was connected to a SecuMate® mini Digital Video Recorder (DVR) set to motion detection. Sensitivity of motion detection was set in the field, and for the most part sensitivity was set high so as to not miss any fish migration. The camera, light, and DVR were powered by two large deep cycle 12volt batteries. Additional batteries were kept near the site in an additional jobox and were connected to a charge controller and two 140 watt solar panels for continuous trickle charge.

Figure 3.4-1. Swim-thru box that housed underwater video camera.

Looking upstream, a partial weir made from 1.2 meter high x 1 meter long cyclone fencing sections was attached to the upstream corner of the box and opposite side of the stream, as well as to the downstream corner of the box to the opposite side of the stream. The constructed weir created a “V” that shunted all upstream and downstream fish passage through the fixed slot in the aluminum box and passed the underwater video camera (Figure 3.4-2).

Figure 3.4-2. Swim-thru box and V weir deployed within P8.

The box and weir were in place from July 30, 2018 until the weir blew out on October 1, 2018 due to heavy debris load. There were four periods of power loss experienced during this time-period. The first loss of power occurred for five days during the first week of August and was due to the underwater swim-thru aluminum box breaking free of its constraints and washing downstream. The three other periods of power loss were in late September and were due to copious leaves and debris flowing passed the video camera and triggering non-stop DVR recordings which pre-maturely drained the batteries. The time the camera and DVR were off during the three periods of power loss in late September ranged from 1 – 3 days.

In all, over 3,000 short video recordings were collected during the period of camera operation (July 30 – October 1). Of these 3,000 recordings, 45 were found to be of bull trout migrating either upstream or downstream pass the underwater video camera (Figures 3.4-4 - 3.4-6). The first instance of bull trout migration was recorded on August 10 as a fish moved upstream. Of the 45 recordings of bull trout migrants, gender was determined of 10 males and 8 females by dimorphic body characteristics. Due to the truncated operation timeframe from the weir blowing out and the four periods of power loss, no empirical total bull trout migration into P8 Creek is available for 2018.

Figure 3.4-4. Still photo from video recording of upstream bull trout migration. Video recording taken within P8 Creek.

Figure 3.4-5. Still photo from video recording of upstream bull trout migration. Video recording taken within P8 Creek.

Figure 3.4-6. Still photo from video recording of upstream bull trout migration. Video recording taken within P8 Creek.

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 2018, the Utilities conducted six Cougar Creek bull trout redd surveys from September 19 to October 31. Surveys begin at the mouth of the creek and end at the creek's spring source, a distance of approximately 2100 m.

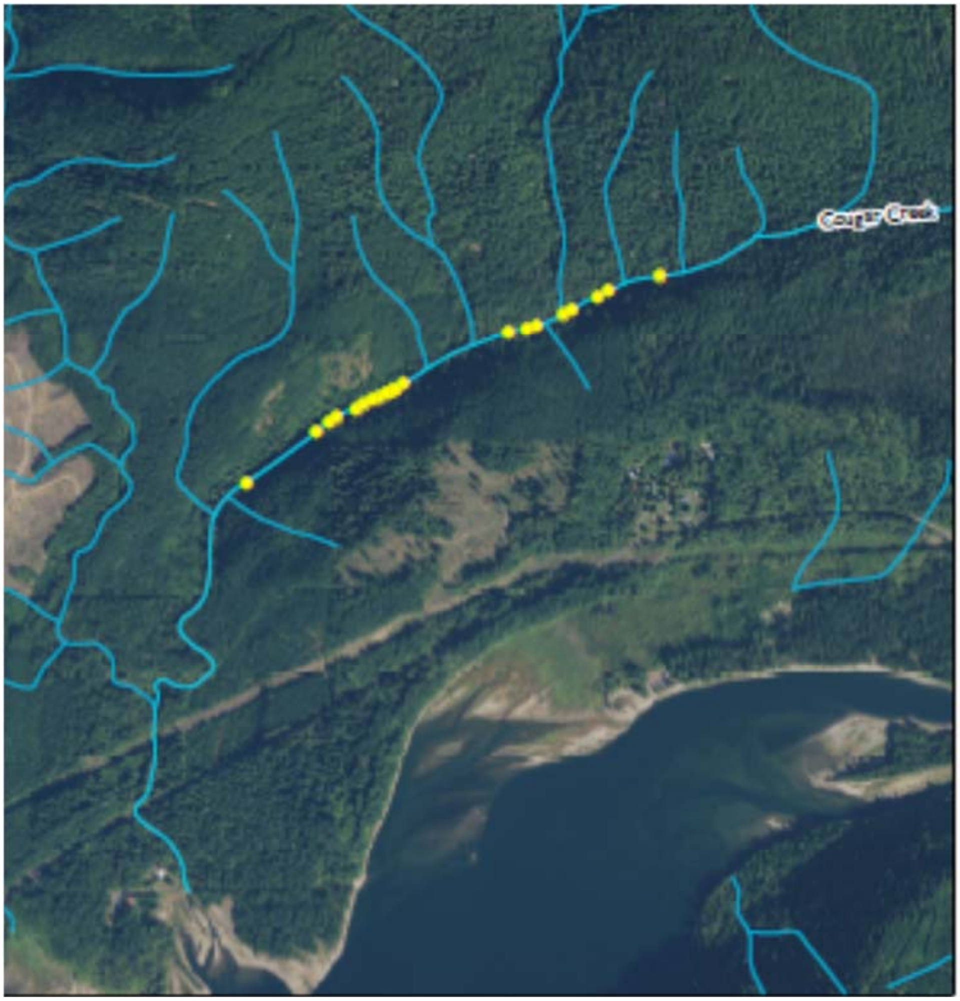

Figure 3.5.1-1. GPS locations of bull trout redds in Cougar Creek in 2018. Each yellow dot represents an individual bull trout redd (n=21).

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 2018, 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 2017 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 2018 to spawn is unknown, there is no reliable way to get an approximate number of fish per redd.

During each 2018 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.

21 individual bull trout redds were observed in Cougar Creek in 2018. 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 recent concern in Cougar Creek, first observed in 2008, are bull trout redds found to be superimposed over one another. During redd counts in 2018, no bull trout redds were observed superimposed over a previously excavated bull trout redd.

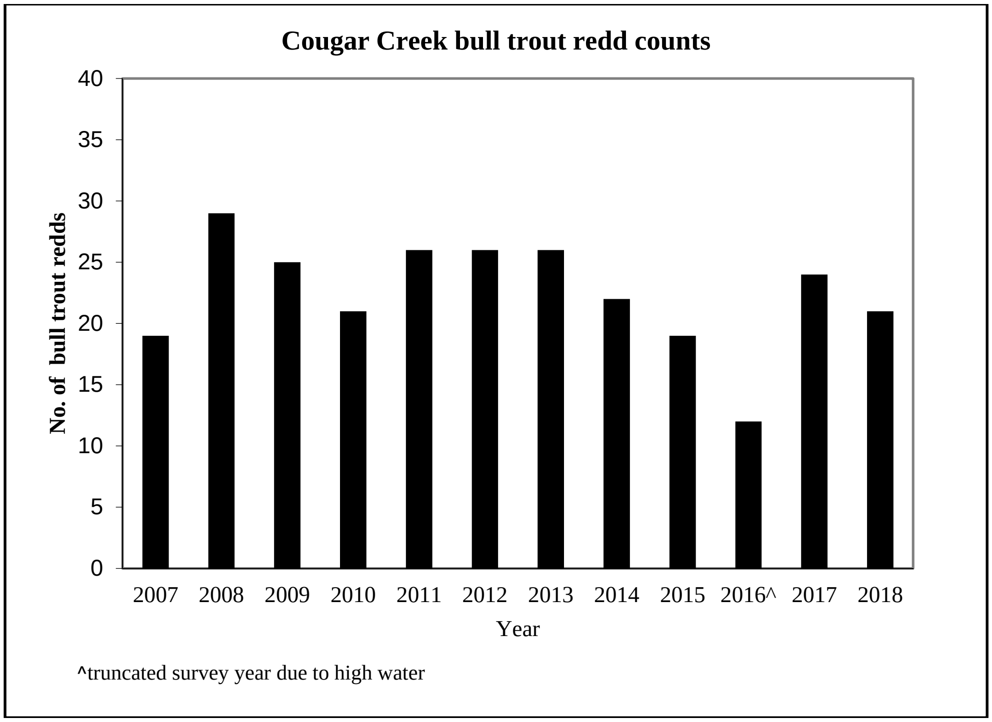

Figure 3.5.1-2. Annual Cougar Creek bull trout cumulative redd counts, 2007-2018.

3.5.2 Bull Trout Redd Surveys of Pine Creek, Pine Creek Tributary P8 & P10, 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 5 – October 24 during the 2018 bull trout spawning season. In all, GPS coordinates were collected from 45 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). Intraspecies redd superimposition was observed of three previously flagged bull trout redds during the 2018 survey period within P8 Creek.

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 2016, 2017, or 2018.

Pine Creek and tributary P10

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 2018 (river mile 0 to river mile 8). In all, eight surveys were completed and 88 redds were recorded and GPS'd. 36 percent of redds were recorded in the lower third of available spawning habitat (32 redds from river mile 0 to river mile 3), 51 percent of redds were recorded in the middle third of available habitat (45 redds from river mile 3.1 to river mile 6), and 13 percent of bull trout redds were recorded and observed in the upper third of available habitat (11 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 2018 (Figure 3.5.2-1).

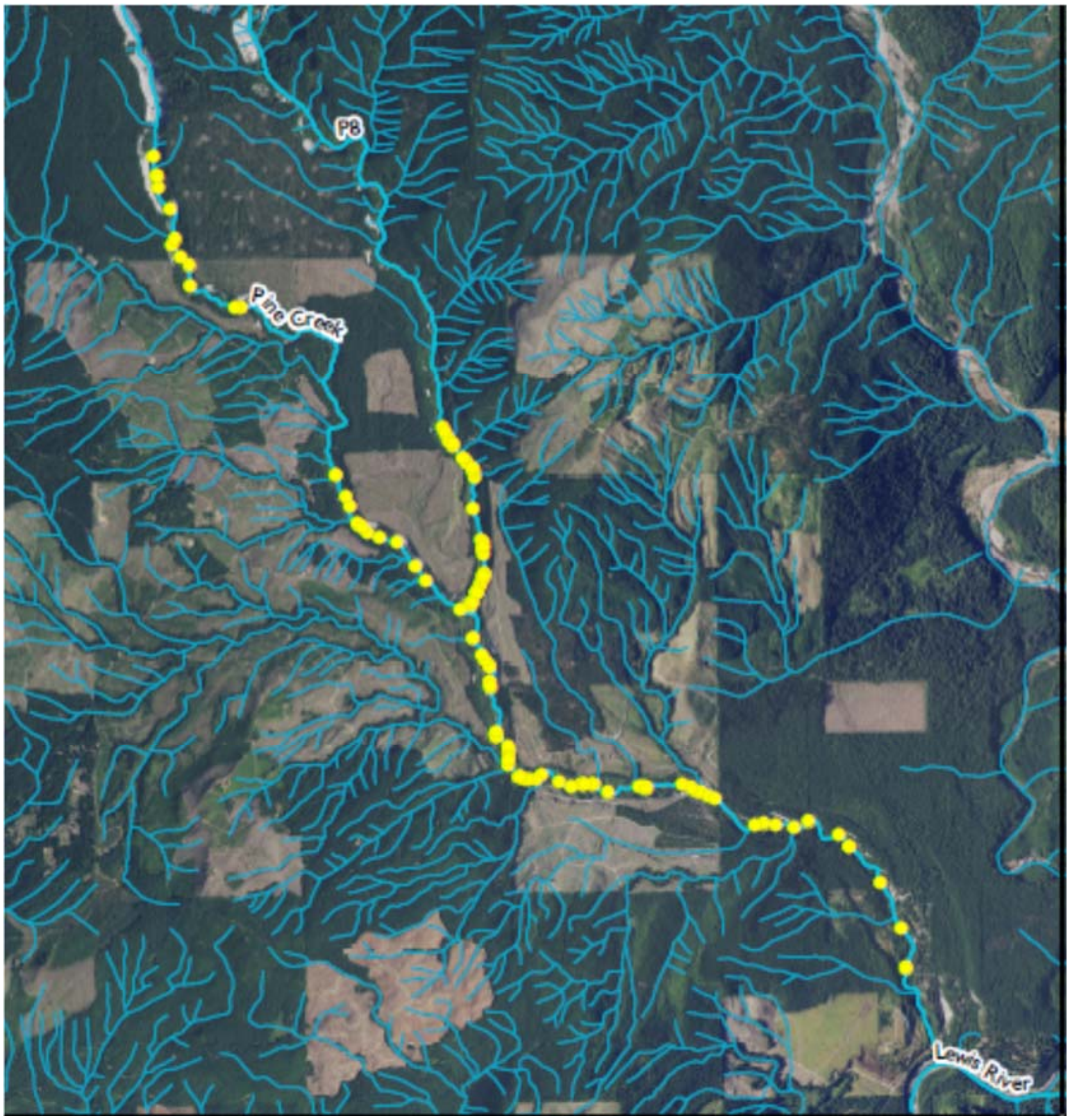

Figure 3.5.2-1. GPS locations of bull trout redds in Pine and P8 creeks in 2018. Each yellow dot represents an individual bull trout redd (n=132).

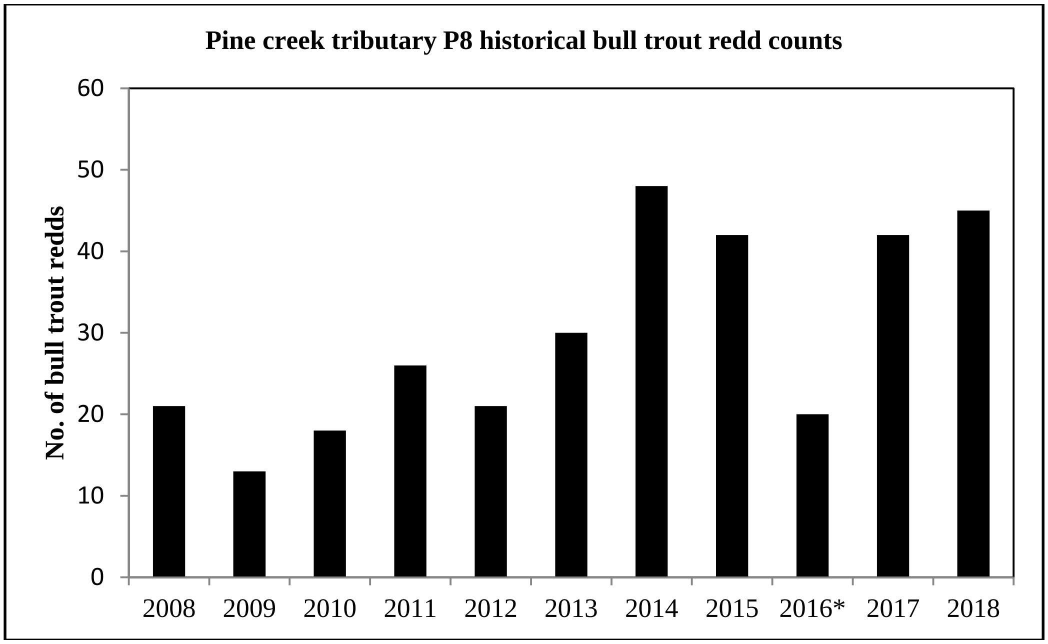

Figure 3.5.2-2. Pine Creek tributary P8 historical bull trout redd counts (2008 and 2009 data courtesy of WDFW).

Rush Creek

Rush Creek was surveyed on four occurrences between September 25 and October 22. 20 redds were observed and marked by flagging and GPS (Figure 3.4.2-3). 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 3.4.2-4.

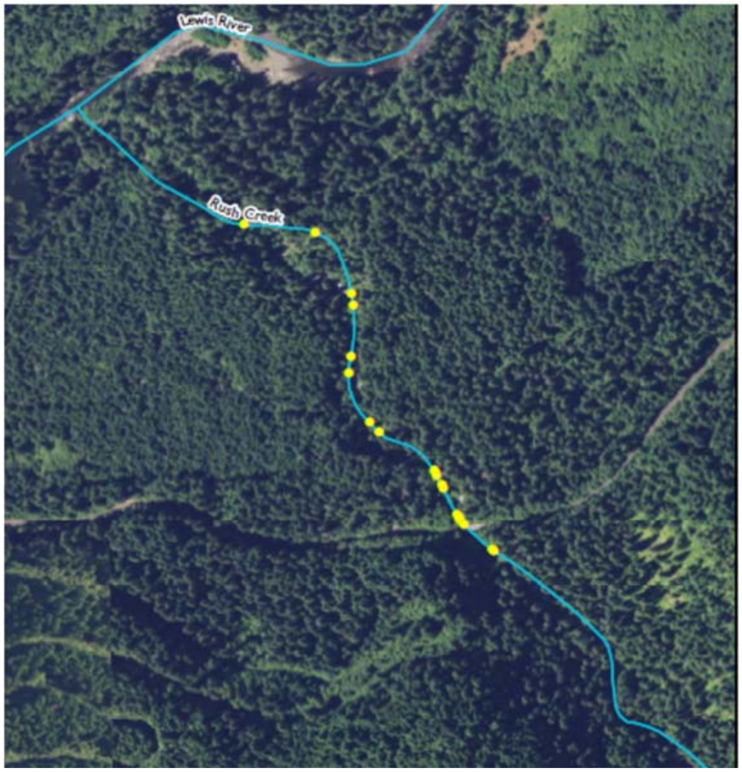

Figure 3.5.2-3. GPS locations of bull trout redds in Rush Creek in 2018. Each yellow dot represents an individual bull trout redd (n=20).

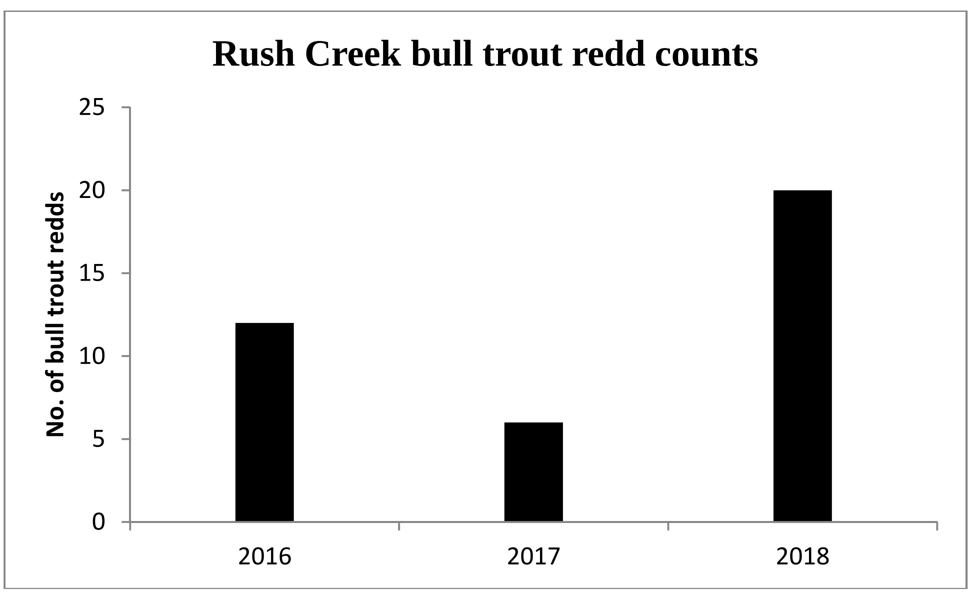

Figure 3.5.2-4. Rush Creek historical bull trout redd counts.

Observer Error Redd Surveys
In order to evaluate and incorporate the inherent error associated with surveyor subjectivity during stream-type redd surveys, numerous observer error redd surveys were performed of each bull trout spawning stream in 2018. Analysis of this data was still pending at the time of submission of this Report. As results and associated memo become available it will be made accessible and included within a later filing 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 2018. 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. Graphical representation of data collected from each site is shown below (Figures 3.6-1 – 3.6-7). All sites experienced continuous data collection at each location during the stipulated time-frame.

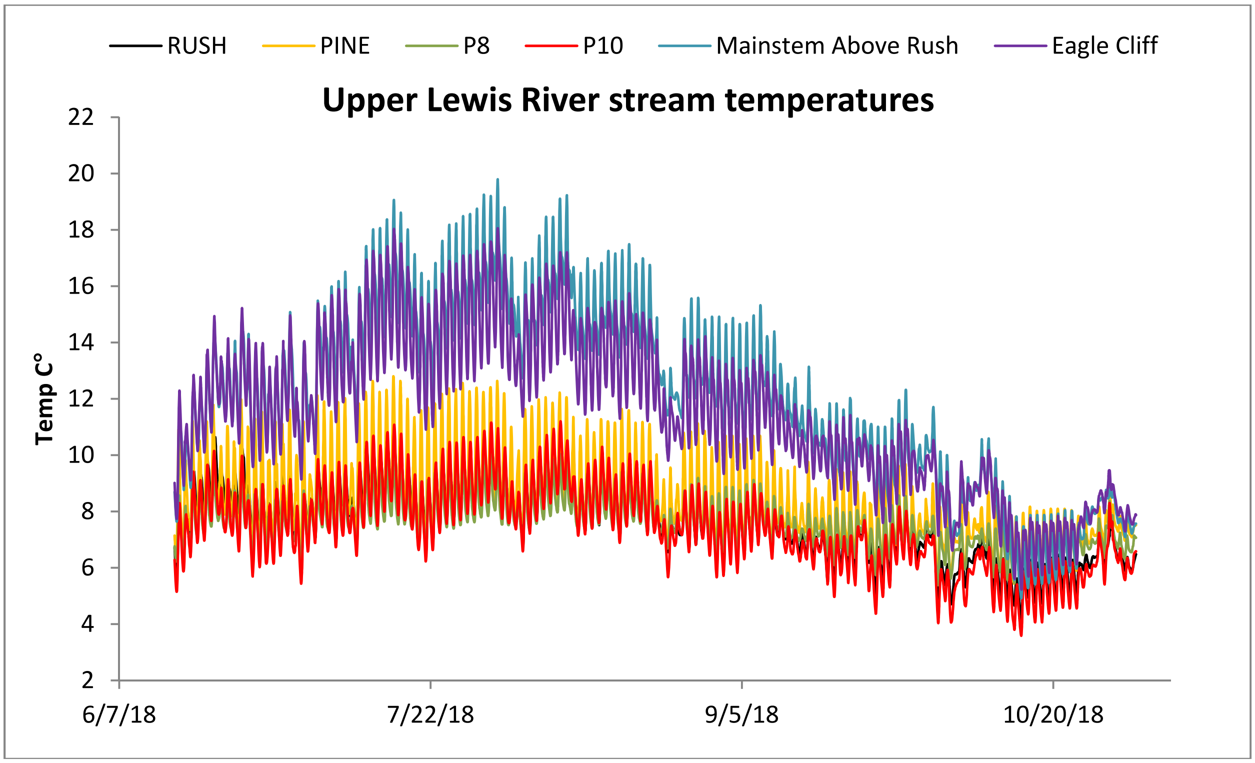

Figure 3.6-1. Plotted hourly stream temperatures for Pine, P8, P10, and Rush creeks as well as the mainstem Lewis River at Eagle Cliff and just upstream of Rush Creek from June 15 – October 31, 2018.

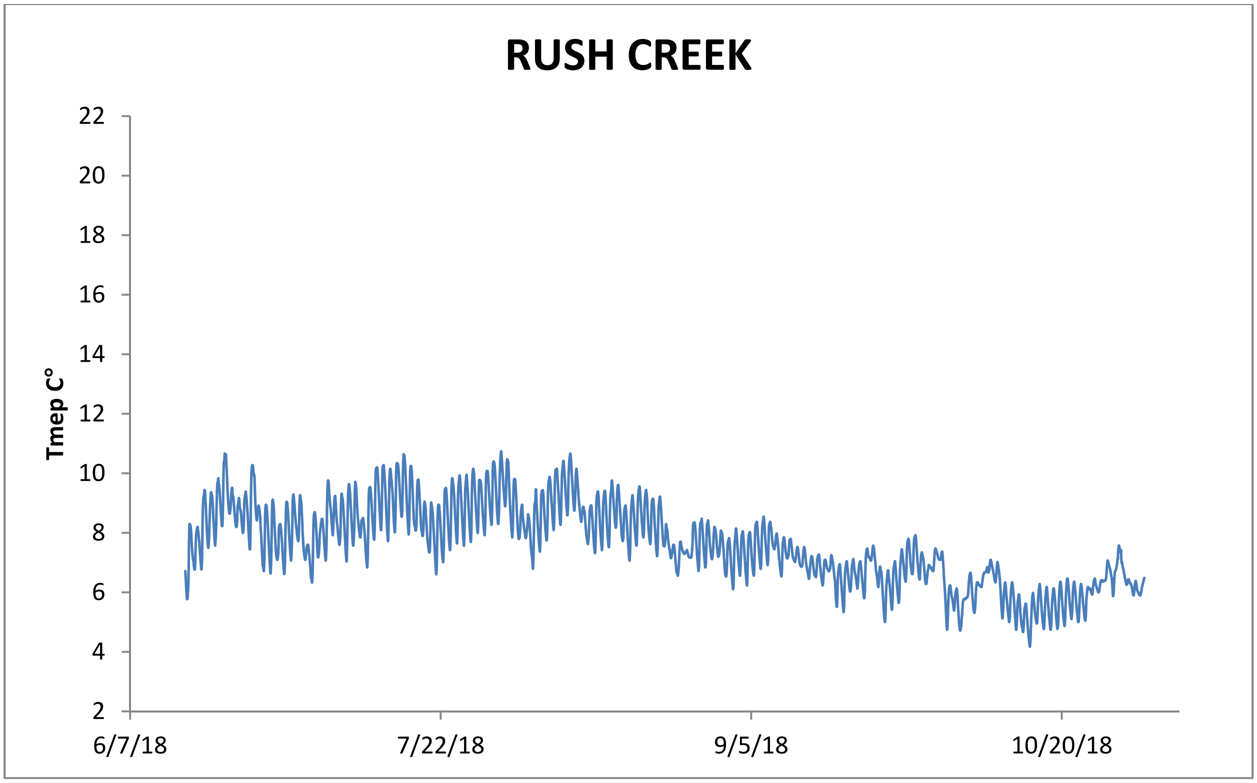

Figure 3.6-2. Plotted hourly stream temperature for Rush Creek from June 15 – October 31, 2018.

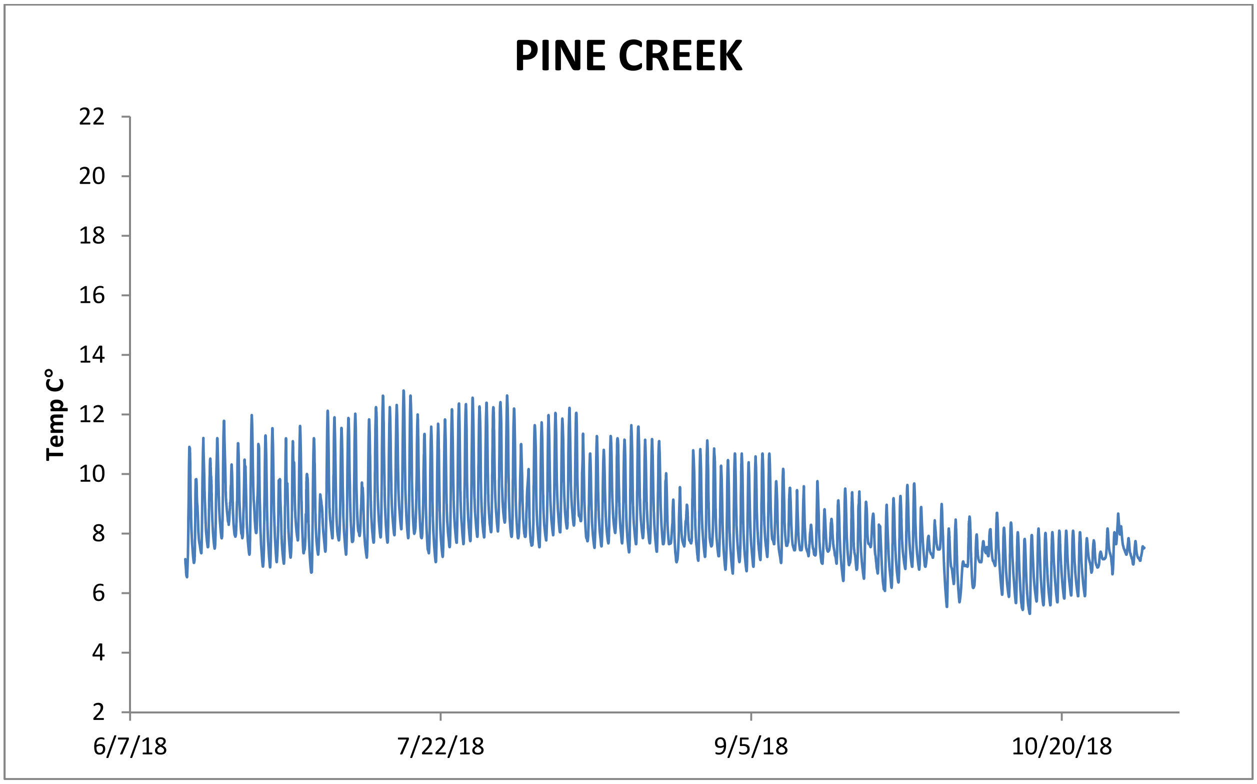

Figure 3.6-3. Plotted hourly stream temperature for Pine Creek from June 15 – October 31, 2018.

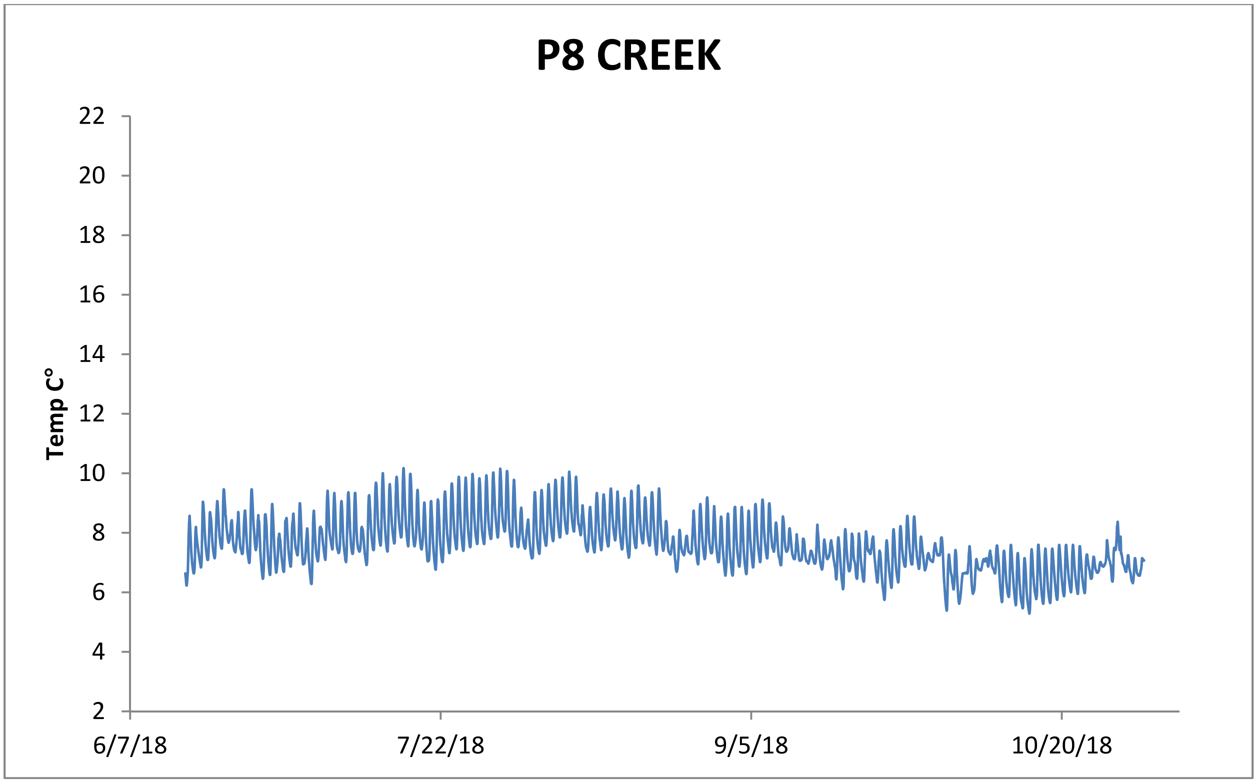

Figure 3.6-4. Plotted hourly stream temperature for Pine Creek tributary P8 from June 15 – October 31, 2018.

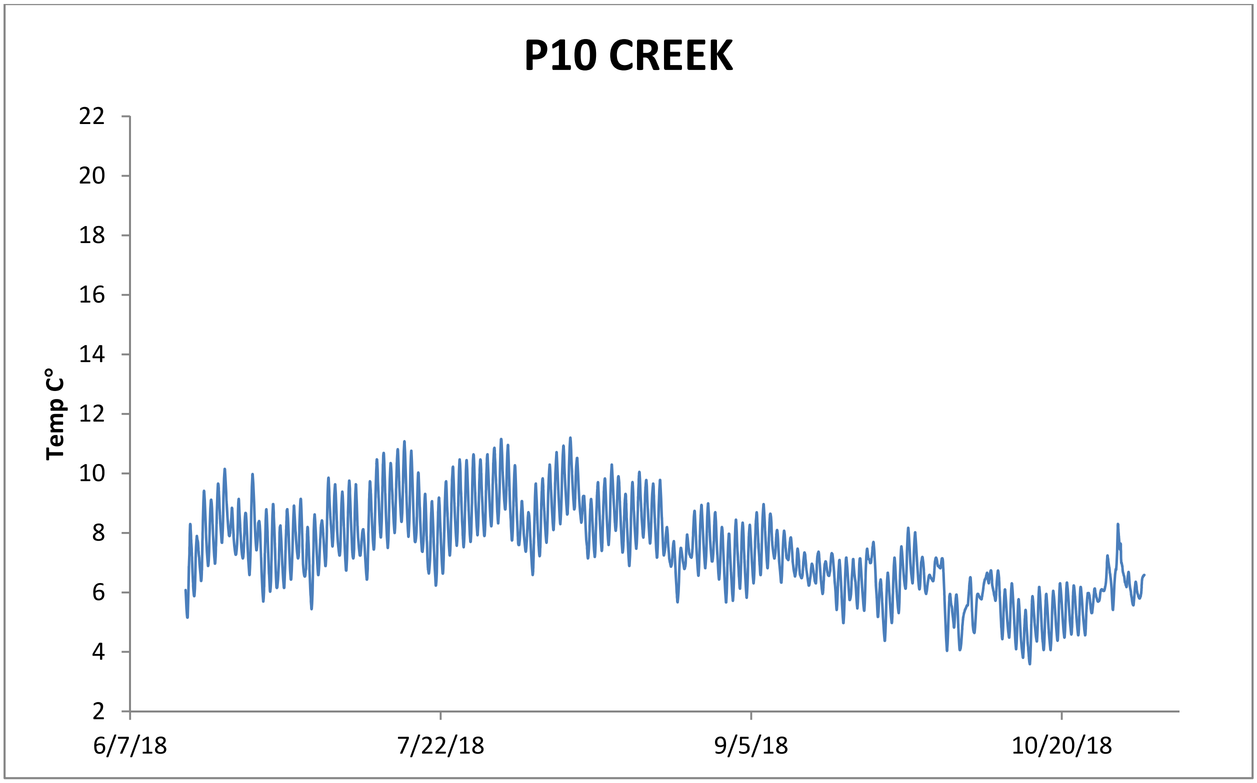

Figure 3.6-5. Plotted hourly stream temperature for Pine Creek tributary P10 from June 15 – October 31, 2018.

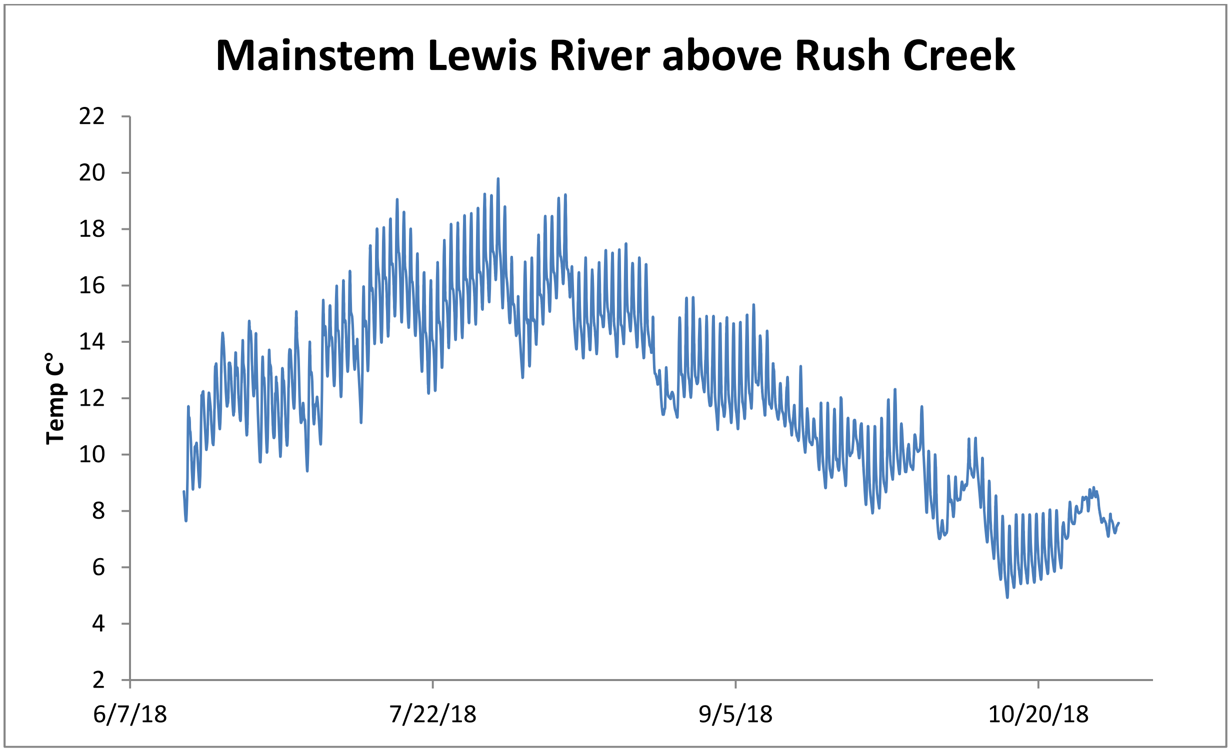

Figure 3.6-6. Plotted hourly stream temperature for the mainstem Lewis River upstream of Rush Creek from June 15 – October 31, 2018.

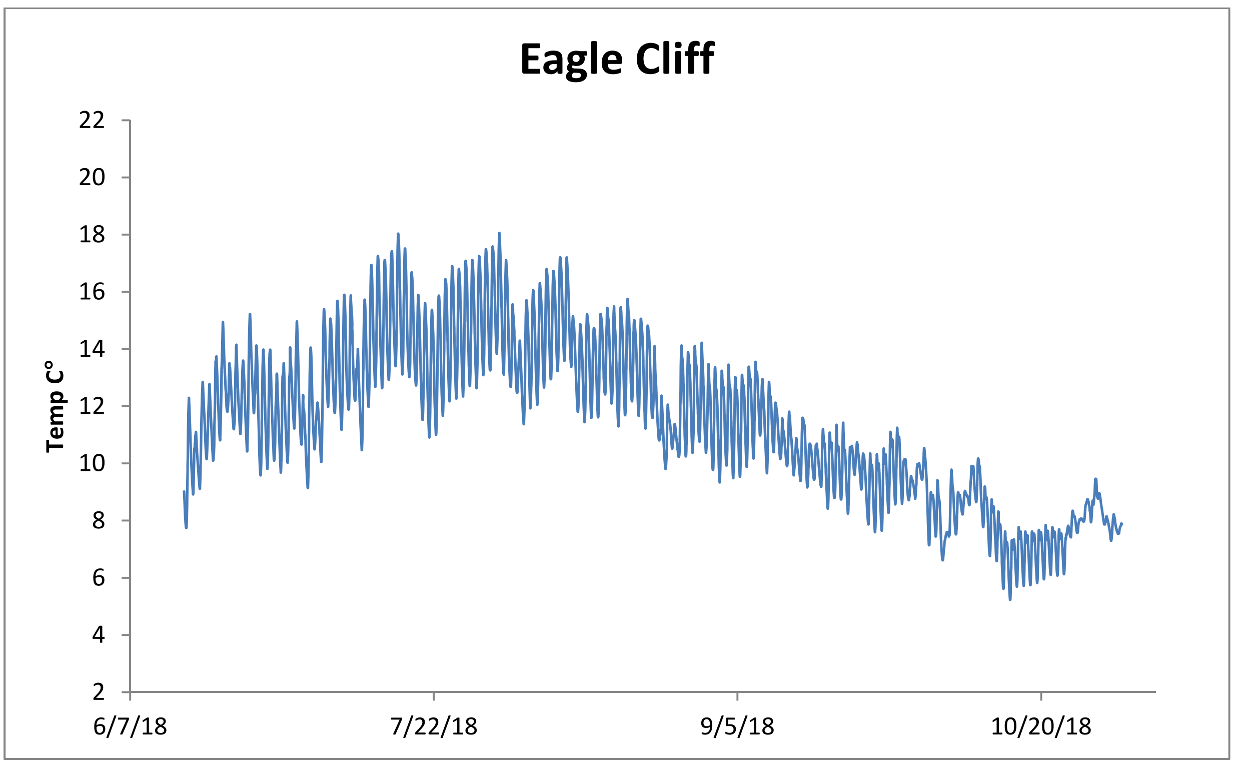

Figure 3.6-7. Plotted hourly stream temperatures for the mainstem Lewis River at Eagle Cliff from June 15 – October 31, 2018.

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.

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APPENDIX A

“PATTERNS OF BULL TROUT SALVELINUS CONFLUENTUS DEMOGRAPHY, LIFE-HISTORY AND ABUNDANCE IN THE NORTH FORK LEWIS RIVER”

DR. ROBERT AL-CHOKHACHY, UNITED STATES GEOLOGICAL SURVEY

Patterns of bull trout *Salvelinus confluentus* demography, life-history and abundance in the North Fork Lewis River—2018 Annual Report

By

Robert Al-Chokhacy[1] and Jeremiah Doyle[2]

Authors affiliations:

[1]U.S. Geological Survey, Northern Rocky Mountain Science Center, 2327 University Way, Suite 2, Bozeman, MT 59715 USA; EM: ral-chokhachy@usgs.gov

[2]PacifiCorp Corporation, [2]PacifiCorp, 105 Merwin Village Court, Ariel, WA 98603

*Denotes corresponding author

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 (Post and Johnston 2002; Rieman et al. 1997). 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 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. 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 (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. *In review*). Similar to numerous other bull trout populations (e.g., Erhardt and Scarnecchia 2014; Johnston et al. 2007; 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 (not considered herein; see Hudson et al. *In review*). 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 (*see* Hudson et al. *In review*). 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. *In review*). Despite the lack of marking events, we used information from previously marked bull trout and passive instream antennas 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 instream PIT-tag antennas. Each year PIT-tag antennas were installed near the mouth of Pine Creek (since 2011) and near the mouth of P8 (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 antennas were taken out of operation.

We used the dates of recaptures at the antennas, and the layout of the antennas 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. *In review*) 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. *In review*). 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 combined the mark-recapture information from the PIT-tag antennas in 2018 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., antenna recaptures) that occur between sampling events (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 antennas 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. *In review*). 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

Two indices of abundance commonly used to monitor bull trout populations (Kovach et al. 2018; Meyer et al. 2014) were conducted each year to evaluate temporal trends in the population above Swift Dam.

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 are 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 2018 began earlier than previous years (year day 201; 20-July) and continued until 3-October. During these surveys, 3 snorkelers floated downstream staying lateral and equidistant to each other and enumerating fish in their lanes (Brenkman et al. 2012). During surveys all adult bull trout >450 mm were enumerated and 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. Given that snorkel surveys have only been consistently completed since 2011, we simply evaluated trends using linear regression models (GLM, Program MASS; Venables and Ripley 2002).

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. We employed the redd data from P8 to estimate bull trout population growth rate (λ) 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 (Al-Chokhachy et al. 2016; Meyer et al. 2014). 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).

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 conducted an observer error study during 2018. 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 as observers and surveys in a stream (Whitacre et al. 2007). In general, higher signal to noise values are better in monitoring with 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 (α = 0.10; two-tailed; Package fishmethods, R CoreTeam 2012).

Results and Discussion

Bull trout spawning migrations

During 2018, a total of 40 individual PIT-tagged bull trout were detected in Pine Creek. Similar to 2017, over half (55%) of the fish were detected only in Pine Creek and 45% were detected in P8 (Figure 2). Since 2012, the proportion of bull trout only detected in Pine Creek has varied from 30% in 2012 and 2013 to 71% in 2016.

The date of upstream spawning migration into Pine Creek has varied across years (Figure 3A). In 2018, the median date of upstream migration was 18-August (Day of year = 231), which is similar to the overall median across years. The median date of upstream migration was strongly correlated with average August air temperature (r = 0.80), 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). We found no apparent relationship with July or September air temperature and median date of upstream bull trout migration (r = 0.41, -0.09, respectively). The median date of downstream migration was 28-September (Day of year = 271; Figure 3B) which again was similar to the median across years (Day of year = 269). The total duration of time bull trout remained in Pine Creek appears to vary across years (Figure 4). In 2018, the average time spent in Pine Creek by migrating bull trout was 52 days (range = 21 – 69 days), which was higher than the overall median (39.5 days).

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 to "stage" well before migrating into P8 and/or spawning. Across years, bull trout used 25 days (median; range = 3 - 39) to migrate from Pine Creek to P8 (Figure 5A). However, downstream migration was considerably more rapid (median = 1 day; range = 0 – 16; Figure 5B), 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 (Nelson 2014) in Washington, where bull trout can remain in streams for months. It remains unclear what influences downstream spawning migrations, but may be driven by a combination of biotic and abiotic factors (Al-Chokhachy et al. *In review;* Barnett and Paige 2013) as well as the ability to recover post spawning.

Merging the migration data from 2018 with previous years, we found very few bull trout to spawn multiple times (Figure 6). Since 2011, 46% of the marked fish have never been detected migrating, while 26.7% only spawned once. Of the 338 PIT-tagged bull trout, only 13.7% have migrated more than two times.

Bull trout survival

Mark-recapture analyses suggested 2 plausible models (i.e., ΔAICc <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 (ΔAICc = 2.1, Wi = 0.26) 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). The results from this analysis are subtly different than recent estimates (Al-Chokhachy et al. *In review*), which suggested differences in survival between subadults and adults. The disagreement in survival by groups may be due to inherent differences in the mark-recapture datasets (i.e., active marking and antenna data) as well as the time series of data, which is considerably shorter here than in Al-Chokhachy et al. (*In review*).

Survival estimates varied significantly through time with survival during 2013 and 2015 significantly lower than 2011, 2012, and 2014 (Figure 7). 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 2013 and 2015 were markedly lower. At this point it is unclear what may be causing the observed fluctuations in survival, and further investigations are warranted. As expected, recent survival estimates (2017 – 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 indicate median counts were higher in 2018 than in 2017 in all sections except the Lewis River from Muddy River to Pine Creek (Figure 8A). Considering the maximum counts suggested higher maximum number of adults in Pine Creek, with similar counts for Rush Creek and Muddy River as 2017 (Figure 8B). For both indices, the number of adult bull trout observed in the section from the Muddy River to Pine Creek was lower in 2018; counts within this section are consistently the lowest among sections. Across both metrics, there are generally declining trends at Rush Creek, highly variable trends at Pine Creek and the Muddy River to Pine Creek section, and no clear trend across metrics at the Muddy River. The median annual counts indicate considerable interannual variability in Pine Creek (CV = 51) and Rush Creek (CV = 41), but much lower interannual variability at the Muddy River site (CV = 15). At least part of this variability may be driven by the large differences in the number of bull trout observed during any given survey (Figure 9). 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 2018 suggested different patterns based on the monitoring metric. Annual median counts (i.e., median across all weekly snorkel surveys within a year) did not suggest any trends in relative abundance (slope = -0.16, SE = 0.88, P = 0.87; Figure 10A). However, maximum counts (i.e., the maximum total number of bull trout observed across sections on a snorkel survey date by year) suggested a declining trend in relative abundance during the same period (slope = -6.43, SE = 3.0, P = 0.08; Figure 10B). 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. *In review*). This discrepancy may hinder the inferences of cross-walking different monitoring data types and suggests the consideration of multiple metrics.

In addition, 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 11). 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. Based on data from PIT-tagged individuals suggests constraining snorkel surveys to dates prior to year day 251 (8-Sepember), which is where 90% of bull trout historically have migrated upstream (Figure 12A) and <10% of downstream migrations have occurred (Figure 12B). Given the plethora of historical data in the Lewis suggests ample amount of information to improve monitoring approaches.

Redd counts. —In 2018, 45 bull trout redds were documented in P8, and annual counts since 2008 suggest substantial increases. 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 ($\lambda = 1.11$; 95% CI = 1.03 – 1.21; Figure 13). 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 2018 88 bull trout redds were counted in Pine Creek and 20 redds were detected in Rush Creek totaling 153 bull trout redds for the population above Swift Dam. Continued monitoring in each of the spawning tributaries 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. For example, the P8 redd data since 2012 were weakly correlated ($r = 0.32$) with the number of migrants to P8 (Figure 2). However, no bull trout have been PIT-tagged since 2016, thus comparisons are not valid. Concomitantly, the snorkel survey trends (Figures 10A, B) 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. Estimates of signal to noise (S:N) suggested that observer error (noise) was most prohibitive to detecting trends in Pine Creek (S:N = 0.9), considerable in Rush Creek and Cougar Creek (S:N = 1.1 and 1.2, respectively), and lowest in P8 (S:N = 5.1; Table 2). However, the low S:N values in Cougar Creek are likely driven by the similarity in counts across surveys 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 Pine Creek (median CV = 39) and Rush Creek (CV = 40) but less variation in P8 and Cougar Creek (CV = 18 and 13, respectively; Table 2; Figure 14). 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 50% declines in Cougar Creek and P8 Creek over 20 years would be 1 and 0.99, respectively (i.e., there is a 0 and 0.01 probability of a type II error- the failure to detect a change, when a change has occurred), but would drop to only 0.59 for Pine Creek and Rush Creek (Figure 15). 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 (Kovach et al. 2016; Rieman and Myers 1997) 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).

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Table 1. The results from the mark-recapture analyses (Barker model) 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
$S_{(t)}$, $p_{(t+length)}$, $R_{(g+t+length)}$, $R'_{(g)}$, $f_{(.)}$, $f'_{(.)}$	2,018.5	0	0.73	31	1,954.2
$S_{(g+t)}$, $p_{(t+length)}$, $R_{(g+t+length)}$, $R'_{(g)}$, $f_{(.)}$, $f'_{(.)}$	2,020.6	2.1	0.26	32	1,954.1
$S_{(g)}$, $p_{(t+length)}$, $R_{(g+t+length)}$, $R'_{(g)}$, $f_{(.)}$, $f'_{(.)}$	2,026.6	8.1	0.01	23	1,979.3

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

Table 2. The average new bull trout redds detected in counts and the median CV of counts across both observers and the number of survey dates (n) by stream and section in bull trout spawning tributaries in the North Fork Lewis River basin, Washington.

Stream	Section	Average counts	Median CV counts	n	Signal to noise
Pine Creek	P3 to P8	9	39	4	0.9
P8	Entire stream	6.5	18	3	5.1
Rush Creek	Entire section	4	40	2	1.1
Cougar Creek	Entire Section	5.5	13	2	1.2

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. Black box in the inset illustrates the location of the study area within the Pacific Northwest, USA.

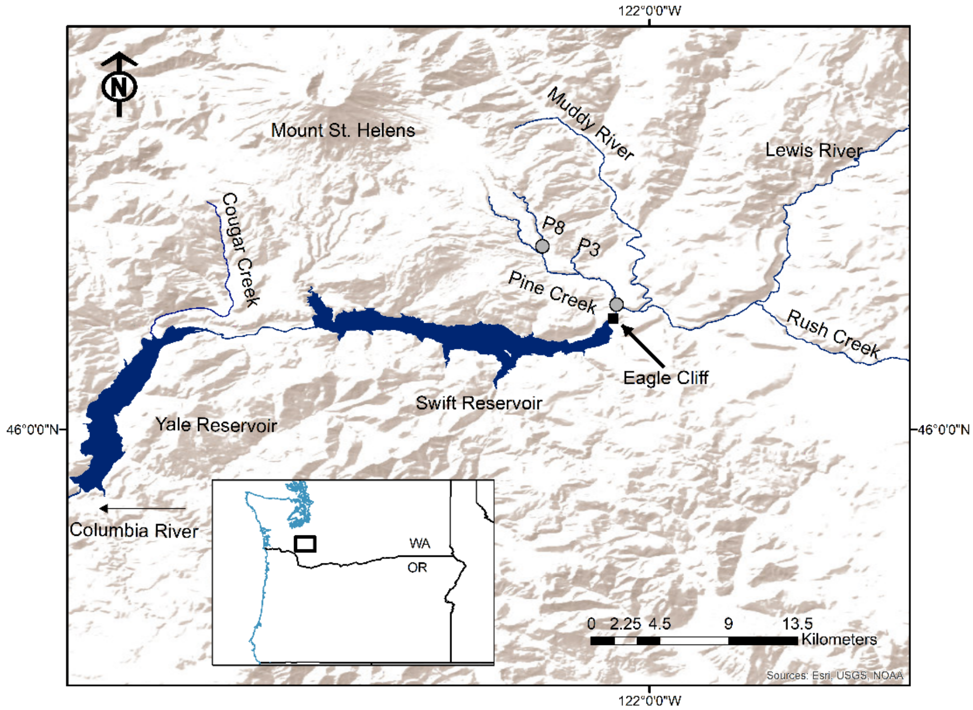

Figure 2. The proportion of PIT-tagged bull trout detected at P8 (white) and Pine Creek (black) antennas from 2011 -2018 in the North Fork Lewis River, Washington.

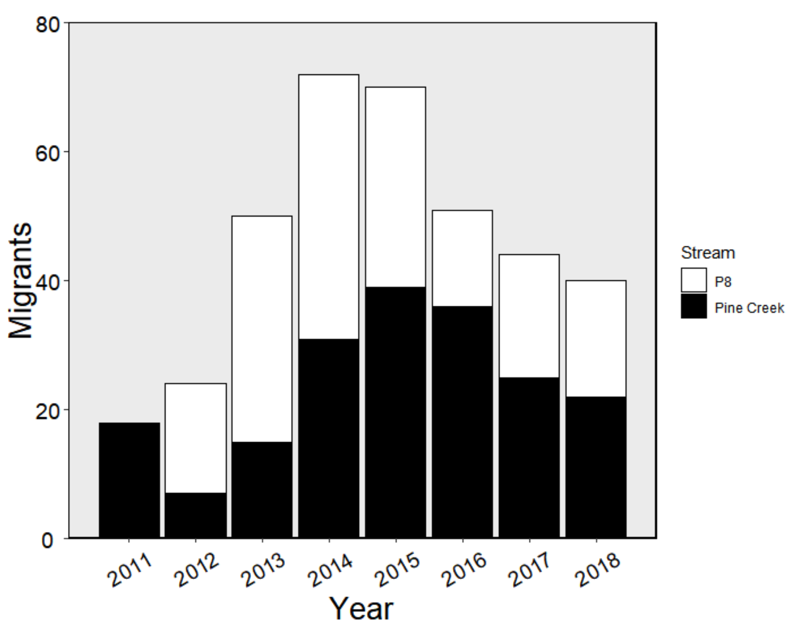

Figure 3. The day of upstream (A) and downstream (B) migration of PIT-tagged bull trout in Pine Creek (2011 – 2018) in the North Fork Lewis River, Washington. For reference 1-August is the 212th day and 1-November is the 305th day of the year. Note: the small sample size in downstream migration in 2012 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.

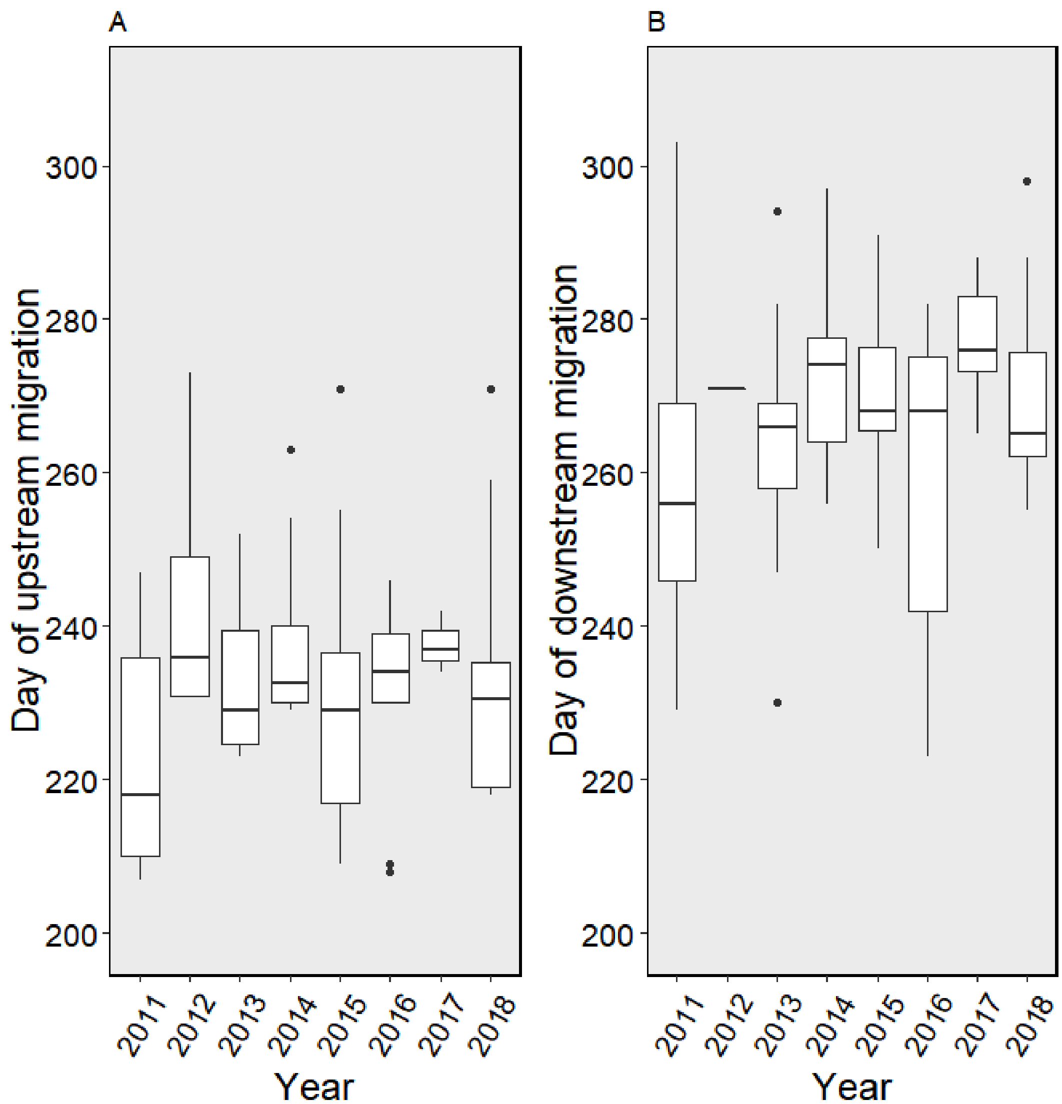

Figure 4. The total duration of time (days) by year that PIT-tagged bull trout remain in Pine Creek, a tributary to the North Fork Lewis River, Washington, during the spawning season.

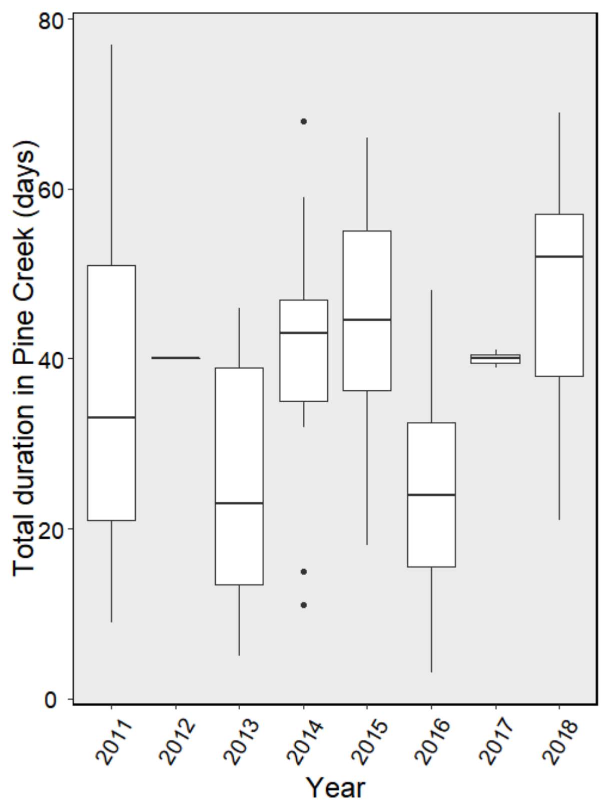

Figure 5. Yearly estimates of the duration of spawning migrations of PIT-tagged bull trout from antennas on lower Pine Creek upstream to P8 (i.e., pre-spawn migration; A) and from P8 downstream to Pine Creek (i.e., post-spawn migration; B), a tributary to the North Fork Lewis River, Washington.

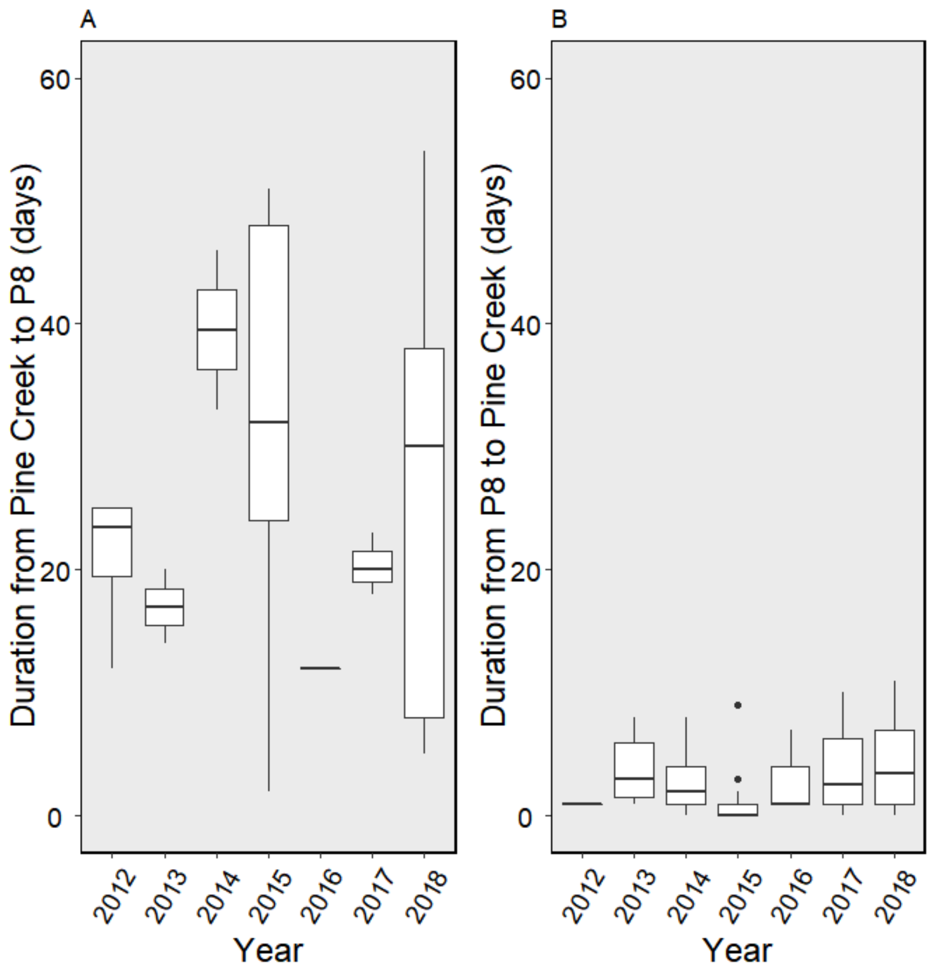

Figure 6. The frequency of the number of spawning migrations of bull trout into Pine Creek in the North Fork Lewis River from PIT-tagged individuals and antenna recaptures (2011-2018)

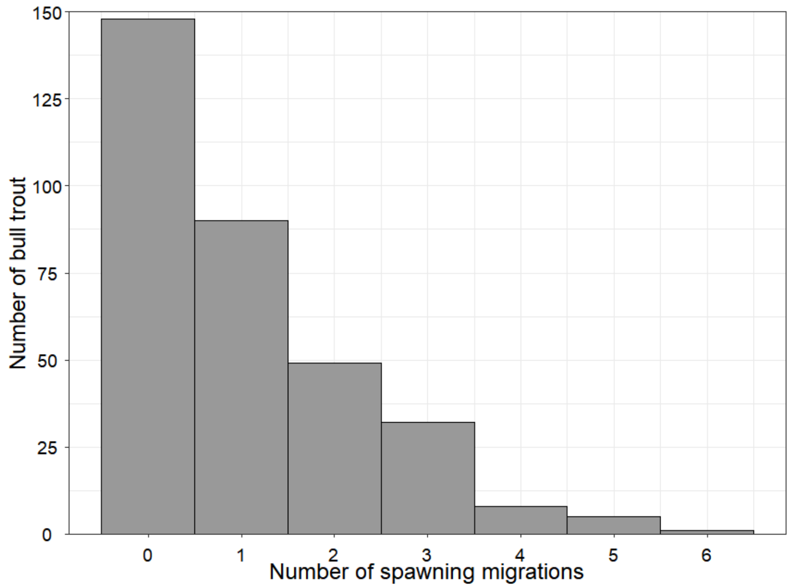

Figure 7. Estimates of annual bull trout survival (adults and subadults) from mark-recapture data from Eagle Cliff sampling and antennas within Pine Creek and Rush Creek, tributaries to the North Fork Lewis River, Washington.

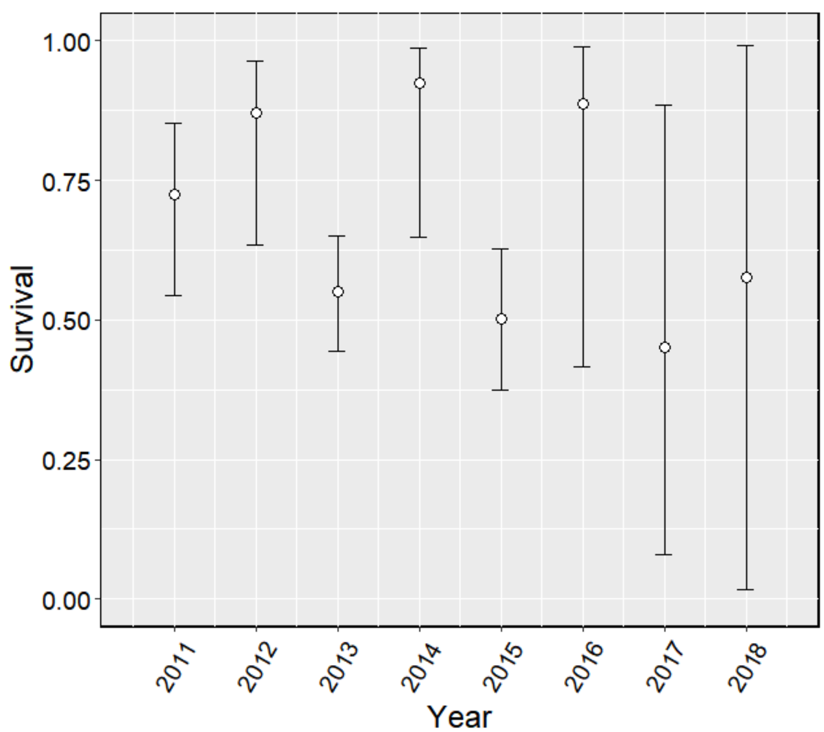

Figure 8. Median (A) and maximum snorkel counts (B) by year of adult bull trout (>450 mm) from the confluence of the North Fork Lewis River and the Muddy River (light grey), the North Fork Lewis River from Muddy River to Pine Creek (black), the confluence of the North Fork Lewis River and Pine Creek (blue), and the confluence of the North Fork Lewis River and Rush Creek (dark grey) in Washington.

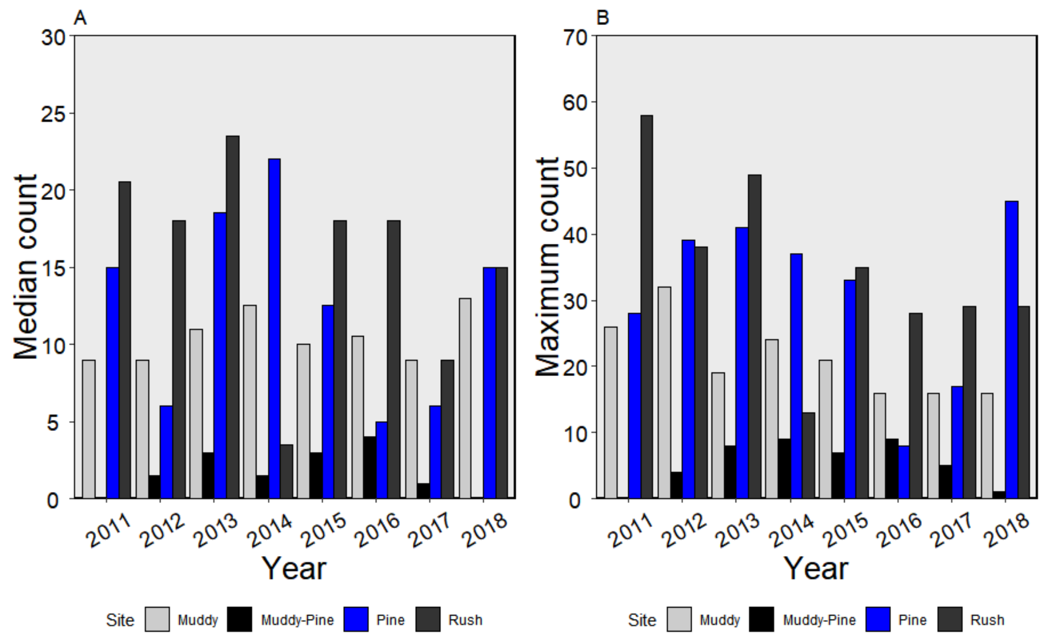

Figure 9. Boxplots of the weekly counts of adult bull trout during snorkel surveys at the Rush Creek site (A), Muddy River site (B), and at Pine Creek (C) in the North Fork Lewis River, Washington.

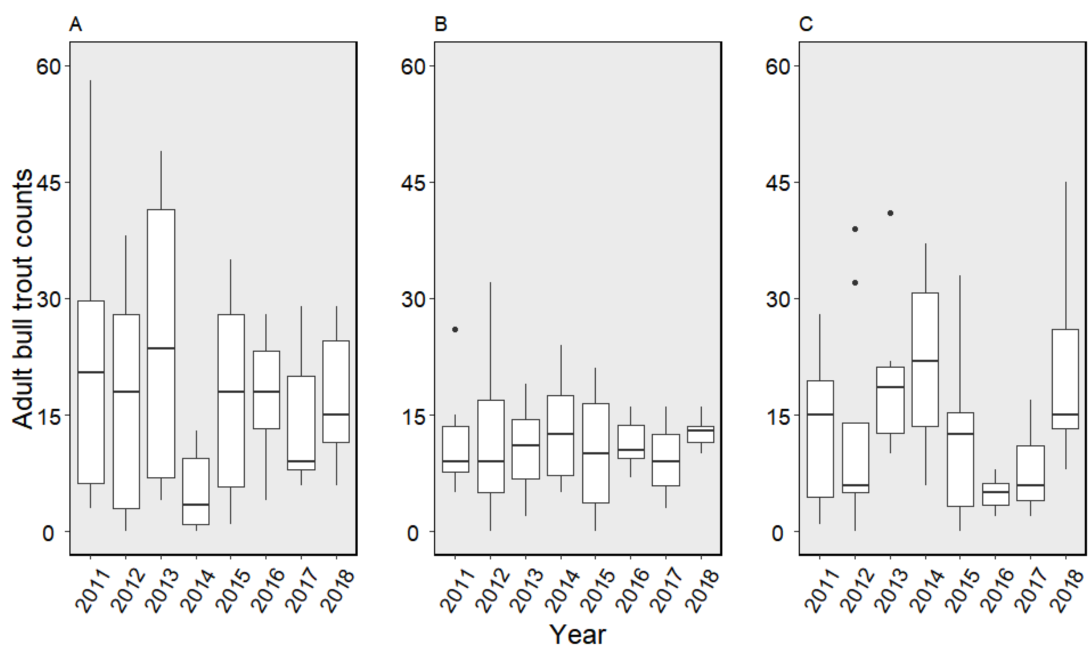

Figure 10. Trends of adult bull trout abundance from median (A) and maximum (B) snorkel counts (totaled across sites for each survey date) from the North Fork Lewis River, Washington from 2011 – 2018.

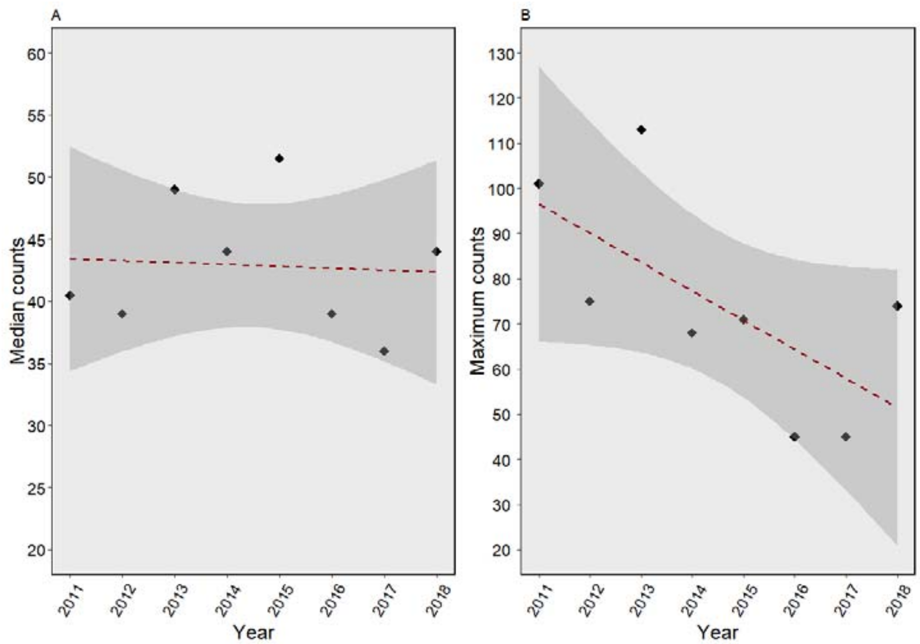

Figure 11. Histograms of the day of year of upstream (green) and downstream (red) bull trout migrations from 2011 to 2018 of PIT-tagged individuals at the PIT-tag antenna near the mouth of Pine Creek in the North Fork Lewis River basin, Washington. For reference, day of year 240, 250, and 260 are 28-August, 7, September, and 17-September, respectively.

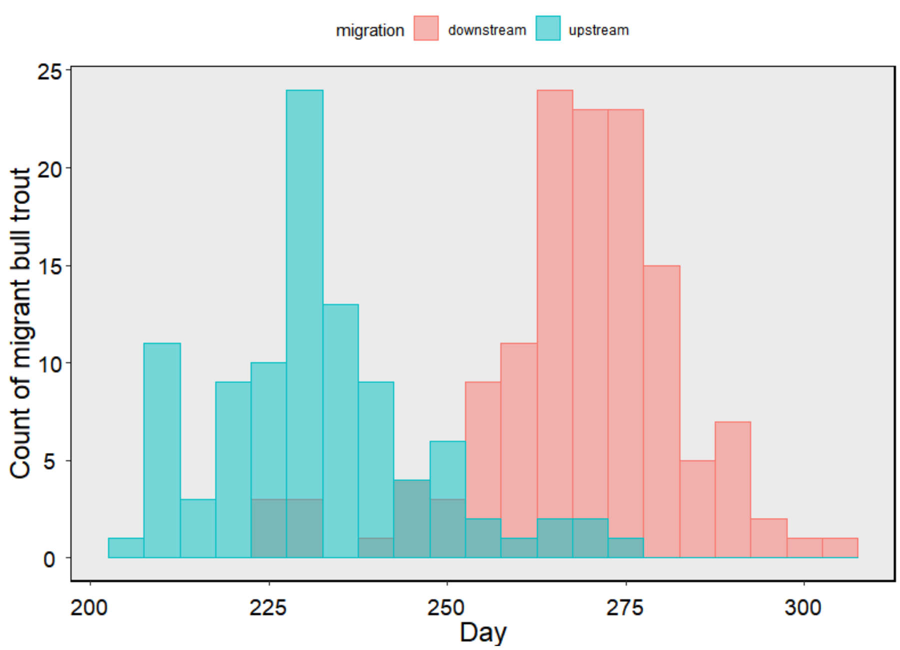

Figure 12. Cumulative frequency histograms for the day of year of upstream (A) and downstream (B) migration of PIT-tagged bull trout past the antenna near the mouth of Pine Creek, a tributary to the North Fork Lewis River, Washington.

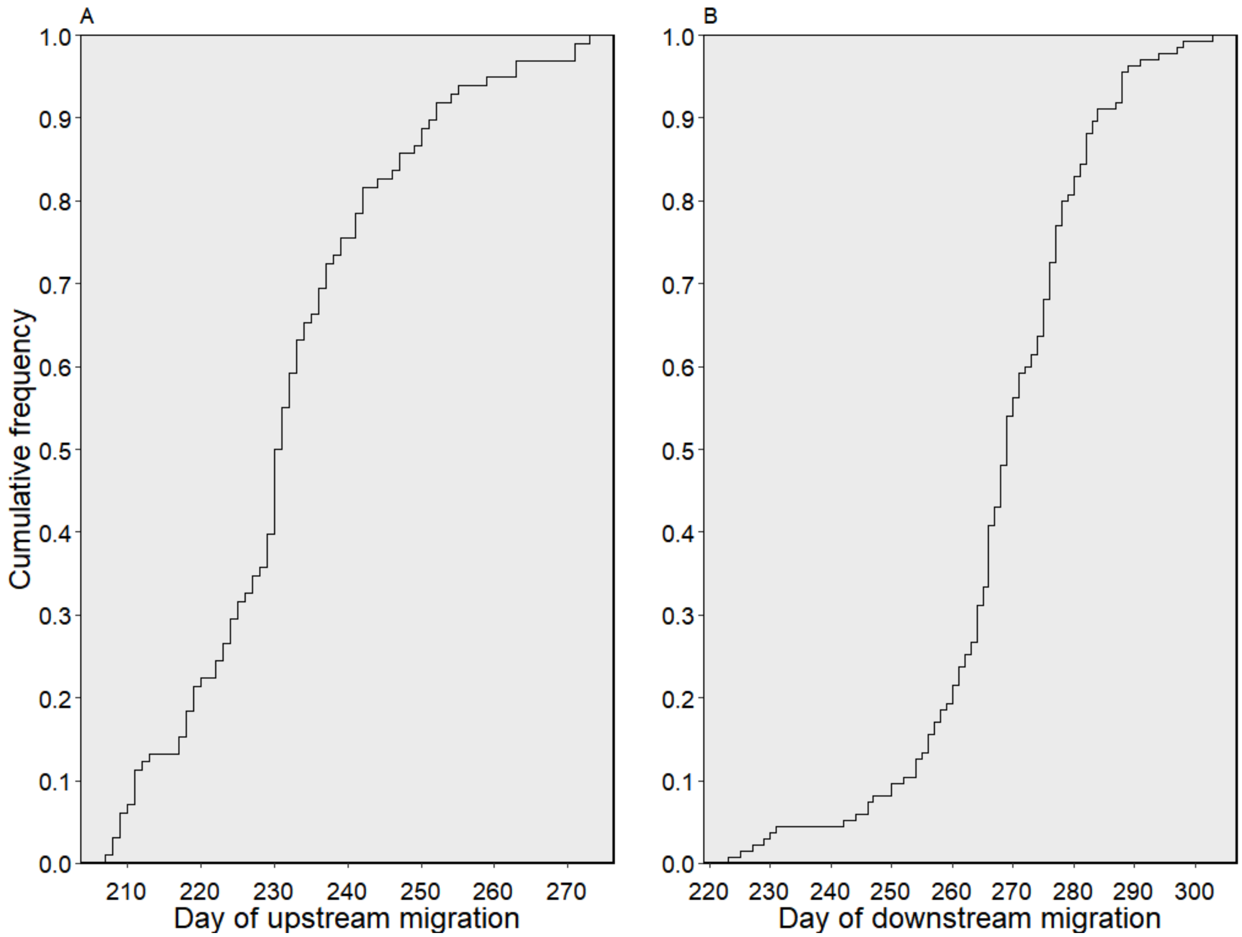

Figure 13. Annual bull trout redd counts from P8, a tributary to Pine Creek in the North Fork Lewis River basin, Washington.

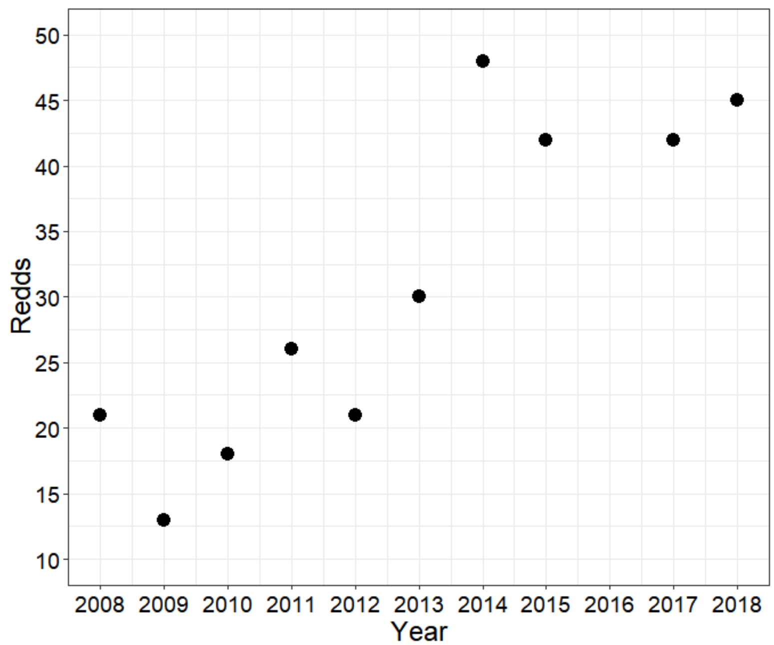

Figure 14. The coefficient of variation (CV) from repeat bull trout redd surveys to quantify observer error at different mean redd counts in Cougar Creek (black), P8 (dark grey), Pine Creek (P3 to P8 section; blue), and Rush Creek (light grey)—tributaries to the North Fork Lewis River, Washington.

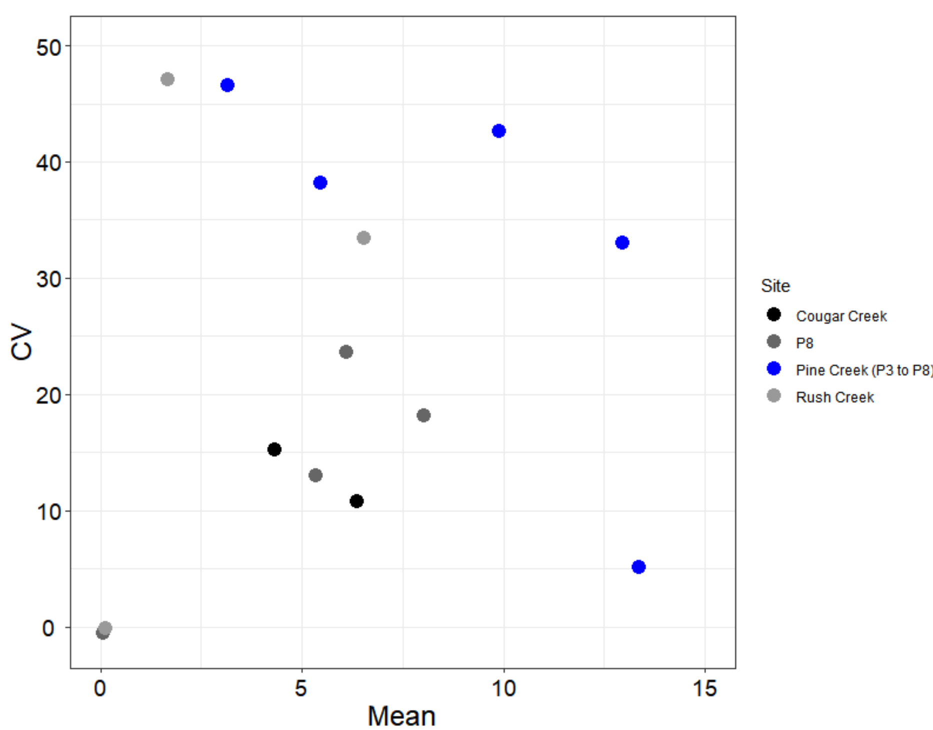

Figure 15. The power to detect different changes in bull trout redd counts over 20 years with CV values from observe error studies for Cougar Creek (CV = 13; black solid), P8 (CV = 18; grey dashed), and Pine Creek and Rush Creek (CV = 40; blue dotted)—tributaries to the North Fork Lewis River, Washington.