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

North Fork Lewis River – 2017

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

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April 2018

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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 2017. For methods and general descriptions of all programs please refer to the Bull Trout Annual Operating Plan for the North Fork Lewis River 2017 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 2017.

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 the 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).

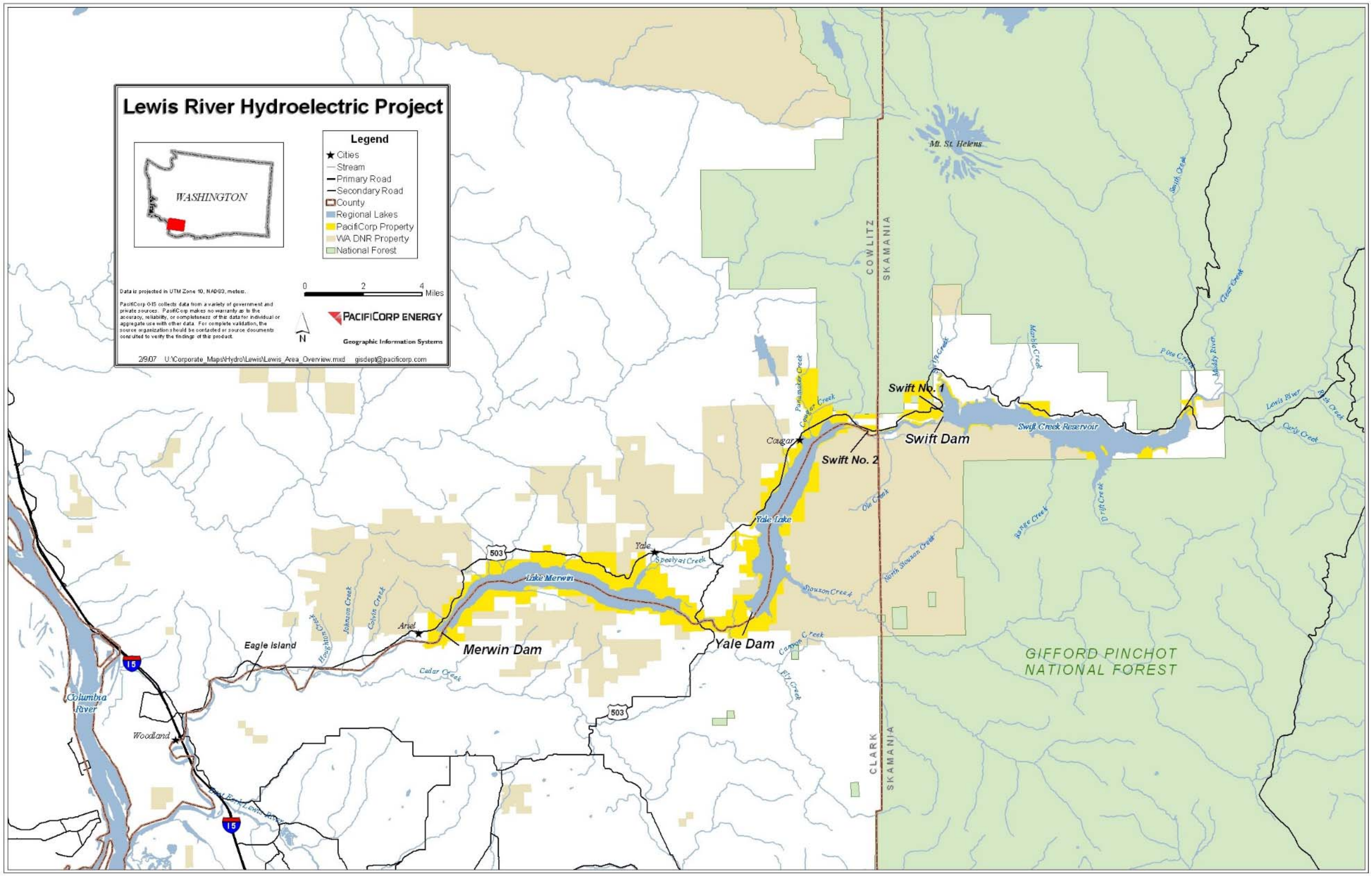

Figure 2.0-1. Map of North Fork Lewis River study area.

3.0 RESULTS FROM 2017 PLANNED ACTIVITIES

During 2017 the Utilities participated in, funded, or initiated five monitoring programs.

1. Swift Reservoir adult migration, Survival (S), and Genetic Estimation of Breeder Population (Nb) estimates
2. Half-duplex Passive Integrated Transponder (PIT) tag antenna arrays in Cougar, Pine, P8, Swift, and Rush Creeks
3. Yale tailrace collection and transport
4. Bull trout redd surveys of Cougar Creek
5. Bull trout redd surveys of Pine and Rush Creeks and Pine Creek tributary P8

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. 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 will commence will 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 August 16 to October 11 for a total of seven 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. 2017 bull trout snorkel survey results for the Muddy River, Rush and Pine Creeks confluence areas with the North Fork Lewis River (recapture).

Date	Location	Total Observed >450mm
16-Aug	Pine, Rush, Muddy confluence areas	45
23-Aug	Pine, Rush, Muddy confluence areas	37
5-Sep	Pine, Rush, Muddy confluence areas	20
14-Sep	Pine, Rush, Muddy, confluence areas	21
27-Sep	Pine, Rush, Muddy, confluence areas	36
4-Oct	Pine, Rush, Muddy confluence areas	36
11-Oct	Pine, Rush, Muddy confluence areas	35
TOTAL	**Pine, Rush, Muddy confluence areas**	**230**

New in 2017 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 weekly snorkel surveys. All bull trout observed were pooled into one total weekly count. Thus no NOREMARK® estimate was generated in 2017.

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 2017 it was not possible to generate an estimate with this program; instead snorkel information was pooled along with other demographic information in an effort to crosswalk historical data to data gathered in 2017. This information can be found in the technical memorandum “Bull Trout Monitoring Methods in the NF Lewis” from Dr. Robert Al-Chokhachy of the United States Geological Survey located in Appendix A of this Report.

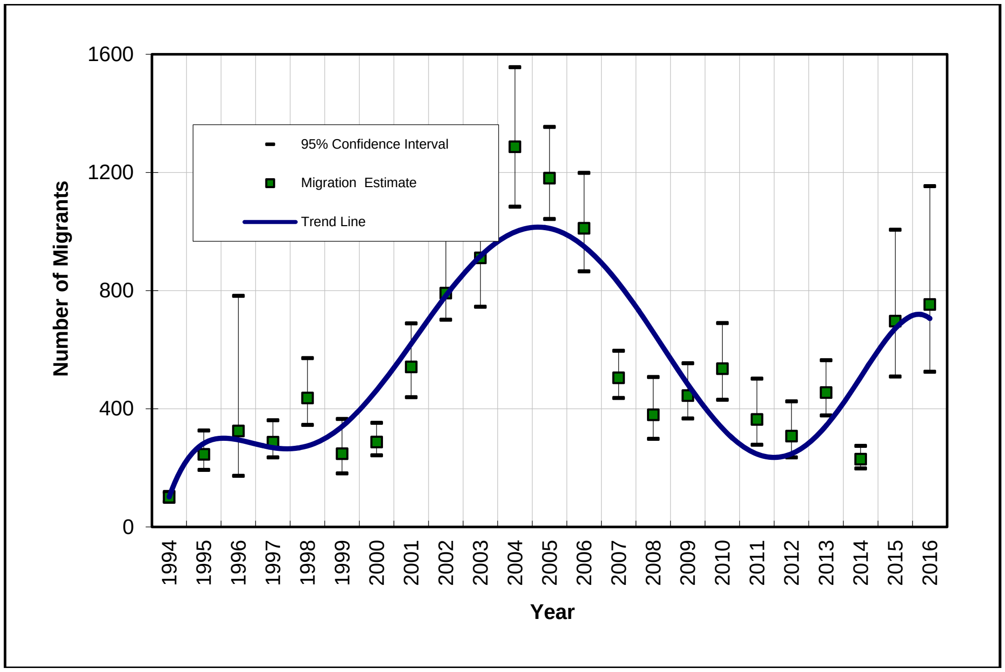

Figure 3.1-1. Estimates of bull trout that migrated from Swift Reservoir up the North Fork Lewis River for the years 1994 through 2016. (1994-2000 Peterson Estimator, 2001- 2016 Program NOREMARK®, Smith 1996)

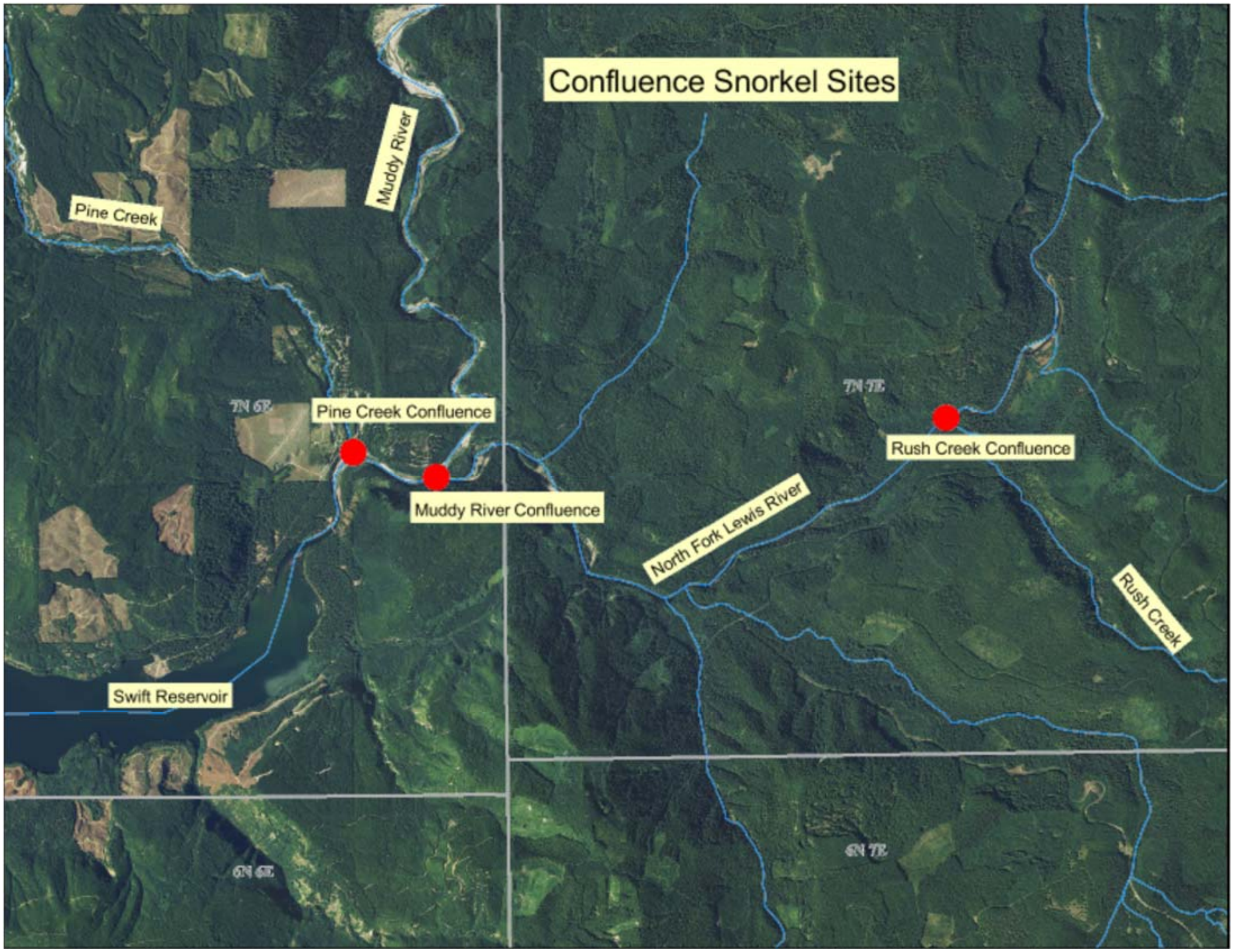

Figure 3.1-2. Snorkel sites (for recapture) associated with the Swift Reservoir bull trout migration estimate

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

For more detailed Results, Analysis, Methods and Equations, please see the technical memorandum "Bull Trout Monitoring Methods in the NF Lewis" from Dr. Robert Al-Chokhachy of the United States Geological Survey located in Appendix A 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 2017. N_e is performed as part of the bull trout demographic characteristics evaluation objective within Section 17 of the Monitoring and Evaluation Plan.

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 17 and July 19 (Figure 3.1.3-1). In all, 36 juvenile bull trout were captured and sampled for genetic tissue. 34 of the captures were less than 70 mm fork length and assumed to be of 2016 brood year origin and so were included within the N_e analysis. The length range of the bull trout utilized within the analysis was 39 mm – 52 mm, with an average fork length of 45 mm.

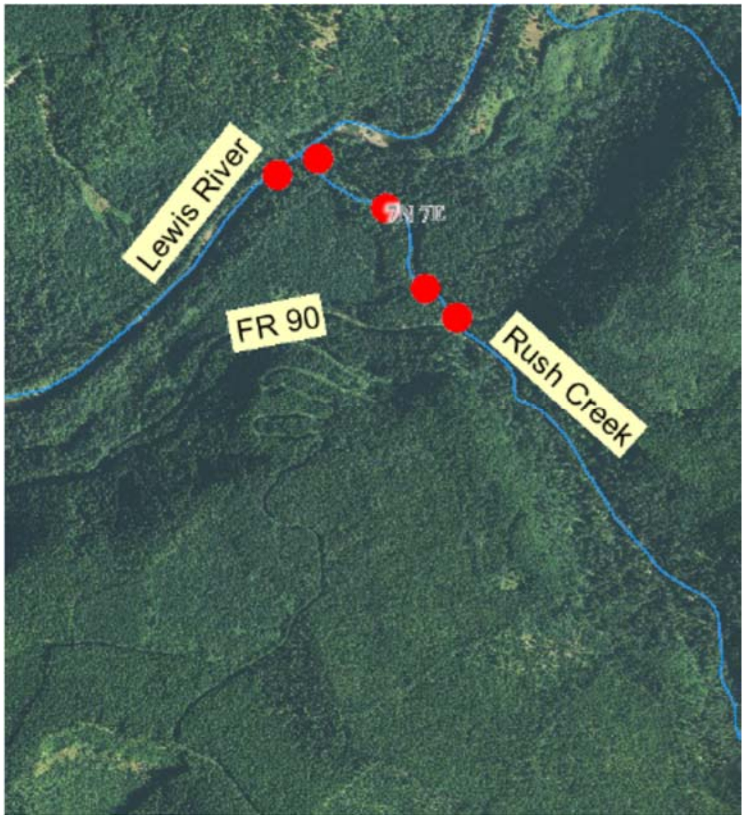

Figure 3.1.3-1. Electrofishing sites within Rush Creek during 2017 juvenile bull trout collection.

Areas within Pine Creek and tributary P8 were sampled for juvenile bull trout with a backpack electrofisher on June 28 and 30, and July 6 and 27 (Figure 3.1.3-2). In all, 62 juvenile bull trout were captured from within P8 with all captures meeting the fork length criteria of less than 70 mm. 48 juvenile bull trout were captured from within areas of Pine Creek, with all captures meeting the fork length criteria used for the N_e analysis. The lengths of the 110 assumed 2016 brood year bull trout captured in the Pine system ranged from 34 mm – 77 mm. 34 bull trout juveniles were captured within Pine Creek during the July 27 survey date, these fish were larger in size than what is typically observed during surveys performed in late June with many exceeding the 70mm cut-off size. Given the extra month of growth, these larger sized fish were included within the analysis. The average fork length of the 34 July 27 captures was 68 mm. The average fork length of all other Pine Creek captures including P8 was 51 mm.

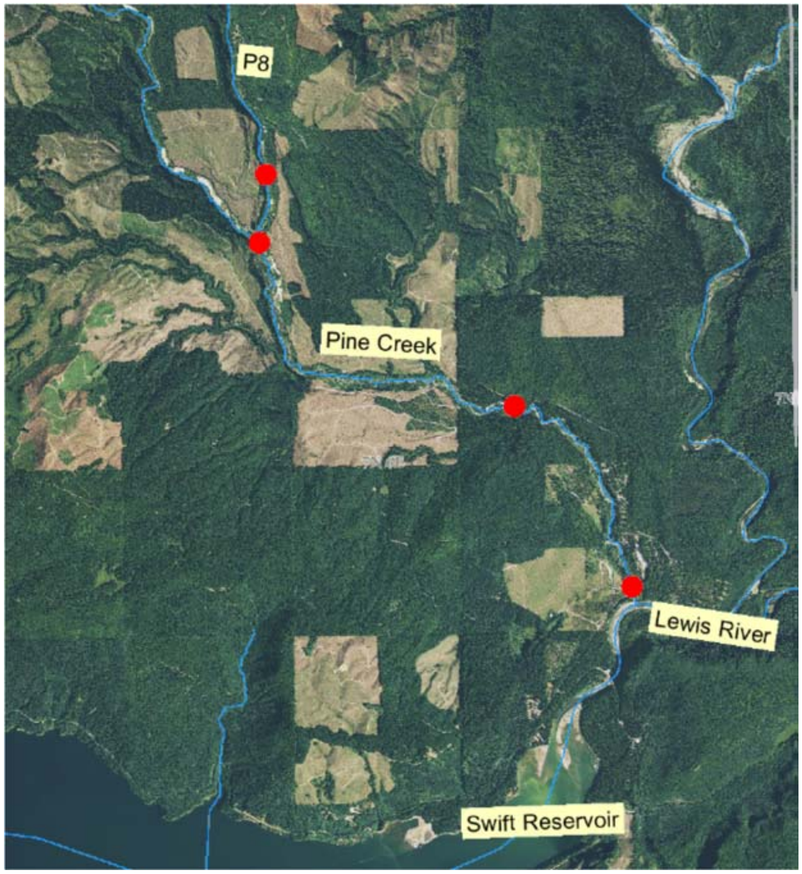

Figure 3.1.3-2. Electrofishing sites within the Pine Creek system during 2017 juvenile bull trout collection.

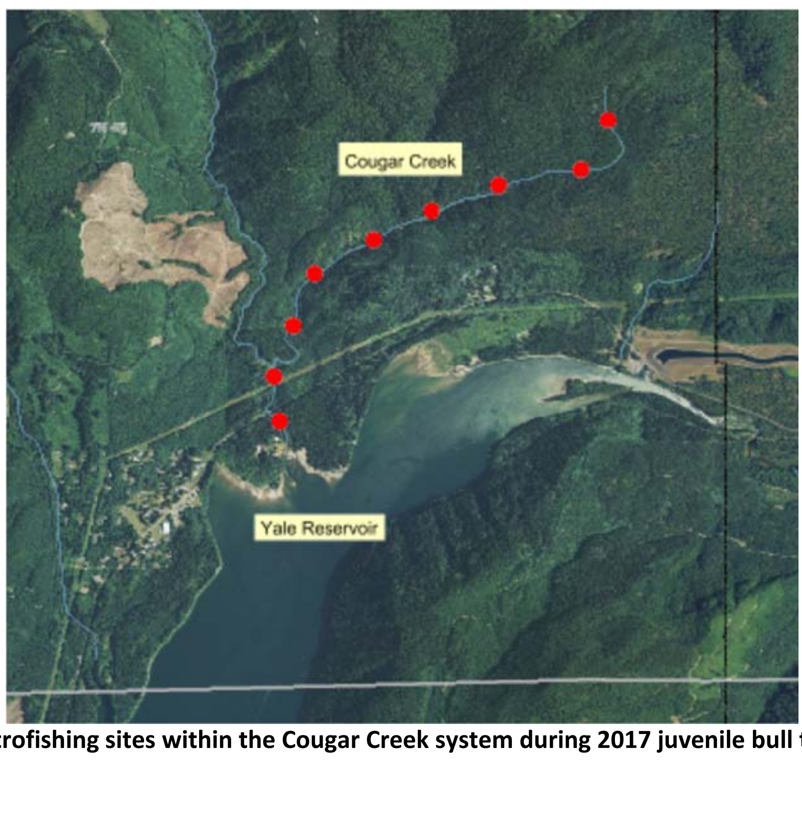

Figure 3.1.3-3. Electrofishing sites within the Cougar Creek system during 2017 juvenile bull trout collection.

Areas within Cougar Creek were sampled with a backpack electrofishing unit on July 12-13 (Figure 3.1.3-3). In all, 68 juvenile bull trout were captured and sampled for genetic tissue. All of the captures were within the accepted fork length range and assumed to be of 2016 brood year origin and so were included within the N_e analysis. The length range of bull trout utilized within the analysis was 39 mm – 72 mm, with an average fork length of 56 mm (Figure 3.1.3-4).

Analysis of N_b for 2016 by the Abernathy Lab as well as material and methods for all genetic analysis performed within the Lewis River basin in 2017 can be found in Appendix B of this Report.

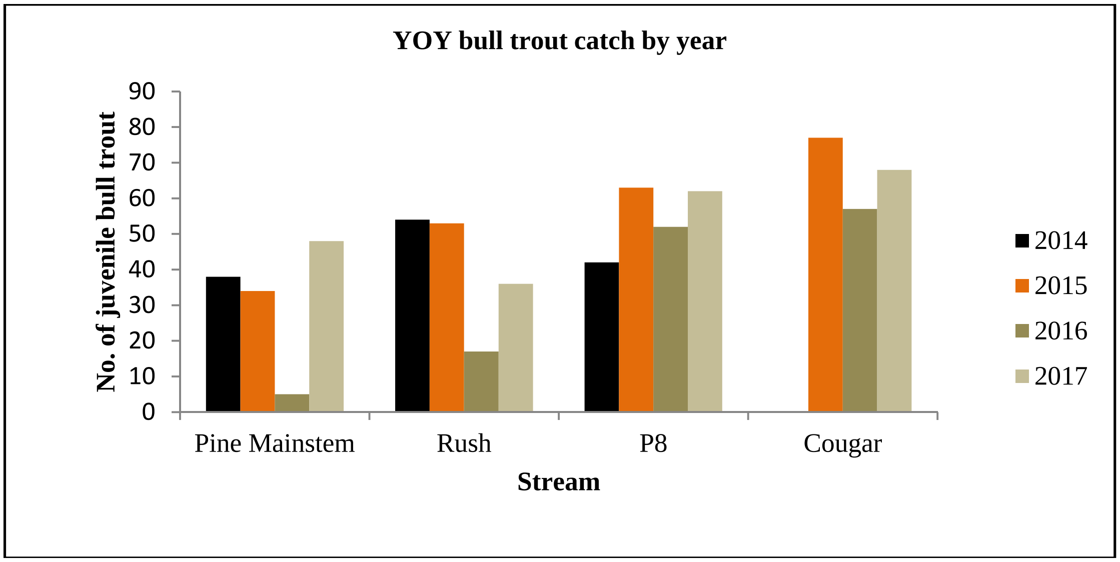

Figure 3.1.3-4. Trend bull trout juvenile catch during stream electrofishing surveys. Cougar Creek was not surveyed in 2014.

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 continued anadromous reintroduction program.

Coho YOY dominated the catch in Pine Creek mainstem totaling 282, while catches in P8 and Rush creeks were nominal, with 28 and 41 captured respectively. This corresponds to a YOY bull trout catch of 48 and a difference in overall collected of 83 percent more YOY coho captures in Pine Creek mainstem. A marked contrast was observed in P8 and Rush creeks, where 62 and 36 YOY bull trout were captured with a difference in overall collected of 23 percent more bull trout in P8 and thirteen percent more coho captured in Rush Creek (Figure 3.1.3-5).

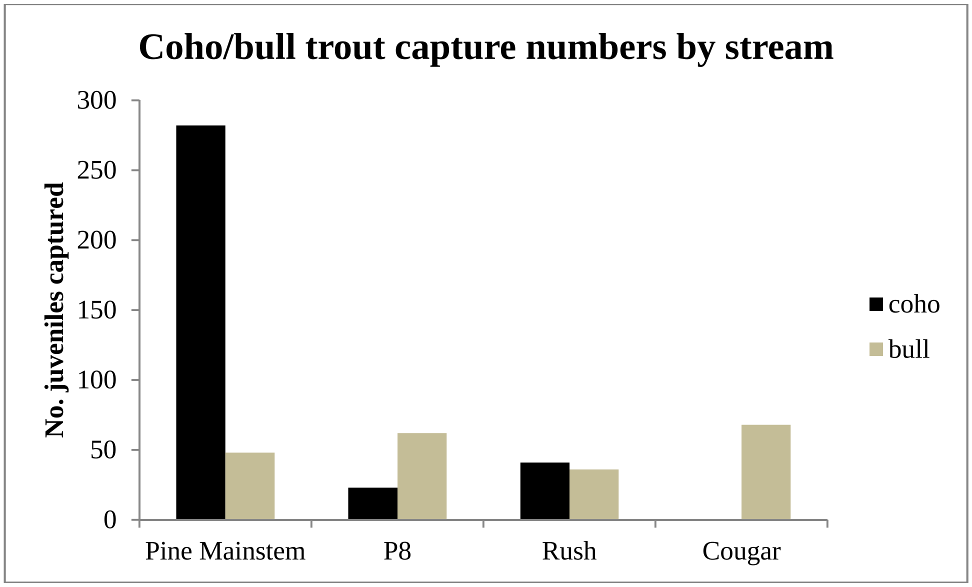

Figure 3.1.3-5

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 coho YOY were marginally larger than bull trout YOY except in Pine Creek mainstem where the bull trout average size was surely skewed by the later July survey date (Figure 3.1.3-6).

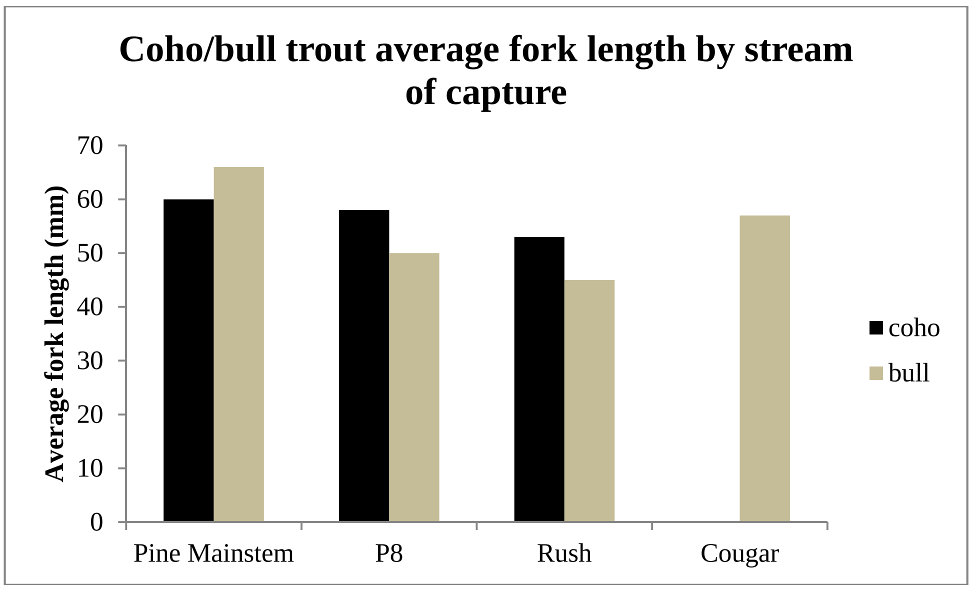

Figure 3.1.3-6

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, Cougar and Swift 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 on Swift Creek was also stream-spanning and was located approximately 100 m upstream from its confluence with Swift Reservoir. 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. New in 2017 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 – 2017.

Figure 3.2.1-2. Half-duplex stream-width PIT tag antenna locations in the Yale Reservoir Basin – 2017.

In 2017 there were 74 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 4 – October 18, 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 160 detections occurred at the antenna resulting in 17 unique bull trout. All of the 118 upstream and downstream movement events occurred during the crepuscular period. Peak migration was observed on September 12 with a total of seven individual bull trout moving past the antenna site (Figure 3.2.1-3).

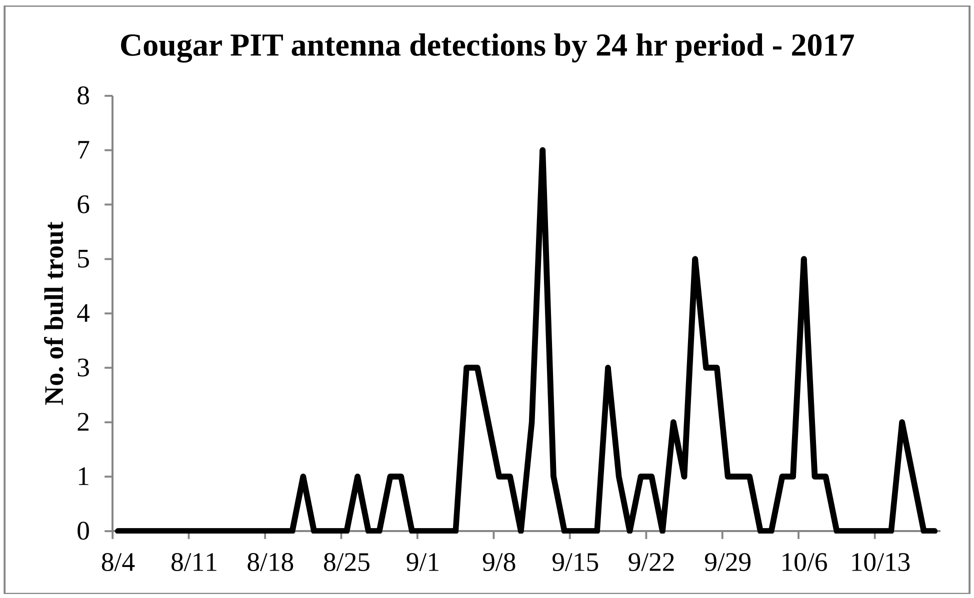

Figure 3.2.1-3

The number of unique bull trout detections in 2017 as compared to historical detections at this site is expressed in Figure 3.2.1-4. Of the 17 bull trout that migrated upstream, thirteen (76 percent) were consecutive spawners with one fish being detected for the last six consecutive years. Four bull trout migrants (24 percent) were maiden detections in 2017.

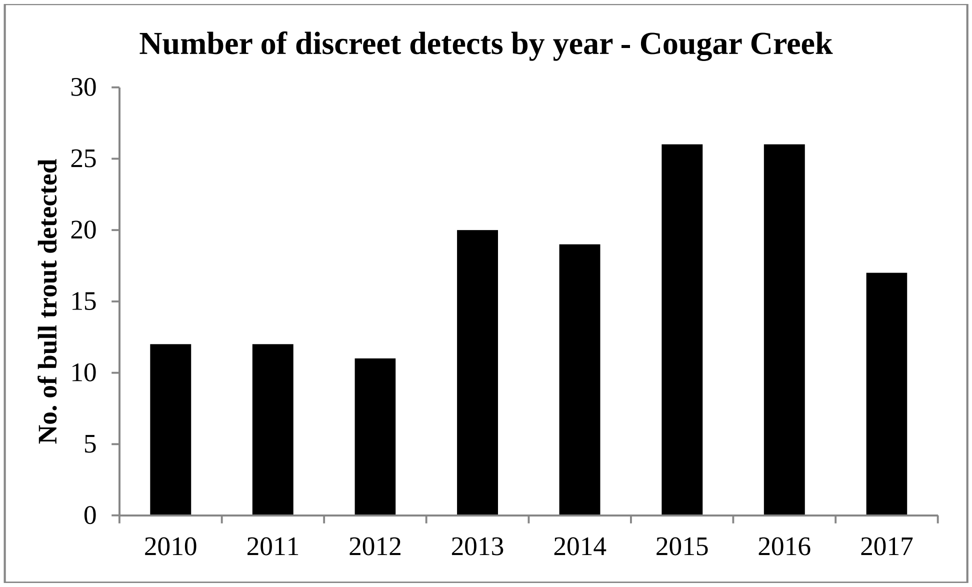

Figure 3.2.1-4

Pine Creek

The PIT antenna at the mouth of Pine Creek was in operation from August 22 to October 24, no power loss was experienced during the survey period. The late August start-up was much later than historical and was due to higher than normal summer water flows which prohibited antenna installation. The antenna loop was destroyed on October 24 due to a high water event. 74 detections were experienced during the period of operation resulting in 44 discrete bull trout tags. Peak migration past this antenna was observed on September 28 and October 3 when four bull trout volitionally swam past (Figure 3.2.1-5).

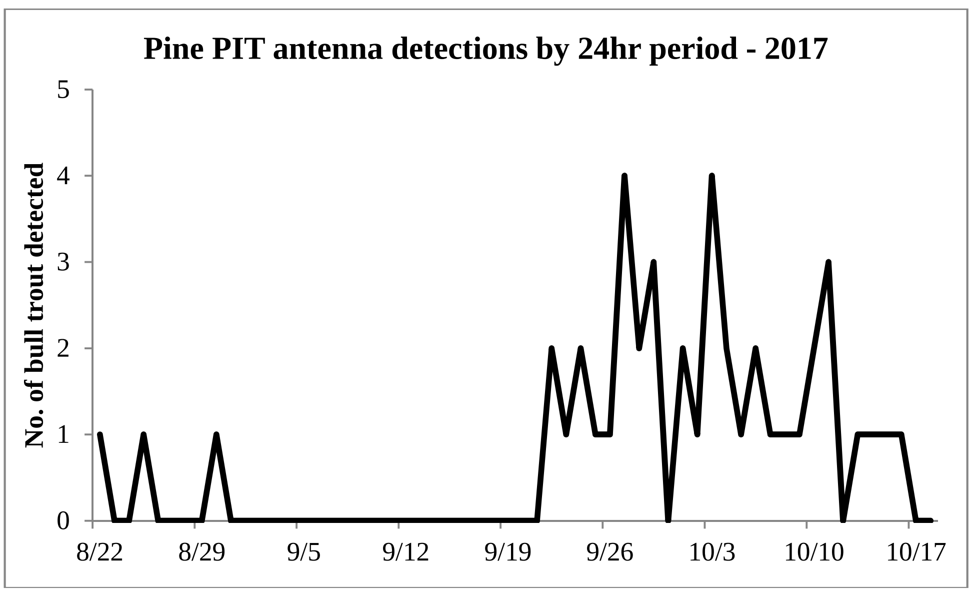

Figure 3.2.1-5

The number of historical discrete detects at the Pine Creek site is expressed in Figure 3.2.1-6. Of the 44 bull trout that migrated upstream past this antenna, 46 percent showed evidence of consecutive year migrations (2, 3, 4 or 5 year consecutive), 41 percent were maiden detections, and 13 percent showed evidence of biennial migrations.

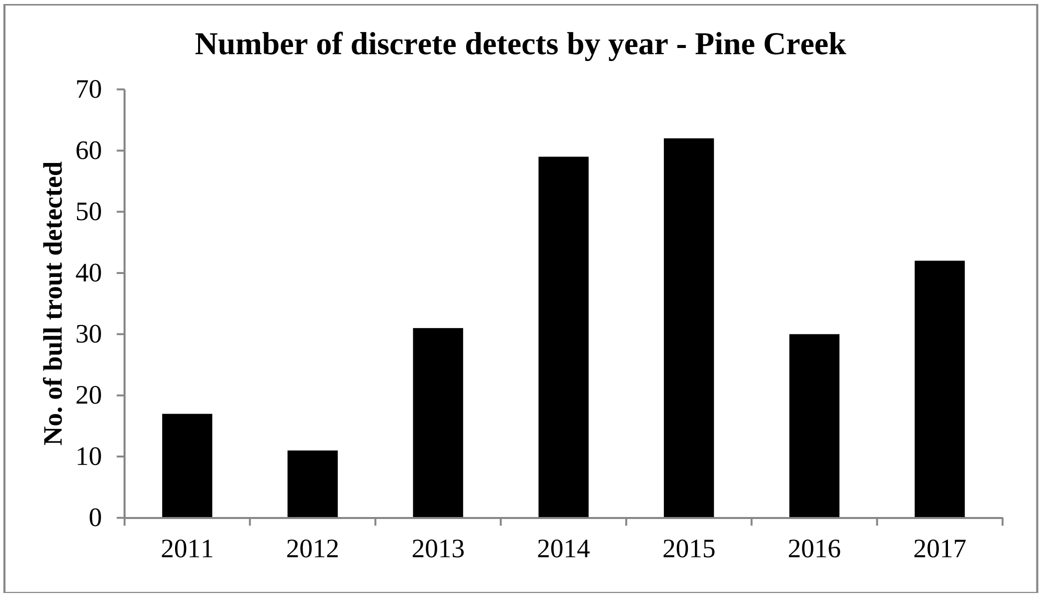

Figure 3.2.1-6

Pine Creek Tributary P8

The PIT antenna at the mouth of Pine Creek tributary P8 was in operation from August 2 to October 31. Power loss was only experienced for one day on September 28 due to a drained battery. The antenna at this site withstood the high water event during the third week of October that knocked out all the antennas at all the other sites in the basin. 741 detections were recorded during the period of operation resulting in 19 discrete bull trout tags. Peak migration was observed on September 30 when six bull trout volitionally swam past this antenna (Figure 3.2.1-7).

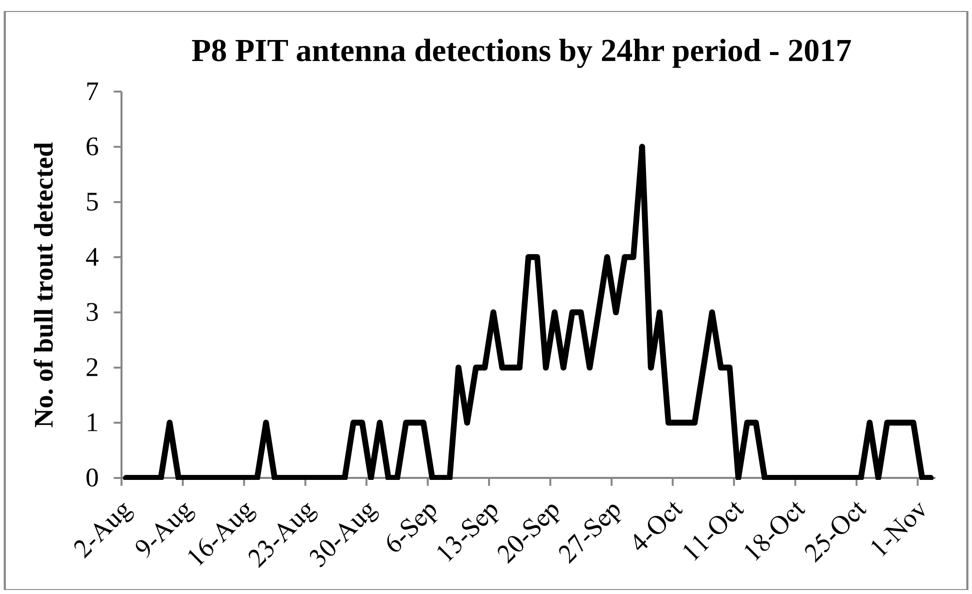

Figure 3.2.1-7

Historical discrete detections at this site are expressed in Figure 3.2.1-8. Of the 19 bull trout detected at this antenna in 2017, 36 percent showed evidence of consecutive year migrations, while 64 percent were maiden detections. 17 of the 19 bull trout detected at the P8 antenna were also detected downstream at the Pine Creek mainstem antenna.

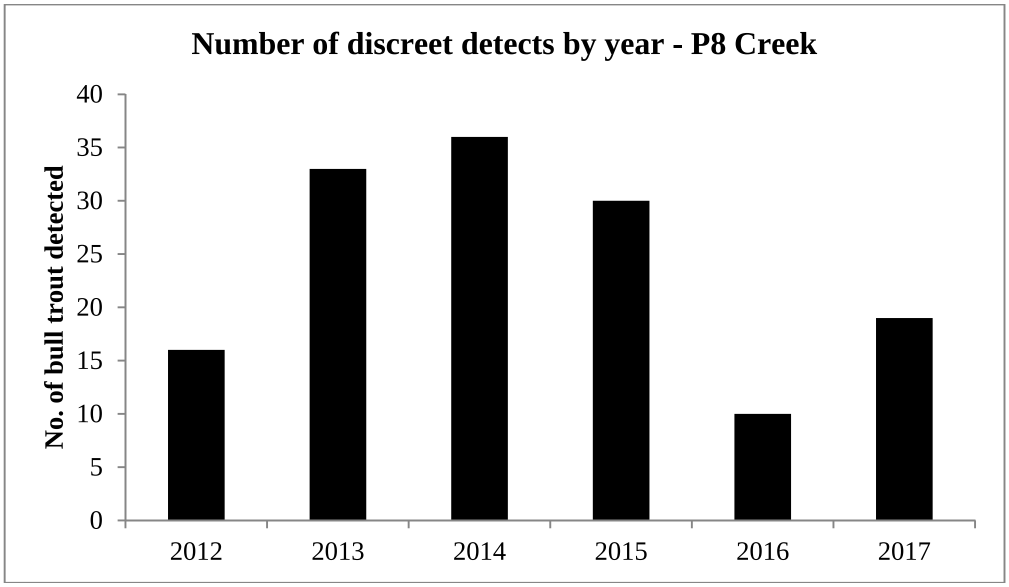

Figure 3.2.1-8

Rush Creek

The PIT antenna near the mouth of Rush Creek was in operation from August 10 to October 3. Power loss was experienced for one day on August 16 due to a drained battery. The antenna at this site succumbed to a high water event during the first week of October that filled the onsite Jobox with water and destroyed the antenna motherboard (Figure 3.2.1-9). 32 detections were recorded during the period of operation resulting in eleven discrete bull trout tags. Peak migration of two bull trout was observed on multiple dates in September and October (Figure 3.2.1-10).

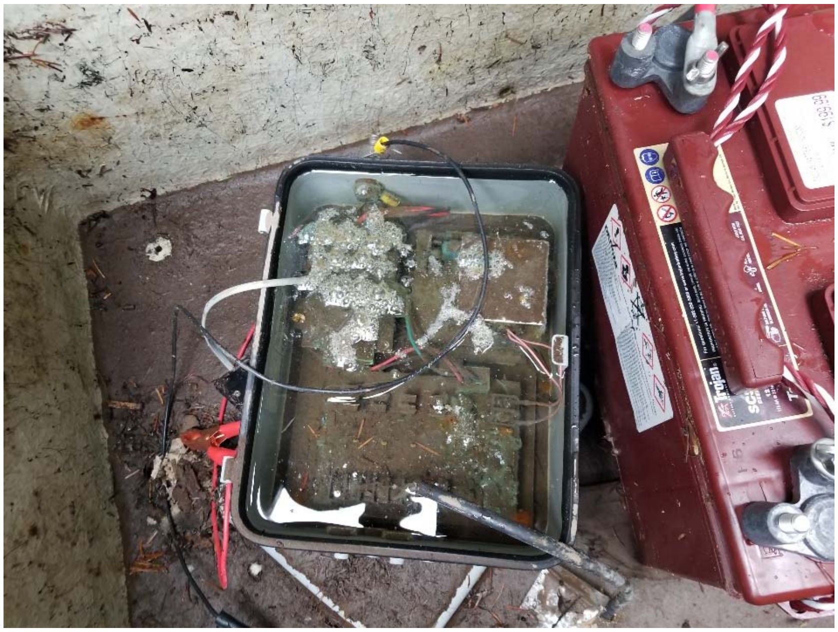

Figure 3.2.1-9. Water damage sustained during October high water event at the Rush Creek PIT antenna site.

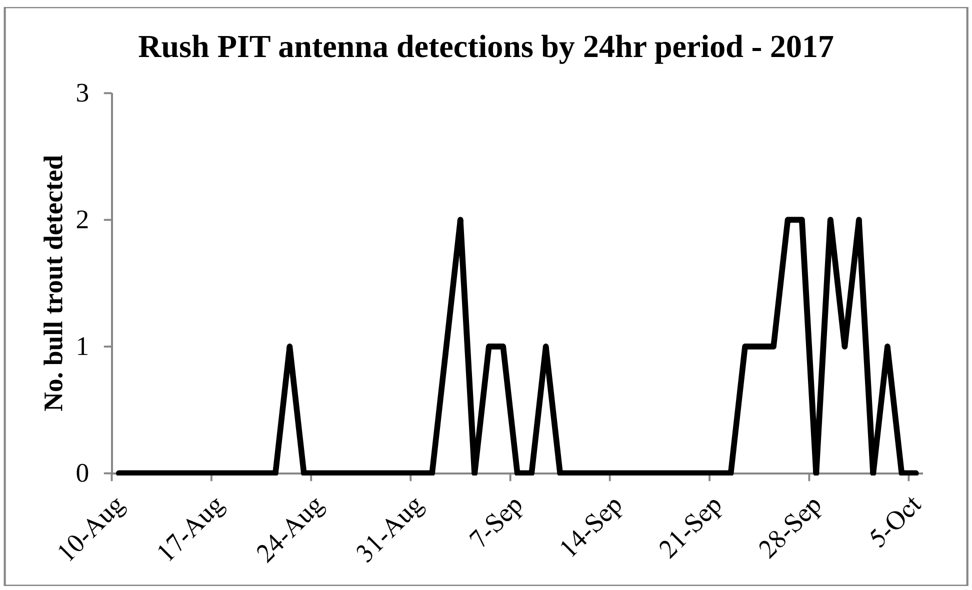

Figure 3.2.1-10

Historical discrete detections at this site are expressed in Figure 3.2.1-11. Of the eleven bull trout detected at this antenna in 2017, 55 percent showed evidence of consecutive year migrations, while 45 percent were maiden detections. For one bull trout, 2017 was the seventh consecutive year it was interrogated within Rush Creek.

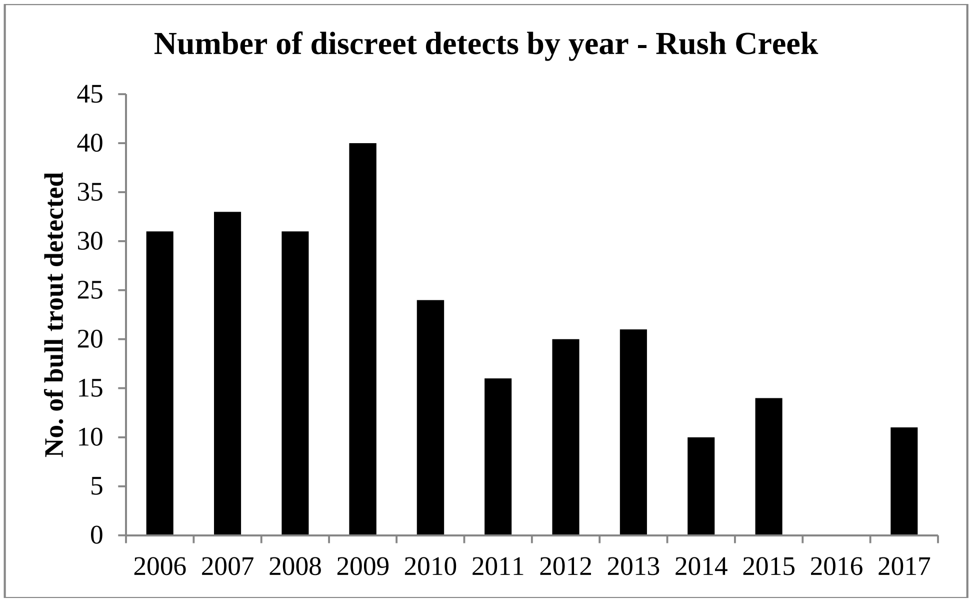

Figure 3.2.1-11

Swift Creek

The PIT antenna near the mouth of Swift Creek was in operation from August 11 to October 26, whereas the antenna loop was destroyed from a high water event. No loss of power occurred during this timeframe and no tagged bull trout were interrogated.

All Detection Analysis

Spawning frequency for the last three years from all detections at all streams combined was analyzed and is expressed in Figure 3.2.1-12. It is noted that a shift from maiden detection to multiple year detection is observed from 2015 to 2017, this shift is expected to become more pronounced as additional data is collected and individual fish are followed through their lifecycle.

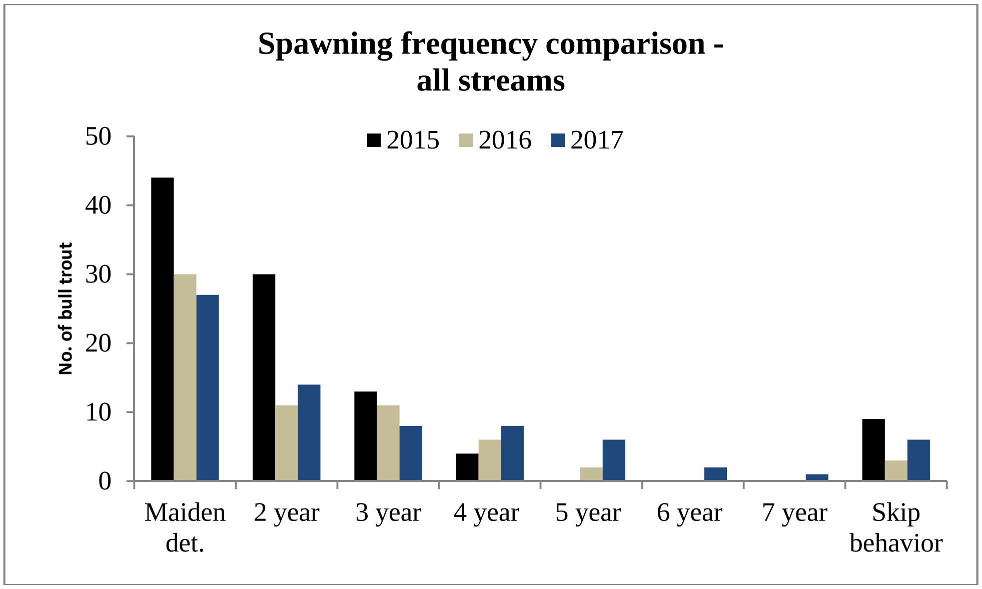

Figure 3.2.1-12

Figure 3.2.1-13 compares annual detections from all sites for all years on record.

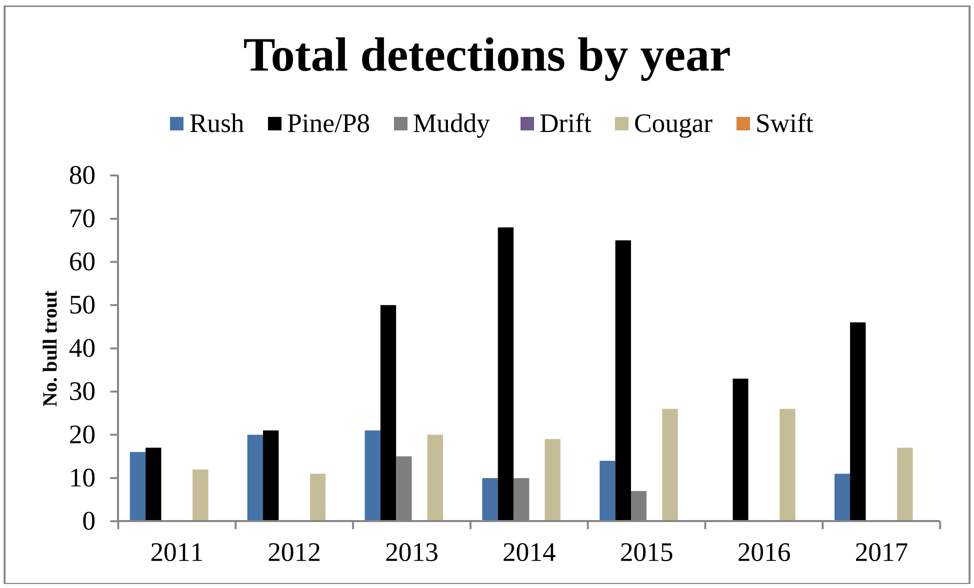

Figure 3.2.1-13

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 2017. 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 will commence will be in 2019.

Figure 3.3.1-2 and Table 3.3.1-2 illustrate historical total capture and transport numbers.

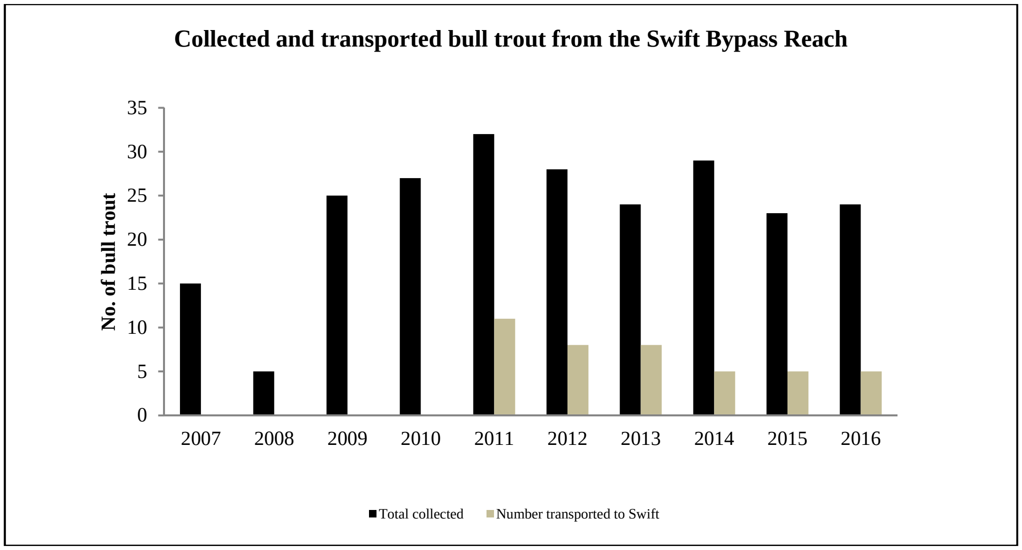

Figure 3.3.1-2. Historical Swift Bypass Reach capture and transport numbers.

Table 3.3.2-1. 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.

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 2017, 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 2017, three capture attempts were completed; June 15, July 14, and August 15 yielding three bull trout. All three bull trout were large (>600mm), were maiden captures and were collected during the July sampling event. All were subsequently transferred upstream for release into Yale reservoir and all were genetically identified as endemic to Cougar Creek. No bull trout were encountered during the June and August sampling events.

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
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 LEWIS RIVER BULL TROUT SPAWNING SURVEYS

3.4.1 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 2017, the Utilities conducted five Cougar Creek bull trout redd surveys from September 18 to November 8. Surveys begin at the mouth of the creek and end at the creek's spring source, a distance of approximately 2100 m.

Figure 3.4.1-1. GPS locations of bull trout redds in Cougar Creek in 2017. Each yellow dot represents an individual bull trout redd (n=24).

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

During each 2017 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 3.4.1-1). 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.

24 individual bull trout redds were observed in Cougar Creek in 2017. 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 3.4.1-1).

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 2017, no bull trout redds were observed superimposed over a previously excavated bull trout redd.

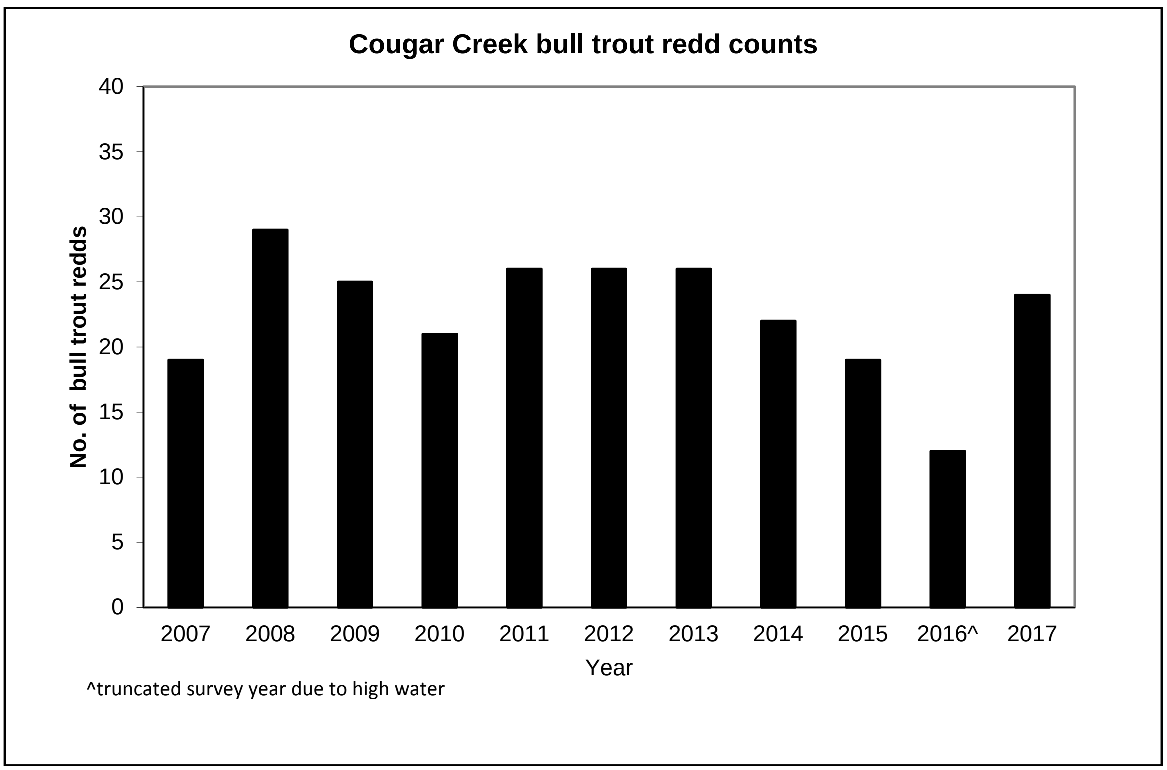

Figure 3.4.1-2. Annual Cougar Creek bull trout cumulative redd counts, 2007-2017.

3.4.2 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 3.4.2-1) 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 five times from September 11 – October 31 during the 2017 bull trout spawning season. In all, GPS coordinates were collected from 42 bull trout redds during the survey period. Redds were observed and counted from the mouth of P8 to 2100 m upstream (Figure 3.4.2-1 and 3.4.2-2).

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 or 2017.

Pine Creek and tributary P10

Redd surveys on a weekly rotation of all available spawning habitat were performed within Pine Creek mainstem and Pine Creek tributary P10 during the months of September and October in 2017. In all, eight surveys were completed and 23 redds were recorded and GPS'd. Nine bull trout redds were recorded for the first time within P10, and fourteen redds were observed within Pine mainstem during the survey period (Figure 3.4.2-1).

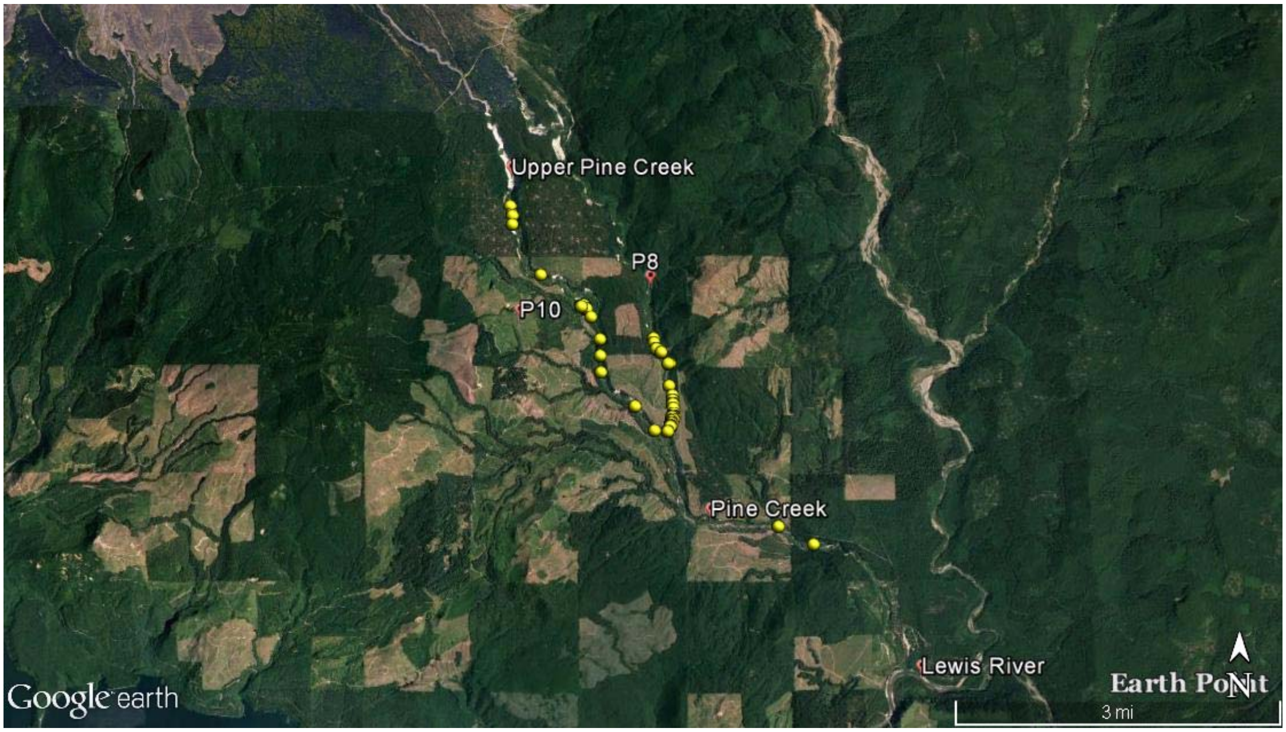

Figure 3.4.2-1. GPS locations of bull trout redds in Pine, P8, and P10 creeks in 2017. Each yellow dot represents an individual bull trout redd (n=65).

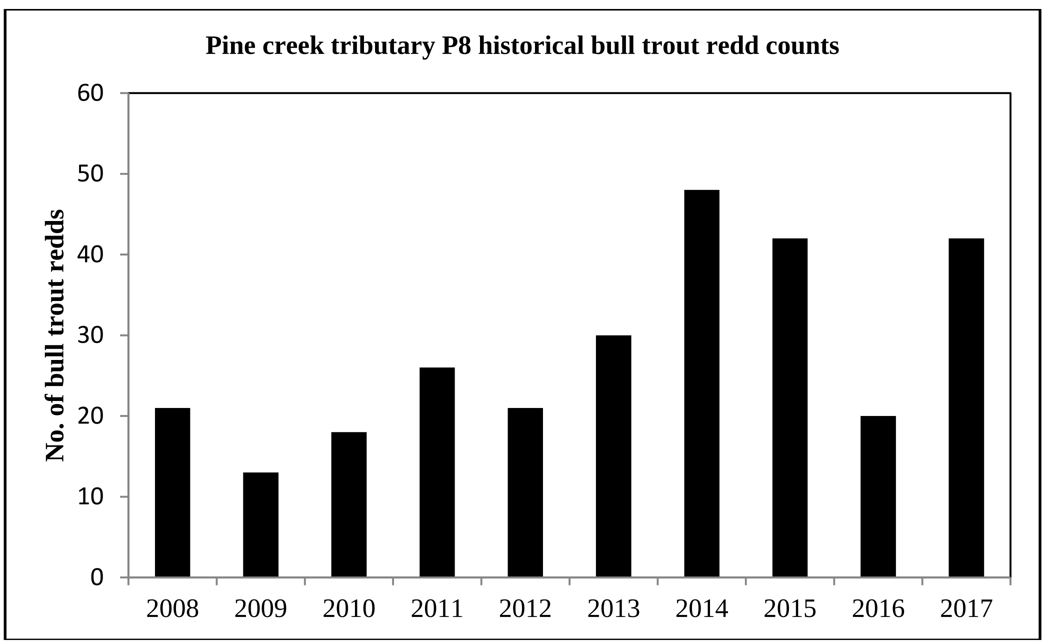

Figure 3.4.2-2. Pine Creek tributary P8 historical bull trout redd counts (2008 and 2009 data courtesy of WDFW).

Rush Creek

Rush Creek was surveyed on four occurrences between September 15 and November 3, six 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.

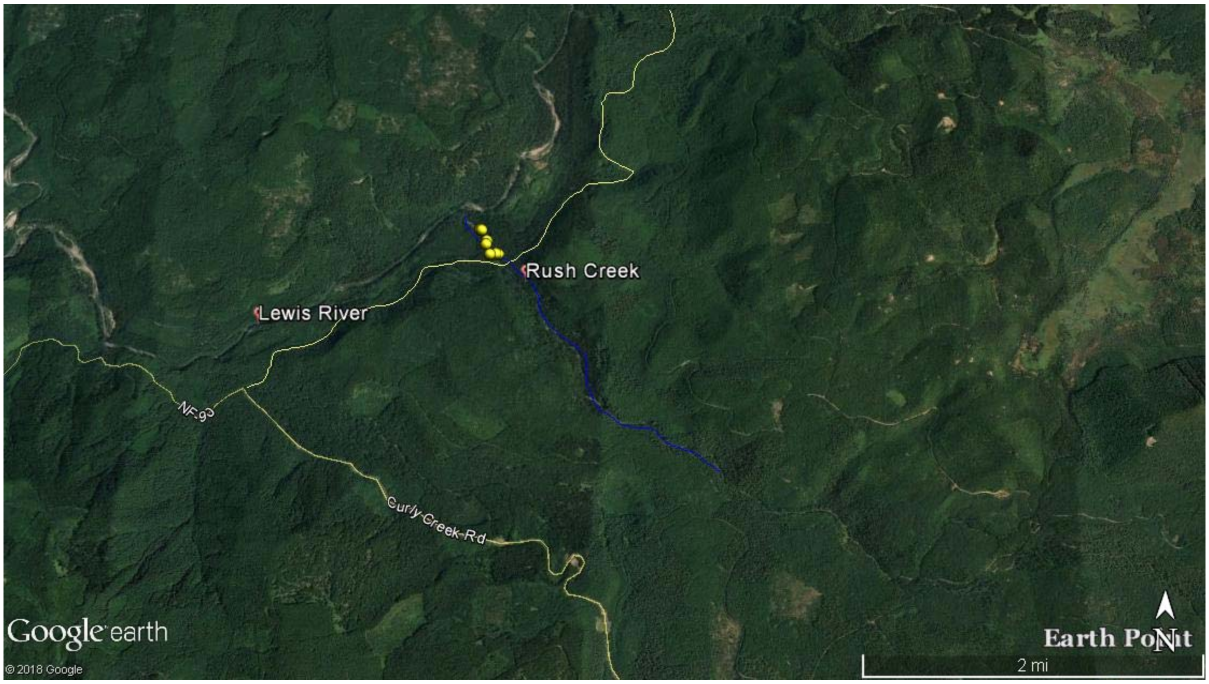

Figure 3.4.2-3. GPS locations of bull trout redds in Rush Creek in 2017. Each yellow dot represents an individual bull trout redd (n=6).

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 Brice Adams from the USFWS for his analysis of genetic estimation of breeder abundance.

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APPENDIX A
MEMO: "BULL TROUT MONITORING STUDIES IN THE NF LEWIS"
DR. ROBERT AL-CHOKHACHY, UNITED STATES GEOLOGICAL SURVEY

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Mark-recapture analyses

Data

Mark-recapture

Each year from 1997 through 2016 we sampled bull trout by drifting gill nets at a major pool feature (Eagle Cliff) just above the head of Swift Reservoir. Sampling typically occurred weekly from early May through early August and the average number of sample days during this study was (9.8; SD = 1.9). During each sample day, a gill net (varying lengths 25 – 40 m) with dyed green 6# monofilament line (varying mesh sizes 2.5 – 7.5 cm; 2 m in depth) was drifted down through the pool to entangle fish. After each pass, the gill net was rapidly retrieved and fish were removed from the net and placed in a holding tank.

Once captured bull trout were anesthetized with Tricaine Methanesulfonate (MS-222), checked for any previous marks, measured in total 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. Beginning in 2002, fish were also marked with 23-mm half duplex PIT-tags in the dorsal sinus to allow for estimates of movement within the basin. Upon full recovery where fish regained equilibrium, individuals were released near the point of capture.

In addition to active marking and recapture data, beginning in 2011, we also installed half-duplex antennas near the mouths of Pine Creek and Rush Creek to better understand adult bull trout movement patterns and provide additional recaptures for survival analyses. The antennas spanned the individual channel widths and detected fish marked with PIT-tags. Each year, the antennas were typically installed during early August and operated continuously through the first week of November.

During 2017, marking of bull trout was temporarily paused to minimize annual handling of bull trout prior to spawning. The decision to scale-back marking was driven by the Lewis River Bull Trout ACC decisions to limit potential handling effects of bull trout. However, past marking efforts, coupled with recaptures from antennas in Pine Creek, P8, and Rush Creek allowed for continued monitoring of bull trout movement patterns and updated estimates of bull trout survival using recapture information from the 2017 field season.

Analyses

Movement.—Here, we summarized movement patterns for 2018 to assess the timing of movement, the duration of time spent within the spawning tributaries, and duration of migration patterns. We report the date of first detection at an antenna for the individual timing and consider both upstream and downstream movements. We only report movement patterns for PIT-tagged individuals with clear upstream and downstream migrations past antennas.

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. For these Barker survival analyses, we only considered data from 2011, which was the first year when PIT-tag antennas were installed in tributaries. We used a multi-model framework to calculate survival (Burnham and Anderson 2002) and considered survival models differing by time and age (sub-adult and adult [>450 mm]).

Results

Movement

In 2017 44 adult PIT-tagged bull trout entered Pine Creek. Of these fish, 57% (n = 25) were only detected at the Pine Creek antenna (not P8) suggesting spawning in areas outside of P8. Adult bull trout typically entered P8 during mid-September (median = September 17; IQR = Sept. 6 – 28) and migrated downstream at the end of September (Sept. 29; IQR = Sept. 22 – October 7; Figure 1). However, there was considerable variation in the timing across individuals (Figure 2). The majority of the fish were not detected at Pine Creek during upstream migration (85%), which is likely due to the timing of the antenna installation (August 22nd). Given that most fish were detected at the Pine Creek antenna during outmigration, these patterns are likely due to the timing of antenna installation and not detection efficiency. During 2017, the median number of days spent in P8 was 11 days (interquartile range = 6 – 21 days). The median time between migrating downstream from P8 to the lower antenna on Pine Creek was 3 days (IQR = 1 – 7 days). The upstream migration did not appear to be related to ambient hydrologic conditions (Figure 3), and most downstream movements occurred before the rising hydrograph in the fall.

In Rush Creek, 11 PIT-tagged adult bull trout were observed spawning in Rush Creek. The median upstream migration date was September 3 and median downstream migration date was

September 27. The median time adult bull trout spent in Rush Creek during the spawning period was 24 days (not shown).

Survival

Modeling results indicated no significant differences between subadult and adult bull trout. However, we did observe considerable interannual variation in survival (Figure 4). We were not able to obtain reliable estimates of survival for 2016 and 2017, which is common in mark-recapture analyses given the integration of the recapture rates into survival estimates (i.e., during 2018, additional data help update whether fish not captured during 2017 were mortalities or not). Average survival estimates for 2011 – 2015 were 0.71; range = 0.82 in 2012 and 0.51 in 2015). The overall estimates of survival are low when compared to adfluvial populations of bull trout (Johnston et al. 2007). This reduced survival in the Lewis population is driven by the low estimated survival during 2013 and 2015 as 2011, 2012, and 2014 were very similar to estimates from Johnston et al. (2007). At this point, it is unclear the factors limiting adult bull trout during years such as 2013 and 2015.

Figure 1.Boxplots (median, box is the interquartile range, whiskers are the 5th and 95th percentile, and points are outliers) of the date of adult bull trout spawning migrations showing upstream movements at P8, downstream movements at P8, and downstream movements at Pine Creek in 2018 in the Lewis River, WA.

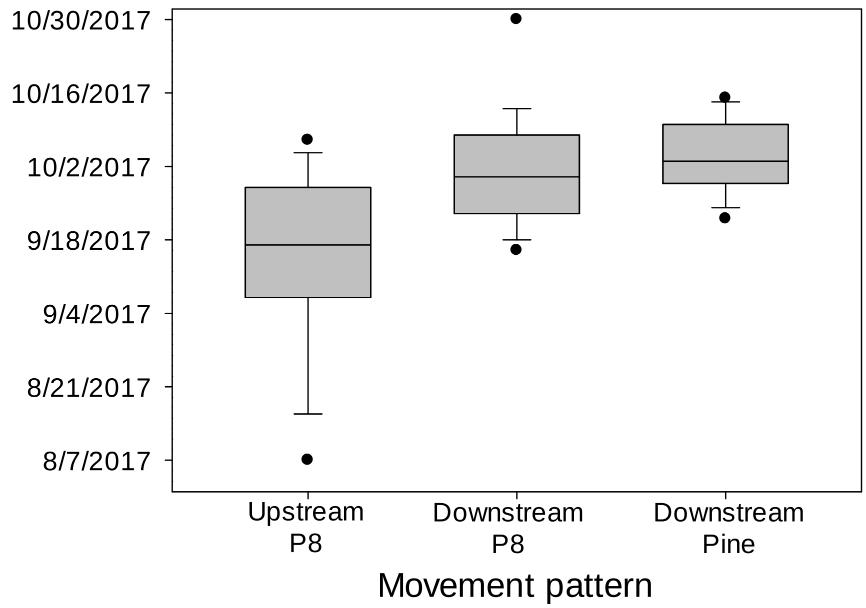


Figure 2. Dates of adult bull trout detection of upstream movements at Pine Creek (grey triangles) and P8 (hollow triangles with +) and downstream movements at P8 (upside down hollow triangles with +) Pine Creek (upside down grey triangle) within the Lewis River, WA.

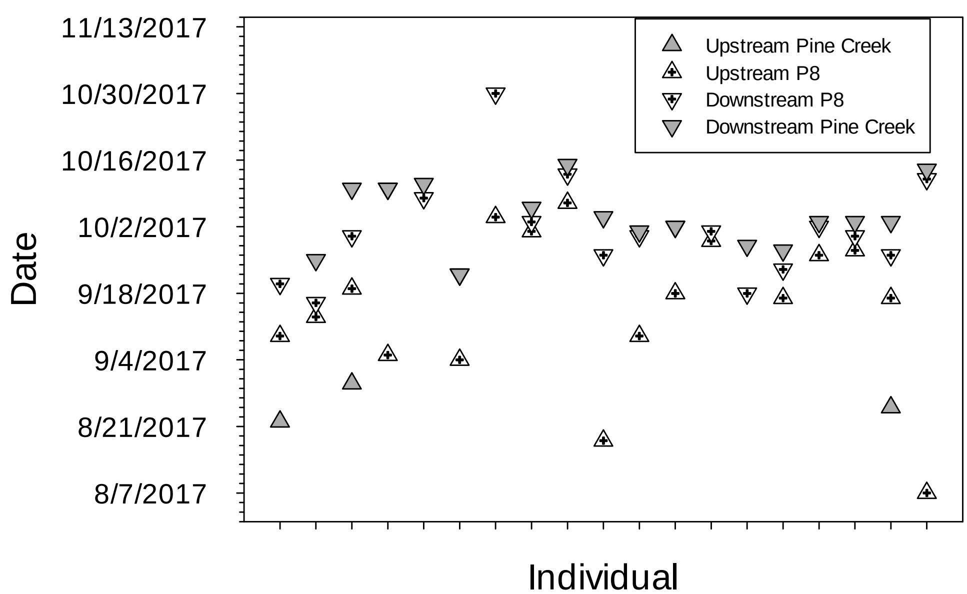


Figure 3. Individual adult spawning migrations during 2017 including upstream movements at Pine Creek (grey upright triangle) and P8 (hollow, upright triangle with +), downstream movements at P8 (hollow, upside-down triangle with +) and Pine Creek (grey, upside down triangle), and the daily discharge on the Lewis River (USGS gage 14216000; above Muddy River), WA.

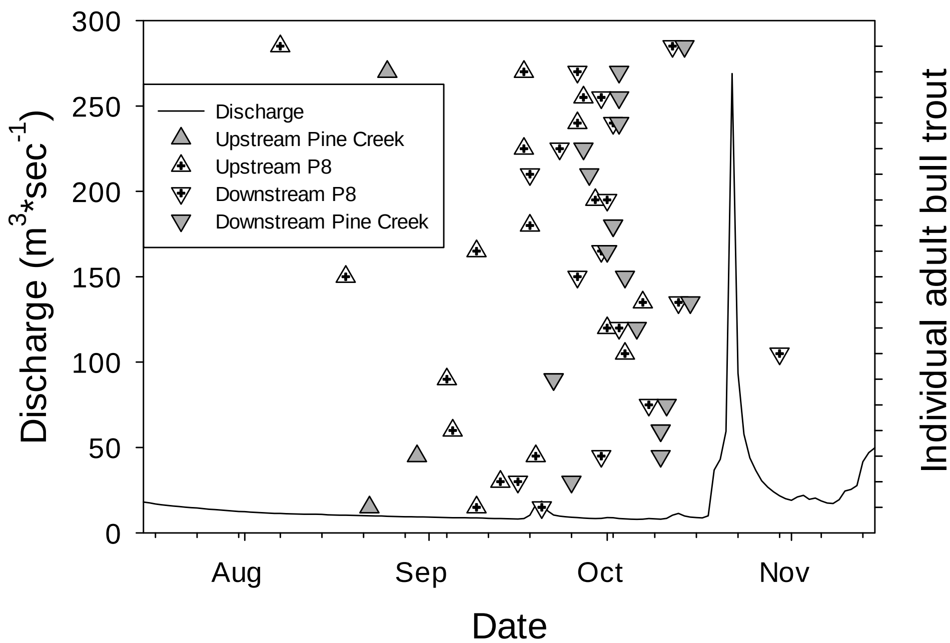
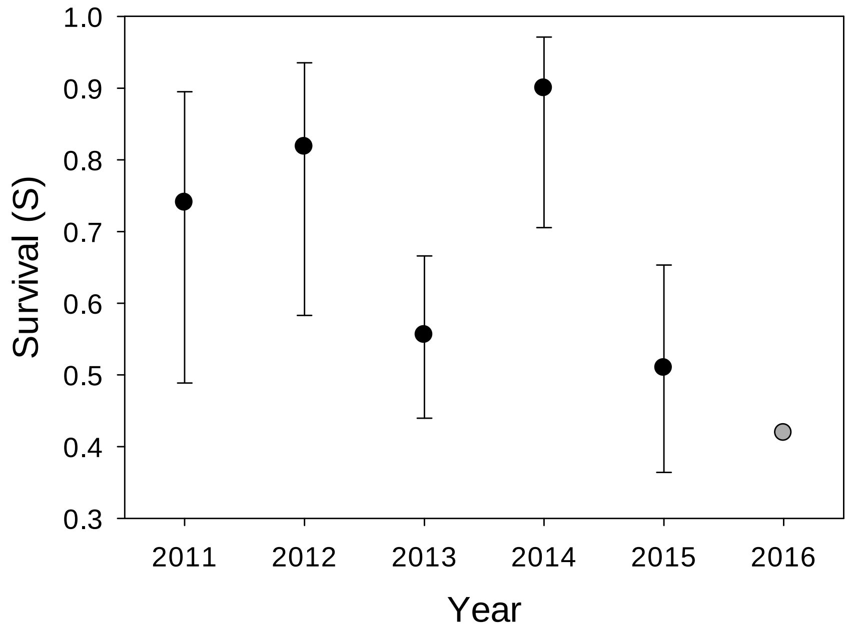


Figure 4. Estimates of bull trout survival from Barker mark-recapture models for the Lewis River upstream of Swift Dam, WA. Results shown are from model-averaged survival estimates for subadult and adult bull trout combined as models did not suggest significant differences across these life stages. Note: no survival estimate was possible for 2017 and no confidence intervals were estimable for 2016 (grey).



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APPENDIX B

2017 USFWS LEWIS RIVER BULL TROUT GENETICS ANNUAL REPORT

Genetic Analysis and Genetic Estimation of Spawner Abundance of Bull Trout Collected in the Lewis River, WA

2017 Annual Report

Final Report Submitted

02/12/2018

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Background

The Lewis River is a Columbia River tributary in Washington which contains one of two Bull Trout populations in the U.S. Fish and Wildlife Service (USFWS) Lower Columbia Critical Habitat Unit (USFWS 2002; USFWS 2010). Bull Trout spawning has been documented in three main tributaries within the Lewis River system: Cougar Creek, Pine Creek, and Rush Creek (Figure 1). Four dams constructed on the mainstem Lewis River fragment Bull Trout habitat and prevent fish that migrate downstream through the dams from returning to spawning habitats. Cougar Creek is located above Yale Dam and is separated from Pine and Rush Creeks by two dams; Swift No.1 and No. 2 (Figure 1).

An initial genetic baseline was completed at the USFWS Abernathy Fish Technology Center Conservation Genetics Program (AFTC) in 2011 for these three spawning Bull Trout populations in the Lewis River drainage (DeHaan and Adams 2011). In subsequent years juvenile Bull Trout have been collected and analyzed for addition to the initial genetic baseline. This baseline provides an opportunity to monitor these populations through time and identify areas for conservation focus (Epifanio et al. 2003). In addition, beginning in 2014 annual juvenile samples collected in Pine and Rush creeks (Adams and DeHaan 2015), and 2015 with Cougar Creek, have been used to estimate the effective number of breeders.

The number of Bull Trout spawning in the Swift Reservoir tributaries of Pine and Rush creeks each year is not well understood. These estimates of spawner abundance are important in developing effective conservation and management plans for Lewis River Bull Trout. Beginning in 1996 PacifiCorp and various state and federal partners (Doyle 2014) initiated annual surveys to track upstream passage of adult Bull Trout into Pine and Rush Creeks. They expanded this by adding annual Bull Trout redd surveys within P8, a tributary to Pine Creek, in 2010. In 2014 PacifiCorp contacted AFTC to provide a genetic estimate of spawner abundance to complement current in-stream methods. Genetic monitoring to estimate spawner contribution can be a more effective way to look at the true reproductive contribution of individuals to a population of concern (Schwartz et al. 2007). This report summarizes this analysis of effective number of breeders (N_b) for Bull Trout in Cougar, Pine and Rush Creeks, the analysis of additional Bull Trout added to the population assignment baseline, as well as the population genetic assignment of three unknown origin Bull Trout collected in the Yale Tailrace during 2017.

Materials and Methods

Baseline Analysis

Fin clips from age-0 Bull Trout were collected by PacifiCorp staff in 2017 from Cougar Creek (n=68), Pine Creek (n=48), P8 (a Pine Creek tributary, n=62), and Rush Creek (n=36) in order to estimate the effective number of breeders within those systems. DNA from fin clips was extracted using QIAGEN DNeasy 96 Blood & Tissue Kits following manufacturer's protocols (Qiagen Inc., Valencia, CA). All individuals were genotyped at the following 16 microsatellite loci: *Omm1128, Omm1130* (Rexroad et al. 2001), *Sco102, Sco105, Sco106, Sco107, Sco109,* (Washington Dept. of Fish and Wildlife *unpublished*), *Sco200, Sco202, Sco212, Sco215, Sco216, Sco218, Sco220* (DeHaan and Ardren 2005), *Sfo18* (Angers et al. 1995) and *Smm22* (Crane et al. 2004). In addition two genes, SRY and 18S rRNA (Yano et al. 2013), were amplified to identify the genotypic sex of the sample. Polymerase chain reactions (PCR) were conducted in 10µL volumes containing 2µL of template DNA, 5µL of 2X Qiagen multiplex PCR master mix (final concentration of 3mM $MgCl_2$), and 0.2µL of oligonucleotide PCR primer mix. PCR conditions were as follows: initial denaturation at 95°C for 15 minutes, then 29 cycles of 95°C for 30 seconds, 90 seconds at the multiplex specific annealing temperature, and 60 seconds primer extension at 72°C, followed by a final extension at 60°C for 20 minutes. Following PCR, capillary electrophoresis was conducted on an ABI 3730 Genetic Analyzer (Applied Biosystems Inc., Foster City, CA) following the manufacturer's protocols.

Age-0 Bull Trout from Pine Creek and P8 genotyped in 2017 were combined for all analyses (DeHaan and Adams 2011). All local spawning populations were then tested for departures from Hardy-Weinberg equilibrium (HWE) expectations using exact tests implemented in the program GENEPOP v4.0.7 (Raymond and Rousset 1995). GENEPOP was also used to test populations for evidence of linkage disequilibrium (LD: non-random association among alleles). Populations were examined for number of full sibling families and number of individuals in each full sibling family using COLONY v2.0 (Wang 2004). Following protocols established in DeHaan and Adams (2011), we retained up to three full siblings from each family and removed all other siblings. Once full siblings had been removed, we conducted HWE and LD tests on the revised dataset.

We used the program NeEstimator v2 (Do et al. 2014) to estimate the effective population size (N_e) for age-0 samples from Cougar, Pine and Rush Creeks based on linkage disequilibrium (Waples 2006). When this estimate is applied to individuals collected in a single cohort it allows us to estimate the effective number of breeders that produced the cohort (N_b; Waples and Teel 1990). To minimize the effect of rare alleles on our estimates we selected P_{crit}=0.02 (Waples and Do 2010). Upper and lower 95% confidence intervals were estimated using the jackknife re-sampling method. To assess the role that large family groups within the dataset had on calculating N_b we made estimates with the original data set (including all age-0 fish) and with the reduced family data (removing all but three individuals assigned to a family group). Estimates of N_b were also obtained during the process of assigning individuals to family groups in COLONY v2.0.

Genetic data from age-0 Bull Trout from Cougar, Pine and Rush creeks were combined with previously genotyped samples from Cougar, Pine and Rush creeks and added to the baseline dataset. We conducted leave-one-out assignment tests to examine the accuracy of the updated baseline for assigning unknown origin fish to their most likely local population of origin. Each baseline individual was removed from the population it was collected from and treated as an unknown, the allele frequencies for all populations were then re-calculated, and the unknown fish was assigned to its most likely population. The number of individuals assigned to the local population they were collected from (presumably their natal tributary) provides a measure of assignment accuracy. Leave-one-out tests were conducted using ONCOR (Kalinowski et al. 2008) and we determined the likelihood for each population assignment and the probability of observing that individual's genotype in the assigned population.

Additional Population Assignments

In 2017 we conducted genetic population assignments for three unknown origin Bull Trout collected in Yale Tailrace. Samples were genotyped using the methods described above. The program ONCOR was used to assign unknown origin individuals collected below Lewis River Dams to their most likely population of origin. Each unknown origin individual was assigned to its first and second most likely local spawning population of origin and the probability of observing the individual's genotype in each local population were also reported. A description of the methods used for the probability calculations can be found in Kalinowski et al. (2008). Typically genetic assignments were not provided within 24 hours for these fish, and none of these fish were transported based on assignment results.

Results and Discussion

Identification of full sibling groups - COLONY Analysis

Two loci, *Sco 215* and *Sfo18*, were fixed for a single allele in all Cougar, Pine, and Rush creek age-0 Bull Trout. Cougar, Pine and Rush creek samples deviated from Hardy-Weinberg equilibrium at *Sco109*; in addition Cougar Creek deviated at *Sco 102*, Pine Creek deviated at

Omm1130, while Rush Creek deviated at *Sco106*, *Sco 212* and *Sco 216*. Four pairs of loci (out of 91 total) exhibited evidence of linkage in Cougar Creek, thirteen pairs of loci showed evidence in Pine Creek, and six pairs of loci showed evidence of linkage in Rush Creek. Results of the linkage disequilibrium tests were consistent with collections of closely related individuals (i.e., full siblings). Results of the COLONY analysis indicated a large number of related individuals in the age-0 samples collected from Cougar, Pine and Rush creeks (Appendix 1). In Cougar Creek, there was one full-sibling family with twelve individuals. In Pine Creek there was one large full-sibling family with ten individuals and two full-sibling families with six individuals. In Rush Creek there was one large full-sibling family detected with ten individuals and one full-sibling family with six individuals. As indicated above, we removed all but three individuals from each full-sibling family prior to adding these individuals to the baseline dataset. After full-siblings were removed from the dataset, one pair of loci (out of 91 total) exhibited linkage in Cougar Creek, six pairs of loci showed evidence in Pine Creek, and two pairs of loci showed evidence in Rush Creek.

Effective number of breeders - N_b

Estimates of effective number of breeders were greatest in Cougar Creek (N_b=18.2; 95% C.I.=14.0-23.7 using the N_b estimator with reduced families), lower in Pine Creek (N_b=15.5; 95% C.I.=12.7-18.8), and lowest in Rush Creek (N_b=12.8; 95% C.I.=9.3-18.0). Overlap in 95% C.I. indicated that these observed differences were not significant. Estimated values of N_b varied with estimation method and number of individuals used per family (Table 1), although they consistently estimated a smaller N_b for Rush Creek when compared to Cougar and Pine creeks. These estimates provide a baseline to track how estimates of N_b fluctuate on an annual basis and can provide an indicator for the health of Bull Trout populations with long term monitoring (Luikart et al 2010). In addition these data can provide a comparison with how redd counts and counts of spawning adults in these two tributaries relate to estimates of N_b. It is important to note that since these estimates of the effective number of breeders were generated using a single cohort of individuals, they are presumably lower than the true N_e (Luikart et al. 2010; Waples and Do 2010). General guidelines have been suggested for minimum viable levels of N_e with a minimum of 50 individuals suggested as necessary to avoid the short term effects of inbreeding and N_e of 500 to help ensure long-term population persistence (Franklin 1980). Although these are just general guidelines and true minimum N_e values vary among species and populations, the relatively low estimates observed for the three Lewis River local Bull Trout populations suggest that these small populations may face increased risks from inbreeding and genetic drift in the short-term.

Baseline Analysis

Two loci, *Sco215* and *Sfo18*, were fixed for a single allele in all three baseline populations. These two loci were primarily included in genotyping efforts to identify hybrid individuals (no hybrid fish were observed in this study) and to facilitate comparisons with other studies. Cougar, Pine, and Rush creeks deviated from Hardy-Weinberg equilibrium expectations at the locus *Sco109* due to a deficiency of heterozygotes. All other loci conformed to Hardy-Weinberg equilibrium expectations in all three populations. Fifteen pairs of loci (out of 91 total) exhibited evidence of linkage in Cougar Creek, thirteen pairs of loci showed evidence of linkage in Pine Creek, and four pairs of loci showed evidence of linkage in Rush Creek. Nearly all (98.2%) of the baseline fish were assigned to the local spawning population that they were collected from in the leave-one-out assignment tests. The exceptions were eight fish collected in Cougar Creek, five of which assigned to Pine Creek and three of which assigned to Rush Creek; and three fish that were collected in Pine Creek, one of which assigned to Cougar Creek and two that assigned to Rush Creek. Probability values for correctly assigned fish to population of origin were 0.957, 0.997 and 1.000 for Cougar, Pine and Rush Creeks respectively (Figure 2). Probability values for correctly assigned fish to region of origin were 0.957 and 0.998 for Swift and Yale Reservoirs respectively (Figure 2).

Additional Population Assignments

During 2017, three Bull Trout were collected for genetic population assignment. All three samples processed assigned to Cougar Creek as their most likely population of origin (Table 2). Probability values for population assignments were 1.000 for all three individuals (Table 2). Genotypes for all three unknown origin Bull Trout analyzed in 2017 can be found in Appendix 2.

Data Management Plan

Raw (genotype) data generated in the course of the work described here have been archived in the U.S. Fish and Wildlife Service Abernathy Fish Technology Center Progeny Database.

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Table 1. Estimates of effective number of breeders (N_b; 95% CI) in three Lewis River tributaries for multiple N_b estimators in 2017 (minimum allele frequencies of 0.02).

Tributary	**N_b Estimator All Individuals**	**N_b Estimator Reduced Families**	**Colony**
Cougar Creek	17.0 (13.5-21.0)	18.2 (14.0-23.7)	24.0 (14.5-42.5)
Pine Creek	13.5 (11.1-16.3)	15.5 (12.7-18.8)	33.5 (22.0-55.0)
Rush Creek	9.8 (7.5-12.5)	12.8 (9.3-18.0)	14.5 (7.5-30.5)

Table 2. Collection information and genetic population assignments for 3 adult Bull Trout collected below Lewis River dams in 2017.

PIT Tag #	Sample #	AFTC Genetic ID	Date Received	Collection Location	Genotypic Sex	Most Likely Population #1	Probability	Most Likely Population #2	Probability
AC776B6	TN 15-125	3140-097	9/25/2017	Yale Tailrace	Male	Cougar Creek	1.000		
AC776B5	TN 15-126	3140-098	9/25/2017	Yale Tailrace	Male	Cougar Creek	1.000		
AC776B7	TN 15-127	3140-099	9/25/2017	Yale Tailrace	Male	Cougar Creek	1.000		

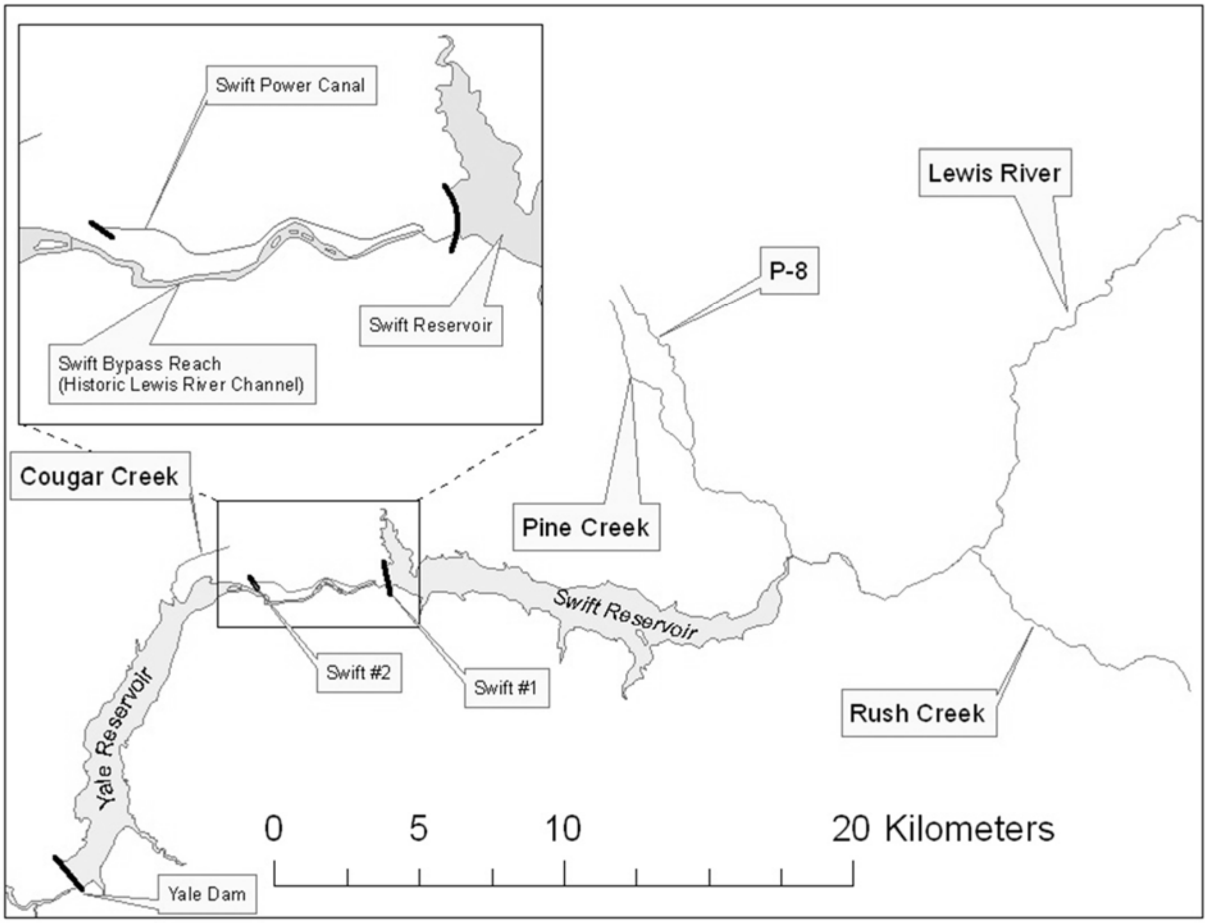

Figure 1. Lewis River system in Washington. Cougar, Pine, and Rush creeks are the primary Bull Trout spawning tributaries and are the three populations in the baseline dataset. Bull Trout for population assignment analysis were collected below Yale Dam.

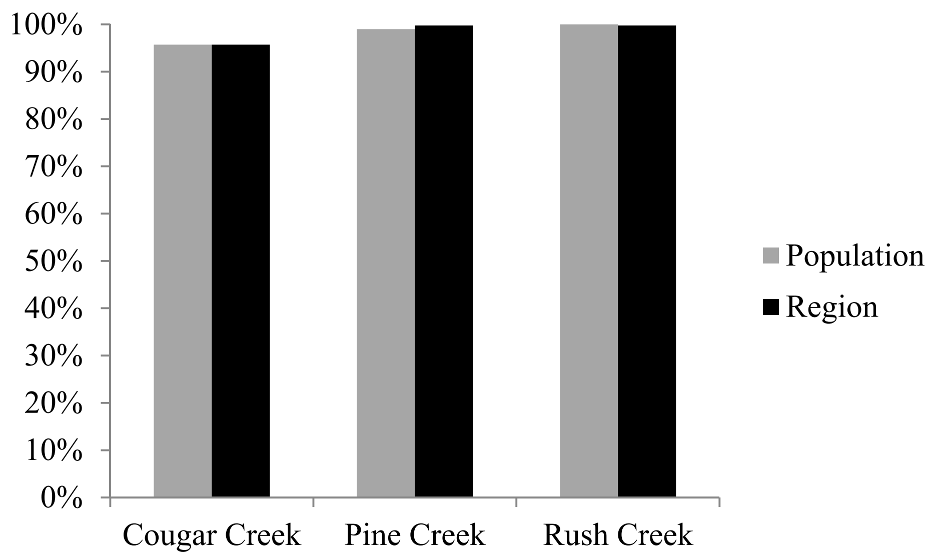

Figure 2.Percentages of baseline individuals correctly assigned to their population of origin (Cougar, Pine and Rush creeks; Grey bars) and to their region of origin (Yale and Swift reservoirs; Black bars) of Lewis River Bull Trout during leave-one-out assignment tests.

Appendix 1. Results of COLONY analysis for age-0 Bull Trout collected from Cougar, Pine and Rush Creeks. Individuals assigned to each full sibling family are listed in the rows of the table.

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Cougar	1	1.000	3141-005											
Cougar	2	0.896	3141-006	3141-039										
Cougar	3	1.000	3141-007											
Cougar	4	1.000	3141-008											
Cougar	5	0.999	3141-009	3141-031	3141-048									
Cougar	6	1.000	3141-010											
Cougar	7	1.000	3141-011	3141-014	3141-020	3141-042	3141-044	3141-051	3141-055	3141-059	3141-060	3141-061	3141-064	3141-070
Cougar	8	1.000	3141-012											
Cougar	9	1.000	3141-013											
Cougar	10	0.995	3141-015	3141-050										
Cougar	11	0.356	3141-016	3141-036										
Cougar	12	1.000	3141-017											
Cougar	13	1.000	3141-018											
Cougar	14	1.000	3141-019											
Cougar	15	1.000	3141-021											
Cougar	16	1.000	3141-022											
Cougar	17	1.000	3141-023											
Cougar	18	1.000	3141-024											
Cougar	19	1.000	3141-025											
Cougar	20	1.000	3141-026											
Cougar	21	0.184	3141-027	3141-041										
Cougar	22	1.000	3141-028											
Cougar	23	1.000	3141-029											
Cougar	24	1.000	3141-030											
Cougar	25	1.000	3141-032											

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Cougar	26	1.000	3141-033											
Cougar	27	1.000	3141-034											
Cougar	28	1.000	3141-035											
Cougar	29	1.000	3141-037											
Cougar	30	1.000	3141-038											
Cougar	31	1.000	3141-040											
Cougar	32	1.000	3141-043											
Cougar	33	1.000	3141-045											
Cougar	34	1.000	3141-046											
Cougar	35	1.000	3141-047											
Cougar	36	1.000	3141-049											
Cougar	37	1.000	3141-052											
Cougar	38	1.000	3141-053											
Cougar	39	1.000	3141-054											
Cougar	40	1.000	3141-056											
Cougar	41	1.000	3141-057											
Cougar	42	1.000	3141-058											
Cougar	43	1.000	3141-062											
Cougar	44	1.000	3141-063											
Cougar	45	1.000	3141-065											
Cougar	46	1.000	3141-066											
Cougar	47	1.000	3141-067											
Cougar	48	1.000	3141-068											
Cougar	49	1.000	3141-069											
Cougar	50	1.000	3141-071											
Cougar	51	1.000	3141-072											
Pine	1	0.998	3140-022	3140-094										

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Pine	2	1.000	3140-023	3143-062										
Pine	3	1.000	3140-024											
Pine	4	0.989	3140-025	3140-090										
Pine	5	1.000	3140-026	3140-029										
Pine	6	1.000	3140-027											
Pine	7	1.000	3140-028											
Pine	8	1.000	3140-030	3140-032	3143-060	3143-064	3143-068	3143-087						
Pine	9	1.000	3140-031											
Pine	10	1.000	3140-033											
Pine	11	1.000	3140-034											
Pine	12	1.000	3140-035	3140-042	3140-043	3140-073	3143-063	3143-073						
Pine	13	1.000	3140-036	3140-053										
Pine	14	1.000	3140-037											
Pine	15	1.000	3140-038											
Pine	16	0.644	3140-039	3140-046										
Pine	17	1.000	3140-040											
Pine	18	1.000	3140-041											
Pine	19	1.000	3140-044											
Pine	20	1.000	3140-045											
Pine	21	1.000	3140-047											
Pine	22	1.000	3140-048											
Pine	23	1.000	3140-049											
Pine	24	1.000	3140-050											
Pine	25	1.000	3140-051											
Pine	26	1.000	3140-052											
Pine	27	1.000	3140-054	3140-068	3140-075	3140-082	3140-083	3140-085	3140-089	3140-091	3140-092	3143-070		
Pine	28	1.000	3140-055											
Pine	29	0.330	3140-056	3143-058										

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Pine	30	1.000	3140-057											
Pine	31	1.000	3140-058											
Pine	32	1.000	3140-059	3140-065										
Pine	33	1.000	3140-060											
Pine	34	1.000	3140-061											
Pine	35	1.000	3140-062											
Pine	36	1.000	3140-063											
Pine	37	0.919	3140-064	3140-078										
Pine	38	1.000	3140-066	3143-061										
Pine	39	1.000	3140-067											
Pine	40	1.000	3140-069											
Pine	41	1.000	3140-070											
Pine	42	1.000	3140-071											
Pine	43	1.000	3140-072											
Pine	44	1.000	3140-074											
Pine	45	1.000	3140-076											
Pine	46	1.000	3140-077											
Pine	47	1.000	3140-079											
Pine	48	1.000	3140-080											
Pine	49	1.000	3140-081											
Pine	50	1.000	3140-084											
Pine	51	1.000	3140-086											
Pine	52	0.452	3140-087	3143-082										
Pine	53	1.000	3140-088											
Pine	54	1.000	3140-093											
Pine	55	1.000	3140-095											
Pine	56	1.000	3140-096											
Pine	57	1.000	3143-057											

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Pine	58	1.000	3143-059											
Pine	59	1.000	3143-065	3143-080										
Pine	60	1.000	3143-066											
Pine	61	1.000	3143-067											
Pine	62	1.000	3143-069											
Pine	63	1.000	3143-071											
Pine	64	1.000	3143-072											
Pine	65	1.000	3143-074											
Pine	66	1.000	3143-075											
Pine	67	1.000	3143-076											
Pine	68	1.000	3143-077											
Pine	69	1.000	3143-078											
Pine	70	1.000	3143-079											
Pine	71	1.000	3143-081											
Pine	72	1.000	3143-083											
Pine	73	1.000	3143-084											
Pine	74	1.000	3143-085											
Pine	75	1.000	3143-086											
Pine	76	1.000	3143-088											
Pine	77	1.000	3143-089											
Pine	78	1.000	3143-090											
Pine	79	1.000	3143-091											
Rush	1	1.000	3141-073											
Rush	2	1.000	3141-074											
Rush	3	1.000	3141-075	3141-077	3141-080	3141-084	3141-090	3141-091	3141-097	3143-032	3143-033	3143-046		
Rush	4	1.000	3141-076											
Rush	5	1.000	3141-078											

Tributary	Full Sib Family #	Prob (Inc.)	Member-1	Member -2	Member -3	Member -4	Member -5	Member -6	Member -7	Member -8	Member -9	Member -10	Member -11	Member -12
Rush	6	1.000	3141-079											
Rush	7	1.000	3141-081											
Rush	8	1.000	3141-082	3141-088	3141-094	3141-098	3143-034	3143-044						
Rush	9	1.000	3141-083											
Rush	10	1.000	3141-085											
Rush	11	1.000	3141-086											
Rush	12	1.000	3141-087											
Rush	13	1.000	3141-089											
Rush	14	1.000	3141-092											
Rush	15	1.000	3141-093											
Rush	16	1.000	3141-095											
Rush	17	1.000	3141-096											
Rush	18	1.000	3143-031											
Rush	19	1.000	3143-041											
Rush	20	1.000	3143-042											
Rush	21	1.000	3143-043											
Rush	22	1.000	3143-045											

Appendix 2. Genotypes at 16 microsatellite loci and the genetic sex identification markers for 3 Bull Trout collected below Lewis River Dams in 2017.

PIT Tag Number	BT_SexID		Omm1128		Omm1130		Sco102		Sco105		Sco106		Sco107		Sco109		Sco200	
AC776B6	67	102	331	351	298	302	166	169	166	190	208	208	297	297	360	360	142	142
AC776B5	67	102	331	331	298	298	166	169	154	190	208	212	293	297	360	360	142	142
AC776B7	67	102	281	281	298	298	173	173	154	190	208	208	293	293	360	360	142	142

Continued

PIT Tag Number	Sco202		Sco212		Sco215		Sco216		Sco218		Sco220		Sfo18		Smm22	
AC776B6	122	122	230	273	289	289	213	213	209	209	294	310	151	151	210	226
AC776B5	122	130	273	273	289	289	213	213	209	209	294	342	151	151	210	226
AC776B7	130	130	273	277	289	289	213	213	209	209	294	342	151	151	222	246