U.S. Fish and Wildlife Service

Clackamas River Bull Trout Reintroduction Project

2019 Annual Report

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U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office

On the cover: *Bull Trout captured in the Pinhead Creek adult trap, Clackamas River Subbasin (Photo by M. Barrows, USFWS)*

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CLACKAMAS RIVER BULL TROUT REINTRODUCTION PROJECT 2019 ANNUAL REPORT

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and authored by

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Over four decades after the last Bull Trout (*Salvelinus confluentus*) was documented in the Clackamas River in 1963, a 2007 feasibility study determined the Clackamas River Subbasin to be a favorable candidate for Bull Trout reintroduction. A multi-agency reintroduction effort initiated in 2011, with the overall goal of re-establishing a self-sustaining population of spawning adults by the year 2030. Bull Trout were first translocated from the Metolius River Subbasin to reaches of the upper Clackamas River and select tributaries in 2011, and these releases continued through 2016. The primary objectives during the ninth year of the project (second phase) were to monitor and evaluate the reintroduction effort. During 2019, continued progress was made toward the project's goal. The effectiveness of the reintroduction strategy was assessed by describing the seasonal distribution of translocated Bull Trout, assessing reproduction, and characterizing potential impacts to Endangered Species Act-listed salmon and steelhead in the subbasin. A video monitoring weir with an associated adult trap, passive integrated transponder (PIT) antenna and laser scaling capability was employed to assess the spawning population in Pinhead Creek. The 2019 spawning population was comprised of individuals that had been translocated as juveniles and subadults in 2012 – 2016, confirming their survival and recruitment into the adult population. The 37 individuals subsampled at the weir trap in 2019 were large, migratory fish and ranged in size from 440 – 728 mm TL. A total of 72 individual Bull Trout were captured or observed at the weir, of which 46 (64%) were female, 25 (35%) were male and 1 was unknown. Of the 46 females, 31 (67%) had been previously tagged and all 25 of the males had been previously tagged. Since all translocated fish were PIT-tagged, the presence of untagged fish suggests a portion of the spawners may have been locally-born, though the disparity between the ratio of tagged to untagged males and females may indicate an elevated rate of tag shedding among the females. Ninety-eight percent of the tagged Bull Trout that encountered the weir successfully passed upstream during the spawning season. Eighty percent of the fish that encountered the weir passed during their first encounter and 89% passed upstream by their second encounter. The laser scaling method developed for passively obtaining lengths from video of Bull Trout passing through the weir was demonstrated to be practical and the relative accuracy of the method averaged 98.2% (range: 95.8 – 100%). Redd counts have increased substantially since the inception of the reintroduction program, and the 93 redds counted during 2019 was the highest count to date. Multiple redds (N = 13) were found in Berry Creek for the first time. Caudal fin tissue was collected from nine additional untagged Bull Trout captured at the Pinhead Creek weir during 2019 and will provide the opportunity for subsequent parentage analysis. Archived tissue samples were used in a parentage analysis of embryos collected from Bull Trout redds in 2017 and parents were identified. Monitoring efforts have not provided evidence of locally-born post-emergent juveniles, or recruitment into the spawning population, both of which are major benchmarks for the reintroduction project, but may be achieved in future years. Implementation and monitoring of the reintroduction project will continue to be evaluated on an annual basis and the reintroduction strategy will be adaptively managed.

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Introduction

Bull Trout (*Salvelinus confluentus*) are native to the Pacific Northwest and Canada. A general decline in abundance across their native range impelled the U.S. Fish and Wildlife Service (USFWS) to list Bull Trout as threatened under the Endangered Species Act (ESA) in 1999 (64FR 58910). Bull Trout exhibit a very complex and veritable continuum of life histories involving movements, migrations, spawning, rearing and foraging on time scales ranging from daily to annually or longer, and over different spatial scales (Schaller et al. 2014). Bull Trout also require very specific habitat conditions including clean and cold water with complex, connected habitats (Rieman and McIntyre 1995; Selong et al. 2001; USFWS 2015a). Various anthropogenic actions, including but not limited to habitat degradation, migration barriers and the introduction of non-native species have negatively influenced Bull Trout populations (Fraley and Shepard 1989; Leary et al. 1993; Schaller et al. 2014). Bull Trout were estimated to occupy only 40 percent of their historical range within Oregon, Washington, Idaho, Montana and Nevada at the time of listing in 1999 (USFWS 2002a).

A primary goal in the USFWS's Final Bull Trout Recovery Plan (USFWS 2015a) is to reestablish self-sustaining populations in watersheds where Bull Trout have been extirpated. In some watersheds, natural recolonization is unlikely or insufficient due to connectivity impairments (e.g., instream barriers, distance, etc.). Translocation and reintroduction efforts from more robust populations may be necessary in some watersheds to establish populations at sustainable levels (Dunham et al. 2014). Bull Trout have been extirpated in multiple Willamette River subbasins, including the Clackamas River (Figure 1). Willamette River Basin Bull Trout recovery efforts have focused primarily on reducing the threats affecting Bull Trout and their habitat. Due to widespread extirpations across the expansive basin with multiple hydrosystem projects, natural recolonization may be unlikely, thus necessitating reintroduction in some areas to establish self-sustaining populations. One or more reestablished Bull Trout local populations through a successful reintroduction effort will expand Bull Trout distribution and may increase population connectivity within the Coastal Recovery Unit (USFWS 2015b).

Progress in the ninth year (2019) of the joint effort between the Oregon Department of Fish and Wildlife (ODFW), USFWS, U.S. Forest Service (USFS), and other collaborators (i.e., the Confederated Tribes of Warm Springs Reservation [CTWSR], National Marine Fisheries Service [NMFS], Portland General Electric [PGE], and the U.S. Geological Survey [USGS)]) to reintroduce Bull Trout into the Clackamas River is detailed in this report. This project was implemented following publication of a final rule establishing a nonessential experimental population of Bull Trout in the Clackamas River under section 10(j) of the ESA (76 FR 35979 on June 21, 2011). Bull Trout were transferred to the Clackamas River Core Area from healthy populations in the Metolius River Subbasin from 2011 through 2016 (ODFW 2012; Barrows et al. 2016). During this timeframe, 2417 juvenile, 371 subadult and 80 adult Bull Trout were released into the upper Clackamas River and select tributaries (Table 1 in Appendix C). No additional Bull Trout translocations to the Clackamas River Subbasin are currently planned.

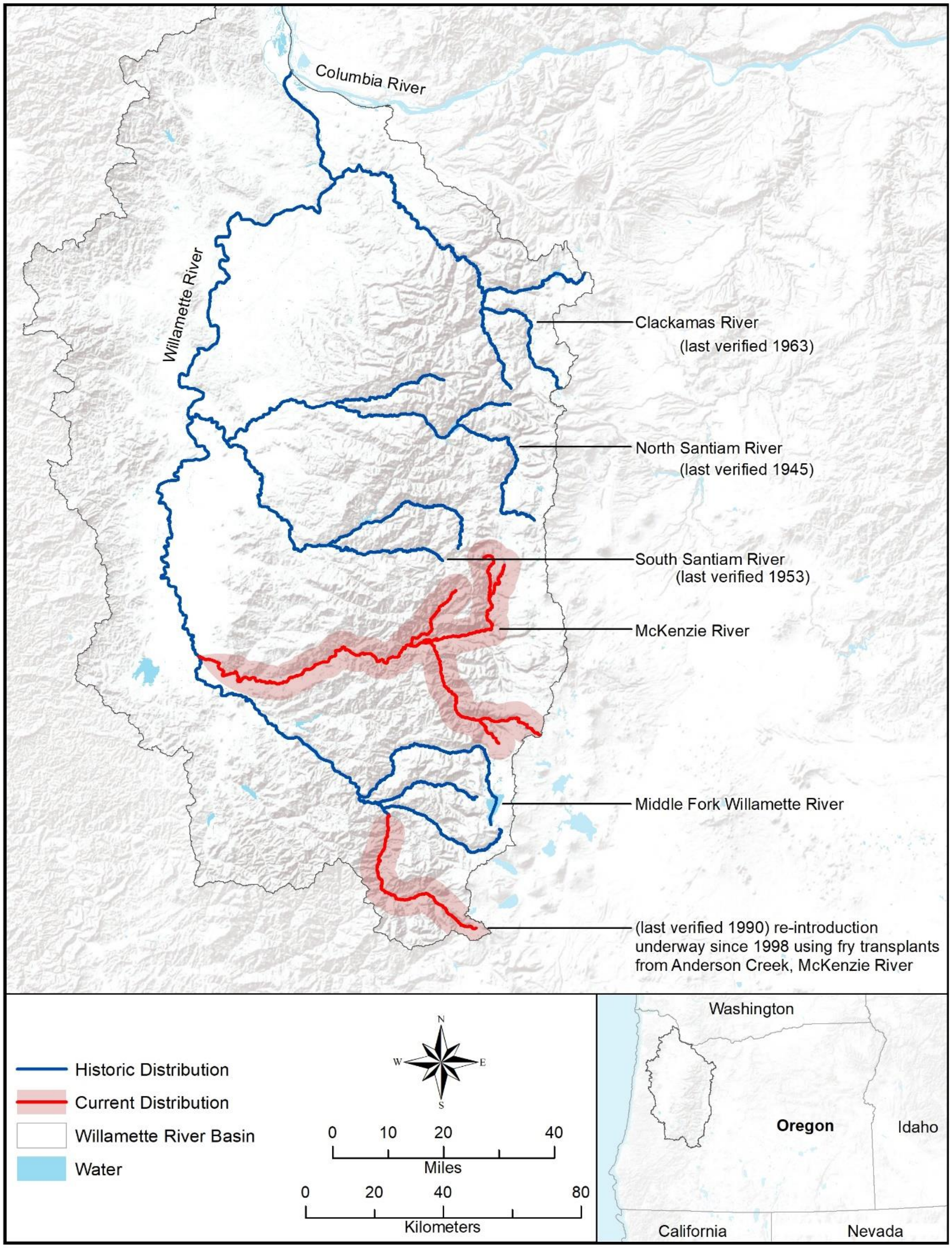


Figure 1. Historical and current Bull Trout distribution in the Willamette River Basin.

The goal of the Clackamas River Bull Trout reintroduction is to re-establish a self-sustaining Bull Trout population of 300 – 500 spawning adults in the Clackamas River Subbasin by 2030. For this project, a self-sustaining population is defined as one that maintains a minimum annual spawning abundance of 100 adults, contains a level of genetic diversity representative of the donor stock, and requires few or no additional translocations. The amount of suitable habitat within the Clackamas River Subbasin suggests there is the necessary habitat to support a population of 300 – 500 spawning adults, but even in core areas with abundant suitable habitat, distribution is often patchy; thus, the actual capacity of the Clackamas River Subbasin for Bull Trout is not known. The numerical goal of 300-500 spawning adults originated with recovery planning targets set in the Bull Trout Draft Recovery Plan (USFWS 2002b) for the abundance necessary to achieve these characteristics. Accomplishing this goal will help achieve conservation and recovery goals within the Coastal Recovery Unit (USFWS 2015b).

The actions described in this report are intended to address the following broad objectives identified in the Implementation, Monitoring, and Evaluation (IM&E) Plan developed by the USFWS Oregon Fish and Wildlife Office and Columbia River Fish and Wildlife Conservation Office (USFWS 2011a):

1. Monitor and evaluate the effectiveness of the Bull Trout reintroduction strategy for re-establishing a self-sustaining Bull Trout population in the Clackamas River Subbasin.

2. Evaluate the effects of Bull Trout reintroduction on ESA-listed salmonids in the Clackamas River Subbasin.

Additional reintroduction project background, management strategy and other information can be found in the IM&E Plan:
(www.fws.gov/oregonfwo/Species/Data/BullTrout/Documents/ClackamasBT_IME_Plan.pdf).

Study Area

The study area includes the Clackamas River Subbasin upstream of River Mill Dam (Figure 2).

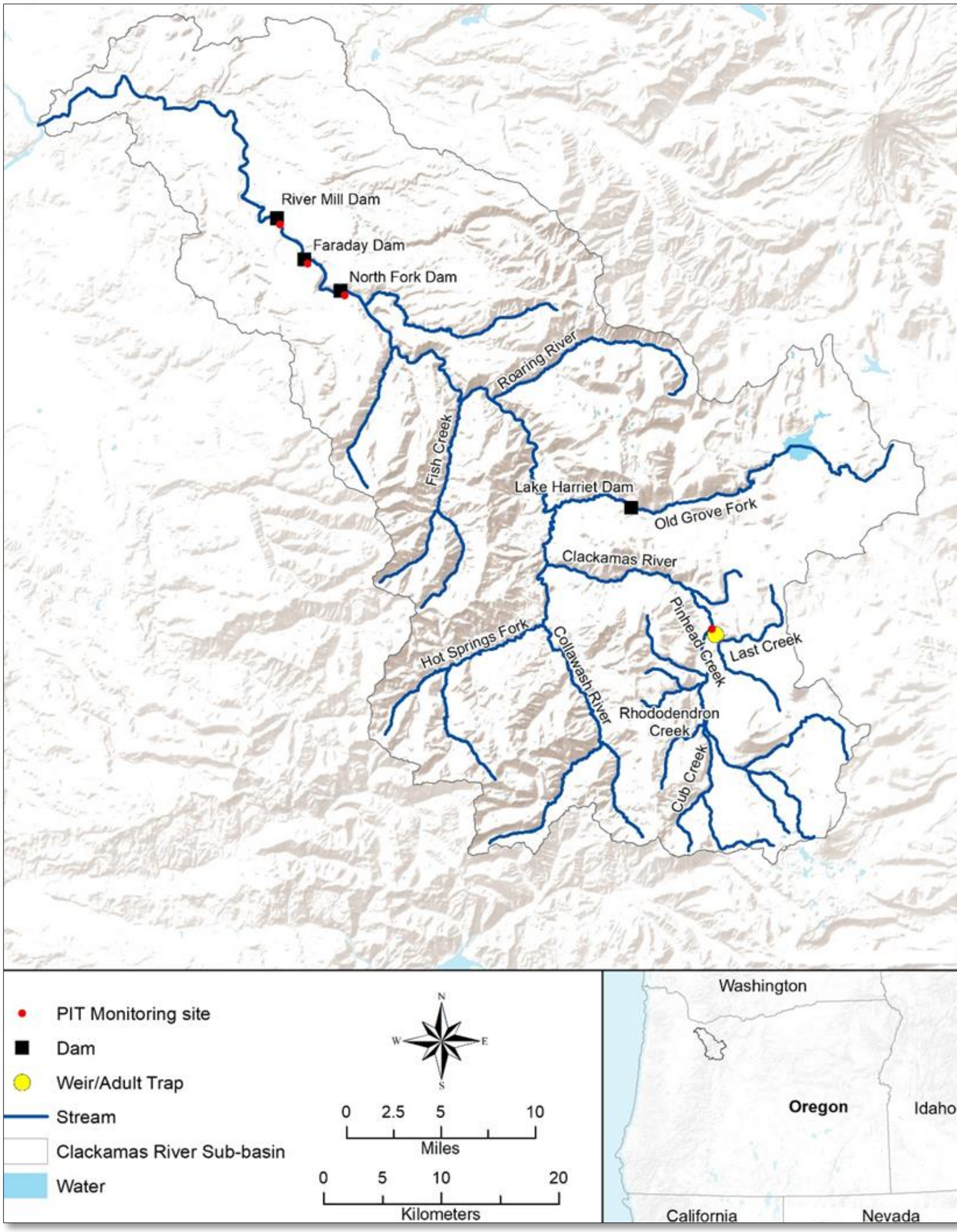


Figure 2. Locations of current monitoring sites in the study area. Multiple PIT monitoring antennas are located throughout PGE's hydro power facilities. A PIT tag monitoring site was installed with the Pinhead Creek weir and was operational from mid-July through early November 2019.

Methods

Movement and Seasonal Distribution

Clackamas River Bull Trout exhibit a migratory life history involving movements, foraging, rearing and spawning over varying temporal and spatial scales. In years following the termination of the radio-telemetry program in 2014, our ability to monitor Bull Trout movements and seasonal distribution throughout the subbasin has been limited. However, an instream half-duplex (HDX) passive integrated transponder (PIT) tag detection array near the mouth of Pinhead Creek has been used to detect Bull Trout presence and infer movement patterns since 2011. In 2018, this channel-spanning antenna was moved approximately 150 m upstream to the picket weir location. During 2019, PIT-detections at this site were used to monitor and assess adult Bull Trout as they move to primary spawning grounds in Pinhead Creek. Due to an abundance of literature noting the piscivorous nature of this species, it is also important to monitor the spatiotemporal distribution of Bull Trout throughout the system, including their presence in the High Vulnerability Zone (HVZ) where native salmonids may be vulnerable to increased predation (specifically, North Fork Reservoir and other areas within PGE's hydro project facilities). In the absence of a radio-telemetry program, we can no longer detect when translocated Bull Trout have entered the HVZ, nor can we determine the total time each fish spent in the HVZ. However, detections of Bull Trout at Clackamas Hydro Project PIT antennas and observations at the adult sorting facility were used to help infer when Bull Trout entered North Fork Reservoir and other areas within PGE's hydro project facilities. We used the available PIT tag monitoring sites to document the behavior, movement and seasonal distribution of juvenile, subadult and adult fish (see Figure 2). These data help to address the following broad questions identified in the IM&E Plan (USFWS 2011a):

1. What are the seasonal movement patterns and distribution of Bull Trout in the Clackamas River Subbasin?

2. Do translocated Bull Trout remain in the upper Clackamas River Subbasin (above River Mill Dam), and if they leave the study area, do they return?

3. Do Bull Trout occupy areas in High Vulnerability Zones (HVZs) in which they could impact listed salmon and steelhead?

Pinhead Creek Spawning

A channel-spanning HDX PIT tag antenna was used to monitor Bull Trout presence and movement approximately 150 meters upstream from the Pinhead-Clackamas confluence, 10 meters downstream of the Pinhead Creek video weir (Figures 2 and 3). In addition to the instream PIT antenna, a small antenna was operated within the Pinhead Creek weir video chute. Both antennas were powered by a bank of 12-volt batteries and an Oregon RFID Multi-Antenna HDX Reader. The video chute PIT antenna was in place from July 11 to October 7, 2019. The instream PIT antenna was in place from July 11 to October 15, 2019. Both antennas were non-operational during only two days due to technological malfunction.

Figure 3. Channel-spanning HDX PIT tag antenna located 150 meters upstream from the Pinhead-Clackamas confluence, approximately 10 m below the Pinhead Creek weir.

High Vulnerability Zone

A total of 13 established PIT detection arrays were operated by PGE at various facilities associated with the Clackamas Hydro Project (Figure 4). Eight of the arrays (9 antennas) were operated with KarlTek (KLK5000) PIT tag readers and five (12 antennas) with Oregon RFID readers. Table 1 is a summary of the PIT detection arrays at the Clackamas Hydro Project. Monitoring by PGE outside the scope of the Bull Trout reintroduction plan is also considered to determine if minimum thresholds for salmon and steelhead lifestages are being met in accordance with the Stepwise Impact Reduction Plan (USFWS 2011b).

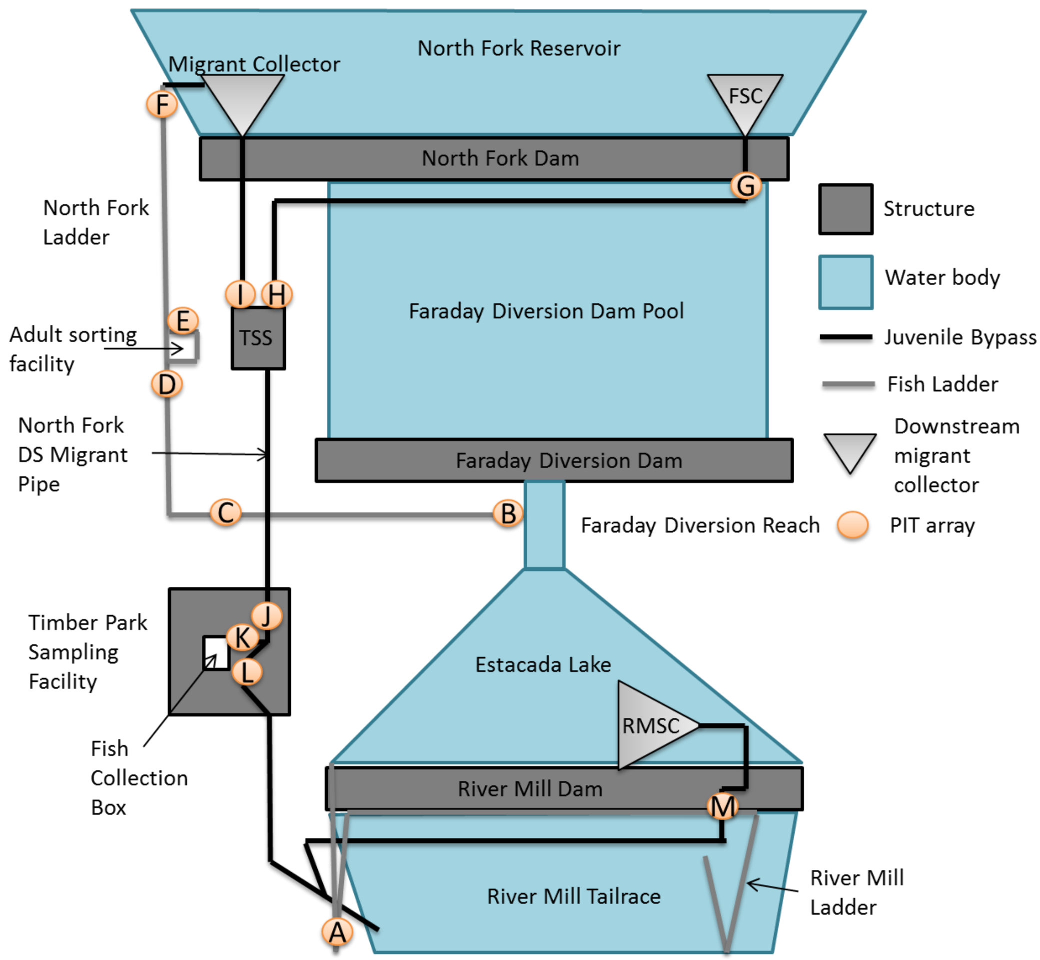


Figure 4. Schematic of PIT antenna array at the Clackamas Hydro Project. FSC = Floating surface collector; TSS = Tertiary screen structure; RMSC = River Mill surface collector. (Figure provided by Portland General Electric.) Also see Figure 2 for locations of these facilities within the Clackamas Subbasin.

Table 1. PIT detection arrays at the Clackamas Hydro Project. (Information provided by Portland General Electric)

Array	Datalogger	Operated Since	Antennas	Site Purpose
A	KarlTek KLK5000	Apr 2013	2	Detect fish passing through the River Mill ladder.
B	Oregon RFID	May 2015/16	2	Detect fish at the entrance of the North Fork fish ladder.
C	OregonRFID	May 2013	4	Detect fish near (upstream and downstream) the old adult sorting facility (North Fork ladder).
D	OregonRFID	Apr 2017	2	Detect fish approaching the adult sorting facility
E	OregonRFID	May 2016	1	Detect fish exiting the adult sorting facility.
F	OregonRFID	May 2015	3	Detect fish exiting the North Fork ladder.
G	KarlTek KLK5000	Oct 2015	1	Detect fish from the FSC just downstream of the flow control structure.
H	KarlTek KLK5000	Oct 2015	1	Detect fish from the FSC just upstream of the tertiary screen structure.
I	KarlTek KLK5000	Oct 2015	1	Detect fish from the North Fork migrant collector just prior to entering the tertiary screen structure.
J	KarlTek KLK5000	Dec 2011	1	Detect fish in flume entering Timber Park.
K	KarlTek KLK5000	Dec 2011	1	Detect fish diverted into the sampling box at Timber Park.
L	KarlTek KLK5000	Dec 2011	1	Detect fish bypassed back to the pipeline at Timber Park.
M	KarlTek KLK5000	Jan 2013	1	Detect fish in the River Mill Surface Collector.

Reproduction

During 2019, two methods were used to monitor and assess the spawning Bull Trout population in Pinhead Creek and in other tributaries and reaches within the Clackamas River Subbasin. Census redd surveys were conducted in Pinhead, Last, Cub, Berry and Hunter creeks in addition to designated reaches of the upper Clackamas River. A picket weir was also operated to monitor the spawning population in Pinhead Creek and to complement the redd surveys. In addition to monitoring the spawning population, we continued efforts to document natural production and recruitment into the adult population. During 2019, the following objectives were addressed:

1. Estimate the number of Bull Trout spawners in tributaries and select reaches in the upper Clackamas River.

2. Determine growth rates of translocated Bull Trout captured in Pinhead Creek.

3. Document natural production in Pinhead Creek.

Redd Surveys

Census redd surveys were led by ODFW and conducted by experienced personnel in potential Bull Trout spawning habitat in the upper Clackamas River and several major tributaries (Objective 1). Surveys were conducted approximately every two weeks, beginning prior to the spawning season (late-August) and continuing through the first week of November 2019. Details concerning the specific methods and survey locations can be found in Appendix C.

Video Weir and Adult Trap

A two-way fixed picket weir and underwater video detection system was operated in Pinhead Creek, a tributary to the Clackamas River, from July 11, 2019 through October 7, 2019 (NOAA 4[d] and Oregon Scientific Take Permit #21002). The confluence of Pinhead Creek and the Clackamas River is located at river kilometer 109. The weir was installed between Last Creek and the NF-46 bridge, about 0.1 kilometers upstream from the mouth of Pinhead Creek. The weir layout in 2019 closely resembled the design used in 2018 (Barrows et al. 2019). The video chute and upstream trap box were positioned in parallel on river right and both picket leads were angled to direct fish to the chute and trap box (Figure 5). During periods when fish were not sampled via the trap box, fish were able to migrate in either direction through the video chute. A PIT antenna was incorporated into the video chute to monitor movements of individual PIT-tagged fish. As previously described in the Movement and Seasonal Distribution section, a channel-spanning HDX PIT tag antenna was installed just below the Pinhead Creek video weir as well. When the upstream trap box was set (i.e., open), an exclusion gate (Figure 6) was added to the video chute to prevent fish from moving upstream while allowing fish to migrate downstream unimpeded and be monitored. The leads were constructed using schedule 40 aluminum pipe held together with two 9.5 mm (3/8 inch) cables with 19 mm (¾ inch) spacers between each picket (Figure 7). T-posts were used to support the leads, and additional T-posts were installed at an angle to provide resistance to downstream pressure. Sandbags and rocks were placed where needed along the bottom of each of the leads and along the banks to make the weir fish-tight.

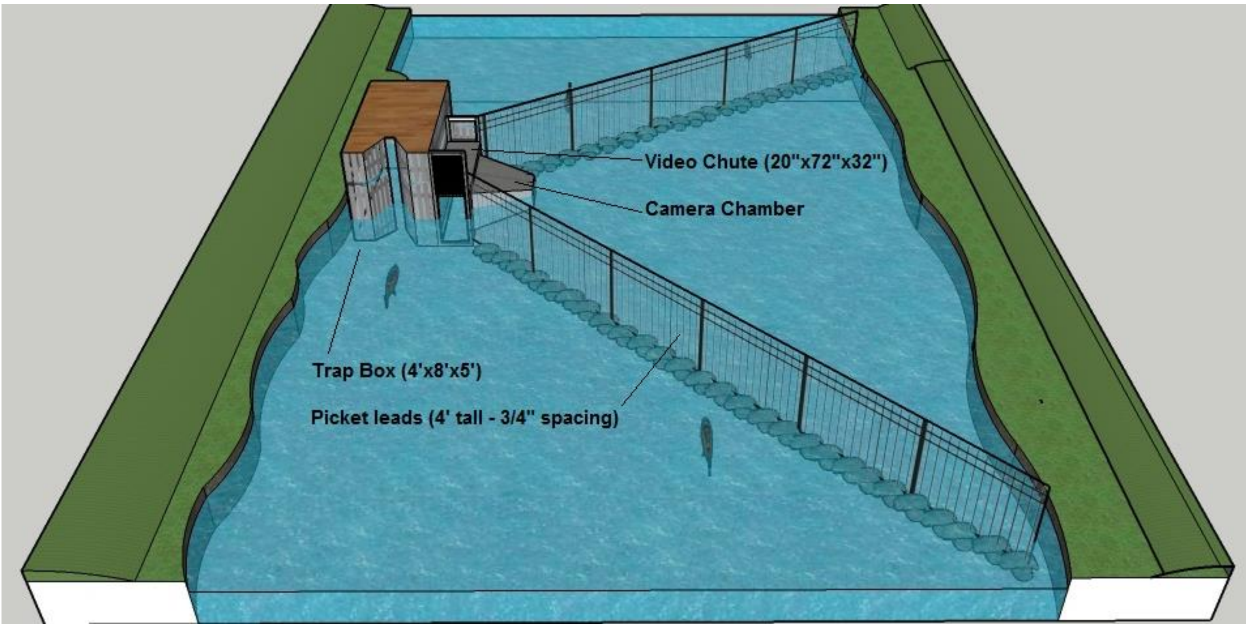


Figure 5. Schematic of the Pinhead Creek weir and trap.

Figure 6. Exclusion gate for video chute.

Figure 7. Photo depicting the aluminum picket leads, video chute and trap box deployed in Pinhead Creek.

The underwater video system that was used during 2018 was again employed in 2019 (Barrows et al. 2018) and the design resembled that of Anderson et al. (2006) on Big Creek near King Salmon, Alaska. A Sony 291,000 pixel Super hole-accumulation diode (HAD) charged-coupled device imager with an auto-iris 3.6-mm wide angle lens and three 12-V LED pond lights were mounted inside a sealed aluminum camera box and attached to the video chute (Figure 8). Safety glass separated the camera box and the video chute. The camera box was filled with clear water and sealed to provide clear viewing into the video chute. Laminate flooring provided a backdrop inside the video chute. A PIT tag antenna was attached to the upstream end of the video chute. The PIT antennas were tested and detection data were downloaded from the site during each visit (from two to five times each week) and correlated to the video footage. Video images were recorded on two SecuMate Mini Portable DVRs and stored on 8 GB SDHC memory cards. Both the primary and backup DVRs were equipped with motion detection to record video clips of fish activity through the video chute. A portable TFT 12 VDC color monitor was used to scan the video footage while in the field. Memory cards were exchanged in the DVRs and brought back to the office for viewing. Both Windows Media Player and VLC media player were used to view the footage. The system was powered by two battery banks, one to operate the video equipment and the other to power the PIT detection antennas. Each battery bank had three 12-V DC batteries (connected in parallel) with a combined 300 Ampere-hours.

Figure 8. Photo depicting the camera chamber (right), video chute (middle) and trap box (left).

The fyke of the trap box and the exclusion gate were set every Monday through Friday between August 12, 2019 and September 20, 2019 for capturing upstream migrating Bull Trout. The Bull Trout were removed from the trap by dip net and anesthetized for sampling in a river water bath that contained 40 mg/l of tricaine methanesulfonate (MS-222) buffered with 80 mg/L sodium bicarbonate. All Bull Trout were scanned for PIT tags. Sampling consisted of recording their PIT ID (if previously tagged), determining their sex, measuring their total length to the nearest 1 mm and weighing to the nearest 0.1 g (Barrows et al. 2014). The Bull Trout without tags were injected subcutaneously with a 23-mm long PIT tag through a 3-mm incision made with a surgical scalpel anterior to the pelvic girdle (Barrows et al. 2014). We collected a tissue sample (upper lobe of the caudal fin) from these fish for DNA analysis and preserved the samples in vials containing alcohol. We then determined the sex (phenotypic characteristics), total length, and weight of each fish. All Bull Trout recovered following sampling in a large tote circulated with aerated river water. After recovering to an upright position, Bull Trout were released to an area with reduced water velocity upstream of the weir.

<u>Spawning Population Estimate</u>

We used data from the adult trap, video observations and PIT tag monitoring data to estimate the number of spawners that moved upstream of the weir in Pinhead Creek.

<u>Weir Passage</u>

The Pinhead Creek weir, by design, funnels migrating Bull Trout through a small passageway, either into the video observation chute or a trap box. The weir itself, or these constricted passageways could deter or delay migrating fish from reaching their spawning grounds. To address this concern, we installed an instream PIT detection antenna approximately 10 meters downstream of the weir to help identify how the weir may be influencing migratory behavior. We defined an upstream weir encounter as a detection at the instream PIT antenna without a preceding PIT detection within two hours in the video chute, to ensure we were evaluating an individual that was encountering the weir from downstream.

To assess the passage rate of PIT-tagged Bull Trout associated with the operation of the Pinhead Creek weir, the percent of PIT-tagged Bull Trout that passed upstream of the weir was calculated as:

$$((V + T) / D) \times 100$$

Where D = the number of individual PIT-tagged Bull Trout detected encountering the weir moving upstream; V = the number of individual PIT-tagged Bull Trout first detected passing successfully through the video chute; and T = the number of individual PIT-tagged Bull Trout first captured in the adult trap.

To assess migration delay of PIT-tagged Bull Trout associated with the operation of the Pinhead Creek weir, we used PIT-tagged Bull Trout that encountered the Pinhead Creek weir from downstream. The time (in days) for an individual PIT-tagged Bull Trout to successfully pass upstream of the weir via the video chute or the adult trap was calculated as:

$$date_v - date_d \text{ (or) } date_{trap} - date_d$$

Where $date_d$ = the date a PIT-tagged Bull Trout was first detected at the instream PIT antenna downstream of the weir; $date_v$ = the date a PIT-tagged Bull Trout first successfully passed upstream via the video chute; and $date_{trap}$ = the date a PIT-tagged Bull Trout first successfully passed upstream via the adult trap. Mean passage times (in days) were calculated from individual passage times from the above equation.

We also assessed passage by documenting the number of weir encounters for each individual. The number of encounters before successfully passing upstream was also documented.

Growth Rates

Total lengths and weight data were collected from Bull Trout captured in the adult trap at the weir. These data were used to calculate growth rates for all translocated individuals that were sampled.

Laser Scaling

We used concepts similar to those described in Yoshihara (1997) to develop a laser scaling method for passively obtaining lengths from video of Bull Trout passing through the Pinhead Creek video weir. During this developmental effort, lengths from video were only estimated for fish that were also captured and measured in the trap.

Two 16 mm x 65 mm 5V DC submersible red laser line generator modules (output power 100mW) were mounted within a 2 gang type-FSC PVC Electrical Box for 1.9 cm conduit (Figure 9). The laser lines were aligned vertically and in parallel at a distance of 65 mm apart from eachother (Figure 10). The laser modules were placed in the camera chamber and projected through the video chute. As a fish passed through the video chute, two verticle laser lines were projected on the body of the fish. Regardless of the distance between the fish and the camera, the measurement between the laser lines was consistently 65 mm. Of the 37 unique individual Bull Trout captured in the adult trap during 2019, 29 were also clearly observed passing either upstream or downstream through the video chute. The 29 observations were used to evaluate the relative accuracy of this method. The total length of each individual Bull Trout captured in the trap was measured to the nearest 1 mm. Video footage corresponding to each Bull Trout was reviewed and a still frame photo was captured at a point when the entire fish was visible and was as parallel to the camera as possible. The relative proportion of the distance measured on the still frame photo between the two laser lines and of the length of the fish was used to estimate the total length of the fish as follows:

$$W_v / L_w = W_k / L_e$$

Where W_v = width measured between the laser lines from the video; L_w = the length of the fish measured from the video; W_k = the actual width measured between the laser lines and L_e = the estimated total length of the fish. The estimated total lengths of each fish were then compared to the total lengths obtained from the trap.

Figure 9. Two submersible red laser line generator modules were mounted within a 2 gang type-FSC PVC Electrical Box for ¾ inch conduit.

Figure 10. The laser lines were aligned vertically and in parallel at a distance of 65 mm apart from each other. The laser modules were placed in the camera chamber and projected through the video chute. As a fish passed through the video chute, two verticle laser lines were projected on the body of the fish.

Documenting Natural Production

A primary indicator of a successful translocation project is spawning by the locally-born progeny of translocated individuals. Locally spawned Bull Trout have not been detected during past electrofishing and minnow-trapping efforts (Barrows et al. 2017; Barrows et al. 2016; Barry et al. 2014). Therefore, we used genetic samples and tag redetection of fish that encounter the weir to address the following questions:

1. Are unknown origin Bull Trout from the Clackamas River Subbasin fish that were translocated from the Metolius River Basin, or fish that were locally-born?

2. Is there evidence of locally-born progeny, and if so, were they recruited into the spawning population?

3. Which translocation strategy (e.g., life stage, year, location) was the most successful?

4. Which individuals (and release groups) produced offspring?

<u>Multilocus Genotype Database and Parentage Analysis</u>

From 2011 to 2016, caudal fin tissue (approximately 1 cm^2) was collected from each of the 2868 Bull Trout translocated to the Clackamas River Subbasin. These samples were archived at the USFWS Abernathy Fish Technology Center (Longview, Washington). The archived tissue samples were used to develop a database of multilocus genotypes that were generated for each of the translocated Bull Trout. This database was constructed to identify individual Bull Trout that were translocated into the Clackamas River basin, and to identify the likely parents of locally-born progeny in Pinhead Creek. It is important to note that addressing these objectives for all individuals is dependent on locating approximately 400 missing Metolius River donor stock samples. As a first step, embryos were collected from two suspected Bull Trout redds in Pinhead Creek by hydraulic sampling in 2017 (Barrows et al. 2018) in an attempt to document the successful reproduction of translocated Bull Trout. Bohling and Piteo (2019) analyzed the parentage of 10 embryos collected from each redd. The likely parents for each embryo were identified using the database of multilocus genotypes.

<u>Tag Retention</u>

Monitoring studies of translocated Bull Trout rely heavily upon PIT tag detection. We examined the proportion of the Bull Trout in the Pinhead Creek spawning population that do not have PIT tags. Since all translocated fish were PIT-tagged, untagged fish passing the weir may be translocated fish that have previously shed their tag, or naturally recruited individuals (see Tag Retention results and discussion). We also examined the disparities in tag encounter rates between male and female fish to understand if tag shedding in translocated fish is related to the sex of the fish. Higher tag encounter rates in male fish could be evidence that untagged fish are a result of tag shedding in female fish rather than locally produced offspring, since female spawning often results in tag shedding. We also collected genetic samples from untagged Bull Trout captured at the weir during 2017 and 2018 for subsequent genetic analysis to confirm whether untagged fish were locally-born progeny or if they were translocated fish that did not retain their tag.

Results and Discussion

Movement and Seasonal Distribution

Pinhead Creek Spawning

Detections of PIT-tagged Bull Trout at the Pinhead Creek weir were used to describe when adult Bull Trout entered Pinhead Creek to spawn. During 2019, a total of 57, unique PIT-tagged Bull Trout were detected at the Pinhead Creek weir from July through October, of which 56 successfully passed upstream (Figure 11). Most of the tags detected in 2019 represented translocated Bull Trout released into the Clackamas River Subbasin in 2012-2016 (Table 2). Thirty-four fish were originally released into the mainstem Clackamas River, 11 were released into Pinhead and Last creeks and two had been released in Berry Creek (Starcevich 2020). As expected, fewer fish from early release groups have been detected in Pinhead Creek at the weir in recent years (Barrows et al. 2018, 2019). This pattern is expected to continue in the future as older fish die and untagged progeny (if they exist) replace them in the spawning population. In addition, three of the six adult Bull Trout PIT-tagged at the Pinhead Creek weir during 2017 were detected during 2019, and three of the five untagged Bull Trout tagged at the trap during 2018 were detected during 2019. Eight of the nine Bull Trout tagged at the trap during 2019 were also subsequently detected at the video chute PIT antenna. The majority of individuals that migrated into Pinhead Creek were relatively large, migratory adult-sized fish (see Video Weir and Trap results and discussion). Despite appearing mature, it is possible that a portion of the fish were not yet mature spawners, and may have entered Pinhead Creek to seek rearing and foraging habitat. It is also possible that a portion of the fish detected in Pinhead Creek did not ultimately spawn upstream of the weir, instead spawning downstream of the weir or in other areas within the Clackamas Subbasin.

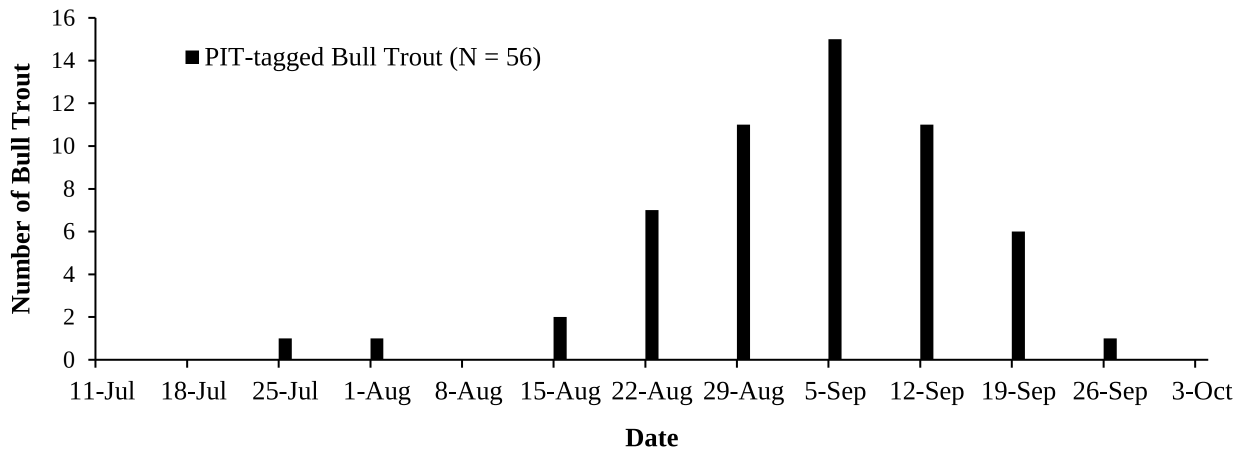


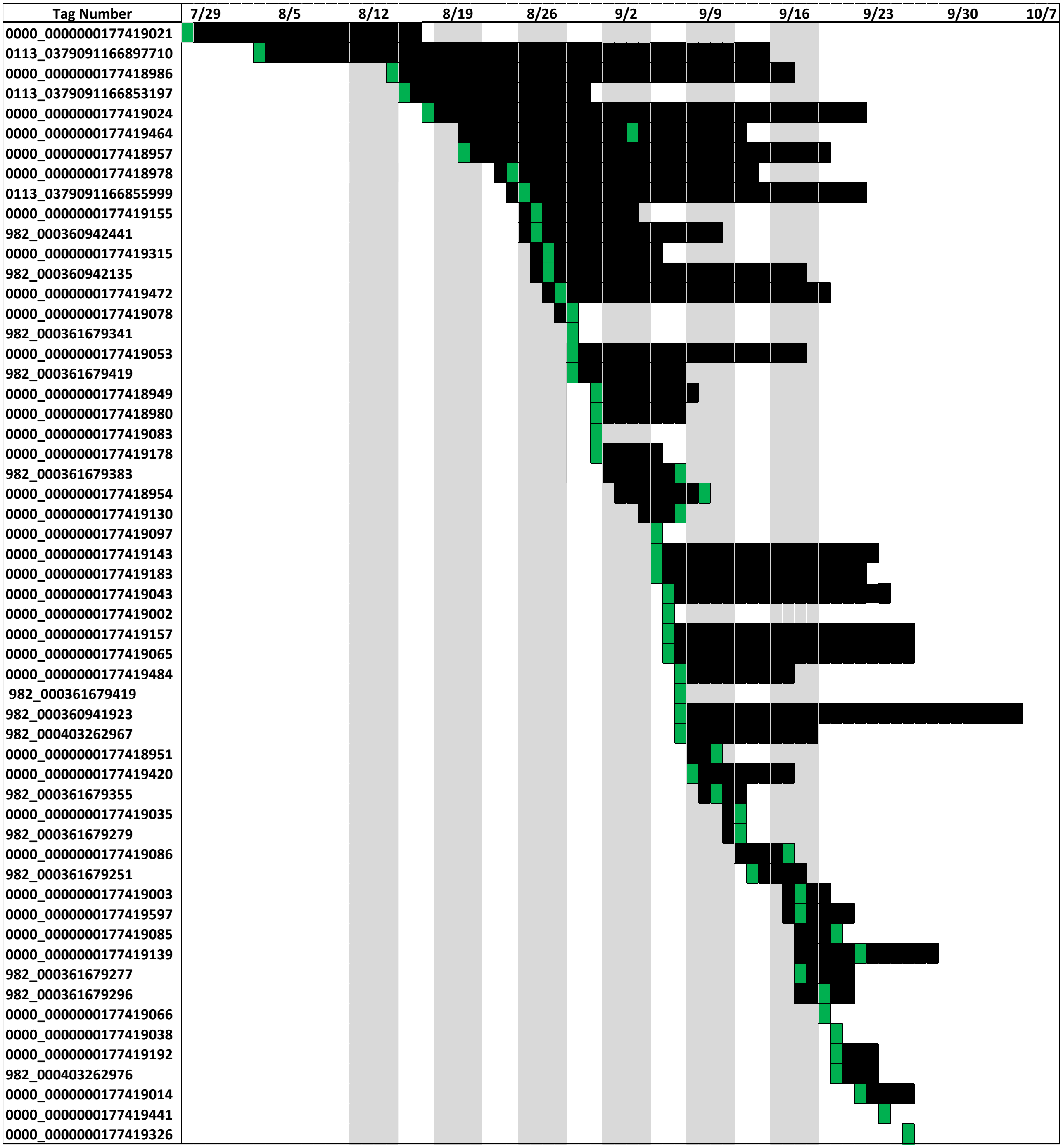
Figure 11. First successful passage attempts by unique PIT-tagged Bull Trout moving upstream past the Pinhead Creek weir. Each bar represents one week. This includes all detected tags in 2019 from fish that moved upstream past the Pinhead Creek Weir via the video chute or the adult trap.

Table 2. Unique PIT tag detections of translocated Bull Trout from release groups in 2012 – 2016 detected in Pinhead Creek during 2019.

Lifestage	2012	2013	2014	2015	2016	Totals
Juvenile	0	11	1	3	14	29
Subadult	1	0	3	5	10	19
Adult	0	0	0	0	0	0
Totals	**1**	**11**	**4**	**8**	**24**	**48**

A PIT detection site at the mouth of Pinhead Creek was operated from 2012 through 2017. This site was decommissioned following 2017, limiting our ability to determine the total amount of time individuals spent in Pinhead Creek during the spawning season. However, the time between the first and last PIT detection at the Pinhead Creek weir gives us an idea of how long individuals spent on the spawning grounds upstream of the weir. Fish that were detected more than once at the weir spent an average of 12.6 days (range, 1 – 42 days) in Pinhead Creek. Several Bull Trout were only detected moving upstream at the weir, suggesting that they either died upstream of the weir, returned downstream during PIT antenna downtime or did not return downstream before the PIT antennas were removed for the season mid-October. Table 3 shows the time span between the first and last detection of each PIT-tagged Bull Trout detected at the Pinhead Creek weir during 2019.

Table 3. Each row of the periodicity table represents the time span between the first and last detection of each PIT-tagged Bull Trout detected at the Pinhead Creek weir during 2019. The green cell indicates the first successful upstream passage attempt by each individual either through the trap or the video chute. The gray bars indicate days the adult trap was operated.



High Vulnerability Zone

Bull Trout use of North Fork Reservoir and occupancy of the HVZ during 2019 is largely unknown. Monitoring efforts have been limited following the end of the reintroduction project's radio-telemetry program in 2014. However, the detection histories of 12 PIT-tagged Bull Trout detected at various PIT antennas at PGE's hydro project facilities during 2019 provide some degree of insight into when and where Bull Trout occupy habitat in the Clackamas River extending from downstream of River Mill Dam to North Fork Reservoir (Appendix A).

It is rational to assume that Bull Trout in the vicinity of PGE's hydro project facilities opportunistically forage on salmon, steelhead and other species, so it is important to know how long Bull Trout reside there. It is often unclear how long an individual Bull Trout has occupied a given area prior to its detection moving through the hydro project, but in some instances, occupancy timing can be inferred through examining detection histories. Following an examination of detection histories, the presence of Bull Trout was confirmed at PGE facilities in January, June through October and December in 2019. Data from previous years indicate Bull Trout encounter PGE facilities and occupy the HVZ during all months (Barry et al. 2014; Barrows et al. 2016, 2017, 2018, 2019).

During 2016, 2017, 2018 and 2019, six, five, nine and twelve Bull Trout were detected at PGE facilities, respectively. The twelve PIT-tagged Bull Trout detected at PIT arrays within PGE's hydro project facilities during 2019 are listed in Table 4. In many cases, an individual was detected at multiple PIT arrays on multiple dates. Six fish were originally released as juveniles (70 – 250 mm TL), five were released as subadults (251 – 450 mm TL) from 2013 to 2016 and one fish was released in 2016 as an adult. An examination of the detection histories and observations of these fish since translocation (Appendix A) indicated 10 were likely adults and two fish released as juveniles in 2016 (PIT ID's 982_000360937173 and 982_000403263035) were likely subadults when detected in 2019.

Table 4. Individual PIT-tagged Bull Trout detected at PGE facilities during 2019.

PIT ID	Length at Release (TL)	Release Date	Release Site
0000_0000000177419007	296 mm	6/13/2016	4650 Bridge
0000_0000000177419021	344 mm	6/13/2016	4650 Bridge
0000_0000000177419076	575 mm	6/3/2016	4650 Bridge
0000_0000000177419142	270 mm	5/27/2016	4650 Bridge
0000_0000000177419199	372 mm	6/19/2014	100 m d/s of 4650 bridge
0000_0000000177419300	381 mm	6/20/2013	Lower 4650 Bridge D/S
0000_0000000177419441	150 mm	5/23/2013	Last Creek u/s of 42 bridge
982_000360937173	91 mm	5/6/2016	Upper Clackamas
982_000360942135	146 mm	5/20/2016	4650 Bridge
982_000361679137	163 mm	5/15/2014	Berry Creek Bridge
982_000361679183	206 mm	4/24/2014	Berry Creek Bridge
982_000403263035	93 mm	5/13/2016	Upper Clackamas

Twelve individual PIT-tagged Bull Trout were detected at PGE facilities during 2019. Of the fish detected, five adults were observed passing upstream of North Fork Dam. Two of these individuals were detected in Pinhead Creek during the spawning season. One of the fish (PIT ID 0000_0000000177419441) passed upstream of North Fork Dam on August 19, 2019 and was subsequently detected 37 days later at the Pinhead Creek weir on September 25, 2019. After presumably spawning in Pinhead Creek, this fish was detected returning downstream of North Fork Dam via the surface collector on December 22, 2019 (Appendix A). Similarly, another Bull Trout (PIT ID 982_000360942135) passed upstream of North Fork Dam on July 29, 2019 and was captured 30 days later in the adult trap on Pinhead Creek. It was captured again on September 19, 2019 and was identified as a 587 mm (TL) male.

Three Bull Trout that moved upstream of North Fork Dam were not subsequently detected during 2019. Two of these fish (PIT ID's 982_000361679137 and 982_000361679183) passed upstream of North Fork Dam on July 31, 2019 and July 18, 2019, respectively. They had both been originally released into Berry Creek during 2014 and may have returned to Berry Creek to spawn. There is no PIT antenna in Berry Creek to confirm this, but 13 Bull Trout redds were counted in Berry Creek during 2019, suggesting this may be plausible. It is also possible that fish without subsequent detections did not spawn during 2019 or spawned elsewhere in the system.

Some Bull Trout detected at PGE facilities have sparse detection histories, limiting what can be inferred from the detections. For example, three Bull Trout (PIT ID's 0000_0000000177419007; 0000_0000000177419021; 0000_0000000177419142) released as subadults in the mainstem Clackamas River in 2016 were detected passing downstream of North Fork Dam via the Floating Surface Collector in 2019. Their sparse detection histories offer very little information pertaining to their whereabouts since translocation. The detections provide only a snapshot of where they were located at a single moment. It remains unknown whether these fish had been residing in the mainstem Clackamas River or foraging in the North Fork Reservoir following release. Similarly, it is unknown where they went after leaving the study area.

Bull Trout detection histories from 2019 and previous years indicate there have been ample opportunities for Bull Trout to interact with anadromous salmonids in the HVZ. Counts of adult and juvenile salmonids (e.g., coho, Chinook, steelhead) are annually recorded through the hydro project in accordance with BiOp Term and Condition 1b (NMFS 2011). This monitoring is conducted by PGE outside the scope of the Bull Trout reintroduction project. Counts of anadromous salmon and steelhead through PGE's hydro facilities on the Clackamas River in 2019 were above thresholds identified in the Stepwise Impact Reduction Plan (Appendix B), suggesting the presence of Bull Trout in the system may not expressively impact salmon and steelhead populations.

It should be noted that PIT detections may only represent an unknown portion of the actual number of Bull Trout occupying the HVZ and encountering PGE facilities due to tag loss and the possible existence of untagged, locally-born individuals.

Reproduction

The number of translocated Bull Trout using spawning tributaries has increased since the reintroduction program began. Bull Trout spawning has consistently been observed and redd counts have increased from a total of 5 in 2011 to a high of 93 in 2019 (Starcevich 2020). Prior to 2019, almost all of the redds counted in the Clackamas Subbasin were recorded in Pinhead Creek, Last Creek and the upper Clackamas River. However, there were 13 redds counted in Berry Creek during 2019. These were the first redds recorded in Berry Creek since redd surveys initiated in 2015 (Starcevich 2020).

Redd Surveys

A total of 93 presumed Bull Trout redds were observed in 2019 (Starcevich 2020). Of the 93 redds, most (N = 71) were observed in Pinhead Creek, 6 were counted in Last Creek, 3 were observed in the mainstem Clackamas River and 13 were counted in Berry Creek (Figure 12). Redd counts in the Pinhead/Last creek system have increased each year since the inception of the reintroduction program until a slight decline in 2018 and 2019 (Starcevich 2020). However, the addition of 13 Berry Creek redds and 3 from the mainstem Clackamas River lifted the total redd count to a new high in 2019 (Starcevich 2020). Additional details concerning 2019 census redd counts associated with this project are described, summarized and discussed in Appendix C.

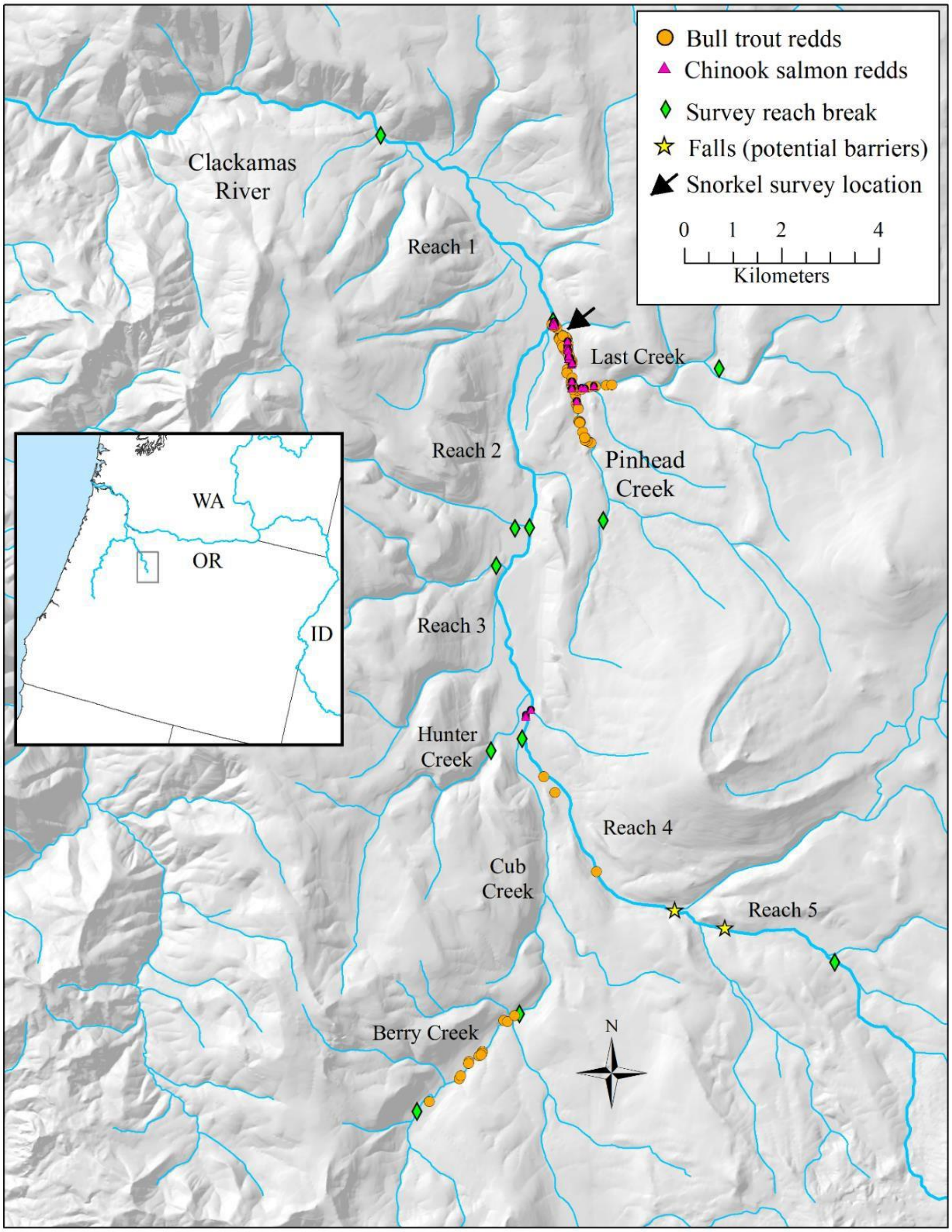
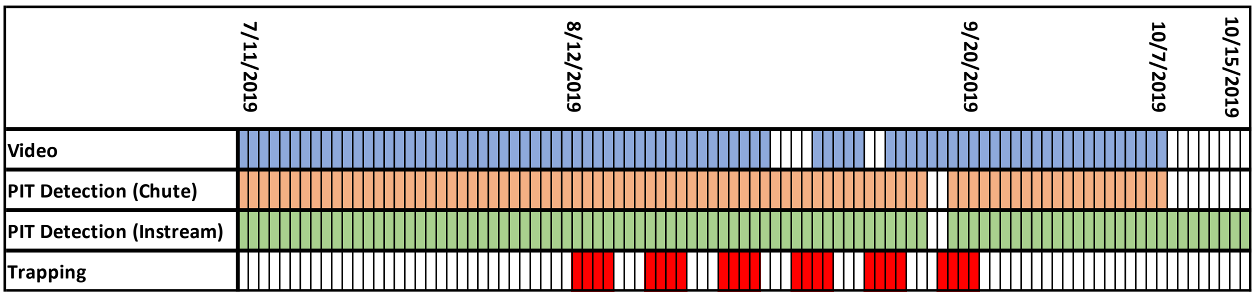


Figure 12. Locations of redds in Pinhead, Last and Berry creeks and the Clackamas River in 2019. Bull Trout redds observed during 2019 are depicted as orange circles. (Clackamas River Bull Trout Reintroduction Project: Characterizing status and thermal habitat suitability in 2019 [Starcevich 2020]).

Video Weir and Adult Trap

The Pinhead Creek weir was installed in early July and was fully operational by July 11, 2019. Fish passing the weir were monitored via video and a PIT antenna from July 11, 2019 to October 7, 2019 (Table 5). In addition, the channel-spanning PIT antenna located just downstream of the weir was operated from July 11, 2019 until it was vandalized on October 15, 2019. Video malfunction occurred during four days in early September and again for two days in mid-September. A PIT transceiver malfunction resulted in a two day lapse in detection capability for both antennas during mid-September. Despite the occasional lapses in detection capability, there were no instances when both the video and PIT monitoring systems were inoperable at the same time. The upstream adult trap was operated Monday through Friday between August 12, 2019 and September 20, 2019.

Table 5. Pinhead Creek weir operation periodicity table during 2019.



During 2019, there were a total of 155 (64 upstream and 91 downstream) video observations of Bull Trout at the Pinhead Creek weir (Table 6). There were also 66 video observations (40 upstream and 26 downstream) of Chinook Salmon (*Oncorhynchus tshawytscha*) and one Coho Salmon (*Oncorhynchus kisutch*) moving through the weir. Many individual Bull Trout were observed moving both upstream and downstream past the weir multiple times. Some fish were also captured in the trap before or after being observed on video passing the weir. From late July to late August, the majority of Bull Trout observed moving upstream past the weir were male, but female upstream observations increased in September (Figures 13 and 14).

Table 6. Video observations of Bull Trout and Chinook Salmon passing the Pinhead Creek video weir during 2019.

Species (Sex)	Upstream	Downstream	Total
Bull Trout (Male)	39	45	84
Bull Trout (Female)	25	46	71
Chinook Salmon (Combined)	40	26	66

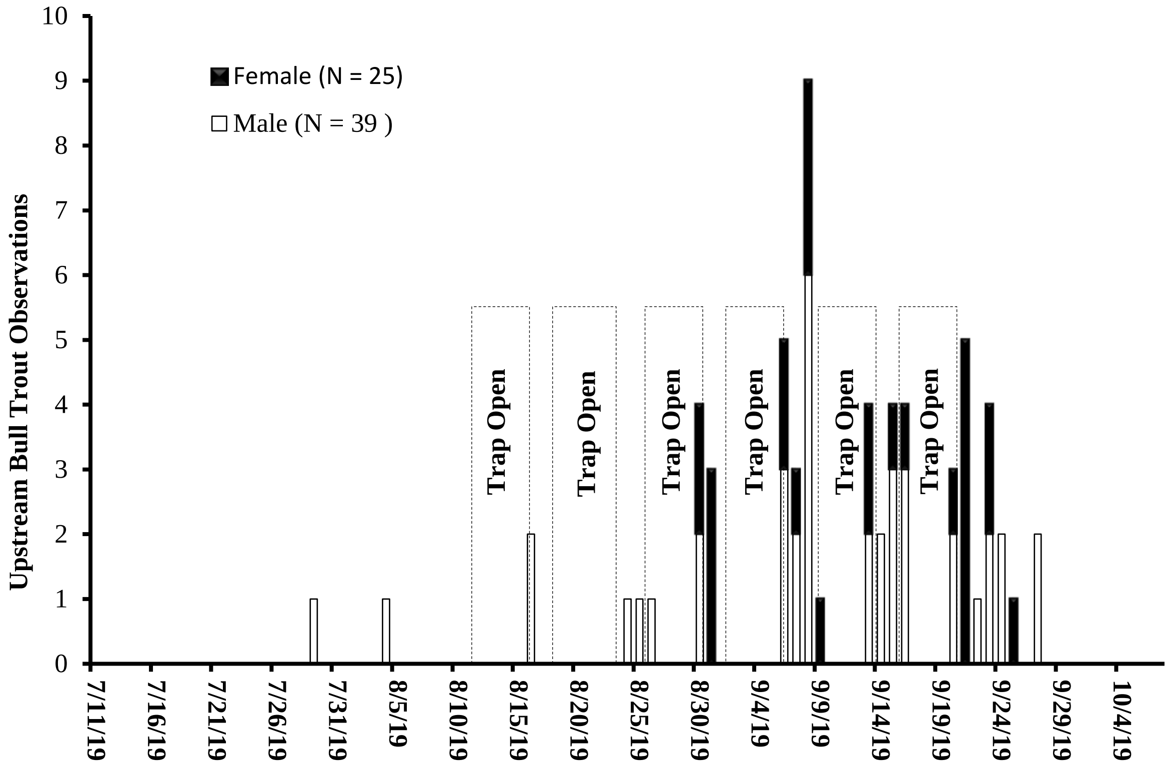


Figure 13. Upstream video observations of male and female Bull Trout at the Pinhead Creek weir during 2019.

Sixty-one individual PIT-tagged Bull Trout were detected while passing upstream or downstream (or both) through the video chute PIT antenna. There was one additional PIT-tagged Bull Trout that was only detected on the instream PIT antenna downstream of the weir, which indicates it did not pass upstream of the weir.

By pairing video observations and corresponding PIT detections, we were able to identify 43 individual, PIT-tagged Bull Trout that passed upstream through the video chute. There were also 6 total observations of untagged Bull Trout passing upstream through the video chute. Table 7 is a summary of individual Bull Trout observed moving upstream through the video chute at the Pinhead Creek weir.

Table 7. Individual Bull Trout observed moving upstream through the video chute at the Pinhead Creek weir.

Sex	Video Observations (PIT-tagged)	Video Observations (Untagged)	Totals
Male	21	0	21
Female	21	6	27
Unknown	1	0	1
Totals	**43**	**6**	**49**

Thirty-seven unique Bull Trout were captured, and nine of those were subsequently recaptured in the trap at the Pinhead Creek weir from August 12, 2019 to September 20, 2019. A majority of Bull Trout captures occurred in early to mid-September (Figure 14). Of the 37 Bull Trout captured, 20 were females and 17 were males. Nine of the females and all of the males had been PIT-tagged previously. One male Chinook Salmon was also captured in the trap during 2019.

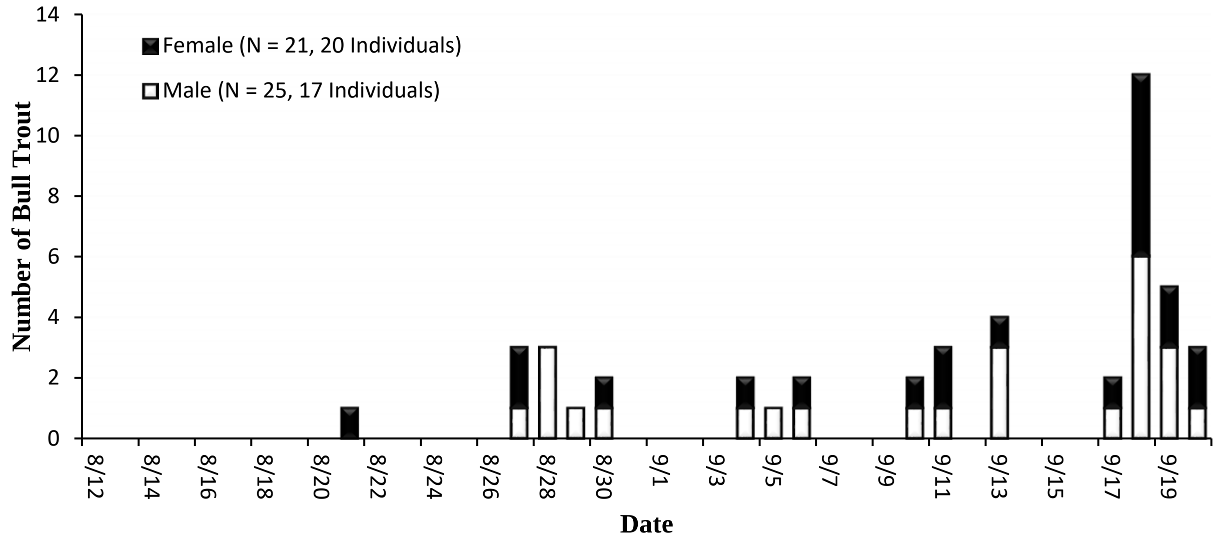


Figure 14. Bull Trout trapped by date and sex at the Pinhead Creek weir during 2019.

The Bull Trout captured in the trap were all relatively large, migratory fish and ranged in length from 440 – 728 mm TL. Many fish were between 575 and 650 mm TL (Figure 15). Female Bull Trout (mean, 627 mm TL; range, 548 – 728 mm TL) were on average longer than the males (mean, 578 mm TL; range, 435 – 665 mm TL). Tagged females (mean, 621 mm TL; range, 548 – 719 mm TL) were on average similar in length to untagged females (mean, 634 mm TL: range, 583 – 728 mm TL). Lengths and weights of Bull Trout captured in the trap are summarized in Table 8.

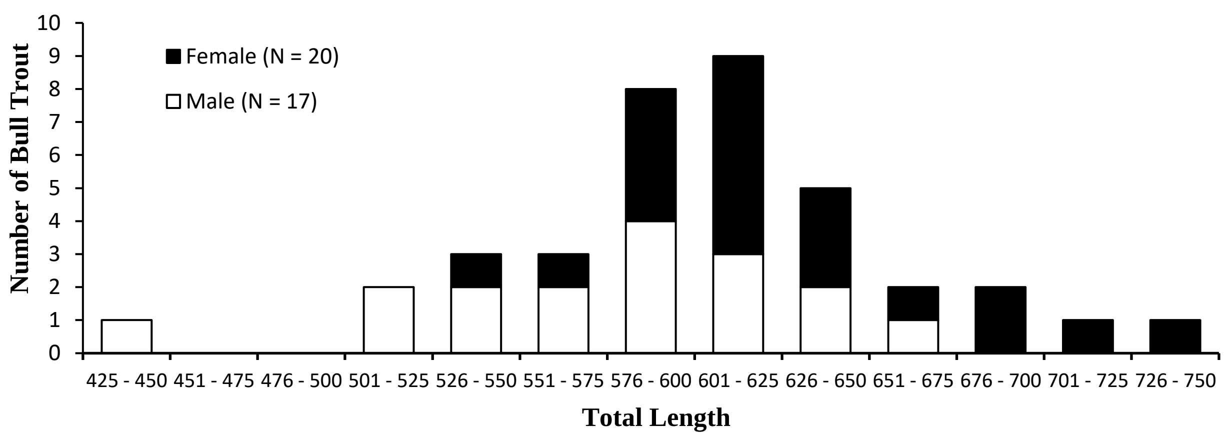


Figure 15. Total lengths by sex of Bull Trout captured at the Pinhead Creek weir during 2019.

Table 8. Lengths and weights of Bull Trout captured in the trap at the Pinhead Creek weir.

Species (Tagged/Untagged)	Total Length (mm)			Weight (g)		
	Min	Max	Mean	Min	Max**	Mean***
Males (Tagged)	435	665	578	1230	> 2800	NA
Females (Tagged)	548	719	621	1715	> 2800	NA
Males (Untagged)*	-	-	-	-	-	-
Females (Untagged)	583	728	634	2009	> 2800	NA

* No untagged males were captured during 2019.
** Multiple individuals were heavier than the upper range of the scale (3000 g).
*** Mean weights were not calculated for groups where individuals exceeded the upper range of the scale (2800 g).

Spawning Population Estimate

A total of 72 individual Bull Trout were captured, observed or detected passing the weir, of which 46 were female, 25 were male and one was unknown (Table 9). Of the 46 females, 31 (67%) were previously tagged and all of the 25 males were tagged. In addition, there was one PIT-tagged Bull Trout detected at the instream PIT antenna just downstream of the weir that was not subsequently captured in the trap or detected while passing upstream of the weir. The total number of Bull Trout that entered Pinhead Creek, but did not pass upstream of the weir to spawn is unknown. The spawning population estimate for 2019 was notably less than estimates for 2017 (N = 97) and 2018 (N = 101). A reason for the decline in adult spawners was not apparent. However, the number of males in 2019 was notably lower than in previous years (Figure 16).

Table 9. Tagged and untagged male and female Bull Trout captured at the trap and observed on video at the Pinhead Creek weir.

Sampling Method	Male		Female		Unknown		Combined	
	Tagged	Untagged	Tagged	Untagged	Tagged	Untagged	Tagged	Untagged
Weir Trap	17	0	11	9	0	0	28	9
Weir Video/PIT Only	8	0	20	6	1	0	29	6
Combined	25	0	31	15	1	0	57	15
Total	**25**		**46**		**1**		**72**	

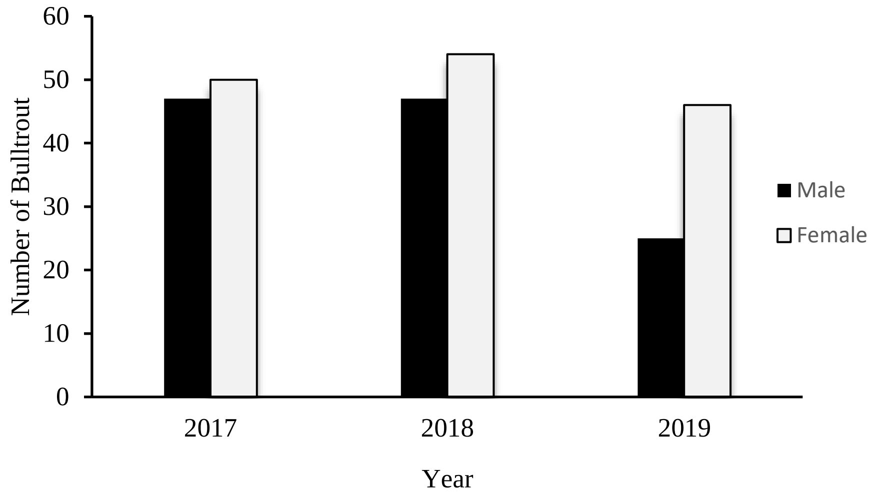


Figure 16. Number of male and female Bull Trout in Pinhead Creek spawning population estimates from 2017 through 2019.

Weir Passage

During 2019, 62 individual PIT-tagged Bull Trout encountered the Pinhead Creek weir from July 29, 2019 to October 6, 2019. Of the 62 PIT-tagged individuals that encountered the weir, 98% (N = 61) were documented successfully passing upstream of the weir via the weir trap or video chute. The PIT-tagged individual that did not subsequently pass upstream during the spawning period may have spawned downstream of the weir in Pinhead Creek, or in other known and unknown spawning areas. On average, each Bull Trout encountered the weir moving upstream 3.2 times (range: 1 – 21) and encountered the weir 1.5 times (range: 1 – 11) before successfully passing upstream through the adult trap or the video chute. A similar pattern was observed during 2018 (Barrows et al. 2019). We presume a similar behavior pattern may occur naturally in the absence of a weir, but little is known of Bull Trout micro-movements within spawning tributaries prior to spawning. Eighty percent of the Bull Trout that encountered the weir passed during their first encounter and 89% passed upstream by their second encounter. This was consistent with results from 2018 (Barrows et al.2019). Of the PIT-tagged fish that encountered the weir, 83% passed upstream of the weir in one day or less following their initial encounter. A similar percentage (82%) passed within one day of their initial encounter in 2018 (Barrows et al. 2019).

Many factors may have influenced weir passage and timing at the weir, including, but not limited to, rain events, run timing and fish density below the weir. Bull Trout have also been suspected of being trap-shy (Barrows et al. 2019; Nelson et al. 2011). A majority of Bull Trout passed upstream of the weir during their first encounter and within a day of initially encountering the weir. Our data suggest passage delay at the weir was minimal for most Bull Trout moving to spawning grounds upstream of the weir.

Growth Rates

Twenty-eight of the adult Bull Trout trapped at the Pinhead Creek weir during 2019 were previously PIT-tagged. One of the 28 previously tagged fish was tagged at the Pinhead Creek weir as an adult in 2017 and two were tagged at the weir in 2018 (Barrows et al. 2018; 2019). The other 25 PIT-tagged fish were translocated individuals. The fish were originally released as juveniles (N = 12), subadults (N = 13), and adults (N = 3) and on average grew at rates of 93.8 mm, 71.3 mm and 45.3 mm per year, respectively (Table 10). These growth rates are generally consistent with previous years (Barrows et al. 2017, 2018, 2019) and findings reported in Harris et al. (2018) in that larger (older) individuals grew in length at a slower rate than smaller (younger) fish. During previous years, we found that translocated male and female Bull Trout grew at similar rates following release, but in 2019, translocated males had grown at a notably faster rate than the females (Table 11). Bull Trout growth within a population likely varies due to many factors including, but not limited to, genetics, life history form, habitat use, sex and age (Harris et al. 2018; Al-Chokhachy and Budy 2008). In future years, as the translocated population matures, and as we recapture additional fish, a more robust growth rate analysis may be warranted to further assess the reintroduction effort.

Table 10. Growth rates since release of translocated Bull Trout captured at the Pinhead Creek weir during 2019.

Lifestage at Release	# of Samples	Growth / Day (mm)	Growth / Year (mm)
Juveniles (70 – 250 mm)	12	0.26	93.8
Subadults (252 – 450 mm)	13	0.19	71.3
Adults (> 450 mm)	3	0.12	45.3

Table 11. Growth rates since release of male and female translocated Bull Trout captured at the Pinhead Creek weir during 2019.

Sex	# of Samples	Growth / Day (mm)	Growth / Year (mm)
Male	16	0.23	92.5
Female	9	0.17	63.0
Combined	25	0.24	81.9

Laser Scaling

There was a strong linear relationship ($Y=0.99X + 2.12$, $R^2=0.96$) between the total length measurements of individual Bull Trout captured in the adult trap and the total lengths estimated through laser scaling (Figure 17). The average difference between measured total lengths from the trap and the estimated total lengths was 10.3 mm and ranged from 0.0 to 25.9 mm. The relative accuracy of the laser scaling method averaged 98.2% (range: 95.8 – 100%). These results suggest our laser scaling method for estimating fish lengths is relatively accurate and may be a reasonable alternative, particularly when other methods to obtain age, weight or length are costly or impractical (Karpov et al. 2009; Yoshihara 1997).

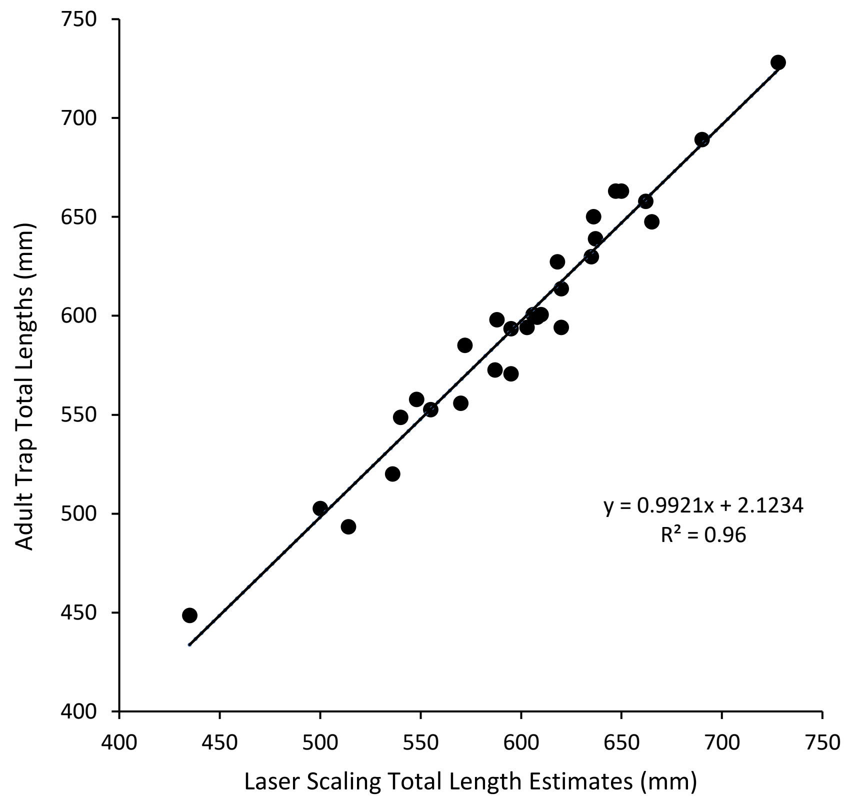


Figure 17. Total lengths measured from individual Bull Trout captured in the Pinhead Creek adult trap as a function of total lengths estimated for the same individuals via the laser scaling method. The line and its equation were estimated using simple linear regression.

Documenting Natural Production

Multilocus Genotype Database and Parentage Analysis

From 2011 to 2016, caudal fin tissue was collected from each fish that was translocated to the Clackamas River Subbasin. In total, 2868 tissue samples (Table 12) have been taken from translocated Bull Trout and have been archived at the USFWS Abernathy Fish Technology Center in Longview, Washington and were used to develop a database of multilocus genotypes that were generated for each translocated Bull Trout (Bohling and Piteo 2019).

Table 12. Count by year and lifestage of Bull Trout captured in the Metolius River Subbasin and translocated to the Clackamas River Subbasin (Appendix C).

Lifestage	Number of Bull Trout Translocated						
	2011	2012	2013	2014	2015	2016	Total
Juvenile	58	517	624	322	300	596	2417
Subadult	25	43	90	45	74	94	371
Adult	35	17	8	7	7	6	80
Totals	**118**	**577**	**722**	**374**	**381**	**696**	**2868**

Embryos were collected from suspected Bull Trout redds in 2017 to identify the likely parents of each embryo in an attempt to document the successful reproduction of translocated Bull Trout. Following a parentage analysis of collected embryos, two family groups corresponding to two separate redds were identified (Bohling and Piteo 2019). Embryos from the first redd had the same two likely translocated parents (PIT ID 0000_0000000177419427 and 0000_0000000177419295), both of which were released in 2013 as juveniles. The female (PIT ID 0000_0000000177419295) was captured in the trap prior to spawning in 2017. At the time of capture, her total length was 585 mm. We also observed the male (PIT ID 0000_0000000177419427) on video prior to spawning (Figure 18).

Figure 18. Male parent (PIT ID 0000_0000000177419427) of the embryos sampled from a redd in Pinhead Creek during 2017.

Bohling and Piteo (2019) determined that the other ten embryos from the second redd all shared one translocated parent (PIT ID 0000_0000000177419515), a juvenile released in 2013. We captured this fish in the trap on August 29, 2017 and determined it to be a 462 mm (TL) male. This fish was also observed passing upstream of the weir on September 2, 2017 (Figure 19). Bohling and Piteo (2019) also determined that seven of the embryos shared the same translocated parent (PIT ID 0113_0379091166858808), also a juvenile released in 2013. This fish was observed on video moving upstream of the Pinhead Creek weir on September 18, 2017 (Figure 19). The other three embryos had three different individuals as the most likely other parent (PIT ID's 0113_0379091166847314, 0113_0379091166991182 and 982_000403262929). Considering these three individuals were never observed or detected following their translocation, they were unlikely to have been the parents. However, Bohling and Piteo (2019) determined the parents of the seven embryos were also the second most likely pairing for these three individuals as well, which is feasible since they were collected from the same redd.

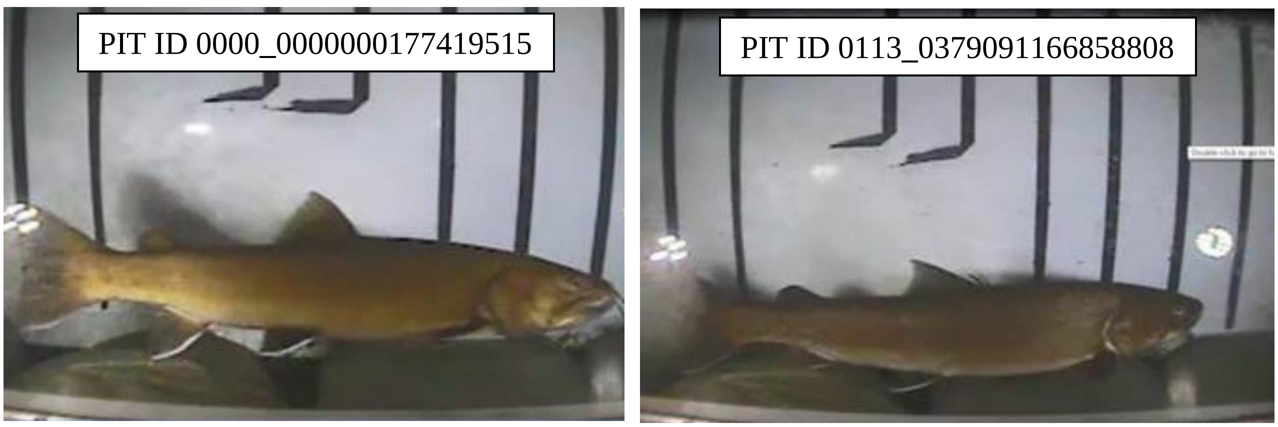


Figure 19. The likely male parent (PIT PIT ID 0000_0000000177419515) and likely female parent (PIT ID 0113_0379091166858808) of the embryos sampled from a redd in Pinhead Creek during 2017.

<u>Tag Retention</u>

Thirty-seven individual Bull Trout were captured in the adult trap during 2019. Nine of these fish were untagged prior to capture. No male Bull Trout without previously implanted PIT-tags were observed at the video weir or captured in the trap. This suggests that very few males in the 2019 spawning population were locally-born progeny. Thirty-one of the 46 females (67%) observed were previously PIT-tagged, suggesting a portion of the female Bull Trout in the population may have been locally-born. However, the notable disparity in tagged to untagged ratios for male and female fish observed at the weir during 2017, 2018 (Barrows et al. 2018, 2019) and 2019, suggests tag retention may be substantially lower for females. Significantly lower PIT tag retention rates in female salmonids have been previously documented (Meyer et al. 2011; Prentice 1990). For this reason, the true percentage of locally-born individuals in the spawning population may be better represented by the males, suggesting very few (if any) locally-born individuals have been recruited into the adult population in Pinhead Creek. The proportion of tagged to untagged individuals in 2019 was similar to findings from 2017 and 2018 (Table 13). However, there were a higher percentage of PIT-tagged males and females in 2019 than in previous years, possibly indicating the beginning of a trend (Figure 20). Cuadal fin tissue samples were collected from the 20 untagged Bull Trout captured at the weir during 2017 (N = 6), 2018 (N = 5) and 2019 (N = 9) for later genetic analysis to determine if they were locally-born progeny or simply translocated Bull Trout that had shed their tags.

Table 13. Tagged and untagged male and female Bull Trout captured at the trap and observed on video at the Pinhead Creek weir from 2017 to 2019.

Year	Male		Female		% PIT-tagged	
	Tagged	Untagged	Tagged	Untagged	Male	Female
2017	47	0	11	9	92	55
2018	42	5	27	27	88	50
2019	25	0	31	15	100	67

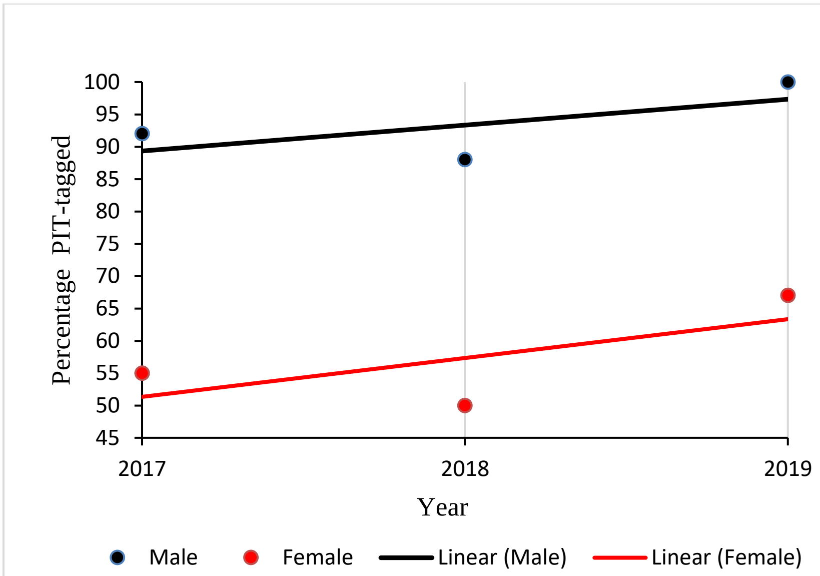


Figure 20. Percentage of PIT-tagged adult Bull Trout observed at the Pinhead Creek weir from 2017 through 2019.

Findings

Bull Trout populations are known to exhibit life histories involving movements, migrations, spawning, rearing and foraging over a range of spatial scales (Schaller et al. 2014). An understanding of these fundamental characteristics is required to inform future management actions and for continued progress toward the project's goal of re-establishing a self-sustaining Bull Trout population in the Clackamas River Subbasin. A high point of the reintroduction effort's second phase (2018 – 2024) has been the recruitment of translocated fish into the adult spawning population. This is again evidenced in 2019 by PIT detections of Bull Trout passing the Pinhead Creek weir that were released as juveniles and subadults. In addition, the number of adult Bull Trout using Pinhead and Last creeks during the spawning season has markedly increased since the early years of the reintroduction effort to a high of 104 individuals during 2018. There have been continued observations of redds in the Pinhead Creek system and newly observed redds in Berry Creek in 2019 (Starcevich 2020). The confirmation of viable embryos and healthy alevins in redds during 2017 was also encouraging (Barrows et al. 2018). However, there continue to be notable data gaps and indicators that may be cause for concern. For example, efforts to provide definitive evidence of post-emergent juveniles have been unsuccessful to date. Adults without PIT-tags have been observed and captured at the weir in Pinhead Creek lending the possibility that locally-born individuals have been recruited into the adult spawning population. However, a substantial disparity between the percentage of tagged males and females suggests an elevated rate of tag shedding in the female portion of the population, indicating many of the untagged fish may actually be translocated individuals. These important benchmarks are crucial to the overall goal of establishing a self-sustaining population of Bull Trout in the Clackamas River Subbasin and may be achieved over time as the reintroduction effort progresses and the population develops. The following is a summary of findings from activities conducted during 2019:

The fates of many translocated Bull Trout are largely unknown. It is possible that a portion of the transferred fish did not survive, have not yet matured, or have shed their PIT tag. In addition, spawning has occurred elsewhere in the subbasin (e.g, Berry Creek), explaining why some fish may not have been detected in Pinhead Creek.

Consistent with findings from previous seasons, all of the individuals that migrated into Pinhead Creek were relatively large, migratory adult-sized fish and appeared to be sexually mature. Despite appearing mature, it is possible that a portion of the fish were not yet mature and may have entered Pinhead Creek to seek foraging habitat rather than to spawn.

Bull Trout use of North Fork Reservoir and occupancy of the HVZ during 2019 is largely unknown. However, the detection histories of 12 PIT-tagged Bull Trout detected at PIT antennas throughout PGE's hydro project facilities confirm that translocated Bull Trout were in the vicinity of the hydro power facilities during most months (Appendix A). It is reasonable to assume that Bull Trout may have foraged on vulnerable juvenile anadromous salmonids pooling in forebays while occupying areas near the hydro project. Regardless, minimum passage thresholds for juvenile salmon and steelhead were exceeded in 2019.

Five Bull Trout returned to the study area upstream of North Fork Dam during 2019 after previously exiting the study area (i.e., downstream of River Mill Dam). Two of the five fish were detected in Pinhead Creek during the spawning season. The other three fish may have reached other unmonitored spawning areas (e.g., Berry Creek). In recent years, adult Bull Trout have regularly been observed returning upstream of North Fork Dam, but a notable outlier was the 2018 season where none were observed.

There has been a marked increase in redds counted in the Clackamas River Subbasin since the inception of the reintroduction program and 2019 counts (N = 93) are the highest to date (Appendix C). Redd counts in Pinhead and Last creeks were down slightly in 2019 to 77 from a high of 85 recorded in 2017, but the addition of 13 redds counted in Berry Creek pushed the overall total in the subbasin to a new high. As translocated individuals and locally-born offspring (if they exist) continue to mature, we expect further recruitment into the spawning population and, thus, increased redd counts in future years.

A total of 72 individual Bull Trout were captured or observed at the weir of which 46 (64%) were female, 25 (35%) were male, and 1 (1%) was not determined. The percentage of females in the Pinhead Creek spawning population estimates from 2017 and 2018 were 52% and 53%, respectively. The notable disparity between the number of females and males in 2019 was puzzling, and no reasonable explanation was apparent. It may be the beginning of a trend and should be monitored in future years.

During 2019, 98% of tagged Bull Trout that encountered the Pinhead Creek weir successfully passed upstream during the spawning season. Eighty percent of the Bull Trout that encountered the weir passed during their first encounter and 89% passed upstream by their second encounter. Of the PIT-tagged fish that encountered the weir, 83% passed upstream of the weir in one day or less following their initial encounter. Whenever an impediment (e.g., weir and trap) is operated within a stream, some level of delay is to be expected, but our data suggest passage delay at the weir was minimal for most Bull Trout moving to upstream spawning grounds. Weir passage in 2019 was consistent with findings in 2018 (Barrows et al. 2019). The weir installation in 2019 was nearly identical to 2018, so similar results were anticipated.

A majority (74%) of the unique PIT tags detected at the Pinhead Creek weir during 2019 represented translocated Bull Trout released into the Clackamas River Subbasin in 2012 – 2016. During 2016, 2017 and 2018, juveniles released into Pinhead and Last creeks during 2013 contributed the most PIT detections of any release group. However, in 2019 juveniles and subadults released in 2016 accounted for 50% of the translocated individuals detected in Pinhead Creek. This influx of adults from 2016 releases is not surprising in that many more juveniles and subadults were released into in the mainstem Clackamas River near the mouth of Pinhead Creek than in any other release year (Starcevich 2018).

As expected, we found that translocated Bull Trout released as juveniles on average grew at faster rates than fish released as subadults. Both groups grew at faster rates than fish tagged as adults. We also found that males on average grew at faster rates than females. This differs from past years where males and females grew at similar rates. We believe this may be due to an influx of younger males into the spawning population from juvenile and subadult release groups in 2016. These growth rates are generally consistent with findings reported in Harris et al. (2018) in that larger (e.g., older) individuals grew in length at a slower rate than smaller (e.g., younger) fish. and both groups grew at much faster rates than fish tagged as adults.

The laser scaling method developed for passively obtaining lengths from video of Bull Trout passing through the Pinhead Creek video weir was demonstrated to be cost-effective, practical and accurate. However, further evaluation and testing should be conducted to confirm the accuracy and usefulness of this method.

Of the 46 females observed, 31 (67%) were previously tagged. All (100%) of the males observed were previously tagged. The existence of untagged female Bull Trout in Pinhead Creek suggests the possibility that locally-born adults may exist in the spawning population. However, the absence of untagged males strongly suggests tag loss in the female component may account for the tagless fish in the adult population. A similar disparity between the percentage of tagged males and females was observed in 2017 and 2018 as well (Barrows et al. 2018, 2019).

Caudal fin tissue was collected from nine untagged Bull Trout captured at the Pinhead Creek weir during 2019. Combined with similar samples from 2017 (N = 6) and 2018 (N = 5), this collection of samples will provide the opportunity for subsequent parentage analysis and possibly the confirmation of locally-born progeny and recruitment into the spawning population.

Bohling and Piteo (2019) analyzed the parentage of embryos collected from two suspected Bull Trout redds in Pinhead Creek by hydraulic sampling in 2017. The likely parents for each embryo were identified using the database of multilocus genotypes. A review of PIT detections and video observations recorded in 2017 at the Pinhead Creek weir provided additional support and confirmation of these findings.

Acknowledgments

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Appendix A

Comprehensive Detection Histories for Bull Trout Detected at PGE Facilities During 2019

Telemetry Code	PIT Tag Code	Size at Tagging or Recapture (TL)	Date Released (*), Detected or Recaptured	Location Released (*), Detected, or Recaptured
NA	**0000_0000000177419007**	**296 mm**	**6/13/2016***	**4650 Bridge***
			8/27/2019	PIT Detect – Fl. Surface Collector (NF Dam)
			8/27/2019	PIT Detect – Timber Park D/S Sampling Fac.
			9/1/2019	PIT Detection – River Mill Ladder
NA	**0000_0000000177419021**	**344 mm**	**6/13/2016***	**4650 Bridge***
			7/29 to 8/17/2019	Video Observation – Pinhead Weir
			10/1/2019	PIT Detect – Fl. Surface Collector (NF Dam)
NA	**0000_0000000177419076**	**575 mm**	**6/3/2016***	**4650 Bridge***
			9/1 to 9/2016	PIT Detection - Pinhead Mouth
			8/25 to 9/25/2018	Video Observation – Pinhead Weir
			8/30/2018*	Pinhead Adult Trap
			6/25/2019	PIT Detect – Fl. Surface Collector (NF Dam)
			6/25/2019	PIT Detect – N.F. Migrant Collector
			7/16/2019	PIT Detect – Timber Park D/S Sampling Fac.
			7/17/2019	PIT Detection – River Mill Ladder
			7/22/2019	PIT Detection – N. F. Old Sorting Facility
			7/22/2019	PIT Detection – N.F. Adult Sorting Facility
			7/23/2019	PIT Detection – N. F. Old Sorting Facility
NA	**0000_0000000177419142**	**270 mm**	**5/27/2016***	**4650 Bridge***
			8/27/19	PIT Detect – Fl. Surface Collector (NF Dam)
			9/2/2019	PIT Detect – Timber Park D/S Sampling Fac
NA	**0000_0000000177419199**	**372 mm**	**6/19/2014***	**100 m d/s of 4650 bridge***
			8/2/2019	PIT Detect – Fl. Surface Collector (NF Dam)
			8/2/2019	PIT Detect – N.F. Migrant Collector
			8/2/2019	PIT Detect – Timber Park D/S Sampling Fac.
NA	**0000_0000000177419300**	**381 mm**	**6/20/2013***	**Lower 4650 Bridge D/S***
			7/7 to 8/31/2015	PIT Detection - Pinhead Mouth
			7/28 to 9/15/2016	PIT Detection - Pinhead Mouth
			8/26 to 9/20/2017	PIT Detection - Pinhead Mouth
			9/15/2017	Video Observation – Pinhead Weir
			8/4/2019	PIT Detect – Fl. Surface Collector (NF Dam)
			8/4/2019	PIT Detect – Timber Park D/S Sampling Fac
			8/13/2019	PIT Detection – River Mill Ladder
NA	**0000_0000000177419441**	**150 mm**	**5/23/2013***	**Last Creek u/s of 42 bridge***
			9/1/2017*	Pinhead Adult Trap
			9/16/2017	Video Observation – Pinhead Weir
			8/18 to 8/19/2019	PIT Detection – N.F. Adult Sorting Facility
			8/19/2019	PIT Detection – N.F. Ladder
			8/19/2019	PIT Detection - North Fork Ladder Exit
			9/25/2019	Video Observation – Pinhead Weir
			12/22/2019	PIT Detect – Fl. Surface Collector (NF Dam)
			12/23/2019	PIT Detect – Timber Park D/S Sampling Fac
NA	**982_000360937173**	**91 mm**	**5/6/2016***	**Upper Clackamas***
			5/17/2018	PIT Detect – DS Migrant Collector (NF Dam)
			5/17/2018	PIT Detect – Timber Park D/S Sampling Fac.
			1/7 to 1/8 (2019)	PIT Detection – River Mill Ladder
			1/21/2019	PIT Detection – N. F. Old Sorting Facility

Telemetry Code	PIT Tag Code	Size at Tagging or Recapture (TL)	Date Released (*), Detected or Recaptured	Location Released (*), Detected, or Recaptured
NA	**982_000360942135**	**146 mm**	**5/20/2016***	**4650 Bridge***
			7/28/2019	PIT Detection – N. F. Old Sorting Facility
			7/28/2019	PIT Detection – N.F. Adult Sorting Facility
			7/29/2019	PIT Detection – N.F. Ladder
			7/29/2019	PIT Detection - North Fork Ladder Exit
			8/27 to 9/18/2019	Video Observation – Pinhead Weir
		587 mm	8/28/2019*	Pinhead Adult Trap
		587 mm	9/19/2019*	Pinhead Adult Trap
NA	**982_000361679137**	**163 mm**	**5/15/2014***	**Berry Creek Bridge***
			5/16/2014	PIT Detection - Cub/Clack Clonfluence
			7/29/2019	PIT Detection – N. F. Old Sorting Facility
			7/30/2019	PIT Detection – N.F. Adult Sorting Facility
			7/31/2019	PIT Detection – N.F. Ladder
			7/31/2019	PIT Detection - North Fork Ladder Exit
NA	**982_000361679183**	**206**	**4/24/2014***	**Berry Creek Bridge***
			9/6 to 9/21/2016	PIT Detection - Pinhead Mouth
			7/18/2019	PIT Detection – N.F. Adult Sorting Facility
			7/18/2019	PIT Detection – N.F. Ladder
			7/18/2019	PIT Detection - North Fork Ladder Exit
NA	**982_000403263035**	**93 mm**	**5/13/2016***	**Upper Clackamas***
			10/13/2019	PIT Detect – N.F. Migrant Collector
			10/13/2019	PIT Detect – Timber Park D/S Sampling Fac.

Appendix B

Counts for Anadromous Salmonids Through the PGE Hydro Facility on the Clackamas River

In accordance with BiOp Term and Condition 1b (NMFS 2011), through monitoring that PGE conducts outside the scope of the Bull Trout reintroduction project, counts of adult and juvenile coho, spring Chinook, and steelhead are annually recorded through the hydro project. This summary is not intended to be an analysis of trends in salmon and steelhead life stage metrics, given the changes in how monitoring has been conducted by PGE over time (Nick Ackerman, PGE, pers. comm.), and is not intended to fulfill any reporting requirements of PGE. Rather, the information provided by PGE is summarized below (Table B1) relative to the Stepwise Impact Reduction Plan (USFWS 2011) and the minimum thresholds identified in Table 2 therein.

Table B1. Summary of adult, juvenile and smolt/adult counts for coho salmon, spring Chinook salmon and steelhead through the PGE hydro facility on the Clackamas River, Oregon, relative to thresholds identified in the Stepwise Impact Reduction Plan (USFWS 2011).

Species	Metric	Threshold	2019*
Coho	Adult	2,160	The adult counts were above the threshold for the fifth year (2013-2019) since implementation of this project.
	Juvenile	54,431	The juvenile counts were above the threshold and have exceeded the threshold in all years since implementation of this project.
	Smolts/adult	38.1	The estimated smolts/adults were above the threshold and have exceeded the threshold in all years since implementation of this project.
Spring Chinook	Adult	780	The adult counts were above the threshold and have exceeded the threshold in all years since implementation of this project.
	Juvenile	6,237	The juvenile counts were above the threshold and have exceeded the threshold in all years since implementation of this project.
	Smolts/adult	3.1	The estimated smolts/adults were above the threshold and have exceeded the threshold in all years since implementation of this project.
Steelhead	Adult	600	The adult counts were above the threshold and have exceeded the threshold in all years since implementation of this project.
	Juvenile	20,374	The juvenile counts were above the threshold and have exceeded the threshold in all years since implementation of this project.
	Smolts/adult	10.2	The estimated smolts/adults were above the threshold and have exceeded the threshold in all years since implementation of this project.

* Annual data provided by Nick Ackerman, PGE.

USFWS. 2011. Stepwise Impact Reduction Plan. USFWS Amendment to the 12/10/2010 Biological Assessment on the Reintroduction of Bull Trout to the Clackamas River.

Appendix C

ANNUAL PROGRESS REPORT
FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: Clackamas River Bull Trout Reintroduction Project: Characterizing status and thermal habitat suitability in 2019

PROJECT NUMBER: Portland General Electric Agreement # 2016-08

PROJECT PERIOD: 2019

Prepared by: Steven J. Starcevich

Oregon Department of Fish and Wildlife 4034 Fairview Industrial Drive
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This project was funded in part by Portland General Electric and the ODFW-Native Fish Investigations Program

Table of Contents

Abstract

Bull Trout were extirpated from the Clackamas River basin over forty years ago by human activities. A reintroduction feasibility assessment and an implementation plan were completed in 2007 and 2011, respectively, with the goal of establishing a self-sustaining population of 300-500 adults in the Clackamas River basin. The status of this reintroduced population has been monitored annually using census redd surveys, PIT-tag detection technology, eDNA surveys, and stream temperature data loggers. This report summarizes the results of monitoring activities in 2019. In census redd surveys, 77 putative Bull Trout redds were identified in Pinhead Creek and Last Creek, 3 redds in the upper Clackamas River (reach 4), and 13 redds in Berry Creek. The redd count in Pinhead creek declined 9% since the peak count in 2017. This was the first time redds and adults have been observed in Berry Creek. There is strong linear relationship between the census redd count and adult abundance estimated from PIT-tag, trap, and video data at weir operated by the USFWS in Pinhead Creek. Tagless adults captured in the trap in 2019 were only female and were larger than the tagged adult female cohort, suggesting tag ejection during previous spawning as the main source of tagless adults. PIT-tagged adults were first detected in Pinhead Creek on July 9 and last detected on October 6 and adults spent a median of 17 d in the creek. Estimated adult age-class at detection ranged from age-5 to age-10, with the average age of adults increasing from 5.8 in 2014 to 7.2 in 2019. Translocated fish released at age-1 and age-2 respectively showed 1.5% and 6.2% rates of survival to adulthood (i.e., age-5 or older) and detection in Pinhead Creek. These survival rates were similar to other natural self-sustaining populations in Oregon. Bull Trout eDNA was detected in and near the translocation areas of Pinhead Creek, Berry Creek and Cub Creek, and the upper Clackamas River. It was also detected far downstream in Roaring River, suggesting potential colonization; more intensive monitoring in this area may be warranted. There was a strong linear relationship between eDNA concentration and the number of adults present on survey dates across the spawning season in Pinhead Creek, suggesting that eDNA concentration may be useful as a relative indicator of adult abundance in Pinhead Creek. Temperature monitoring suggests there is extensive thermally suitable habitat for Bull Trout in the Clackamas River basin upstream of its confluence with the Collawash River. Trap results and declining redd and adult abundance from 2017-2019, along with the increased age of detected adults, suggest the natural annual mortality of out-of-basin adults has not yet been offset by locally-born offspring recruiting to adulthood. Given the rapid annual increase in adults and redds observed from 2014 to 2018 in Pinhead Creek, much larger locally-born cohorts associated with this trend increase the likelihood of recruiting some individuals into adulthood starting in 2021; and, provided normal survival of juvenile age-classes, locally-born adult abundance is expected to increase annually through 2025.

Introduction

Bull Trout (*Salvelinus confluentus*) were once abundant and widely distributed in the Clackamas River basin (Shively et al. 2007). Over 40 years ago, Bull Trout were extirpated from this basin by a range of human activities, including dam construction without fish ladders or lacking adequate fish passage facilities, overfishing, habitat alteration, and the introduction of nonnative species (Shively et al. 2007). Range-wide conservation concern and renewed local interest in this species in the 1990s led to extensive fish surveys in the Clackamas River basin, during which no extant populations were located, and instigated efforts to reintroduce the species. These efforts produced a feasibility assessment (Shively et al. 2007) and an implementation plan (US Fish and Wildlife Service [USFWS] 2011), which provided the foundation for the methods and protocols for the reintroduction of Bull Trout. The long-term goal of the reintroduction project was to establish a self-sustaining population of 300-500 adults in Clackamas River basin. The first phase of the project involved translocating Bull Trout from the Metolius River basin to various locations in the upper Clackamas River basin (see Figure 1 and Table 1) and monitoring progress toward the reintroduction goal. Translocations occurred annually from 2011 through 2016 and totaled 2,836 fish, 82% of which were age-1 or age-2 (Figure 2). Each translocated fish was given a unique passive integrated transponder (PIT) tag, and some were radio-tagged, and then monitored using radio telemetry, PIT tag detection arrays, environmental DNA (eDNA) surveys, and redd surveys. The second phase began in 2017 and entailed continued monitoring of progress toward the reintroduction goal.

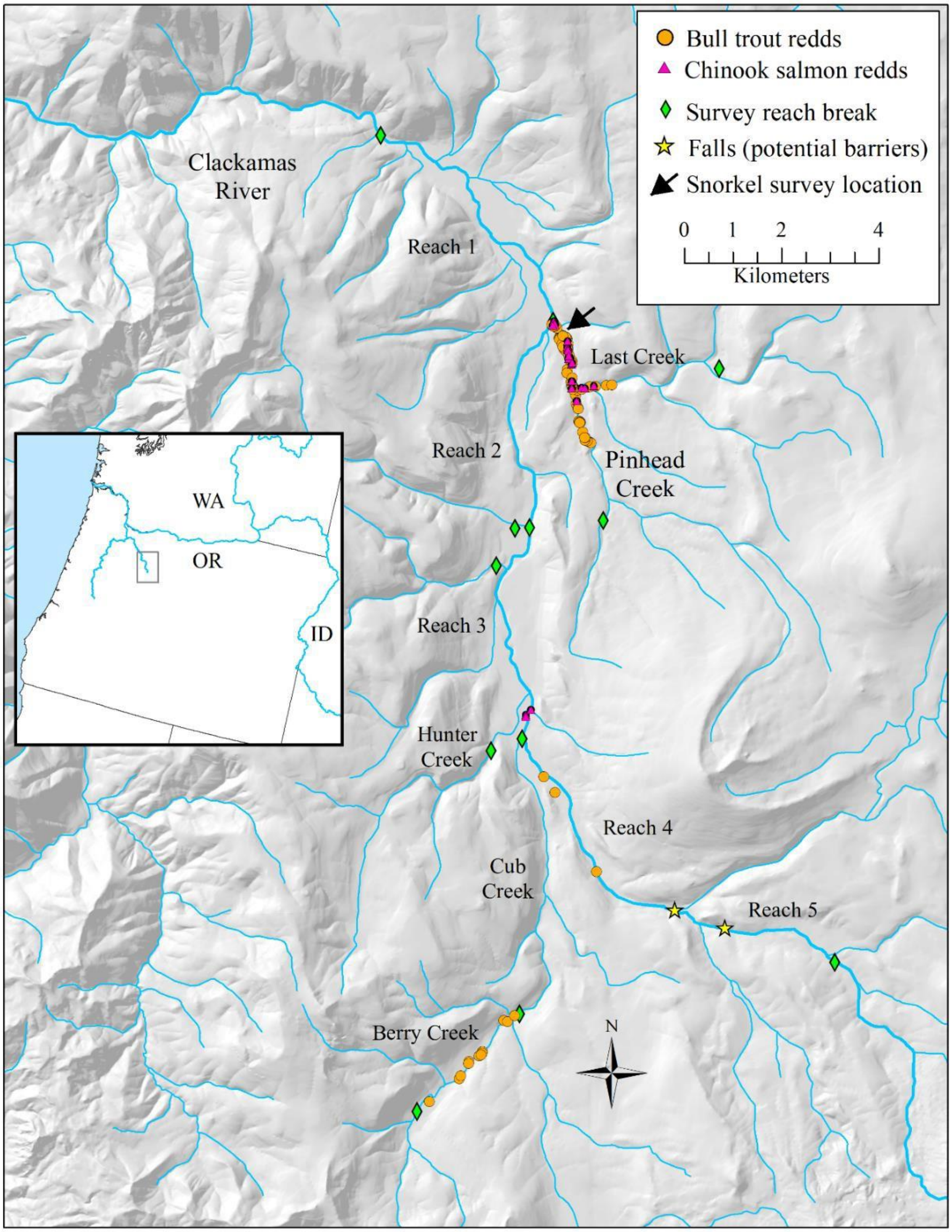

Figure 1. Census survey extent for all survey years and redd distribution in Pinhead Creek, Last Creek, Reach 3 and 4 of the Clackamas River, Hunter Creek, Cub Creek, and Berry Creek in 2019.

Table 1. PIT-tagged Bull Trout translocated from the Metolius River basin to the Clackamas River basin in the first phase of the reintroduction project. Age-class-at-release was defined by size-at-age studies (see text) and were as follows: age-1, 70-110 mm; age-2, 111-160 mm; age-3, 161-240 mm; age-4, 241-380 mm; age-5, 381-580 mm; age-6 and older, >580 mm. Annual translocations occurred from 2011 through 2016.

		Age Class						Release date	
Year	Release location	1	2	3	4	5	≥6	Min	Max
2011	Clackamas River	0	0	0	0	5	7	30-Jun	30-Jun
	Clackamas River 1	0	0	0	11	5	1	30-Jun	30-Jun
	Clackamas River 2	0	0	0	2	25	5	30-Jun	15-Jul
	Last Creek	2	14	15	11	0	0	30-Jun	15-Jul
	Pinhead Creek	5	10	1	0	0	0	21-Jul	21-Jul
	2011 Subtotal	*7*	*24*	*16*	*24*	*35*	*13*		
2012	Clackamas River 1	0	0	0	8	2	0	14-Jun	14-Jun
	Clackamas River 2	0	0	0	29	13	10	14-Jun	12-Jul
	Last Creek	57	60	33	0	0	0	3-May	28-Jun
	Pinhead Creek	215	122	20	0	0	0	10-May	31-May
	2012 Subtotal	*272*	*182*	*53*	*37*	*15*	*10*		
2013	Clackamas River	0	0	1	28	6	2	6-Jun	13-Jun
	Clackamas River 1	0	0	0	44	18	3	6-Jun	27-Jun
	Last Creek	83	153	90	4	0	0	11-Apr	27-Jun
	Pinhead Creek	98	137	46	0	0	0	2-May	30-May
	2013 Subtotal	*181*	*290*	*137*	*76*	*24*	*5*		
2014	Clackamas River 1	0	10	15	39	15	0	5-Jun	25-Jun
	Berry Creek	145	121	15	0	0	0	24-Apr	29-May
	2014 Subtotal	*145*	*131*	*30*	*39*	*15*	*0*		
2015	Clackamas River 1	0	0	7	63	22	1	15-May	5-Jun
	Berry Creek	94	128	65	1	0	0	10-Apr	5-Jun
	2015 Subtotal	*94*	*128*	*72*	*64*	*22*	*1*		
2016	Clackamas River 1	0	39	51	92	12	1	20-May	13-Jun
	Clackamas River 5	425	71	4	0	0	0	8-Apr	13-May
	2016 Subtotal	*425*	*110*	*55*	*92*	*12*	*1*		
	Age Class Total	*1124*	*865*	*363*	*332*	*123*	*30*	*Grand Total*	*2837*

Since the project began, redd surveys have been the primary method of monitoring adult abundance and distribution. From 2011 through 2014, redd surveys were conducted in Pinhead and Last creeks by an *ad hoc* multi-agency group of observers. In 2015 and 2016, the sample frame was expanded to include all potential spawning habitat in the upper Clackamas River basin and census redd surveys were conducted by a crew of five experienced observers from the Oregon Department of Fish and Wildlife (ODFW), with assistance from other agencies and volunteers. In 2017 and 2018, the redd survey sampling frame included only Pinhead Creek, Last Creek, and reach 4 of the Clackamas River, which were areas where Bull Trout spawning was consistently observed in 2015 and 2016. In 2019, the census sampling frame was expanded to include Berry Creek, Cub Creek, Hunter Creek, and reach 3 of the Clackamas River. The expansion was because of eDNA detections in 2017 and 2018; and, based on age-at-release of translocated fish in 2014 and 2015 in Berry Creek, many fish would reach age-5 and age-6 (i.e., adulthood) this year. Reach 3 was added because of an observation, by an ODFW crew conducting salmon spawning surveys, of a Bull Trout pair on a suspected new redd in 2018 (personal communication, Brian Cannon, ODFW). These census surveys were conducted by three ODFW surveyors of varying experience, with help from experienced surveyors from the U.S Forest Service (USFS), USFWS, and Portland General Electric (PGE). To monitor Bull Trout distribution and thermal habitat suitability in areas not covered by spawning surveys, eDNA surveys were conducted again in 2019 and an array of water temperature data loggers were maintained throughout the upper Clackamas River basin.

In 2019, the specific objectives were to the following: 1) characterize Bull Trout abundance using census spawning surveys in known or high potential spawning areas, 2) examine the relationship between redd counts and estimated adult abundance in the Pinhead Creek watershed, 3) document juvenile Bull Trout rearing in Pinhead Creek using night snorkel surveys, 4) use eDNA surveys to characterize Bull Trout distribution in potential spawning and rearing areas and adult abundance in Pinhead Creek, and 5) refine the sampling frame using water temperature data loggers to focus spawning and eDNA surveys in thermal habitat suitable for Bull Trout spawning and rearing.

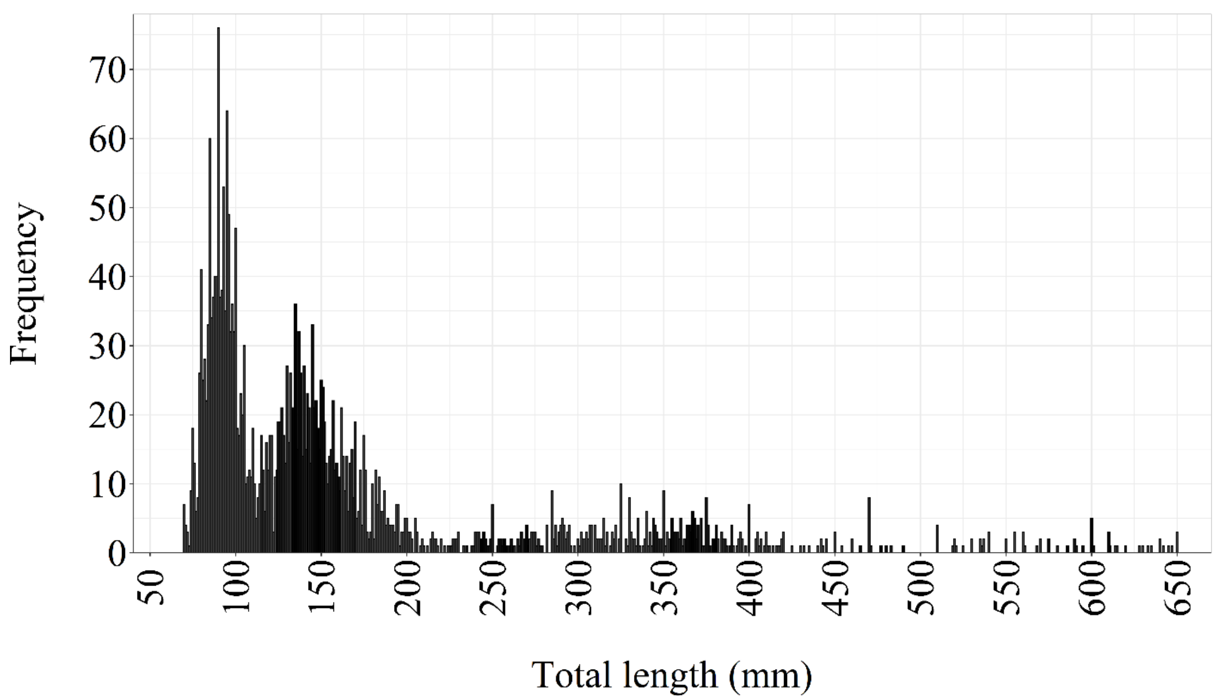

Figure 2. Length-frequency histogram (1-mm bins) of Bull Trout captured in the Metolius River basin, PIT- tagged, and released in the upper Clackamas River basin, 2011-2016.

Table 2. Census survey reaches and schedule and the number of redds counted in each census. Some reaches were not surveyed (NS) in each census.

	Census (2019)												
Reach	Count 1		Count 2		Count 3		Count 4		Count 5		Count 6		Total
Clackamas 3	28-Aug	0	11-Sep	0	25-Sep	0	NS	-	23-Oct	0	NS	-	0
Clackamas 4	NS	-	11-Sep	1	26-Sep	2	NS	-	NS	-	NS	-	3
Berry Creek	NS	-	NS	-	25-Sep	9	9-Oct	2	23-Oct	2	NS	-	13
Cub Creek	NS	-	NS	-	26-Sep	0	NS	-	NS	-	NS	-	0
Pinhead 1	27-Aug	0	10-Sep	9	24-Sep	27	8-Oct	6	22-Oct	4	5-Nov	7	53
Pinhead 2	27-Aug	0	10-Sep	7	24-Sep	1	7-Oct	6	21-Oct	4	4-Nov	0	18
Last Creek	26-Aug	0	9-Sep	2	25-Sep	1	7-Oct	3	21-Oct	0	4-Nov	0	6
Bull Trout		0		19		40		17		10		7	93
Chinook Salmon		*0*		*0*		*5*		*3*		*6*		*10*	*24*

Methods

Census redd surveys

Census redd surveys were conducted in Pinhead Creek, Last Creek, Cub Creek, Berry Creek, Hunter Creek, and reaches 3 and 4 of the upper Clackamas River (Figure 1). Census surveys were completed every two weeks from August 26 to November 4 (Table 2). The first survey, conducted prior to the putative start of Bull Trout and Chinook Salmon spawning, was used to familiarize the field crew with redd identification by analyzing characteristics of old redds from a previous season (i.e., salmonid redds constructed prior to August) and flagging areas that could be mistaken for new redds. A new Bull Trout redd was identified by its pocket-mound structure, gravel size (2-64 mm in diameter), and the contrast of brighter disturbed gravel relative to a darker surrounding matrix. Salmon redds were distinguished by their relatively large surface area and substrate size and, on occupied redds, by identifying the species of adult salmon. The crew flagged new Bull Trout redds and recorded the following data: GPS location, maximum length and width, species and number of adults occupying the redd, and brief descriptions of the redd and observer certainty.

Bull Trout and salmon redd data were entered in an Access database that contained data from previous Bull Trout spawning surveys in the upper Clackamas River basin. From 2011-2014, some spawning surveyors recorded redd descriptions such as "potential", "possible", "likely", "test dig?", or another variant observational uncertainty; these descriptions were included in the database. From 2015-2019, observers were trained to include a brief description of their certainty in each new redd identified so that an experienced surveyor could review in subsequent surveys those redds identified with high uncertainty. These descriptions were entered as a comment in the database. (See Appendix I for dataset from 2019.)

Pinhead Creek adult monitoring

The use of Pinhead Creek by PIT-tagged fish has been monitored since the start of the project in 2011. From 2017 through 2019, Pinhead Creek was monitored with two channel-spanning PIT antennae: one 200 m upstream of the Clackamas River confluence and one, another 15 m upstream, affixed to a fish passage station (described below). The USFWS activated the PIT detection array in June or July and maintained it through November (Barrows et al. 2020). PIT tag detection data from Pinhead Creek were used to describe the annual number, duration, timing, age-at-release, and release location of PIT-tagged adults present in Pinhead Creek during the spawning season.

From 2011 through 2016, as a relative measure of annual abundance, age-5 and older fish (hereafter referred to as "adults") detected at the PIT-tag array were counted by year. This age cutoff was used because migratory Bull Trout in the Metolius River basin are thought to begin to mature at age-5 (Ratliff et al. 1996), which is similar to Bull Trout populations in other basins. For example, a study in the Lake Pend Oreille basin showed that at least 50% of age-5 Bull Trout had reached adulthood (McCubbins et al. 2016). In a study in the Flathead Lake basin, Bull Trout first matured at age-5 and all individuals age-6 and older were mature (Fraley and Sheppard 1989). To count the number of PIT-tagged adults using Pinhead Creek annually, age-class at detection was approximated in two steps: first, assigning an age-class at release for all translocated fish; and second, calculating the detection interval between translocation release date and PIT-tag detection date. Age-class at release was approximated for age-1 and age-2 fish based on a length-frequency histogram of translocated fish (Figure 2), length-at-age studies of Bull Trout from the Metolius River basin (Pratt 1991, see Figure 3), and throughout their range (Fraley and Sheppard 1989; Salow 2004). Age-class at release was approximated as follows: age-1, 70-110 mm; age-2, 111-160 mm; age-3, 161-240 mm; age-4, 241-380 mm; age-5, 381-580; and age-6 or older, >580 mm. Age-class at detection was estimated by summing age-class at release and the interval between the date of release in the Clackamas River basin and date of detection in Pinhead Creek. More specifically, to estimate the annual number of PIT-tagged Bull Trout age-5 or older detected in Pinhead Creek, the following detection intervals were used: >1,360 d (i.e., 3 yr and 265 d) for age-1 at release, >995 d for age-2, >630 d for age-3, >265 d for age-4, and >0 d for age-5 and older.

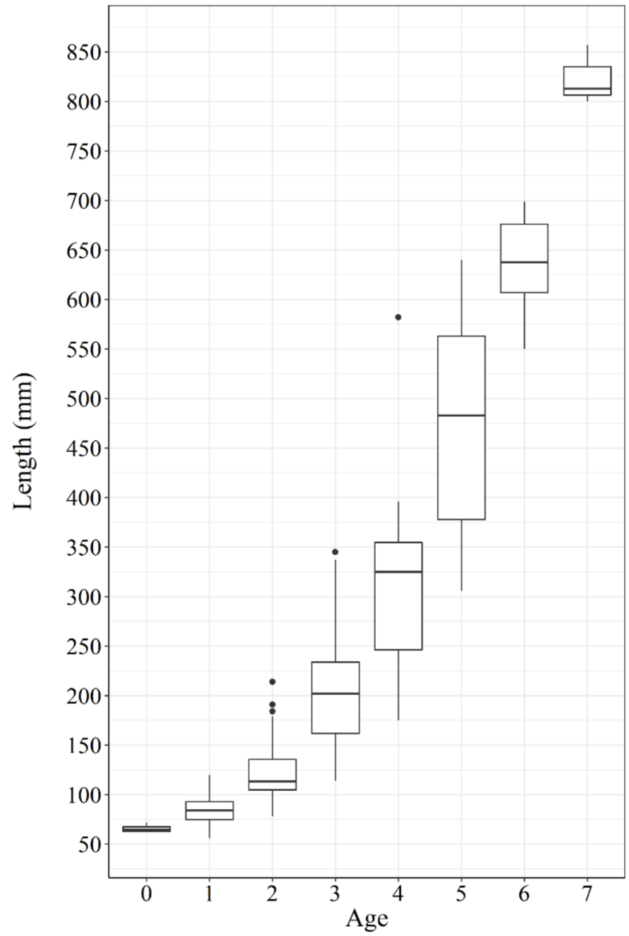

Figure 3. Total length-at-age boxplots for Bull Trout from the Metolius River Basin. Age was determined by scale analysis and data from Pratt (1991).

From 2017 through 2019, in addition to the PIT-tag detection array, a fish passage station, consisting of a weir trap and video monitoring station, was installed and maintained by the

USFWS in Pinhead Creek about 200 m upstream from the confluence with the Clackamas River (Barrows et al. 2020). Adding the fish passage station was deemed necessary to get an accurate adult count because there were several potential sources of tagless adults. These sources included tag ejection by juveniles and tag loss by adults during spawning (Meyer et al. 2011, Mamer and Meyer 2016) and untagged adults from locally-born offspring surviving to adulthood. Considering these sources of untagged adults, an accurate count of adults using Pinhead Creek during the spawning season could not rely solely on PIT tag detections. Therefore, the annual adult count in these years was composed of two sources: 1) unique PIT-tagged adults detected at the PIT tag array (installed at the weir site in 2018) and the weir trap, and 2) unique untagged adults identified at the trap or moving upstream through the video station (Barrows et al. 2018, Barrows et al. 2019, Barrows et al. 2020).

Simple linear regression was used to assess the relationship of the annual adult count in Pinhead Creek (the explanatory variable, X), and the annual count of redds in Pinhead and Last creeks (the response variable, Y), from 2011-2018 (Ramsey and Schafer 1997). The simple linear regression model used is as follows: $\mu\{Y|X\} = \beta_0 + \beta_1 X$. The parameter β_0 is the y-intercept of the line. The parameter β_1 represents the slope of the line.

Spawning duration of PIT-tagged adults in Pinhead Creek was calculated as the number of days between the first detection and last detection of each fish at the PIT-tag array (2011-2019) or trap (2017-2019) in a single monitoring season. Duration was summarized by year but excluded individuals detected for ≤ 6 d. This exclusion attempted to reduce the influence of prespawning or courtship behavior, short-term non-spawning use, and tag loss and mortalities upstream of the array on the estimated spawning duration in Pinhead Creek. Timing of adult use of Pinhead Creek was represented by boxplots of first detections of all individuals and last detections for individuals with spawning duration > 6 d for each annual monitoring season. Last detections were restricted for the same reasons stated above for spawning duration.

The annual count of PIT-tagged adults in Pinhead Creek was summarized by age-class at detection, age-class at release, and translocation release area. The estimation of age-class at detection for adults was described above. The rate at which translocated fish survived to adulthood and were detected in Pinhead Creek was calculated for each age-class at release by dividing the total number released by the total number of adults for each age-class.

Distribution surveys

Night snorkeling was used to determine juvenile Bull Trout presence and distribution in this study area. A single snorkel survey was conducted by a 4-person crew on October 8 between 9:30 PM and 1:00 AM. The survey covered 750 m within Pinhead Creek (see Figure 1 for start location). Each snorkeler used a dive light and the team surveyed rearing habitat within 2 channels of this 3-channel reach.

Bull Trout eDNA surveys were used to determine the presence or absence of the species in several candidate streams. Surveys were conducted according to the field collection protocol and sampling equipment recommended by Carim et al. (2016). To draw water through a filter, a peristaltic pump was operated with either a battery-powered mechanical drive (Geopump, Geotech, Colorado, USA) or a rechargeable cordless drill (DeWalt Industrial Power Tools, Inc, Maryland, USA). At each study site, the pump pulled 5 L of stream water through a 1.5-µm-pore fiberglass filter. The filters were immediately stored in a plastic bag with silica desiccant. Within 10-48 hours, these samples were placed in a –20 °C freezer for storage until analysis by the National Genomics Center for Fish and Wildlife Conservation (USFS Rocky Mountain Research Station, Fort Collins, Colorado).

Candidate eDNA survey streams were classified by two priority levels for monitoring for Bull Trout distribution. High priority streams were known to be thermally suitable (i.e., <16 °C maximum), lacking fish barriers, and within the suitable patches identified in the reintroduction feasibility study (Shively et al. 2007). Second priority streams, outside of known suitable thermal patches, were identified through historical anecdotes as potentially occupied streams (Shively et al. 2007). All high priority streams were surveyed. Second priority streams were surveyed for eDNA when thermal habitat monitoring showed these areas to be suitable for juvenile rearing.

Detection probability of eDNA when present in the stream is positively related to fish density and negatively related to stream discharge (Wilcox et al. 2016). The minimum number of sample sites needed to reach a detection probability > 0.85 in a survey stream was calculated using baseflow discharge estimates and an assumed density of 1 Bull Trout per 100 m, using parameterized models from Wilcox et al. (2016). Generally, sites were allocated systematically every 2 km to Cub Creek, Berry Creek, and the upper Clackamas River reaches to determine presence and distribution of Bull Trout in tributaries where Bull Trout were previously translocated. Non-detection of eDNA in a stream reach, from this perspective, would mean there was > 0.85 probability that Bull Trout density was < 1 fish per 100 m.

Additionally, eDNA surveys were conducted in 2017 and 2018 in Pinhead Creek to examine the relationship between Bull Trout eDNA concentration (i.e., DNA copies/L) and adult abundance. Surveys were conducted at three sites in Pinhead Creek: 400 m upstream of the mouth (PIN1), and 50 m (PIN2) and 1 km (PIN3) upstream of the Last Creek confluence. All sites were surveyed on dates corresponding to different levels of adult relative abundance: May 30, no adults present several months after the previous spawning season and at least one month prior to adult presence for the upcoming season; August 27, moderate abundance at the start of the active spawning season; September 18 and 19, high abundance near peak spawning; October 2 and 3, low abundance near the end of spawning; and October 30, no adults present within 2 to 3 weeks after spawning ended. On each date and at each location, 2 to 4 eDNA samples were collected consecutively to quantify intra-site variation in eDNA sampling and to compare the two methods of operating the peristaltic pump. An individual sample took 15 minutes to collect. The relative effectiveness of the pump method was evaluated by taking replicate samples at each site on two of the sampling dates, then comparing eDNA concentration for each pump method. Likelihood ratio tests were used to assess the goodness of fit of competing models using nested combinations of site, date, and pump method covariates to explain the variation in eDNA concentration.

Adult abundance in Pinhead Creek was estimated for each eDNA survey date in three steps. First, each individual PIT-tagged adult was counted as present in Pinhead Creek on a specific survey date when that survey date fell between the first and last PIT tag detection date of that fish. To increase the chance that these adults were actually present, only adults with spawning duration greater than 6 d were included in this calculation. These PIT-tagged adults present during eDNA surveys were summed by survey date (A_P). Second, PIT-tagged adult abundance for each survey date was divided by the total number of PIT-tagged adults (spawning duration > 6 d) for the entire spawning season (A_T) was calculated, which produced an abundance ratio for each date. Third, this ratio was multiplied by the total adult abundance (A_N), which was estimated using a combination of results at the weir trap, video station, and PIT tag array 200 m upstream of the mouth of Pinhead Creek (see Barrows et al. 2018, Barrows et al. 2019, and Barrows et al. 2020). The product provided the estimate for the number of adults present on each eDNA survey date (A_D), following this equation:

$$A_D = A_P / A_T \times A_N$$

Linear regression was used to assess the relationship between eDNA concentration and the estimated number of adults present in Pinhead Creek at each eDNA survey. To normalize the response variable, eDNA concentration variable was $\log_{10}$-transformed.

The National Genomics Center (NGC) for Wildlife and Fish Conservation (U.S. Forest Service, Rocky Mountain Research Station, Missoula, MT) conducted the analysis of the eDNA samples. At the NGC, samples were stored at –20 °C until analysis. The extraction of eDNA followed a modified protocol described in Franklin et al. (2019). All samples were analyzed for Bull Trout eDNA markers developed at the NGC (Dysthe et al. 2018). Each sample was analyzed in triplicate on a StepOne Plus qPCR Instrument (Life Technologies) or a QuantStudio 3 qPCR System (Life Technologies). A sample was considered positive for the presence of the target species if at least one of the three qPCR reactions amplified DNA of that species. According to Jennifer Hernandez, NGC eDNA Program Coordinator, all reactions included an internal positive control to ensure that the reaction was effective and sensitive to the presence of Bull Trout DNA and all laboratory experiments were conducted with negative controls to insure there was no contamination during DNA extraction or qPCR setup.

Table 3. Stream temperature metrics used to delineate suitable Bull Trout rearing habitat (from Isaak et al. 2009) and spawning habitat (see text for details).

Thermal suitability	Rearing maximum (°C)	Spawning daily mean (°C)
High	< 16	< 9
Medium	16 to 19	9 to 12
Low	>19	> 12

Stream temperature

Digital temperature data loggers (Onset™ Hobo Water Temp Pro v2 U-22) were set to record stream temperature every 30 minutes and deployed in 35 locations in the upper Clackamas River basin by June, 2018. Of these, 28 were successfully downloaded between late September and early November, 4 of which were removed; 5 loggers were lost because of bed scour, 2 of which were replaced in a more secure nearby location; 2 loggers were checked but not downloaded, and one logger was deployed in October. Juvenile rearing habitat was evaluated with the maximum daily temperature criteria proposed by Isaak et al. (2009) to delineate suitable habitat patches

(Table 3). Bull Trout are generally thought to initiate spawning when stream temperature declines below 9 °C (McPhail and Murray 1979; Weaver and White 1985; Fraley and Shepard 1989; Kitano 1994). More specifically, Bull Trout initiated spawning at mean daily stream temperatures between 9.3 and 11.5 °C in Pine Creek, Oregon (Chandler et al. 2001), and 9.4 and 11.7 °C in the Lostine River, Oregon (Howell et al. 2010). In the Skagit River basin, the median spawning date for Bull Trout coincided with mean daily stream temperatures around 9 °C (Austin et al. 2019). As peak Bull Trout spawning in Pinhead Creek and elsewhere in northeast Oregon (Starcevich et al. 2012) generally occurs in September, we used mean daily temperatures of <9 °C, 9-12 °C, >12 °C in early September to respectively classify spawning habitat as high, medium, and low thermal suitability (Starcevich et al. 2017).

Results and Discussion

Census redd surveys

In census redd surveys, 77 Bull Trout redds were identified in Pinhead Creek and Last Creek, 3 redds in reach 4 of the upper Clackamas River, and 13 redds in Berry Creek (Figure 4, Table 4, Appendix I). The total count in 2019 decreased 5% relative to 2018 and a 9% relative to 2017 (Table 5). The census count in the upper Clackamas River has totaled 3 or 4 redds since 2016 and this year was similarly low. In Berry Creek, Bull Trout redds and adults were observed for the first time since surveys were initiated in 2015. The first Bull Trout redd was observed in early September and 82% of the redds were counted by early October (Table 2). Bull Trout were seen actively spawning on or occupying 5 redds (6% of total) in Pinhead and Last creek and on one redd (8%) in Berry Creek.

In Pinhead and Last creeks, 24 Chinook Salmon redds were counted (Table 2, Appendix I). The first salmon redd was observed in late September and a slight increase in salmon spawning was observed during the final survey in early November. Chinook Salmon were observed actively spawning on or occupying 4 redds (17% of total). Most Bull Trout redds had been identified prior to the increase in salmon spawning in Pinhead Creek, which decreases the influence of salmon redds as a factor confounding the number of Bull Trout redds counted.

No Bull Trout redds were observed in Cub Creek or reach 3 of the Clackamas River. Several Chinook Salmon redds were seen in the upper section of reach 3, which was near the location of an unconfirmed observation of a Bull Trout pair on a redd reported by an ODFW salmon crew in 2018.

Pinhead Creek adult monitoring

The number of adult Bull Trout detected in Pinhead Creek during the spawning season steadily increased from 21 adults in 2013 to a peak count of 104 in 2018 and then declined in 2019 to 73 (Table 5; Barrows et al. 2018, 2019, 2020). There was a strong linear relationship ($Y=1.0X + 8.6$, $R^2=0.92$, P-value<0.001) between the annual census redd count (X) and number of adults (Y) estimated to pass the weir (Figure 5). The relationship of 0.9 adults per redd in 2019 was similar to previous years (mean, 1.0; range, 0.9-1.5; 2012-2017). Although the adult-to-redd ratio has been low relative to those of other Bull Trout populations (see Howell and Sankovich 2012), the census redd count was a consistent proxy for adult abundance in the Pinhead Creek watershed and can be a useful monitoring tool for estimating adult abundance in other spawning areas.

Table 4. Bull Trout redds counted during census surveys in the upper Clackamas River basin, 2011-2018. In certain years, some stream reaches were not surveyed (NS).

		Bull trout redd count									
Stream	Reach	2011	2012	2013	2014	2015	2016	2017	2018	2019	Reach breaks
Pinhead Creek	1	3	9	10	21	13	34	33	57	53	Mouth–Last Cr.
Pinhead Creek	2	2	5	2	14	34	25	40	23	18	Last–FS140 Rd
Last Creek	1	0	2	3	2	0	3	12	1	6	Mouth–Camp Cr.
Clackamas R.	1	NS	NS	NS	NS	2	0	NS	NS	NS	4650 Br.–Pinhead
Clackamas R.	2	NS	NS	NS	NS	5	2	NS	NS	NS	Pinhead–Lowe Cr.
Clackamas R.	3	NS	NS	NS	NS	2	0	NS	NS	0	Lowe Cr.–Cub Cr.
Clackamas R.	4	NS	NS	1	NS	2	4	4	3	3	Cub Cr.–1st falls
Clackamas R.	5	NS	NS	NS	NS	0	NS	NS	NS	NS	1st falls–Ollalie Cr.
Oak Grove Fk.	1	NS	NS	2	NS	1	0	NS	NS	NS	1st 2.5 km
Lowe Creek	1	NS	NS	NS	NS	0	0	NS	NS	NS	1st 1 km
Rhodo. Cr.	1	NS	NS	NS	NS	0	0	NS	NS	NS	1st 1 km
Hunter Creek	1	NS	NS	NS	NS	0	0	NS	NS	0	1st 1.5 km
Cub Creek	1	NS	NS	NS	NS	0	0	NS	NS	0	Mouth–Berry Cr.
Cub Creek	2	NS	NS	NS	NS	0	NS	NS	NS	0	1st 2 km.
Berry Creek	1	NS	NS	NS	NS	0	0	NS	NS	13	1st 3 km
TOTAL		5	16	18	37	59	68	89	84	93	

In 2019, the median duration of PIT-tagged adults spent in Pinhead Creek was 17 days (Table 5). Adults were first detected in the creek on July 9 and last detected on October 6 (Figure 6). Similar to previous years, this timing information suggests that Bull Trout likely have completed spawning by mid-October in Pinhead Creek. In 2019, 17 Bull Trout redds were counted in late October and early November (Table 2). The identification of new Bull Trout redds after the last PIT tagged adult exited the creek, which occurred in every year since 2015, can be explained by at least two potential explanations. First, these late-identified Bull Trout redds may have been missed during previous surveys. Pinhead Creek has a large amount of instream wood and overhanging vegetation and several multi-channel reaches, which are factors that can increase the probability of observers missing new redds during an individual survey. The protocol of repeating the census survey every two weeks is used in part to correct these errors of omission in subsequent surveys. Second, small salmon redds and test digs may have been misidentified. The potential influence of this confounding factor was greatest during the last round of the census survey when salmon spawning increased (Table 2); however, interspecific size differences in redd dimensions and spawning gravel makes misidentification of redd species less likely.

PIT-tagged adults detected in Pinhead Creek in 2019 ranged from age-5 to age-11 (Table 6). The average age of adults increased from an estimated 5.8 in 2014 to 7.2 in 2019. Their release locations were mainly in reach 1 of the Clackamas River, Pinhead Creek, and Last Creek and included two fish released as far away as Berry Creek (Table 6). There were 63 PIT-tagged adults detected in Pinhead Creek in 2019. Of these adults, 2% were released at age-1, 16% at age-2, 27% at age-3, 27% at age-4, and 29% at age-5 and older (Figure 7). The observed peak in

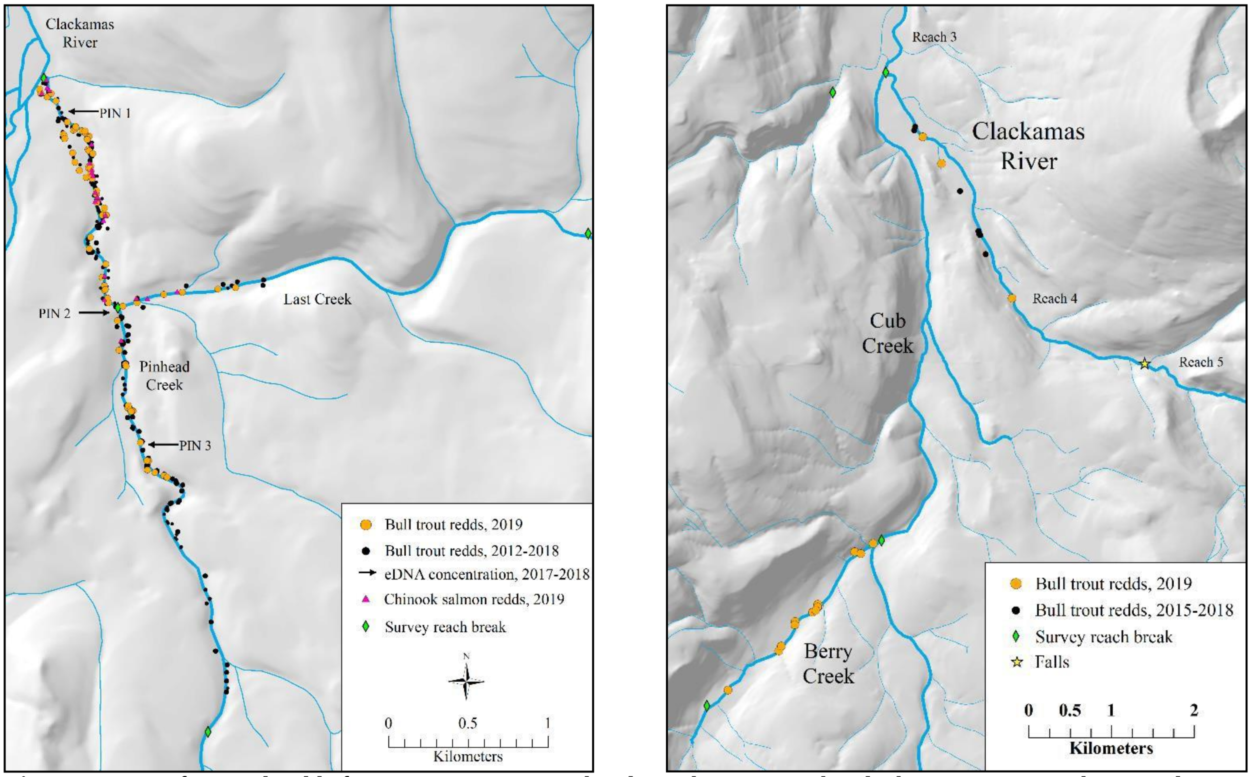

Figure 4. Georeferenced redds from 2012-2019 in Pinhead Creek, Last Creek, Clackamas River reaches 3 and 4, and Berry Creek from 2012-2019. Some redds were georeferenced in secondary channels, which are not shown.

Table 5. Annual estimate of Bull Trout redds and adults (i.e., age-5 and older) in Pinhead Creek and the estimated duration PIT-tagged adults spent in this watershed. From 2011-2016, the adult estimate included only translocated PIT-tagged adults. In 2017-2019, the count was composed of tagged and untagged adults detected at the PIT-tag array, caught in the weir trap, or observed passing upstream through the video station. Duration was defined as the number of days between the first and last detection at the PIT array in Pinhead Creek for adults with duration >6 d.

Census Survey			PIT/Trap/Video		Duration		
Year	Redds	Annual Change	Adults	Annual Change	Median	Min	Max
2011	5	NA	20	NA	27	17	78
2012	16	220%	19	-11%	35	12	55
2013	15	-6%	21	18%	27	7	68
2014	37	147%	40	75%	24	7	93
2015	47	27%	72	51%	25	7	94
2016	62	32%	76	36%	26	7	88
2017	85	37%	96	33%	22	7	91
2018	81	-5%	104	8%	20	7	47
2019	77	-5%	73	-30%	17	7	42

the number of adults released at age-2 in Pinhead Creek was in 2016 (Figure 7). Relative to older age-at-release classes, the steep decline in subsequent years was likely influenced by higher tag ejection rates. While age-4 and older fish usually were tagged in the dorsal musculature, the small size of translocated fish under age-4 necessitated intraperitoneal tagging, which has a substantially lower tag retention rate during spawning (Mamer and Meyer 2016). Among the 18 adults released at age-5 and older and detected in 2019 (Figure 7), 15 (83%) were tagged at the Pinhead Creek weir trap, including 9 captured and tagged in 2019.

The decline in adult abundance in Pinhead Creek, documented in the census redd count and weir estimate in 2019, can be explained by multiple factors. First, translocations ended in 2016; therefore, no translocated adults were added to the population after that year and few translocated juveniles were recruited into the adult population in 2019. Second, most of the fish translocated in 2014-2016 were released at Berry Creek and reach 5 of the Clackamas River, not Pinhead Creek. Both of these areas are thermally suitable, and fish released at these sites would not need to disperse to find rearing habitat. For fish that did disperse from the release sites, these areas are upstream and relatively far from Pinhead Creek, which decreases the likelihood of dispersal to Pinhead Creek. So far, only a few fish from Berry Creek have been detected as adults in Pinhead Creek (Table 6). Lastly, locally-born fish in Pinhead Creek are not yet surviving to maturity in numbers sufficient to replace translocated adults lost to mortality.

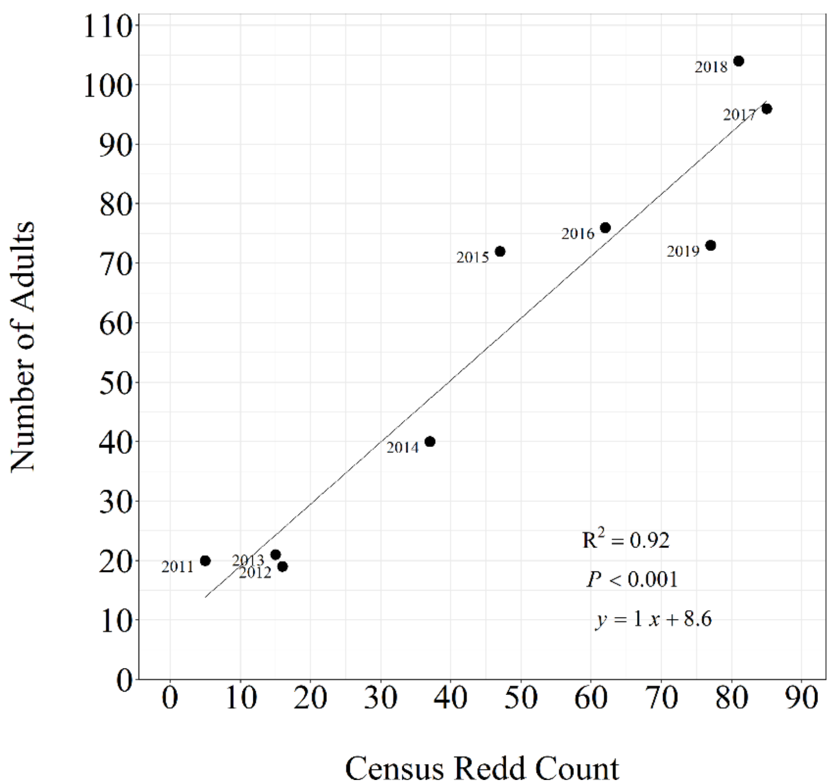

Figure 5. Annual number of Bull Trout redds counted in Pinhead and Last creeks as a function of the annual number of adult Bull Trout (i.e., age-5 and older) detected entering Pinhead Creek during the spawning period. From 2011-2016, the adult count consisted of PIT-tagged adults detected at the PIT array (solid circles). Starting in 2017, the adult count consisted of an adult estimate from the weir trap, video station, and PIT-tag detections. The line and its equation were estimated using simple linear regression.

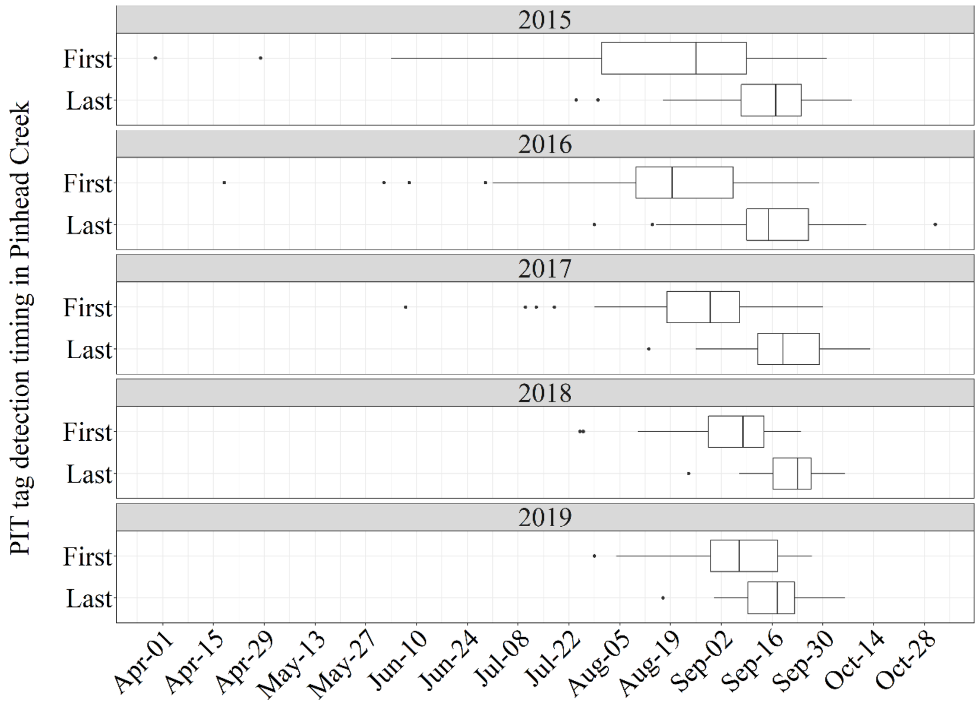

Figure 6. Timing of first and last detection of PIT-tagged Bull Trout, age-5 and older, at the PIT array near the mouth of Pinhead Creek. The boxplot displays a median line and two middle quartile boxes; the whiskers are defined as 1.5*interquartile range (IQR), outliers are beyond this spread, and together they represent the early and late quartiles. PIT-tag detection timing data included first-detection dates for all adults and last-detection dates for adults with spawning duration >6 d.

Table 6. Estimated age-class at detection and release area of PIT-tagged adult Bull Trout in Pinhead Creek. Translocated fish were released in Berry Creek in 2014-15 and trapping in Pinhead Creek began in 2017 so no data were available (NA) for years prior to releases. No individuals released in 2016 in Clackamas River 5 have been detected yet in Pinhead Creek.

	Age-at-detection								Release area						
Year	11	10	9	8	7	6	5	Mean	L.Clackamas	Clackamas 1	Pinhead-Last	Pinhead Creek Trap	Clackamas 2	Berry Creek	Total
2011	0	0	0	0	0	4	16	5.2	6	2	0	NA	12	NA	20
2012	0	0	0	0	0	12	7	5.6	1	2	1	NA	15	NA	19
2013	0	0	0	0	7	6	8	6.0	0	4	3	NA	14	NA	21
2014	0	0	0	1	6	15	18	5.8	6	16	9	NA	9	0	40
2015	0	0	0	3	14	27	28	5.9	9	30	28	NA	5	0	72
2016	0	0	1	3	10	31	31	5.8	0	29	44	NA	2	1	76
2017	0	0	1	4	25	26	13	6.3	1	27	32	6	0	3	69
2018	0	1	2	15	19	19	6	6.9	0	34	16	9	1	2	62
2019	1	1	9	10	19	19	4	7.2	0	34	11	15	1	2	63

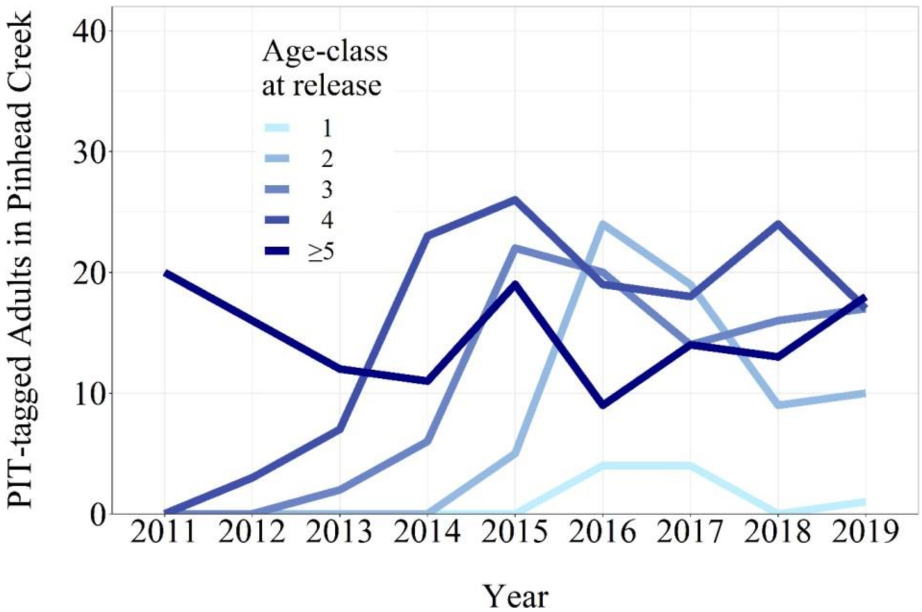

Figure 7. Age class at which PIT-tagged Bull Trout were released into the upper Clackamas River basin and subsequently detected at the Pinhead Creek PIT-array prior to and during the spawning season as adults (i.e., age-5 and older).

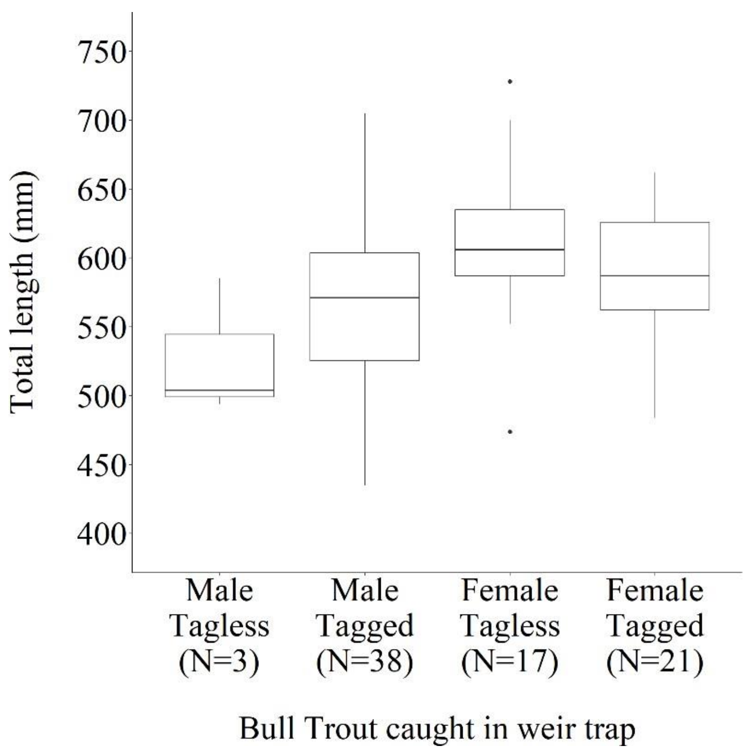

Figure 8. Total length comparison of tagless and PIT-tagged adults captured in the weir trap in Pinhead Creek since trapping began (2017-2019). Individuals were grouped and counted (N) by sex because females have a greater tendency of ejecting a PIT tag during spawning. The boxplot displays a median line and two middle quartile boxes; the whiskers are defined as 1.5*interquartile range (IQR), outliers are beyond this spread, and together they represent the early and late quartiles.

An examination of adults captured in the Pinhead Creek weir trap provides little evidence of an influx of locally-born adults into the population. From 2017 through 2019, 20 tagless and 76 tagged adults were captured in the trap and measured for total length (Figure 8). While the presence of tagless adults suggests the possibility of locally-born adults, the sex ratio of these individuals and their relative body size suggest that the lack of a tag is a more likely explained by tag loss. Among the tagless group, there were many more females (N=17) than males (N=3). The sex disparity suggests tag ejection during spawning accounts for most tagless adults, since this phenomenon is more prevalent among females (Meyer et al. 2011, Mamer and Meyer 2016). The mean total length observed was 528 mm for tagless males, 567 mm for tagged males, 613 mm for tagless females, and 609 mm for tagged females. Tagless females and males were not significantly smaller than the general tagged population (two-sample t-tests, P-value $\geq$ 0.30).
First-time spawners are expected to be younger and smaller than the general population of tagged adults. Although the smaller tagless adults from these groups cannot be ruled out as locally-born, the low number of males and lack of size difference between cohorts suggest they were more likely the result of general tag shedding during the juvenile stage or tag ejection during previous spawning. Until there is a clearer signal of relatively small tagless adults showing up in Pinhead Creek to spawn, it is uncertain whether this reintroduced population will become self-sustaining.

Provided that some locally-born offspring are surviving to adulthood (i.e., generally age-6), a clearer signal of local recruitment should increase after 2020. This is because locally-born offspring from 2011 through 2013 came from relatively few spawning adults and cohorts reaching adulthood in 2018 through 2020 would likewise be sparse (Table 7). The number of spawning adults in Pinhead Creek increased rapidly every year from 2014 through 2018. The number of locally-born offspring would be expected to increase in tandem with the increase in spawners (and spawner body length). Much larger locally-born cohorts are more likely to recruit some individuals to adulthood starting in 2021 and those cohorts are likely to increase through at least 2025 (Table 7).

Table 7. The number of Bull Trout redds and adults by spawning year and the corresponding juvenile year-classes until these cohorts reach adulthood (green). Bull Trout in the Metolius River basin generally reach adulthood at age-6, while a small proportion matures at age-5.

			Year-class (age)													
Spawn year	Redds	Adults	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2011	5	19	0	1	2	3	4	5	6	7	8	9	10			
2012	16	17		0	1	2	3	4	5	6	7	8	9	10		
2013	15	20			0	1	2	3	4	5	6	7	8	9	10	
2014	37	35				0	1	2	3	4	5	6	7	8	9	10
2015	47	53					0	1	2	3	4	5	6	7	8	9
2016	62	72						0	1	2	3	4	5	6	7	8
2017	85	96							0	1	2	3	4	5	6	7
2018	81	104								0	1	2	3	4	5	6
2019	77	72									0	1	2	3	4	5

Age-class at release and survival to adulthood in Pinhead Creek

The Pinhead Creek weir and PIT-tag detection array provide an opportunity to evaluate survival to adulthood by each age-class at release of translocated fish. Translocated fish released at age-1 and age-2 respectively showed 1.5% and 6.2% rates of survival to adulthood (i.e., age-5 or older) and detection in Pinhead Creek (Figure 9). The survival rate for fish released at age-3 was 19%, age-4 was 27%, and age-5 or older was 45% (Figure 9). The rate of survival to adulthood for age-1 and age-2 translocated fish in the Clackamas River basin appears low. However, given annual survival rates reported for different age classes of Bull Trout in the South Fork Walla Walla River basin (SFWW), survival rate to adulthood for these early age classes are similar other self-sustaining populations. In the SFWW, the annual survival rate for age-1 Bull Trout was 0.22 (Bowerman and Budy 2012); depending on the study, age-2 survival was 0.23 (Bowerman and Budy 2012) or ranged from 0.15 to 0.35 (Al-Chokhachy and Budy 2008). For age-3 and age-4 classes, annual survival rates varied from 0.50 to 0.65 for Bull Trout (Al-Chokhachy and Budy 2008) and ranged from 0.42-0.54 for other resident salmonids (Budy et al 2007).

Applying these annual survival rates by age-class from the SFWW to the number of translocated fish released in or near Pinhead Creek, the expected number (N_E) of age-1 and age-2 fish surviving to adulthood was similar to the actual number (N_A) detected as adults in Pinhead Creek (Table 8). Age-1 and age-2 survival rates of translocated fish may be a good proxy for survival of locally-born offspring in Pinhead Creek because more than 99% of these translocated cohorts (1,232 fish) were released in Pinhead Creek. Conversely, among the age-3 and age-4 translocated released in Pinhead Creek or neighboring river reaches (i.e., Clackamas 2 and downstream), only 36% were released in Pinhead Creek. Although Pinhead Creek, as the primary spawning ground in this basin, is a good location for this evaluation; these survival estimates come with many caveats. First, the overall N_A is likely higher because some translocated fish survived to adulthood and attempted to spawn in areas other than Pinhead Creek, especially among the cohorts released elsewhere in the basin. Second, this exercise assumed all fish matured at age-5; therefore, N_E is likely lower than predicted, because many of these fish matured at age-6, which would require multiplying this reported N_E by an age-5 survival rate. Annual survival rates for immature age-5 resident salmonids are not well known, presumably it is less than 1 and would further lower N_E. Finally, annual survival rates for the age-0 cohort, which can vary greatly and be an important driver of adult abundance (Kanno et al. 2016), are not known for the Clackamas and SFWW populations. With these caveats in mind, this approximation still suggests that locally-born offspring that survive to age-1 are likely to experience survival rates similar to other self-sustaining Bull Trout populations.

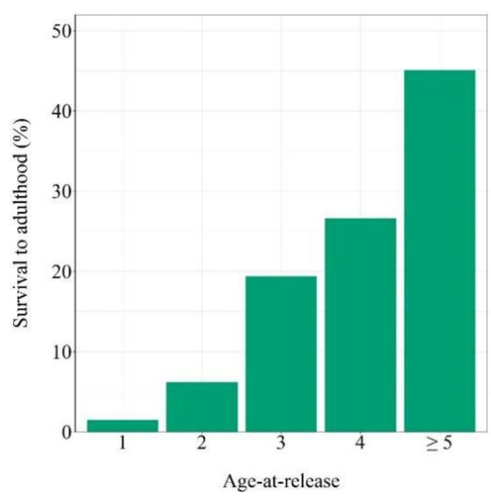

Figure 9. Rates of survival to adulthood and PIT-tag detection of adult Bull Trout in Pinhead Creek by age-class at release into the Clackamas River Basin. Fish translocated to Berry Creek in 2014-15 and reach 5 of the Clackamas River in 2016 (see text).

Table 8. Comparison of the number of translocated fish (N_R) released at various age-classes expected to survive to adulthood (N_E), based on reported annual survival rates by age-class (see text); and the actual number of adults detected in Pinhead Creek (N_A).

Release		Survival by age-class				Adults		
Age	N_R	s1	s2	s3	s4	N_E	N_A	N_A/N_E
1	460	0.22	0.23	0.6	0.6	8	7	84%
2	545	--	0.23	0.6	0.6	45	34	75%
3	279	--	--	0.6	0.6	100	54	54%
4	331	--	--	--	0.6	199	88	44%

Snorkel surveys and juvenile sampling

In a 750 m snorkel survey of reach 1 of Pinhead Creek, no juvenile Bull Trout were observed among the high densities of juvenile Coho Salmon (*O. kisutch*) and Chinook Salmon. To date, no juvenile Bull Trout have been observed during juvenile fish surveys in 2016 (see Barrows et al. 2017), young-of-the-year surveys in the lateral habitat of Pinhead Creek in 2017, and similar snorkel surveys in Pinhead Creek in 2016 through 2018. Much smaller spawning populations in Oregon produce offspring that are readily detected during night snorkel surveys (e.g., Starcevich et al. 2017). The lack of detection of juvenile Bull Trout in Pinhead Creek is puzzling for three reasons: 1) viable alevins and nearly-emergent fry were captured during hydraulic redd sampling in 2 redds in Pinhead Creek in 2018 (Barrows et al. 2019) and 6 redds in 2019 (Barrows et al. 2020); 2) alevins were developing normally relative to a temperature unit equation and had no abnormalities or known diseases after histological testing in 2019 (Barrows et al. 2020); and, 3) as noted above, translocated fish released at age-1 and age-2 in Pinhead Creek appear to have normal rates of survival to adulthood.

Environmental DNA - Distribution

In genetic sampling from 2017 through 2019, Bull Trout eDNA was detected near translocation areas in Pinhead Creek, Berry Creek, and upper Clackamas River, and far downstream of these areas in Roaring River (Figure 10; Appendix II). In 2019, Pinhead Creek and Last Creek were sampled in July, prior to the arrival of migratory adults, to focus on the upstream distribution of resident fish or juvenile rearing. Bull Trout eDNA was detected in the lower end of reach 2 of Pinhead Creek but not at the site 2 km upstream, which was upstream of most spawning. Bull Trout eDNA was not detected in any of the three sites sampled in 2019 in Last Creek, suggesting that juveniles were either absent or at low densities upstream of these sites. Bull Trout eDNA was detected in Last Creek in 2017; these samples were collected in late September, when Bull Trout were observed actively spawning in this stream.

In the Berry Creek/Cub Creek translocation area, Bull Trout eDNA was detected in all three years of sampling and in the following spatial pattern: detections in Cub Creek and none in Berry Creek except at its confluence with Cub Creek, which was the release site for translocated fish (Figure 10). Detections in Cub Creek sites occurred on July 17 (2019) and September 13, 26, and 27 (2017-2018) (Appendix II). Non-detections in Berry Creek occurred July 17 (2019), September 26-27, and October 17 (2017-2018). Given that adult entry into Pinhead Creek begins in late July and the median entry date is in early September (Figure 6), a lack of detection in 2019 in Berry Creek suggests Bull Trout that spawned there had not yet arrived by the July

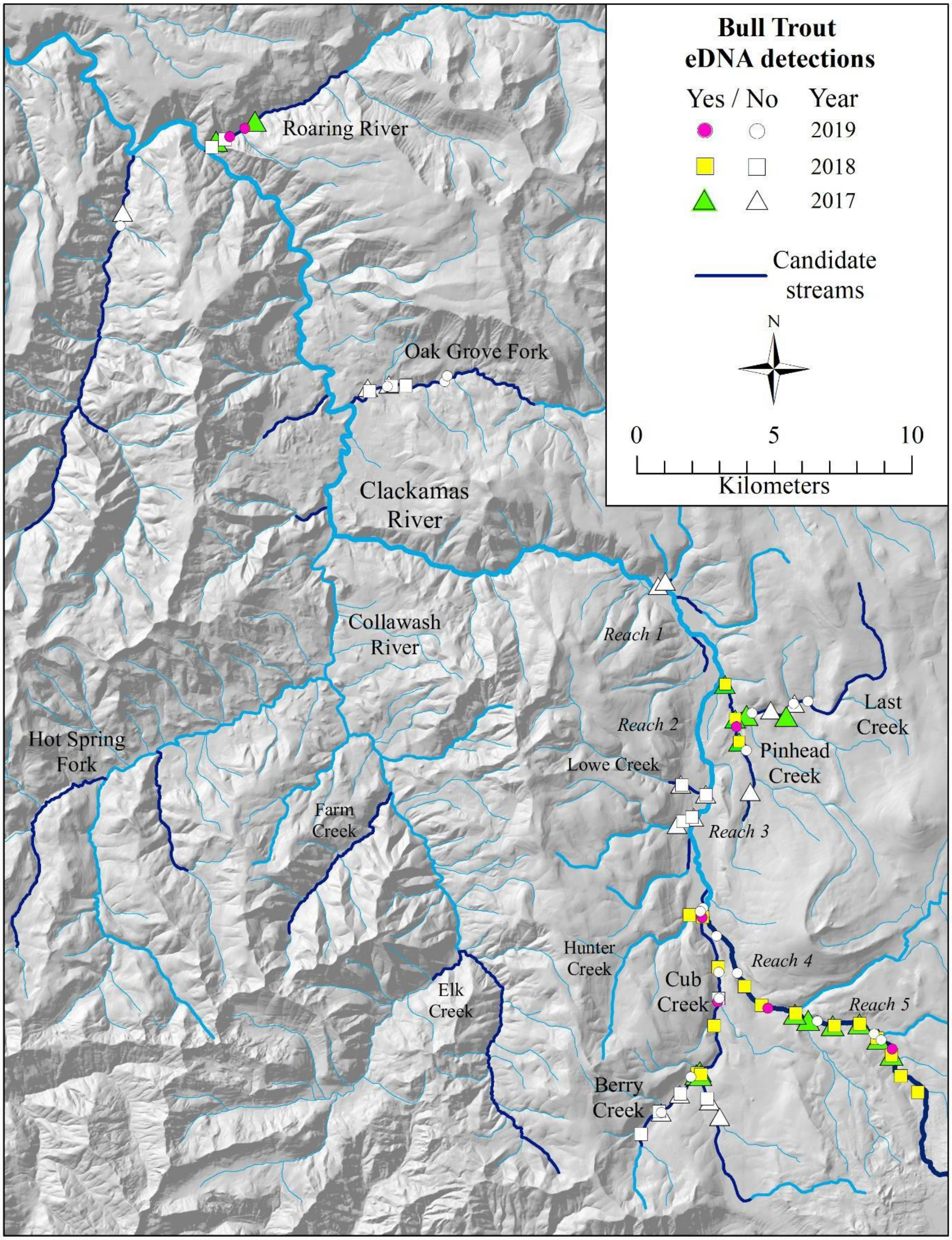

Figure 10. Environmental DNA survey results from survey sites in 2017 through 2019. Candidate streams were estimated to be thermally suitable and lacking fish barriers or through historical anecdotes of Bull Trout presence.

sample date. Non-detections also may signify an absence, or undetectably low density, of juvenile Bull Trout and suggest successful spawning has not occurred prior to 2019. In light of Bull Trout spawning in September in Berry Creek, detections in lower Cub Creek in July, 2019, suggest these adults may have been staging downstream of their spawning area.

Translocated Bull Trout were released in reach 5 of the upper Clackamas River basin in 2016. Bull Trout eDNA was detected widely in reach 5 and upper reach 4 in 2017 and 2018 (Figure 10), suggesting at least some of these fish had remained and spread out within this translocation area. In 2019, eDNA was detected in only one of the four sites surveyed in reach 5. This reduction in distribution may reflect low survival, or movement downstream out of reach 5 to find better foraging habitat.

Downstream from the translocation areas, Bull Trout eDNA was detected in 2017 and 2019 at both sites sampled in lower Roaring River (Figure 10). These samples were collected on September 23 and 27, which was close to peak spawning timing in Pinhead Creek. In 2018, no Bull Trout eDNA was detected at two sites surveyed on October 22, which was two weeks after all PIT-tagged adult Bull Trout had exited Pinhead Creek. These eDNA results, given their sampling dates, may indicate Bull Trout attempting to spawn in Roaring River and suggest an increased monitoring effort is warranted.

In the Oak Grove Fork of the Clackamas River, even though it is situated closer to translocation release areas and is colder than Roaring River, Bull Trout eDNA has not been detected at any sites sampled in all three years. The surveys were conducted on July 18 and between October 3 and 22 (Appendix II). In regard to eDNA results in general, it is important to acknowledge that false positives and negatives are possible. The following steps were taken to reduce the chance of false results: 1) the field crew received extensive training in eDNA protocols, which are designed to prevent contamination by the crew, and these protocols were assiduously followed; 2) survey sites were allocated to ensure detection probabilities for individuals streams were over 0.85; 3) eDNA surveys were conducted prior to spawning surveys or temperature logger maintenance in any given location to ensure samples sites were not contaminated by the crew; and 4) high priority streams are sampled annually, which allows us to evaluate the consistency of results.

Environmental DNA – Concentration and Adult Abundance in Pinhead Creek

Bull Trout eDNA concentration varied by adult abundance and location in Pinhead Creek and among samples taken consecutively at the same site (Figure 11, Appendix III). Bull Trout eDNA surveys in Pinhead Creek were conducted at three sites and during five time periods in 2017 and 2018. The samples were analyzed in May 2019. There was a strong linear relationship between adult abundance and eDNA concentration at all three sites (R^2 range: 0.67-0.74; Figure 11). The highest density spawning was immediately upstream of the first eDNA survey site (i.e., PIN 1; see Figure 4), which recorded the highest eDNA concentrations. The lowest concentrations ranged from 0-82 eDNA copies per L on May 30, which was nearly 8 months after the last adult PIT-tag detection in Pinhead Creek. The highest concentrations ranged from 1,673-20,008 eDNA copies per L and were recorded on September 18 and 19, which was near peak spawning timing in Pinhead Creek. Overall, eDNA concentration in samples collected consecutively at the same site and on the same date varied by an average of 15 times (range, 1.2-88.0 times).

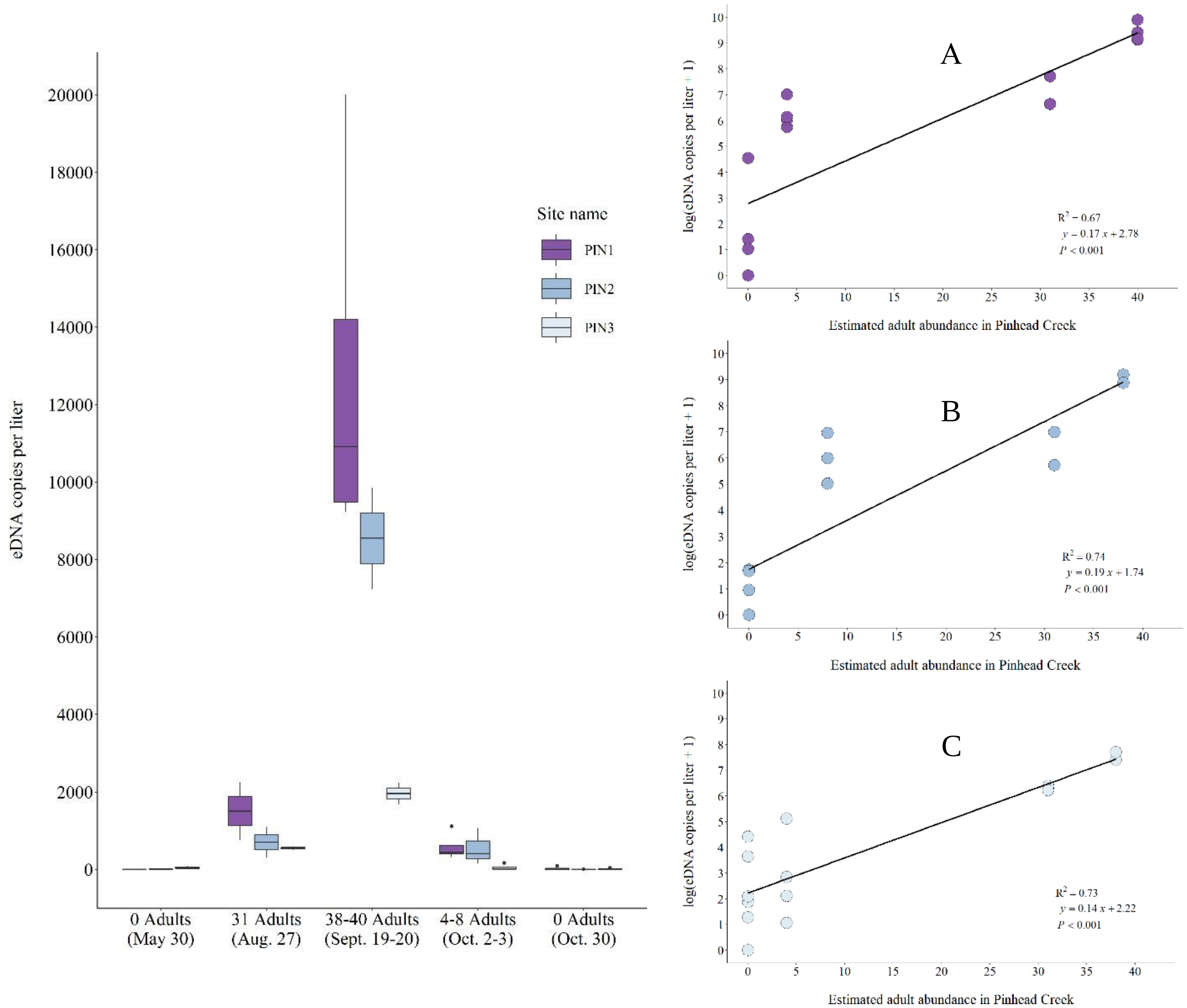

Figure 11. Bull Trout eDNA concentration by date in Pinhead Creek (left panel) and the linear relationships (right panels) between eDNA concentration ($\log_{10}$-transformed) and the estimated adult abundance on eDNA survey dates at three locations in Pinhead Creek: A) PIN1, 400 m upstream of the Clackamas River; B) PIN2, 50 m upstream of Last Creek confluence; and C) PIN3, 1 km upstream of Last Creek. Adult abundance was estimated using PIT-tag, video, and trap data (see text for details).

The linear relationship between adult abundance and eDNA concentration suggests eDNA surveys may be useful for tracking relative adult abundance within and among streams. Tillotson et al. (2018) found the daily change in eDNA concentrations in an Alaskan stream reflected Sockeye Salmon (*O. nerka)* abundance at fine time scales across the spawning season, suggesting eDNA surveys provide a snapshot of current abundance. Variation in eDNA concentration among consecutive samples taken at the same site can be explained by a number of factors: upstream proximity and density of fish (Wilcox et al. 2016), decomposing carcasses of semelparous salmon (Tillotson et al. 2018), and active spawning activity and gamete production (Lance et al. 2017). Spawned out carcasses of iteroparous Bull Trout have not been observed by surveyors in Pinhead Creek; and, while Bull Trout tend spawn at night, eDNA surveys were conducted in the middle of the day. These factor likely contribute less to the eDNA load relative to salmon and suggests that the variation in this study was mainly due to proximity and abundance of adults upstream of the survey site. Given that eDNA in lotic systems generally reflects organisms present nearby rather than an accumulation (Wilcox et al 2016, Tillotson et al. 2018), eDNA concentration decreasing in the upstream direction in Pinhead Creek likely reflected the decreasing trend in localized spawning and adult abundance.

Bull Trout eDNA was detected in low concentration when adults were not present in Pinhead Creek, which suggests these surveys may also be useful for detecting juvenile populations. Other confounding factors for these detections may include decomposing adult carcasses (Tillotson et al. 2018), remnant egg casings in the gravel (Tillotson et al. 2018), and resuspension of eDNA stored in sediments (Barnes et al. 2014). Detection probabilities (from 4 replicate samples) on October 30, three weeks after adults exited Pinhead Creek, were 0.50 at site PIN 1, 0.25 at PIN 2, and 1.00 at PIN 3 (Appendix III). On May 30, eight months after the last PIT-tagged adult was detected in Pinhead Creek, eDNA detection probabilities (from 2 replicate samples) were 0.50 for PIN 1 and PIN 2 and 1.00 for PIN 3. Wilcox et al. (2016) estimated detection probabilities for 1 fish per stream km at 0.18 and for densities ≥3 fish per 100 m at ≥0.99. Using these detection probabilities, and provided that juvenile fish are the sole eDNA source, Pinhead Creek likely has a range between >1 juvenile Bull Trout present per km and <3 per 100 m. The detection probability estimates in Wilcox et al. (2016) were from small streams (3 m wetted width). Pinhead Creek discharge is much greater (10-12 m wetted width). Given that higher discharge would dilute eDNA concentrations and reduce detection probability, the range of likely juvenile densities could be much greater as well.

Stream temperature

Continuous water temperatures were recorded on 30 data loggers distributed throughout the upper Clackamas River and Collawash River basins (Figure 12-14). As maximum temperature increases above 16 °C, the occupancy probability of juvenile Bull Trout decreases in these thermal habitat patches (Isaak et al. 2009); as temperatures decrease below this threshold, the probability of occupancy increases (Isaak et al. 2009, Dunham et al. 2003). Maximum temperatures in the lower Collawash River and Hot Spring Fork and in the Clackamas River downstream of the Collawash River confluence were between 16.7-23.2 °C, which exceeded the 16 °C juvenile rearing criterion for suitable thermal habitat. Upstream of the Collawash River confluence, maximum temperatures in the Clackamas River and its tributaries were below 16 °C. Using this thermal suitability scale, highly suitable habitat was present in Pinhead Creek and Last Creek (Figure 15), and reaches 4 and 5 of the Clackamas River (Figure 14). Habitat with moderately high suitability for juvenile rearing included Oak Grove Fork, Hunter Creek, and Berry Creek (Figure 13) and reaches 1 and 3 of the Clackamas River (Figure 12).

Highly suitable thermal habitat for spawning (i.e., <9 °C daily mean in early September) occurred in Pinhead Creek, Last Creek, Oak Grove Fork, Hunter Creek, Berry Creek, and reach 1 (starting between “clack6” and “clack7”, see Figure 12) through reach 5 of the Clackamas River (Figure 13-15). Moderately suitable thermal habitat for spawning (i.e., <12 °C daily mean in early September) occurred in Elk Creek, Lowe Creek, Roaring River, lower Cub Creek, and the Clackamas River from the Collawash River confluence to the start of reach 1. Cub Creek and this lower section of the Clackamas River were on the borderline of moderate-to-high suitability. Apart from Elk Creek, the Collawash River basin did not contain any suitable thermal habitat for spawning.

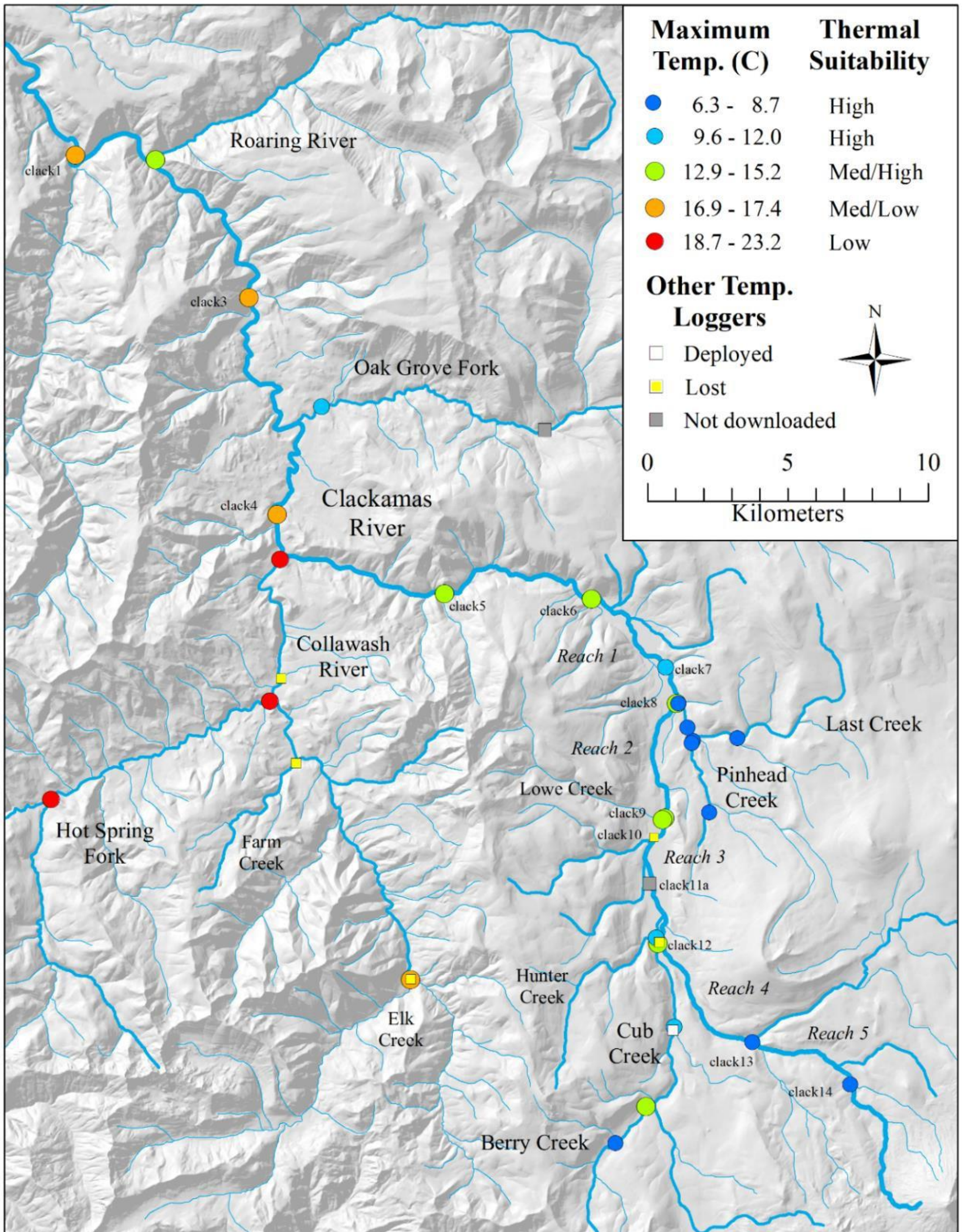

Figure 12. Maximum water temperature at each data logger location in the Clackamas River basin in 2019.

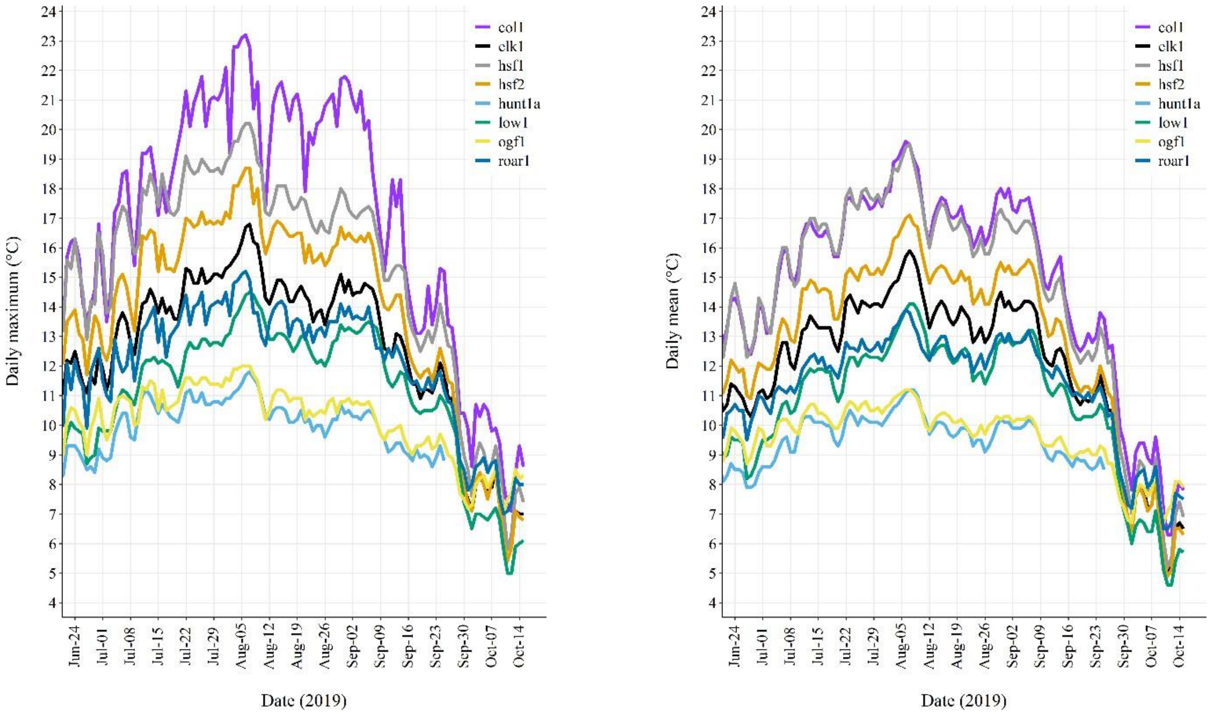

Figure 13. Maximum (left) and mean (right) daily water temperature at data logger locations (location codes in legend) in the Collawash River basin and other Clackamas River tributaries in 2019. (For map of coded locations, see Figure 12.)

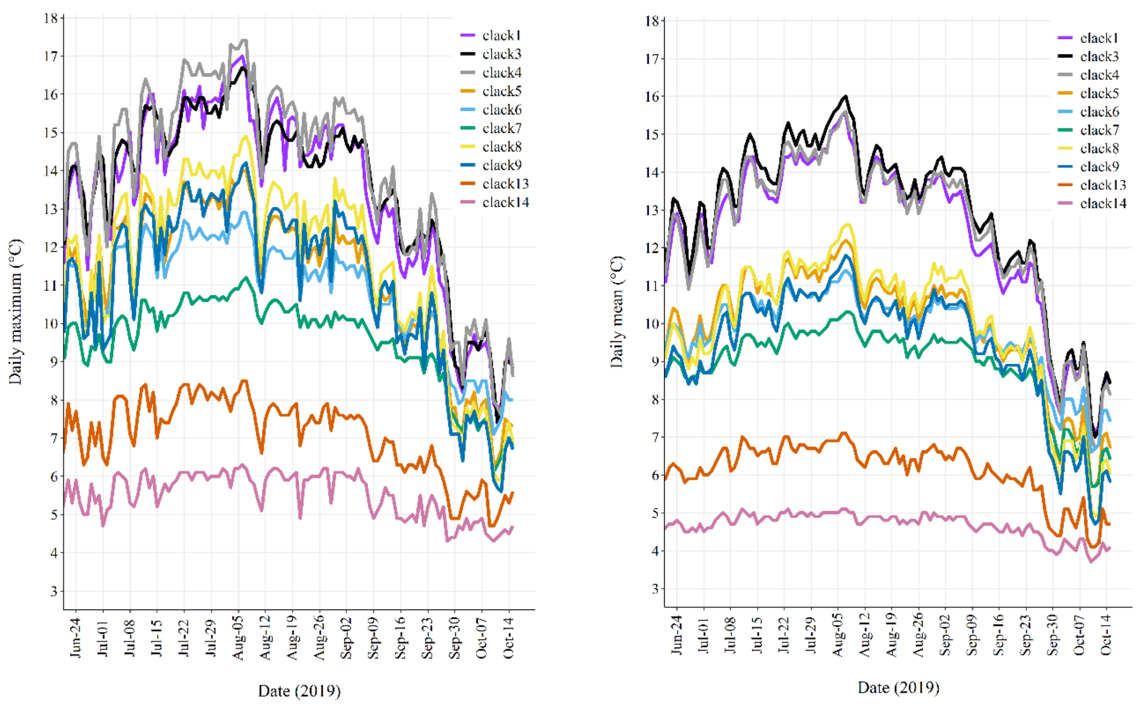

Figure 14. Maximum (left) and mean (right) daily water temperature at data logger locations in the Clackamas River in 2019. (For a map of coded locations, see figure 12.)

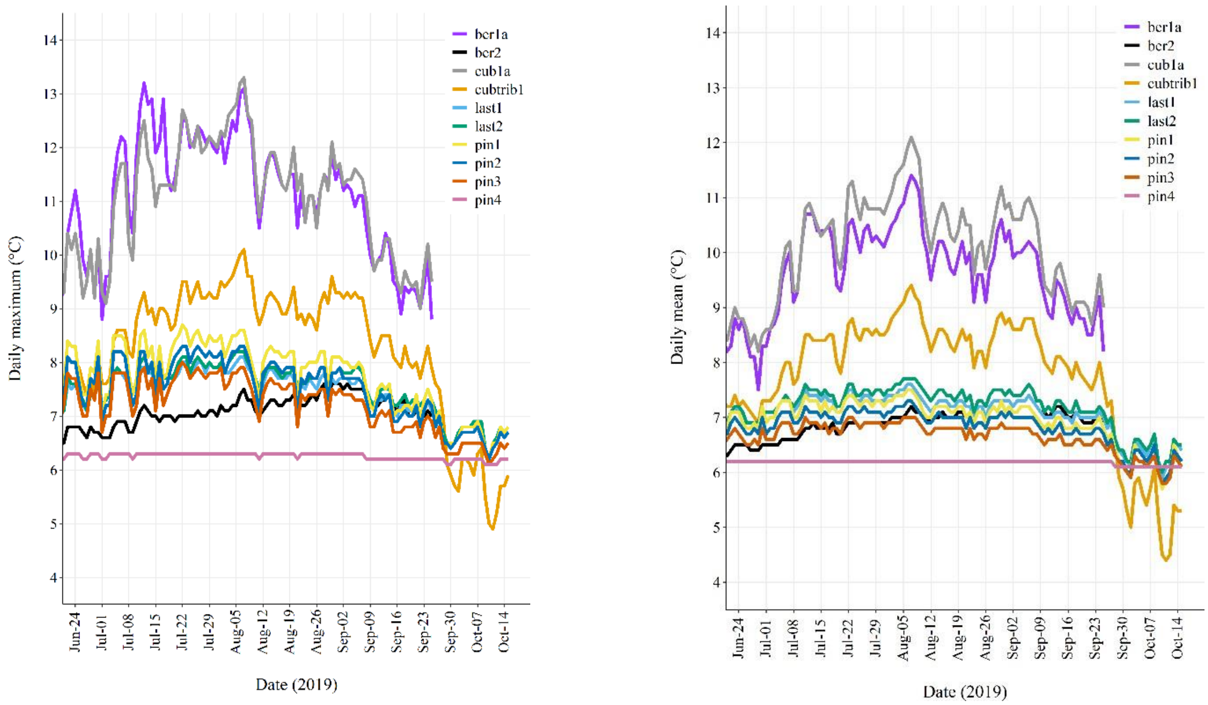

Figure 15. Maximum (left) and mean (right) daily water temperature at data logger locations in Pinhead, Last, Cub, and Berry creeks in 2019. (For a map of coded locations, see figure 12.)

Thermal suitability for spawning has not been defined as precisely as it has for rearing habitat (Starcevich et al. 2017). The thermal suitability categories delineated in this report were based on criteria derived from two case studies conducted in Oregon (see Chandler et al. 2001, Howell et al. 2010) and one from the Skagit River in Washington (Austin et al. 2019). These are among the few studies that reported the temperature metric used to describe the initiation or median date of spawning. They report mean daily stream temperatures between 9.3 and 11.5 °C marking the initiation of spawning in these Oregon streams and 9 °C at the median spawning date in the Washington streams. Stream temperature declines fast throughout the upper Clackamas River basin in September. All temperature monitoring locations were below the 9 °C threshold for spawning by early October. However, the precise date when reaching these spawning temperature thresholds would be too late to support spawning in a particular stream or river reach is still unknown. Given the reported range in spawning phenology for Bull Trout in Oregon and Washington, with spawning starting as early as August (e.g., Howell et al 2010) and median spawning in late October (e.g., Austin et al. 2019), the early September cutoff date should be considered provisional until more data is available, and habitats near thresholds for thermal suitability should not be excluded completely from monitoring.

Monitoring in 2020

In 2020, census spawning surveys will continue in Pinhead Creek, Last Creek, reach 4 of the Clackamas River, and Berry Creek. Based on eDNA results, exploratory redd surveys will be added to Roaring River. This final season of eDNA surveys will include Roaring River, Oak Grove Fork, upper Collawash River basin tributaries, Pinhead Creek, Last Creek, upper Clackamas River (upstream of Pinhead Creek confluence), Cub Creek, and Berry Creek. Surveys will be conducted during peak water temperatures in July and August to focus on the juvenile rearing distribution and a portion of the surveys will be conducted in mid-September during peak spawning in potential spawning areas. Temperature monitoring will continue in the upper Clackamas River basin.

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Appendices

Appendix I. Bull Trout and Chinook Salmon redd data from 2019 in the upper Clackamas River basin. Page 1 of 3.

Stream/Reach	Date	Redd ID	Species	Easting	Northing	LN (cm)	WD (cm)	Description
Berry Creek 1	9/25/2019	C4SS	BuT	586622	4966699	100	70	clean gravel, pm present, small redd
Berry Creek 1	9/25/2019	C9SS	BuT	586153	4966165	140	90	small p/m, fish on redd, updated redd larger on 10/9/19
Berry Creek 1	9/25/2019	C1SS	BuT	587071	4967363	120	60	small redd, clear digging, not much gravel in mound, 2nd chan
Berry Creek 1	9/25/2019	C2SS	BuT	587145	4967342	170	100	nice redd
Berry Creek 1	9/25/2019	C6SS	BuT	586560	4966633	110	55	clean gravel, pm present, small redd
Berry Creek 1	9/25/2019	C8SS	BuT	586182	4966225	200	80	Clear p/m, clean gravel , nice redd
Berry Creek 1	9/25/2019	C5SS	BuT	586598	4966655	100	70	clean gravel, pm present, small redd
Berry Creek 1	9/25/2019	C10SS	BuT	587293	4967464	150	50	nice redd, under ohv alder
Berry Creek 1	9/25/2019	C7SS	BuT	586346	4966480	80	55	clean gravel, pm present, small redd
Berry Creek 1	10/9/2019	D2SS	BuT	586352	4966522	120	70	nice small redd
Berry Creek 1	10/9/2019	D1SS	BuT	586626	4966730	200	60	nice redd
Berry Creek 1	10/23/2019	E1AG	BuT	586625	4966696	150	60	BT gravel small
Berry Creek 1	10/23/2019	E3AG	BuT	585539	4965694	210	80	bt smaller gravel
Clackamas River 4	9/11/2019	B1SS	BuT	587893	4972374	120	80	P/m present, nice redd, test dig 2- 3 m us
Clackamas River 4	9/26/2019	C1AG	BuT	588120	4972055	180	100	clear p/m, gravel too small for chk
Clackamas River 4	9/26/2019	C2AG	BuT	588973	4970425	150	50	clear p/m, fluffed up gravel, light algal growth, 90% certain from this season
Last Creek 1	9/9/2019	B1AG	BuT	588668	4980335	220	60	100% redd, p.m. present
Last Creek 1	9/9/2019	B1SS	BuT	588812	4980483	85	45	definite digging, p.m. present
Last Creek 1	9/24/2019	C4JW	BuT	588579	4980313	90	45	borderline redd, probably new digging
Last Creek 1	10/21/2019	E2AP	BuT	589174	4980422	200	100	bt 100%
Last Creek 1	10/21/2019	E3AP	BuT	589285	4980430	200	70	50% test dig? On an old redd
Last Creek 1	10/21/2019	E1AP	BuT	588950	4980400	140	100	bt, good pocket, small mound
Pinhead Creek 1	9/10/2019	B2AP	BuT	588469	4980418	220	60	100% redd
Pinhead Creek 1	9/10/2019	B1ZW	BuT	588278	4981215	100	40	95% confident
Pinhead Creek 1	9/10/2019	B2ZW	BuT	588448	4980494	185	60	95% confident
Pinhead Creek 1	9/10/2019	B3ZW	BuT	588488	4980335	170	70	100% confident
Pinhead Creek 1	9/10/2019	B2SS	BuT	588283	4981437	140	50	clear pocket, small mound
Pinhead Creek 1	9/10/2019	B2AG	BuT	588475	4980884	200	100	100% redd, clear digging, p/m
Pinhead Creek 1	9/10/2019	B3SS	BuT	588475	4980884	160	55	nice p/m
Pinhead Creek 1	9/10/2019	B4SS	BuT	588472	4980577	130	90	nice p/m, 100%
Pinhead Creek 1	9/10/2019	B1AP	BuT	588469	4980418	320	150	2 pockets, 1 mound
Pinhead Creek 1	9/24/2019	C6AP	BuT	588379	4981194	150	90	fresh pocket, old mound, test dig?, 50/50
Pinhead Creek 1	9/24/2019	C3JW	BuT	588364	4981373	160	60	90% confident
Pinhead Creek 1	9/24/2019	C2JW	BuT	588340	4981401	175	70	90% confident, small substrate
Pinhead Creek 1	9/24/2019	C1JW	BuT	588267	4981417	95	60	80% confident
Pinhead Creek 1	9/24/2019	C8AG	BuT	588482	4980364	190	90	Clear p/m, 100%
Pinhead Creek 1	9/24/2019	C7AP	BuT	588364	4981179	150	70	Clear p/m, 100%
Pinhead Creek 1	9/24/2019	C6AG	BuT	588367	4981192	230	100	clear p/m, 100%
Pinhead Creek 1	9/24/2019	C4CS	BuT	588377	4981144	120	60	50/50 redd, fresh dig, on past redd
Pinhead Creek 1	9/24/2019	C4AG	BuT	588281	4981441	140	50	small redd

Appendix I. Continued, page 2 of 3.

Stream/Reach	Date	Redd ID	Species	Easting	Northing	LN (cm)	WD (cm)	Description
Pinhead Creek 1	9/24/2019	C3AG	BuT	588279	4981425	220	120	BuT on redd
Pinhead Creek 1	9/24/2019	C5AP	BuT	588230	4981468	230	100	large mound, 100%
Pinhead Creek 1	9/24/2019	C4AP	BuT	588159	4981599	150	90	clear p/m, at weir, 100%
Pinhead Creek 1	9/24/2019	C7AG	BuT	588373	4981178	150	110	clear p/m, deep
Pinhead Creek 1	9/24/2019	C1CS	BuT	588322	4981412	160	90	clearly defined redd
Pinhead Creek 1	9/24/2019	C3CS	BuT	588356	4981358	140	75	less confident, mixed with clean and algaed gravel in mound
Pinhead Creek 1	9/24/2019	C5CS	BuT	588464	4980412	140	90	large dig area, two diff mounds
Pinhead Creek 1	9/24/2019	C1SS	BuT	588206	4981391	150	55	distinct p/m
Pinhead Creek 1	9/24/2019	C2SS	BuT	588212	4981380	270	130	huge redd, but gravel
Pinhead Creek 1	9/24/2019	C3SS	BuT	588214	4981363	110	70	small p/m
Pinhead Creek 1	9/24/2019	C4SS	BuT	588265	4981273	125	70	small redd
Pinhead Creek 1	9/24/2019	C5SS	BuT	588348	4981121	200	80	nice redd
Pinhead Creek 1	9/24/2019	C8AP	BuT	588463	4980929	100	70	p/m present
Pinhead Creek 1	9/24/2019	C1AG	BuT	588105	4981624	230	120	big redd next to chk redd
Pinhead Creek 1	9/24/2019	C1AP	BuT	588129	4981647	150	60	100% redd
Pinhead Creek 1	9/24/2019	C9AP	BuT	588368	4980673	110	60	big pocket, small mound
Pinhead Creek 1	9/24/2019	C3AP	BuT	588057	4981675	120	90	deep pocket, small mound
Pinhead Creek 1	9/24/2019	C2CS	BuT	588341	4981411	170	75	Clearly defined
Pinhead Creek 1	10/8/2019	D4JW	BuT	588463	4980442	140	80	95% certainty, brightness faded
Pinhead Creek 1	10/8/2019	D2JW	BuT	588379	4981162	150	50	75% certainty, flagged as test dig on C survey
Pinhead Creek 1	10/8/2019	D1JW	BuT	588368	4981286	120	50	75% certainty
Pinhead Creek 1	10/8/2019	D5SS	BuT	588375	4980746	100	30	small redd, clear p/m
Pinhead Creek 1	10/8/2019	D2SS	BuT	588391	4981269	160	70	small, p/m within larger test digging, clear digging
Pinhead Creek 1	10/8/2019	D1SS	BuT	588367	4981380	100	60	bright p/m
Pinhead Creek 1	10/22/2019	E2SS	BuT	588411	4981017	150	1	p/m present, nice, 100%
Pinhead Creek 1	10/22/2019	E5AG	BuT	588118	4981111	180	80	75% bt
Pinhead Creek 1	10/22/2019	E1AG	BuT	588414	4981038	210	70	first marked as test dig, bt redd
Pinhead Creek 1	10/22/2019	E5AP	BuT	588065	4981646	140	90	bt pocket and small mound
Pinhead Creek 1	11/5/2019	F5SS	BuT	588416	4980963	190	50	BuT redd, older, missed prev(?), clear digging edge, mound a little dark to be within last 2 wks
Pinhead Creek 1	11/5/2019	F4SS	BuT	588411	4981015	100	60	BuT redd and test dig, 2 pockets, 1 mound
Pinhead Creek 1	11/5/2019	F2SS	BuT	588360	4981295	100	60	BuT redd, small
Pinhead Creek 1	11/5/2019	F4AP	BuT	588448	4980883	100	40	Potentially missed bull trout redd
Pinhead Creek 1	11/5/2019	F3AP	BuT	588459	4980894	200	110	Small gravel, 50/50
Pinhead Creek 1	11/5/2019	F2AP	BuT	588386	4981114	110	60	Small bt redd, under bank, could have been missed previously
Pinhead Creek 1	11/5/2019	F2JW	BuT	588449	4980883	140	60	BuT redd 95% certain
Pinhead Creek 2	9/10/2019	B2AP	BuT	588612	4979691	170	80	bull trout pair on redd
Pinhead Creek 2	9/10/2019	B2AG	BuT	588624	4979666	230	85	large mound, 100% redd
Pinhead Creek 2	9/10/2019	B3AG	BuT	588636	4979657	220	90	bull trout pair on redd
Pinhead Creek 2	9/10/2019	B3AP	BuT	588630	4979654	160	95	classic redd
Pinhead Creek 2	9/10/2019	B4AP	BuT	588729	4979345	210	90	bull trout pair on redd
Pinhead Creek 2	9/10/2019	B1AP	BuT	588595	4979948	130	30	definite digging, distinct p/m, small mound
Pinhead Creek 2	9/10/2019	B1AG	BuT	588599	4979937	260	110	100%, clear p/m

Appendix I. Continued, page 3 of 3.

Stream/Reach	Date	Redd ID	Species	Easting	Northing	LN (cm)	WD (cm)	Description
Pinhead Creek 2	9/24/2019	C1AG	BuT	588688	4979460	60	40	fish on redd, just started digging, check next round
Pinhead Creek 2	10/7/2019	D2AG	BuT	588856	4979240	100	60	very small, clear p/m
Pinhead Creek 2	10/7/2019	D1AP	BuT	588555	4980038	90	50	very small, test dig?
Pinhead Creek 2	10/7/2019	D2AP	BuT	588643	4979657	100	60	BT redd
Pinhead Creek 2	10/7/2019	D1AG	BuT	588779	4979272	140	85	long redd, 100% bt redd
Pinhead Creek 2	10/7/2019	D4AP	BuT	588732	4979288	170	70	
Pinhead Creek 2	10/7/2019	D3AP	BuT	588740	4979344	190	100	large mound, 100%
Pinhead Creek 2	10/21/2019	E3AG	BuT	588837	4979252	130	70	right next to E4AP
Pinhead Creek 2	10/21/2019	E1AG	BuT	588545	4980223	140	100	75% certain bt redd
Pinhead Creek 2	10/21/2019	E2AG	BuT	588610	4979676	120	70	100% bt redd
Pinhead Creek 2	10/21/2019	E4AP	BuT	588837	4979252	100	50	next to E3AG
Clackamas River 3	9/25/2019	C1SS	CHK	587523	4973646	450	250	chk redd, 6 redd total within 120 m
Clackamas River 3	9/25/2019	C2SS	CHK	587628	4973749	600	300	chk redd
Clackamas River 3	10/23/2019	E4AG	CHK	587522	4973603	390	140	Chinook redd
Last Creek 1	11/4/2019	F1AP	CHK	588663	4980364	600	200	ChK redd, chk on redd
Last Creek 1	11/4/2019	F2AG	CHK	588733	4980360	450	110	ChK redd, chk near redd
Last Creek 1	11/4/2019	F3AG	CHK	588920	4980405	150	80	Chinook redd, smaller
Pinhead Creek 1	9/24/2019	C2AG	CHK	588099	4981732	430	150	chk redd? Ask ss
Pinhead Creek 1	9/24/2019	C2AP	CHK	588104	4981684	400	140	chk redd, chk on redd
Pinhead Creek 1	9/24/2019	C5AG	CHK	588371	4981210	290	130	chk on redd
Pinhead Creek 1	10/8/2019	D3JW	CHK	588428	4980984	350	150	Chinook sized redd
Pinhead Creek 1	10/8/2019	D3SS	CHK	588385	4981169	250	90	chk redd
Pinhead Creek 1	10/8/2019	D4SS	CHK	588417	4980998	170	130	chk redd
Pinhead Creek 1	10/22/2019	E1AP	CHK	588405	4980969	260	100	likely Chinook, on top of C8AP
Pinhead Creek 1	10/22/2019	E1SS	CHK	588383	4981329	120	70	old redd? Missed during prev surveys, still bright with ohv obscuring from view
Pinhead Creek 1	10/22/2019	E2AG	CHK	588457	4980851	310	90	big redd, bt sized gravel, maybe ChK
Pinhead Creek 1	10/22/2019	E3SS	CHK	588470	4980884	330	130	Chinook redd
Pinhead Creek 1	10/22/2019	E4AG	CHK	588118	4981667	350	90	chinook redd, superimposed on bt redd C1AG
Pinhead Creek 1	11/5/2019	F1AG	CHK	588464	4980503	180	70	ChK redd, 50/50 small for ChK but large gravel
Pinhead Creek 1	11/5/2019	F1AP	CHK	588385	4981150	300	150	50/50 probability, Chinook redd but Bull trout sized
Pinhead Creek 1	11/5/2019	F1JW	CHK	588392	4981131	300	70	ChK redd, bt sized gravel, 3 mounds w/in 3 m redd, maybe BuT redd
Pinhead Creek 1	11/5/2019	F1SS	CHK	588070	4981648	170	100	Chk redd/test
Pinhead Creek 1	11/5/2019	F2AG	CHK	588463	4980355	250	100	ChK redd
Pinhead Creek 1	11/5/2019	F3SS	CHK	588406	4981029	180	160	ChK redd/test
Pinhead Creek 2	11/4/2019	F2AP	CHK	588568	4980099	280	120	ChK redd, large pocket

Appendix II. Bull Trout eDNA detection results from surveys conducted from 2017 through 2019, page 1 of 2.

Stream	Easting	Northing	Date	Year	eDNA detection
Berry Creek	587272	4967459	Sep-27	2017	**Y**
Berry Creek	587147	4967345	Sep-27	2017	**Y**
Berry Creek	586533	4966636	Oct-17	2017	N
Berry Creek	585865	4965969	Oct-17	2017	N
Berry Creek	587187	4967388	Sep-26	2018	**Y**
Berry Creek	586570	4966645	Sep-26	2018	N
Berry Creek	585793	4965998	Sep-27	2018	N
Berry Creek	585144	4965177	Sep-27	2018	N
Berry Creek	586944	4967251	Jul-17	2019	N
Berry Creek	585862	4965962	Jul-17	2019	N
Clackamas River	590724	4969549	Oct-3	2017	**Y**
Clackamas River	591209	4969328	Oct-3	2017	**Y**
Clackamas River	593071	4969201	Oct-3	2017	**Y**
Clackamas River	592101	4969132	Oct-3	2017	**Y**
Clackamas River	593758	4968642	Oct-16	2017	**Y**
Clackamas River	594242	4968060	Oct-16	2017	**Y**
Clackamas River	589519	4969859	Sep-12	2018	**Y**
Clackamas River	588907	4970550	Sep-12	2018	**Y**
Clackamas River	590756	4969572	Sep-12	2018	**Y**
Clackamas River	593092	4969185	Sep-13	2018	**Y**
Clackamas River	592173	4969113	Sep-13	2018	**Y**
Clackamas River	593721	4968663	Oct-10	2018	**Y**
Clackamas River	594241	4968050	Oct-11	2018	**Y**
Clackamas River	594585	4967290	Oct-11	2018	**Y**
Clackamas River	595213	4966703	Oct-11	2018	**Y**
Clackamas River	587872	4972373	Jul-17	2019	N
Clackamas River	588621	4971035	Jul-18	2019	N
Clackamas River	589742	4969749	Aug-29	2019	**Y**
Clackamas River	591544	4969287	Aug-29	2019	N
Clackamas River	593598	4968816	Aug-29	2019	N
Clackamas River	593854	4968594	Sep-25	2019	N
Clackamas River	594254	4968268	Sep-25	2019	**Y**
Cub Creek	587295	4967320	Sep-27	2017	**Y**
Cub Creek	587625	4966384	Sep-27	2017	N
Cub Creek	587988	4965806	Sep-27	2017	N
Cub Creek	587375	4973078	Sep-13	2018	**Y**
Cub Creek	587945	4971244	Sep-26	2018	**Y**
Cub Creek	587795	4969116	Sep-26	2018	**Y**
Cub Creek	587301	4967353	Sep-26	2018	**Y**
Cub Creek	587543	4966466	Sep-26	2018	N
Cub Creek	587351	4973052	Jul-17	2019	**Y**
Cub Creek	587953	4971057	Jul-17	2019	N
Cub Creek	587906	4969984	Jul-17	2019	**Y**
Cub Creek tributary	587952	4970106	Sep-26	2018	N

Appendix II. Continued, page 2 of 2.

Stream	Easting	Northing	Date	Year	eDNA detection
Cub Creek tributary	587961	4970108	Jul-18	2019	N
Fish Creek	566283	4998679	Sep-27	2017	N
Fish Creek	566175	4998191	Sep-23	2019	N
Hunter Creek	586900	4973140	Sep-27	2018	**Y**
Hunter Creek	587374	4973386	Jul-18	2019	N
Hunter Creek	587277	4973272	Jul-18	2019	N
Last Creek	590710	4980835	Sep-27	2017	N
Last Creek	589843	4980592	Sep-27	2017	N
Last Creek	588969	4980412	Sep-27	2017	**Y**
Last Creek	590411	4980372	Sep-27	2017	**Y**
Last Creek	590678	4980824	Jul-16	2019	N
Last Creek	589166	4980473	Jul-16	2019	N
Last Creek	591199	4980904	Sep-25	2019	N
Lowe Creek	586580	4977901	Sep-27	2017	N
Lowe Creek	587488	4977535	Sep-27	2017	N
Lowe Creek	586619	4977864	Oct-10	2018	N
Lowe Creek	587494	4977511	Oct-10	2018	N
Oak Grove Fork	575959	4992430	Oct-3	2017	N
Oak Grove Fork	588191	4981536	Oct-3	2017	N
Oak Grove Fork	575259	4992189	Oct-11	2018	N
Oak Grove Fork	576575	4992393	Oct-22	2018	N
Oak Grove Fork	576063	4992378	Oct-22	2018	N
Oak Grove Fork	578080	4992736	Jul-18	2019	N
Oak Grove Fork	577984	4992532	Jul-18	2019	N
Oak Grove Fork	575897	4992343	Jul-18	2019	N
Pinhead Creek	589105	4977625	Sep-27	2017	N
Pinhead Creek	588596	4979978	Jul-17	2019	**Y**
Pinhead Creek	588960	4979120	Jul-17	2019	N
Pot Creek	586018	4985274	Sep-27	2017	N
Pot Creek	585749	4985113	Sep-27	2017	N
Rhododendron Creek	587050	4976708	Sep-27	2017	N
Rhododendron Creek	586439	4976420	Sep-27	2017	N
Rhododendron Creek	586996	4976703	Oct-9	2018	N
Rhododendron Creek	586659	4976546	Oct-9	2018	N
Roaring River	571088	5002002	Sep-27	2017	**Y**
Roaring River	569665	5001270	Sep-27	2017	**Y**
Roaring River	569999	5001328	Oct-22	2018	N
Roaring River	569524	5001062	Oct-22	2018	N
Roaring River	570712	5001732	Sep-23	2019	**Y**
Roaring River	570168	5001421	Sep-23	2019	**Y**

Appendix III. Bull Trout eDNA concentration in Pinhead Creek at three sites on dates corresponding to a range of adult numbers estimated to be present in the creek. Each sample filter was analyzed in triplicate (i.e., each reaction was 1/50th of whole filter), the mean number and standard deviation (SD) of eDNA copies per reaction was calculated, the mean was multiplied by 50 to calculate total copies per whole filter, and this total was standardize by dividing it by the number of liters (usually 5 L) of stream water drawn through filter. The number of adults present (N) in Pinhead Creek at the date of sampling was estimated using a combination of video, PIT tag, and trap data (see text for full description). Page 1 of 2.

					eDNA concentration (copies)		
Site	Easting	Northing	Date	Adults (N)	Mean per reaction	SD (reaction)	Mean per L (filtered)
PIN1	588172	4981503	10/30/2017	0	0	0	0.0
PIN1	588172	4981503	10/30/2017	0	0	0	0.0
PIN1	588172	4981503	10/30/2017	0	0.3	0.3	3.1
PIN1	588172	4981503	10/30/2017	0	9.4	4.5	93.8
PIN1	588194	4981530	5/30/2018	0	0	0	0.0
PIN1	588194	4981530	5/30/2018	0	0.2	0.3	1.8
PIN2	588563	4980257	10/30/2017	0	0	0	0.0
PIN2	588563	4980257	10/30/2017	0	0	0	0.0
PIN2	588563	4980257	10/30/2017	0	0	0	0.0
PIN2	588563	4980257	10/30/2017	0	0.2	0.3	1.6
PIN2	588563	4980257	5/30/2018	0	0.4	0.4	4.4
PIN2	588563	4980257	5/30/2018	0	0.5	0.5	4.7
PIN3	588694	4979434	10/30/2017	0	0.3	0.5	2.6
PIN3	588694	4979434	10/30/2017	0	0.5	0.6	5.5
PIN3	588694	4979434	10/30/2017	0	0.7	0.6	7.1
PIN3	588694	4979434	10/30/2017	0	3.8	1	37.6
PIN3	588694	4979434	5/30/2018	0	0	0	0.0
PIN3	588694	4979434	5/30/2018	0	8.2	2.1	82.4
PIN1	588191	4981536	10/2/2017	4	31.5	6.9	315.3
PIN1	588191	4981536	10/2/2017	4	41.8	5	418.2
PIN1	588191	4981536	10/2/2017	4	46.2	5	462.3
PIN1	588191	4981536	10/2/2017	4	111	0.8	1109.9
PIN3	588694	4979434	10/2/2017	4	0.2	0.3	1.9
PIN3	588694	4979434	10/2/2017	4	0.7	0.1	7.3
PIN3	588694	4979434	10/2/2017	4	1.6	1.1	16.3
PIN3	588694	4979434	10/2/2017	4	16.8	2	168.0
PIN2	588563	4980257	10/3/2017	8	15.2	4.4	152.5
PIN2	588563	4980257	10/3/2017	8	40.3	9.6	403.3
PIN2	588563	4980257	10/3/2017	8	106.5	10.4	1064.9
PIN1	588189	4981524	8/27/2018	31	76.2	16.6	761.7
PIN1	588189	4981524	8/27/2018	31	224.6	13.4	2245.9
PIN2	588558	4980272	8/27/2018	31	30.8	1.8	308.3
PIN2	588558	4980272	8/27/2018	31	109.2	9.4	1091.9
PIN3	588694	4979434	8/27/2018	31	50.7	4.5	507.3
PIN3	588694	4979434	8/27/2018	31	59.5	5.7	594.8
PIN2	588563	4980257	9/19/2017	38	724	39.4	7240.2

Appendix III. Continued, page 2 of 2.

Site	Easting	Northing	Date	Adults (N)	eDNA concentration (copies) Mean per reaction	SD (reaction)	Mean per L (filtered)
PIN3	588694	4979434	9/19/2017	38	167.3	7.7	1673.4
PIN3	588694	4979434	9/19/2017	38	224.3	6.8	2242.9
PIN1	588194	4981530	9/18/2017	40	923.8	39.3	9237.5
PIN1	588194	4981530	9/18/2017	40	956.6	30.2	9566.3
PIN1	588194	4981530	9/18/2017	40	1226.2	33.9	12262.2
PIN1	588194	4981530	9/18/2017	40	2000.8	54.8	20007.8

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