U.S. Fish and Wildlife Service

Estimating the Abundance of Adfluvial Bull Trout Spawning in Cougar Creek

2022 Final Report

Marshall G. Barrows, Julianne E. Harris and William G. Simpson

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

On the cover: *Adult male Bull Trout as it moved upstream through the Cougar Creek video weir near Cougar, WA (screen capture from video by Marshall Barrows, FWS).*

The correct citation for this report is:

Barrows, M.G., J.E. Harris and W.G. Simpson. 2023. Estimating the Abundance of Adfluvial Bull Trout Spawning in Cougar Creek, 2022 Final Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

ESTIMATING THE ABUNDANCE OF ADFLUVIAL BULL TROUT SPAWNING IN COUGAR CREEK 2022 FINAL REPORT

Funding provided by

PacifiCorp

Conducted pursuant to

Section 7 of the Endangered Species Act of 1973
Sec. 9.6.2 of the Lewis River Settlement Agreement
Sec. 2.17, Objective 17 of the Lewis River M&E Plan

and authored by

Marshall G. Barrows, Julianne E. Harris and William G. Simpson

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

September 29, 2023

Disclaimers

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

ESTIMATING THE ABUNDANCE OF ADFLUVIAL BULL TROUT SPAWNING IN COUGAR CREEK
2022 FINAL REPORT

Marshall G. Barrows, Julianne E. Harris and William G. Simpson

U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office, Vancouver, WA

Abstract – In response to a general decline in abundance across their native range, Bull Trout (*Salvelinus confluentus*) were listed as threatened under the Endangered Species Act in 1999. Gaining a better understanding of the reproductive component of a population is important for Bull Trout recovery and persistence. Accurately monitoring the trend in abundance of spawners is essential to inform future management actions that may affect populations in the North Fork Lewis River subbasin. To estimate the abundance of the adfluvial Bull Trout spawning population, a resistance board weir and underwater video system were operated on Cougar Creek, a tributary to Yale Reservoir on the North Fork Lewis River, from July 25, 2022 through November 2, 2022. Forty observations of adults moving upstream through the weir were recorded from late-July through late October, with the peak occurring in late-September. Most of the Bull Trout observed were relatively large, migratory fish. However, smaller migratory adults and subadults were observed as well. Individual Bull Trout were documented passing the weir multiple times both upstream and downstream, which would overestimate the true population size if only upstream observations were simply enumerated. To address this concern, we used PIT tag detections in addition to a photo-identification technique to allow recognition of individuals based on natural marks, such as colors, spots, scars, and fin shapes and to estimate the number of individuals that passed upstream of the weir. The estimated total number of spawning Bull Trout that moved upstream through the Cougar Creek weir during 2022 was 32 (95%: 29 – 34). The estimated number of unique females and males that moved upstream through the weir was 25 (95%: 22 – 36) and 8 (95%: 6 – 8), respectively. These data, combined with a redd count of 23 during 2022, result in a spawner/redd ratio of 1.4. During this four-year monitoring effort (2020 – 2022), yearly spawning population estimates ranged from 32 – 76 and spawner/redd ratios ranged from 1.3 – 4.0.

Page intentionally left blank

Table of Contents

List of Tables

List of Figures

Introduction

Bull Trout (*Salvelinus confluentus*) are native to the Pacific Northwest, but a general decline in abundance across their native range compelled 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 require complex, connected habitat characterized by clean and cold water (Rieman and McIntyre 1995; Baxter and McPhail 1996; USFWS 2015). Habitat degradation, migration barriers (e.g., dams), the introduction of non-native species, and other anthropogenic actions have negatively affected Bull Trout populations (Fraley and Shepard 1989; Leary et al. 1993; Barrows et al. 2016). When Bull Trout were listed in 1999, they were estimated to occupy only 40 percent of their historical range (USFWS 2002).

New operating licenses for the Lewis River hydroelectric projects were issued by the Federal Energy Regulatory Commission (FERC) during 2008. Subsequently, an Aquatic Monitoring and Evaluation Plan (M&E Plan) for the Lewis River was developed and first implemented in 2010. The original M&E Plan has recently been evaluated and rewritten (PacifiCorp and Cowlitz County PUD 2017). New Bull Trout monitoring mandates were established and integrated into the Annual Operating Plan (AOP). Multiple programs and associated tasks were proposed for action under the AOP. One such task was to estimate the number of adult Bull Trout present in known spawning locations (i.e., Pine Creek, Rush Creek and Cougar Creek).

Bull Trout populations often exhibit a continuum of life histories involving movements, migrations, spawning, rearing and foraging over a wide range of time and spatial scales (Schaller et al. 2014). Successful monitoring of Bull Trout populations requires a sufficient understanding of these characteristics and is essential to inform future management actions that may affect populations in the North Fork Lewis River subbasin. The ability to accurately monitor the trend in abundance of the reproductive component of a population is exceedingly important in Bull Trout recovery efforts (Al-Chokhachy et al. 2005). Cumulative redd counts are commonly used to monitor spawning populations due to their relatively low cost and time effectiveness when compared to other methods. However, observer variability and other factors including turbidity, habitat complexity and streamflow can reduce accuracy (Maxell 1999; Al-Chokhachy et al. 2005).

This report discusses the suitability of the weir location and design for sampling in Cougar Creek and summarizes the results of operating a video weir to estimate the adfluvial Bull Trout spawning population in Cougar Creek during 2022. The relationship between the population estimate resulting from the video weir, and 2022 redd counts, were used to estimate the spawner to redd ratio in Cougar Creek and may be used to help evaluate other spawning Bull Trout populations in the subbasin (i.e., those in Pine and Rush creeks).

Study Area

The study area includes Cougar Creek, a tributary to Yale Lake, which is the second of three reservoirs formed by hydroelectric dams owned and operated by PacifiCorp and Cowlitz Public Utilities District (PUD) on the North Fork Lewis River (Figure 1). The subbasin is located on the western slopes of the Cascade Mountains, southwest of Mount St. Helens National Volcanic Monument in southwest Washington. Cougar Creek emerges from a lava tube and flows approximately 2.1 river kilometers (rkm), draining a 10.4 square kilometer watershed before entering the reservoir (Stevens 1910; Doyle 2018) (Figure 2). Cougar Creek is the only tributary of Yale Reservoir where Bull Trout spawning is known to occur. There are two other known Bull Trout populations in the Lewis River subbasin, both of which are upstream of Swift Dam in Pine and Rush creeks (Figure 1). Only the adfluvial life history has been documented in the Lewis River populations and each is genetically distinct (DeHaan and Adams 2011; Hudson et al. 2019). Occasionally, migratory Bull Trout are captured by recreational anglers targeting the kokanee salmon and resident trout populations in Yale Reservoir, but retention of Bull Trout is prohibited (reviewed in Hudson et al. 2019).

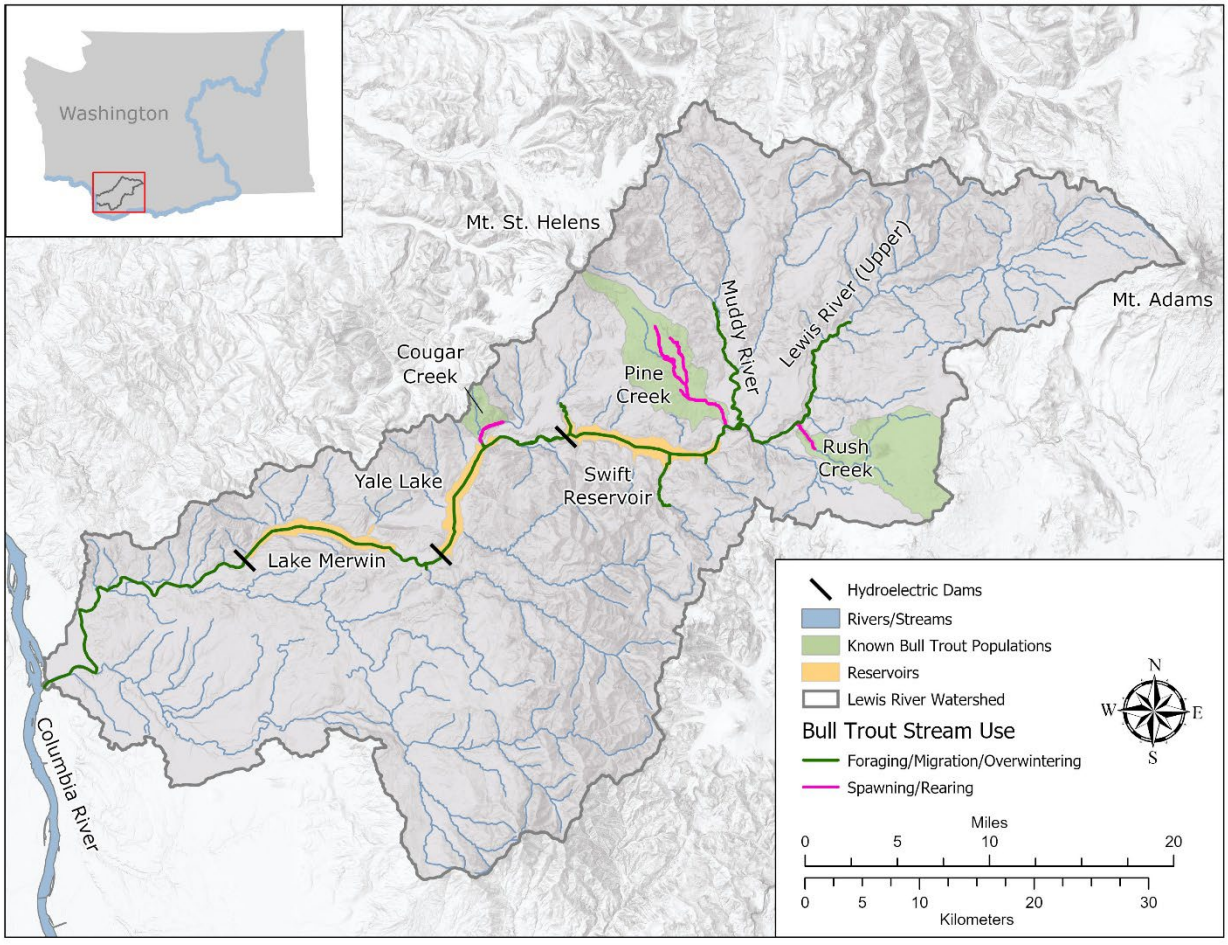


Figure 1. Bull Trout distribution in the Lewis River subbasin.

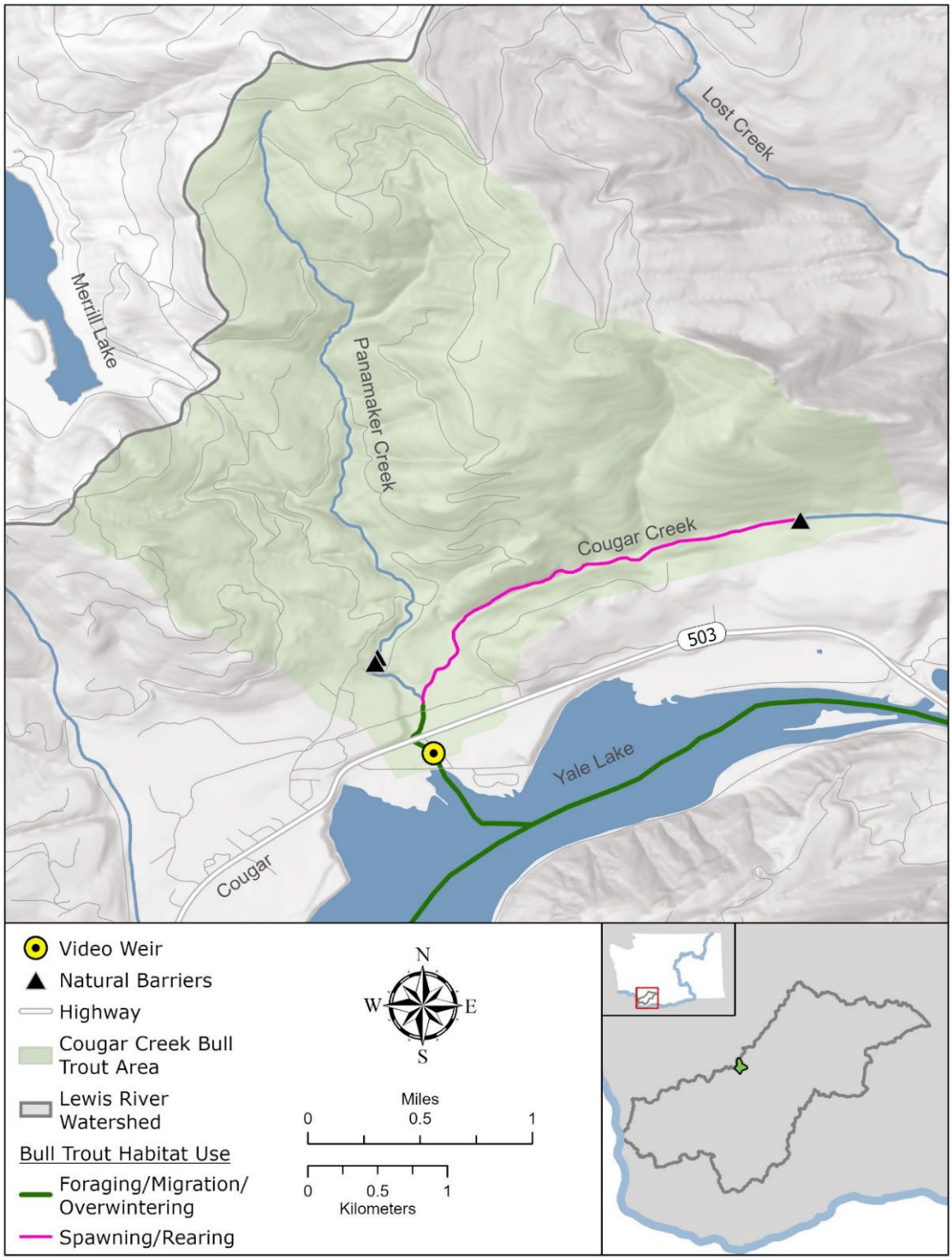


Figure 2. Location of the video weir within the study area. Multiple PIT monitoring were located both upstream and downstream from the weir site in Cougar Creek during 2021.

Methods

The goal of this project was to monitor and assess the Bull Trout spawning population in Cougar Creek. The primary objective was to estimate the number of Bull Trout spawning in Cougar Creek. This objective was initially addressed in 2019 by operating a two-way fixed- picket weir and underwater video system. The weir was installed approximately 200 meters upstream from the mouth (Figure 2). An important component of this effort was to determine the suitability of the weir location and design for sampling in Cougar Creek. Since high debris and elevated streamflows beginning in late September 2019 made operating this type of weir challenging (Barrows et al. 2020), the design was altered in 2020 to incorporate resistance board weir panels that were better at accommodating higher seasonal flows and debris (Barrows 2021). As a result, the modified design incorporating resistance board weir panels was used in the remaining years of the study (2021 and 2022).

Weir Location, Design Suitability and Passage

A video weir to monitor Bull Trout in Cougar Creek had not been used prior to this project. Locating a reasonable site, designing a functional weir, and evaluating the suitability of the method for future monitoring were important aspects of this effort. We consider a functional weir to be one that efficiently allows Bull Trout to pass both upstream and downstream through the video chute during various flows and conditions. Accessibility is limited for most of the stream except for the lowest portion, which is heavily used for recreation (e.g., camping, swimming). In 2019, we chose to install the weir at a location approximately 200 m from Cougar Creek's mouth. The weir site was easily accessible, and no vandalism occurred. In addition, no redds were observed downstream of the weir location during 2019, suggesting the site was located below the Bull Trout spawning grounds in Cougar Creek. For these reasons, we reused the same site for the weir in 2020 and 2021. Due to streambed changes and erosion resulting from portions of the weir that were left to overwinter in the creek, we relocated the weir approximately 30 m upstream for the 2022 monitoring season.

In 2019, the weir design closely resembled an aluminum picket weir used to estimate the spawning Bull Trout population in the Clackamas River subbasin, Oregon (Barrows et al. 2018, 2019). This design worked well prior to the onset of high streamflows and debris loads in October. In an effort to better accommodate the adverse conditions, channel-spanning resistance board weir panels were incorporated in 2020 (Figure 3). The camera chamber, video chute and picket leads were fabricated out of aluminum and of sturdy construction to withstand elevated streamflow and debris. This design proved to handle high flows and increased debris loads better than the previously used design, prompting its use in the remaining years of the study (2021 and 2022).

Figure 3. Photo depicting the aluminum picket leads, resistance board weir panels, video chute and camera chamber deployed in Cougar Creek.

The video chute and attached camera chamber were positioned on river right and picket leads were angled to funnel fish to the chute (Figure 3). Fish were able to move in either direction through the monitored video chute. The picket leads were constructed using schedule 40 aluminum pipe strung together with two ⅜ inch cables with ¾ inch PVC spacers between each picket. T-posts were secured into the substrate to support the leads, and additional T-posts were installed at an angle to provide support from water pressure. Sandbags were placed along the bottom of each of the leads and along the banks to make the weir fish-tight to adult Bull Trout. Resistance board weir panels spanned the center of the stream between two plywood bulkheads. The weir panels blocked passage and forced adult fish to find the video chute to pass.

The design for the underwater video system closely resembled that of Barrows et al. (2018, 2019, 2020) on Pinhead Creek near Estacada, Oregon. A full HD (1920 x 1080P) stainless steel bullet camera with a Sony Exmor CMOS image sensor with a 3.6-mm megapixel lens and three 12-V LED fountain lights were mounted inside a sealed video chamber made of aluminum sheeting and attached to the video chute (Figure 4). A pane of safety glass was sealed to the camera chamber to form the interface between the chamber and the video chute. The camera chamber was filled with water to provide clear viewing into the video chute. The backdrop inside the video chute was constructed with white plastic secured to plywood. Video images were recorded on a Paramont DVR from InVid Technologies (model: PD1A-42TB) with four channels and two TB of memory. The DVR was equipped with motion detection to record all fish activity. A color monitor was used to review video footage when in the field and the office. The AC power source at the weir site was provided by PacifiCorp.

Figure 4. Photo depicting the camera chamber (left) and video chute (right).

The Cougar Creek weir, by design, funnels migrating Bull Trout through a small passageway (i.e., video observation chute). The weir itself, or the constricted passageway could deter or delay migrating fish from reaching their spawning grounds. To address this concern, PacifiCorp installed six Biomark 1.53 m diameter IS1001 fully submersible PIT tag detection antennas both upstream and downstream of the weir at pinch points within the thalweg where fish detection was probable (Figure 5). A channel-spanning PIT antenna powered by a Biomark IS1001 Master Controller and IS1001 Reader was added to the upstream entrance of the video chute to monitor passage and enhance the identification of individual Bull Trout. We examined detection histories of PIT-tagged Bull Trout to determine upstream weir passage (i.e., conversion) rates. The number of times each unique individual passed upstream of the weir was also recorded.

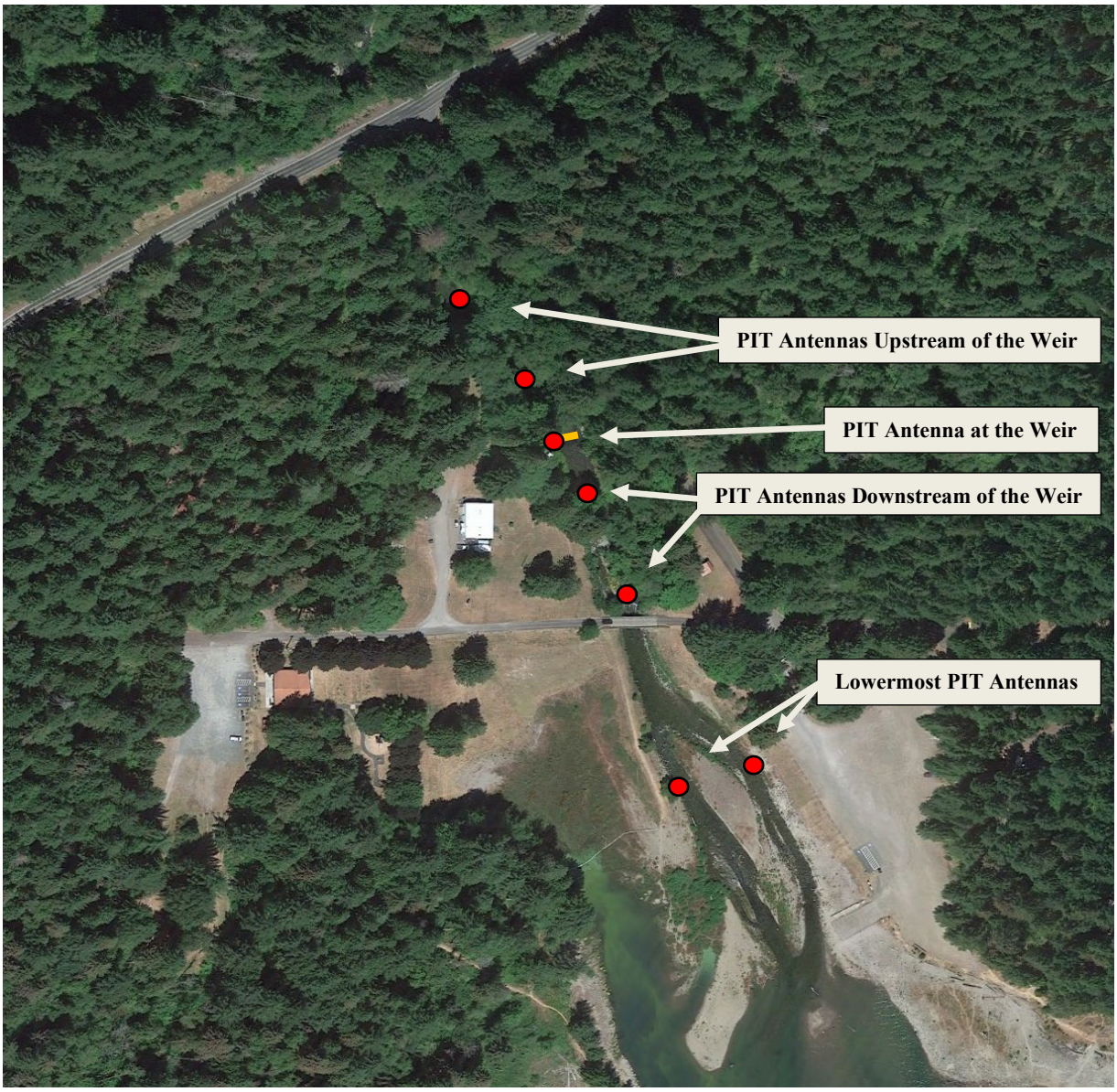


Figure 5. Aerial photo depicting locations of PIT antennas in Cougar Creek upstream and downstream of the weir during 2022 (Google Earth imagery date: July 25, 2021).

Spawning Population Estimate

The spawning population of Bull Trout in Cougar Creek was estimated as the number of unique adults (i.e., Bull Trout with fork lengths > 550 mm) that moved upstream through the video weir during the spawning season. Bull Trout may move upstream and downstream through a video weir multiple times during a spawning season (Barrows et al. 2018, 2019, 2020). Since some individuals pass through the weir multiple times, the total number of Bull Trout observed overestimates the true population size; thus, it was necessary to estimate the number of unique individuals that passed the video weir. We used two methods to identify individual Bull Trout, PIT detections at the weir antenna and the distinguishing features of fish observed on the video.

PIT tags have been used to identify individual Bull Trout moving through video weirs (Barrows et al. 2018, 2019, 2021). In 2022, PacifiCorp biologists PIT-tagged one adult Bull Trout in the bypass channel at the head of Yale reservoir prior to the spawning season. PacifiCorp had also PIT-tagged 16 and 3 Bull Trout in the bypass channel in 2020 and 2021, respectively. A portion of the fish tagged during those years were expected to survive to be detected in subsequent seasons (i.e., 2022). There were also an unknown number of remnant PIT-tagged individuals in the population resulting from previously conducted studies in the system (J. Doyle, personal communication, 2021). Timestamps allowed PIT detections to be assigned to video footage of tagged adult Bull Trout during passage. However, since the majority of individuals in the Cougar Creek population are not PIT-tagged, we used distinguishing features (such as color variation, spots, scars, fin shapes, and size) to differentiate between most individuals. Similar techniques have been successfully used to distinguish individuals in studies of various other fish species (Bachman 1984; Marshall and Pierce 2012; Giglio et al. 2014; Dala-Corte et al. 2001).

Sexual dimorphism in Bull Trout may be more obvious during the reproductive period and less clear during non-reproductive periods in some populations (Nitychoruk et al. 2013). Experienced biologists used phenotypic characteristics including body form, head shape, jaw characteristics and coloration to categorize fish as male or female. To estimate numbers of spawning male and female Bull Trout in Cougar Creek in 2022 from total counts of fish passing the weir, we needed to account for individuals that passed the weir more than once (individuals passed 1-3 times). We accomplished this by examining video images of males and females at the weir for the presence of naturally distinguishing characteristics, such as color variation, spots, scars, and distinct fin shapes. Those with distinguishable characteristics or PIT tags were categorized as marked males or marked females. To estimate the spawning population, we made four notable assumptions. First, we assumed detection of Bull Trout passing the weir was 100%. Second, we assumed marks were not gained or lost during the season. Third, we assumed marks were always correctly detected. Fourth, we assumed no difference in passage behavior between marked and unmarked fish at the weir.

We used data on the number of marked individuals (M; defined as Bull Trout with PIT tags or untagged fish with distinct visual characteristics), the number of observations of marked individuals (m), and the number of observations of unmarked individuals (u), to estimate the total number of unmarked individuals ($\widehat{U}$) and the total number of spawning individuals ($\widehat{N}$). Since all fish were identified as either male or female, we estimated the total numbers of males and females separately using the same analysis method (described below). Separate estimates of males and females helped to better assess the spawning population and potentially increased accuracy, since females passed the weir more times than males. First, we estimated the proportion of the observations of marked fish that were unique individuals ($\hat{p}$):

$$M \sim Binomial\ (\hat{p}, m)$$

We then used this proportion to estimate the number of unique unmarked individuals ($\widehat{U}$) expected to produce the counted number of unmarked observations:

$$\widehat{U} \sim Binomial\ (\hat{p}, u)$$

The total number of individuals ($\widehat{N}$) was then estimated as a combination of marked and unmarked fish:

$$\widehat{N} = M + \widehat{U}$$

The total number of spawning adults was estimated by summing the number of spawning females and the number of spawning males.

Models were analyzed by Bayesian methods using JAGS software (Plummer 2003) called from Program R (R Core Team 2013). We used package jagsUI (Kellner, 2018), three chains, adaption and burn-in values of 5,000, an iteration interval of 20,000, and saved enough iterations to meet convergence (Rhat scores <1.1 for all estimated parameters; Gelman & Hill, 2007; Kéry & Schaub, 2012). Medians the posterior distributions were reported for estimated parameters, along with 95% credible intervals ("95%") to describe variability. We used an uninformative uniform prior (range 0-1) to estimate $\hat{p}$ for both males and females.

Results

Weir Location, Design Suitability and Passage

Streambed changes and erosion resulting from portions of the weir that were left to overwinter in the creek prompted our decision to relocate the weir approximately 30 m upstream from where the weir had been successfully operated from 2019 – 2021. The suitability of the new site for operating a resistance board weir was qualitatively evaluated based on sampling results and observations throughout the season. As in past seasons, the selected location was near the mouth of Cougar Creek, ensuring most Bull Trout would spawn upstream of the weir. During surveys, Pacificorps biologists did not observe any Bull Trout redds constructed downstream from the weir during 2022, suggesting all of the spawners in the system moved past the weir to upstream spawning grounds.

Water depth was low throughout the summer months, requiring dam boards to be installed downstream of the weir to increase depth at the video chute. During October, rainfall events and leaf-fall increased, and required frequent cleaning, but there was no damage to the leads or weir panels. Toward the end of the monitoring season, there were infrequent, short timeperiods (i.e, hours) where the weir panels were overtopped. However, it was unlikely that Bull Trout passed upstream of the weir site un-monitored.

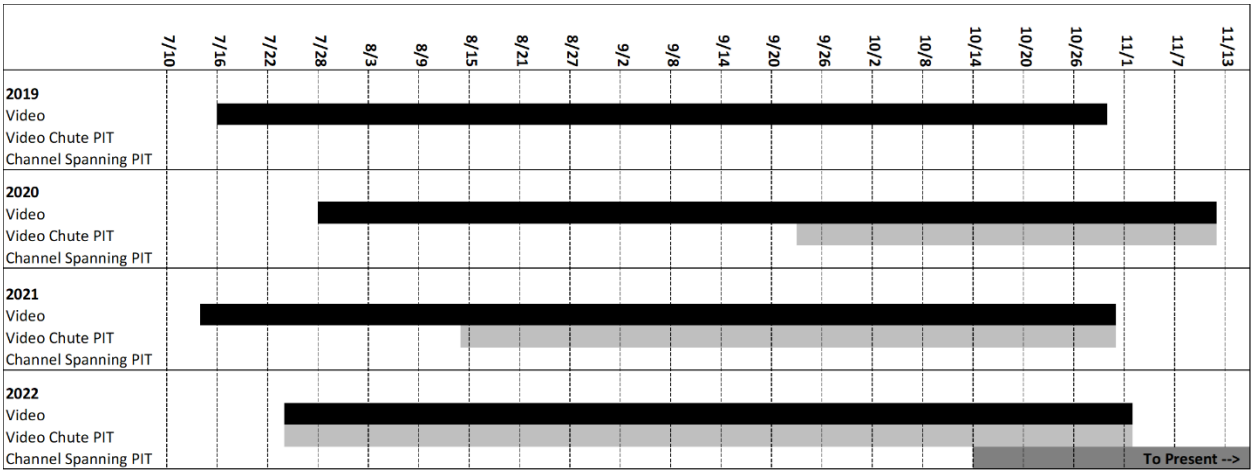
An analysis of video observations and detections revealed that nine PIT-tagged adult Bull Trout were detected in Cougar Creek during 2022. All nine PIT-tagged adults were detected downstream of the weir and moved upstream through the video chute at least once. The overall conversion rate for Bull Trout was 100%. Some fish were not detected continuing upstream after being detected at PIT antennas downstream of the weir, but instead moved back downstream (probably to the reservoir) before moving above the weir at a later date. Similarly, some fish that had previously passed upstream of the weir, moved back downstream of the weir before returning upstream to presumably spawn. Twenty-six unique individual Bull Trout passed upstream of the weir a total of 32 times, an average of 1.2 times per individual (range: 1 – 3).

Spawning Population Estimate

The Cougar Creek video weir was installed on July 25, 2022 and fish passing the weir were continuously monitored via video from July 25, 2022 to November 2, 2022. A PIT detection antenna was installed on the upstream entrance to the video chute to enhance the identification of individual Bull Trout. An instream PIT antenna was also installed on October 13, 2022 (Figure 6). Cougar Creek weir operation periodicity from 2019 through 2022 is summarized in Table 1.

Figure 6. Instream PIT antenna that was installed just upstream from the Cougar Creek video weir on October 13, 2022.

Table 1. Cougar Creek weir operation periodicity table from 2019 through 2022.



During 2022, there were a total of 40 video observations of adult Bull Trout passing upstream of the Cougar Creek video weir (Table 2). There were also a minimum of 734 upstream

observations of Kokanee Salmon (*Oncorhynchus nerka*) recorded at the weir since they were not consistently enumerated later in the season due to time constraints. There were also 18 upstream observations of adult Chinook Salmon (*Oncorhynchus tshawytscha*) and 214 upstream observations of Coho Salmon (*Oncorhynchus kisutch*) (Figure 7). The Coho Salmon observed at the weir were a portion of the 1801 adults that were released into Yale Reservoir as part of the Yale Habitat Preparation Plan (J. Doyle, personal communication, 2022). Juvenile Bull Trout, Mountain Whitefish (*Prosopium williamsoni*), Rainbow Trout (*Oncorhynchus mykiss*), Coastal Cutthroat Trout (Oncorhynchus clarkii clarkii) and adult Chinook Salmon (*Oncorhynchus tshawytscha*) were also occasionally observed throughout the season. It is important to note that the 25.4 mm spacing between the PVC pickets of the weir panels allowed smaller fish (e.g., juvenile fish and smaller Kokanee Salmon) to pass the weir unmonitored.

Table 2. Upstream video observations of adult Bull Trout and salmon at the Cougar Creek video weir from 2019 – 2022.

Species	Sex	2019	2020	2021	2022
Bull Trout	Male	43	15	17	10
Bull Trout	Female	50	21	49	30
Chinook Salmon	NA	1	2	2	18
Coho Salmon	NA	0	0	0	214
Kokanee Salmon	NA	7,197	8,190	1598*	734*

*Incomplete count

Figure 7. Examples of Bull Trout (upper left), Coho Salmon (upper right), Chinook Salmon (lower left) and Kokanee Salmon (lower right) observed moving upstream through the Cougar Creek video weir during 2022.

The first observation of a Bull Trout moving upstream through the video weir was on July 28, 2022. Upstream observations were sparse until mid-August when observations at the weir notably increased (Figure 8). Upstream observations of male and female Bull Trout remained steady from late August through the end of September (Figure 9). Bull Trout continued to move upstream past the weir until October 15, 2022. Spring Chinook Salmon passed upstream of the video weir from mid-August through mid-September. Kokanee and Coho salmon were both first observed moving into Cougar Creek past the video weir in late September. Upstream observations of Coho Salmon peaked in mid-October and fish continued being observed moving upstream until the weir was removed in early November. Additional information regarding PIT-detections of Coho Salmon in Cougar Creek is provided in Appendix A. The migration timing of Bull Trout and Kokanee Salmon into Cougar Creek was similar to previous years. However, many more adult Chinook Salmon were observed than in past seasons. No Coho Salmon had entered Cougar Creek during years prior to the 2022 releases.

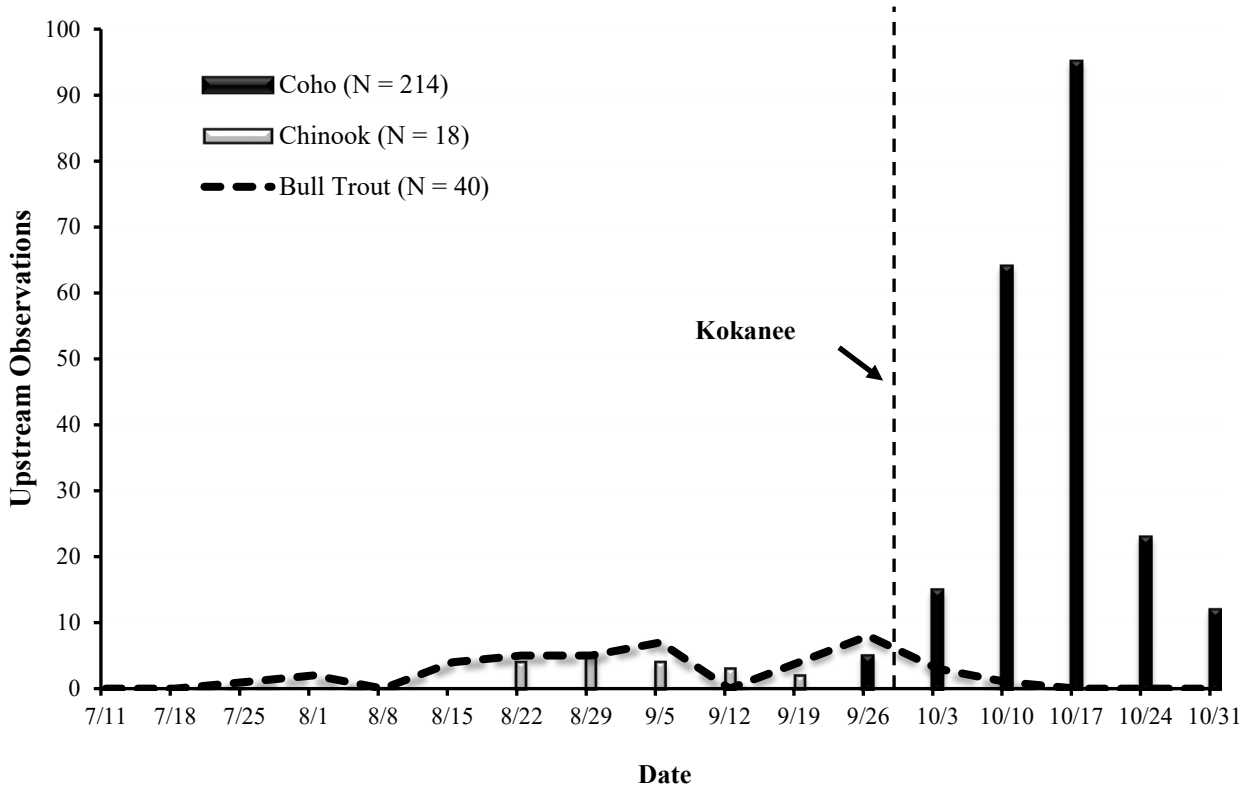


Figure 8. Observations of adult Bull Trout, Chinook Salmon and Coho Salmon moving upstream through the video chute at the Cougar Creek weir during 2022. The dashed vertical line indicates when Kokanee Salmon began moving through the weir.

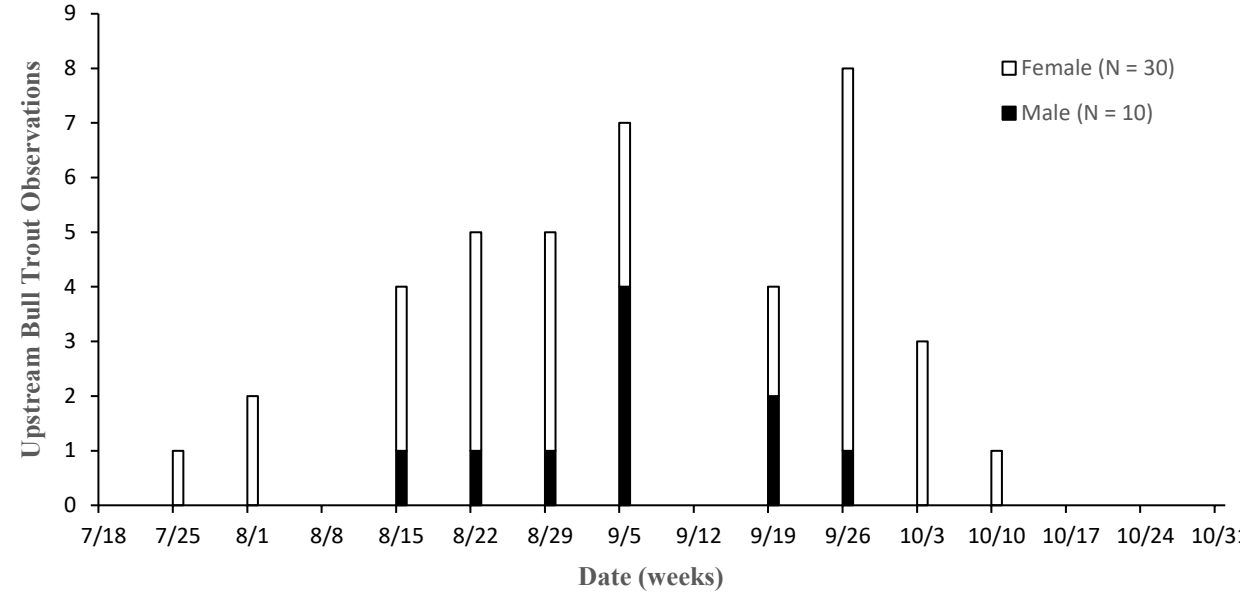


Figure 9. Observations of male and female Bull Trout moving upstream through the video chute at the Cougar Creek weir during 2022.

There were nine adult Bull Trout that that were detected at PIT antennas in Cougar Creek, of which all nine were detected or observed moving through the video chute. Following a thorough, systematic review of the 40 upstream observations of adult Bull Trout at the video weir to identify individuals and the associated PIT detections, we observed 20 marked females a total of 24 times, and 6 observations were made of unmarked females. The estimated number of unique females in the population was 25 (95%: 22-26). At the weir, we observed six marked males a total of 8 times, and we made two observations of unmarked males. The estimated number of spawning males was 8 (95%: 6-8). The total number of spawning adults that moved through the video weir was estimated as 32 (95%: 29-34). Distributions for the estimated number of unique females and the estimated number of unique males were both left skewed (i.e., the left tail was longer than the right tail, making the median larger than the mean). This was especially pronounced for the distribution of the estimated number of unique males, which was based on a small sample size. Since there was left skew and an estimate of the total number of spawning adults through the weir was made within each run of the model by summing the estimated number of males and the estimated number of females in that run, the median of the distribution for the estimated total (i.e., 32) was slightly smaller than what would be obtained by simply adding the medians of the distributions for the estimated number of females (i.e., 25) and the estimated number of males (i.e., 8). We suggest that the estimate of the total population observed at the weir be considered along with its associated error; the estimate for the total number of individuals was between 29 and 34.

In 2022, there were 23 Bull Trout redds counted in Cougar Creek (J. Doyle, personal communication, 2022). This was considered to be a complete count due to a lack of high water events that had resulted in incomplete redd counts during 2021 and 2019 (Table 3). These data suggest a spawner/redd ratio of 1.4. During the four years of this study, redd counts ranged from 11 – 27 and spawner/redd ratios ranged from 1.3 – 4.0.

Table 3. Estimated Bull Trout spawner/redd ratios from 2019 - 2022.

Year	Population Estimate	Redd Count	Spawner/Redd Ratio
2022	32	23	1.4
2021	42	11	3.8
2020	34	27	1.3
2019	76	19	4.0

Findings

The effort during 2022 to estimate the spawning population with a video weir was another important step toward improving monitoring efforts in Cougar Creek. The combined findings from this four-year monitoring effort (2019 – 2022) will inform interpretation of past and future

redd counts in Cougar Creek and throughout the Lewis River subbasin. The following are summarized findings from 2020 through 2022.

The spawning population estimate of 32 adults in 2022 was similar to our 2020 and 2021 estimates of 34 and 42, respectively. There may be several factors contributing to the interannual differences in the spawning population estimates including survival, recruitment and the accuracy of the estimates themselves. Estimates from 2020 through 2022 were notably lower than the 2019 estimate of 76. It is difficult to make inferences concerning population trends with only four estimates; however, the spawning population in Cougar Creek appears to be relatively small and stable since 2020. Despite general stability in the total number of spawners each year, the percentage of individual males in the population appears to be trending downward. The percentage of males in the population decreased during each year of the study from a high of 46% in 2019 to 25% in 2022. This yearly increase in disparity between the percentage of males and females was notable and may indicate a trend.

We estimated spawner/redd ratios to be 1.4, 3.8, 1.3 and 4.0 in 2022, 2021, 2020 and 2019, respectively. Studies have recorded spawner/redd ratios ranging from 1.2 to as high as 4.3 (Baxter and Westover 2000; Barrows et al. 2019; Taylor and Reasoner 2000; Al-Chokhachy et al. 2005). While our spawner/redd ratio was within this reported range during all four years of this study, values differed substantially between years in Cougar Creek. There are several factors potentially contributing to these interannual differences in the relationship of adult counts to redd counts, including measurement error in both counts (Howell and Sankovich 2012). In this study, errors in the population estimate and redd counts may have affected the estimated spawner to redd ratio. Elevated flows in October likely affected the accuracy of redd counts during 2021 and 2019. There were no consequential flow events in 2020 and 2022 during the spawning season, therefore we believe the population estimates, redd counts and the resulting spawner/redd ratios (i.e., 1.3 and 1.4, respectively) for those years are the most accurate.

During all four years of the study, the majority of Bull Trout observations at the Cougar Creek video weir were of adult fish and occurred in late summer and early fall, suggesting most of the fish entering the tributary were doing so to subsequently spawn. However, a small portion of the Bull Trout observed on video were subadult-sized (< 550 mm) and juveniles that likely were using Cougar Creek for rearing and foraging habitat.

From 2019 through 2022, thousands of kokanee salmon moved upstream past the video weir beginning in mid-September. This run continued past weir removal in November each year. Obtaining accurate kokanee counts during 2021 and 2022 was deprioritized due to time constraints and the fact that an unknown portion of the fish were small enough to pass through the weir panels unmonitored. Any future efforts could consider the use of machine learning software to locate adult Bull Trout in the video footage to facilitate the video review process when high numbers of kokanee are present.

The combination of using PIT detections and photo-identification at the video weir proved to be an effective method to identify fish as individuals during this study. Marking fish with PIT tags is a time-tested method for identifying individuals, however, if the number of PIT-tagged fish in the population is lower or absent, photo-identification of individuals is a serviceable alternative.

Monitoring in 2022 was the fourth (and final) year of operating a Bull Trout video weir in Cougar Creek. It marked the third season of incorporating resistance board weir panels to the design. The addition of weir panels allowed for successful operation of the weir from the 2020 to 2022 spawning seasons. The panels allowed the weir to better accommodate the higher late-season streamflows and debris loads. We strongly recommend that future efforts to monitor Bull Trout via weir in Cougar Creek (or similar spawning tributaries) incorporate resistance board panels in the design.

Acknowledgments

We would like to thank and acknowledge the following individuals for their assistance in planning, implementation, document review and monitoring efforts: Jeremiah Doyle, Andrea Houts, Mike Hudson, Paul Sankovich, Brian Davis, Will Simpson, Jamie Sprando, Karisma Sexton, Rachel Rule, Hayato Murai, Nate Queisser, Tim Blubaugh, and Tim Whitesel.

Literature Cited

Al-Chokhachy, R., P. Budy and H. Schaller. 2005. Understanding the Significance of Redd Counts: a Comparison between Two Methods for Estimating the Abundance of and Monitoring Bull Trout Populations. North American Journal of Fisheries Management 25:1505–1512.

Bachman, R.A. 1984. Foraging Behavior of Free-Ranging Wild and Hatchery Brown Trout in a Stream. Transactions of the American Fisheries Society. 113 (1-32).

Barrows, M.G., D.R. Anglin, P.M. Sankovich, J.M. Hudson, R.C. Koch, J.J. Skalicky, D.A. Wills and B.P. Silver. 2016. Use of the Mainstem Columbia and Lower Snake Rivers by Migratory Bull Trout. Data Synthesis and Analyses. Final Report. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA.

Barrows, M. G., M. B. Davis, J. M. Hudson, R. K. Sholes, C. E. Davies and S. Fitzmaurice. 2018. Clackamas River Bull Trout Reintroduction Project, 2017 Annual Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

Barrows, M. G., J. M. Hudson, K. Hauser. 2019. Clackamas River Bull Trout Reintroduction Project, 2018 Annual Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

Barrows, M.G., J.E. Harris, C.P. Franklin, R.C. Gugler, and M.R. Gibson. 2020. Cougar Creek Bull Trout Video Weir, 2019 Annual Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

Barrows, M.G. 2021. Estimating the Abundance of Adfluvial Bull Trout Spawning in Cougar Creek, 2020 Annual Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

Barrows, M. G., J. M. Hudson, C. Franklin, and J. Sprando. 2021. Clackamas River Bull Trout Reintroduction Project, 2019 Annual Report. U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington.

Baxter, J.S., and J.D. McPhail. 1996. Bull trout spawning and rearing habitat requirements: summary of the literature. Fisheries Technical Circular No. 98, 27 p.

Baxter, J. S., and W. T. Westover. 2000. An overview of the Wigwam River bull trout program (1995– 1999): Habitat Conservation Trust Fund final report. British Columbia Ministry of Water, Land, and Air Protection, Fisheries Project Report KO58, Cranbrook.

Dala-Corte, R.B, J.B. Moschetta and F.G. Becker. 2001. Photo-identification as a technique for recognition of individual fish: a test with the freshwater armored catfish *Rineloricaria aequalicuspis.* Neotropical Ichthyology, 14(1).

DeHaan, P., and B. Adams. 2011. Analysis of genetic variation and assessment of population assignment methods for Lewis River bull trout. U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, Longview, Washington.

Doyle, J. 2018. 2017 Lewis River bull trout annual operations report. PacifiCorp. Ariel, WA.

Fraley, J. J. and B. B. Shepard 1989. Life history, ecology, and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake and River system, Montana. Northwest Science 63: 133-143.

Gelman, A., & Hill, J. (2007). Data analysis using regression and multilevel/hierarchical models. New York, NY: Cambridge University Press.

Giglio, V. J., J. Adelir-Alves & A. A. Bertoncini. 2014. Using scars to photo-identify the goliath grouper, Epinephelus itajara. Marine Biodiversity Records, 7: e108(4 p).

Howell, P.J. and P.M. Sankovich. 2012. An Evaluation of Redd Counts as a Measure of Bull Trout Population Size and Trend, North American Journal of Fisheries Management, 32:1, 1-13

Hudson, J.M., J. Doyle, J. Lamperth, R. Al-Chokhachy, G. Robertson, and T. Wadsworth. 2019. Lewis River bull trout: a synthesis of known information. U.S. Fish and Wildlife Service-Columbia River Fish and Wildlife Conservation Office, Vancouver, Washington. 54 pp.

Kellner, K. 2018. A Wrapper Around 'rjags' to Streamline 'JAGS' Analyses. From https://cran.r-project.org/web/packages/jagsUI/jagsUI.pdf

Kéry, M. and M. Schaub. 2012. Bayesian Population Analysis Using WinBUGS: A Hierarchical Perspective. Academic Press.

Leary, R. F., F. W. Allendorf, and S. H. Forbes. 1993. Conservation genetics of Bull trout in the Columbia and Klamath River drainages. Conservation Biology [CONSERV. BIOL.] 7:856-865.

Marshall, A. D. & S. J. Pierce. 2012. The use and abuse of photographic identification in sharks and rays. Journal of Fish Biology, 80: 1361-1379.

Maxell, B. A. 1999. A prospective power analysis on the monitoring of bull trout stocks using redd counts. North American Journal of Fisheries Management. 19: 860-866.

Nitychoruk, J.M., L.F.G Gutowsky, P.M. Harrison, T.J. Hossie, M. Power, and S.J. Cooke. 2013. Sexual and seasonal dimorphism in adult adfluvial bull trout (*Salvelinus confluentus*). Canadian Journal of Zoology. Vol. 91, Issue 7: 480-488.

Pacificorp and Cowlitz County PUD. 2017. Aquatic Monitoring and Evaluation Plan for the Lewis River – First Revision. Portland, OR and Longview, WA. April 2017.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. In K. Hornik, F. Leisch, & A. Zeileis (Eds.), Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003). Vienna, Austria: R Foundation for Statistical Computing.

R Core Team. 2013. R: A language and environment for statistical computing [computer program]. Vienna, Austria: R Foundation for Statistical Computing.

Rieman, B. E. and J. D. McIntyre 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124: 285-296.

Schaller, H.A., P. Budy, C. Newlon, S.L. Haeseker, J.E. Harris, M. Barrows, D. Gallion, R.C. Koch, T. Bowerman, M. Conner, R. Al-Chokhachy, J. Skalicky and D. Anglin. 2014. Walla Walla River Bull Trout Ten Year Retrospective Analysis and Implications for Recovery Planning. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA. 520 pp.

Stevens, J. 1910. Water Powers of the Cascade Range Part 1-Southern Washington. United States Geologic Survey.

Taylor, G. and A. Reasoner. 2000. Bull trout Salvelinus confluentus population and habitat surveys in the McKenzie and Middle Fork Willamette basins, 1999. Bonneville Power Administration, Project 1995-05300, Portland, Oregon.

USFWS. 2002. Chapter 1, Introduction. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon, U.S. Fish and Wildlife Service: 137 pps.

USFWS. 2015. Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*). Portland, Oregon xiii + 179pp.

Appendix A.

PacifiCorp released 900 PIT-tagged adult Coho salmon into Yale Reservoir in autumn of 2022. Fish were released from Saddle Dam or Yale Park from September 12th to October 18th 2022. After their release 21% of these fish were detected on at least one PIT antenna in Cougar Creek (Table A1), where they presumably spawned. Travel time between their release site and their first detection at any antenna in Cougar Creek (Figure 5) ranged from 0.3 to 44.8 days, and travel times appeared shorter for fish release later in the season compared to those released earlier in the season (Figure 1).

Table A1. Number and proportion of PIT-tagged adult Coho Salmon detected in Cougar Creek by release location and year. Number detected represent the minimum number of adult Coho that entered Cougar Creek.

Year	Release location(s)	Number released	Number detected	% detected
2022	Saddle Dam	449	74	16.5
2022	Yale Park	451	94	20.8
2022	All	900	168	18.7

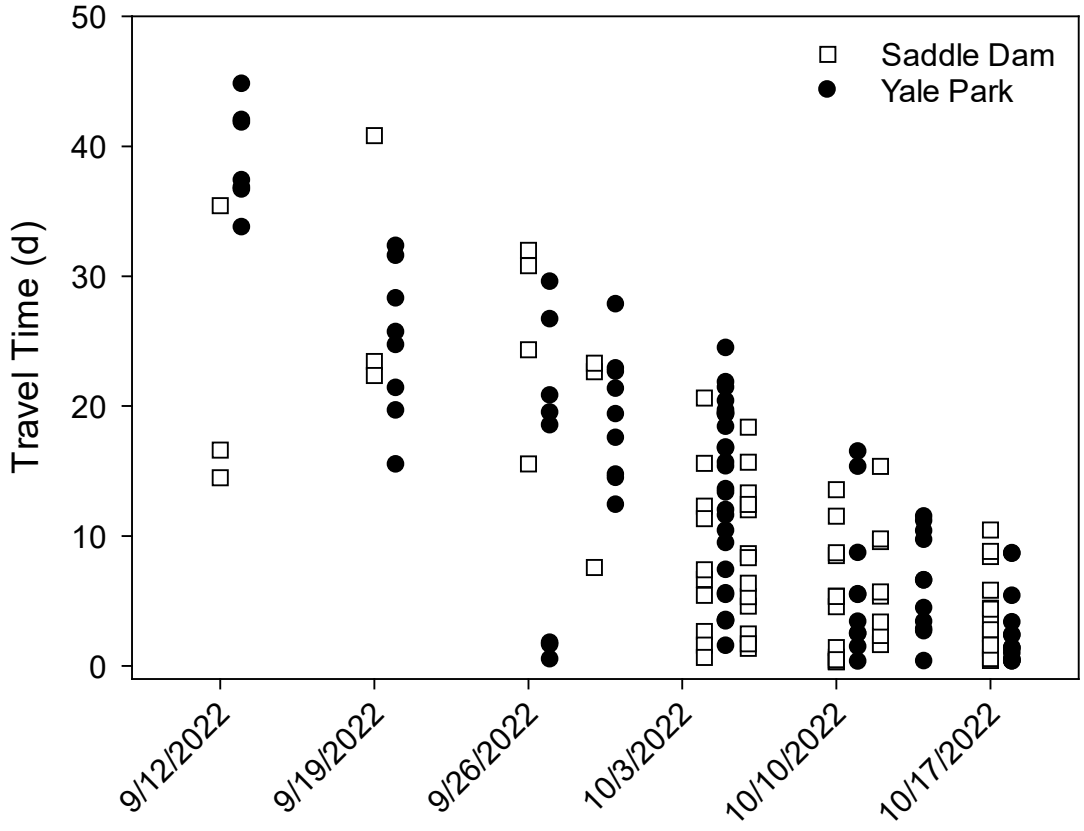


Figure A1. Travel time of PIT-tagged adult Coho Salmon from release to detection in Cougar Creek. Fish were released at Saddle Dam or Yale Park. We presumed all fish releases occurred at noon.

U.S. Fish and Wildlife Service

September 2023