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Estimating the Abundance of Adfluvial Bull Trout Spawning in Cougar Creek

2021 Annual Report

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

On the cover: *Cougar Creek video weir near Cougar, WA (photo by Marshall Barrows, FWS).*

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2021 ANNUAL REPORT

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ESTIMATING THE ABUNDANCE OF ADFLUVIAL BULL TROUT SPAWNING IN COUGAR CREEK
2021 ANNUAL REPORT

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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 15, 2021 through October 31, 2021. A total of 66 observations of adults moving upstream through the weir were recorded from mid-July through late October, with the peak occurring in late-September. The majority of Bull Trout observed were relatively large, migratory fish. However, smaller migratory adults and subadults were observed as well. Since an individual could pass the weir multiple times during the spawning season, the number of recorded upstream observations may have been an overestimate of the true population size. 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 in Cougar Creek during 2021 was 42 (95%: 35 – 47) unique individuals. The estimated number of males and females in the spawning population was 28 (95%: 22 – 33) and 14 (95%: 11 – 15), respectively. These data, combined with a redd count of 19 during 2021, suggest a spawner/redd ratio of 3.8. However, redd count accuracy was negatively influenced by the onset of high flows in late October. In future years, additional PIT-tagging efforts and improved PIT tag detection capability should further improve population estimates.

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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 2021. The relationship between the population estimate resulting from the video weir, and 2021 redd counts, were used to estimate the spawner to redd ratio in Cougar Creek. However, this estimate from Cougar Creek may be used to help evaluate other spawning Bull Trout populations in the subbasin (i.e., 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).

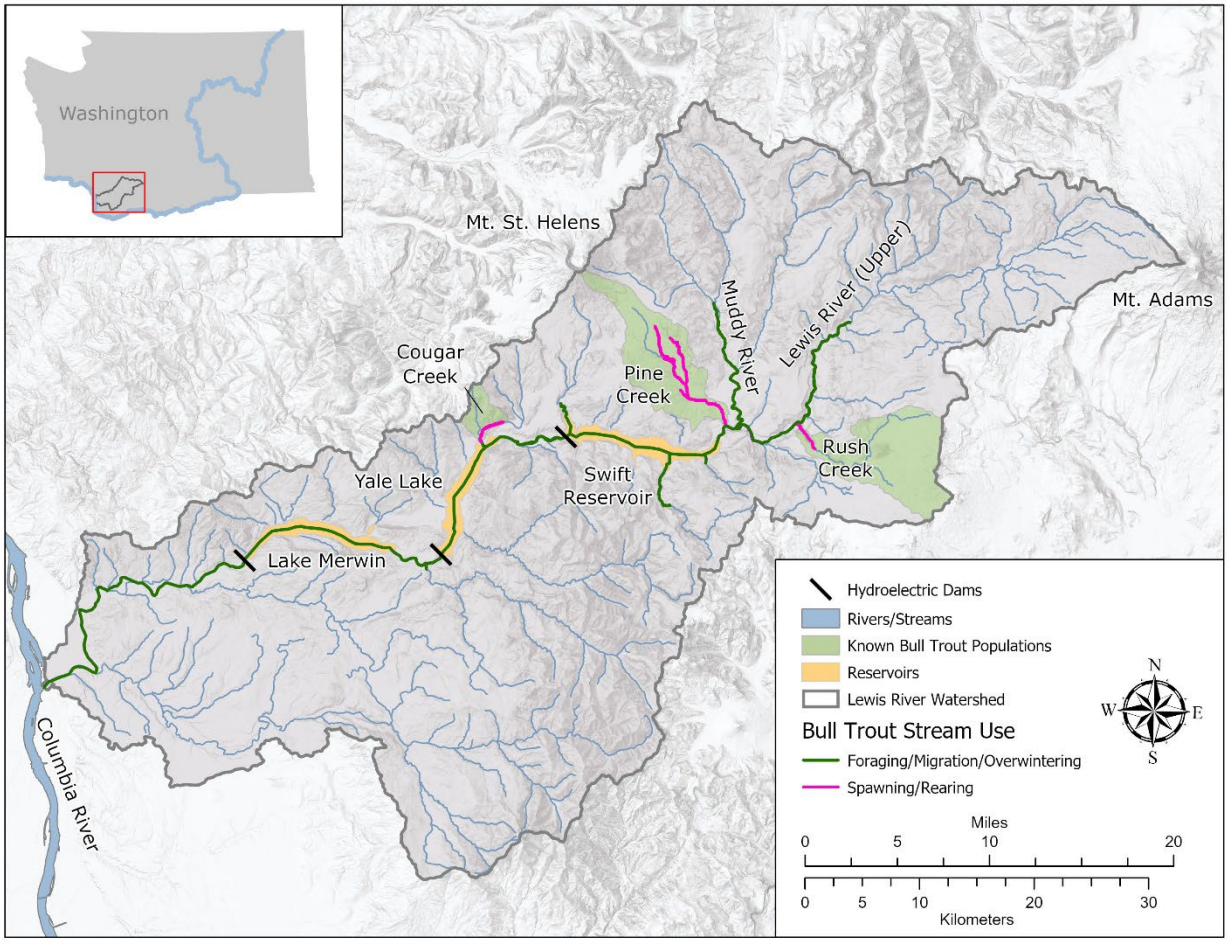

Figure 1. Bull Trout distribution in the Lewis River subbasin.

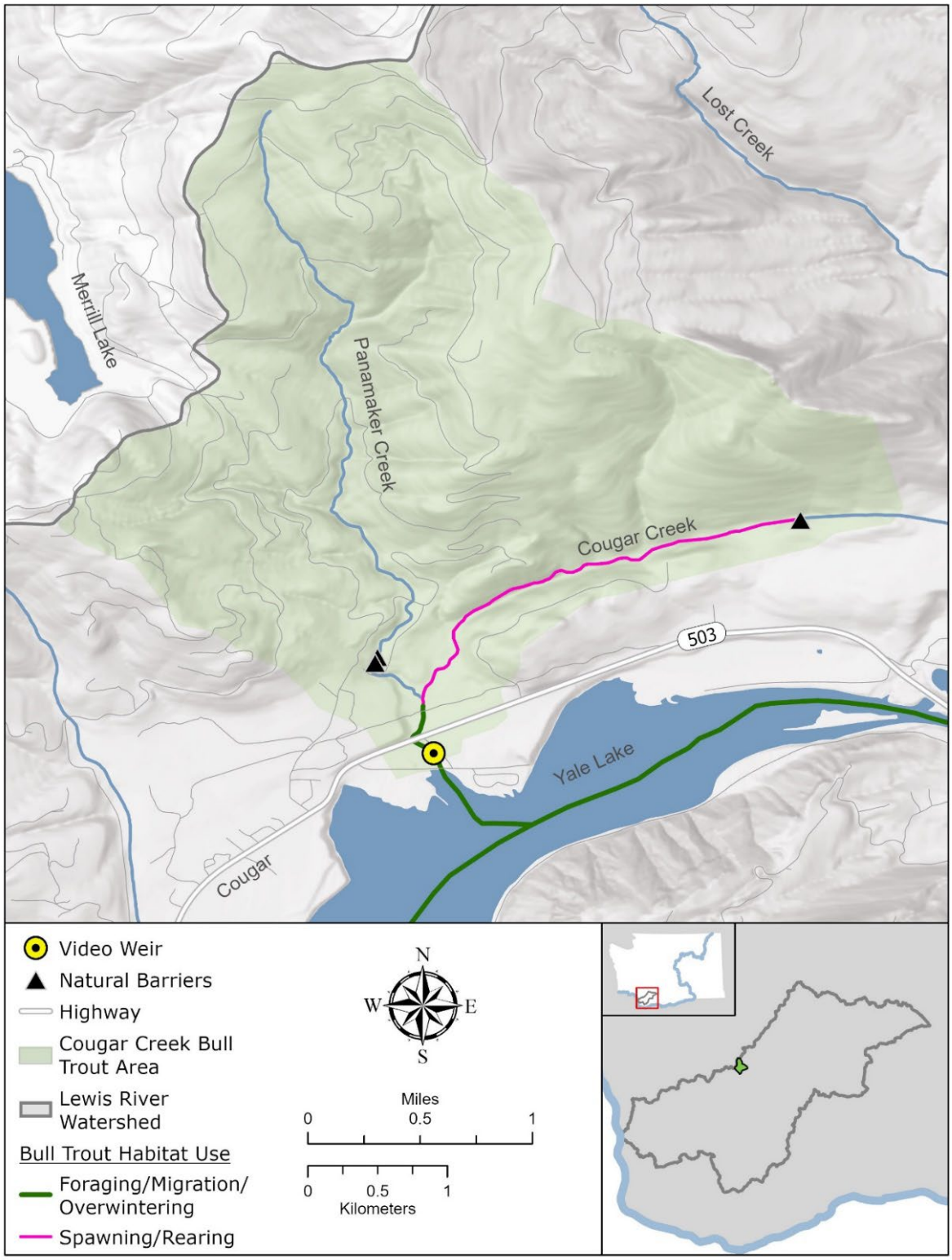

Figure 2. Location of the video weir within the study area. Multiple PIT monitoring were located both upstream and downstream from the weir site in Cougar Creek during 2021.

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 are presumably better at accommodating higher seasonal flows and debris (Barrows 2021). The modified design incorporating resistance board weir panels was used again in 2021.

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. Easy access to the stream is limited, and the lower portion of the study area 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.

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 unseasonably 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 in 2021 as well.

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 downstream water pressure. Sandbags were placed where needed 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. The DVR was exchanged regularly with an identical second DVR to download and review video footage. 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 multiple 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). In addition, a 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 fish to determine upstream weir passage (i.e., conversion) rates. In addition, we assessed upstream passage by documenting the number of weir encounters for each PIT-tagged individual. For this study, we considered an upstream weir encounter to be a PIT detection at the antenna directly below the video weir prior to being observed at (or upstream) of the weir. The number of encounters for each individual before successfully passing upstream were also documented.

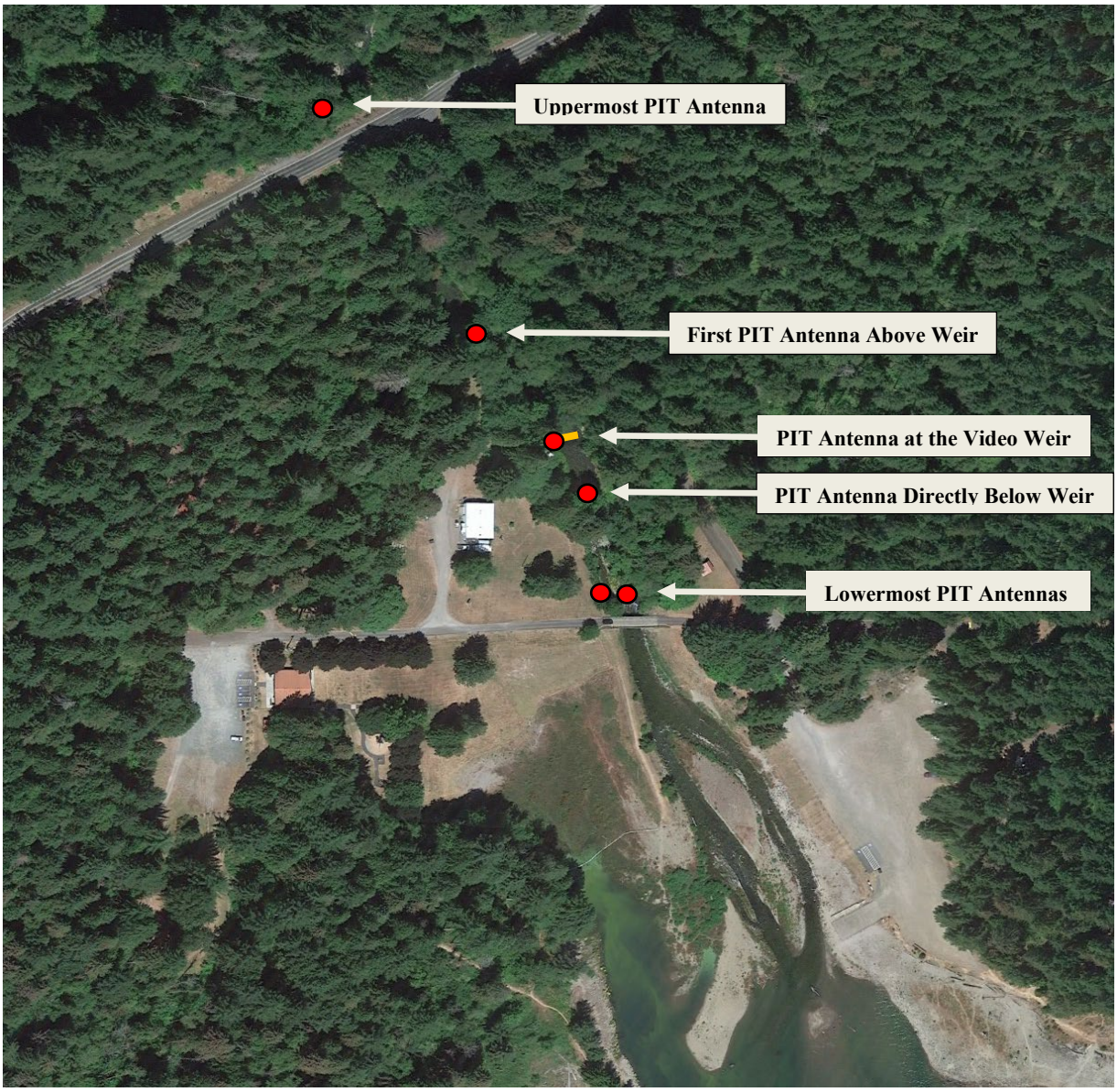

Figure 5. Aerial photo depicting locations of PIT antennas in Cougar Creek upstream and downstream of the weir during 2021 (Google Earth imagery date: July 25, 2021).

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 an individual could pass through the weir multiple times, the total number of Bull Trout observed could be an overestimation of 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 2021, PacifiCorp biologists PIT-tagged three adult Bull Trout in the bypass channel at the head of Yale reservoir prior to the spawning season. PacifiCorp had also PIT-tagged 16 Bull Trout in the bypass channel in 2020, of which 11 were adult-sized (>550 mm) and five were considered subadults. A portion of the fish tagged during 2020 may survive to be detected in subsequent seasons (i.e., 2021). 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 1-4 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), 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 better understand the spawning population and potentially increased accuracy, since females potentially 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

Given the success of operating a weir at the chosen site during 2019 and 2020, we decided that the best course of action was to use the same site during 2021. The suitability of the 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. However, Pacificorps biologists observed two Bull Trout redds constructed downstream from the weir during 2021, suggesting we may not have viewed all of the spawners in the system. No vandalism of the weir and monitoring equipment was observed.

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. As in 2019 and 2020, September brought extensive leaf-fall (primarily from Alder trees). However, the resistance board weir handled the increased debris load well, and required only minimal cleaning and maintenance. By early October, rainfall events combined with extensive leaf-fall, required more 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 where the weir panels were overtopped. However, it was unlikely that Bull Trout passed upstream of the weir site un-monitored.

An analysis of detections revealed that nine PIT-tagged adult Bull Trout were detected below the weir in Cougar Creek during 2021. All nine of these PIT-tagged adults moved upstream of the video weir through the video chute at least once, an overall conversion rate of 100%. Some fish did not continue upstream after first encountering the weir, but instead moved back downstream (probably to the reservoir) before moving above the weir. Similarly, some fish that had previously passed upstream of the weir, moved back downstream of the weir before returning upstream to spawn. PIT-tagged fish encountered the weir an average of 1.7 times (range: 1 – 4 times). If a Bull Trout encountered the weir without moving back downstream, the average time it took to pass

the weir was 35 minutes (range: 19 – 51 minutes). All PIT-tagged fish that passed upstream through the video chute were observed on video (100% efficiency).

Spawning Population Estimate

The Cougar Creek video weir was installed in mid-July and fish passing the weir were continuously monitored via video from July 15, 2021 to October 31, 2021. A PIT detection antenna was installed on the upstream entrance to the video chute to enhance the identification of individual Bull Trout. However, detection capability was unreliable until mid-August, due primarily to excessive electrical interference and equipment malfunction.

During 2021, there were a total of 145 (70 upstream and 75 downstream) video observations of attempts by adult Bull Trout to pass the Cougar Creek video weir. Of these attempts, there were 66 observations of Bull Trout successfully passing upstream and 42 successfully passing downstream of the weir (Table 2). There were also 1,767 observations (1598 upstream and 169 downstream) of Kokanee Salmon (*Oncorhynchus nerka*) recorded at the weir. However, kokanee were not consistently enumerated later in the season due to time constraints. 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 a many of the smaller Kokanee Salmon and juvenile fish to pass the weir unmonitored.

Table 1. Upstream and downstream video observations of adult Bull Trout and Kokanee Salmon at the Cougar Creek video weir from 2019 – 2021.

Species (Sex)	Year	Upstream	Downstream	Total
Bull Trout (Male)	2021	17	13	30
Bull Trout (Male)	2020	15	7	22
Bull Trout (Male)	2019	43	35	78
Bull Trout (Female)	2021	49	28	77
Bull Trout (Female)	2020	21	17	38
Bull Trout (Female)	2019	50	29	79
Bull Trout (Unknown)	2021	0	1	1
Bull Trout (Unknown)	2020	0	5	5
Bull Trout (Unknown)	2019	0	0	0
Kokanee Salmon	2021	1598*	169*	1767*
Kokanee Salmon	2020	8,190	2,501	10,691
Kokanee Salmon	2019	7,197	614	7,811

*Incomplete count.

During 2020, only one adult Bull Trout was observed moving upstream of the video weir between the weir's installation (July 29, 2020) and August 22, 2020. Comparatively, 12 adult Bull Trout had passed upstream of the weir during the same time period in 2021. The number of upstream observations were steady through much of July and August before peaking in

September. Adult Bull Trout continued to move upstream past the weir through mid-October (Figure 7). Only females were observed prior to August 9, 2021.

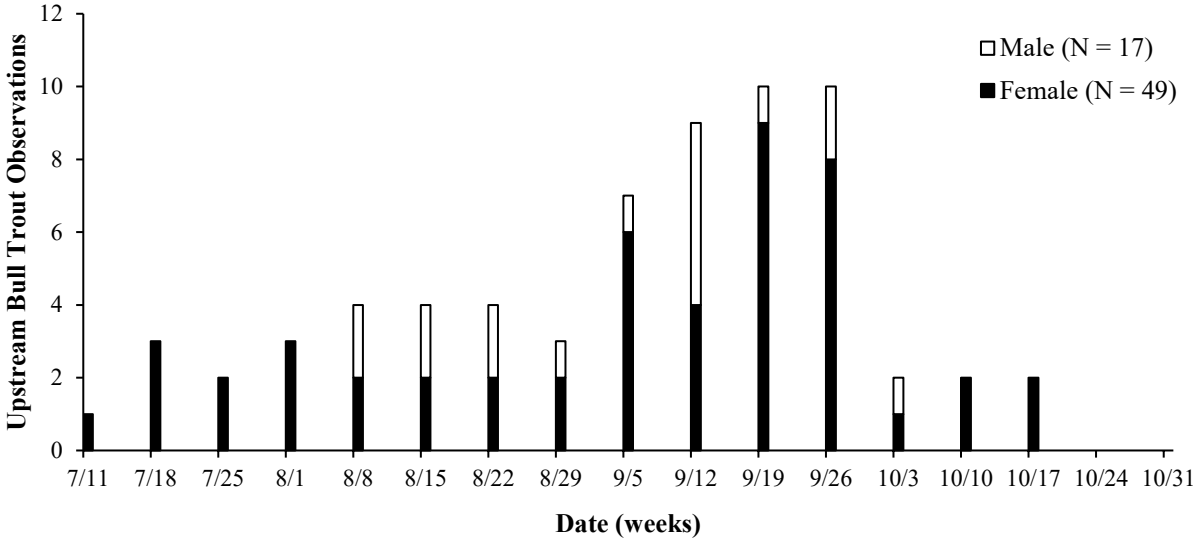

Figure 6. Observations of male and female Bull Trout moving upstream through the video chute at the Cougar Creek weir during 2021.

Of the 3 adfluvial adult-sized (i.e., > 550 mm FL) Bull Trout PIT-tagged in the bypass reach at the head of Yale Reservoir during 2021, 2 (67%) were subsequently detected at PIT antennas in Cougar Creek. There were also seven adult Bull Trout that were PIT-tagged during previous years (i.e., tagged prior to PacifiCorp's effort in 2021) that were detected. In addition, one juvenile Bull Trout and one winter steelhead were detected at PIT antennas in Cougar Creek during 2021.

Following a thorough, systematic review of the 66 upstream observations of adult Bull Trout at the video weir and the associated PIT detections, we observed 16 marked females a total of 28 times and 21 observations were made of unmarked females. The estimated proportion of observations of marked females that were unique individuals was 0.57 (95%: 0.39 – 0.74). The estimated number of unmarked females was 12 (95%: 6 – 17) and the estimated total number of spawning females in the population was 28 (95%: 22 – 33). At the weir, we observed nine marked males a total of 11 times, and we made six observations of unmarked males. The estimated proportion of observations of marked males that were unique individuals was 0.78 (95%: 0.52 – 0.95). The estimated number of unmarked males was five (95%: 2 – 6) and the estimated total number of spawning males was 14 (95%: 11 – 15). The total number of spawning adults was estimated as 42 (95%: 35 – 47).

In 2021, there were 11 Bull Trout redds counted in Cougar Creek (J. Doyle, personal communication, 2021). This was considered to be an incomplete count due to high water events preventing redd surveys following October 20, 2021 (Table 4). These data suggest a spawner/redd ratio of 3.8, but the actual ratio is likely lower due to the incomplete count.

Table 2. Estimated Bull Trout spawner/Redd ratios from 2019 - 2021.

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

Findings

The effort during 2021 to estimate the Cougar Creek spawning population with a video weir was another important step toward improving the accuracy of redd counts. The combined findings from 2019, 2020 and 2021 will inform interpretation of past and future redd counts in Cougar Creek and throughout the Lewis River subbasin. The following are findings from activities conducted during 2021.

The spawning population estimate of 42 adults in 2021 was similar to our 2020 estimate of 34. However, both years were notably lower than the 2019 estimate of 76. There may be several factors contributing to the interannual differences including survival, recruitment and the accuracy of the estimates themselves.

We estimated spawner/redd ratios to be 3.8, 1.3 and 4.0 in 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 three years, 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. In future years, improvements to the weir design, increased PIT-tagging and better PIT detection capability may improve our ability to demonstrate the accuracy of population estimates at the weir during 2022.

As in 2019 and 2020, the majority of Bull Trout observations at the Cougar Creek video weir in 2021 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 portion of the Bull Trout observed on video were subadult-sized (< 550 mm) and juvenile fish may have been using Cougar Creek for rearing and foraging habitat.

From 2019 through 2021, 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 was deprioritized. Future efforts should 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.

We believe the combination of using PIT detections and photo-identification at the video weir was an effective method to identify fish as individuals during 2021. However, additional PIT-tagging of the adult population would likely further increase the accuracy of identifying individuals as they pass upstream of the weir.

Due to equipment failure, we were unable to utilize the laser scaling method we used for passively obtaining lengths from video of Bull Trout passing through the Cougar weir during 2020. Estimating the lengths of fish observed at the video weir not only provided previously unavailable information, but also contributed to identifying individuals during 2020. It would be beneficial to reinstall the system in 2022.

Monitoring in 2021 was the third year of operating a Bull Trout video weir in Cougar Creek. It marked the second season of incorporating resistance board weir panels to the design. The addition of weir panels allowed for successful operation of the weir during the 2020 and 2021 spawning seasons. The panels allowed the weir to better accommodate the higher late-season streamflows and debris loads. We believe these changes ultimately resulted in more accurate estimates of the spawning Bull Trout population in Cougar Creek and we intend to use this design during 2022. However, high late-season streamflows resulted in downcutting in the riverbed and minor damage to weir components. For this reason, the weir may need to be moved slightly upstream during 2022.

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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.

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