Yakima Bull Trout Trap, Transport, and Monitoring Project

2022 Progress Report

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Mid-Columbia Fish and Wildlife Conservation Office
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Foreword

Bull Trout (*Salvelinus confluentus*) are listed as Threatened under the Endangered Species Act, and recovery strategies for this species are divided into six biologically-based recovery units including the Mid-Columbia. The Yakima River Basin is one of 24 core areas within the Mid-Columbia River Recovery Unit, which stretches across eastern Washington, eastern Oregon, and portions of Idaho. Historically, the Yakima River Basin was home to 15 genetically distinct populations of Bull Trout, three of which have been extirpated. Bull Trout in the Yakima River Basin exhibit three generally accepted life history types: resident, fluvial, and adfluvial. In the Yakima River Basin, most Bull Trout populations exhibit an adfluvial life history characterized by spawning and juvenile rearing in tributary habitats and sub-adult and adult rearing in lakes and reservoirs. A primary threat to Yakima Basin Bull Trout is loss of habitat connectivity and migration corridors due to the construction of dams without fish passage. Fish exit headwater systems through the dam outlet works and are unable to return to their natal streams to spawn (U.S. Fish and Wildlife Service 2015). Until permanent fish passage can be installed, interim trap and haul measures are used to transport Bull Trout upstream of dams so that entrained individuals can access their natal spawning tributaries.

A study on the North Fork Tieton River to assess Bull Trout passage at Clear Creek Dam from 2012-2015 found a need to improve on-site fish passage (Thomas et al. 2013, 2014; Thomas and Monk 2015, 2016). As a result, a trap and haul program was implemented in 2016 at Clear Creek Dam as an interim fish passage measure. Given the success of the program at Clear Creek Dam (Thomas and Monk 2015, 2016; Thomas et al. 2017, 2018), trap and haul was implemented at other dams in the Yakima Basin (Bumping, Kachess, and Keechelus dams in 2019 and Tieton Dam in 2020). As reported here for 2022, we collected 14 Bull Trout below Clear Creek Dam and a single sub-adult below Kachess Dam, the first we have collected there. We did not collect any Bull Trout below Bumping, Keechelus, or Tieton dams in 2022, but we observed two below Keechelus Dam during snorkeling surveys.

Monitoring sites detected Bull Trout movement throughout our study area. Of the eight Bull Trout transported above Clear Creek Dam in 2022, we detected six individuals, presumably spawners, at our PIT antennas in the upper North Fork Tieton River. We also detected three fish at the upstream end of the fish ladder at the Clear Creek Dam spillway in November after they had been detected in the upper North Fork Tieton, indicating they likely passed downstream of the dam after spawning. Two other fish of North Fork Tieton origin were detected in the outlet channel below the dam as well. Although we did not detect the sole fish that was transported from below Kachess Dam to Kachess Reservoir this year, we detected two fish from previous years: one in lower Gold Creek that was transported from Keechelus Dam to Keechelus Reservoir in 2021, and another in lower Box Canyon Creek that was transported from Keechelus Dam to Little Kachess in 2020. PIT antenna operations were limited in some areas, particularly upper Gold Creek, by high water which destroyed our antennas. However, we began the use of

a smaller 'submersible' PIT antenna near the mouth of the upper Kachess River that withstood high flows and continued to operate despite being displaced downstream.

Goals and Objectives

The ongoing goals of the Bull Trout Transport Project are to increase viability of Bull Trout populations and provide connectivity for fish disconnected from natal spawning tributaries above Bumping, Clear Creek, Kachess, Keechelus, and Tieton dams. Our specific objectives were to: 1) capture Bull Trout in stilling basins directly below Bumping, Clear Creek, Kachess, Keechelus, and Tieton dams, 2) implant Passive Integrated Transponder (PIT) tags in captured Bull Trout and obtain tissue samples for rapid response genetic testing, 3) snorkel sampling areas when feasible to evaluate the efficacy of collection methods and estimate the abundance of other fish species, 4) transport and release tagged Bull Trout above the dams to provide access to their natal tributaries as determined from rapid response genetic testing, and 5) use PIT tag antenna sites to monitor the movement and survival of transported Bull Trout.

Methods

Study Area

Bull Trout trap and haul occurred in two main regions of the Yakima River Basin: the upper Yakima River Basin and the upper Naches River Basin.

In the upper Yakima River Basin, collection occurred within the stilling basins of Kachess and Keechelus dams. These dams are located upstream of Easton Dam, which impounds the Yakima River at river kilometer (RKM) 326.1 to form Easton Reservoir near Easton, Washington. The 'Keechelus Arm' of the Yakima River extends northwest from Easton Reservoir about 18 km upstream to Keechelus Dam (RKM 345.8), which impounds Keechelus Reservoir. The lower Kachess River extends north about 2 km upstream from Easton Reservoir to Kachess Dam (RKM 3.7), which impounds Kachess Reservoir. Kachess Reservoir is comprised of Little Kachess Lake on the north end of the reservoir and Big Kachess Lake on the south end of the reservoir, connected by a channelized area called The Narrows (Figure 1).

In the Naches River Basin, collection occurred within the stilling basins of Bumping Dam, Clear Creek Dam, and Tieton Dam. Bumping Dam impounds Bumping Lake and is located on the Bumping River, a tributary of the Naches River. The Bumping River flows northeast, where it joins the American River and then the Little Naches River, to form the Naches River. The Bumping and Little Naches confluence is about 89 km upstream of where the Naches River enters the Yakima River near Yakima, Washington. Tieton Dam, which impounds Rimrock

Reservoir, is located on the Tieton River, 35 km upstream of the Tieton River and Naches River confluence near the town of Naches, Washington. About 1 km upstream of Rimrock Reservoir, Clear Creek Dam impounds the confluence of the North Fork Tieton River and Clear Creek to form Clear Lake.

Monitoring Locations

PIT antennas and arrays (i.e., two antennas per site) were used to monitor the movement of Bull Trout throughout our study area and were installed and maintained collaboratively with Yakama Nation Fisheries Program. Monitored Bull Trout natal streams in the upper Yakima River Basin included Gold Creek, a tributary of Keechelus Reservoir, and Box Canyon Creek and the upper Kachess River, tributaries of Kachess Reservoir. There were two sites on Gold Creek, a lower antenna site located about 0.5 km upstream of its mouth at Keechelus Reservoir between the eastern span of I-90 and National Forest Road 4832 and an upper array located about 4 km upstream of its mouth. Upstream of Kachess Dam, an array site in Box Canyon Creek was located 0.2 km upstream of its mouth at Kachess Reservoir. Further, there were two antenna sites on the upper Kachess River, a lower site and an upper site that were located 0.2 km and 1 km upstream of Kachess Reservoir.

Monitored Bull Trout natal streams in the upper Naches River Basin included Indian Creek and the South Fork Tieton River, tributaries of Rimrock Reservoir, as well as North Fork Tieton River, which is both a tributary of Rimrock Reservoir and Clear Lake. References to the North Fork Tieton River in this report refer to reaches upstream from Clear Lake unless otherwise specified. There were two antenna sites on the South Fork Tieton River, a lower site and an upper site that were located 0.5 km and 8.5 km upstream of Rimrock Reservoir. The array site in lower Indian Creek was about 0.9 km upstream of its mouth at Rimrock Reservoir. At Clear Creek Dam, an antenna was located in the outlet channel 80 m downstream of the dam, and an additional antenna site was located at the upstream end of the fish ladder within the spillway channel, north of the dam (Figure 1). Above Clear Creek Dam, there were two antenna sites on the North Fork Tieton River, a lower site located 1.2 km upstream of its mouth at Clear Lake and an upper site located 9.5 km upstream of its mouth, just downstream of the Scatter Creek confluence. Deep Creek, a tributary of Bumping Reservoir, is another natal stream in the Naches River Basin, but it is not monitored at this time because we have only collected and tagged one individual in the Bumping watershed. Further, monitoring would be challenging because the active stream channel of lower Deep Creek oscillates between a west and east channel. Should we collect and tag more Bull Trout in the Bumping Dam stilling basin during future sampling events, we will reconsider the feasibility of PIT monitoring in Deep Creek.

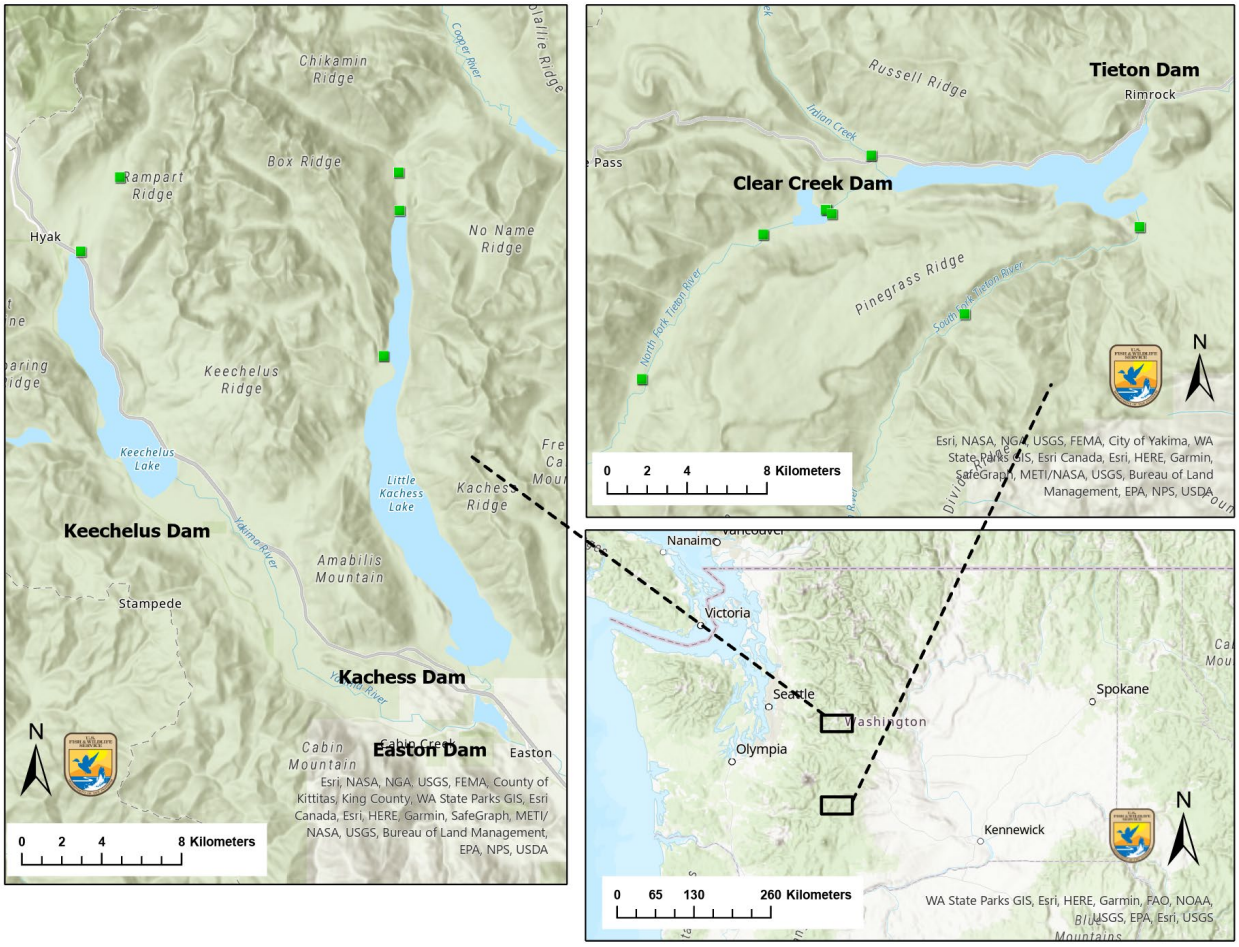

Figure 1. Map of study sites in the upper Yakima Basin (left), upper Tieton Basin within the Naches River Basin (upper right), and their orientation within Washington state (lower right). Green squares represent PIT-tag antenna locations. The map includes Kachess, Keechelus, Easton, Clear Creek, and Tieton dams. Bumping Dam (upper Naches River Basin) is not pictured.

Antenna Configuration and Installation

At each monitoring site we deployed either a single PIT antenna or an array, consisting of two antennas placed approximately 20 m apart. Each antenna contained a 24V antenna motherboard with PIT tag reader (IS1001, Biomark Inc., Boise, Idaho), housed and attached to external antenna wires and power cords within a waterproof case (Pelican Products, Inc., Torrance, California). Antenna wire (12-gauge copper Litz wire) was coiled 2-4 times through polyethylene piping (1 in). Ends of the piping were connected to a 3-way PVC 'T' fitting (2 in, 5.1 cm) within which both ends of the coiled wire were soldered to both a collection of capacitors chosen based on the inductance of the antenna coil as well as a HydroVolt cable (AK Industries, Rancho Domingo, California) that was attached to the antenna motherboard within the waterproof case. Power was supplied to the motherboard using DC power from four, 6-volt

batteries wired together in series, forming a 24-volt configuration. Batteries were charged by 300W/24V solar panels (Grape Solar, Eugene, Oregon) mounted to a wooden frame that faced 120° - 150° (Southeast). Output from the solar panels was regulated by solar controllers (ProStar PS-15 or PS-30, Morningstar Inc., Newtown, Pennsylvania). The solar controller and batteries were housed in a steel storage chest (Ridge Tool Company, Elyria, Ohio). The Box Canyon Creek array was powered by a thermoelectric generator (TEG; Global Power Technologies, Calgary, Alberta, Canada) and fueled by propane stored in a 94.6-L (25-gal) tank, which supplied 24 volts of continuous DC power to the array.

Antenna coils were installed in either a horizontal *pass-by* (i.e., flat-plate) or vertical *pass-through* configuration. Generally, flat-plate antennas are less susceptible to being displaced by high water events and associated debris, whereas pass-through antennas better detect fish across a range of water levels but are more susceptible to damage during high water events. Most monitoring sites were set up in a flat-plate configuration, lying flat on the creek bed from bank to bank (Figure 2). The antenna piping was affixed to the stream bed using barbed rebar anchors (0.8 cm, 5/16 in) with threadless eye nuts (2.5 cm, 1 in) welded near the top of the rebar. The anchors were driven into the stream bed using a gas-powered post driver (Titan, Nevada, Missouri), and the antenna piping was secured to the anchors with nylon straps (NRS Inc., Moscow, Idaho). Pass-through antennas were operated at lower Gold Creek (G90) and Clear Creek Dam fish ladder (ULD). At the lower site on Gold Creek the antenna was about 2 m tall and spanned the entire width of the stream. An antenna support cable (1/2in, 1250 lb Greenlee pulling tape) was affixed from one bank to the other, with each end attached to a U-channel sign post (10 ft, 3.1 m). Zip ties and/or nylon straps were used to affix the antenna to the support cable. The bottom portion of the pass-through antenna was affixed to the streambed following the same methods as for the flat-plate configuration. A pass-through antenna was also installed at the upper section of the fish ladder at Clear Creek Dam but was sized to fit the upstream terminus of the fish ladder, which was designed as an exit point for upstream migrating fish and an entry point for downstream migrating fish.

New for 2022, we deployed a submersible antenna (Biomark Inc, Boise, Idaho) in the spillway below Keechelus Dam as well as at the lower site on the upper Kachess River (KACL). The submersible antenna is a 2 m circular flat plate design that contains a waterproof housing for the IS1001 and a rechargeable battery pack (Figure 3).

Figure 2. Example of a flat-plate antenna monitoring the movement of PIT-tagged Bull Trout.

Figure 3. Example of a submersible antenna monitoring the movement of PIT-tagged Bull Trout.

Fish Collection, Processing, and Release

Collection

Sampling methods consisted of a combination of hook-and-line angling, snorkeling, and deploying tangle nets. The sampling methods used at any particular dam depended on water velocities suitable for safely deploying nets and snorkeling, water clarity suitable for snorkeling, and water temperatures within the range specified in our sampling permit for handling and tagging fish (i.e., < 15°C). During 2022, we attempted to sample at least three times at each of the five stilling basins, but the sampling frequency was increased as fish continued to be encountered. For example, higher numbers of Bull Trout were present at Clear Creek Dam, so this location was sampled with greater frequency (Thomas et al. 2017).

Upon arrival at a site, we sampled via hook-and-line angling, using artificial lures with a single, barbless hook. This method was typically implemented for 1-2 hours depending on the number of fish captured. The crew focused mainly on sampling in the stilling basin below the dams, but hook-and-line sampling additionally occurred slightly downstream of the stilling basins at Clear Creek and Keechelus dams. We also sampled in the spillway channel at Clear Creek Dam.

Our snorkeling crew consisted of snorkelers and a data collector following Thurow and Schill (1996). We quantified the number of adult Bull Trout present, with the survey starting point below each stilling basin as determined by the predominate instream conditions at the time of the survey. Thurow and Schill (1996) found no significant difference between day and night abundances of adult Bull Trout, therefore we conducted our surveys during mid-morning. In addition to Bull Trout, we also enumerated the quantity of other fish in our surveys. Snorkeling and estimation of non-Bull Trout was not conducted at Clear Creek and Tieton dams because of reduced clarity and high velocities typically present at those sites.

After snorkeling, tangle nets with 7.5-cm stretch mesh and 3.5-kg (8-lb test) monofilament were fished. Nets were fished using one of two methods, either by placing them across stream reaches where snorkelers directed fish towards the nets, or by passively fishing without snorkelers. In both cases, nets were constantly monitored, and fish were immediately removed from nets using knot-free dip nets. Net meshes were cut as needed to minimize fish injury during removal.

Upon capture, Bull Trout were placed in a holding pen (0.9 m x 1.2 m x 1.8 m) constructed of perforated stainless steel with lockable latches that was submerged in the river where there was generally good flow (Figure 4). The holding pen was used to protect Bull Trout until they could be released into their natal watersheds based on rapid response genetic results. Bull Trout generally remained in the holding pen for no more than 28 hours.

Processing

Following collection, each fish was individually removed from the holding pen using a dip net and placed in a 75.7-liter (80-quart) cooler containing a buffered anesthetic solution, created using river water, 50 mg/L of MS-222, and $NaHCO_3$ buffer (i.e., baking soda). MS-222 is acidic, so buffer was added until pH was approximately 7, as measured by a Eutech Instruments pHTestr20 (Cole-Parmer, Vernon Hills, Illinois). We removed fish from the solution when they were fully sedated (2-5 minutes), scanned them for a tag using a HPR Lite Handheld PIT Tag Reader (Biomark, Boise, Idaho), and measured their length (total length in mm). For individuals without a preexisting tag, we used sterilized surgical scissors to collect a small tissue sample from the anal fin, which was placed in a vial of ethanol. We then inserted a PIT tag (APT12, FDX-B, 12.5 x 2.1 mm, 134.2 kHz; Biomark, Boise, Idaho) into the base of the dorsal fin (dorsal sinus) using a preloaded APT12 12-gauge needle and MK25 PIT Tag Implanter (Biomark, Boise, Idaho). Processing generally took less than 1 minute. To recover from sedation, Bull Trout were placed in a perforated PVC recovery tube (1-m length, 15-cm diameter) with adequate flow to allow fish to regain equilibrium before being returned to the holding pen. Tagged and processed fish were kept separated from unprocessed fish in the holding pen until all fish were processed.

After all fish were processed, the vials containing fin clips were immediately hand-delivered to the U.S. Fish and Wildlife Service (USFWS) Abernathy Fish Technology Center (AFTC) for rapid response genetic assessment to determine population origin and to identify Brook Trout x Bull Trout hybrids (see Genetic Testing).

Figure 4. Stainless steel pen (0.9 m x 1.2 m x 1.8 m) used for holding Bull Trout after collection and before rapid response genetic testing and transport to natal watershed.

Release

Fish were transported and released the following day upon receipt of genetic results. Bull Trout were loaded with a hand dip net into a transport vehicle outfitted with a large cooler filled with river water and oxygenated by a battery-powered aerator with air stones. Individual Bull Trout were then released via hand dip net into the reservoir connected to their natal streams as determined by the genetic assessment results. Any genetically identified hybrids were euthanized on site.

In the upper Yakima Basin, captured Bull Trout originate from Gold Creek, Box Canyon Creek, and the upper Kachess River. Bull Trout of Gold Creek origin (a Keechelus Reservoir tributary) move downstream through Keechelus Dam where they are collected and then transported and released into Keechelus Reservoir. Bull Trout originating from Kachess Reservoir tributaries (i.e., Box Canyon Creek and Kachess River) move downstream through Kachess Dam or adjacent spillway channel and migrate either back upstream to the base of Kachess Dam or downstream through Easton Reservoir and then upstream to the base of Keechelus Dam. These fish are transported and released into Kachess Reservoir.

At Clear Creek Dam, encountered Bull Trout originate from Indian Creek, the South Fork Tieton River, and the North Fork Tieton River. Bull Trout of North Fork Tieton River origin (a Clear Lake tributary) move downstream through Clear Creek Dam or an adjacent spillway channel and migrate back upstream to the base of the dam where they are collected (Thomas et al. 2017). These fish are transported upstream and released into Clear Lake. Bull Trout originating from Rimrock Reservoir tributaries (i.e., Indian Creek and South Fork Tieton River) routinely migrate upstream to Clear Creek Dam but are not transported above the dam to Clear Lake. These fish are instead released into the North Fork Tieton River directly below the Clear Creek Dam stilling basin.

Genetic Testing

We used a real-time genotyping and analysis method (DeHaan et al. 2011) to identify natal origin as well as hybrid individuals (Brook Trout x Bull Trout). Upon arrival of samples in the laboratory, genomic DNA was extracted twice from each individual fin clip to ensure consistency using a modified chelex extraction protocol (Miller and Kapuscinski 1996) with incubation at 55°C for 15 min, and then at 103°C for 8 min. Individuals were genotyped at the following 16 microsatellite loci: Omm1128, Omm1130 (Rexroad et al. 2001), Sco102, Sco105, Sco106, Sco107, Sco109, [Washington Department of Fish and Wildlife (WDFW) unpublished], Sco200, Sco202, Sco212, Sco215, Sco216, Sco218, Sco220 (Dehaan and Ardren 2005), Sfo18 (Angers et al. 1995) and Smm22 (Crane et al. 2004). Allele calling at each of these loci was previously standardized between our laboratory and WDFW Molecular Genetics Laboratory using a protocol akin to the one described by Stephenson et al. (2009) to facilitate data sharing.

Several Bull Trout and Brook Trout loci have diagnostically different allele sizes and can be used to identify species and individuals with hybrid ancestry.

We used the baseline genotypes described by Small et al. (2016) to assign fish to population groups and evaluated the power of the baseline to accurately assign individuals using a simulation approach. The probability of an individual originating from each baseline population was estimated following Rannala and Mountain (1997) as implemented in the computer program ONCOR (Kalinowski et al. 2007). Preliminary leave-one-out simulations suggested a high probability (95 % - 100 %) of correct assignment to the twelve populations in the baseline (Table 1). Based on the leave-one-out results, we decided that the baseline had enough power to assign individual Bull Trout to one of twelve populations. Each of the Bull Trout captured in 2022 were thus assigned to one of these populations.

Survival Modeling

We calculated mean annual survival probability and detection probabilities for the North Fork Tieton (NFT) Bull Trout population in the upper Naches River Basin by fitting a Cormack-Jolly-Seber model (CJS; Cormack 1964; Jolly 1965; Seber 1965) with a random time effect in a Bayesian framework following methods outlined by Kéry and Schaub (2012). The CJS model was fit using JAGS (Plummer 2003) software and executed in program R (R Core Team 2022) via the "rjags" package (Plummer et al. 2022). Model assumptions require that sampling periods are instantaneous, tags are always recorded correctly and are not lost, all individuals have the same survival and recapture probabilities, and the fate of individuals are independent of each other.

Data for this analysis were derived from NFT-origin Bull Trout captured and PIT tagged during trap and haul operations at Clear Creek Dam and their subsequent detections at PIT antenna monitoring locations (LLD, LSFT, NFT, OCH, SFT, ULD, UPNFT) or recapture during trap and haul at Clear Creek Dam. An individual was recorded as 'recaptured' if it was detected at any monitoring location or captured during a given year. From these data, a capture-recapture history was generated for each tagged individual over the duration of the study period with tagging occasions occurring in 2012-2021 and annual recapture occasions occurring in 2013-2022.

Table 1. Results of simulations used to assess the accuracy with which the genetic baseline could be used to assign Bull Trout to 13 reporting groups. The left column indicates the true origin, and subsequent columns indicate numbers of fish assigned to each reporting group. Bold values indicate correct assignments.

Reporting Groups	Brook Trout	Gold Creek	Box Canyon	Kachess River	NF Teanaway	Deep Creek	American/ Union	Rattlesnake	Crow	NF Tieton	Indian	SF Tieton	Ahtanum	Percent Correct
Brook	**25**	0	0	0	0	0	0	0	0	0	0	0	0	100%
Gold Creek	0	**46**	0	0	0	0	0	0	0	0	0	0	0	100%
Box Canyon	0	0	**18**	1	0	0	0	0	0	0	0	0	0	95%
Kachess	0	0	0	**28**	0	0	0	0	0	0	0	0	0	100%
NF Teanaway	0	0	0	0	**10**	0	0	0	0	0	0	0	0	100%
Deep	0	0	0	0	0	**57**	0	0	0	0	0	0	0	100%
American/ Union	0	0	0	0	0	0	**56**	0	0	0	0	0	0	100%
Rattlesnake	0	0	0	0	0	0	1	**36**	0	0	0	0	0	97%
Crow	0	0	0	0	0	0	0	0	**24**	0	0	0	0	100%
NF Tieton	0	0	0	0	0	0	0	0	0	**46**	1	0	0	98%
Indian	0	0	0	0	0	0	0	0	0	1	**108**	3	0	96%
SF Tieton	0	0	0	0	0	0	0	0	0	0	1	**75**	0	99%
Ahtanum	0	0	0	0	0	0	0	0	0	0	0	0	**54**	100%

Results

Antenna Operation

Antennas were operated at different times throughout the year based on snow depth, solar angle, and streamflow that can affect site access, in-river safety, and power. Antenna operations were intermittent at many of our sites due to high flows from large rain events (UGC1, UGC2, G90, LSFT), power failures (BOX1, BOX2, ULD, OCH, SFT), and tuning issues (G90, LSFT) at some point during the monitoring period, disrupting otherwise continuous operations (Figure 5).

In the upper Yakima Basin, the upper Gold Creek array (UGC1, UGC2) operated continuously from August 19 until November 4 when the antennas were destroyed by high flows. The lower Gold Creek antenna (G90) operated from April 20 to May 14, when high flows and resulting Keechelus Reservoir pool elevation rise inundated the site. When pool elevation lowered, new batteries were installed, and the site was brought back online on July 19. There were tuning issues between July 26 and August 19, after which time the site was continuously operational through the end of the year. At the upstream array site in upper Kachess River, the upstream antenna (KR1) operated continuously from July 21 to November 4. However, the downstream (KR2) antenna was destroyed over the winter of 2021-2022 and was not operational during 2022. The submersible antenna at the lower site in the upper Kachess River (KACL) operated continuously from July 7 until it was removed on November 16. Antennas in Box Canyon Creek (BOX1, BOX2) began operation on July 7. During the monitoring period, the site experienced occasional power disruption and connection issues; however, at least one of the antennas was operational until December 18.

In the Naches River Basin, antennas in the North Fork Tieton River (UPNFT, NFT) operated continuously from the time they were brought online until they were shut down, May 17 to November 12 (UPNFT) and April 29 to November 21 (NFT). The antenna at Clear Creek Dam outlet channel (OCH) operated nearly continuously for the entire year except for a few power outages in December 2022. Conversely, the Clear Creek Dam fish ladder site (ULD) was plagued with power issues for much of the year. It operated from May 9 until May 23 and from June 24 to Sept 8. On October 4, the old ORFID board at this site was replaced with a new motherboard (IS1001, Biomark Inc., Boise, Idaho) and was then operational until the end of the year. At the Indian Creek array site, antennas operated from their installation on September 1 (IND2) and September 2 (IND1) until they were both shut down on November 21. The upper South Fork Tieton River antenna (SFT) operated from its construction on July 13 until August 14 when the batteries started failing and then again from September 9 until it was shut down on November 21. After being damaged sometime between winter 2021 and spring 2022, a new lower South Fork Tieton (LSFT) antenna was installed on August 29 and brought online on September 8 until October 20 when high flows caused tuning issues. The antenna then operated continuously from November 21 through the end of the year.

We also deployed water temperature loggers at most of our antenna sites, continuously logging water temperature every 15 min (Onset, Bourne, Massachusetts).

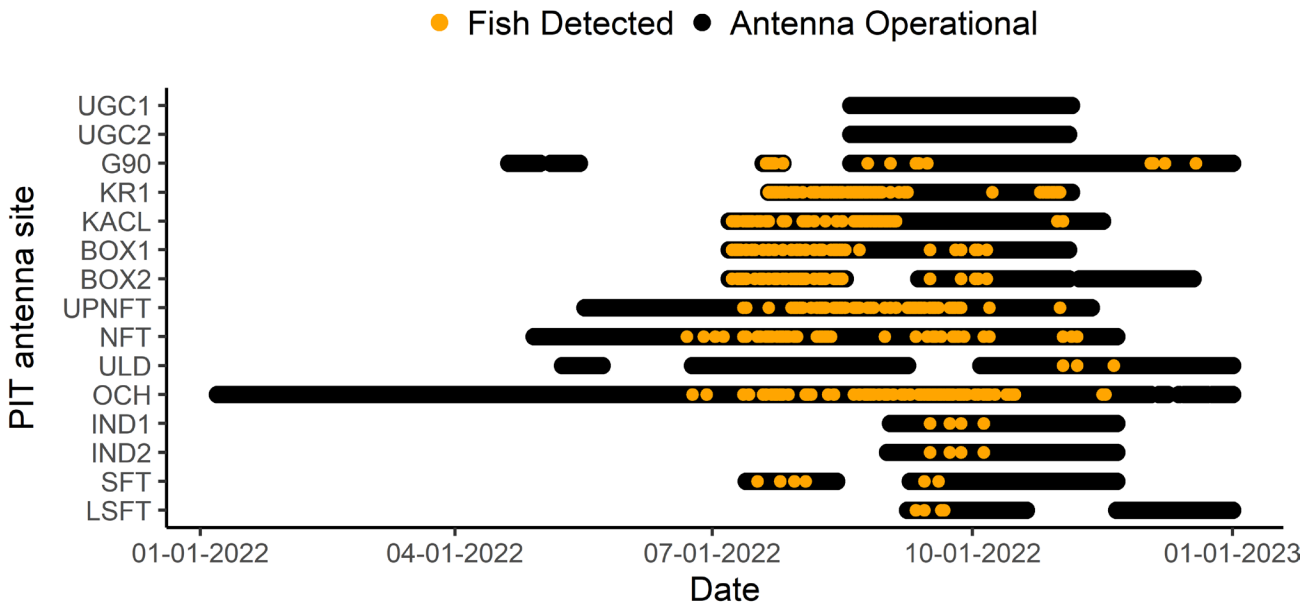

Figure 5. Antenna operations (black lines) and fish detections (orange points) during 2022. Black lines consist of a series of points that represent an hour in which the given antenna was operational (UGC1 = upper Gold Creek (upstream antenna), UGC2 = upper Gold Creek (downstream antenna), G90 = lower Gold Creek, KR1= upstream site in upper Kachess River, KACL = downstream site in upper Kachess River, BOX1= Box Canyon Creek (upstream antenna), BOX2 = Box Canyon Creek (downstream antenna), UPNFT = upper North Fork Tieton River, NFT = lower North Fork Tieton River, ULD = upper ladder in the spillway channel at Clear Creek Dam, OCH = outlet channel at Clear Creek Dam, IND1= Indian Creek (upstream antenna), IND2= Indian Creek (downstream antenna), SFT = South Fork Tieton River, and LSFT= lower South Fork Tieton).

Fish Collection and Transport

Fish collection occurred from July to November 2022 at Kachess, Keechelus, Bumping, Clear Creek, and Tieton dams. We sampled on five days at Clear Creek Dam, two days at Kachess Dam, two days at Keechelus Dam, one day at Bumping Dam, and one day at Tieton Dam. We captured 14 Bull Trout at Clear Creek Dam and one at Kachess Dam (a recapture), but none elsewhere. We observed Bull Trout at both Clear Creek and Kachess dams that we were unable to collect (Table 2). Of the 14 fish collected at Clear Creek Dam, eight were identified as North Fork Tieton origin (Table 3) and were subsequently transported and released above the dam. Three fish were identified as South Fork Tieton origin and three were identified as Indian Creek

origin. All six of these Bull Trout were released below the dam. No hybrids were captured at any of the sampling locations.

Table 2. Stilling basin, survey date, number of Bull Trout observed, number of Bull Trout collected (recaptures inclusive), and number of Brook Trout/Bull Trout hybrids collected during trap and haul in 2022.

Stilling Basin	Survey Date	Bull Trout Observed	Bull Trout Collected (Recaptures Inclusive)	Brook Trout/Bull Trout Hybrids Collected
Clear Creek Dam	07/11/2022	1	1	0
Clear Creek Dam	07/20/2022	4	4	0
Bumping Dam	07/25/2022	0	0	0
Clear Creek Dam	07/27/2022	4	4	0
Clear Creek Dam	08/03/2022	3	3	0
Clear Creek Dam	08/08/2022	4	2	0
Tieton Dam	08/15/2022	0	0	0
Keechelus Dam	09/14/2022	1	0	0
Keechelus Dam	10/03/2022	2	0	0
Kachess Dam	10/26/2022	1	1(1)	0
Kachess Dam	11/09/2022	0	0	0
Totals		**20**	**15(1)**	**0**

Table 3. Stilling basin, release date, PIT-Tag ID, total length, and stock of Bull Trout collected in 2022.

Stilling Basin	Release Date	PIT-Tag	Total Length (mm)	Stock
Clear Creek Dam	07/12/2022	3DD.003D481180	365	Indian Creek
Clear Creek Dam	07/21/2022	3DD.003D48119B	360	South Fork Tieton
Clear Creek Dam	07/21/2022	3DD.003D481182	475	North Fork Tieton
Clear Creek Dam	07/21/2022	3DD.003D481184	445	North Fork Tieton
Clear Creek Dam	07/21/2022	3DD.003D481181	505	Indian Creek
Clear Creek Dam	07/28/2022	3DD.003D4811A8	445	North Fork Tieton
Clear Creek Dam	07/28/2022	3DD.003D4811A4	448	South Fork Tieton
Clear Creek Dam	07/28/2022	3DD.003D4811B3	630	Indian Creek
Clear Creek Dam	07/28/2022	3DD.003D481198	345	North Fork Tieton
Clear Creek Dam	08/04/2022	3DD.003D4811A7	520	North Fork Tieton
Clear Creek Dam	08/04/2022	3DD.003D48118B	415	North Fork Tieton
Clear Creek Dam	08/04/2022	3DD.003D481178	275	South Fork Tieton
Clear Creek Dam	08/10/2022	3DD.003D4811BB	460	North Fork Tieton
Clear Creek Dam	08/10/2022	3DD.003D481195	460	North Fork Tieton
Kachess Dam	10/26/2022	3DD.003D59D7EF*	298	Kachess

*Recapture

Since trap and haul began in the upper Yakima River in 2019, we have collected 20 fish below Keechelus Dam and one below Kachess Dam. The one and only Bull Trout captured below Kachess Dam occurred in October 2022. This individual was reared at Yakama Nation's La Salle reconditioning facility and released near the upper end of the lake in June 2022. The Bull Trout measured 254 mm (fork length) at the time of release and 298 mm (total length) at time of recapture. We subsequently transported and released the fish in the Kachess Dam forebay. This is the first documented case of a La Salle reared fish being entrained in the upper Yakima River.

In addition to observing Bull Trout during snorkeling, we also observed Brook Trout (*Salvelinus fontinalis*), adult and juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), adult and juvenile Kokanee (*Oncorhynchus nerka*), Cutthroat Trout (*Oncorhynchus clarkii*), Mountain Whitefish (*Prosopium williamsoni*), Rainbow Trout (*Oncorhynchus mykiss*), and Suckers (*Catostomus* spp.). Overall, we observed relatively large numbers of Mountain Whitefish and lesser numbers of Chinook Salmon, Kokanee, and Rainbow Trout (Table 4).

Table 4. Common and scientific names of nontarget fish species that were observed in the stilling basins of Bumping, Kachess, Keechelus, Tieton, and Clear Creek dams during trap and haul efforts in 2022. Numbers observed from the Tieton Dam and Clear Creek stilling basins are from fish collected and released during hook-and-line sampling only as no snorkeling was attempted. At the other dams, numbers encompass both fish collected during hook-and-line sampling and the estimated number observed while snorkeling.

Common Name	Scientific Name	Bumping	Kachess	Keechelus	Tieton[#]	Clear Creek[#]
Brook Trout	*Salvelinus fontinalis*	-	-	10	-	<10
Chinook Salmon	*Oncorhynchus tshawytscha*					
Adults		1	-	2	-	-
Juveniles		-	-	>100	-	-
Kokanee	*Oncorhynchus nerka*					
Adults		-	-	1	-	-
Juveniles		-	-	10-100	-	-
Cutthroat Trout	*Oncorhynchus clarkii*	-	-	2	1	22
Rainbow Trout	*Oncorhynchus mykiss*	6	1	19	-	1
Mountain Whitefish	*Prosopium williamsoni*	20	>100	>100	-	-
Unidentified Sucker	*Catostomus* spp.	-	-	-	-	1

[#]no snorkeling attempted; fish collected from hook and line sampling only

Fish Movements and Water Temperature

Upper Yakima River Basin

At our upper Gold Creek site, mean daily water temperatures ranged from a high of 12.3°C on July 29 to a low of 0°C in January and December (Figure 6). No Bull Trout were detected on either antenna (UGC1, UGC2). In 2021, two bull trout were detected at the upper Gold Creek array in June and July, months during which this site was not operational in 2022.

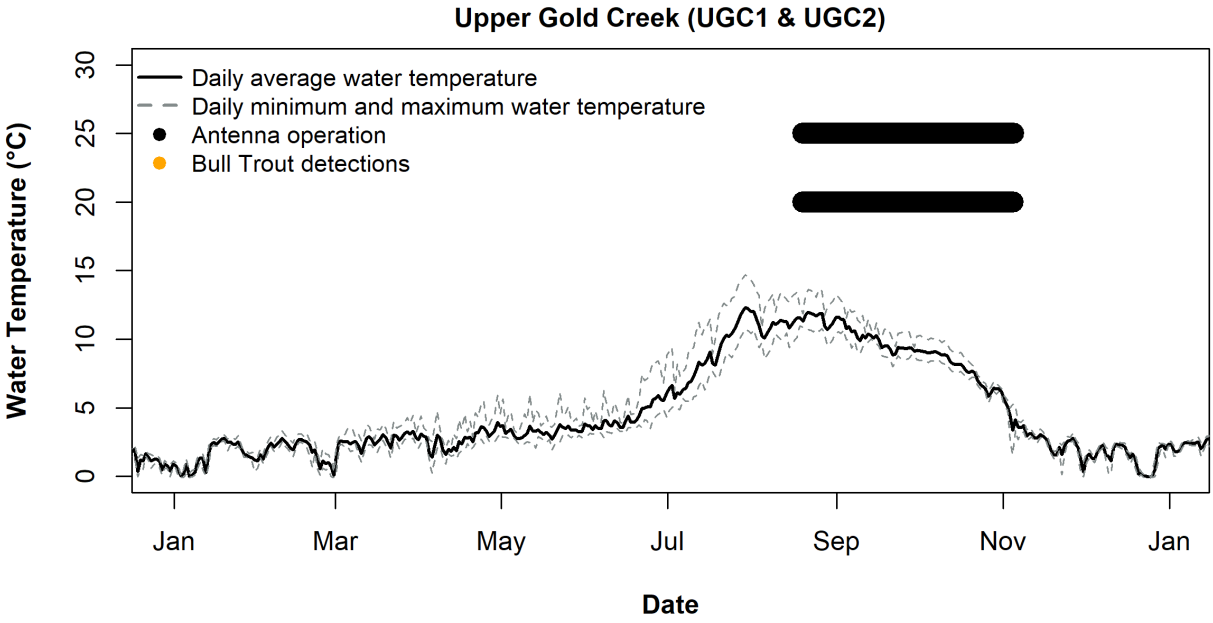

Figure 6. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the upper Gold Creek array (UGC1 and UGC2) during 2022. The top bar indicates UGC1 operation, and the bottom bar indicates UGC2 operation.

Downstream at our lower Gold Creek site, a total of 12 Bull Trout were detected (Table A1). Eight of these detected fish were reared at Yakama Nation's La Salle Reconditioning Facility and released near our antenna site in 2022. Three of the detected fish were tagged by the Washington Department of Fish and Wildlife (WDFW) during their rescue operations in 2021 and 2022. The last fish (3DD.003D481165) was captured and tagged during trap and haul operations in 2021. Bull Trout were generally detected at this site from July 19 to July 25, August 25 to September 15, and again from December 2 to December 19.

Our temperature logger at this site was lost due to a high flow event in November 2021 and not reinstalled until November 16, 2022. During December when Bull Trout were present, mean daily water temperatures ranged from 3.2 to 4.1°C (Figure 7).

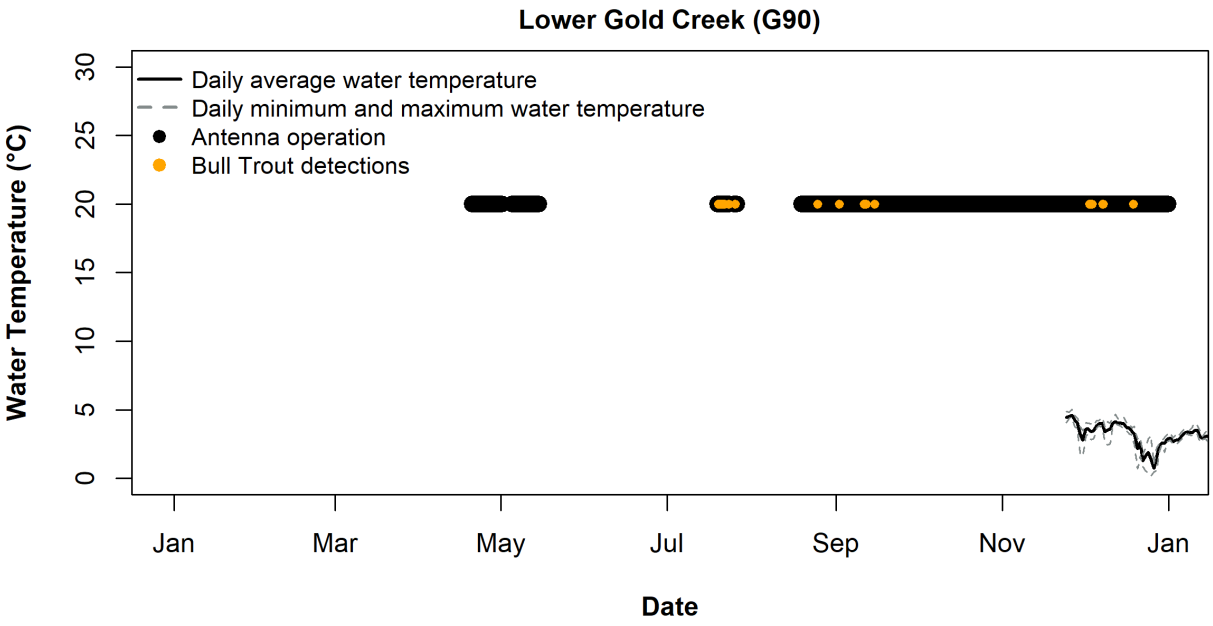

Figure 7. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged Bull Trout at the lower Gold Creek antenna (G90) during 2022.

A total of 13 Bull Trout were detected at the upstream site in the upper Kachess River (KR1), 11 of which were rescued by WDFW in various years: two in 2020, eight in 2021, and one in 2022. The other two Bull Trout were reared at the Yakama Nation's La Salle Reconditioning Facility and released near the mouth of the reservoir in 2022 (Table A2). Bull Trout were generally detected at this site from July 22 to September 7 and again from October 24 to October 31. A single fish deviated from this general pattern, being detected on October 8 (Figure 5). Three Bull Trout (3DD.003D2F0496, 3DD.003D2F0535, 3DD.003D2FA32F) were also detected at the downstream PIT antenna (KACL). No water temperature data was collected at this site in 2022.

Thirteen Bull Trout were also detected on our submersible antenna at the downstream site on the upper Kachess River (KACL; Figure 8). Ten of these fish were reared at the Yakama Nation's La Salle Reconditioning Facility and released near our antenna site in 2022. The other three fish were rescued by WDFW in previous years: one in 2020 and two in 2021 (Table A3). Most Bull Trout were present at KACL between June 7 and September 3, but two individuals were detected later in fall. Both of these late season fish were also detected at the upstream PIT antenna (KR1). The first fish (3DD.003D2FA32F) was originally detected at the upper site (KR1) between October 24-30 before being detected at the lower site (KACL) on October 31. The second fish (3DD.003D2F0535) was detected at the downstream site on July 25 and 26, at the upper site on July 30 and October 27, and then again at the lower site on November 1.

Mean daily water temperatures peaked at 9.9°C on July 22, with 17 days in July that were at or above 9°C, the warmest temperatures recorded at this site (Figure 8). The river was likely dry

during September and October when no water temperature or fish detections occurred. Water temperature data collection resumed in early November which likely coincided with the rewetting of the stream and outmigration of the two late season fish.

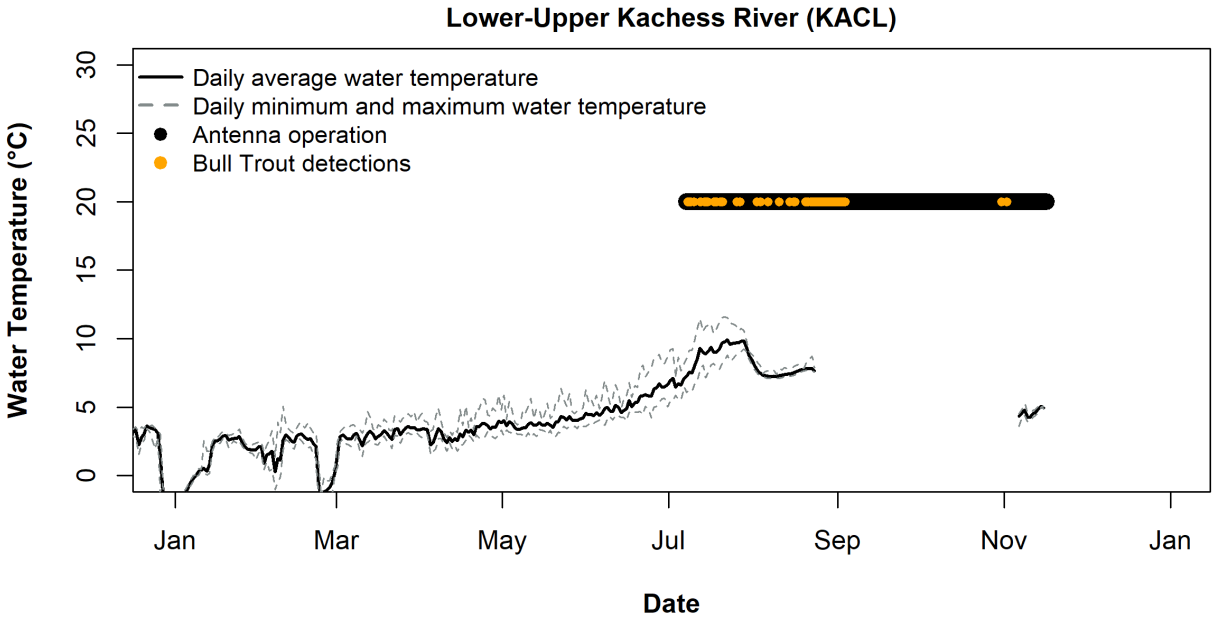

Figure 8. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the downstream site on the upper Kachess River (KACL) during 2022.

A total of 28 Bull Trout were detected at the Box Canyon Creek array (BOX1 and BOX2), 24 of which were reared at the Yakama Nation's La Salle Reconditioning Facility and released in Little Kachess Lake in 2022. Additionally, one detected Bull Trout was caught in 2021 below Keechelus Dam during trap and haul operations, one was rescued from the upper Kachess River in 2021 by WDFW, and two were tagged at Peekaboo Falls in Box Canyon Creek in 2020 by USFWS (Table A4). The upstream antenna (BOX1) had one unique detection and the downstream antenna (BOX2) had six unique detections. Bull Trout were generally detected at this site from July 7 to August 22, and again from September 16 to October 6 (Figure 5). Water temperature was not recorded at this site in 2022.

Naches River Basin

In total, we detected 19 Bull Trout at the upper North Fork Tieton antenna site (UPNFT; Figure 9) and 21 Bull Trout at the lower North Fork antenna site (NFT; Figure 10) in 2022. The two fish detected at the lower site but not at the upper site included one 2018 transport (000.000AC3B27B) and one 2019 transport (000.000AC3B26F). Of the 19 fish detected at the

upper antenna (UPNFT), six were transported above Clear Creek Dam in 2022, which accounts for 75% of all 2022 transports at this site. These six fish were detected at both our lower (NFT) and upper (UPNFT) North Fork Tieton sites. In addition to the six transports from 2022, we also detected transports from 2018-2021 (Table 5). Two of the fish transported into Clear Lake in 2022 were not detected at either of the North Fork Tieton antennas, at the Clear Creek Dam fish ladder (ULD), or at in the Clear Creek Dam outlet channel (OCH). This indicates that although these two fish probably did not spawn in 2022, they did not appear to exit the reservoir and may spawn in subsequent years.

Bull Trout were detected at the lower North Fork Tieton (NFT) site from June 22 to November 6. During this time, the mean daily water temperature ranged from 3.3 to 12.3 °C with a maximum temperature of 14.4 °C occurring on August 22 (Figure 10). At the upper North Fork Tieton site (UPNFT), Bull Trout were detected from July 11 to October 31. During this time, the mean daily water temperature ranged from 4.3 to 11.5 °C with the maximum temperature of 13.1 °C occurring on August 20 (Figure 9).

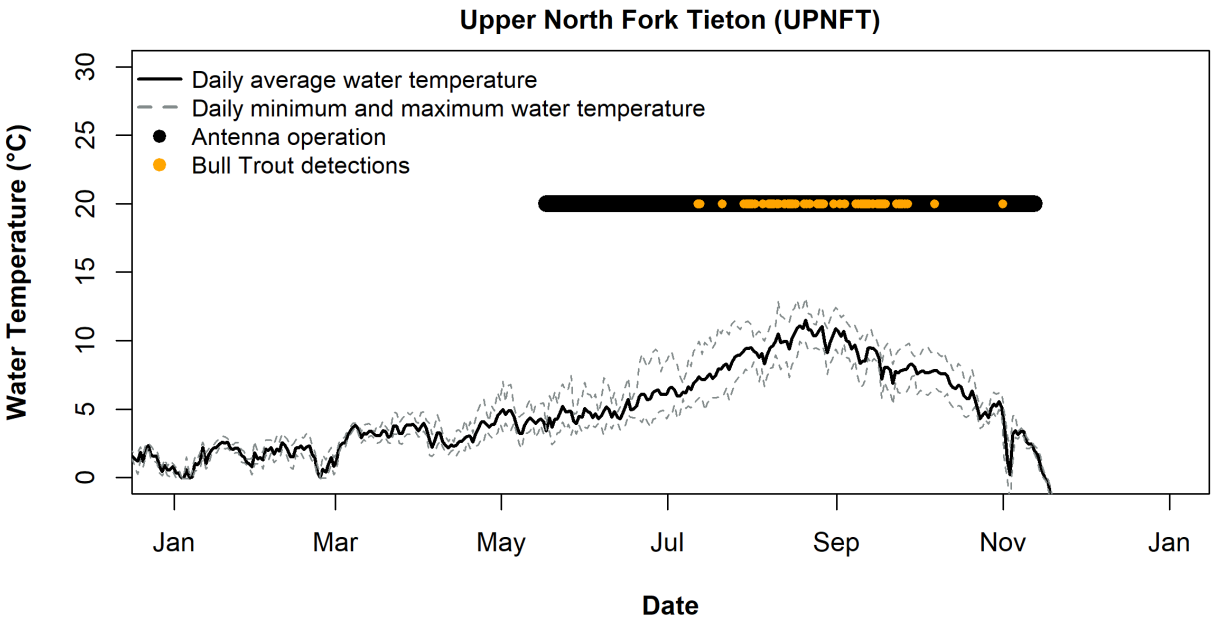

Figure 9. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the Upper North Fork Tieton antenna (UPNFT) during 2022.

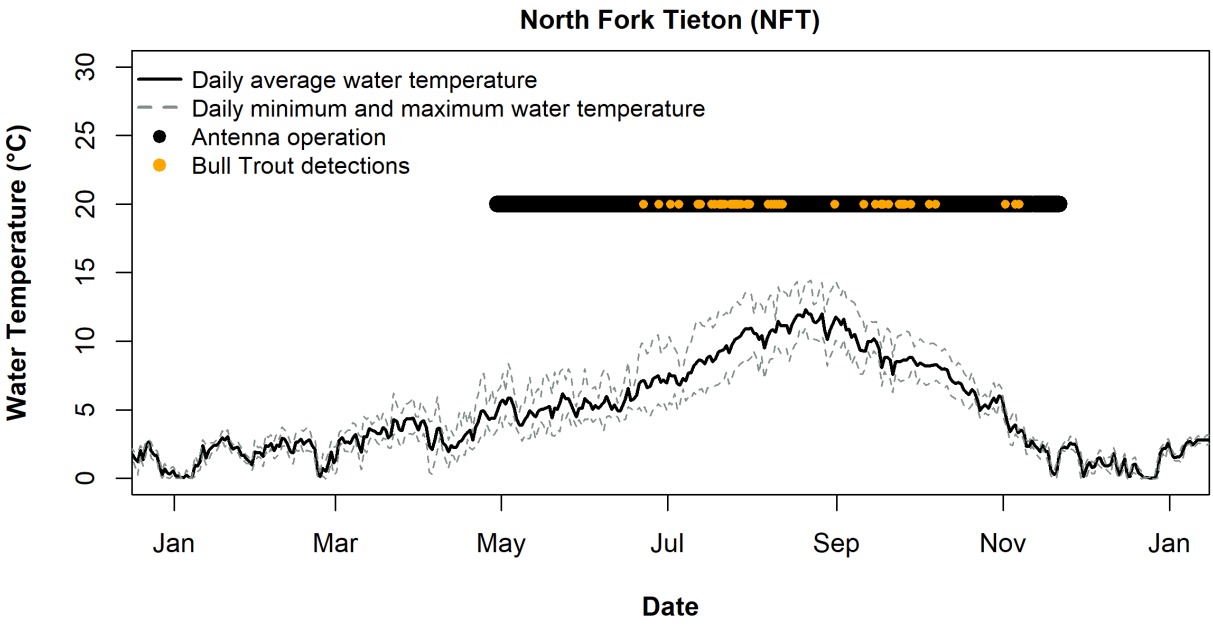

Figure 10. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the lower North Fork Tieton antenna (NFT) during 2022.

Table 5. Number of Bull Trout transported to Clear Lake by year and the number of unique Bull Trout detected at the North Fork Tieton antenna sites in 2022. We did not detect any Bull Trout transported prior to 2018.

Year Tagged	Number Transported	Number Detected at the lower North Fork (NFT) site in 2022	Number Detected at the upper North Fork (UPNFT) site in 2022
2018	22	2	1
2019	19	4	3
2020	3	2	2
2021	15	7	7
2022	8	6	6
Total	**67**	**21**	**19**

We detected three Bull Trout (one 2020 transport, one 2021 transport, and one 2022 transport) at the Clear Creek Dam fish ladder site (ULD), indicating that they may have exited Clear Lake. All of these fish were detected at both the upper and lower North Fork Tieton sites prior to being detected at the fish ladder between November 2 and November 19. The 2020 fish was first detected at the upper ladder site (ULD) on November 2 and then at the lower North Fork antenna site (NFT) on November 5. This indicates that individuals detected at the upper ladder site do not necessarily go down the fish ladder.

The mean daily water temperature in the Clear Creek Dam fish ladder ranged from 0.7 to 13.1 °C with a maximum temperature of 15.5 °C, occurring on June 30. However, data do not capture the warmest months of the year due to logger failure. Bull Trout were only observed entering the ladder post-spawn after water temperatures had decreased (Figure 11).

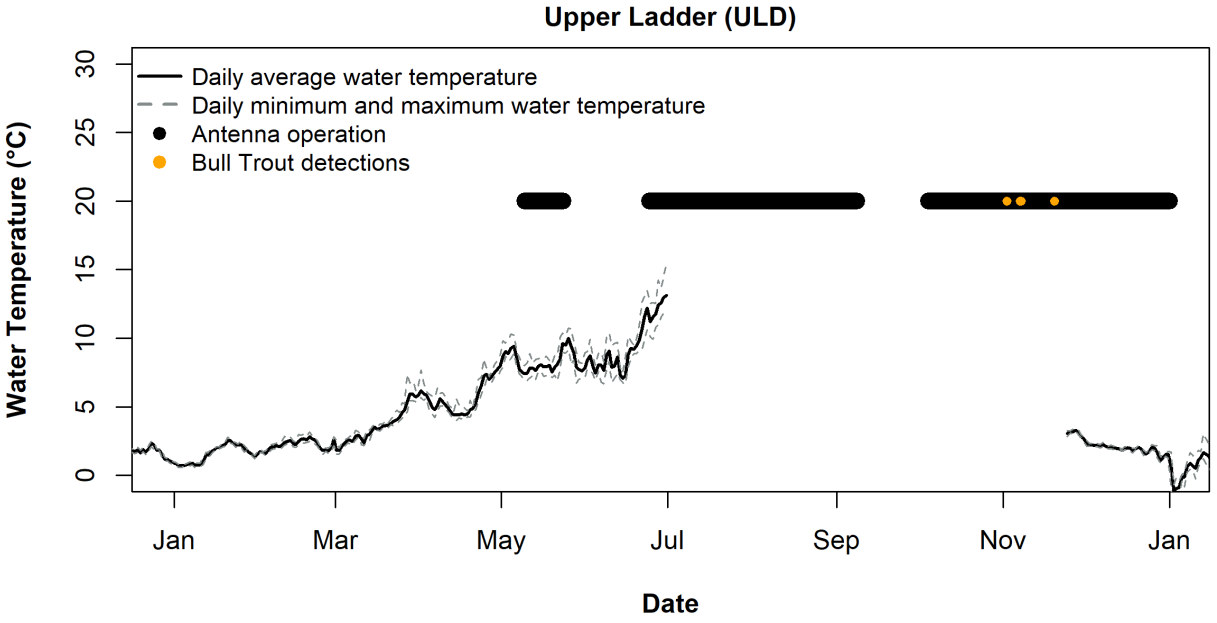

Figure 11. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the upper ladder antenna of the Clear Creek Dam spillway (ULD) during 2022.

At our antenna site in the outlet channel downstream of Clear Creek Dam (OCH), we detected 11 Bull Trout in 2022 between June 23 and November 16 (Figure 7). Eight of these fish were Indian Creek or South Fork Tieton-origin fish, collected in the Clear Creek Dam stilling basin and released downstream. Of the Indian Creek fish, one was tagged in 2020, two were tagged in 2021, and three were tagged in 2022. The two South Fork Tieton fish were both tagged in 2022. Three North Fork Tieton-origin Bull Trout (one 2018 transport, one 2020 transport, and one

2021 transport) were also detected below Clear Creek Dam (OCH). The fish tagged in 2018 (000.000AC3B225) was detected on June 23 and June 28. The fish tagged in 2021 (3DD.003D48116C) remained in the Clear Creek Dam stilling basin and was detected numerous times between July 19 and October 6. The fish tagged in 2020 (000.000AC772C3) was first detected at the lower North Fork Tieton (NFT) site on July 24 and then at the upper North Fork Tieton (UPNFT) site on August 12 before returning downstream to NFT site on November 1. This fish subsequently entered the Clear Creek fish ladder (ULD) on November 2, was detected at the NFT site on November 5 and again in the fish ladder on November 7. The fish then made its way to the Clear Creek Dam stilling basin (OCH) on November 16.

Between June 23 and August 9, the only period when temperature data coincided with Bull Trout presence at this site, mean daily water temperature ranged from 8.2 to 12.6 °C. The highest recorded water temperature of 12.6 °C was observed on August 1; however, it is possible that higher temperatures were realized at this site after August 9 when our temperature logger was lost (Figure 12).

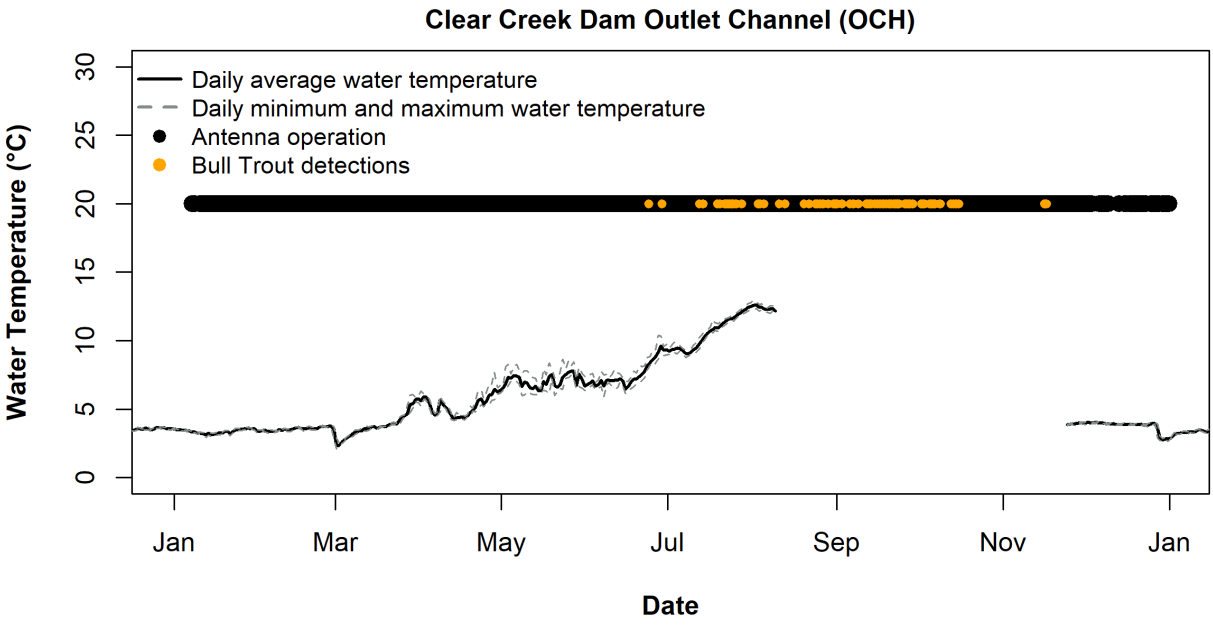

Figure 12. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the Clear Creek Dam Outlet Channel antenna (OCH) during 2022.

In 2022, we detected four Bull Trout at our Indian Creek array (IND1, IND2) between September 15 and October 4 (Figure 13). All fish were Indian Creek origin and were previously collected and released below Clear Creek Dam (OCH), two in 2021 and two in 2022. Unfortunately, this site was not operational until September 2 and therefore we only detected fish that were

presumably leaving Indian Creek post-spawning. We did not detect these Bull Trout as they entered Indian Creek. In 2021, detections at Indian Creek occurred between June 30 and October 6.

A water temperature logger was installed at this site in 2022, reading between 1 and 3.5°C from November 30 through December 30.

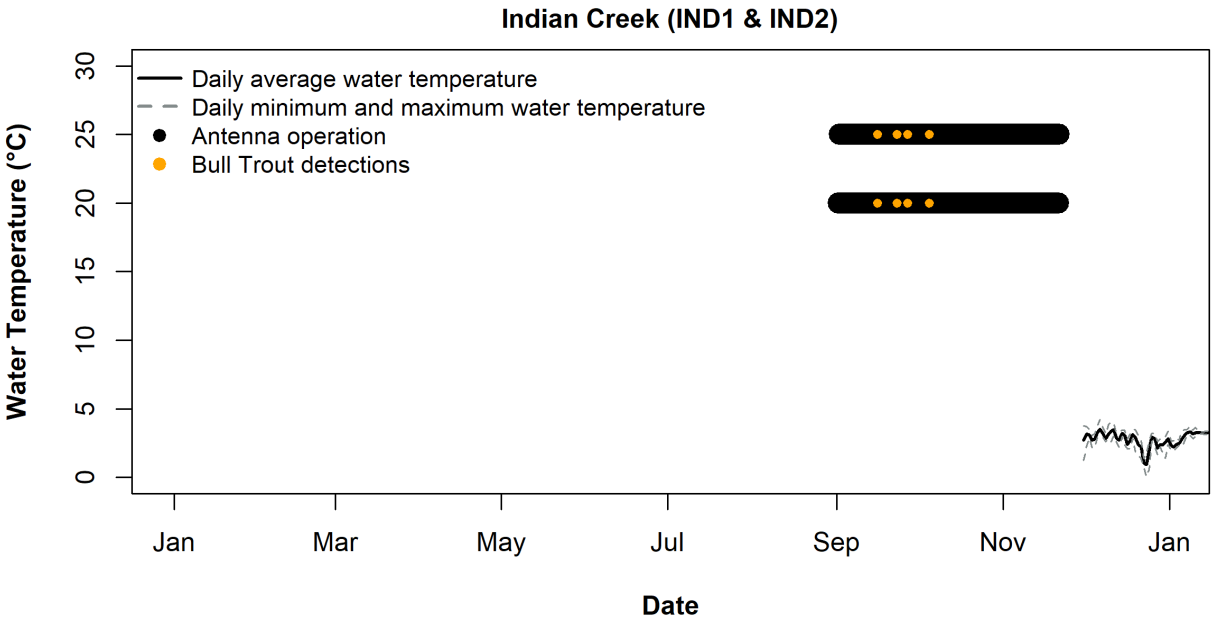

Figure 13. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the Indian Creek array (IND1 and IND2) during 2022. The top bar indicates IND1 operation, and the bottom bar indicates IND2 operation.

In 2022, we detected six Bull Trout at the upper South Fork Tieton antenna site (SFT; Figure 14) and four Bull Trout at the lower South Fork antenna site (LSFT; Figure 5). All fish were South Fork Tieton origin. Five fish were originally captured and released downstream of Clear Creek Dam, one in 2018, three in 2020, and one in 2021. One fish (3D9.1C2E05D1B3) was captured downstream of Tieton Dam in 2020 and subsequently detected in the South Fork Tieton River in 2020, 2021, and 2022. We did not detect any of the 14 South Fork Tieton-origin fish captured during 2022 trap and haul operations below Clear Creek Dam.

Bull Trout were present at the lower South Fork Tieton site (LSFT) from September 9 to September 14 (Figure 5). However, this site was operational beginning on September 8, so detections likely only captured some of the post-spawn outmigration. No water temperature data was collected at this site in 2022. At the upper South Fork Tieton site (SFT), Bull Trout were detected from July 16 to September 19. During this time, the mean daily water temperature

ranged from 6.0 to 13.7°C with a maximum temperature of 16.7°C occurring on August 20 (Figure 14).

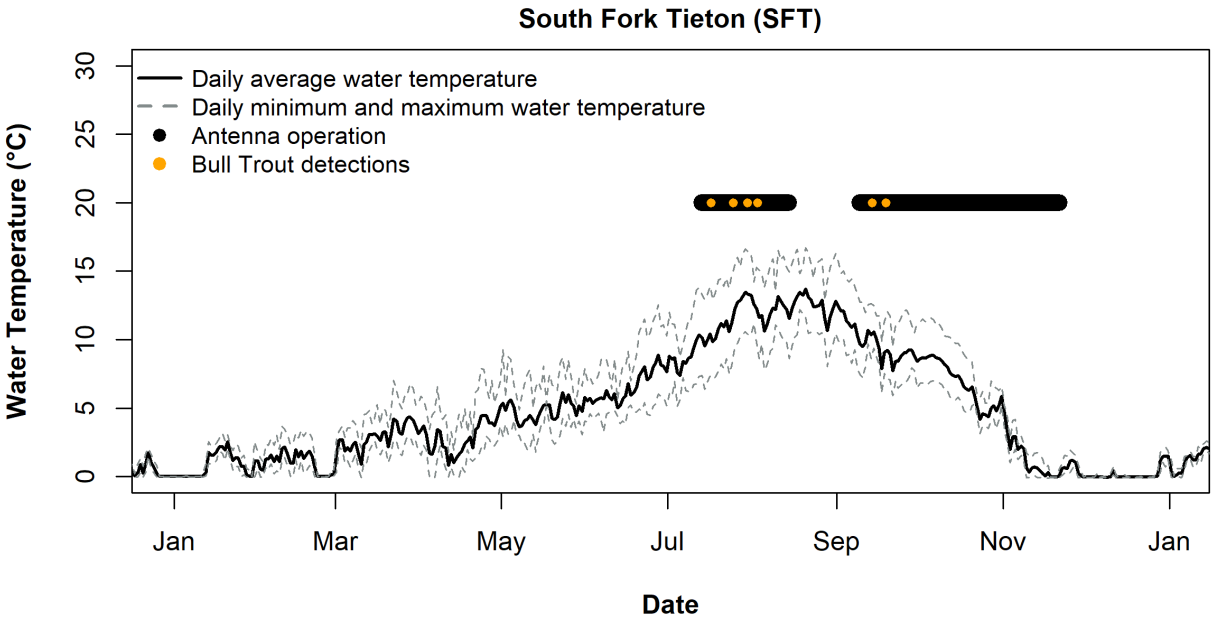

Figure 14. Seasonal change in water temperature, antenna operation, and detections of PIT-tagged adult Bull Trout at the upper South Fork Tieton antenna (SFT) during 2022.

Survival and Detection Probability

Survival analysis utilized detection histories of 130 North Fork Tieton-origin individuals marked between 2012-2021 over 10 observation periods (i.e., recapture events) from 2013-2022. Mean survival probability across all study years was 64.1% (95% CRI: 56.2 - 72.1%) with the lowest annual survival probability of 60.0% occurring in 2017 and the highest annual survival probability of 69.5% occurring in 2018. The annual survival probability for 2022 was 61.2% (95% CRI: 46.7 – 71.8%), which is below the mean survival probability (Figure 15). Detection probabilities (i.e., probability of recapture) were between 82.2% and 99.3% across all simulations with an average detection probability of 94.4% (Figure 16).

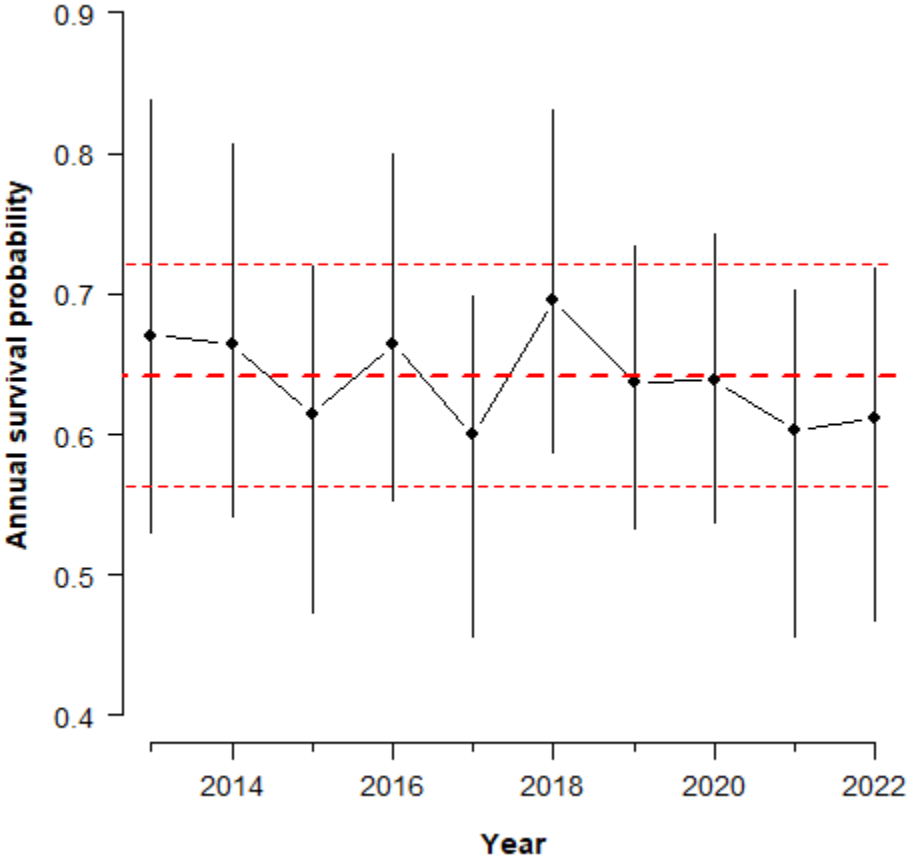

Figure 15. Annual survival probability of NFT adult Bull Trout (closed circles, with 95% CRIs) and mean survival (red line, with 95% CRI dotted) across study years.

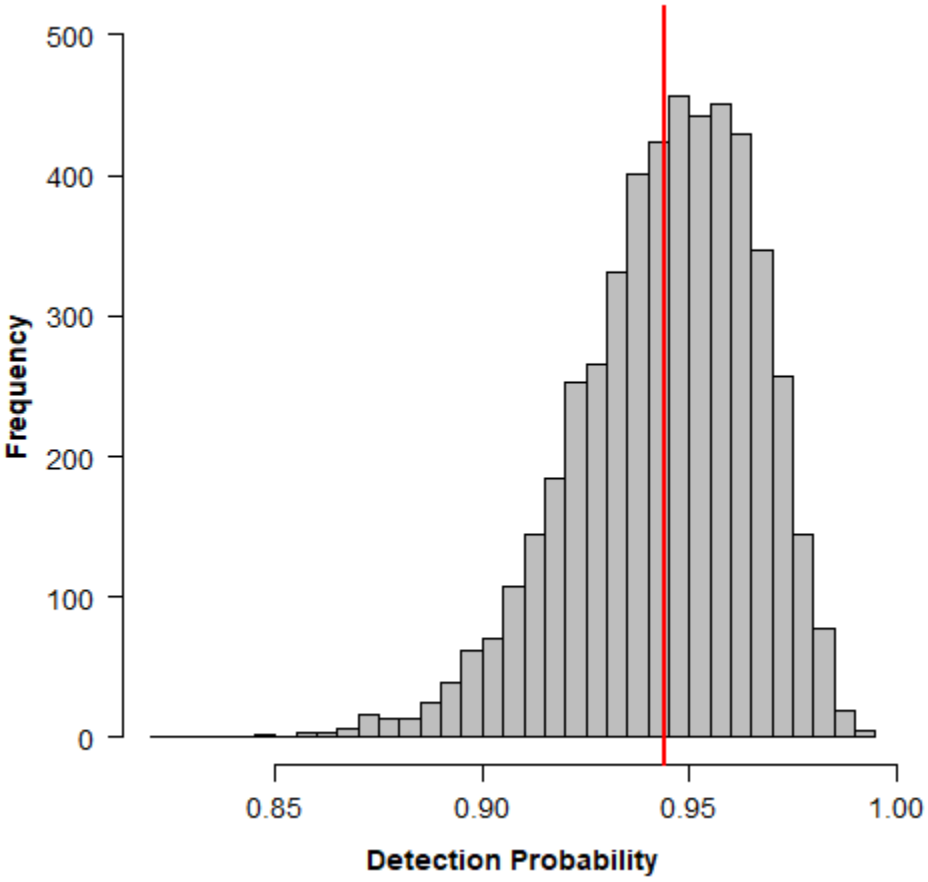

Figure 16. Posterior distribution of detection probabilities from 2013-2022. Red line indicates average detection probability.

Discussion

Our data indicate that fish continue to be entrained at Yakima Basin dams in both the upper Yakima River Basin and the Naches River Basin, particularly at Clear Creek Dam where we have captured 100 North Fork Tieton-origin Bull Trout (including recaptures) since the program began in 2016. For the last two years, more than half of all Bull Trout captured during trap and haul were North Fork Tieton-origin fish captured below Clear Creek Dam. Data suggest these entrained Bull Trout most likely exit Clear Lake through the fish ladder and spillway on the north side of the dam but are unable to use the same pathway to migrate upstream (Thomas and Monk 2016). We continue to see no evidence to suggest Bull Trout are migrating upstream in the spillway channel as we have not detected any individuals in the fish ladder or in the North Fork Tieton that were not transported previously through our trap and haul program. At this time, we have not quantified the entrainment through the outlet works at Clear Creek

Dam. Although we capture most Bull Trout below Clear Creek Dam, entrainment occurs at the other dams as well. Since 2019, we have captured 20 Bull Trout at Keechelus Dam, two at Tieton Dam (trap and haul here began in 2020), one at Bumping Dam, and one at Kachess Dam. Unlike the Indian Creek and South Fork Tieton-origin fish we collect at Clear Creek Dam, all upper Yakima Basin fish captured during trap and haul have been entrained. To better understand Bull Trout entrainment, we plan to improve and install PIT antennas below the upper Yakima Basin dams in 2023.

In 2022, we detected 21 tagged adult Bull Trout in the North Fork Tieton River, six in the South Fork Tieton River, four in Indian Creek, three in Box Canyon Creek, and one in Gold Creek. Bull Trout have been tagged in the North Fork Tieton River since 2012 and during trap and haul operations at Clear Creek Dam since 2014. In total, we have tagged 173 adult Bull Trout at Clear Creek Dam, amounting to 115 North Fork Tieton, 34 Indian Creek and 24 South Fork Tieton River-origin Bull Trout. In the upper Yakima River Basin, trap and haul operations first started in 2019 and have resulted in the capture, tagging, and transport of 20 adults, 18 of which were Gold Creek origin. In addition to limited numbers of tagged adults, the lack of detections, particularly in Gold Creek, was likely exacerbated by limited antenna operations during migration periods. Gold Creek antennas were not operational during June and July, times when adult Bull Trout were detected in 2021. Consequently, it is possible that detections were missed during times of antenna inactivity.

The timing of intermittent flows in tributaries, particularly during spawning migration, inhibit upstream movement into spawning areas and may contribute to a lower percentage of marked fish being detected. For example, the lower 4 km of Gold Creek regularly dewaters during the period from late July to late September. This led to Bull Trout spawning on the reservoir bed downstream of I-90 in 2022. Fish that migrate in early June or early July could ascend the creek, but later arriving fish are prevented from doing so by insufficient streamflow and connectivity. Similarly, the lower mile of the upper Kachess River dewaters every year during summer and fall, and Bull Trout were documented spawning on the reservoir bed in 2019. In the Tieton River Basin, Indian Creek and South Fork Tieton maintain connectivity with Rimrock Reservoir during upstream migration. However, outmigration may be problematic as reservoir pool elevation drops in late summer and fall when irrigation demand is met using Rimrock Reservoir. For example, the South Fork Tieton River develops a barrier waterfall after August 10, posing a threat to out-migrating Bull Trout.

Survival probability for adult North Fork Tieton-origin Bull Trout showed some variability across years (0.60 - 0.695). However, considerable variability of adfluvial adult Bull Trout survival is not uncommon. For example, studies have found annual survival estimates ranging from 0.32 to 0.48 in Lake Pend Oreille in Idaho (Mucciarone et al. 2022), from 0.20 to 0.79 (since ESA-listing) in the upper Lewis River in Washington (Al-Chokhachy et al. 2019), and from 0.69 to 0.90 in lower Kananaskis Lake in Alberta (Johnston and Post 2009). A previous study of nearby Yakima Basin Bull Trout subpopulations estimated adult survival ranging from 0.51 to 1 in Indian Creek,

0.33 to 1 in South Fork Tieton River, and 0.70 to 1 in Deep Creek (James 2002). Comparatively, our annual survival probabilities for North Fork Tieton River-origin adults ranged from 0.60 to 0.69. Interestingly, our highest annual survival probability occurred in 2018, coinciding with the Miriam Creek wildfire that was located west of Clear Lake and the North Fork Tieton River. This fire resulted in the closure of the entire area for much of the summer and fall months, times which normally experience heavy recreational use (e.g., camping, fishing).

Maintaining antenna sites continues to be challenging. High flows from rain on snow events frequently destroy antennas. We are unable to reinstall destroyed antennas until flows are sufficiently low to allow for safe instream work which, in some cases, could take months. For example, our lower Gold Creek site (G90) was both destroyed by high flows and then inundated for two months by the resulting rise in Keechelus Reservoir pool elevation. During those two months, we were unable to collect any detection data at that site. Additionally, when high flow events are widespread, many sites may be destroyed simultaneously. To address this difficulty, we began using a submersible PIT antenna that is more portable than a traditional antenna, allowing us to quickly deploy antennas into areas where permanent antennas are unsuitable or frequently destroyed. We tested a submersible antenna within the Keechelus spillway channel, which was temporarily activated this year, to ascertain if Bull Trout use the spillway channel to emigrate from Keechelus Reservoir. No fish were detected on this antenna likely because the spillway channel remains too shallow for fish to enter, and any entrained fish would likely die from falling over the entrance and on to the concrete below. We also deployed a submersible antenna at the upper Kachess River site (KACL), where previous fixed antennas had been destroyed by high flows and streambed mobilization. When a large flow event occurred in Kachess River in 2022, although the submersible antenna became dislodged and carried downstream approximately 100 m from where it was deployed, the antenna was still operational. However, while the submersible antennas have been useful, their dimensions generally do not span the entire wetted channel and therefore must be placed strategically (e.g., in the thalweg) to maximize efficacy. In future years, we will carry out trials to determine detection efficiency of these antennas.

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TE-702631 (granted to the USFWS MCFWCO) for work at Clear Creek Dam. Fish were collected under permit# 21-187 and transported under permit# 8537-03-22-21 granted by WDFW. Funding for this program was provided by the USBR Yakima River Basin Water Enhancement Project administered by Wendy Christensen and is a fulfillment of our contractual obligations under Interagency Agreement# R17PG00108 between the USBR and the USFWS Mid-Columbia Fish and Wildlife Conservation Office.

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Appendix A

Bull Trout detections in the Upper Yakima Basin

Table A1. Bull Trout detected at the lower Gold Creek antenna (G90) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2021	USFWS	3DD.003D481165	Gold Creek	9/2/2022 1:52	9/15/2022 3:44
2021	WDFW	3DD.003D2F055D	Gold Creek	12/19/2022 1:53	12/19/2022 1:53
2022	WDFW	3DD.003D2F0512	Gold Creek	12/2/2022 21:33	12/7/2022 22:05
2022	WDFW	3DD.003D2F051E	Gold Creek	8/25/2022 4:03	8/25/2022 4:03
2022	YN	3DD.003D2EEDCF	Gold Creek	7/20/2022 4:56	7/20/2022 4:56
2022	YN	3DD.003D2F0914	Gold Creek	7/19/2022 21:37	7/22/2022 4:34
2022	YN	3DD.003D59D218	Gold Creek	7/20/2022 4:37	7/23/2022 15:04
2022	YN	3DD.003D59D363	Gold Creek	7/19/2022 22:57	7/19/2022 23:34
2022	YN	3DD.003D59D615	Gold Creek	7/25/2022 22:55	7/25/2022 22:55
2022	YN	3DD.003D59D8F5	Gold Creek	7/25/2022 21:50	7/25/2022 21:50
2022	YN	3DD.003D5A3DE6	Gold Creek	7/19/2022 20:40	7/20/2022 4:46
2022	YN	3DD.003D5A3FAF	Gold Creek	7/19/2022 21:00	7/22/2022 3:00

Table A2. Bull Trout detected at the upper site on the upper Kachess antenna (KR1) in 2022. Genetics have not been run on these fish yet and could have mixed parentage (Box Canyon x Kachess River).

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2020	WDFW	3DD.003D2FA32F	unknown	10/24/2022 20:15	10/30/2022 16:36
2020	WDFW	3DD.00776D9E0A	unknown	7/24/2022 4:24	7/25/2022 20:43
2021	WDFW	3DD.003D2F0496	unknown	7/22/2022 14:41	7/27/2022 12:47
2021	WDFW	3DD.003D2F0502	unknown	7/25/2022 7:59	7/25/2022 16:25
2021	WDFW	3DD.003D2F0519	unknown	8/1/2022 23:35	10/30/2022 17:24
2021	WDFW	3DD.003D2F0535	unknown	7/30/2022 20:38	10/27/2022 20:18
2021	WDFW	3DD.003D2F054A	unknown	7/31/2022 3:44	7/31/2022 3:44

2021	WDFW	3DD.003D2F055A	unknown	7/30/2022 3:49	10/31/2022 17:09
2021	WDFW	3DD.003D2F055C	unknown	7/27/2022 0:36	10/8/2022 5:29
2021	WDFW	3DD.003D2F055F	unknown	8/5/2022 4:08	10/27/2022 19:54
2022	YN	3DD.003D2EEDE6	unknown	7/29/2022 2:56	7/29/2022 2:56
2022	YN	3DD.003D59D797	unknown	8/9/2022 2:41	10/28/2022 18:09
2022	WDFW	3DD.003D2F050C	unknown	8/9/2022 20:38	8/9/2022 21:22

Table A3. Bull Trout detected at the downstream site on the upper Kachess River submersible antenna (KACL) in 2022. Genetics have not been run on these fish yet and could have mixed parentage (Box Canyon x Kachess River).

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2020	WDFW	3DD.003D2FA32F	unknown	10/31/2022 1:34	10/31/2022 1:46
2021	WDFW	3DD.003D2F0496	unknown	8/22/2022 5:30	9/3/2022 17:30
2021	WDFW	3DD.003D2F0535	unknown	7/25/2022 23:59	11/1/2022 22:12
2022	YN	3DD.003D59CF2E	unknown	7/27/2022 3:40	8/30/2022 17:12
2022	YN	3DD.003D59CF31	unknown	7/7/2022 21:09	7/7/2022 21:09
2022	YN	3DD.003D59CF35	unknown	8/20/2022 4:32	9/3/2022 16:40
2022	YN	3DD.003D59CF45	unknown	7/18/2022 14:15	7/18/2022 14:17
2022	YN	3DD.003D59D14F	unknown	7/8/2022 5:01	7/12/2022 19:11
2022	YN	3DD.003D59D15B	unknown	7/15/2022 5:21	9/3/2022 1:42
2022	YN	3DD.003D59D171	unknown	7/10/2022 4:40	7/14/2022 20:00
2022	YN	3DD.003D59D7AC	unknown	7/19/2022 22:19	7/19/2022 22:19
2022	YN	3DD.003D59D7E7	unknown	8/15/2022 20:41	8/16/2022 5:00
2022	YN	3DD.003D59D807	unknown	7/12/2022 21:06	7/20/2022 17:13

Table A4. Bull Trout detected at Box Canyon antennas (BOX1 and BOX2) in 2022. Genetics have not been run on many of these fish yet and could have mixed parentage (Box Canyon x Kachess River).

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2020	USFWS	3D9.1C2E060133	Box Canyon	8/3/2022 2:07	8/3/2022 2:45

2020	USFWS	3D9.1C2E0603CE	Box/Kachess	9/16/2022 2:28	9/16/2022 2:36
2021	USFWS	3DD.003D481189	Box Canyon	9/27/2022 7:28	9/27/2022 8:37
2021	WDFW	3DD.003D2F0502	unknown	7/28/2022 17:40	7/31/2022 12:23
2022	USFWS	3DD.003D481166	Kachess	7/19/2022 0:31	7/19/2022 8:49
2022	USFWS	3DD.003D481168	Kachess	8/14/2022 2:18	8/14/2022 2:18
2022	USFWS	3DD.003D481171	Kachess	7/19/2022 5:21	8/15/2022 20:30
2022	USFWS	3DD.003D48119A	Kachess	7/18/2022 22:15	7/19/2022 8:36
2022	USFWS	3DD.003D48119D	Kachess	7/20/2022 23:50	7/20/2022 23:54
2022	USFWS	3DD.003D48119F	Kachess	7/19/2022 8:40	7/19/2022 8:40
2022	YN	3DD.003D2EEC30	unknown	7/22/2022 21:15	7/22/2022 21:16
2022	YN	3DD.003D59CF31	unknown	7/10/2022 17:08	7/12/2022 20:17
2022	YN	3DD.003D59D11C	unknown	8/6/2022 11:37	8/6/2022 11:47
2022	YN	3DD.003D59D130	unknown	7/13/2022 4:08	7/13/2022 4:08
2022	YN	3DD.003D59D13A	unknown	8/12/2022 22:13	8/12/2022 22:27
2022	YN	3DD.003D59D13B	unknown	8/13/2022 2:09	8/15/2022 20:40
2022	YN	3DD.003D59D14D	unknown	8/8/2022 19:42	8/8/2022 19:43
2022	YN	3DD.003D59D152	unknown	7/30/2022 3:58	10/6/2022 0:27
2022	YN	3DD.003D59D1B4	unknown	7/8/2022 0:00	7/29/2022 23:14
2022	YN	3DD.003D59D1BE	unknown	8/15/2022 22:25	10/3/2022 2:18
2022	YN	3DD.003D5A43F0	unknown	7/16/2022 0:19	7/16/2022 4:23
2022	YN	3DD.003D5A43F8	unknown	7/26/2022 8:02	7/26/2022 8:13
2022	YN	3DD.003D5A4405	unknown	8/22/2022 5:19	8/22/2022 5:19
2022	YN	3DD.003D5A4414	unknown	7/7/2022 18:32	7/15/2022 16:23
2022	YN	3DD.003D5A4421	unknown	7/18/2022 4:55	7/18/2022 4:55
2022	YN	3DD.003D5A4431	unknown	7/26/2022 23:27	8/2/2022 1:02
2022	YN	3DD.003D5A4440	unknown	7/24/2022 5:34	8/12/2022 21:22
2022	YN	3DD.003D5A4443	unknown	7/8/2022 3:48	10/1/2022 19:47

Appendix B

Bull Trout detections in the Naches River Basin

Table B1. Bull Trout detected at the upper North Fork Tieton antenna (UPNFT) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2018	USFWS	000.000AC3B212	NF Tieton	7/12/2022 21:10	7/12/2022 21:10
2019	USFWS	000.000AC3B1C6	NF Tieton	8/1/2022 22:17	9/15/2022 19:52
2019	USFWS	000.000AC3B2F6	NF Tieton	8/1/2022 23:37	8/1/2022 23:37
2019	USFWS	000.000AC3B28B	NF Tieton	7/30/2022 00:06	9/24/2022 19:35
2020	USFWS	000.000AC77290	NF Tieton	7/29/2022 21:35	9/14/2022 04:30
2020	USFWS	000.000AC772C3	NF Tieton	8/12/2022 23:33	10/31/2022 18:21
2021	USFWS	3DD.003D481169	NF Tieton	7/11/2022 22:53	9/17/2022 02:20
2021	USFWS	3DD.003D48116F	NF Tieton	8/4/2022 21:01	8/26/2022 03:31
2021	USFWS	3DD.003D481175	NF Tieton	8/14/2022 03:38	9/26/2022 23:19
2021	USFWS	3DD.003D48117E	NF Tieton	7/31/2022 05:17	10/6/2022 19:43
2021	USFWS	3DD.003D48118C	NF Tieton	8/6/2022 23:04	9/24/2022 01:15
2021	USFWS	3DD.003D4811A2	NF Tieton	7/20/2022 21:38	9/17/2022 6:10
2021	USFWS	3DD.003D4811AE	NF Tieton	8/10/2022 01:39	9/14/2022 06:25
2022	USFWS	3DD.003D481182	NF Tieton	8/8/2022 22:25	9/23/2022 22:27
2022	USFWS	3DD.003D481184	NF Tieton	7/31/2022 00:00	9/23/2022 23:11
2022	USFWS	3DD.003D48118B	NF Tieton	8/16/2022 22:03	9/22/2022 20:32
2022	USFWS	3DD.003D481195	NF Tieton	8/14/2022 22:37	9/14/2022 02:41
2022	USFWS	3DD.003D4811A7	NF Tieton	8/12/2022 21:17	9/24/2022 22:56
2022	USFWS	3DD.003D4811BB	NF Tieton	8/15/2022 00:44	9/25/2022 21:48

Table B2. Bull Trout detected at the lower North Fork Tieton antenna (NFT) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2018	USFWS	000.000AC3B212	NF Tieton	6/22/2022 00:35	6/22/2022 00:35
2018	USFWS	000.000AC3B27B	NF Tieton	6/27/2022 18:16	6/27/2022 18:16
2019	USFWS	000.000AC3B1C6	NF Tieton	7/12/2022 21:28	9/19/2022 22:26

2019	USFWS	000.000AC3B26F	NF Tieton	7/12/2022 03:03	7/12/2022 03:03
2019	USFWS	000.000AC3B28B	NF Tieton	7/1/2022 21:58	9/25/2022 03:30
2019	USFWS	000.000AC3B2F6	NF Tieton	7/29/2022 23:27	7/29/2022 23:27
2020	USFWS	000.000AC77290	NF Tieton	7/11/2022 22:52	9/15/2022 01:43
2020	USFWS	000.000AC772C3	NF Tieton	7/24/2022 21:58	11/6/2022 18:39
2021	USFWS	3DD.003D481169	NF Tieton	7/04/2022 22:48	9/17/2022 05:54
2021	USFWS	3DD.003D48116F	NF Tieton	7/25/2022 05:09	7/30/2022 23:36
2021	USFWS	3DD.003D481175	NF Tieton	7/25/2022 23:21	10/4/2022 20:57
2021	USFWS	3DD.003D48117E	NF Tieton	7/16/2022 23:29	10/7/2022 03:21
2021	USFWS	3DD.003D48118C	NF Tieton	7/25/2022 00:14	9/24/2022 20:37
2021	USFWS	3DD.003D4811A2	NF Tieton	7/1/2022 23:14	9/18/2022 02:42
2021	USFWS	3DD.003D4811AE	NF Tieton	7/12/2022 00:38	9/15/2022 04:57
2022	USFWS	3DD.003D481182	NF Tieton	7/30/2022 22:37	9/24/2022 05:13
2022	USFWS	3DD.003D481184	NF Tieton	7/24/2022 01:39	9/24/2022 21:18
2022	USFWS	3DD.003D48118B	NF Tieton	8/11/2022 21:00	9/23/2022 20:23
2022	USFWS	3DD.003D481195	NF Tieton	8/9/2022 23:16	8/9/2022 23:16
2022	USFWS	3DD.003D4811A7	NF Tieton	8/7/2022 23:49	9/25/2022 21:17
2022	USFWS	3DD.003D4811BB	NF Tieton	8/11/2022 22:32	9/28/2022 04:27

Table B3. Bull Trout detected at the Clear Creek Dam fish ladder (ULD) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2020	USFWS	000.000AC772C3	NF Tieton	11/2/2022 08:24	11/7/2022 13:56
2021	USFWS	3DD.003D4811A2	NF Tieton	11/19/2022 19:17	11/19/2022 19:17
2022	USFWS	3DD.003D481182	NF Tieton	11/7/2022 02:06	11/7/2022 02:06

Table B4. Bull Trout detected at the Clear Creek Dam outlet channel (OCH) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2018	USFWS	000.000AC3B225	NF Tieton	6/23/2022 22:30	6/28/2022 22:00
2020	USFWS	000.000AC3B2C1	Indian	7/20/2022 03:13	8/26/2022 21:05
2020	USFWS	000.000AC772C3	NF Tieton	11/16/2022 03:07	11/16/2022 19:42

2021	USFWS	3DD.003D48116C	NF Tieton	7/19/2022 02:45	10/6/2022 23:17
2021	USFWS	3DD.003D48117A	Indian	7/24/2022 22:55	7/26/2022 02:43
2021	USFWS	3DD.003D4811B8	Indian	7/23/2022 23:02	7/26/2022 00:39
2022	USFWS	3DD.003D481180	Indian	7/12/2022 16:01	7/14/2022 00:49
2022	USFWS	3DD.003D481181	Indian	7/21/2022 22:46	7/24/2022 08:17
2022	USFWS	3DD.003D48119B	SF Tieton	7/21/2022 21:52	9/22/2022 22:07
2022	USFWS	3DD.003D4811A4	SF Tieton	8/3/2022 04:11	10/15/2022 19:56
2022	USFWS	3DD.003D4811B3	Indian	8/3/2022 03:27	8/3/2022 03:27

Table B5. Bull Trout detected at the Indian Creek antennas (IND1 and IND2) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2021	USFWS	3DD.003D48117A	Indian	9/27/2022 00:46	9/27/2022 00:48
2021	USFWS	3DD.003D4811B8	Indian	9/15/2022 23:31	9/15/2022 23:37
2022	USFWS	3DD.003D481181	Indian	9/22/2022 23:32	9/22/2022 23:34
2022	USFWS	3DD.003D4811B3	Indian	10/4/2022 21:10	10/4/2022 21:11

Table B6. Bull Trout detected at the upper South Fork Tieton antenna (SFT) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2018	USFWS	000.000AC3B1D3	SF Tieton	8/2/2022 22:21	8/2/2022 22:21
2020	USFWS	000.000AC3B2D1	SF Tieton	7/30/2022 04:30	9/19/2022 01:59
2020	USFWS	000.000AC3B2E5	SF Tieton	7/16/2022 21:52	7/16/2022 21:52
2020	USFWS	000.000AC772C9	SF Tieton	7/16/2022 21:54	7/16/2022 21:54
2020	USFWS	3D9.1C2E05D1B3	SF Tieton	9/14/2022 00:28	9/14/2022 00:28
2021	USFWS	3DD.003D4811C0	SF Tieton	7/24/2022 22:02	7/24/2022 22:02

Table B7. Bull Trout detected at the lower South Fork Tieton antenna (LSFT) in 2022.

Mark Year	Organization	PIT-Tag	Origin	First Detection	Last Detection
2020	USFWS	000.000AC3B2D1	SF Tieton	9/19/2022 21:40	9/19/2022 21:40

2020	USFWS	000.000AC772C9	SF Tieton	9/10/2022 21:28	9/10/2022 21:28
2020	USFWS	3D9.1C2E05D1B3	SF Tieton	9/14/2022 04:05	9/14/2022 04:05
2021	USFWS	3DD.003D4811C0	SF Tieton	9/20/2022 23:21	9/20/2022 23:21