Site C Clean Energy Project

Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b)

Task 2b – Peace River Bull Trout Spawning Assessment

Construction Year 10 (2024)

Note: This report has been redacted for the protection of Bull Trout (*Salvelinus confluentus*)

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July 2, 2025

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2024 Peace River Bull Trout Spawning Assessment (Mon-1b, Task 2b)

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A. Putt, D. Ramos-Espinoza, and M. Chung. 2025. Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program – 2024 Peace River Bull Trout Spawning Assessment (Mon-1b, Task 2b). Report prepared for BC Hydro – Site C Clean Energy Project – Vancouver, BC, 67 pages and 5 appendices.

Executive Summary

We report findings of the 2024 Peace River Bull Trout Spawning Assessment (Mon-1b, Task 2b), including Bull Trout redd abundance estimates for tributaries of the Halfway Watershed, and kelt abundance for the Chowade River and Cypress Creek from resistivity counter data. Both methodologies provide abundance indices for Bull Trout spawning in the Halfway Watershed and inform spawn timing, spawner size, and spawner distribution.

We used a Gaussian area-under-the-curve (GAUC) method combining aerial and ground surveys to estimate Bull Trout redd abundance and peak counts in the Chowade River, Cypress Creek, Fiddes Creek, Turnoff Creek, and the upper Halfway River. In 2024, GAUC redd abundance estimates ranged from 1 in Turnoff Creek to 359 (SE = 85) in the Chowade River. GAUC estimates were within the range of baseline peak count estimates for the Halfway Watershed from 2002 to 2012; however, a comparison of peak count and GAUC estimates suggests peak counts underestimate redd abundance.

The GAUC method incorporates error in observer efficiency and survey life to generate a robust abundance estimate. In 2024, the average aerial observer efficiency of Bull Trout redds was variable within and among tributaries, ranging from 0.08 in Fiddes Creek to 0.59 in the upper Halfway River. Aerial observer efficiency was more variable in 2024 relative to previous years, likely due to low counts within the ground reach in some tributaries and surveys. Increased variability in average aerial observer efficiency is reflected in large uncertainty in GAUC estimates. Average redd survey life, defined as the period during which a redd is observable, was 16.5 days (SE 1.6 days).

Resistivity counter data suggest the Chowade River kelt migration began on August 29, with a unimodal peak on September 14. After accounting for counter accuracy, the Bull Trout kelt abundance was 280. The low number of recorded kelt migrants at Cypress Creek did not provide sufficient data to fit a normal distribution curve, Therefore, the Cypress Creek kelt migration was informed by historical kelt dates and assumed to begin on September 6 and peaked on September 19, with a kelt abundance of 24 Bull Trout. Kelt abundance may be underestimated as a portion of the kelt migrations likely occurred after monitoring equipment was removed.

We also monitored fish behaviour in the Chowade River and Cypress Creek using PIT arrays that detected directional movements of tagged fish. The Chowade River PIT array detected 50 unique tags, while the Cypress Creek array detected 13 unique tags. Bull Trout residence time averaged 32.9 days (SD 24.1 days) in the Chowade River. Due to low detection numbers, residence time could not be adequately determined for Cypress Creek Bull Trout.

Acknowledgements

We acknowledge this research is being conducted on the traditional territory of Treaty 8 First Nations of Dunne Zaa, Cree and Tse'khene cultural descent. The Peace River Bull Trout Spawning Assessment is funded by BC Hydro's Site C Clean Energy Project. We would like to thank Brent Mossop and Nich Burnett at BC Hydro for administering this project. We would also like to thank Kevin Rodgers and all staff at Canadian Helicopters for making our flights safe and effective. Many additional InStream staff were critical to the project, including LJ Wilson, Luke Irwin, Jordan Bastin, Cypress Hunder-Rookes, Ben Wade, Dan Scurfield, Cynthia Gajda, Sarah Bennett, and Rhys Moore. Thanks to Josh Korman, Eric Parkinson, and Douglas Braun for valuable comments and discussions on study design.

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1. Introduction

1.1 Project Background

BC Hydro developed the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP) in accordance with Provincial Environmental Assessment Certificate Condition No. 7 and Federal Decision Statement Condition Nos. 8.4.3 and 8.4.4 for the Site C Clean Energy Project (the Project). The Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) represents one component of the FAHMFP and aims to determine the effects and effectiveness of mitigation measures of the Project on fish populations (and their habitat) that migrate to tributaries of the Site C Reservoir. A subcomponent of this program (Task 2b) assesses Bull Trout (*Salvelinus confluentus*) spawning populations in the Halfway Watershed. Data collected for this task will be used to directly address management questions and hypotheses:

> How does the Project affect Peace River fish species that use Site C Reservoir tributaries to fulfill portions of their life history over the short (10 years after Project operations begin) and long (30 years after Project operations begin) terms?
>
> H_0: There will be no change in Bull Trout spawner abundance in the Halfway River relative to baseline estimates.
>
> H_1: Bull Trout spawner abundance in the Halfway River will decline by 20 to 30% relative to baseline estimates.

The objective of the Peace River Bull Trout Spawning Assessment (Mon-1b, Task 2b) is to assess abundance, timing, and distribution of Bull Trout spawning in the Halfway Watershed. We monitor Bull Trout spawning populations by (1) enumerating redds using a Gaussian area-under-the-curve (GAUC) method that accounts for observer error and survey life, and (2) resistivity counters and PIT arrays in the Chowade River and Cypress Creek that monitor adults during their upstream and downstream (kelt) migrations. Monitoring builds upon Bull Trout spawning assessments conducted prior to construction of the Project, including a fish fence operated in the Chowade River in 1994 (R.L. & L. Environmental Services LTD. 1995); angling and redd surveys in the mid-1990s (Baxter 1997); and aerial, ground, and snorkel surveys of peak redd abundance (2002-2012; Diversified Environmental Services and Mainstream Aquatics Ltd. 2009; 2011; 2013).

The 2024 monitoring year marks the fourth year of river diversion, which may provide a barrier to fish migrating past the Project (Cook et al. 2023). While only a smaller proportion of Bull Trout are known to migrate past the Project (Taylor et al. 2013), any potential barriers to migrating fish may impact the number of spawners observed in tributaries of the Halfway River.

1.2 Redd Enumeration

Redd abundance is the primary metric to assess changes in Bull Trout populations resulting from construction and operation of the Project. Bull Trout redd abundance in the Halfway Watershed was previously assessed using redd surveys in key spawning tributaries (Diversified Environmental Services and Mainstream Aquatics Ltd. 2009; 2011; 2013). Historic redd surveys combined aerial helicopter surveys, snorkel surveys, and stream walks to generate peak redd count indices. While these peak counts provide an index of Bull Trout population status, they do not incorporate measurement error and have low spatial and temporal coverage, making it difficult to accurately assess changes in population status over time.

Area-under-the-curve (AUC) methods are widely used to estimate spawner or redd abundance from visual count data (Hilborn et al. 1999). Unlike peak count indices, AUC methods incorporate measurement error (i.e., aerial observer efficiency; OE) and survey life (the length of time a redd is detectable by an observer; SL) to estimate total population abundance. For example, Millar et al. (2012) developed a Gaussian AUC approach using a normally-distributed timing model that accounts for uncertainty in OE and SL. This approach outperformed other commonly used AUC approaches and was robust to normal model assumptions when estimating Pink Salmon (*Oncorhynchus gorbuscha*) abundance (Millar et al. 2012). We use this GAUC method to enumerate redds in tributaries of the Halfway River (Putt et al. 2023), which improves upon historic peak count indices by estimating total redd abundance over the full spatial and temporal extent of the Bull Trout spawning period.

1.3 Resistivity Counters and PIT Arrays

We operate resistivity counters and PIT arrays in the Chowade River and Cypress Creek to enumerate upstream and downstream (kelting) migrating Bull Trout, inform the relationship between redd abundance and spawner abundance, and estimate key demographic parameters (survival between life stages, recruitment, etc.; Putt et al. 2023). Resistivity counters are composed of in-river electrode sensors that create an electrical field in the water column. Resistance is a function of water conductivity, and the resistance field is disrupted when a fish swims over the electrodes (i.e., fish are more conductive than the water they displace). The magnitude and direction of the change in resistance is interpreted by the counter to determine whether the disruption was a fish movement, and in what direction the fish was travelling. Resistivity counters are a highly accurate enumeration tool and are cost-effective, adaptable, and easy to maintain (Putt et al. 2021 and Braun et al. 2016).

It has been challenging to monitor upstream migrants in the Halfway Watershed because river discharges are high for a large portion of the migration, preventing the use of fences or electronic counters. In the absence of upstream enumeration, Bull Trout kelt estimates have been used as indices of spawner abundance for the Chowade River and Cypress Creek (as in Andrusak 2009). Annual variation in kelt abundance also informs life history dynamics of Bull Trout (Monnot et al. 2008) and can be used to develop ratios of redd to kelt abundance. Evidence from the Chowade River and Cypress Creek resistivity counters suggests that the kelt migration occurs over a short period and closely follows a normal distribution, facilitating an accurate and reliable estimate (e.g., Putt et al. 2023). We estimate annual kelt abundance as an index of spawner abundance, but we attempt to install the resistivity counters in mid-July of each monitoring year to collect data on upstream migration timing, spawner abundance, and the relationship between upstream migrant and kelt abundance.

We also monitor adult migrants in the Chowade River and Cypress Creek using directional PIT arrays, located at the resistivity counter sites, to inform migration timing and estimate demographic parameters including survival and stage transition probabilities (Brännäs et al. 1994). We use two PIT antennas at each site to determine the direction of movement for PIT-tagged fish. PIT arrays in the Chowade River and Cypress Creek detected movements of fish tagged by other monitoring programs to inform migration patterns and spawning timing.

2. Methods

2.1 Redd Enumeration

2.1.1 Visual Survey Methods

We performed weekly redd count surveys on Cypress Creek, the Chowade River, the upper Halfway River[1], Fiddes Creek, and Turnoff Creek during the Bull Trout spawning period [REDACTED] (Figure 2.1[2]). We also performed a single aerial and ground survey in Needham Creek [REDACTED] to generate a peak redd count.

Two experienced biologists conducted redd counts consisting of aerial surveys in all known spawning reaches and ground surveys in high-density spawning reaches[3]. Redds were identified as areas with disturbed and cleaned substrate, with a crest at the upstream end of the disturbed area, a tailspill area with accumulated substrate, and a depression between the crest and tailspill (Gallagher et al. 2007). These criteria were confirmed by periodic observations of active spawning. Bull Trout redds were often found in overlapping clusters, and the number of redds per cluster was defined as the number of crest-tailspill pairs.

Aerial surveys were conducted by helicopter flying 50 to 100 m above ground at 15 to 40 km hr^{-1} (Trouton 2004). Aerial surveys covered the entire length of potential spawning habitat (Braun et al. 2017b), and were continuous except in Cypress Creek, where two separate surveys were conducted to omit a short section of unsuitable habitat. Redds observed from the air were counted and georeferenced using a GPS accurate to ± 3 m. For the Chowade River, Cypress Creek and the upper Halfway River, aerial surveys were conducted by flying in an upstream direction, but flight direction for Fiddes and Turnoff creeks varied depending on light and wind conditions. Aerial surveys were typically conducted at mid-day when the sun was directly overhead, and visibility

[1] We define the upper Halfway River as the portion of the Halfway River from its source to the confluence of the Halfway and Graham Rivers.

[2] All map images were created in R (R Core Team 2023) using packages *ggplot2* (Wickham 2016), *sf* (Pebesma 2018; Pebesma and Bivand 2023), and *ggsn* (Santos Baquero 2019).

[3] Link to a video of the visual survey methods (BC Hydro 2024).

conditions were optimal. Turbidity measurements were relatively consistent in all tributaries, and we assumed water clarity did not substantially influence OE during visual surveys.

Ground surveys were located to maximize the number of redds marked, and ground reaches ranged from 1.5 to 4.3 km (Table 2.1). The length of ground surveys reflected redd densities, safe helicopter landing zones, and the ability of crews to perform surveys within the available time. Survey boundaries have been consistent since 2016, except in Cypress Creek, where the survey was extended by ~2 km in 2021 to mitigate low sample sizes in prior surveys. Surveys began at upstream boundaries and progressed downstream to lower boundaries, including all side channels within. All redds were counted and geo-referenced using a handheld GPS. No ground survey was conducted on Turnoff Creek because the helicopter could not safely land.

During ground surveys, all accessible redds were marked with a unique tag ID attached to a green bristle tag to estimate OE and SL. Unique tag IDs were tracked throughout the monitoring period and removed when the redd was no longer identifiable. During each survey, tag IDs were recorded along with their geolocation and age class (Gallagher et al. 2007). The location and number of unmarked redds was noted. Lengths and widths of all redds were recorded to the nearest centimeter, where length was the distance between upper crest and end of the tailspill, and width was the distance of disturbed substrate measured perpendicular to the length axis.

Table 2.1 Summary of redd survey reaches. Distances are in river km.

Tributary	Ground Survey Length (km)	Direction Walked	Aerial Survey (km)	Direction Flown
Chowade River	4.0	Downstream	27.0	Upstream
Cypress Creek	4.3	Downstream	18.5	Upstream
Fiddes Creek	2.0	Downstream	14.8	Variable
Turnoff Creek	-	-	15.0	Variable
Upper Halfway River	1.5	Downstream	22.5	Upstream
Needham Creek	2.2	Downstream	8.1	Upstream

[Figure 2.1 – REDACTED]

2.1.2 Redd Distribution

We visually displayed redd distributions using positional data for redds observed during aerial and ground surveys. We plotted survey-specific redd locations for each tributary to examine the change in redd locations over time and identify critical spawning areas. We also summarized redds by river kilometer (rkm) across all surveys to compare distributions among survey years. River kilometers were measured along the course of the tributary. For the Chowade River, Cypress Creek, Fiddes Creek, and Turnoff Creek, rkm 0 was the confluence with the Halfway River. For Needham Creek, rkm 0 was the confluence with the Graham River, and for the upper Halfway River, rkm 0 was the beginning of the aerial survey (~235 km from the confluence with the Peace River). We created rkm sections along an east-west axis for Fiddes and Turnoff creeks, and along a north-south axis for all other tributaries (see Appendix A in Putt et al. 2023). This method yielded simple river sections that could be compared among years, and comparable to river kilometers used by the Site C Fish Movement Assessment (Mon-1b, Task 2d; Hatch et al. 2023).

2.1.3 Redd Abundance

Observer Efficiency

Survey- and tributary-specific ground OE were estimated by dividing the number of marked redds observed by the number of marked redds available to be observed (similar to mark-recapture methods; Melville et al. 2015). Total redd abundance in the ground reach was then calculated for each survey as the number of observed redds divided by the mean ground survey OE. This method assumed no tag loss, which we verified using a fixed number of test tags in each tributary. Test tags were deployed in areas with substrate and flow characteristics suitable for Bull Trout spawning and recovered during the final survey.

Aerial OE was then estimated as the aerial redd count within the ground reach divided by the total ground abundance (i.e., ground count corrected for ground OE). Ground surveys were not conducted on Turnoff Creek and we used OE values from Fiddes Creek (with similar substrate and flow characteristics) during GAUC estimation.

Survey Life

Survey life (the number of days a redd was observable and available to be counted) was estimated by tracking redd ages over consecutive ground surveys. Redd age class was recorded following the methods of Gallagher et al. (2007):

Age-1 = new since last survey but clear (the first measurable age class);

Age-2 = still measurable but already measured, negligible periphyton growth;

Age-3 = no longer measurable due to degrading edges and periphyton growth, but still apparent; and

Age-4 = no redd apparent.

We estimated mean SL across all surveyed tributaries using a linear mixed effects (LME) model of survey date in relation to redd age class. The model related normalized survey day (day 1 was the day a redd was first observed and tagged) to redd age class. We defined SL as the predicted normalized survey day at which redds became age-4, or no longer apparent. Optimal random effects structures (random intercept and random slope for tag ID) were tested using AIC model selection and likelihood ratio testing. The most complex model was:

(1.1)
$$y_{ij} \sim N(\mu_{ij}, \sigma^2)$$

$$\mu_{ij} = \beta_0 + \beta_{0_i} + (\beta_1 + \beta_{1_i}) * redd\_age_{ij}$$

where β_0 and β_1 are normally distributed intercept and slope parameters incorporating random variation for the *j*th observation at tag ID *i*. Survey life can vary among tributaries due to physical and biological characteristics such as substrate, flow, and periphyton growth (Gallagher et al. 2007), and we examine tributary as a fixed effect during survey life modelling. All linear mixed effects modelling was performed in R (R Core Team 2024) using *lme4* (Bates et al. 2015).

GAUC Abundance

We used a GAUC method to generate redd abundance estimates for each tributary. Redd count data were modelled using a quasi-Poisson distribution with spawn-timing described by a normal distribution (described in Millar et al. 2012). The advantage of the GAUC approach over conventional AUC and peak count indices is the ability to incorporate variance in OE and SL, fit spawn-timing using maximum likelihood, and estimate uncertainty in redd abundance.

The number of redds observed at time *t* (C_t) is

(1.2)
$$C_t = a\,exp\left[-\frac{(t-m_s)^2}{2\tau_s^2}\right]$$

where *a* is the maximum height of the redd count curve, m_s is the date of peak redds, and τ_s^2 is the standard deviation of the arrival timing curve. Because the normal density function integrates to unity, the exponent term in Equation 1.2 becomes $\sqrt{2\pi\tau_s}$ and the AUC described by Equation 1.2 can be expressed as

(1.3) $$F = a\sqrt{2\pi\tau_s}$$

where *F* is the number of observed fish. The final redd abundance ($\hat{E}$) is then estimated (using maximum likelihood) by applying OE (*v)* and SL (*l*) to expected number of observed redds ($\hat{F}$)

(1.4) $$\hat{E} = \frac{\hat{F}}{l * v}$$

where $\hat{F} = \hat{a}\sqrt{2\pi\hat{\tau}_s}$, $\hat{a}$ and $\hat{\tau}$ are the ML estimates of *a* and τ_s.

Equation 1.3 can be re-expressed as a linear model, allowing the estimation to be performed as a log-linear equation with an over-dispersion correction factor. The correction accounts for instances where the variance of the redd observations exceeds the expected value. The expected number of observed fish ($\hat{F}$) can be estimated by

(1.5) $$\hat{F} = \sqrt{\frac{\pi}{-\hat{\beta}_2}}exp\left(\beta_0 - \frac{\hat{\beta}_1^2}{4\hat{\beta}_2}\right)$$

where β_0, β_1, β_2 are the regression coefficients of the log-linear model. Uncertainty in OE and SL are incorporated into the estimated redd abundance using the covariance matrix of the modeled parameters ($\beta_0,\ \beta_1,\ \beta_2$) via the delta method (described in Millar et al. 2012).

Mean abundance estimates and input parameters are presented along with standard error, 2.5% and 97.5% confidence limits, and percent relative uncertainty (%RU)

(1.6) $$\%RU = \left(\frac{|u - \mathrm{SE}|}{u}\right) \cdot 100$$

where u is the mean abundance estimate and SE is the standard error of the mean.

We examined the effect on GAUC estimation of adding zero counts to the beginning and end of the spawning period. An initial zero count was added one week before the first survey (because surveys were conducted weekly), and a final zero count was added to the date when the last new redd was observed plus an approximate SL (e.g., if the last age-1 redd was observed during Survey 3 and SL was 14 days, the final zero would be 14 days after Survey 3).

To create a continuous dataset integrating peak counts from 2002 to 2012, we calculated a peak count index for each tributary following the methods described in Diversified Environmental Services and Mainstream Aquatics Ltd. (2013). Historic redd counts consisted of stream walks and/or snorkeling in accessible high-density spawning areas, and aerial surveys covering either the full survey length[4], or areas not covered by ground surveys. Peak count surveys were generally conducted during one or two survey weeks [REDACTED] (Diversified Environmental Services and Mainstream Aquatics Ltd. 2011, 2013). Peak count indices were calculated by summing redds observed [REDACTED] (i.e., the historic survey period) on Survey 1 but not on Survey 2 to the total number of redds observed on Survey 2. To generate a peak count comparable to historic methods, we summed redds observed during ground surveys with aerial counts that occurred outside of the ground survey reach. Due to the spacing of our surveys, the peak count generally included data from only one survey week.

2.2 Resistivity Counters

We monitored Bull Trout spawners and kelts in the Chowade River and Cypress Creek using Logie 2100C resistivity counters (Windsford, UK). Counters in the Chowade River and Cypress Creek were located at 22.8 rkm and 15.9 rkm, respectively, upstream of their confluences with the Halfway River (Figure 2.1). The Chowade River counter was moved in 2023 to be situated upstream of a large side channel that has taken more of the mainstem flow within recent years. In 2024 the counter remained in the same spot that was selected in 2023. The Chowade River and Cypress Creek are dynamic and ever-changing systems, and the Chowade River counter site has been moved twice since monitoring began in 2016. Counter sites are carefully selected to maximize river coverage and detection efficiency, and equipment is calibrated for each site and year to ensure kelt estimates are comparable among years.

Counter sites were selected for their ease of access for equipment installation, suitable stream characteristics (e.g., flow, substrate size), and location downstream of known Bull Trout spawning

[4] The full survey lengths for historic surveys are similar, but not identical to, aerial surveys completed in 2016 through 2020 (see Diversified Environmental Services and Mainstream Aquatics Ltd. 2013).

areas (Diversified Environmental Services and Mainstream Aquatics Ltd. 2009; 2011; 2013). The counters consisted of four channels configured to span the full width of the tributary (Figure 2.2). We used flat pad sensors with two 6” strips of white puck board that increased visibility during video validation and reduced the risk of pad displacement during high water events.

All electronic equipment was powered by custom solar-powered battery banks. Each battery bank was designed to supply power to their respective equipment for a minimum of seven days without solar charge. The required number of batteries and solar panels was calculated using a conservative estimate of four hours daily solar radiation. We used a generator to charge batteries during extended periods of poor solar conditions.

Adult Bull Trout typically migrate to spawning grounds in the Chowade River and Cypress Creek from mid-July to early September, and downstream migration occurs from late August to early October (R.L. & L. Environmental Services Ltd. 1995, Braun et al. 2017a). It is typically not possible to monitor the upstream migration due to high and unpredictable discharge in early to mid-July. Flows during the August to October kelt period are usually lower and more conducive to equipment installation and operation, which allows us to generate an estimate of kelts in each year.

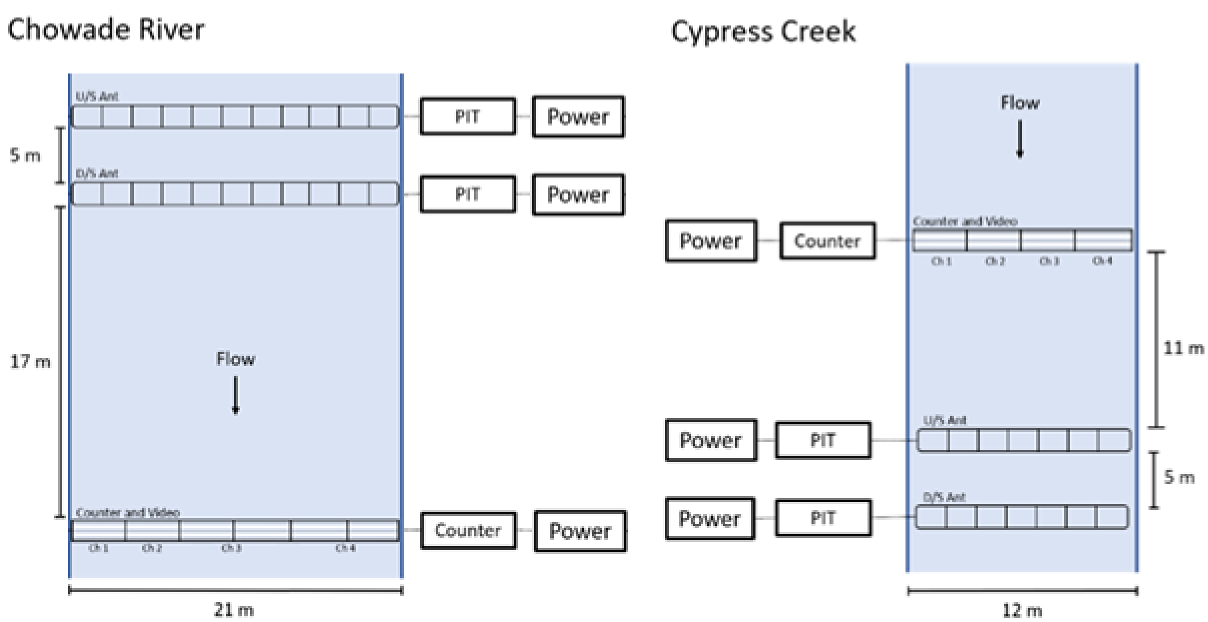

Figure 2.1 Approximate configuration of the resistivity counter sensor pads, PIT arrays, power system and video validation system in the Chowade River and Cypress Creek.

2.2.1 Counter Validation

We continuously operated a video monitoring system at each counter site to validate resistivity counter data and determine fish species. Video cameras were placed directly above sensor pads (one camera per pad) on a cableway system with LED lights for nighttime recording.

Fish species were determined by fish length (R.L. & L. Environmental Services Ltd. 1995), body size, movement patterns, and coloration. We measured each fish observed during video validation and used the ratio of the on-screen counter pad length and on-screen total fish length (nose to end of tail) to determine fish size.

We summarized counter errors for Bull Trout according to three categories:

1. True Positive (TP): The counter recorded a movement, and a fish was observed during video validation.
2. False Positive (FP): The counter recorded a movement, but a fish was not observed during video validation.
3. False Negative (FN): The counter did not record a movement, but a fish was observed during video validation.

Typically, TP, FP, and FN rates are determined by randomly validating video segments; however, due to relatively small Bull Trout populations in the Chowade River and Cypress Creek, we used a multi-step validation process to maximize efficiency. First, we performed targeted validation of all counter up and down records to determine the number of TPs and FPs. Each counter record was validated by watching the corresponding video data 30 seconds before to 30 seconds after the counter record. We then performed additional random validation to estimate a FN rate, which was expanded to the full study period to estimate total FNs. Total random validation was approximately 10% of the video record, with a higher relative proportion of night video being validated (most Bull Trout movements occur at night).

Counter accuracy[5] was calculated by assuming that all TP, FP, and FN observations were multinomially distributed random variables:

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[5] Prior to 2021, counter accuracies were calculated using a binomial method derived from a confusion matrix model. Benefits of moving to the multinomial method are described in Putt and Ramos-Espinoza 2021, and Putt et al. 2022.

(2.1) $$V \sim \boldsymbol{multinomial(N, \theta)}$$

where V is a vector of the total number of TPs, FPs, and FNs (V_{TP}, V_{FP}, V_{FN}), θ is a vector of estimated probabilities of being in each of the three states (θ_{TP}, θ_{FP}, θ_{FN}), and N is the total number of observations from the counter-validation comparison ($TP + FP + FN$). Counter accuracy is defined as, θTP, or as the proportion of fish passing the counter that are correctly recorded by the counter algorithm.

2.2.2 Estimating Abundance

We used resistivity counter data to estimate Bull Trout abundance in the Chowade River and Cypress Creek using the method outlined in Figure 2.3.

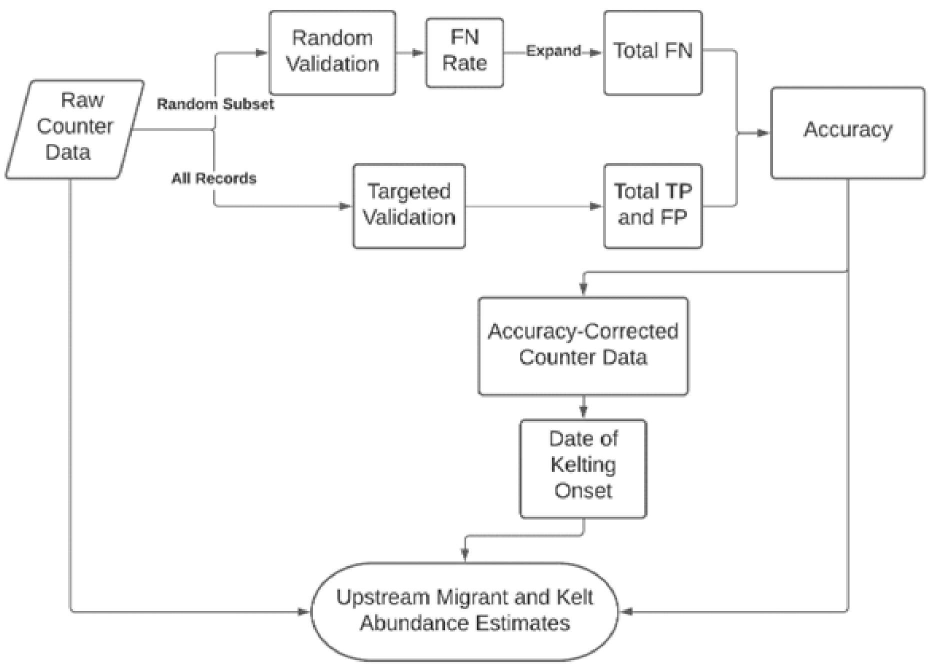


Figure 2.2 Method to validate resistivity counter data and determine accuracy-corrected abundance of upstream migrants and kelts.

Determining Kelt Onset

Estimating spawner or kelt abundance is not as simple as summing upstream or downstream movements recorded by the counter. Fish often move up and down past a counter site multiple times during their migration, and movements can be described as:

1. Up-migration: Moving upstream to spawn;

2. ‘Recycling’: Movement back and forth across the counter site; or
3. Kelting: Moving downstream after spawning completion.

A kelt date must be determined to differentiate kelting and recycling and estimate abundance for either movement direction. When estimating upstream migrant abundance, downstream movements prior to the kelt date are assumed to be recycling and are subtracted from up counts (i.e., to remove fish that have not yet committed to migrating upstream). Total upstream abundance is therefore ups minus downs prior to the kelt date, plus total ups following the kelt date. When estimating kelt abundance, downs prior to the kelt date are not included, and total kelt abundance is the sum of downs after the kelt date.

Kelt onset and peak kelt dates were estimated by fitting a normal probability density function to accuracy-corrected daily down counts. We estimated the mean, standard deviation, and scale parameter for the normal distribution. The fitted mean represented the peak date of kelt migration, while the scale parameter provided an estimate of kelt abundance (which can also be compared to resistivity counter kelt abundance). Using daily abundance predicted by the normal model, we defined the date of kelt onset as the date when 5% of kelts had migrated downstream.

Abundance Estimates

We estimated accuracy-corrected kelt abundance for the Chowade River and Cypress Creek (Putt et al. 2021):

(2.2)
$$E_k = \sum_{i=1}^{I} \sum_{k=1}^{K} \frac{\mathrm{D_{k,i}}}{\mathrm{A_{d,i}}}$$

where E_k is the kelt estimate, D_k is the downstream counts for each day from the onset of the kelt migration (k) to the date of the last confirmed Bull Trout down-count (K), and A_D is downstream counter accuracy. The subscript i represents counter channel, from 1 to I channels, which allows channel specific accuracies to be applied to downstream counts.

We were unable to estimate an upstream migrant abundance due to a potentially incomplete upstream migration dataset. In future years, upstream abundance (corrected for recycling prior to the kelt onset) may also be estimated (Putt et al. 2021):

(2.3) $$E_{Up} = \sum_{i=1}^{I}\left(\sum_{t=1}^{T}\left(\frac{U_{t,i}}{A_{u,i}}\right) - \sum_{t=1}^{K-1}\left(\frac{D_{t,i}}{A_{u,i}}\right)\right)$$

where U_t and D_t are the upstream and downstream counts for each day (t) from day 1 to the final day of the migration (T), and A_{ui} is the channel-specific upstream accuracy.

2.3 PIT Arrays

Directional PIT arrays were installed in the Chowade River and Cypress Creek (two antennas per tributary) to monitor fish tagged under other components of the FAHMFP. Each antenna spanned the full width of the tributary and was approximately 1.25 m wide with structural cross braces every 1.5 m. Antennas lay flat on the streambed so that fish were detected as they swam over the antenna. Each antenna was connected to a remote tuner box and a single reader (Oregon RFID, Portland, OR), and readers were synchronized to minimize interference and optimize antenna read range (i.e., the distance above an antenna within which a tag is detectable).

We conducted detailed read-range testing during site visits (every 7 to 10 days) to determine seasonal read-ranges for each antenna. We determined read ranges for 12 mm, 14 mm, 23 mm, and 32 mm PIT tags at 1.5 m increments along the length of each antenna and determined the proportion of the water column within which each tag size was detectable. We also summarized the mean detectable area of the water column across all surveys. For example, if the mean detectable area for a 12 mm tag was 75%, a 12 mm tag had a very high probability of being detected within 75% of the water column, but the probability of detection was near zero within the remaining 25% of the water column (typically near the surface above deeper areas of the water column).

We collated and summarized PIT data using the ORFID package for R (Marques and Putt 2022) developed by Fishtag Consulting and InStream Fisheries Research. We determined detection efficiency – the percentage of tags detected by both antennas in the array – for both upstream and kelt migrations (for all tag sizes combined). Detections were summarized to determine movement direction and residence time for fish that were detected moving upstream and downstream past the arrays. Species information and tagging biodata were obtained from WSP.

3. Results

In 2024, the Chowade River and Cypress Creek resistivity counters and PIT arrays were operational from July 19 to October 4, and July 18 to October 3, respectively. Aerial and ground redd surveys occurred between September 4 and September 28, 2024. Since 2022, water levels in the Halfway River during Bull Trout spawning have been low throughout the monitoring period (i.e., the extent of Mon-1b, Task 2b monitoring; Figure 3.1) relative to 2016 through 2021.

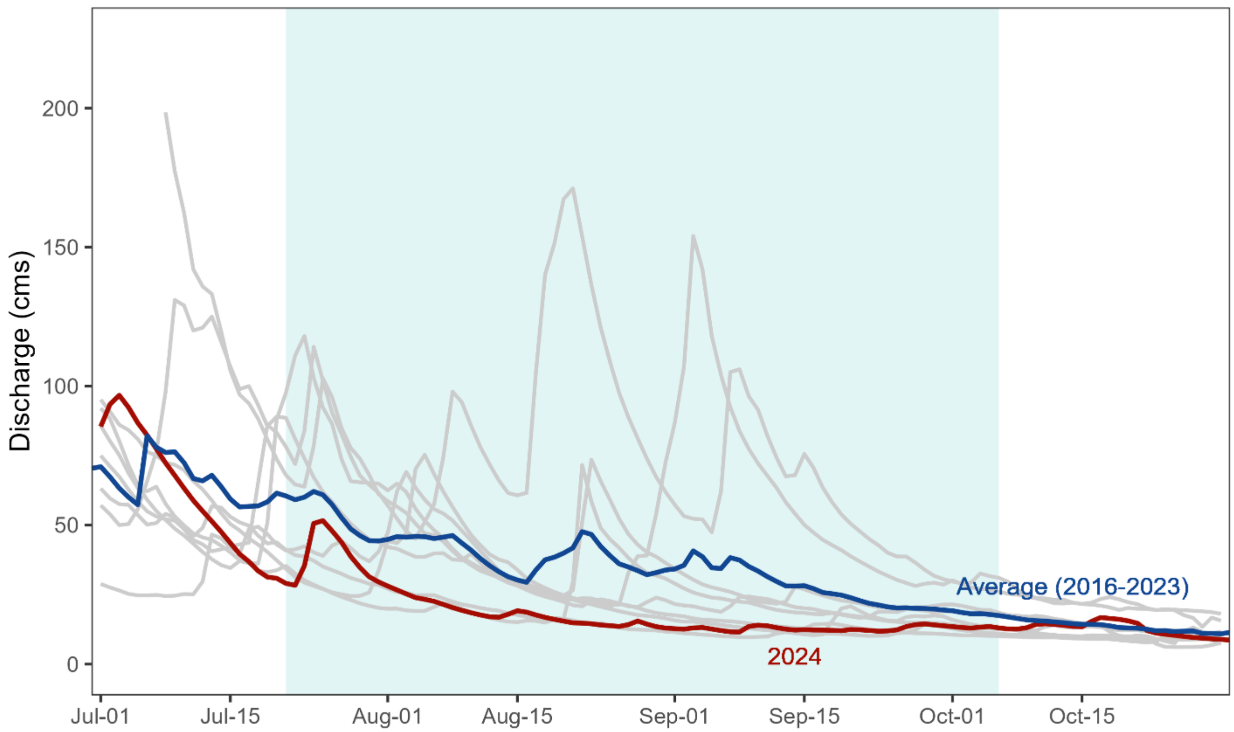


Figure 3.1 Discharge (cms) from the Halfway River above the Graham River (Water Survey of Canada monitoring site 07FA003) from 2016 to 2024. Red line represents 2024 discharge and blue line is the average discharge from 2016 to 2023 (grey lines are individual years from 2016 – 2022). Shaded area represents the Mon-1b, Task 2b monitoring period.

3.1 Redd Enumeration

Redd surveys (aerial and ground) were conducted weekly [REDACTED] except for Needham Creek, which was surveyed for a peak count (aerial and ground) [REDACTED]. Several issues changed flight surveys for the upper Halfway River in 2024 including a helicopter issue on September 5 and a high turbidity event on September 19, which affected flights on the upper Halfway River, Fiddes Creek, and/or Turnoff Creek. Upper Halfway River flights were repeated, resulting in five aerial and ground surveys in the upper Halfway River, and four surveys in all other tributaries.

3.1.1 Redd Distribution

Redd distributions were relatively consistent among years in the upper Halfway River, the Chowade River, and Fiddes Creek. In 2024, redds were observed throughout the Chowade River survey reach, with the highest densities observed in the upper third (rkm 43 – rkm 48) (Figure 3.2). Aerial redd densities were similar among monitoring years, with redds typically being concentrated between rkm 38 and rkm 48 (Figure 3.3). In the upper Halfway River, redds were almost exclusively observed above rkm 15 (with one exception; Figure 3.6 and Figure 3.7), while distributions were less consistent in Fiddes Creek (Figure 3.6, Figure 3.8). Only one redd was observed during aerial surveys in each of Turnoff and Needham Creek in 2023 (Figure 3.9, Figure 3.10, Figure 3.11).

In Cypress Creek, low water levels continue to decrease the spatial extent of redd construction. In all years, redds have been observed between rkm 29 and 32. In 2024, zero redds were observed between rkms 48 and 52, which has typically been an area of high redd density (Figure 3.4, Figure 3.5). Redd densities in this area were also low in 2023, possibly due to a combination of declining spawner abundance, a shift in habitat quality, or spatial preference (potentially due to low water levels).

[Figure 3.2 – REDACTED]

[Figure 3.3 – REDACTED]

[Figure 3.4 – REDACTED]

[Figure 3.5 – REDACTED]

[Figure 3.6 – REDACTED]

[Figure 3.7 – REDACTED]

[Figure 3.8 – REDACTED]

[Figure 3.9 – REDACTED]

[Figure 3.10 – REDACTED]

[Figure 3.11 – REDACTED]

3.1.2 Redd Abundance

Observer Efficiency

Mean ground OE was high (> 0.8) with relatively low variability for all tributaries (Table 3.1; Appendix A). Mean aerial OE was highly variable for several tributaries in 2024, and difficult to characterize. In the Chowade River, redd counts were typical of previous years and redds were observed during all surveys. Aerial OE ranged from 0.2 to 0.44, which was similar to previous years.

Almost no redds were observed outside of the ground reach during aerial surveys in Cypress Creek, likely due to low spawner abundance and an aggressive algal bloom that made redds difficult to identify. During the third survey, the number of redds available to be observed was 1.2 (ground count expanded by the average ground OE) but two were counted during the aerial survey, leading to an aerial OE of 1.67 and a range in OE across all surveys of 0.26 to 1.67. High OE values in Cypress Creek are partly an artifact of low spawner abundance, and are unlikely to reflect true OE throughout the full spawning extent. We used an aerial OE of 0.25 (SE 0.2) during GAUC modeling, which is reflective of efficiency values calculated in previous years for Cypress Creek.

Fiddes Creek aerial OE was low relative to previous years. Redds marked during the ground survey in Fiddes were substantially smaller than in previous years, and most were deposited in a newly channelized area hidden beneath undercut banks. These small redds would have been difficult or impossible to observe during aerial surveys. GAUC modeling assumes aerial efficiency in the ground reach reflects conditions throughout the tributary, but GAUC may be overestimated if aerial OE is biased low relative to the full spatial extent of spawning. Finally, mean aerial OE in the upper Halfway River was similar to previous years despite ranging from 0.19 to 0.94. Uncertainty in OE is included within GAUC estimates, and the large uncertainty in the upper Halfway River is reflected in an uncertain GAUC estimate for 2024.

Table 3.1 Mean ground and aerial observer efficiency with standard deviation.

Tributary	Mean Ground OE (SD)	Mean Aerial OE (SD)
Chowade River	0.88 (0.1)	0.30 (0.1)
Cypress Creek	0.83 (0.7)	0.25[b]
Fiddes Creek	0.89 (0.1)	0.08 (0.1)
Upper Halfway River	0.94 (0.1)	0.60 (0.4)

Needham Creek	-	0[a]

a: Aerial count/uncorrected ground count for singe peak count survey. In 2024, zero redds were observed in the ground reach during the aerially survey. b: aerial OE for Cypress Creek was biased high and we used an average value of 0.25 during GAUC modeling.

Survey Life

A total of 71 bristle tags were applied to redds during ground surveys and used to estimate SL. We estimated mean SL for all redds using an LME model of normalized survey day in relation to redd age (Figure 3.12). The optimal random effect structure was a random intercept for tag ID. The fixed effect of tributary was not significant, and we used the average SL among all tributaries during GAUC modelling. The estimated SL was 16.5 days with a standard error of 1.6 days, which was low but within the range of previous estimates (Table 3.2).

Table 3.2 Annual survey life and standard error for Halfway River tributaries.

Year	Survey Life	Survey Life SE
2016	13.7	1.8
2017	24.2	2.3
2018	18.5	2.2
2019	21.2	1.9
2020	17.9	2.0
2021	16.5	2.1
2022	16.1	1.8
2023	19.6	2.3
2024	16.5	1.6

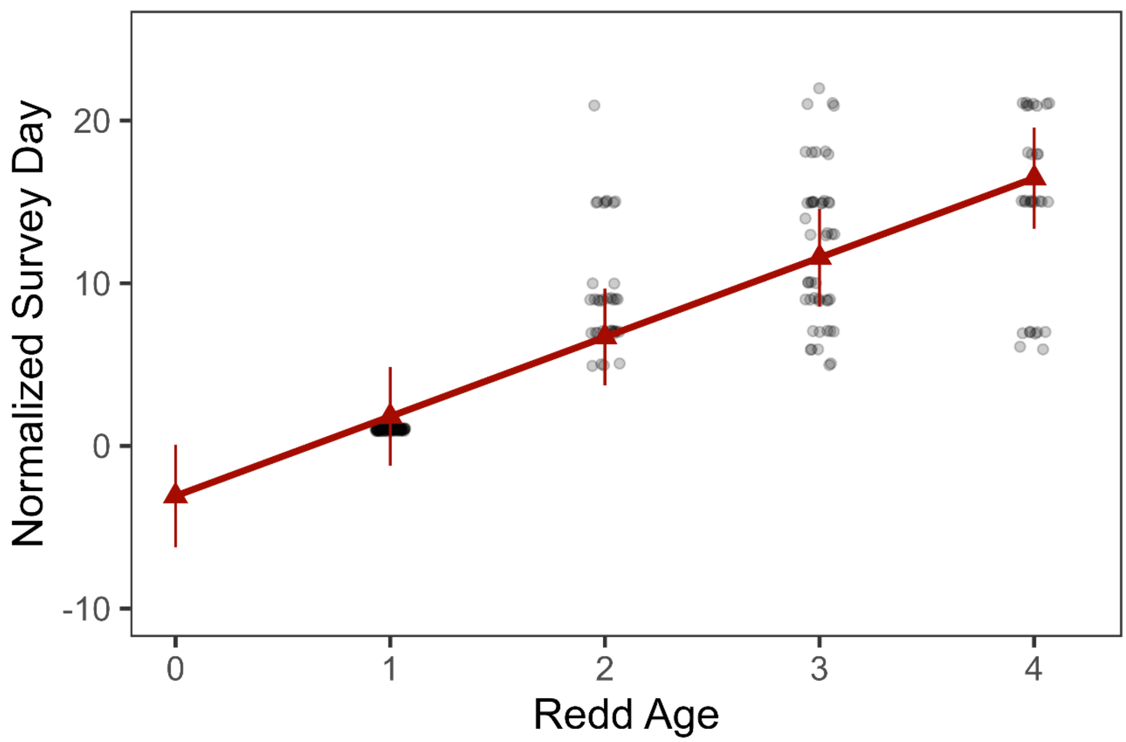


***Figure 3.2** Redd age within all tributaries by normalized survey day, with points jittered for presentation. Red line shows mean SL for all redds, and vertical error bars are the 95% confidence interval based on a normal approximation. Negative normalized survey days correspond to days between the redd being built and the first observation (age-1).*

GAUC Abundance

Redd counts were highly variable in 2024, which was one of the lowest water years within the current study (Figure 3.1). GAUC estimates ranged from one redd in Turnoff Creek to 359 redds in the Chowade River (Table 3.3). It was particularly difficult to characterize aerial OE in 2024, and this uncertainty partially explains elevated standard errors in GAUC estimates. Peak count estimates consistently underestimated redd abundance relative to the GAUC method, and peak counts estimated by this monitoring program were lower than the most recent historic peak counts in 2010 and 2012 (Figure 3.14).

Table 3.3 GAUC redd abundance, relative uncertainty in abundance, Mean OE (with SE), and peak counts for Bull Trout in the Halfway Watershed.

Tributary	GAUC Abundance (SE)	2.5% CL	97.5% CL	% CV	Aerial OE (SE)	Survey Life (SE)	Peak Count Index
Chowade River	359 (85)	226	571	76.3	0.30 (0.06)	16.5 (1.6)	72
Cypress Creek	19 (15)	4	92	21.0	0.25 (0.20)	16.5 (1.6)	6
Fiddes Creek	47 (29)	14	159	38.3	0.08 (0.04)	16.5 (1.6)	14
Turnoff Creek	1	-	-	-	-	-	1
Upper Halfway River	40 (16)	18	86	60.0	0.59 (0.20)	16.5 (1.6)	36
Needham Creek	-	-	-	-	-	-	36

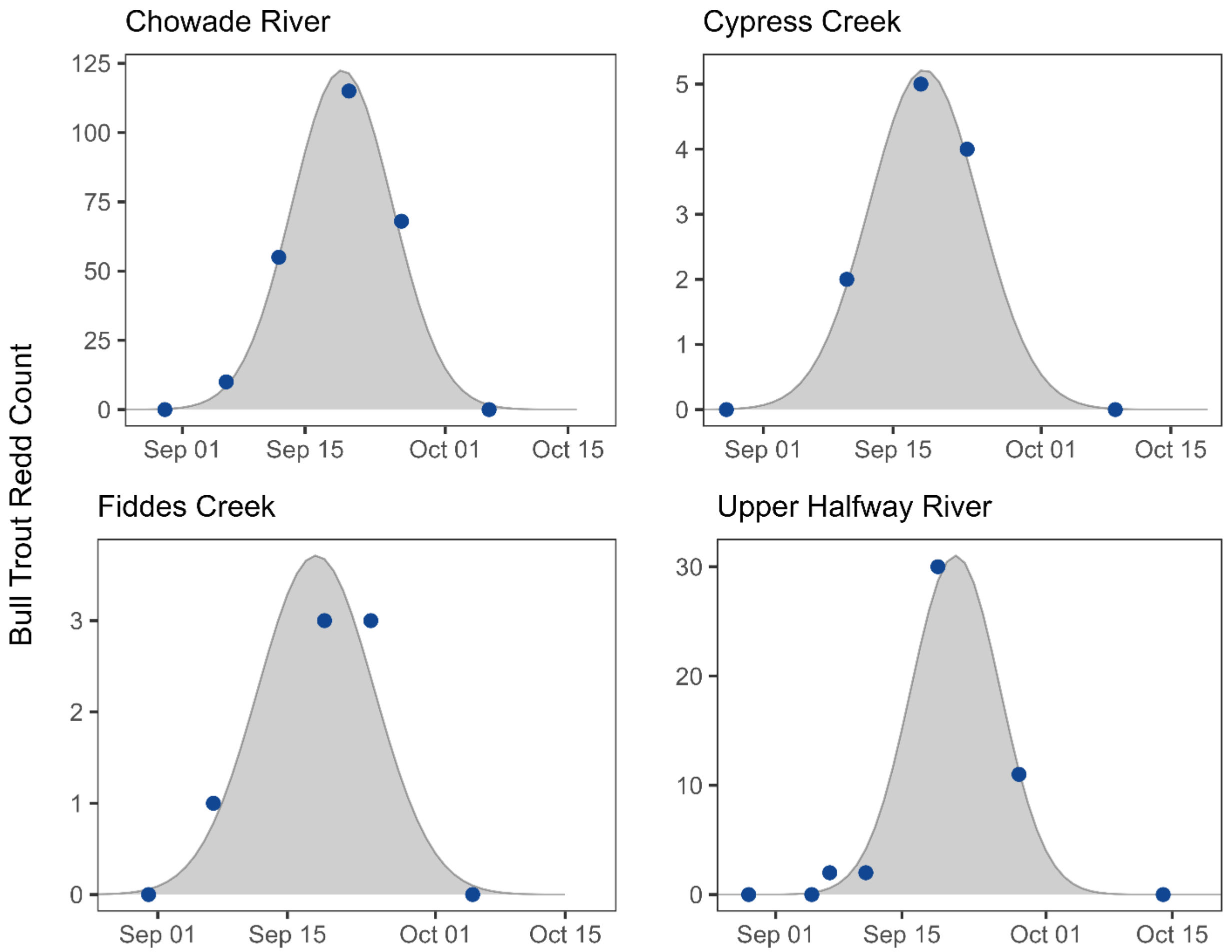


Figure 3.3 Bull Trout redd counts (blue points) and modelled survey period (grey shaded area) in Halfway River tributaries. Zero counts bounding the spawning period were added during GAUC modelling and do not represent observed counts. The GAUC model was not run in Turnoff Creek as only one redd was observed within the survey period.

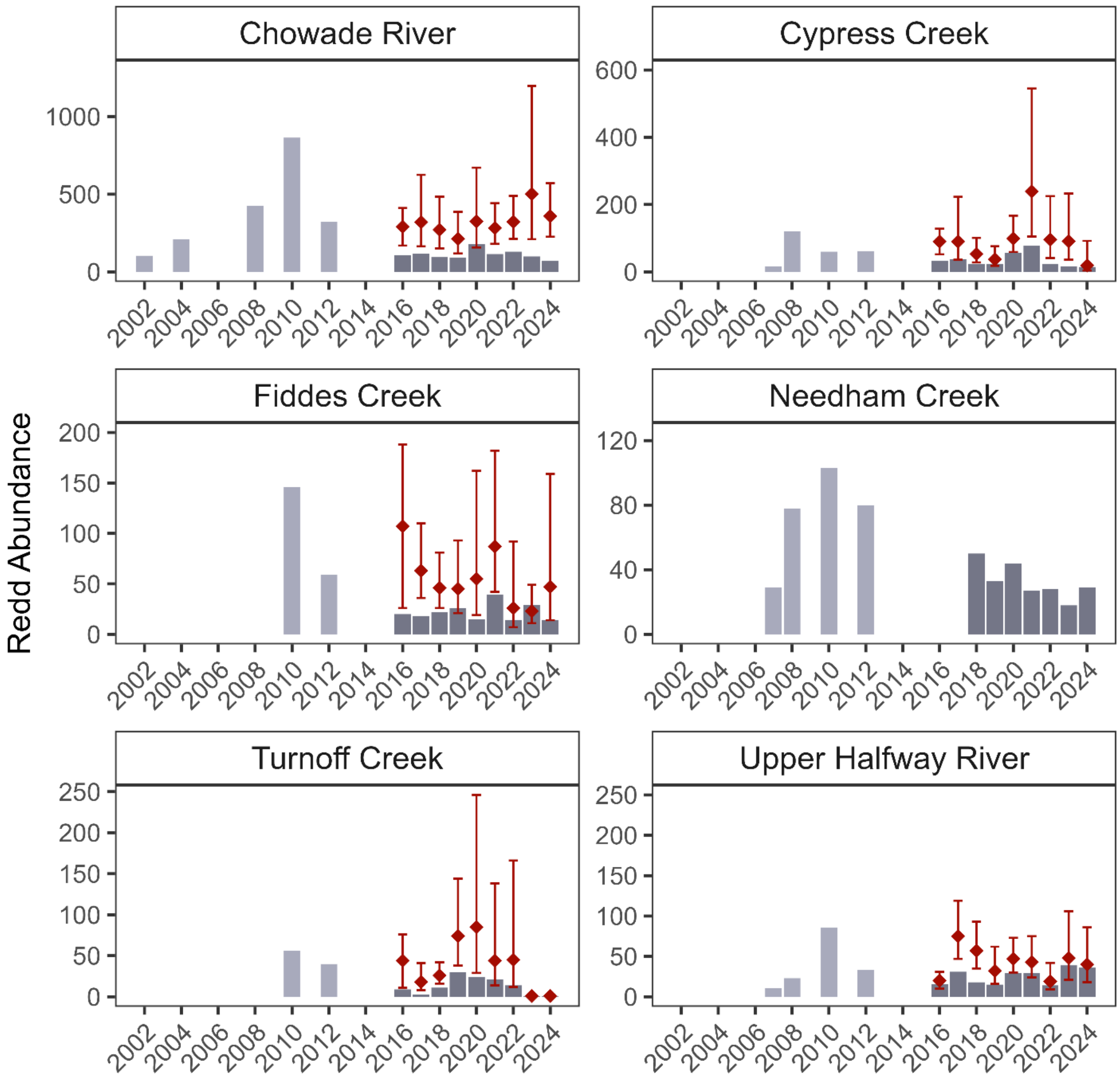


Figure 3.4 Bull Trout peak count redd indices from 2002 to 2014 (light grey bars; Diversified Environmental Services and Mainstream Aquatics Ltd. 2009, 2011, and 2013); from 2016 to 2024 (dark grey bars; this monitor). GAUC abundance with CI are shown as red diamonds.

3.1.3 Monitoring Time Series of OE and GAUC Abundance

We compared OE (mean across the four surveys) and GAUC redd abundance among study years in the Halfway Watershed (Figure 3.15). Ground OE was relatively consistent among survey years, but aerial OE and GAUC were variable. The confidence intervals for all measurements suggest substantial overlap among years.

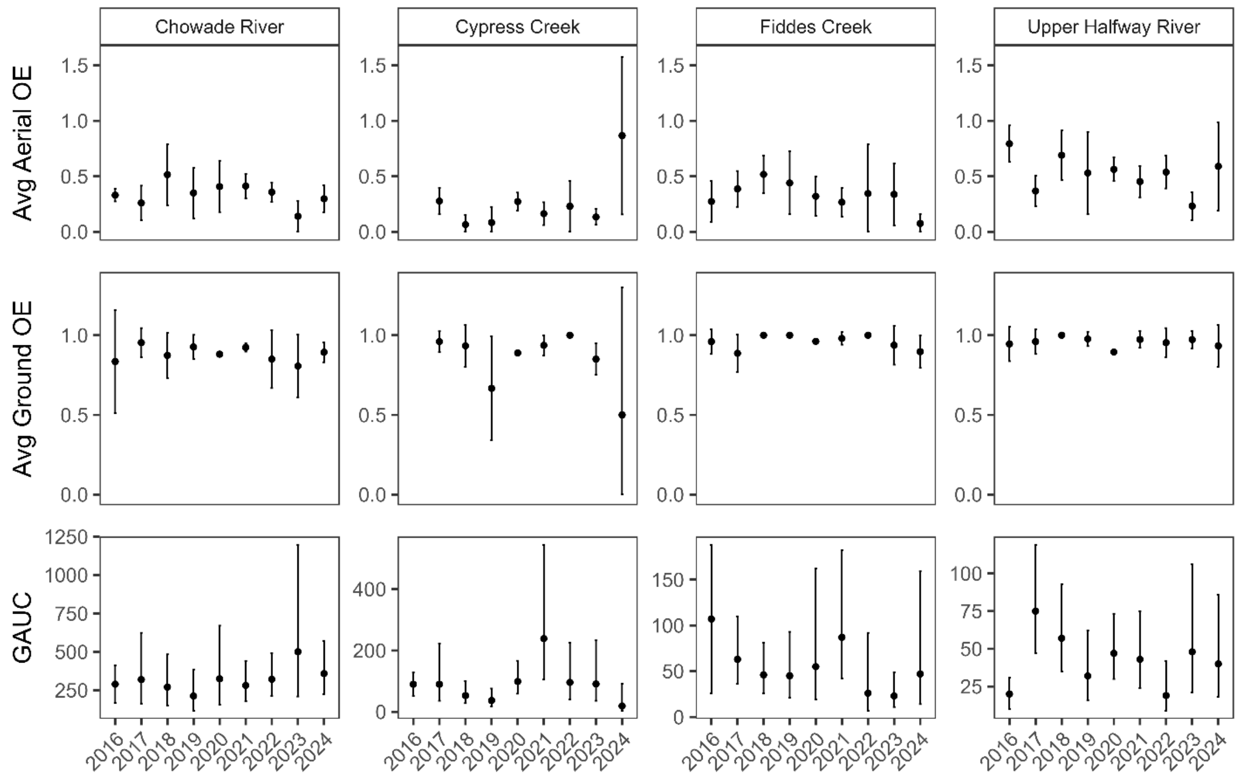


Figure 3.5 Mean aerial OE, mean ground OE, and GAUC abundance (error bars are 95% confidence intervals) in the Halfway Watershed.

3.2 Resistivity Counters

3.2.1 Chowade River

The Chowade River resistivity counter operated from July 19 to October 4. Bull Trout (n = 461), Mountain Whitefish (n = 756), and Rainbow Trout (n = 176) were confirmed during video validation. Total length for Bull Trout ranged from 460 mm to 960 mm (mean = 655 mm, SD = 114 mm), Mountain Whitefish ranged from 220 mm and 480 mm (mean = 357 mm, SD = 46 mm), and Rainbow Trout ranged from 230mm to 580 mm (mean = 411 mm, SD = 52 mm). Total length data from 2024 were within the range of previous monitoring years (Appendix B).

Counter accuracy varied among channels from 85% to 100% for downstream movements and 93% to 100% for upstream movements (Table 3.4). False negatives occurred at a greater frequency compared to false positives, suggesting the counter underestimated the true number of movements. Most movements occurred on channel 2, located in the thalweg on river right (Figure 3.15).

The normal density function estimated that the 2024 Bull Trout kelt outmigration began on August 29 and peaked on September 14 (SD = 9.45 days; Figure 3.17). After accounting for counter accuracy and the date of kelt onset, kelt abundance for the Chowade River was 254 (Figure 3.18). The ratio of kelts to redds (estimated via GAUC) was 0.7 (Table 3.5). The date of the onset of upstream spawning migration remains uncertain, but the resistivity counter was installed the earliest in the season since the start of the project. The majority of upstream movements were likely recorded in 2024. The total cumulative upstream count for Bull Trout was 274 during the enumeration period (Figure 3.17). An estimated 223 (net) Bull Trout were observed moving upstream past the counter in 2024.

Table 3.4 Chowade River counter accuracies for Bull Trout.

Channel	Direction	Accuracy
1	D	85%
1	U	95%
2	D	87%
2	U	99%
3	D	98%
3	U	93%
4	D	100%
4	U	100%

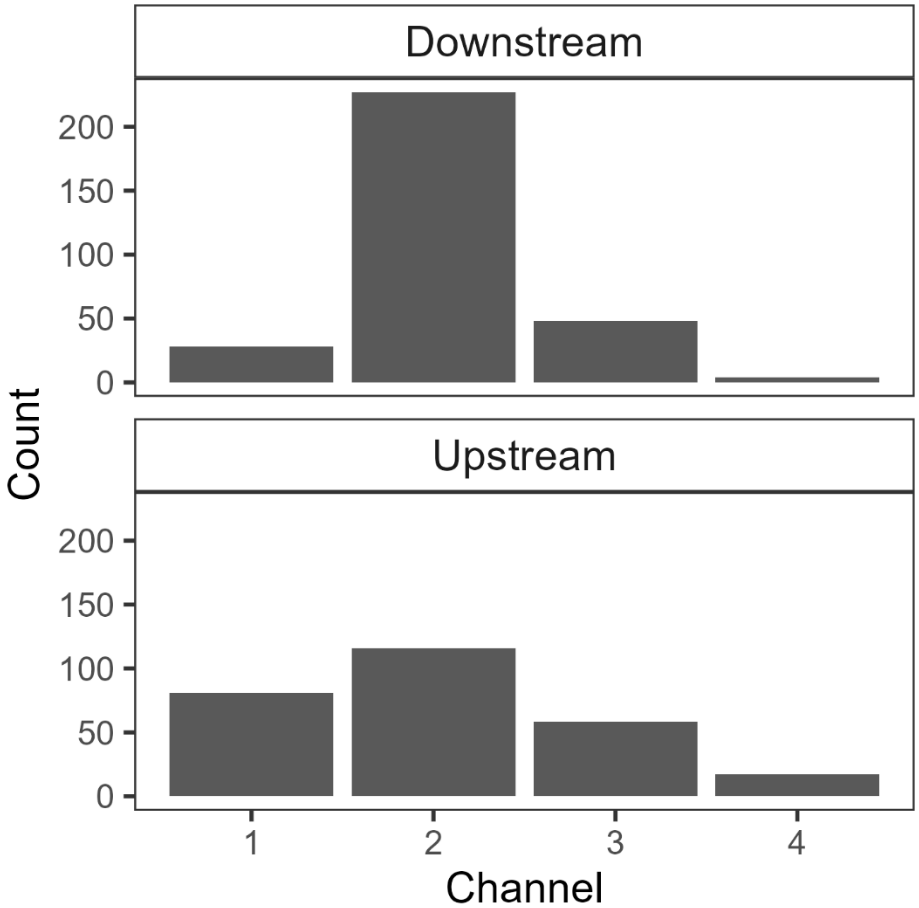


Figure 3.6 Accuracy-corrected counts of Bull Trout moving upstream and downstream past the Chowade River resistivity counter.

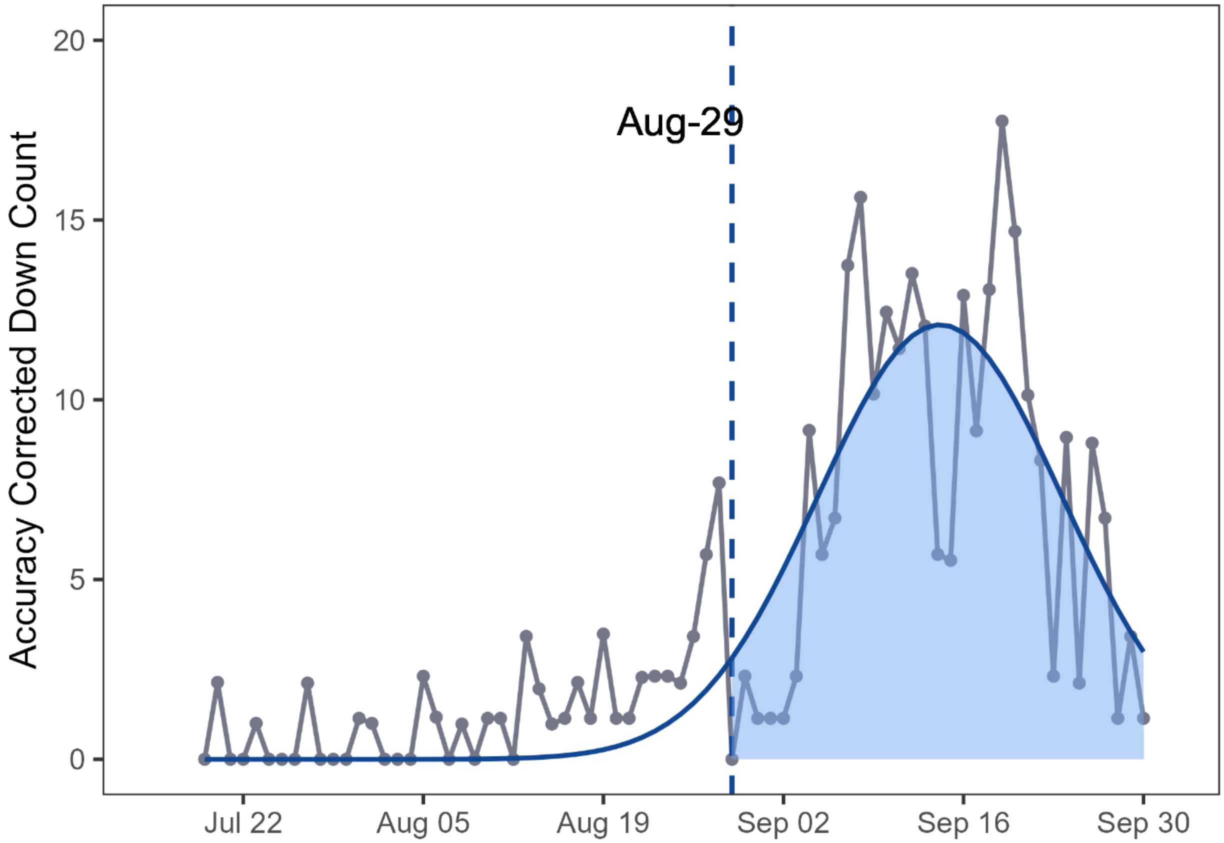


Figure 3.7 Accuracy corrected daily down counts of verified Bull Trout (grey points and lines) and modelled kelt out-migration timing (solid blue line and blue shading) in the Chowade River. The vertical dashed line marks the date which the normal model estimated 5% of the kelts had out-migrated, which was assumed to be the onset of the kelt out-migration.

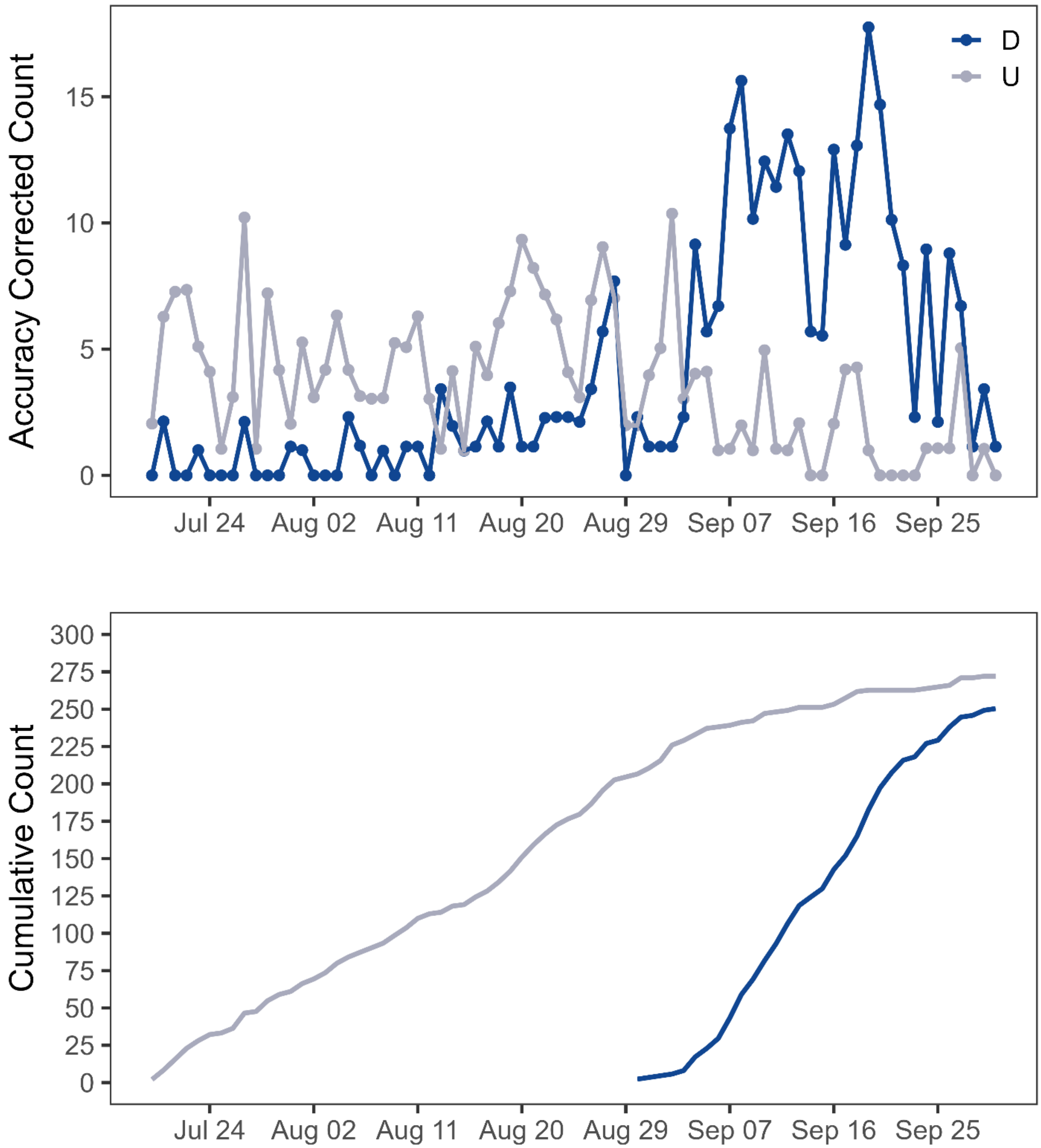


Figure 3.8 Top panel: accuracy corrected up and down counts of Bull Trout moving past the Chowade River resistivity counter. Bottom panel: cumulative up and down counts. Cumulative down counts were set as zero until August 29, the onset of the kelt out-migration.

Table 3.5 Kelt abundance estimated by the Chowade River resistivity counter, redd abundance with 95% CI from GAUC estimation, and kelt to redd ratios (the number of kelts per redd) with 95% confidence intervals.

Year	Kelt Abundance	GAUC Redd Abundance (95% CI)	Kelt:Redd Ratio (95% CI)
2017	319	320 (164 - 625)	1.0 (0.5 - 1.9)
2018	564	271 (151 - 484)	2.1 (1.2 - 3.7)
2019	144	213 (118 - 386)	0.7 (0.4 - 1.2)
2020	568	325 (157 - 671)	1.7 (0.8 - 3.6)
2021	279	282 (180 - 442)	0.9 (0.6 - 1.6)
2022	151	322 (212 - 490)	0.5 (0.3 - 0.7)
2023	117	501 (210 - 1197)	0.2 (0.1 - 0.6)
2024	254	359 (226 – 571)	0.7 (0.4 – 1.1)

3.2.2 Cypress Creek

The Cypress Creek resistivity counter operated from July 18 to October 3. Bull Trout (n = 98), Mountain Whitefish (n = 362), and Rainbow Trout (n = 32) were confirmed during video validation. Bull Trout total lengths ranged from 460 mm to 850 mm (mean = 595 mm, SD = 90.1 mm), Mountain Whitefish ranged from 230 mm and 490 mm (mean = 350 mm, SD = 40 mm), and Rainbow Trout ranged from 310 mm to 560 mm (mean = 400 mm, SD = 54 mm). Total length data from 2024 were within the range of previous monitoring years (Appendix B).

Counter accuracy varied among channels from 49% to 100% for downstream movements and 93% to 100% for upstream movements (Table 3.6). As with the Chowade River counter, false negatives occurred at a greater frequency compared to false positives, suggesting the counter underestimated abundance. Movements occurred predominantly on channel 3, the centermost channel within the Cypress Creek thalweg (Figure 3.19). The kelt migration pattern of the 2024 Cypress Creek Bull Trout did not follow a normal distribution. The kelt outmigration date was informed by the mean of historical kelt dates, September 6 (range: September 1 to September 11), and peaked on September 19 (Figure 3.20). After accounting for counter accuracy and the date of kelt onset, kelt abundance for Cypress Creek was 24 Bull Trout (Figure 3.21). The ratio of kelts to redds (estimated via GAUC) was 1.26 (Table 3.7). Cumulative upstream movements over the full monitoring period were 77, with a net upstream count of 34 individuals past the counter after accounting for recycling behaviour.

Table 3.6 Cypress Creek counter accuracies for Bull Trout.

Channel	Direction	Accuracy
1	D	49%
1	U	100%
2	D	100%
2	U	100%
3	D	84%
3	U	93%
4	D	100%
4	U	100%

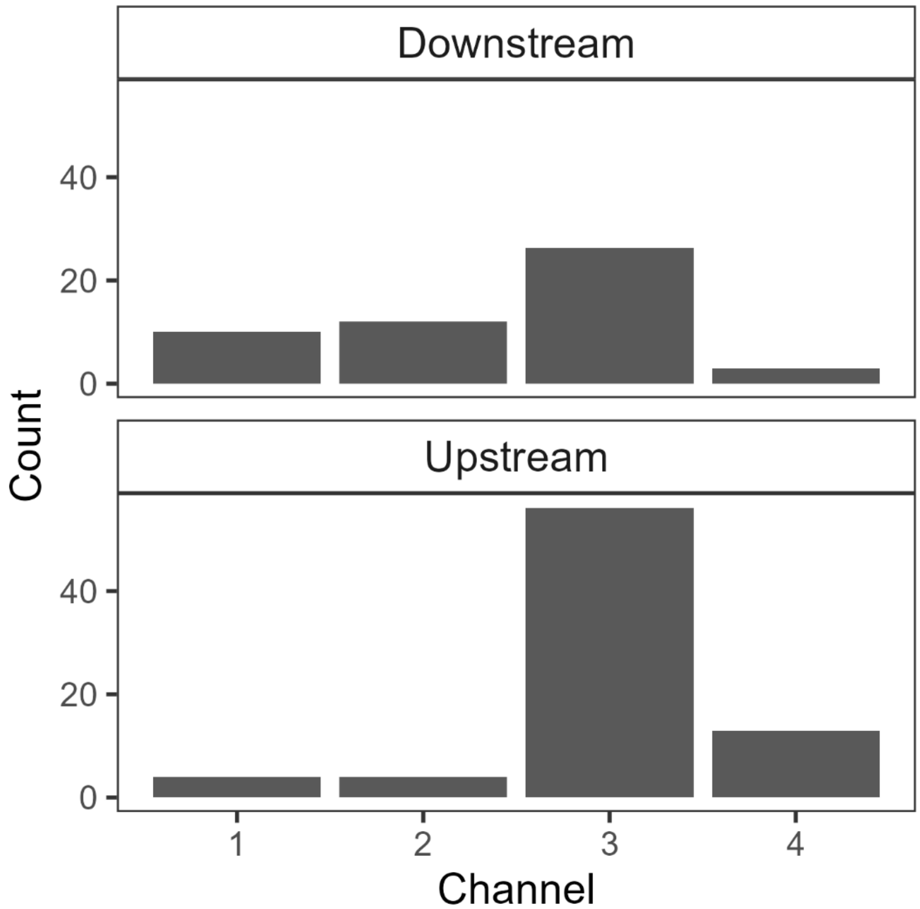
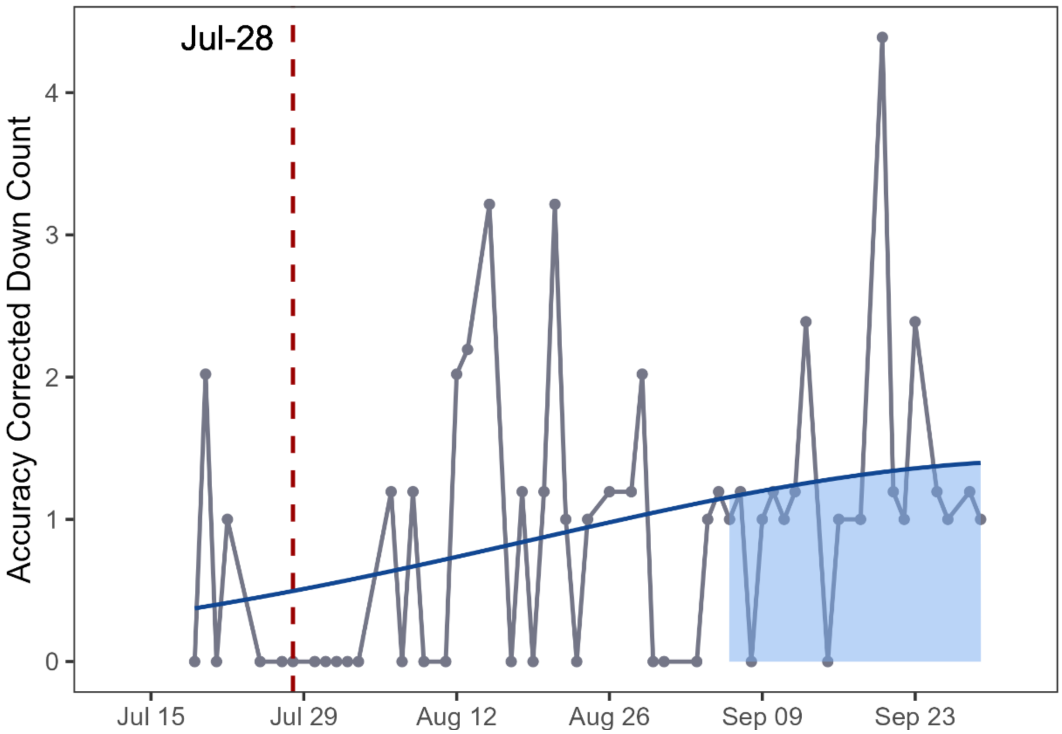


Figure 3.9 Accuracy-corrected counts of Bull Trout moving upstream and downstream past the Cypress Creek resistivity counter.



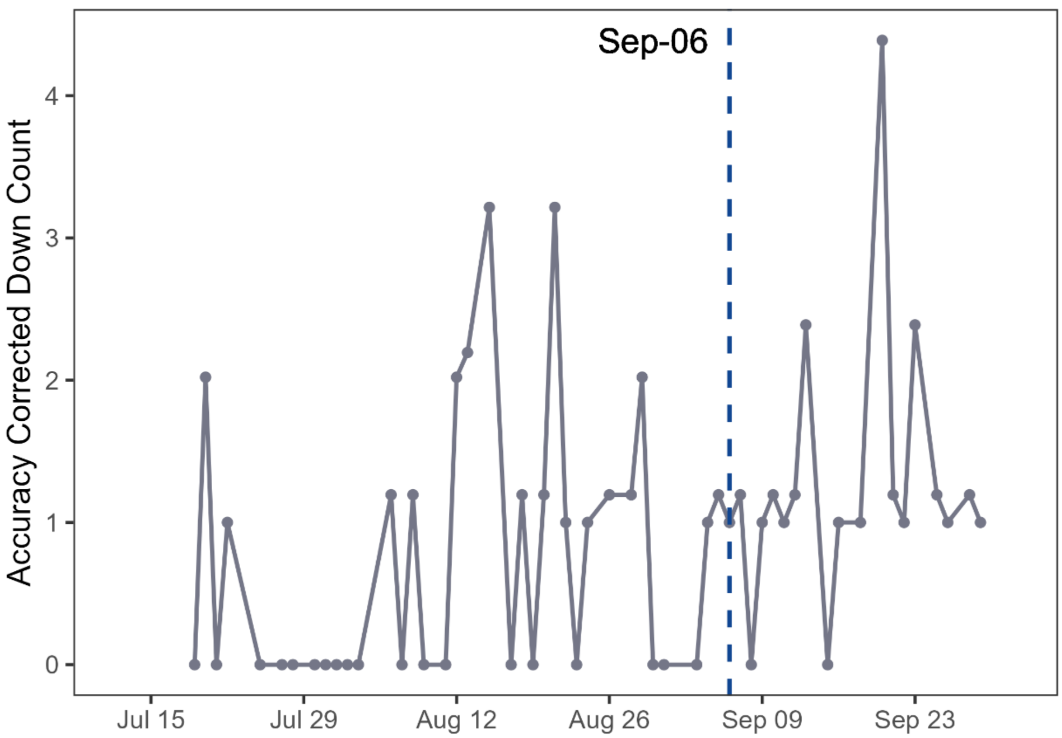


Figure 3.10 Top panel: Accuracy corrected daily down counts of verified Bull Trout (grey points and lines) and modelled kelt out-migration timing (solid blue line and blue shading) in Cypress Creek. Vertical dashed red line marks the date when the normal model estimated 5% of the kelts had out-migrated. The normal distribution model does not fit well and creates an unrealistic kelt migration start date. Bottom panel: Accuracy corrected daily down counts of verified Bull Trout (grey points and lines) in Cypress Creek. Vertical dashed blue line marks the mean historical kelt dates from 2018 to 2023.

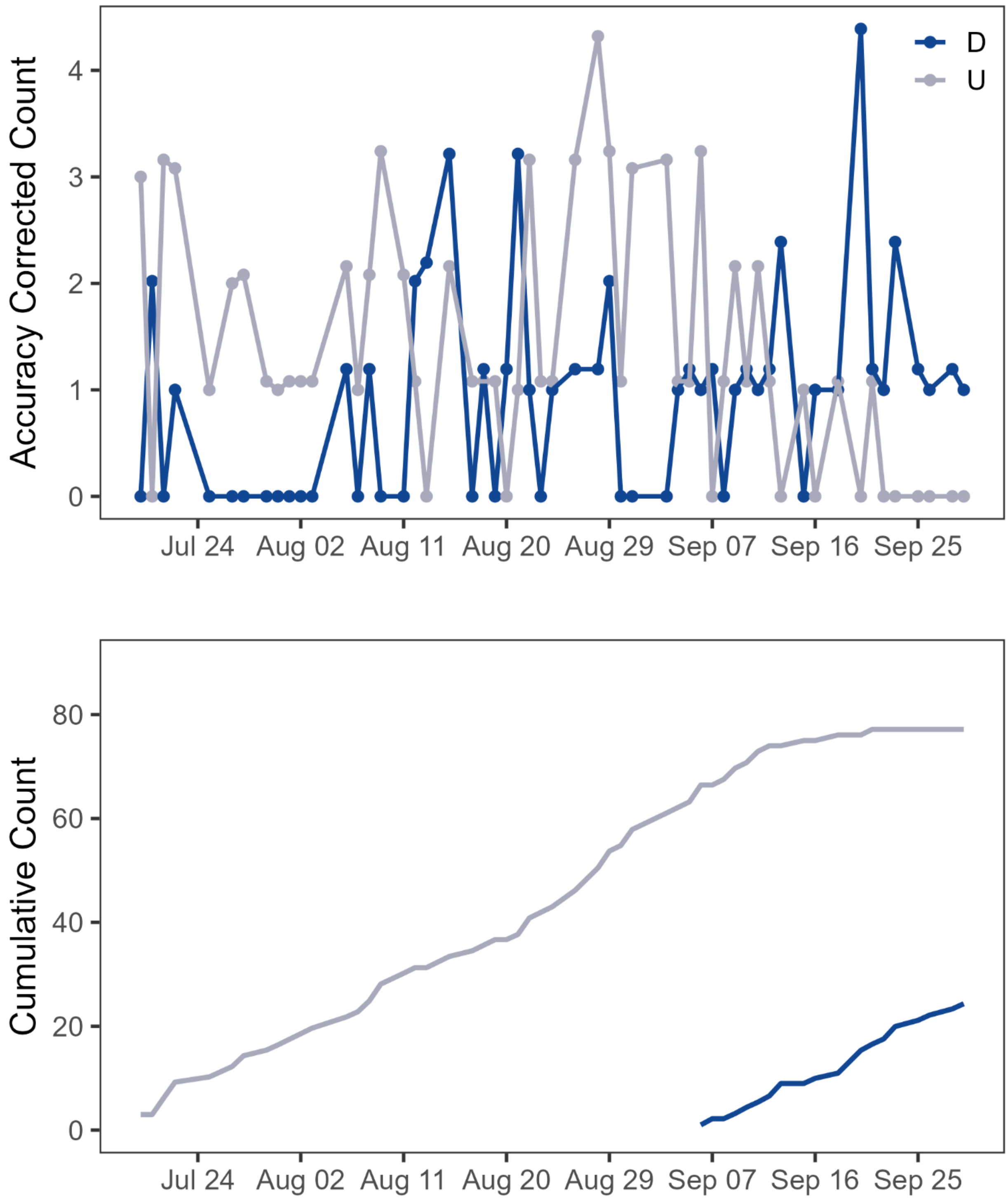


Figure 3.11 Top panel: accuracy corrected up and down counts of Bull Trout moving past the Cypress Creek resistivity counter. Bottom panel: cumulative up and down counts. Cumulative down counts were set as zero until September 6, the onset of the kelt out-migration.

Table 3.7 Kelt to redd ratios (the number of kelts per redd) and 95% confidence intervals using kelt abundance estimated by the Cypress Creek resistivity counter, and redd abundance and 95% CI from GAUC estimation.

Year	Kelt Abundance	GAUC Redd Abundance (95% CI)	Kelt:Redd Ratio (95% CI)
2017	91	90 (36-223)	1.0 (0.4-2.5)
2018	132	53 (28-101)	2.5 (1.3-4.7)
2019	-	37 (18-76)	-
2020	55	99 (59-167)	0.6 (0.3-0.9)
2021	73	239 (105-545)	0.3 (0.13-0.69)
2022	131	96 (41-225)	1.4 (0.6-3.2)
2023	77	91 (36-233)	0.8 (0.3-2.1)
2024	24	19 (4-92)	1.26 (0.3-6.0)

3.3 PIT Array

3.3.1 Range Testing

Read ranges for 32 mm PIT tags were relatively high for both antennas in the Chowade River, and 32 mm tags were detectable in at least 85% of the water column throughout the monitoring period (Figure 3.22). The read range of 23 mm tags was moderate, as >70% of the water column was detectable during the monitoring period. The mean proportion of the water column within which 14 mm tags was detectable was 71% and 12 mm tags were detectable at approximately 50% (Figure 3.21). This is the second year operating the Chowade River antennas at this site, and read ranges were lower in 2024 relative to 2023.

Read ranges in Cypress Creek were consistently high throughout the monitoring period. The proportion of the water column within which 32 mm and 23 mm tags could be detected was nearly 100% (Figure 3.23). The mean proportion of the water column within which 14 mm tags were detected was 90%, and 12 mm tags were detectable at 78% (Figure 3.22).

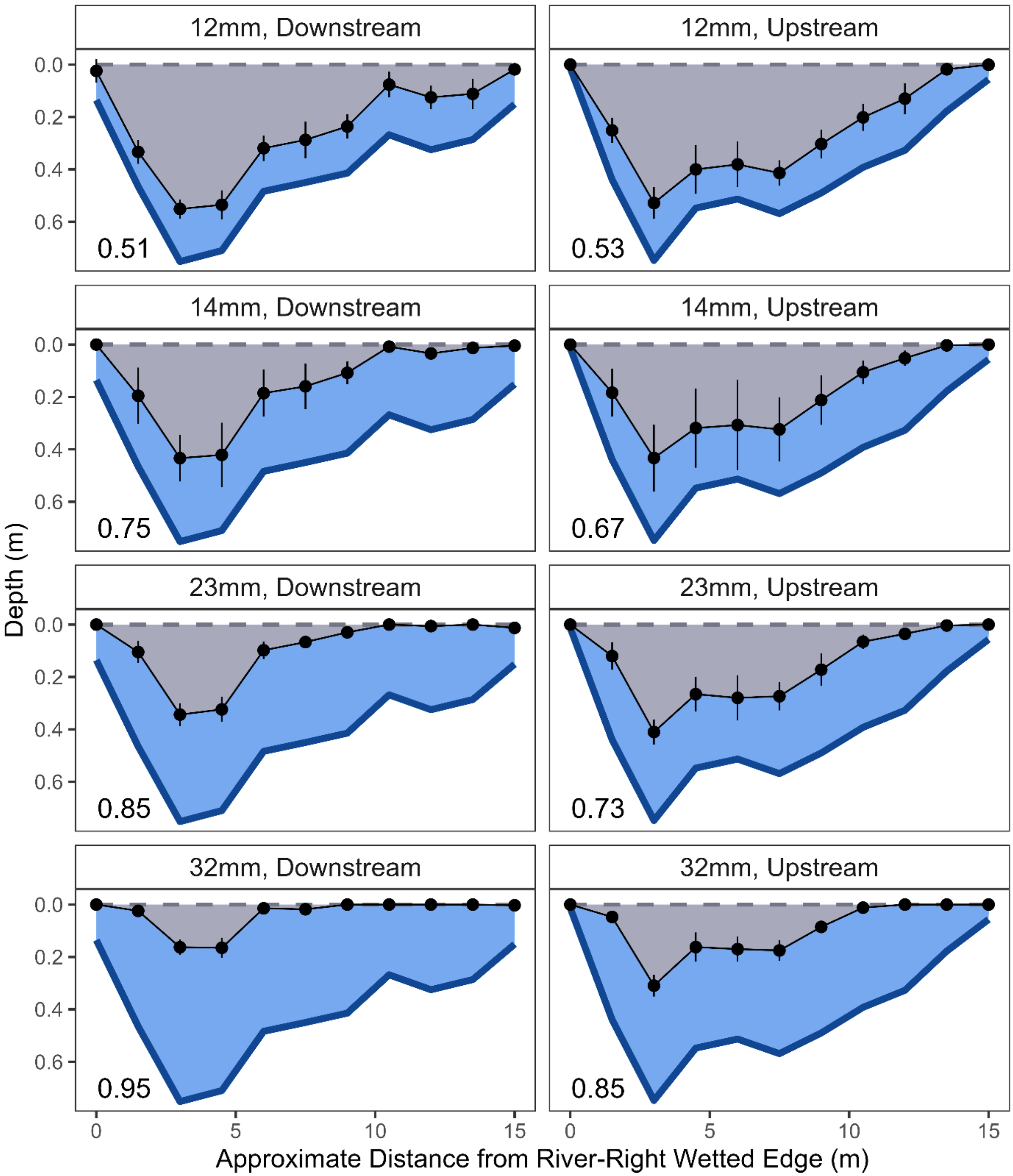


Figure 3.12 Proportion of the water column (points show mean ± SD) in the Chowade River within which PIT tags (12 mm, 14 mm, 23 mm, and 32 mm) were detectable throughout the monitoring period. Blue shading represents areas where tags are detectable (the number within the blue area is the mean detectable proportion of the water column), while grey shading designates areas where tags are not detectable.

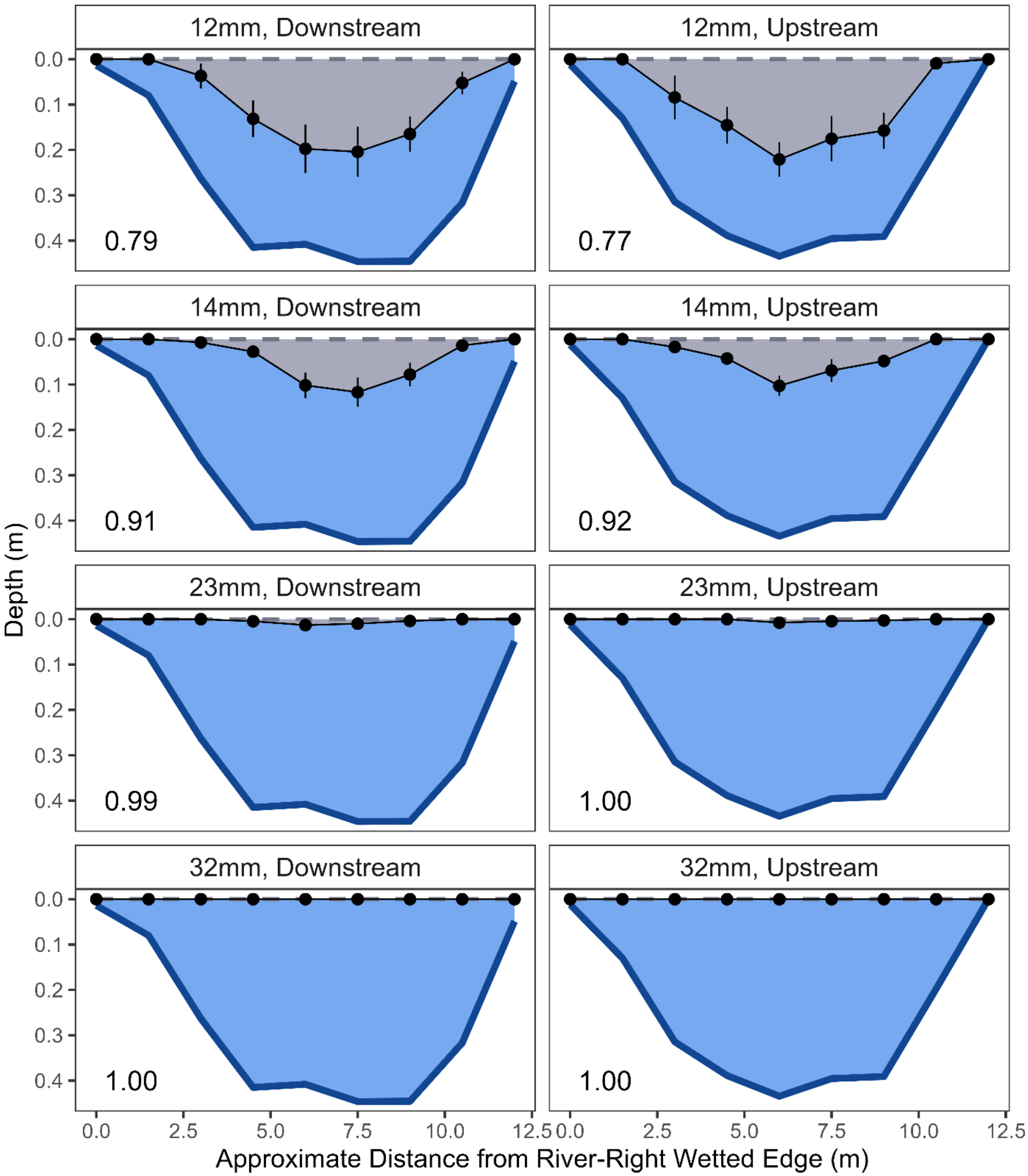


Figure 3.13 Proportion of the water column (points show mean ± SD) in Cypress Creek within which PIT tags (12 mm, 14 mm, 23 mm, and 32 mm) were detectable throughout the monitoring period. Blue shading represents areas where tags are detectable (the number within the blue area is the mean detectable proportion of the water column), while grey shading designates areas where tags are not detectable.

3.3.2 Tag Detections

At the Chowade River PIT array, upstream detection efficiency (for all species and tag sizes) was 78%, while downstream detection efficiency was 69%. Fifty unique tags were detected by the array, including 41 Bull Trout, 1 Rainbow Trout, 6 Mountain Whitefish, and 2 unknowns[6]. Passage direction was determined for 30 of the tag IDs detected at the Chowade River PIT array (the remaining tags were only detected by one antenna; Appendix C). Seven Bull Trout were detected moving upstream then downstream (with a time difference of greater than three days), with upstream detections from July 19 to September 6 and downstream detections from August 22 to September 24. The average residence time of Bull Trout spawning upstream of the Chowade River PIT array was 32.9 days (SD 24.1, range 0.2-57.9). Nine of the PIT tags detected by the Chowade array in 2024 had been previously detected during spawning migrations on the Chowade River. Of the nine redetected PIT tags, six were Bull Trout, one was a Rainbow Trout, one was a Mountain Whitefish, and one was an unknown fish. Two Bull Trout were redetected in three different years, one Rainbow Trout was redetected for four different years, while the rest were redetected twice in separate years (Appendix D).

In Cypress Creek, upstream detection efficiency was 83%, while downstream detection efficiency was 91%. Thirteen unique tags were detected (9 Bull Trout, 3 Rainbow Trout, and 1 Mountain Whitefish), and direction was determined for ten tags (2 Rainbow Trout, 1 Mountain Whitefish, and 7 Bull Trout; Appendix C). Three Bull Trout were detected moving upstream (between July 28 and September 21) then downstream (between September 14 and September 22), recycling for 0.3 days, and residence time of 6.1 days and 48.7 days. This suggests residence time was not adequately captured by the array in 2024. Interestingly, one Bull Trout (484 mm FL at time of tagging on 2022-06-01 in Peace River) travelled downstream then upstream, with a residence time downstream of the array of 16 days, highlighting the variable behaviour of Bull Trout in this system. One PIT tag (a Bull Trout) detected in 2024 by the Cypress array was also previously detected by the same array (Appendix D).

[6] Two PIT IDs detected by the Chowade River array appeared in the PIT tag database only once and were identified at the temporary upstream passage facility (TUF). There were errors in species identification issues at the TUF in 2023 and we have designated their species as unknown until additional detection information (recapture) becomes available.

PIT arrays were installed relatively early in 2024 (mid-July) and removed in early October. The longer monitoring period suggests spawning and kelt migration in Cypress Creek and the Chowade River are complex. In Cypress Creek, upstream movements occurred between July 23 and September 21, and downstream movement occurred between July 27 and September 22. In the Chowade River, upstream movements were recorded between July 19 and September 27 and downstream movements occurred between July 20 and September 27. While not all observed movements constitute Bull Trout spawning migrations, they reveal the extended and variable movement patterns of Bull Trout and other species within the Halfway River watershed. Notably, two Bull Trout were detected in both the Chowade River and Cypress Creek over multiple years. This further supports the growing evidence of diverse spawning patterns and the use of various spawning tributaries by Bull Trout. Understanding these movement patterns is critical for evaluating the potential impact of the Project on regional fish populations. There is a continued necessity for monitoring movements through the use of PIT tags and radio telemetry.

4. Discussion

The objective of Mon-1b, Task 2b is to assess the abundance, migration timing and distribution of Bull Trout spawning in the Halfway Watershed. We estimated redd abundance and peak count indices in the Chowade River, Cypress Creek, the upper Halfway River, Fiddes Creek, Turnoff Creek, and Needham Creek (peak count only), and kelt abundance in the Chowade River and Cypress Creek. The results of this monitoring program build on previous observations of Bull Trout spawning, including peak redd counts in five tributaries from 2002 to 2012 (Diversified Environmental Services and Mainstream Aquatics Ltd. 2009; 2011; 2013), spawner assessments and fence data from the Chowade River in 1994 and 1995 (R.L. & L. Environmental Services LTD. 1995; Baxter 1997), and radio telemetry data collected from 1996 to 1999 throughout the Peace Region (e.g., AMEC Earth & Environmental and LGL Ltd. 2010).

The 2024 monitoring year marks the fourth year of river diversion, which may provide a migration barrier to fish migrating downstream and upstream past the Project (Cook et al. 2023). While only a small proportion of Bull Trout are known to migrate past the Project (Taylor et al. 2013), any potential barriers to migrating fish may impact the number of spawners observed in the Halfway tributaries.

4.1 Abundance

4.1.1 Redd Enumeration

Understanding and quantifying sources of error is integral to producing an accurate and precise estimate of redd abundance using the GAUC method. Ground OE was high in all tributaries surveyed, which agrees with literature suggesting detailed ground surveys are an accurate redd counting method (Dunham et al. 2001). Aerial OE is typically lower and more variable than ground OE, which is expected given tributary-specific river conditions (flow, temperature, turbidity), visual survey conditions (water depth, clarity, and glare), helicopter survey conditions (e.g., glare, survey height, and survey speed) and redd distributions.

In 2024, aerial OE was particularly variable relative to previous years, which contributed to elevated uncertainty in GAUC abundance. Flow conditions were unusually low throughout the survey sites, making redd ageing challenging and resulting in heighted plant growth. Also, algal growth and low redd sample sizes within the ground reach made it more difficult to accurately characterize observer efficiency. When spawner abundance is low, site-specific conditions within the ground reach become more prominent and may result in biased efficiency estimates relative to the full spatial extent of spawning. Difficult conditions in 2024 highlight the benefit of incorporating uncertainty in SL and OE within GAUC estimates as our uncertainty in OE and SL is captured within GAUC confidence intervals.

Each year, SL and OE are carefully considered, and several analysis methods have been compared to ensure these parameter estimates are robust among methods. As additional project years are completed, SL and OE information can be shared among years (e.g., using multilevel analyses), which will likely increase precision in these parameters and subsequent GAUC abundance, but should not substantially alter mean estimates.

4.1.2 Kelt Enumeration

Resistivity counter accuracy was high for both downstream and upstream counts (93% and 97% for the Chowade River, 83% and 98% for Cypress Creek, respectively). Kelt estimates have high precision due to extensive validation efforts. Upstream and downstream counter accuracy were relatively consistent with previous monitoring years and comparable salmonid enumeration programs in British Columbia (Ramos-Espinoza et al. 2011). Resistivity counter accuracy is typically lower for downstream movements relative to upstream movements because fish moving downstream travel higher and faster in the water column, and are therefore further from the counter electrodes. High densities of nontarget species (e.g., Mountain Whitefish) can also reduce counter accuracy because the counters are calibrated for large-bodied fish and struggle to distinguish among schooling individuals.

Relatively low water levels in the Halfway watershed in 2024 resulted in moderate to high accuracy of counter data and a robust estimate of both upstream and downstream Bull Trout migrations during the monitoring period. Although the migration occurred over a similar duration compared to previous years, the low number of recorded kelt migrants (24) did not provide sufficient data to fit a normal distribution curve or determine the starting outmigration date.

Abundance estimates were generated for both upstream and downstream migrants in 2024, but the full spawning migrations were not recorded in either study system. Low flows in 2024 allowed for earlier equipment installation relative to previous years, and the resistivity counter recorded a larger portion of the upstream migration. Upstream counts estimated by the resistivity counters were higher than kelt estimates, which may indicate the counters were removed prior to the conclusion of the kelt migration.

Much like 2023, the 2024 season confirmed that the upstream migration occurs over a much longer period relative to the contracted downstream migration of kelts. Counter data suggest the upstream migrations begin prior to our install date in early July and continue into mid-September, while downstream migrations begin in early September and conclude past our demobilization date in early October. Opportunistically installing and removing resistivity counters and radio telemetry receivers to encompass a longer duration will continue to inform the timing of the upstream and downstream Bull Trout spawning migrations.

4.1.3 Spawner Abundance in the Halfway Watershed

Bull Trout peak redd counts have occurred periodically since 2002, and we repeated peak counts from 2016 to 2024 along with GAUC abundance estimates. Peak counts collected during this monitoring program are several orders of magnitude lower than peak count estimates from 2010 and 2012, but methodological differences (survey type, duration, timing, and area surveyed) among historic counts and between historic and modern counts make it difficult to assess trends in peak counts through time. In this monitor, GAUC estimates are consistently higher than peak counts, suggesting historic counts likely underestimated true redd abundance.

Variability in peak redd counts may be partially related to count methodologies, which highlights the importance of a robust enumeration methodology. Historically, peak counts were subject to minor variations in counting methods, personnel, and survey length. Also, we found peak counts from 2016 through 2024 were sensitive to the type and number of surveys that were included in the peak spawning window. This sensitivity highlights the inherent uncertainty in peak counts and suggests GAUC estimates may be a more accurate and consistent method of estimation.

Variable redd abundance may also be related to high rates of process error (i.e., natural variation in population size). A power analysis found high process error in historic Bull Trout redd counts in the Halfway Watershed (Ma et al. 2015), and process error is generally known to be high in Bull Trout spawner estimation (e.g., Kovach et al. 2018, Maxwell 1999). Finally, changes in peak counts may be related to regional weather patterns, fishing pressure, or additional impacts that have not been identified. For example, Diversified Environmental Services and Mainstream Aquatics (2013) noted a decline in spawning activity and redd building starting from 2010, which they suggested may have been related to an increasing trend of recreational fishing in the region, and extreme hydrological events in 2011 and 2012 (Diversified Environmental Services and Mainstream Aquatics Ltd 2013).

Radio telemetry analyses of tagged Bull Trout spawners indicate diverse behaviours of Bull Trout in the Halfway River watershed (Hatch et al. 2024). Tagged Bull Trout have migrated into the same tributary in consecutive years (presumably to spawn), while others have migrated into different tributaries, and some have exhibited skip-spawning behaviour (Hatch et al. 2024). Continued telemetry monitoring (PIT and radio) within this monitor and under other components of the FAHMFP will build behavioural and life history knowledge of Bull Trout in the Halfway River watershed, including spawning behaviour, site fidelity, and survival.

Using redd abundance to detect changes in Bull Trout spawner abundance assumes redd counts are correlated with adult spawner abundance, and changes to redd abundance represent corresponding changes in population abundance. Kelt to redd ratios for the Chowade River (0.7) and Cypress Creek (1.3) are low relative to literature values from western North America (~1-4 spawners/redd; Howell and Sankovich 2012; Andrusak 2009; Al-Chokachy et al. 2005; Dunham et al. 2001). Clearly, the relationship between spawners, kelts, and redds in the Halfway River watershed is complex. Additional years of enumeration and assessments of spawner behavior will help to inform these relationships, which are critical for understanding how changing redd abundance inform Bull Trout population trends.

Previous research suggests redd counts and spawner abundance can be correlated but highly variable (Al-Chokachy et al. 2005; Dunham et al. 2001). Variability in the ratio of spawners to redds can result from observation or process error. For example, the spatial distribution of redds, size of redds and spawners, spawner density, life histories (e.g., the proportion of resident vs migratory spawners), skip-spawning rates, and spawning stream characteristics (e.g., substrate composition, turbidity, and discharge) can all influence spawner to redd ratios (Howell and Sankovich 2012; Al-Chokachy et al. 2005). Observation error of both redd and spawner counts can result from the survey timing and frequency, the spatial extent of surveys, surveyor experience, and stream characteristics during surveys (Howell and Sankovich 2012). However, although observation error is inherent to count estimates, our GAUC and electronic counter estimation methods account for error and reduce uncertainty around the estimates.

Detecting trends in Bull Trout abundance can be particularly challenging over short assessment periods (e.g., <10 years). Bull Trout typically have a five-year generation time, which can result in a substantial lag-time between the occurrence of a stressor and a response in redd or spawner abundance (Howell and Sankovich 2012). Spawner to redd ratios are also spatially variable, and changes in Bull Trout abundance can occur due to stressors proximate to spawning areas (e.g., beaver dams, landslides) or regional stressors (e.g., disruption to overwintering habitat or migration routes; Kovach et al. 2018; High et al. 2008). Separating the effects of localized changes to spawning tributaries from the effects of regional stressors, such as the construction and operation of the Project will add additional uncertainty to trend analyses. Bull Trout spawner assessments used in this monitoring program prioritize accurate and precise estimates of both redd abundance and spawner abundance to maximize the power to detect a decline in Halfway River Bull Trout.

4.2 Migration Timing

In 2024, resistivity counters were installed the earliest since the start of the program, and the upstream to downstream ratios captured more upstream than downstream counts. Angling surveys in 1995 suggest Bull Trout first appear in the Chowade River in early August, with peak spawning [REDACTED] (Baxter 1997). In contrast, counter data suggest upstream migration begin even earlier in July and peak sooner than previously indicated by Baxter (1997). Furthermore, the upstream migration may not follow a typical normal distribution, as is usually observed for downstream kelts, and the tail end of the upstream migration may extend into September. Further exploration of migration timing using the radio telemetry data from the Site C Fish Movement Assessment (Hatch et al. 2024) would be beneficial in determining the exact start of the upstream migration.

Radio telemetry data currently being collected in the Halfway Watershed informs migration timing, residence time, and site fidelity (Hatch et al. 2024). Juvenile emigration is variable, with some individuals migrating in the year they were tagged, while others delay emigration for several years. Future survey years will provide natal fidelity when these Bull Trout reach maturity and undergo their first spawning migrations as mature adults.

4.3 Distribution

According to redd surveys, Bull Trout spawner distributions show minor variations both within and among tributaries of the Halfway River. Although some areas consistently saw redd activity from 2016 to 2024, many areas of high-quality spawning habitat had zero redds in some years. Historic peak count surveys also noted annual changes in Bull Trout distributions, and increased spawning outside of wildlife habitat areas created in 2000 to protect critical Bull Trout spawning habitat (Diversified Environmental Services and Mainstream Aquatics Ltd 2011, 2013).

Telemetry data suggest Bull Trout exhibit diverse spawning behaviour, including repeat spawning within the same tributary, spawning in different tributaries in consecutive years, and skip-spawning (Hatch et al. 2024). The two Bull Trout redetected at the PIT antennas in both the Chowade River and Cypress Creek, along with multiple redetections of various Bull Trout over several years in the same tributary (Appendix D), support the growing evidence of diverse spawning patterns and the use of the same or different spawning tributaries. This variation is likely related to Bull Trout behaviour variability and annual environmental conditions within the watershed. Discharge may affect spawner timing and distribution (e.g., Sinnatamby et al. 2018), and discharge during the Bull Trout migration has varied considerably from 2016 to 2024 (Figure 3.1). Data suggest years with high discharge may be associated with higher GAUC redd abundance in smaller tributaries such as Fiddes and Turnoff Creeks. Changes in water temperature or groundwater discharge can also affect the distribution and abundance of spawning salmonids (e.g., Baxter and McPhail 1999). We will continue to monitor redd distribution in the Halfway Watershed to investigate the complex nature of redd site selection.

4.4 Site- and Year-Specific Characteristics

Monitoring under Mon-1b, Task 2b was highly successful in 2024 for both the Chowade River and Cypress Creek. Low flows facilitated early installation of resistivity counters and PIT arrays, and no outages or data gaps occurred over the monitoring period. The Chowade River monitoring site was moved in 2023 to ensure the full river was monitored (the site was moved upstream of a growing side channel); the site remained in the same position in 2024. The selected site was successful, as evidenced by high counter accuracy and high PIT array detection efficiency.

Algal growth has been increasing in Cypress Creek in recent years, and high macrophyte density in 2023 and 2024 likely negatively affected monitoring efficiency. High volumes of filamentous macrophytes floated downstream past the counter site and became entangled in counter pads and PIT antennas (Appendix E). Increased drag from macrophyte debris caused the PIT antennas to distort, causing reduced detection efficiency and increased wear on equipment. Also, macrophytes obscured redds and redd markers during redd surveys, likely reducing aerial and ground detection efficiency relative to previous years. Site-specific conditions, such as increased macrophyte growth, are assessed each year and site modifications are made whenever possible to maximize monitoring efficiency. The increase in terrestrial vegetation also decreased the efficiency in solar power generation. Regular maintenance and upkeep of foliage is required to ensure power generation is sufficient for our equipment.

4.5 Conclusion

Accurately and consistently estimating abundance and detecting changes in abundance is critical to understanding potential population-level effects of the Project. Since 2016, we have produced redd abundance estimates and kelt abundances for tributaries of the Halfway River, which build upon historic peak counts dating back to the early 2000s. Our GAUC method is more accurate and robust relative to peak counts, increasing the probability of detecting future changes in Bull Trout populations.

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Appendix A: Aerial and Ground Redd Counts

Table A1. Survey-specific ground counts, aerial counts, ground OE, expanded ground counts, and aerial OE.

Tributary	Survey	Ground Count	Aerial Count (within ground reach)	Avg Ground OE	Expanded Ground (ground count / mean ground OE)	Aerial OE (aerial count / expanded ground count)
Chowade River	1	13	3	0.88	14.81	0.2
	2	29	12	0.88	33.03	0.36
	3	50	25	0.88	56.94	0.44
	4	42	9	0.88	47.83	0.19
Cypress Creek	1	0	0	0.83	0.00	-
	2	1	2	0.83	1.20	1.67
	3	5	4	0.83	6.00	0.67
	4	13	4	0.83	15.60	0.26
Fiddes Creek	1	5	0	0.89	5.63	0
	2	6	0	0.89	6.75	0
	3	6	1	0.89	6.75	0.15
	4	6	1	0.89	6.75	0.15
Upper Halfway River	1	0	0	0.94	0.00	-
	2	1	1	0.94	1.06	0.94
	3	5	1	0.94	5.31	0.19
	4	12	12	0.94	12.75	0.94
	5	16	5	0.94	17.00	0.29
Needham Creek	1	20	0	-	-	0.00[a]

a: Aerial count/ground count for single peak count survey

Appendix B: Total Lengths from Video Validation

Table B1. Fish Total lengths estimated in the Chowade River through video validation.

	N	Mean (mm)	Range (mm)	SD (mm)
Bull Trout				
2016	30	700	410-930	120
2017	361	613	300-1080	143
2018	525	632	300-1036	152
2019	157	637	223-943	139
2020	436	623	240-970	122
2021	438	642	500-1000	90
2022	205	622	354-1080	123
2023	192	728	470-995	113
2024	461	655	460-960	114
Mountain Whitefish				
2016	187	240	110-490	70
2017	156	323	120-494	44
2018	180	323	211-480	55
2019	30	297	206-405	52
2020	821	289	80-480	78
2021	1223	286	20-520	69
2022	94	410	150-540	62
2023	212	253	120-420	55
2024	756	357	220-480	46
Rainbow Trout				
2016	-	-	-	-
2017	11	326	300-343	17
2018	10	387	265-587	101
2019	28	420	200-586	91
2020	71	380	230-550	62
2021	269	353	160-530	67
2022	106	402	263-563	49
2023	313	354	250-625	48
2024	176	410	230-580	52

Table B2. Calculated Fish standard lengths estimated in Cypress Creek through video validation.

	N	Mean (mm)	Range (mm)	SD (mm)
Bull Trout				
2017	76	556	38-844	133
2018	230	496	279-900	97
2020	48	594	430-920	127
2021	129	642	550-940	85
2022	269	596	321-900	125
2023	235	669	430-970	99
2024	98	595	460-850	90
Mountain Whitefish				
2017	207	259	83-463	70
2018	20	323	243-380	32
2020	304	207	80-390	68
2021	204	302	100-540	93
2022	39	354	197-407	41
2023	103	280	120-430	70
2024	362	350	230-490	40
Rainbow Trout				
2017	9	308	171-400	73
2018	3	354	292-450	84
2020	71	278	180-440	61
2021	59	318	170-450	65
2022	26	387	197-460	70
2023	135	393	300-640	74
2024	32	400	310-560	54

Appendix C: PIT Detection Histories

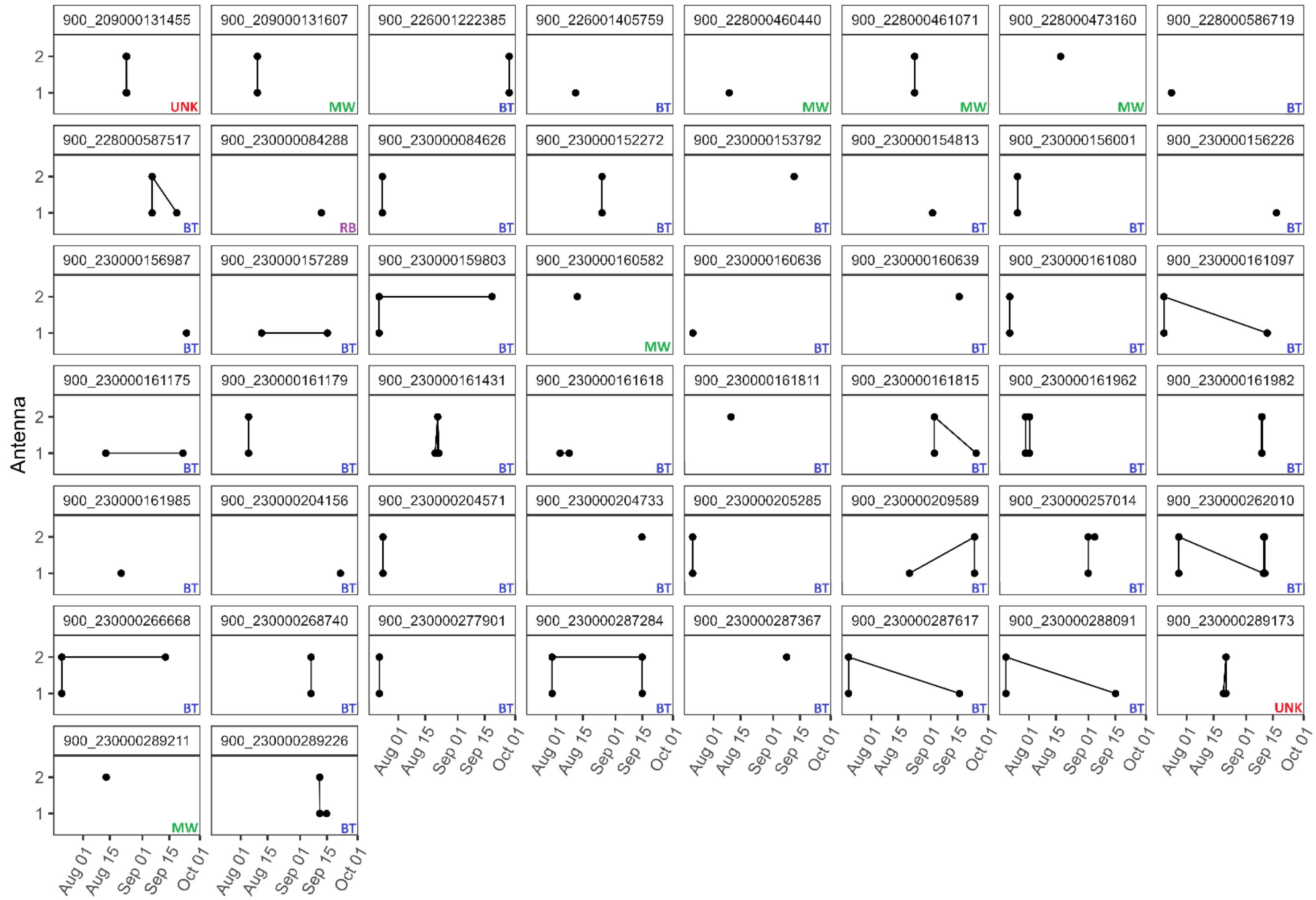

Figure C1. Detection histories of PIT tags detected by the Chowade River array. Antenna 1 is the downstream antenna, while Antenna 2 is the upstream antenna.

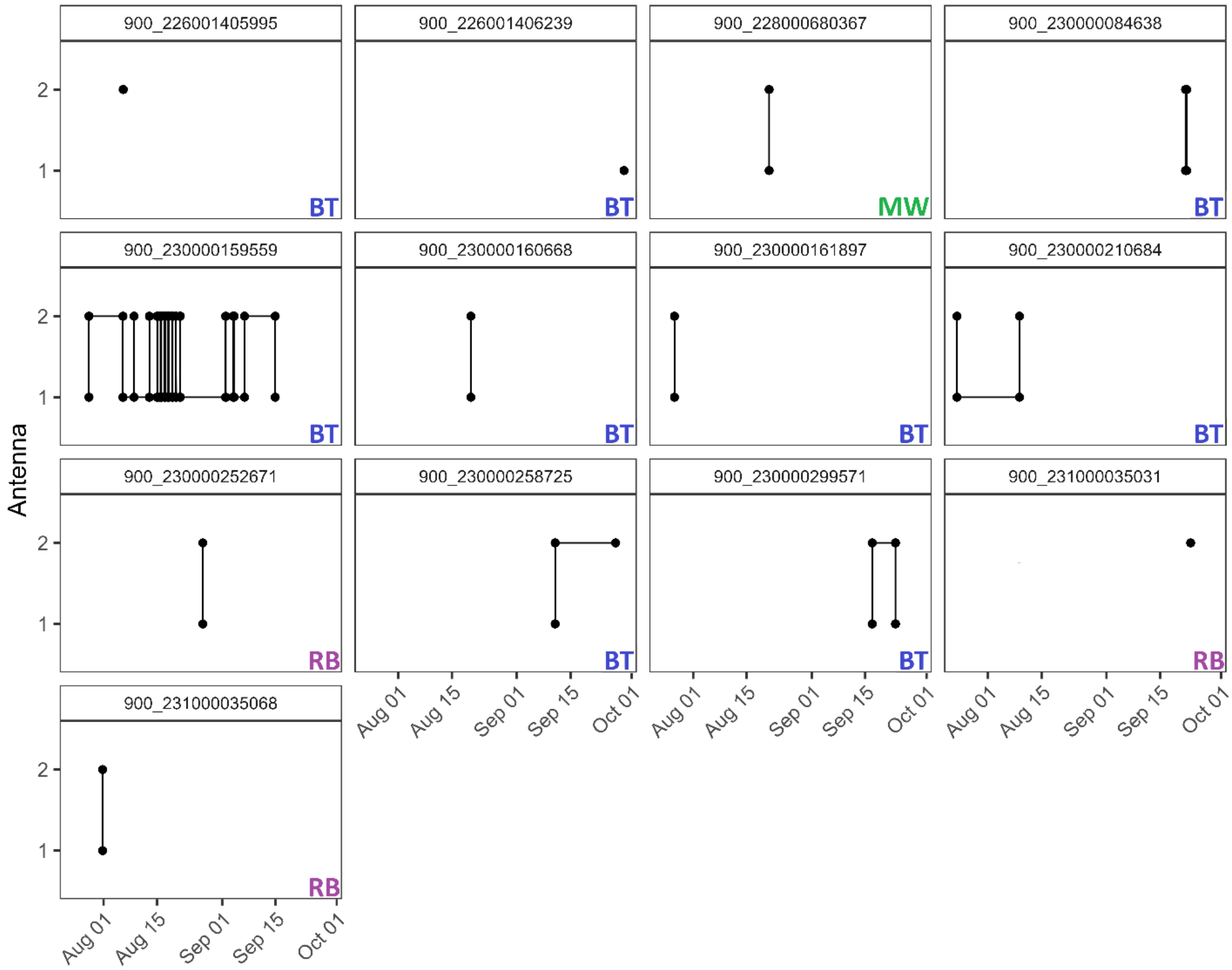

Figure C2. Detection histories of PIT tags detected by the Cypress Creek array. Antenna 1 is the downstream antenna, while Antenna 2 is the upstream antenna.

Appendix D: Redetected PIT-Tagged Fish

Table D1. Redetected PIT tagged fish from Chowade River and Cypress Creek, and their associated biodata. Tags highlighted in red show fish that were redetected at both Chowade River and Cypress Creek.

IFR data			Biodata from WSP					
PIT Code	**Detected at Chowade River**	**Detected at Cypress Creek**	**Species**	**Initial Capture Date**	**Initial length and weight**	**Initial Capture Location**	**Program - Initial Capture Method**	**Subsequent Recapture Date from WSP**
900-2280 00369262	2021, 2022		BT	2018-09-30	336, 358	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2280 00369481	2020, 2021		BT	2018-10-01	625, 2851	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2280 00369911		2021, 2022	BT	2018-09-19	289, 256	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2280 00460440	2021, 2024		MW	2020-09-13	275, 250	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2280 00541567	2018, 2020		RB	2016-08-23	247, 196	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Small Fish Boat Electroshocking	
900-2280 00586719	2022, 2024		BT	2017-08-24	282, 220	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2280 00587517	2022, 2023, 2024		BT	2017-08-26	371, 509	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00030533	2020, 2023		BT	2016-09-09	440, 891	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2017-09-13, 2018-08-27
900-2300 00031276	2018, 2020, 2021		RB	2016-08-25	352, 515	Cypress Creek	Site C Reservoir Tributaries Fish Population Indexing - Small Fish Boat Electroshocking	
900-2300 00031672	2018, 2020		BT	2016-09-11	390, 585	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2018-10-01, 2020-09-21

PIT Code	Detected at Chowade River	Detected at Cypress Creek	Species	Initial Capture Date	Initial length and weight	Initial Capture Location	Program - Initial Capture Method	Subsequent Recapture Date from WSP
900-2300 00032412	2018, 2020		BT	2017-08-25	593, 2390	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00055260	2018, 2020, 2021		BT	2017-09-09	614, 2510	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00056692		2020, 2021	BT	2017-09-12	387, 592	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2021-05-13
900-2300 00057956	2020, 2021, 2022, 2023		BT	2017-09-29	524, 1816	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00074947		2018, 2020	RB	2018-08-09	366, 651	Cypress Creek	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	
900-2300 00075006	2021, 2022		BT	2018-08-29	300, 251	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2018-09-26
900-2300 00077455	2020, 2021		BT	2018-09-24	615, 2996	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00079156		2020, 2021, 2022	BT	2018-09-19	604, 2394	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2019-09-30
900-2300 00080382	2020, 2021		BT	2018-09-25	494, 1039	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2021-07-08
900-2300 00084288	2020, 2021, 2023, 2024		RB	2019-07-19	384, 641	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	
900-2300 00084555	2021, 2023		BT	2019-08-03	542, 1458	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	
900-2300 00084626	2023, 2024		BT	2021-09-13	400, 600	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00084639	2020, 2021		BT	2019-07-20	603, N/A	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	

PIT Code	Detected at Chowade River	Detected at Cypress Creek	Species	Initial Capture Date	Initial length and weight	Initial Capture Location	Program - Initial Capture Method	Subsequent Recapture Date from WSP
900-2300 00124018	2018, 2020, 2021		BT	2016-08-20	592, 1861	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Small Fish Boat Electroshocking	2018-09-25
900-2300 00124295	2018, 2019		RB	2016-08-19	324, 439	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Small Fish Boat Electroshocking	
900-2300 00124726	2018, 2020, 2023		BT	2016-09-23	619, 2938	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2019-09-30
900-2300 00124782		2018, 2020, 2021, 2022	BT	2016-09-19	446, 764	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00125144	2020, 2021		BT	2016-09-27	394, 581	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00126571		2020, 2021, 2022	BT	2015-09-28	383, 606	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2016-08-31
900-2300 00127421	2018, 2020		BT	2016-09-09	414, 671	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00154813	2023, 2024		Initially MW, ingested by BT in 2022	2018-08-27	302, 303	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2022-10-04
900-2300 00202501	2020, 2021, 2022		BT	2019-09-22	576, 2138	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2022-10-04
900-2300 00203129	2022, 2023		BT	2019-09-13	398, 553	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2020-08-29
900-2300 00205393	2021	2022, 2023	BT	2015-09-30	400, 585	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2020-09-22
900-2300 00206640		2020, 2021	BT	2019-10-03	572, 1675	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2021-05-26
900-2300 00209033		2020, 2021	RB	2020-08-01	420, 716	Cypress Creek	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	

PIT Code	Detected at Chowade River	Detected at Cypress Creek	Species	Initial Capture Date	Initial length and weight	Initial Capture Location	Program - Initial Capture Method	Subsequent Recapture Date from WSP
900-2300 00209907		2020, 2021	RB	2020-07-31	357, 548	Cypress Creek	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	
900-2300 00209923	2020, 2021, 2022, 2023		RB	2020-08-09	307, 370	Chowade River	Site C Reservoir Tributaries Fish Population Indexing - Backpack Electrofishing	
900-2300 00210226		2021, 2022	BT	2022-06-01	732, 4734	Peace River	Site C Contingent Fish Capture - Large Fish Boat Electroshocking	
900-2300 00210511	2021, 2023		BT	2022-09-16	656, 2928	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00211175	2022, 2023		BT	2020-09-26	344, 556	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	2021-09-06
900-2300 00258388	2022, 2023		BT	2021-10-05	555, 1473	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00258725		2022, 2024	BT	2022-05-18	626, 3057	Peace River	Site C Contingent Fish Capture - Large Fish Boat Electroshocking	
900-2300 00259769	2022, 2023		BT	2022-05-04	715, 5301	Peace River	Site C Contingent Fish Capture - Large Fish Boat Electroshocking	
900-2300 00268872		2021, 2022	BT	2020-10-03	529, 1336	Peace River	Peace River Large Fish Indexing Survey - Large Fish Boat Electroshocking	
900-2300 00269481	2023	2021	BT	2021-05-26	503, 1319	Peace River	Site C Contingent Fish Capture - Large Fish Boat Electroshocking	
900-2300 00277901	2021, 2023, 2024		BT	2021-08-18	490, 1334	Peace River	Temporary Upstream Fish Passage Facility - TUF	
900-2300 00287367	2022, 2024		BT	2022-08-14	750, 4103	Peace River	Temporary Upstream Fish Passage Facility - TUF	
900-2300 00287617	2023, 2024		N/A	N/A	N/A, N/A	N/A	N/A	N/A

Appendix E: Cypress Creek Algal Growth

Algae or macrophytes (species unknown) entangled in Cypress Creek PIT antennas (left) and resistivity counter pads (right).