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 – A Pilot Study to Assess the Feasibility of a Resistivity Counter and Passive Integrative Transponder Antenna in the Chowade River

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Douglas Braun, PhD
InStream Fisheries Research Inc.

Daniel Ramos-Espinoza, BSc
InStream Fisheries Research Inc.

Nicholas Burnett, MSc
InStream Fisheries Research Inc.

Michael Chung, BSc
InStream Fisheries Research Inc.

Jennifer Buchanan, BSc
InStream Fisheries Research Inc.

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Peace River Bull Trout Spawning Assessment – A Pilot Study to Assess the Feasibility of a Resistivity Counter and Passive Integrative Transponder Antenna in the Chowade River (Mon-1b, Task 2b)

Douglas C. Braun*, Daniel Ramos-Espinoza, Nicholas J. Burnett, Michael Chung, Jennifer Buchanan

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*Corresponding author

Executive Summary

The feasibility of operating a resistivity counter and passive integrated transponder (PIT) antenna in the Chowade River was assessed in a pilot study in 2016. The specific objectives of the study were to:

1. determine if the resistivity counter could accurately enumerate Bull Trout spawners, collect information on migration timing, spawning duration and size of spawners; and
2. determine if the detection range of a PIT antenna would be sufficient to detect salmonids moving past the counter site to determine the migration patterns of adult and juvenile salmonids.

The remote counter and PIT system was installed at the end of July and operated through to October. The feasibility of the counter was assessed by performing video validation of counter records and showed that the counter detected adult Bull Trout with 80% accuracy. Video was also used to identify species and measure fish lengths; these data were used to determine if the counters' fish size index could be used to discriminate raw counts by species. The counters' sizing index effectively differentiated between larger Bull Trout and smaller Mountain Whitefish, although Arctic Grayling and Rainbow Trout could not be distinguished through video validation or the counter sizing index and therefore were grouped into a single small salmonid category. Bull Trout migration patterns revealed that most individuals migrated during nighttime hours. There was insufficient data collection, due to sporadic power outages, to determine the arrival, peak and kelt timing of adult Bull Trout spawners in 2016.

The feasibility of the PIT antenna was determined through range testing, which indicated that read ranges were near the manufacturer's specification. The detection range for the largest PIT tags (32 mm) used in Mon-1b Task 2c covered the entire water column, even under high flow conditions. However, the smaller tags (12 mm) used to tag small juvenile fish had a much lower detection range, covering approximately 50% of the water column under average flow conditions.

While the feasibility assessment of the resistivity counter and PIT antenna showed that both systems could collect data that would meet the project objectives, generating enough power to continuously operate the counter and PIT system proved challenging and requires improvement.

Acknowledgements

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1 Project Background

The Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) objectives are to determine the effects and effectiveness of mitigation measures of the Site C Dam on fish populations, and their habitat, that migrate to tributaries of the reservoir. A subcomponent of this monitoring program (Task 2b) aims to assess spawning populations of Bull Trout in the Halfway River Watershed. Data collected for this task will be used to directly address the following management hypotheses:

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.

Historic data on the Halfway River meta-population have been collected through various spawner assessment methods, including aerial, ground and snorkel surveys of Bull Trout redds. Bull Trout redd surveys will continue from 2016 onwards for comparisons with baseline peak count data but may be supplemented with estimates of spawner abundance and movement behaviour data from electronic fish counters and passive integrated transponder (PIT) telemetry. These data will be compared to redd count estimates produced from Task 2b (Braun et al. 2017) and used to calibrate the redd count estimates. In 2016, a pilot study was implemented to test the feasibility of installing and operating a remote resistivity counter and PIT antenna system. The pilot study was conducted in the Chowade River and was selected because of the historic high abundance of Bull Trout relative to other spawning streams in the Halfway Watershed and relative ease of accessibility.

2 Introduction

Accurate estimates of fish populations are important for assessing the current and future state of populations. Historically, population estimates in the Chowade River and other Halfway River Bull Trout spawning tributaries have been estimated from visual surveys of redds (Braun et al. *In Review*). More recently, population indexing of juvenile salmonids has been conducted using electroshocking (Golder 2016). Visual surveys of redds can provide precise estimates of redd abundance and can be useful for examining changes in populations over time, but it is difficult to assess how closely estimates of redd abundance represent the spawning population due to the unknown relationship between the number of redds created per fish (Dunham et al. 2001; Gallagher and Gallagher 2005). Population indexing for juveniles can provide catch information but may not allow for accurate estimates of juvenile survival or recruitment. Alternative enumeration approaches, including resistivity counters and PIT arrays, can provide independent estimates of spawner abundance, migration timing, spawning duration, survival, juvenile recruitment and fish size.

Resistivity counters can be up to 99% accurate for enumerating salmonids (Braun et al. 2016; Casselman et al., 2015). Furthermore, resistivity counter technology offers various advantages over other electronic counter technologies, including: low cost of purchase compared to other counting technologies, low power demands, low maintenance, small footprint and sensor customization to stream characteristics. Resistivity counters, however, are not appropriate in all streams or may not meet the study objectives for monitoring programs (Braun et al. 2016), and their site-specific feasibility needs to be assessed. PIT telemetry uses arrays of antennas to detect small passive tags implanted into fish, and can be an effective method for tracking the key life history events of individuals, including migrations, growth and survival (Brännäs et al. 1994). Furthermore, PIT telemetry allows for individual-based measurements and tracking of fish through their life cycle.

The objective of this pilot study was to evaluate the feasibility of a resistivity counter and PIT array in the Chowade River. Specifically, the goals of the resistivity counter were to enumerate Bull Trout spawners, collect information on migration timing, spawning duration and the size of spawners. The goals of the PIT array were to detect salmonids moving past the counter site to determine the migration patterns of adult and juvenile salmonids. This study will inform future monitoring in the Chowade River and the feasibility of this counting system in other Bull Trout tributaries of the Halfway Watershed.

3 Methods

3.1 Study Site

In April 2016, the Chowade River and Cypress Creek were visited to identify feasible counter sites. The Chowade River was selected for the pilot study because the Bull Trout population abundance is greater than in Cypress Creek, increasing sample sizes for testing fish sizing relationships and species identification. The general location was selected because it provided access needed for the installation and removal of equipment and was downstream of the known extent of Bull Trout spawning. During the initial site visit, the location was assessed by walking 1 km upstream from the access road and 0.5 km downstream of the access road. In this length of the river, we identified two potential counter sites with suitable stream characteristics for deploying and effectively operating the resistivity counter and PIT telemetry equipment. We selected a site with reduced visibility from the access point, which would potentially reduce public interference.

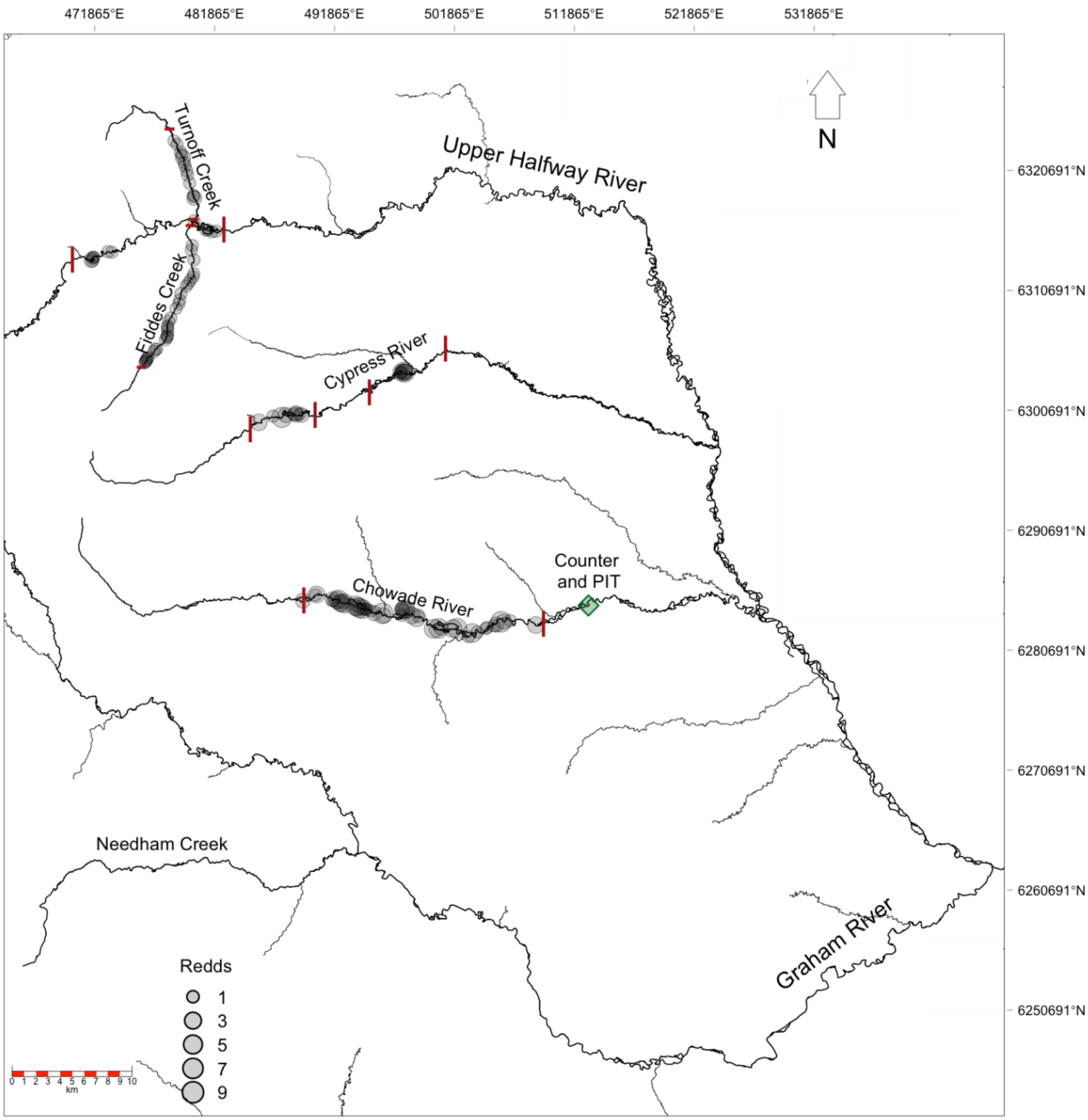

Figure 1. Map of the Halfway Watershed above the Graham River and all fourth order and larger streams. For reference, the grey circles indicate the locations of Bull Trout redds observed during the peak of spawning in 2016 (see Braun et al. 2017 for details on redd counts). The size of the circles indicates the number of redds at each location. Red lines are the boundaries for redd surveys conducted in 2016. The green diamond indicates the location of the resistivity counter and PIT antenna.

A resistivity counter and PIT antenna were installed in the Chowade River 21.7 river kilometers upstream of the Halfway River confluence and approximately 400 m upstream of a decommissioned bridge on the access road (Figures 1 and 2). The Chowade River is a fifth order stream with a mainstem length of 87.1 km. Resident fish species include Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Arctic Grayling

(*Thymallusarcticus*), Mountain Whitefish (*Prosopium williamsoni*) and Slimy Sculpin (*Cottus cognatus*). Adult Bull Trout typically migrate upstream past the counter site from late July to early September, and their downstream migration occurs from late August to early October (R.L. & L. Environmental Services Ltd. 1995). Other species moving past the site include Rainbow Trout, Arctic Grayling and Mountain Whitefish, although most of their movements between August 22 and October 01 were in the downstream direction (R.L. & L. Environmental Services Ltd. 1995). Previous estimates of abundance from a full spanning fish fence operated in 1994 indicated that Mountain Whitefish have the largest population size (8 034 individuals), followed by Rainbow Trout (529 individuals), Bull Trout (319 individuals) and Arctic Grayling (119 individuals); these are likely minimum population estimates due to the limited operation time of the fence (August 22 to October 01) (R.L. & L. Environmental Services Ltd. 1995). While the focal species for the current pilot study was Bull Trout, we attempted to identify all species (excluding Slimy Sculpin) passing over the counter.

Figure 2. The location of the counter site in relation to the access road. This location corresponds to the green diamond in Figure 1.

3.2 Environmental Conditions

We recorded water depth and temperature at the study site from installation (July 26) to removal (October 14). Two HOBO U20 water level loggers were deployed at the site. One logger was in a stilling well on river right just upstream of the Channel 1 sensor pad, and the other was attached to a tree on shore. The onshore logger was used to calibrate the pressure of the in-river logger by measuring the ambient air pressure. Pressure and temperature were set to record every hour. Water depth was calculated from the pressure measurements using HOBO's proprietary software (HOBOware Pro, Version 3.7.10).

We also downloaded stage and discharge data from the Water Survey of Canada hydrometric station located in the Halfway River (Station Name: Halfway River above Graham River; Station No: 07FA003). This hydrometric station is located downstream of the confluence between the Chowade River and Halfway River. We downloaded all historical data (1977 to 2015) to assess the inter-annual variation in discharge and to determine if the Halfway River hydrometric station, which provides real-time data outputs, could serve as a proxy for the water depth at the Chowade River counter site. We examined the relationship between the Halfway River discharge and water depth at the counter site using Pearson's correlation coefficient (r). A strong relationship between the two sites would suggest that the Halfway River could be used as an indicator of the Chowade River water depth and would help inform pre-season planning and in-season management of the counter, such as installation dates and potential data gaps.

3.3 Resisitivity Counter and PIT Operation

Installation of the resistivity counter and PIT telemetry equipment began on July 26 and was completed on July 30. During this period, the counter, sensor pads, water level logger, computer, video cameras and power system were installed. The PIT reader and antenna were installed on August 5. Due to power supply issues, the equipment was not operable for the full period of deployment (Table 1).

3.4 Resistivity Counter

The 2100C resistivity counter operates in conjunction with up to four electrode sensors (e.g. flat pad sensors) to detect the upstream and downstream passage of fish over the sensors. Briefly, the counter measures the resistance between two pairs of electrodes: one pair consists of the downstream electrode and the center electrode, and the other pair consists of the upstream electrode and the center electrode. The resistance that is measured is a function of water conductivity. There is a change in resistance when a fish swims over the electrodes (the fish is more conductive than the water it displaces); this change is recorded by the counter. A fish moving over the sensor pad creates a change in resistance which is then interpreted by the counter algorithm to determine if it is consistent with that of a fish and the direction is recorded along with a date and time stamp. The resistivity counter can be programmed to record and display these graphical traces or changes in resistance (Figure 3). Review of these graphical traces can be used to validate the counter algorithm (see Section 3.4.1 Counter Validation). Each counter record can be classified as one of the following: 1) up, 2) down, or 3) event. If the change in resistance is determined to not follow a typical trace but the values reach some predefined threshold value, the record is classified as an event instead of an up or down count. Events can be due to a fish interacting with the electrodes but not completely passing over the three electrodes or from electrical noise. For each record (up, down or events), the counter also records the peak signal size (PSS) that corresponds to the peak of a sinusoidal curve that is created when a fish passes over the sensor pad. PSS is related to mass and can thus be used as a proxy for fish size (McCubbing et al. 2000) or species if the difference in size between species is large enough.

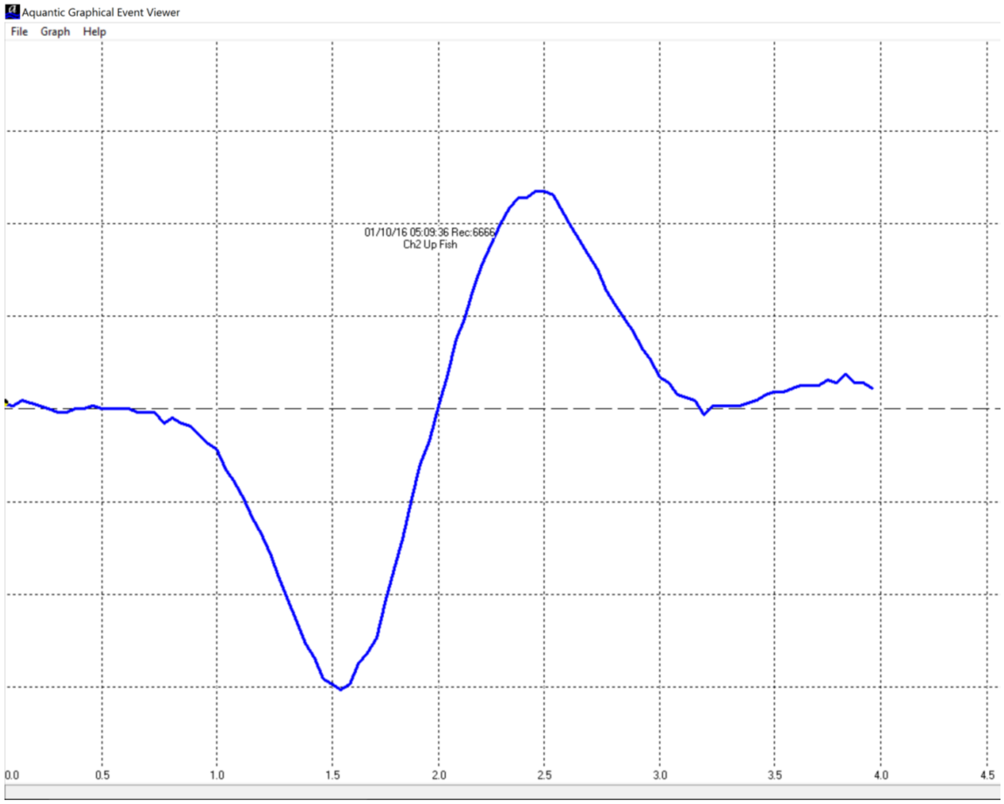

Figure 3. A graphical trace showing a true "up" movement with two equal but opposite peaks, indicating the size and direction of the fish movement. The counter algorithm applies specific criteria to each record, which allow for some flexibility in the ratio of the peaks.

Flat pad sensor units were constructed out of nonconductive material and were used as the support structure for the three electrodes. The six sensor pads covered a river width of 14.6 m. We used a sensor configuration of four channels. Channels 1 to 3 were placed where the water was deepest and the majority of fish movement was expected. Channel 4 spanned a larger section of the river, where fewer fish were expected to migrate (Figure 4).

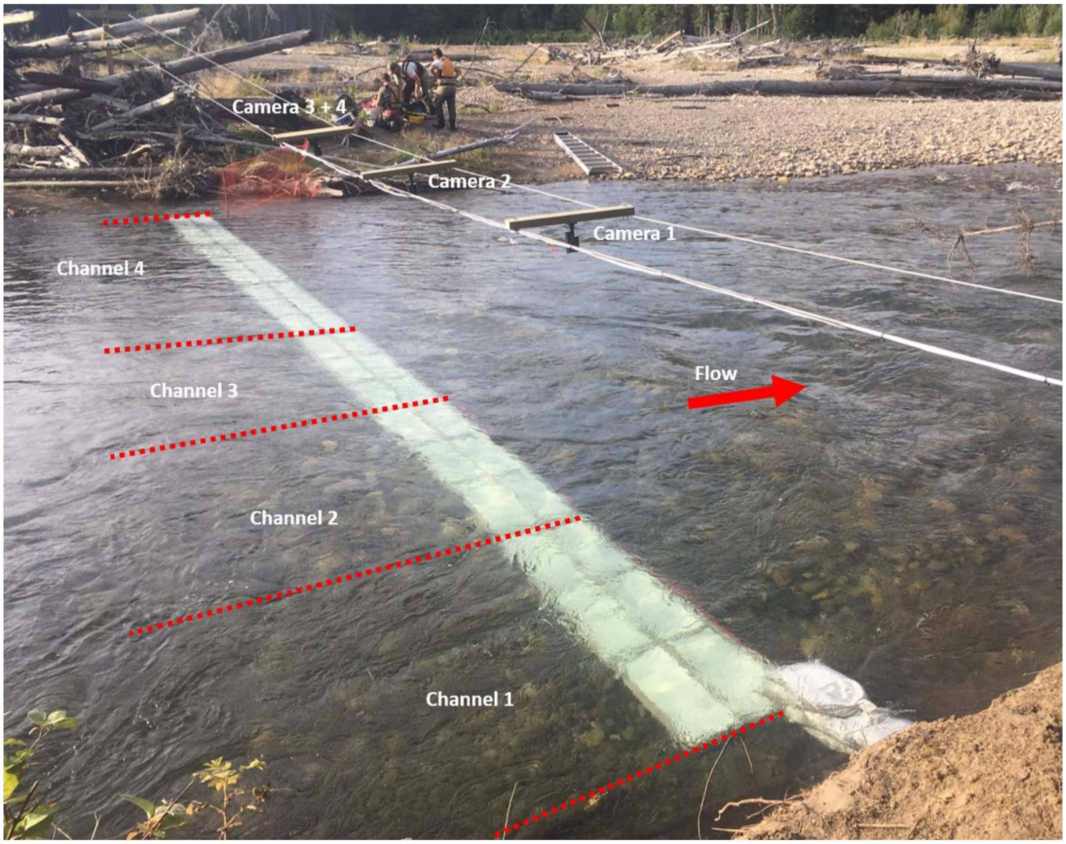

Figure 4. Configuration of the resistivity counter sensor pads and camera system in the Chowade River, 2016.

Electrical equipment, consisting of the counter, video, computer and power system, was positioned on the river right bank. All the equipment was stored in three large, steel 4-foot job site boxes. A custom-built desktop computer that served as a Digital Video Recorder (DVR) and counter interrogation unit was operated 24 hours a day and was housed alongside the counter (Figure 5). Four video cameras were placed directly above the sensor pads on a cableway system (Figure 4) and centered to capture the full span of the pad. The DVR was operated 24 hours a day when power was sufficient (Table 1). All four cameras recorded video in five minute segments and the footage was stored in the computer.

Figure 5. A) Solar panel array charged a battery bank B) to create a 12V power source. C) The battery bank powered the resistivity counter, video and PIT telemetry equipment.

Table 1. Summary of operating period for the video and counter equipment, which includes the collection of graphical trace data. White indicates when equipment was operational. Grey indicates where data are lacking. Times when all data types are missing generally indicate a power outage.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jul	Video																															
	Counter																															
Aug	Video																															
	Counter																															
Sep	Video																															
	Counter																															
Oct	Video																															
	Counter																															

3.4.1 Counter Validation

Counter data were validated to determine true positives and error rates, including false positives and false negatives, and calculate the counter accuracy. True positives for up and down counts were defined as any time the counter recorded an up or down record that corresponded to a fish passing over the sensor in the recorded direction; this can be verified from a graphical trace or video footage. We defined false positives as any time the counter recorded an up or down count and the corresponding record or fish was not observed in a graphical trace or video passing upstream or downstream over the counter sensor. False negatives were defined as any time a fish passed upstream or downstream over the counter sensor, as determined by video, but the counter did not record an up or down count. We used a four-stage validation approach (Figure 6) that included: (1) review of graphical traces (Figure 3) for each counter record to determine false positives and false negatives created by the counter algorithm, (2) targeted video validation to identify false positives produced by the counter, and (3) random video validation to identify false negatives by the counter, and (4) calculation of counter accuracy using the number of true positives, false positives and false negatives.

For each counter record, the continuous change in resistance is recorded and can be plotted using Aquantic's proprietary software (Figure 3). Review of the graphical traces pseudo-validates the counter algorithm, which determines if the change in resistance detected by the sensor pad is due to a fish moving upstream, downstream or actively moving near or on the sensor pad but does not result in a passage event. All records that were misclassified by the counter algorithm were corrected. If completed by an experienced analyst, this is a cost-effective approach to correct many of the algorithm's false positive and false negative counts.

Using graphical trace data, all counter records (up, down, events) were reviewed for true fish traces (Figure 3). Once found, a true fish trace was matched with the corresponding 5 min segment of video footage (10 min if the fish event occurred at the time of video change over) and viewed to verify the counter accuracy and estimate the false positive and false negative error rate. Over 33 hours of video footage were viewed for targeted validation. Video validation is an independent method of validating the counter system (i.e. the counter algorithm and the sensor pads) and allows for length measurements and visual species identification. Because the targeted validation focuses on fish that have been detected by the counter, it does not provide a random assessment of false negative errors. To do this, we also reviewed a subset of randomly selected video and recorded all false negatives, which we term 'random validation'. For each day of data, 18 randomly selected 10 min segments of video were reviewed and any false negatives were recorded. Over 34 hours of video footage were viewed for random validation. Fish observed on the video that were not registered by the counter were inserted into a new row in the validation document and measured for length as described above. We compared the corrected counter records (based on review of the graphical trace data) and video validation to determine the error rates. All true positives, false positives and false negatives were recorded and counter accuracy for up and down counts of large- and small-sized fish by each counter channel were calculated. The number of false negatives were expanded based on the proportion of video validated (combined validation hours from targeted and random validation, 67 hours) relative to the total amount of video that could be used to validate the counter (i.e. when both the counter and video were operational, 254 hours).

Raw Counter Measurement

-the counter measures the change in resistance as fish pass over the counter sensors

Counter Algorithm

-interprets the change in resistance and records the change as an up, down or event
-**up** count is a fish moving upstream, passing over all three electrodes
-**down** count is a fish moving downstream, passing over all three electrodes
-**event** may be partial or incomplete passage of fish over counter electrodes (in any direction) as a result of fish nosing up, falling back or sitting on electrodes. Events may also be caused by air entrainment or debris flow over the electrodes.

Step 1: Review Graphical Traces (Figure 3)

-validation of counter algorithm
-identify **false positives** (counter indicates a fish but one did not pass over the counter)
-identify **false negatives** (counter does not indicate a fish but graphical trace indicates a fish passed over the counter)
-all misclassified records are corrected

Step 2: Targeted Review of Video Footage

-target positive fish records evaluated in Step 1
-review times that should include the counter record
-focuses on quantifying false positives

Step 3: Random Validation of Video or Sonar Footage

-watch subsets of random video footage
-focuses on quantifying false negatives

Step 4: Calculate Accuracy

-quantify the number of true positives, false positives, false negatives
-calculate accuracy

Figure 6. Counter validation protocol.

Counter accuracy was then calculated from the number of false positives, false negatives and true positives:

Equation 1
$$A = \frac{TP}{TP + FP + FN}$$

where TP is the number of true positives, FP is the number of false positives and FN is the number of false negatives. Counter accuracy was broken down into PSS cutoffs to determine if there was a difference in accuracy for Bull Trout and small-bodied fish (Table 3). Counter accuracy was also broken down by counter channel (Table 4).

Some counter records were not video validated due to: (1) a lack of video footage, (2) fish lost in shadows when crossing at night, or (3) extreme high water events causing increased turbidity making the counter pads and fish difficult to see. In this case, the validated graphical trace records were assumed to be accurate and used in further analyses.

Using the validated counter data, we calculated the error rates by channel, species, and grouped by large (Bull Trout) and small (Mountain Whitefish) PSS.

3.4.2 Fish Length

Fish observed within the validated time frames were measured when possible. Each fish observed in the video footage was measured on-screen to aid in species identification and examine the relationship between PSS and fish size. Since the length of the counter pads was measured upon installation, it can be used along with the ratio of fish length to pad length measured during validation to determine the standard length of the fish, as follows:

Equation 2
$$FL_s = \frac{FL_m}{PL_m}\ x\ PL_s$$

where FL_s is the standard fish length, FL_m is the measured fish length on the video screen, PL_m is the measured distance between electrodes at the point where the fish crossed on the video screen, which may be different than the standard distance PL_s between the upper and lower electrodes (60 cm) due to distortion of the image from the wide-angle camera lenses.

Fish that were observed when visibility was high were identified to species. The main characteristics used to identify fish species were: length (R.L. & L. Environmental Services Ltd. 1995), colouration (e.g. white-leading edge of the pectoral fins for Bull Trout), and shape (e.g. narrow and small-bodied for Mountain Whitefish). We observed Bull Trout, Mountain Whitefish and Rainbow Trout when reviewing the video footage. Fish were classified as unknown when species could not be identified.

3.4.3 Migration Timing

Migration timing was assessed for Bull Trout and Mountain Whitefish from video validation data. To determine the diurnal migration patterns, fish movements over the counter were summarized by species and hour. The migration timing of adult Bull Trout over the spawning migration could not be determined due to inconsistencies in counter operations.

3.5 PIT Telemetry

A single PIT antenna (16 × 1 m) was constructed as 'pass-over' and anchored to the streambed so that fish would have to swim over the antenna to be detected. We selected this design over a 'pass-through' antenna due to the uncertainty of flow conditions at the site. Pass-over antennas lie flat on the streambed and as such are more robust and can withstand high flow events. The PIT antenna was connected to a remote tuner box (Oregon RFID, Portland, OR) and a multi reader (Oregon RFID) via twin-axial cable. We manually tuned and tested the PIT antenna to ensure optimal read range and tag-reading performance. PIT antennas were tested to determine the read range of 12 and 32 mm half duplex PIT tags (Oregon RFID). Range testing was performed by holding the two sizes of PIT tags at varying distances above the antenna which followed the streambed profile.

3.6 Solar Power and Battery Bank

We installed solar panels and a battery bank to power electronic equipment on site. The power system was designed to provide enough power to operate the equipment and provide 3-4 days of backup power if solar conditions were insufficient. Poor solar conditions (overcast) in August rendered the battery bank insufficient. We increased the storage capacity of the battery bank by adding two batteries on September 01.

4 Results

4.1 Environmental Conditions

Discharge measured in the Halfway River and the water depth measured at the Chowade River counter site were strongly correlated (when Halfway River discharge is log transformed: $r=0.98$; $p<0.001$) (Figure 7A). Average water depth at the counter site between July 29 and October 3 was 0.44 m (range: 0.3 m on October 03, 0.77 m on September 02 and 03) (Figure 7B).

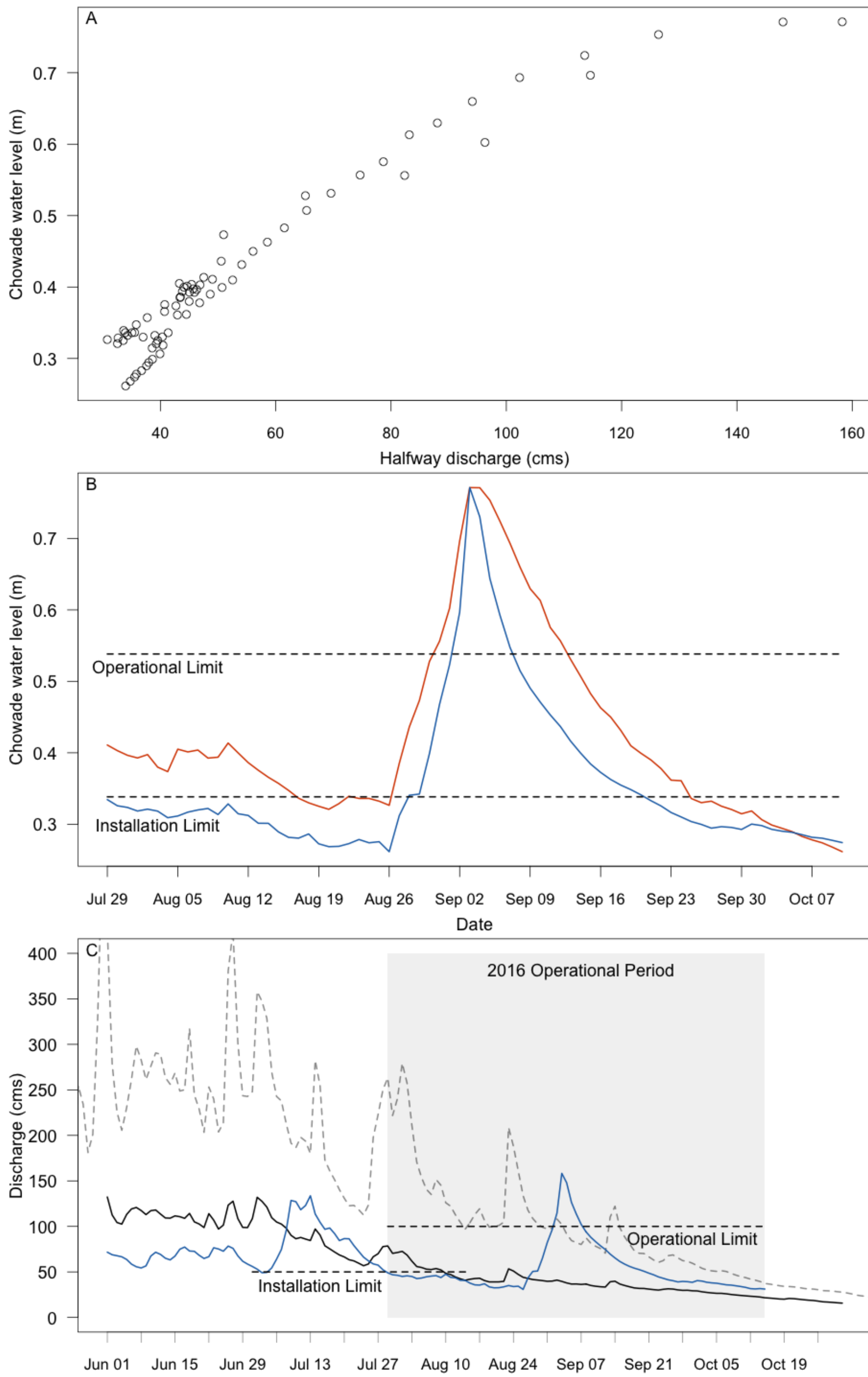

Figure 7. A) The relationship between the Halfway River discharge (Station 07FA003) and water depth at the Chowade River counter site from July 29 to October 09. B) Daily means of Halfway River discharge (blue line) and Chowade River water depth (red line). Dashed lines indicate the Halfway River discharge that corresponded to the highest flows that the counter can be safely installed and

effectively operated in 2016. The installation limit is based on the crew's ability to safely install the sensor pads in the water, and the operational limit is a conservative estimate based on the Halfway River discharge that corresponded to when the sensor pads were dislodged due to high flows. C) Comparison of historical (1977-2015) and 2016 discharges for the Halfway River between June 01 and October 31. Solid black line is for the historical daily mean, grey dashed line is the upper limit plus 2 SD, solid blue line is the 2016 daily mean discharge. Horizontal dashed black lines are the installation and operational limits for the counter. Grey shaded area shows the operational period in 2016.

The high-water event observed in the Chowade River in early September was also observed in the Halfway River (Figure 7A and B). The Halfway River discharge peaked on September 03 and 04 at 158 $m^3 s^{-1}$, which is 1.5 times greater than high discharge events (historical mean discharge plus 2 standard deviations (SD)) observed in the historical dataset (1977-2015) (Figure 7C).

The installation limit, defined as the upper water level that the counter could safely be installed in 2016, was assessed during the installation period. Specifically, IFR crew were unable to begin installation until water levels decreased to approximately 0.4 m, as measured at the counter site by the water level logger. A water depth of 0.4 m at the counter site corresponded to 50 $m^3 s^{-1}$ in the Halfway River (Figure 7B and C).

The operational limit, defined as the upper water level that the counter could be effectively operated in 2016, was assessed during the high-water event in early September when high flows washed out the Channel 1 sensor pad and disconnected Channel 2. The water depth at the counter site and corresponding discharge in the Halfway River was 0.58 m and 100 $m^3 s^{-1}$, respectively (Figure 7B and C).

4.2 Resistivity Counter

4.2.1 Species Identification and Length

Video footage for identifying fish species and measuring lengths was best during the day (Figure 8). Nighttime images were often less clear due to the glare produced by the infrared lights reflecting from the water's surface. For Channels 1, 2, and 3, the cameras were placed directly overhead of the sensor pad. Channel 4 was comprised of two or three connected sensor pads, and thus the camera was angled to try and capture the length of the sensor pad in the video footage, making it difficult to observe fish during the day and reduced glare made fish more visible during night (Figure 9). Turbidity also affected the visibility of fish. Fish were observable even under moderate turbidity (Figure 10). We were not able to observe fish passing over the sensor pad during the high-water event in September.

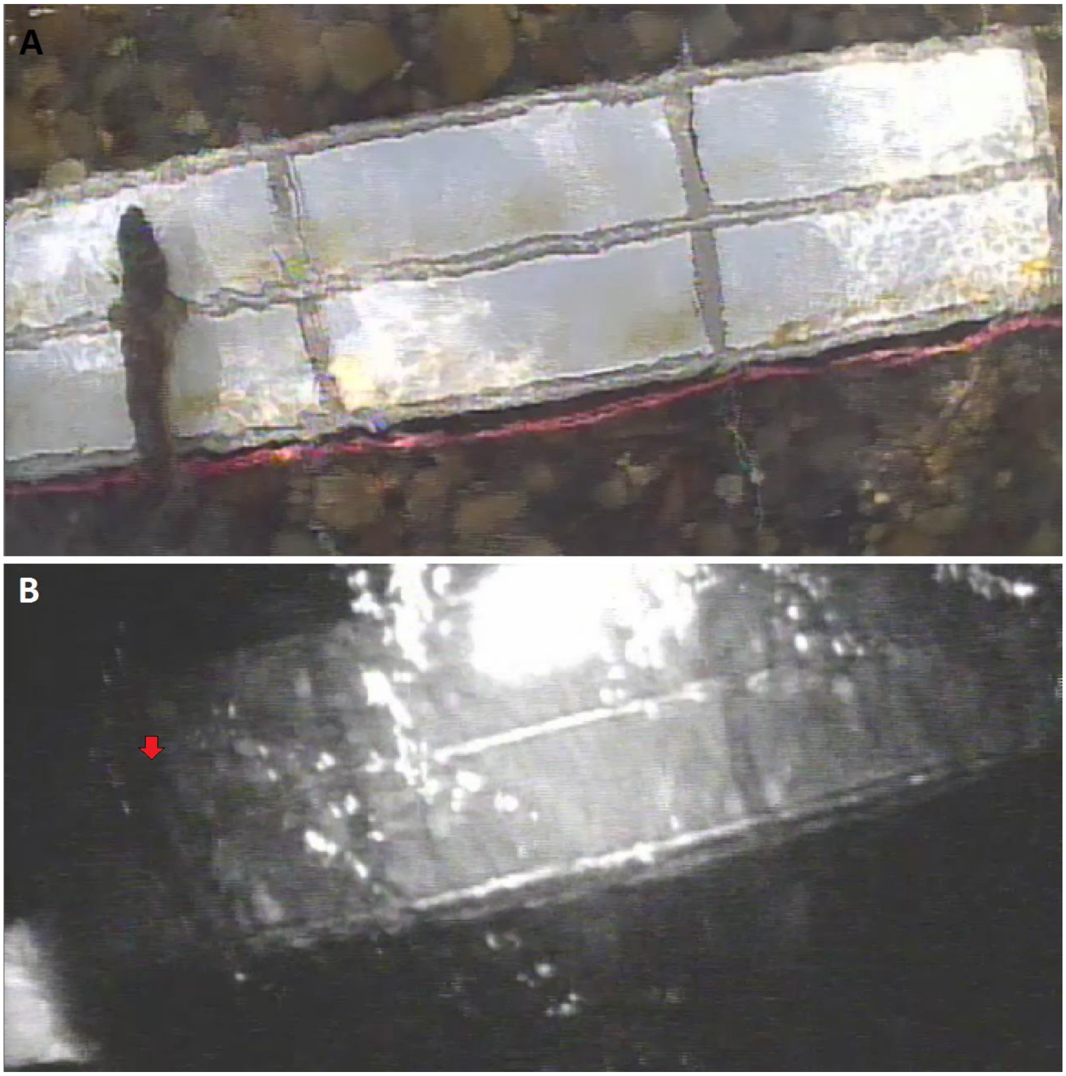

Figure 8. Comparison of video footage from A) day and B) night. Both fish were identified to be Bull Trout and swam over the same section of pad. The red arrow indicates the location of the Bull Trout in image B. For scale, both pads measure 60 cm between the outside edge of the upper and lower electrodes.

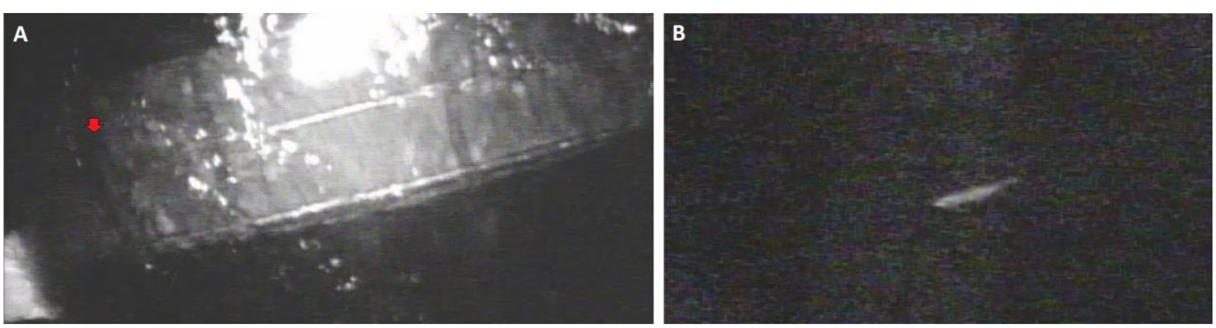

Figure 9. Comparison of images from A) the overhead camera on Channel 1 to B) the angled camera on Channel 4. The red arrow in image A shows where the Bull Trout is located.

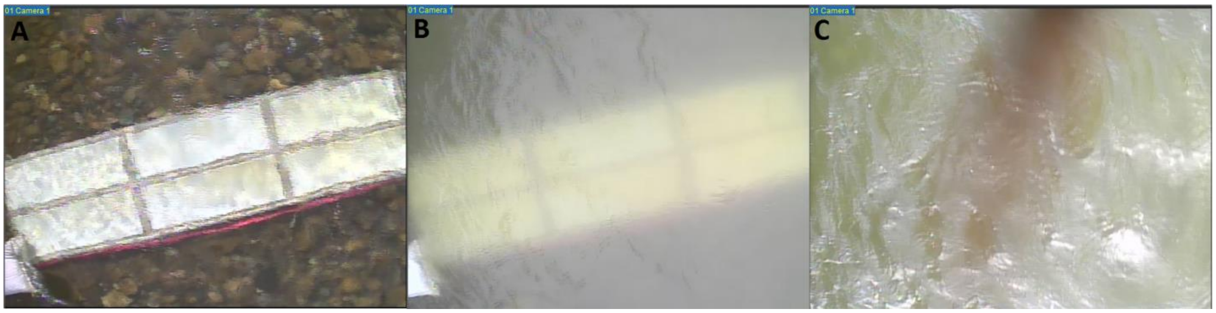

Figure 10. Comparison of turbidity levels observed between July 29 and October 3, 2016: A) low turbidity (normal conditions), B) moderate turbidity due to rain, C) high turbidity and high water. All images are of Channel 1.

Species were identified through video validation where possible. The two most abundant species observed were Bull Trout (n=59) (Figure 11A) and Mountain Whitefish (n>142) (Figure 11B). Fish could be reliably identified into three categories: 1) large Bull Trout (≥40 cm), 2) Mountain Whitefish, and 3) smaller salmonids (<40 cm), which could include Rainbow Trout, Arctic Grayling and Bull Trout. It was difficult to obtain an exact number of Mountain Whitefish because of their schooling behaviour (Figure 11B). Rainbow Trout and Arctic Grayling may have been present but were difficult to identify because there were few distinguishing characteristics that could be viewed by the overhead cameras (Figure 11C) and therefore all of these species were included in the small salmonid category. Bull Trout usually appeared large-bodied with the white-leading edges on the pectoral fins obvious when viewed from above. Mountain Whitefish appeared smaller-bodied with pointed noses and generally crossed the counter pads in large schools. A small portion of fish were not identified. Unidentified fish generally either crossed the pads at night in low visibility areas and could not be clearly observed for confident identification or the fish did not fit the characteristics of Bull Trout or Mountain Whitefish.

Fish lengths estimated from video footage were similar to lengths measured in the Chowade River in 1994 (Table 2). There was a small overlap between the size of Bull Trout and all other fish species in both 1994 and 2016.

Using the fish identified to species from the video, we examined the relationship between the standard length measured from the video and the PSS measured by the counter. We found a positive relationship between standard length and PSS. We determined a PSS cutoff of ≥84 distinguished between Bull Trout and Mountain Whitefish (Figure 12) and minimized the overlap between the two species' PSS size distributions (Figure 13).

Table 2. Comparison of lengths for Mountain Whitefish, Rainbow Trout, and Bull Trout measured in 2016 from video footage and in 1994 in the Chowade River. In 2016, standard lengths were estimated by measuring the length of each fish from screen captured images and comparing to a reference

length (i.e. the known length between electrodes). In 1994, fork lengths were measured for each fish captured at a full spanning fish fence (R.L. & L. Environmental Services Ltd. 1995).

	2016				1994			
Species	**N**	**Mean**	**Range**	**SD**	**N**	**Mean**	**Range**	**SD**
Mountain Whitefish	187	240	110-490	70	2681	274	149-431	43
Rainbow Trout	-	-	-	-	529	317	207-431	46
Arctic Grayling[A]	-	-	-	-	114	338	255-390	22
Bull Trout[B]	30	700	410-930	120	173	622	397-905	104
Small Salmonids < 40 cm (may include Rainbow Trout, Arctic Grayling, and Bull Trout)	2	330	300-360	40	-	-	-	-

[A]Arctic Grayling could not be confirmed in 2016.

[B]Only Bull Trout that could be identified as sexually mature were included in the sample.

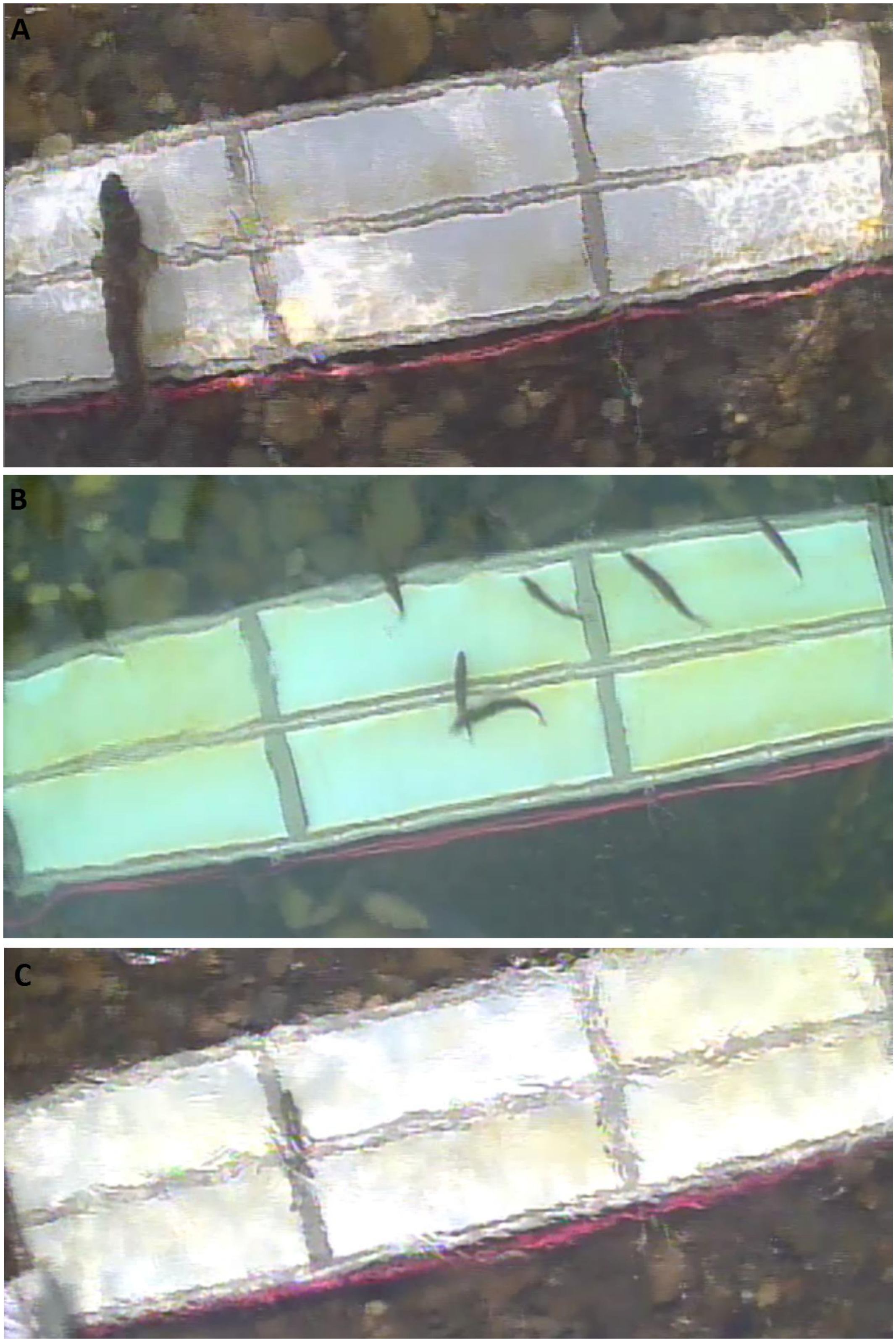

Figure 11. Example of species identification from video footage: A) large-bodied Bull Trout, B) small school of Mountain Whitefish, C) species unknown.

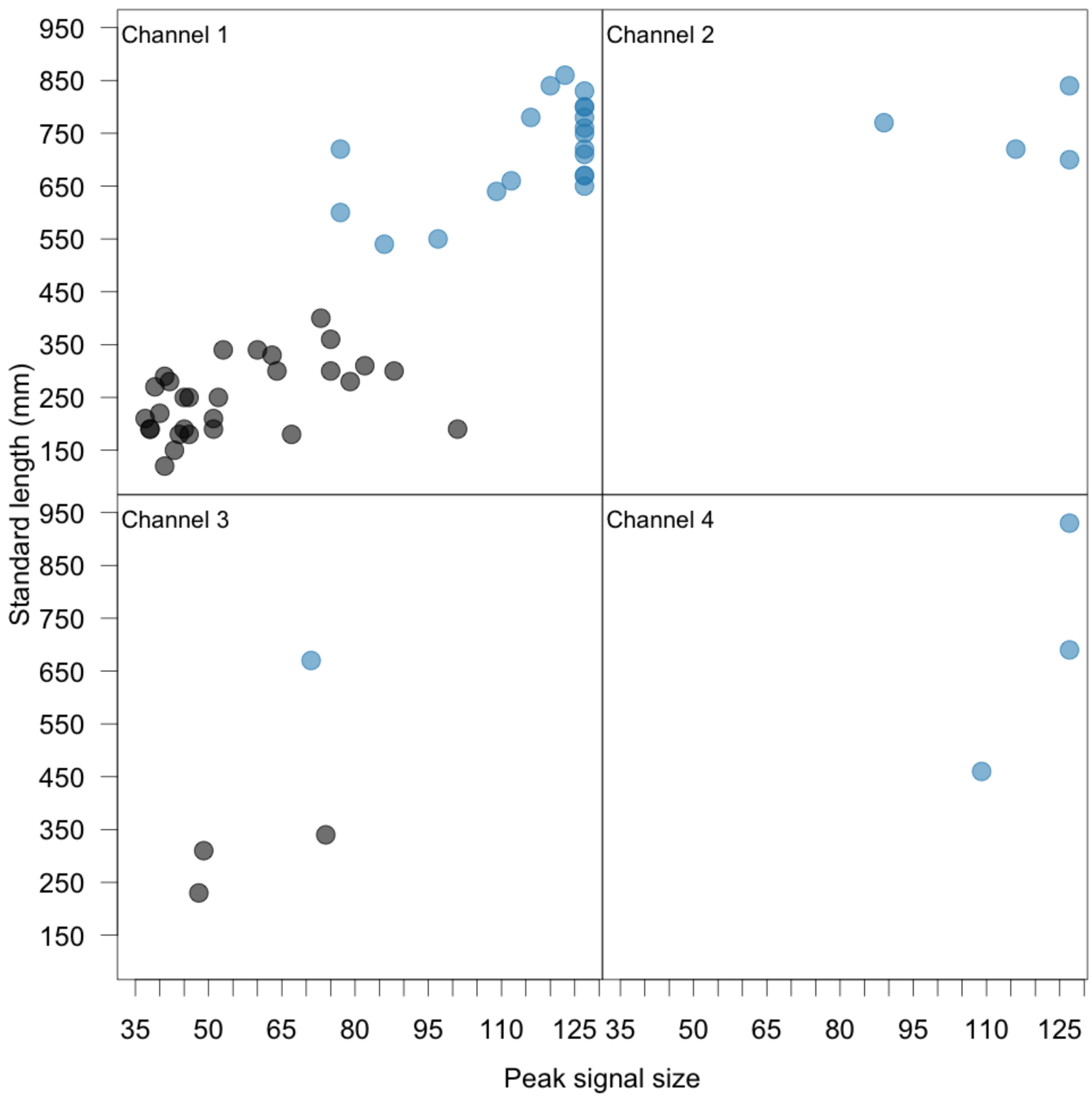

Figure 12. Peak signal size relationship to standard length (mm) of Bull Trout (blue) and Mountain Whitefish (grey) observed during video validation on each counter channel.

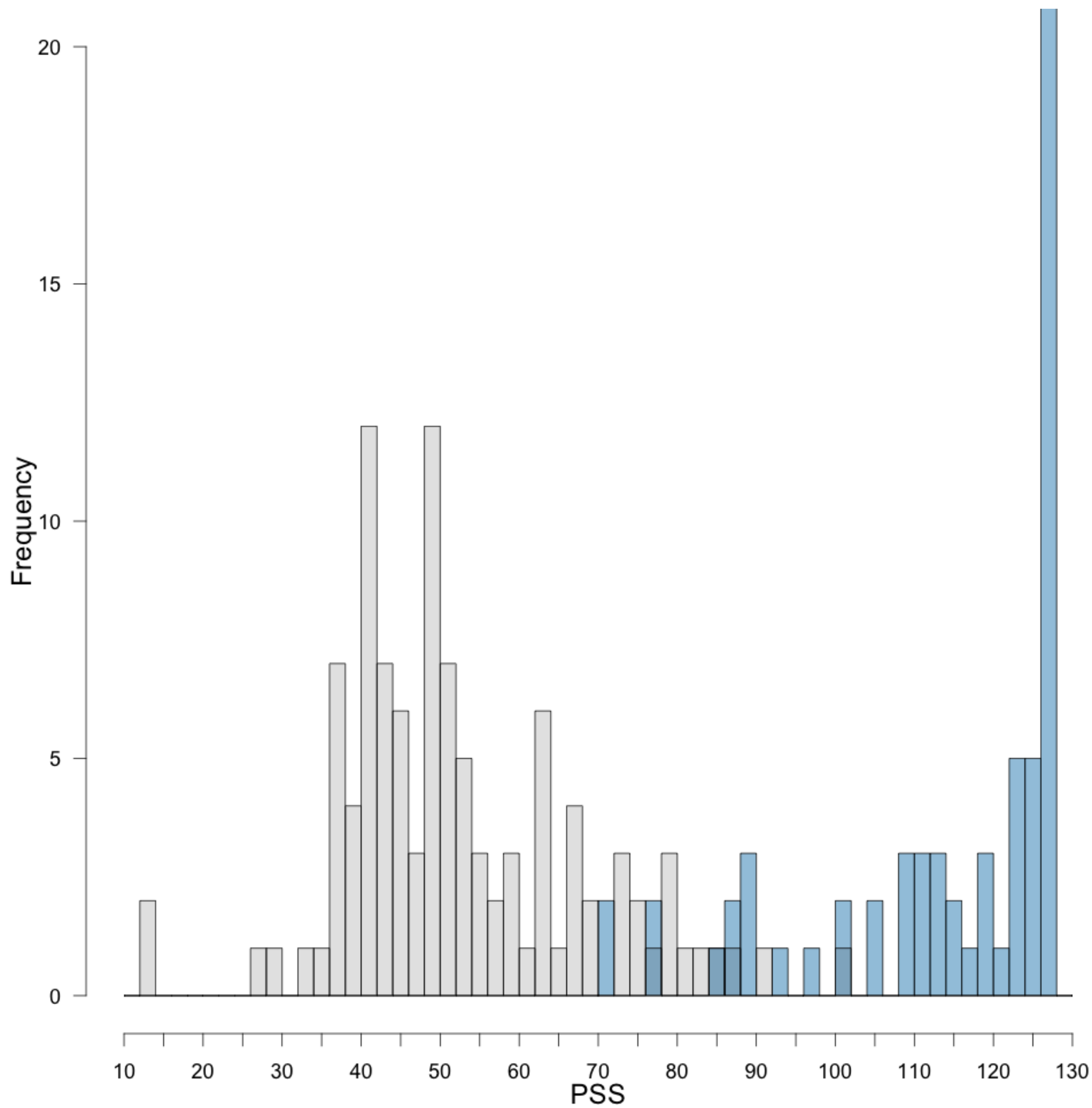

Figure 13. Frequency distribution of peak signal sizes for confirmed Bull Trout (blue) and Mountain Whitefish (grey) observed during video validation.

4.2.2 Migration Timing

The first Bull Trout detected by the counter was on July 29 at 23:23 (Pacific Daylight Time) moving upstream. The last observed Bull Trout moving upstream was on August 24 at 22:19. The first, and only, Bull Trout observed on video moving downstream occurred on August 8 at 23:29. Due to a high-water event on September 02, two counter pads were washed-out and disconnected. This left a large gap across the river channel where fish were able to pass over without being detected by counter sensor pads. The counter pads were disconnected until water depth decreased and crews could safely re-install them on

September 20, with the counter coming fully back online on September 24. This 22-day gap in data may have missed the peak of downstream migrating Bull Trout and the majority of kelting activity that would have occurred.

Most Bull Trout moved upstream between sunset and sunrise, where 50 individuals moved between 18:00 and 06:00 and only 9 individuals moved between 06:00 and 18:00. More Mountain Whitefish moved at night, where 96 individuals moved during the day and 126 moved at night (Figure 14).

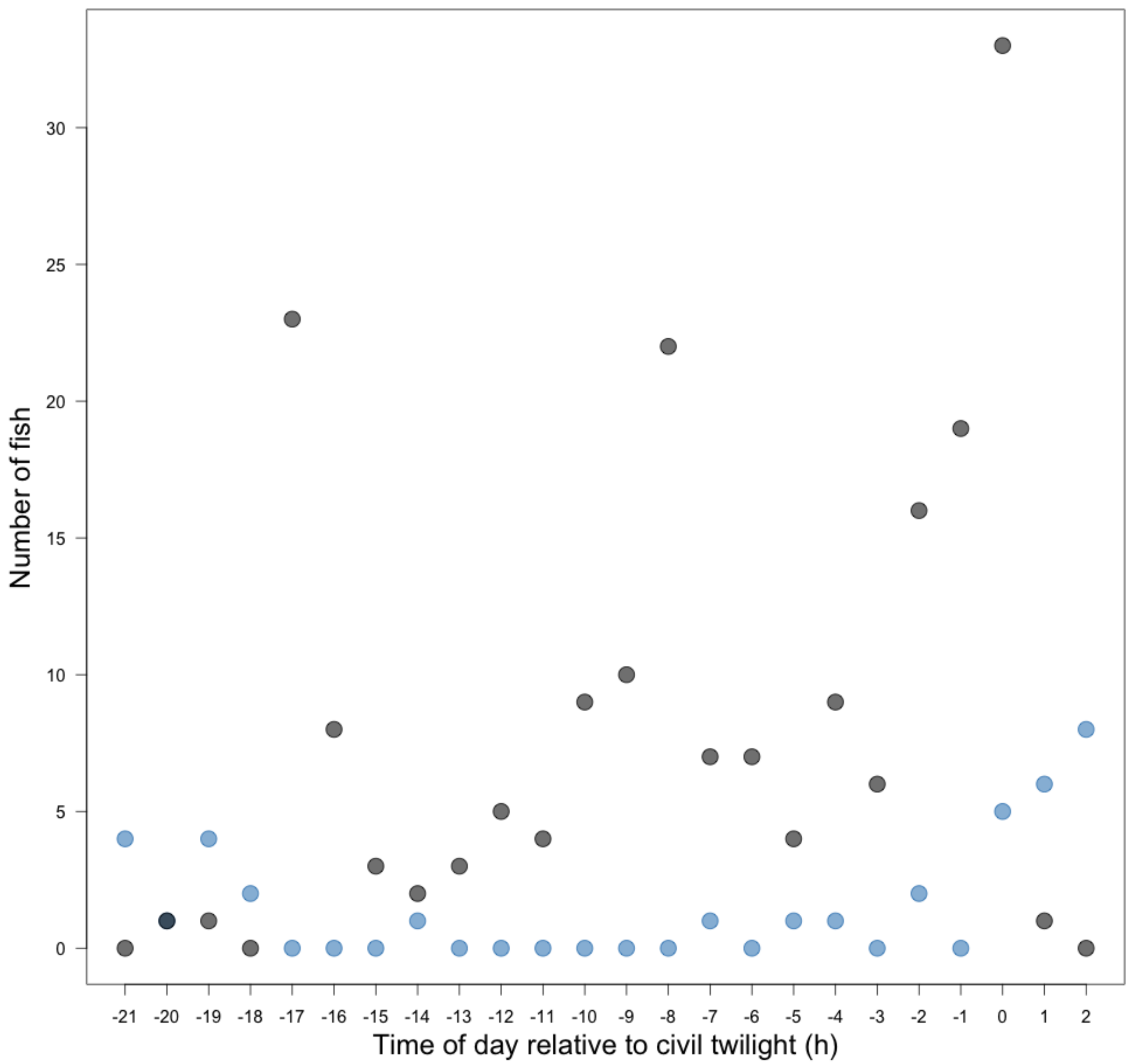

Figure 14. Number of Bull Trout (blue) and Mountain Whitefish (dark grey) observed from video during each hour over the counter pads from August 18 to October 3, 2016.

4.2.3 Counter Accuracy

The counter overestimated the number of Bull Trout moving upstream over the counter with an accuracy of 75% (Table 3). Down count accuracy was zero for Bull Trout because the one Bull Trout observed moving downstream on the video was not detected by the counter. However, the total number of down counts were likely low as only one Bull Trout was observed moving downstream on the video (Table 3). As expected, the accuracy for Mountain Whitefish was much lower, underestimating the number of Mountain Whitefish with an accuracy of 26% and 12% for up and down counts, respectively.

Table 3. Summary of counter accuracy data for Bull Trout and Mountain Whitefish. The graphical trace of each counter record is reviewed and assessed to be correctly classified or not. Counter accuracies are then calculated by dividing the true positives by the sum of the true positives, false positives and false negatives determined from video footage. False positives are expanded based on the proportion of video reviewed from the total available (i.e. when both counter and video were operational). Over or under estimates were determined by comparing the number of false positives and false negatives. More false positives than false negatives indicate the counter is providing an over estimate of the actual number of fish present. A higher number of false negatives than false positives indicates the counter is underestimating the number of fish in the system.

Species	Direction	True (+)	False (+)	False (-)	Accuracy (%)
Bull Trout	Up	32	7	3.8	75 (over est.)
Bull Trout	Down	0	3	15.1	0
Mountain Whitefish	Up	30	8	75.8	26 (under est.)
Mountain Whitefish	Down	31	4	231.1	12 (under est.)

Most Bull Trout (76%) moved upstream over Channel 1 (river right), which had an accuracy of 86% (Table 4). Other channels showed similar but lower accuracies, however sample sizes were low and estimates were likely uncertain. Three out of the four Bull Trout that moved downstream were observed on Channel 4 (river left) and none of them were detected by the counter.

Table 4. Summary of counter accuracy data for Bull Trout on each counter channel. The graphical trace of each counter record was reviewed and assessed to be correctly classified or not. Counter accuracies were then calculated by dividing the true positives by the sum of the true positives, false positives and false negatives determined from video footage.

Channel	Direction	True (+)	False (+)	False (-)	Accuracy (%)

Channel	Direction	True (+)	False (+)	False (-)	Accuracy (%)
1	Up	25	4	0	86 (over est.)
1	Down	0	0	3.8	0
2	Up	4	1	0	80 (over est.)
2	Down	0	0	0	0
3	Up	0	1	0	0
3	Down	0	3	0	0
4	Up	3	1	3.8	38
4	Down	0	0	11.3	0

4.3 PIT Telemetry

The detection range of the pass-over PIT antenna at the counter site was consistently 0.25 m for 12 mm tags and ranged between 0.60 and 0.75 m for 32 mm tags (Figure 15). Given the streambed profile and water depths during testing, the vertical coverage for the 12 mm tags was approximately 50% of the water column, while the coverage for the 32 mm tags exceeded 100% at all water depths (Figure 12).

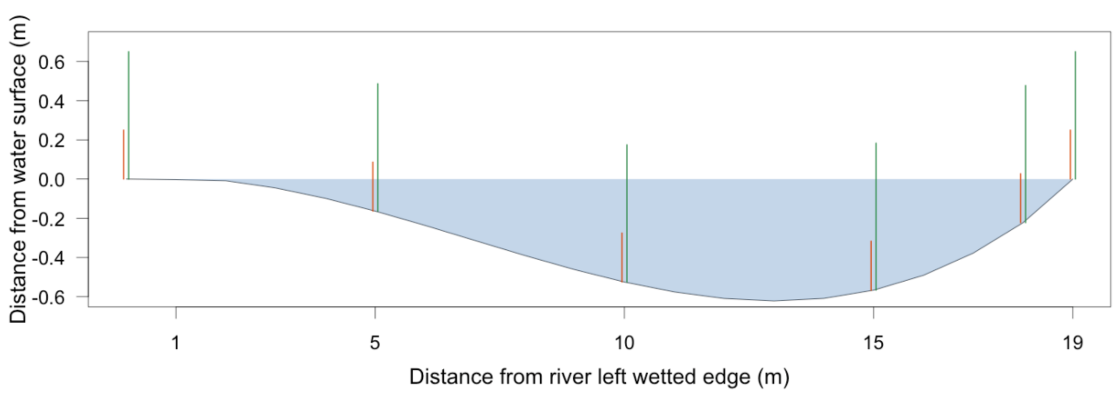

Figure 15. Detection ranges for 12 mm (red bars) and 32 mm (green bars) PIT tags along the streambed profile.

5 Discussion

We conducted a pilot study to determine the feasibility of operating a resistivity counter and PIT telemetry equipment in the Chowade River to enumerate Bull Trout. We used video validation for species identification and to determine fish size and counter accuracy for enumerating Bull Trout and Mountain Whitefish. The feasibility of the resistivity counter is discussed in terms of: 1) the accuracy of the counter; and 2) the ability to determine fish size and species from counter data. We also conducted range testing of the PIT antenna to determine its effectiveness for detecting two tag sizes. We provide a discussion of the feasibility of the equipment, system configuration and logistics.

5.1 Resistivity Counter

The main objective of the resistivity counter was to generate an abundance estimate for Bull Trout in the Chowade River, however no estimate was generated because of the large number of power outages during the spawning migration.

Up count accuracy for Bull Trout was high (75%), indicating that the feasibility of enumerating adult Bull Trout is high. This estimate is higher than other validated flat pad counter sensors with similar site and fish characteristics (Burnett et al. 2017). For example, the accuracy for flat pad counter sensors used to enumerate Coho Salmon in the Bridge River in 2016 was 70% for up counts (Burnett et al. 2017). However, the accuracy estimated for the Chowade River counter system does not include data from the high-water event in early September, and would likely be lower at higher water depths.

Down count accuracy was zero for the 4 fish observed during the video validation process. Down count accuracy is typically lower than up count accuracy as fish swim at variable heights above the counter sensor pads. In the Bridge River, the counter accuracy was 44% for Coho Salmon swimming downstream over the counter (Burnett et al. 2017). This estimate is based on the validation of 36 records in contrast to the 4 down counts validated in this study and likely provides a more likely estimate of down count accuracy. Although it is important to provide accurate estimates of counter accuracy, there were so few fish observed on the video migrating downstream and no evidence of fish recycling over the counter (repeatedly moving up and down over the counter). Thus, a low down count accuracy would have little impact when estimating population abundance.

Accurately detecting fish migrating downstream post spawning (kelts) could provide an alternative approach to estimating population abundance. Bull Trout are iteroparous and have been observed migrating out of the Chowade River after spawning beginning in the second week of September through to October (R.L. & L. Environmental Services Ltd. 1995). This is during a time when discharge is lower and more stable than during their upstream migration in July and August (Figure 7). Low accuracy detecting downstream migrating (<60%) Bull Trout may not be adequate for estimating population abundances because the uncertainty would be too high. The down count accuracy for the Chowade River counter remains unknown due to a small sample size and requires further validated observations of downstream moving fish.

The target species for enumeration was migratory adult Bull Trout. The counter sensors were designed with that in mind; the electrode spacing was set accordingly and should be maintained in the future to target Bull Trout. Many other species were observed moving in the Chowade River during the same period the counter was operated. For example, Mountain Whitefish, Rainbow Trout and Arctic Grayling were enumerated at a counting fence installed approximately 800 m downstream of the current resistivity counter site. While enumerating species other than Bull Trout would provide valuable information, other species are on average smaller than migratory adult Bull Trout. Broadening the size range by attempting to enumerate fish smaller than Bull Trout would mean reconfiguring the sensors and would reduce the counter accuracy for larger fish and skew the PSS to standard length relationship. In general, counter accuracy decreases when the size range of fish being targeted increases. To maintain a high accuracy for detecting Bull Trout, the counter system (gain and electrode spacing) was configured to target fish within the Bull Trout size range for sexually mature individuals found in the Chowade River (mean fork length: 622 mm; range: 414 – 830 mm) (R.L. & L. Environmental Services Ltd. 1995). This resulted in a lower estimated up count accuracy for Mountain Whitefish than for Bull Trout. Mountain Whitefish are typically much smaller, although there is some size overlap between smaller Bull Trout and larger Mountain Whitefish (R.L. & L. Environmental Services Ltd. 1995). This low accuracy for Mountain Whitefish was also due to their movement behaviour. Mountain Whitefish are much more abundant than Bull Trout; therefore reducing the detection of smaller and more abundant Mountain Whitefish and targeting larger Bull Trout will reduce validation effort and counting errors.

Bull Trout showed a strong diurnal pattern of movement over the sensor pads during nighttime hours. This information could help guide future validation efforts and reduce power consumption by decreasing the amount of video recorded during daylight hours. The low numbers of Bull Trout moving over the sensor pads during the day suggests that reducing or eliminating recording video during the day would have little impact on the number of Bull Trout available to be validated. Efforts could be made to improve nighttime validation and species identification. This approach should be considered with caution since this is based on a single study year with sporadic data collection.

Species identification and sizing were achieved through video validation. The main distinguishing features used to identify species were length, shape and schooling behaviour. For example, Bull Trout are large and moved over the counter one at a time, whereas Mountain Whitefish were small and swam in schools. It is likely that Rainbow Trout and Arctic Grayling were misidentified as Bull Trout due to overlapping sizes (R.L. & L. Environmental Services Ltd. 1995) and because there was no way to differentiate among these species using video footage when fish were <500 mm. Two Bull Trout <500 mm were identified, two Rainbow Trout were identified (both <400 mm) and the remaining fish were confidently identified as Mountain Whitefish due to schooling behaviour and were all <400 mm, except for one individual that was estimated to be 490 mm. Size distributions estimated through video validation are consistent to those observed during the 1994 operation of a full spanning fish fence (R.L. & L. Environmental Services Ltd. 1995).

Resistivity counters can also provide information on fish size. The greatest change in resistance measured by the counter as fish move over the sensor pads is recorded and is termed the peak signal size (PSS); this can be used as a proxy for fish size. Fish length measured from the video footage was correlated with PSS recorded by the counter and can be used to determine size cutoffs for species identification. For example, there was minimal overlap in length between the smallest mature Bull Trout and the largest Mountain

Whitefish. For Rainbow Trout and Arctic Grayling, there was little to no overlap in length with mature Bull Trout. This suggests a size cutoff of 500 mm could be used to accurately (over 95% of fish) distinguish between mature Bull Trout and all other salmonid species. The corresponding PSS value of 84 can be applied to all invalidated counter records and a species can be confidently assigned. While it is feasible to use PSS to estimate a size cutoff and distinguish between species, fish length cannot be estimated from PSS using the current data. Many larger Bull Trout (>650 mm) produced the maximum PSS value of 127 (Figure 12), which lead to a truncated PSS distribution, preventing estimates of lengths for fish >650 mm. Adjustments to the counter system could provide greater resolution for larger fish (i.e. >650 mm), which would increase the feasibility of using PSS as an index of fish size. Another benefit of these changes would be reducing the number of small fish detected. Future PIT tagging of Bull Trout, Rainbow Trout and Arctic Grayling as part of Mon-1b Task 2c (Site C Reservoir Tributaries Fish Population Indexing Survey) will provide additional information about species identification as tagged fish pass over the resistivity counter and PIT arrays.

High water levels in the Chowade River can impede installation and operations. To aid in planning and operations, it would be advantageous to know the discharge levels in the Chowade River in real-time, however there is no real-time water level gauge. We explored using the Water Survey Canada real-time gauge on the Halfway River as a proxy for discharge conditions in the Chowade River. We observed a strong correlation between Halfway River discharge and the water depth at the Chowade River counter site, which suggests that the real-time discharge data from the Halfway River hydrometric station will be a useful proxy for water depth in the Chowade River. The real-time station provides uncorrected data up to 6 hours prior to the current time. This can be used to determine if water depth at the counter site is low enough to install, fix or remove equipment in the water. It can also be used to determine if equipment is still operating and whether the counter might need repair. Such information is important due to the remoteness of the counter site and thus the time required to access the site.

Unseasonably high water levels in the Chowade River washed out the sensor pads for Channels 1 and 2 in early September and delayed repairs. This high water corresponded to a peak discharge in the Halfway River of over 150 cms (Figure 7). Although the outages caused by this high water event were significant, it is unlikely that other enumeration methods such as a full spanning fish fence or visual surveys would be feasible due to high debris flow and low water clarity. High discharge and debris flow would have made the counting fence susceptible to overturning and damage. Low water clarity would have made for poor conditions for visual surveys and high water would have prevented the ground survey portion of the visual surveys (Braun et al. *In Review*).

The power system used to operate the counter and other electronics experienced outages throughout the season. The battery bank on its own was sufficient to operate for approximately 3-4 days without recharging, and under normal solar conditions, could be recharged daily. This design worked well for the first two weeks of August, but failed when an unseasonal weather pattern of precipitation and overcast weather resulted in a high number of days (>3 days) where the battery bank was not charged. This resulted in a power deficit that could not be met by charging rates. Two additional batteries were added to increase storage capacity. While this extended the length of time the battery bank could power the counter, it did not fully compensate for the poor solar conditions. The atypical solar conditions in 2016 provided valuable information about the minimum power requirements needed to operate equipment during August and September.

5.2 PIT Telemetry

The PIT antenna was only operated during the installation period and for range testing due to limited power supply. Range testing showed that detection ranges were similar to the manufacturers' specification (http://support.oregonrfid.com/support/solutions/articles/5000006214-expected-hdx-read-range) and that the feasibility of detecting 12 and 32 mm PIT tags is high. Detection range could be improved by altering the antenna shape. For the 32 mm tags, detection range exceeded water depths, which means that even during high water events, all tagged fish would be within the detection range. As expected, the detection range of the 12 mm tags was much less, but still covered 50% of the water column. Although the detection range could be increased, it is unlikely that the detection range of 12 mm tags can cover the extent of the water column. To account for the lower detection range, detection probability should be estimated under a range of water depths. Detection efficiency will also be influenced by where fish swim in the water column. For example, upstream migrating fish tend to swim near the bottom where drag is lowest, whereas downstream migrating fish tend to swim closer to the surface. This will likely result in lower detection efficiencies for downstream migrating adults post-spawn and juveniles.

5.3 Logistical Considerations

Transporting equipment from the road access point to the selected counter site was one of the more challenging components of the field work. The distance, amount of equipment and terrain made it difficult to safely carry gear to the site. This was also made challenging by the fact that the equipment needed to be transported across river crossings. Given the amount of effort required for the installation, we had planned to remove the equipment using a helicopter longline system but early snowfall and low cloud cover prevented us from using this method. The early snowfall allowed us to use a sled to transport the equipment during the removal, but may not be an option in future years.

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