Bessette Creek Coho Enumeration Using a Resistivity Counter (Year 1 of 3)

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1.0 INTRODUCTION

1.1 Project Background

This project addresses Interior Fraser Coho (IFC) of the South Thompson conservation unit (CU), which is one of 5 IFC CUs. The Interior Fraser River Management Unit (IFCMU) consists of a large number of small populations that each contributes a small proportion of spawners to the Management Unit as a whole. The Bessette Creek watershed, including Harris, Duteau and Creighton creeks provides spawning and rearing habitat for a sub-population of the Middle Shuswap River and averaged the 9th largest natural Coho escapement of all IFC between 1998 and 2015. With 1076 spawners it comprises 18% of the South Thompson CU and 4% of the IFCMU on average.

From 2013-2015 escapement of most IFC were estimated using visual methods (streamwalks or aerial). A subset of the systems were enumerated using resistivity counters, resulting in higher quality escapement estimates, however none were used on the sub-population which includes Bessette Creek Coho. Escapements in this system are historically estimated using streamwalks and the Area-Under-the-Curve (AUC) method.

Migrations of returning Coho are multimodal and often extended over a long period. Their propensity to move during high water events, to occupy systems intermittently and to behave cryptically/defensively once at their spawning grounds can make visual enumerations difficult. As a result, it is a challenge to accurately enumerate Coho returns using ground surveys in complex habitat such as the Bessette Watershed. In this system, visual counting conditions are frequently poor due to high flows, turbid and dark water conditions (tannins), likely leading to an underestimate of the spawning escapement. Resistivity counters are effective when enumerating fish in these conditions, because they are able to remain in place during high water events if properly situated can see past turbid conditions and can remain running for extended periods of time. A resistivity counter was operated on Bessette Creek during the 2017 Coho escapement season to assess whether it could yield more accurate escapement estimates.

1.2 Project Objectives

The goal of this project is to determine the feasibility of replacing the existing stream-walk spawner estimates for Coho Salmon with automated counts via resistivity counter. To do so, a resistivity counter will be operated concurrently with stream-walk surveys during Coho spawning season over three years. This data will assist in evaluating the status of these populations, measuring their productivity patterns, application of escapement goals and evaluating the recovery potential of the populations.

2.0 METHODS

2.1 Location

Bessette Creek is a tributary of the Middle Shuswap River, with its mouth 12 km NE of the village of Lumby, BC. The Bessette watershed is 795 km^2 and includes three main tributaries: Harris, Duteau and Creighton creeks. In addition to Coho Salmon, the watershed provides habitat for other key fish species, such as Chinook and Kokanee salmon and Rainbow Trout.

The resistivity counter was installed in Bessette Creek at a location 6 km NE of Lumby, BC (Figure 1) from September 26 to November 30, 2017. At this site the stream is approximately 12 m wide with a mean cross section depth of 0.3 m (Figure 2). This location is situated downstream of the majority of Coho spawning areas, ensuring that most of the spawners migrating into the system would be enumerated. In 2015 the counter was successfully operated on a trial basis at this location. At the site, the stream consists of a relatively wide and shallow glide with a uniform channel suitable for counter installation.

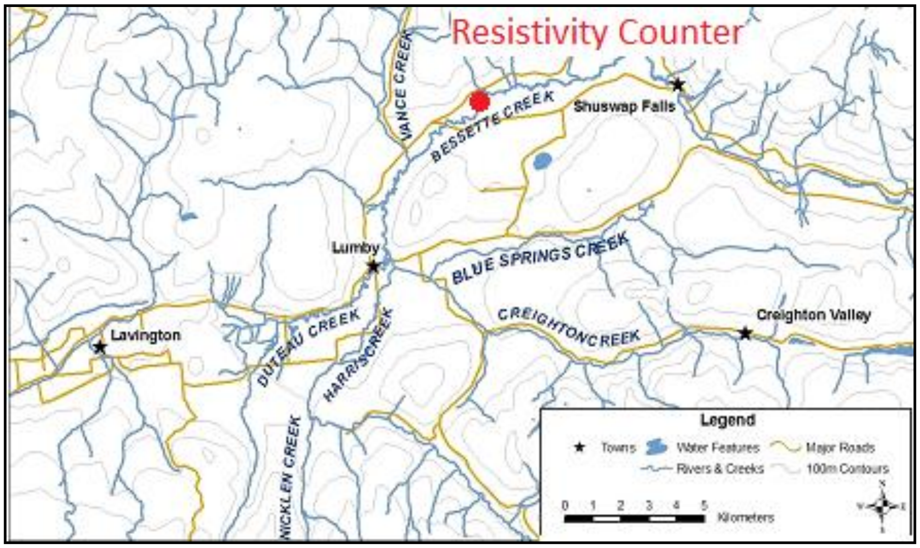

Figure 1: Location of resistivity counter on Bessette Creek.

Figure 2: Resistivity counter installed in Bessette Creek, BC.

2.2 Resistivity Counter

The Logie 2100C resistivity counter consists of panels (2.44 m by 0.635 m) which each house three electrodes - negative, ground and positive. The electrodes are spaced 0.3 m apart and run the length of each panel (Figure 3). The bulk resistance of the water column above is continuously measured. When an object passes over the electrodes a change in resistance is detected, and if spanning two electrodes simultaneously, an event is recorded. Each record includes the date, time, direction of movement, channel number, and peak signal size (PSS). In addition to the record, trace data (Figure 4) is also stored for each event and can be graphically visualized to help verify counter events. The counter's internal algorithm was developed to discern a fish passage event (compared to mammals or vegetation) by monitoring the trace data and a change in electrical resistance which exceeds a threshold. When categorized as a fish the corresponding event is recorded as an up (U) or down (D) fish movement, otherwise it is assigned an "E" for unclassified event. Movement direction is determined by the order in which the fish passes the negative and positive electrodes.

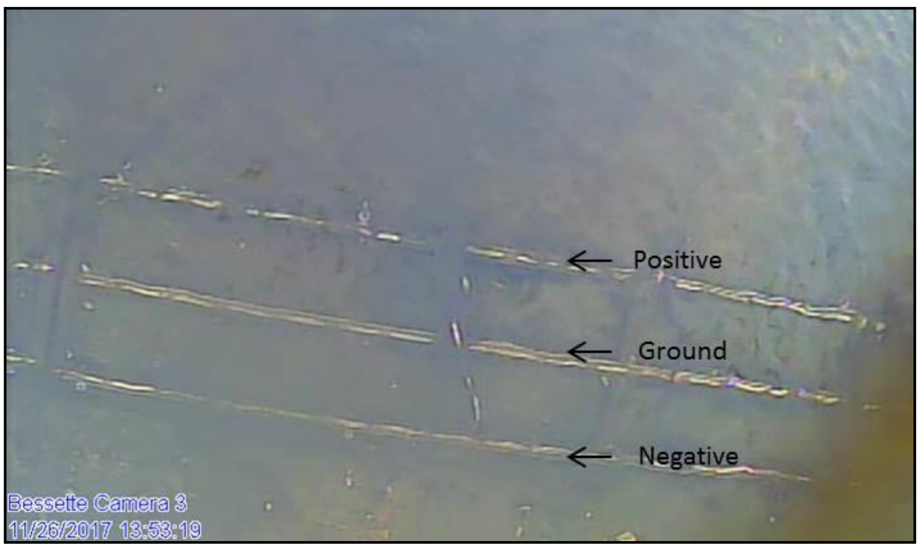

Figure 3: Video screenshot of upstream migrating Coho salmon over resistivity panel in Bessette Creek, BC.

Four resistivity panels were installed in a series to span approximately 10 m of the stream at the site. Channel 1 was on the near (right) bank and channel 4 on the far (left) bank, with the remaining stream margins blocked for fish passage using fencing (Figure 2). A video camera with infrared lighting was mounted above each panel and recorded the panels continuously. Lights were installed to illuminate the stream and reduce the glare of the infrared lights in the video footage. Video was used to validate the effectiveness of the resistivity counter.

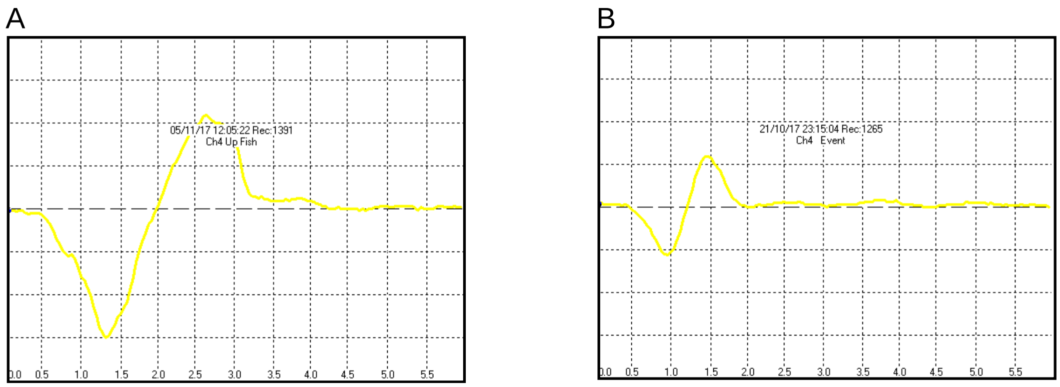

Figure 4: Trace data for resistivity counter at Bessette Creek, BC: A) correct counter assignment of a Coho Salmon upstream movement, and B) incorrect counter assignment of a Coho Salmon upstream movement as unclassified event.

2.3 Analysis

Trace data was visually assessed for correct counter assignment of each event. When trace data indicated the event was incorrectly assigned as an unclassified event (Figure 4B) or as a fish movement a note was made in the event's record. To confirm the validity of each misidentified event targeted video validation commenced by reviewing video camera footage for the presence or absence of a fish passage at the time of the event. Data recorded included channel number, video start and end time, video duration, and if a Coho was present the direction of movement and the onscreen length of the fish and width of the resistivity panel. This exercise was extended to verify all events categorized as fish movements.

To minimize error associated with analysis, 10-15% of all video during Coho Salmon migration was reviewed (Ramos-Espinoza 2017 pers. comm.). Power outages resulted in no video footage from October 8 - 11, 14 - 18 and 31 - November 1. Total video footage was calculated from October 19 until the removal of the counter on November 30 and random 10-15 min video clips were reviewed for all panels at 2-8X speed until the threshold was reached. When previously undetected Coho were identified during random validation identical data fields to previous Coho passages were recorded.

To gain an estimate of the size of migrating Coho Salmon in the Bessette Creek watershed fish length (L) was calculated from onscreen measurements as,

$$L = l * W/w$$

using the onscreen fish length (l) and the known (W) and measured onscreen (w) panel widths. Fish length was compared with PSS to determine if the PSS value can be used to identify fish species. This was conducted by calculating the strength of the regression relationship (R^2) between the two.

Counter accuracy (q) for up and downstream movements of each panel were calculated to determine how effective the resistivity counter was at detecting Coho movements as,

q = (Fc/Fv) * 100

using the number of fish detected from the resistivity counter (*Fc*) and the number of fish detected from the video in addition to the extrapolated value following random video validation (*Fv*).

Coho escapement (*E*) could now be estimated as,

$E = (C_{up}/q_{up}) – (C_{down}/q_{down})$

where *C* is the number of Coho up or down counter observed by the resistivity counter and *q* is the accuracy for the up and down counts.

2.4 Operation

The resistivity counter and video cameras were operational in Bessette Creek for 65 days, with the exception of approximately 14.5 days where video footage was not recorded due to power outages. Truncating the focus of video validation to begin on October 19 (when video footage resumed) resulted in 38.41 days (55,308.85 min) of video per panel and following targeted and random video validation, 10.06% of the video was reviewed.

Table 1: Total amount of video footage at Bessette Creek and periods when video recording of resistivity panels was not available because of power outages.

	Dates			
	From	To	Days	Mins
Overall	October 15	November 30	38.41	55309
Video Down	October 15	October 19	6.34	9135
	October 29	November 1	3.33	4796

Analysis was conducted using video data beginning on October 19 and using counter data beginning on October 15. Although no video was available from October 14 – 18, Coho Salmon occurrence is possible during this period in Bessette Creek based on previous years' escapement surveys.

3.0 RESULTS

Analysis was conducted on data between October 15 and November 30 to align with the period of Coho Salmon migration in Bessette Creek. The first video validated Coho Salmon detection was on October 21 and the last Chinook Salmon video validated detection was on October 19, meaning that counter detections between October 15 and 19 which does not have corresponding video footage could have been Coho or Chinook salmon.

The counter classified 251 total fish movements, 59 of these occurring when no video was available (Table 2). This count includes an estimated 195 net upstream migrating Coho and was achieved following the removal of 47 false positives from the counter data which were visually verified as non-Coho movements (Whitefish, otter and Chinook Salmon) or when no fish was visually detected while visibility was high (Table 3).

Table 2: Summary of resistivity counter events in Bessette Creek during the typical Coho migration period (October 15 - November 30) and while the video system was down. Counter logged as fish movement upstream (U) and downstream (D) and unclassifiable events (E) with the Net movements representing U-D.

	Dates	Counter Events			
		D	U	Total	Net
Video Down	October 15 – 19	2	45	47	43
	October 29 – November 1	5	7	12	2
Overall		28	223	251	195

Table 3: Counter detection movements verified as non-Coho events from video validation.

	D	U	Total
No fish observed	5	23	28
Whitefish	2	13	15
Otter	1	2	3
Chinook	0	1	1
Total	8	39	47

Video validation identified a total of 168 Coho movements, 146 Coho corresponding with counter detections. The remaining 22 of these Coho movements were observed during video validation and were not detected by the counter (False negatives). To estimate the total number of Coho missed by the counter, the false negatives were extrapolated across all unwatched video, resulting in an estimated 219 undetected Coho (Table 4). The number of Coho observed through video validation was 105 less than detected by the counter - 59 which corresponded with no video and 46 which had video that was unverifiable because of various visual obstructions (ice, light glare on water surface, spider on lens, heavy precipitation, etc.).

Table 4: The extrapolation of Coho Salmon in Bessette Creek which were undetected by the resistivity counter, including the number of fish which were confirmed only by visual detection and the total video watched.

	Video Counts		Video			Extrapolated		
Channel	D	U	Watched	Total	%	D	U	Total
1	0	0	5489.00	55308.85	9.92	0	0	0
2	0	1	5516.52	55308.85	9.97	0	10	10
3	1	1	5605.72	55308.85	10.14	10	10	20
4	7	12	5645.82	55308.85	10.21	69	118	187
Total	8	14	22257.05	221235.4	10.06	79	138	217

The overall counter accuracy was lower than anticipated (67%; Table 5), and was largely impacted by the high number of extrapolated fish (219) that were missed by the counter. The accuracy was substantially lower for downstream movements of fish, and also lowest for panel 4. Most Coho detections occurred on panel 4, which was the deepest section of the creek, adjacent to the left bank.

Table 5: Summary for the number of Coho Salmon observed during video validation, those detected by the counter and the panel accuracy by movement direction (*q*) in Bessette Creek, BC. Counter

accuracy was determined by dividing the number of Coho detected via resistivity counter by the sum of video validated Coho and the extrapolated number of Coho (Table 4) across all video.

	No. of Coho detected						Accuracy		
	Counter			Video					
Channel	D	U	Total	D	U	Total	D	U	Total
1	2	8	10	1	1	2	2.00	8.00	5.00
2	1	9	10	0	2	2	1.00	2.00	3.00
3	7	70	77	1	28	29	0.64	1.84	1.57
4	18	136	154	13	100	113	0.22	0.63	0.51
Total	28	223	251	15	131	146	0.30	0.83	0.69

Up and downstream counter estimates of Coho salmon totaled 223 and 28 respectively, but when corrected for counter accuracy the estimate increase to 269 and 94 respectively. Based on the corrected counter data, the escapement estimate (net upstream movements) for Coho Salmon in Bessette Creek is 175 fish.

Nearly all upstream movements occurred between sunset and sunrise (Figure 5). This supports the notion that Coho may be hard to detect during the daytime escapement survey walks, possibly leading to incorrectly low escapement estimates.

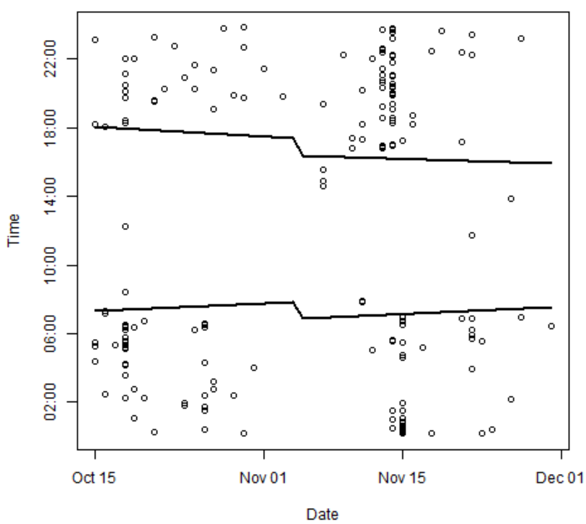

Figure 5: Time of day that upstream migrating Coho Salmon were detected by resistivity counter in Bessette Creek, BC, 2017. Daily sunrise and sunset indicated by black horizontal lines.

The overall return of Coho peaked in mid-November, with >60% returning from November 11 – 16, while a large pulse of fish was detected on October 18 by the counter (**Error! Reference source not found.**). The average length of the measured Coho Salmon was 62.88 ± 4.85 cm and the relationship between fish length and peak signal size was very weak, with a R^2 <0.01 (Figure 7).

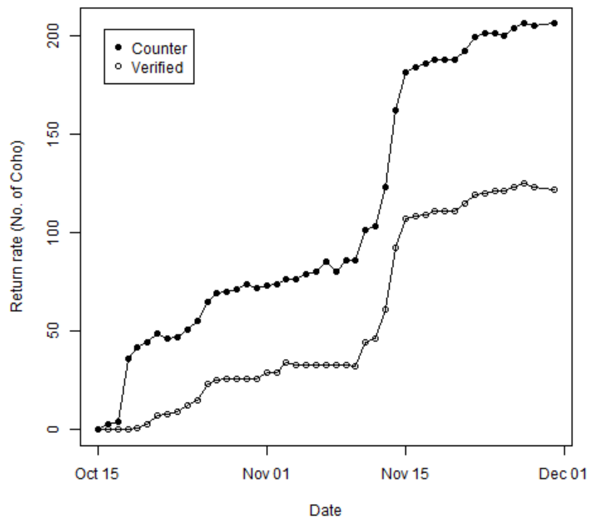

Figure 6: Coho returns at Bessette Creek, BC, as daily upstream subtract downstream Coho passages, estimated by resistivity counter (Counter) and those detections which were verified through video validation (Verified).

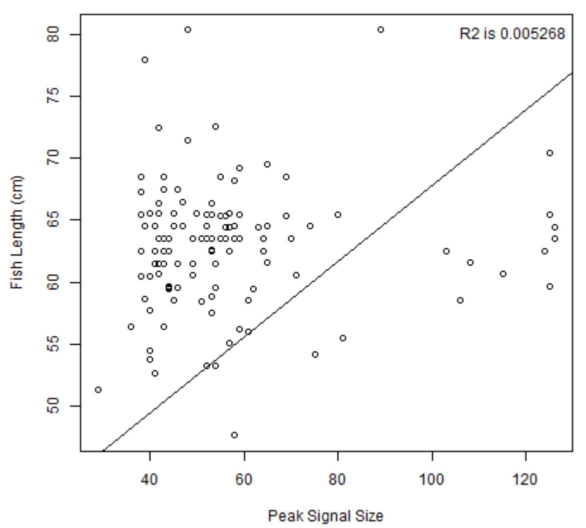

Figure 7: Regression analysis of peak signal size and fish length.

4.0 DISCUSSION AND RECOMMENDATIONS

The electronic counter was able to detect a large number of fish movements, with a relatively clean dataset, free of an excessive number of false positives or events. Losing video during mid-October was unfortunate as Coho and Chinook presence in Bessette Creek overlaps, and species identification necessitates video. With video resuming on

October 19, the last verified Chinook counter movement was on October 19 and the first Coho on October 21. From October 14 – 18 there were 47 fish movements registered by the counter, 32 on October 18 alone. Water levels in Bessette Creek began to increase on October 17, so many of these 32 detections, most which occurred over night, could be Coho.

Counter accuracy was lower than anticipated and was largely influenced by the high extrapolation value for undetected Coho. Only three Coho in panels 1, 2 and 3 were visually detected in the video and undetected by the counter. Low counts, such as these single detection events indicate rarity and extrapolation can inflate their estimated occurrence beyond what is reasonable. When removing these detections, the overall counter accuracy increases by 7%, up to a reasonable 76%.

Escapement estimates were made using two survey types, the resistivity counter and stream walks. Stream walks and AUC calculation produced an estimated escapement of 324 Coho for the Bessette Creek watershed, which is nearly double that of the resistivity counter, 175. The escapement estimate for the counter data incorporates a correction factor (counter accuracy) which accounts for the Coho which the counter did not detect (extrapolated value). The extrapolated value was high, indicating that the counter failed to detected 216 Coho movements – nearly as many as was detected by the counter (251). The extrapolation value was achieved by watching approximately 10% of all the video footage, and it is unknown if this estimate would change if more random video segments were reviewed.

The accuracy of downstream moving fish was very low overall and merely 22% in channel 4. Similar to the overall accuracy, this was largely affected by the high extrapolation value, where in this case 69 downstream moving Coho were deduced for channel 4. It is interesting to note that the proportion of downstream moving Coho is substantially lower in the detections by counter and video, 11 and 14% respectively, compared with the extrapolation, 37%. Further, if we assume downstream passage is proportional across all measures and correctly classified at 14% of all movements, adjusting the extrapolation value to match these would increase the overall accuracy to 82% and the escapement estimate increases to 231 Coho. It is therefore a certainty that the estimate and count of downstream moving Coho needs to be addressed in order to achieve accurate escapement estimates. This also suggests that the value obtained using AUC calculations from streamwalk surveys is very likely an overestimate of the actual escapement.

There was essentially no relationship between peak signal size (PSS) and fish length. A strong relationship between these variables would allow for potential species identification through data interpretation alone, therefore eliminating the need to verify through video validation. Stream conditions at the counter site may have influenced PSS for each Coho passage. In an ideal situation the depth of water would be only sufficient for fish passage. This would eliminate vertical stratification of fish while swimming over the electrodes. When water depth is enough that fish pass at different distances from the electrodes (water depths), the bulk resistance can vary and therefore the PSS will vary with lower values for fish further from the electrodes (McDubbing et al. 2000). If the same fish passed over the electrodes at different depths, each passage would result in a unique PSS value.

Video validation was not definitive in many instances. This was due to the view being obstructed by spiders on the camera lenses, ice formation on the stream, heavy precipitation, and light glare on the water surface. Fish movements at night were also a challenge, with >95% of the Coho movements occurring between sunset and sunrise. Combining these obstructions with a propensity to migrate at night, and video validation does not provide certainty in all situations. This introduces a presence/not-detected exercise, with certainty only being applied when a fish is visualized.

The majority of the fish migrated passed the counter during five days in mid-November. This period followed a drop in temperatures and snow accumulation. On November 11th, daytime lows remained >0.0°C and snow and ice melt persisted. This melt increased the water discharge and likely influenced the pulse of Coho Salmon that were detected. This was a particularly dry summer and fall, with water levels in Bessette Creek being below normal. In situations such as this it is common for salmon to hold at the mouth of a tributary, waiting for water levels to increase. Although this situation is not uncommon, the next year may bring different water levels and migration patterns for these Coho, so counter installation should remain consistent.

Channel 4 accounted for 61% of all Coho movements, indicating this region of the stream is the desired location for Coho migration. It is therefore reasonable to expect channel 4 to contain the largest number of undetected fish. Water velocity and depth is greatest in this section of Bessette Creek, but the velocity remains relatively low. One side effect of slower flowing sections of streams is the collection of debris and smaller substrate. A buildup of fine sediment was witnessed on a few occasions, but only in channel 4, and to the extent that a small (10cm) portion of one of the electrodes was being buried. This tended to happen during/immediately following periods of increased discharge, which also coincided with the main pulses of Coho. It is therefore possible that some of the undetected Coho were results of passing over the portion of electrode which was buried by sediment. Similarly, small branches occasionally became caught on the panel, and it is possible that their presence negatively impacted the electrodes ability to detected differences in bulk resistance, and fish movements. Although debris and sediment can explain fish movements going undetected, it may not be the only reason. Other possible explanations are organic buildup on the electrode's housing or fish moving higher in the water column where, although relatively shallow, the counter may be less sensitivity.

To help mitigate some of the issues and potentially increase counter accuracy, we propose the following changes for future years:

- Power outages prevented video footage from being saved during a period of Coho returns. A backup power supply could be used to keep the counter operational during outages which last <15 min. This would eliminate the need to physically visit the site and restart the computer following intermittent power.

- The location of the electrode panels should be revisited. A riffle exists approximately 10 m upstream of the present site, and the water conditions here (increased velocity and reduced depth) may allow for an increase in counter detection and accuracy. The increased velocity will require fish to move more rapidly upstream and potentially reduce downstream movements and the uncertainty surrounding their estimate/count. The increased velocity should also reduce debris and sediment buildup as the current will carry these downstream, avoiding the accumulation and burying/disruption of the counter. The lower depth will also require fish to pass within close proximity of the electrodes, and in the area of highest counter sensitivity. With passage distance from the electrodes being closer and more consistent across all fish, a relationship may exist between PSS and fish length.

- Steps to limit visual obstruction of the cameras should include a thorough cleaning of the lenses to remove spiders during each maintenance visit and adjustment of the light sources to reduce glare on the water surface and potentially improve visibility during heavy precipitation.

- Increasing observation effectiveness during video validation could be accomplished by introducing a light-coloured background (construction-grade moisture barrier, fine mesh fencing, etc.) beneath the panels which would increase contrast and the ability to see fish. This may also reduce the number of fish that are undetected during targeted video validation (28 fish; Table 3). Materials would simply be anchored beneath the panels and cleaned during maintenance visits.

5.0 REFERENCES

McDubbing, D. J. F., B. Ward, and L. Burroughs. 2000. Salmonid escapement enumeration on the Keogh River: a demonstration of a resistivity counter in British Columbia. Fisheries Technical Circular No. 104.