Bessette Creek Coho Enumeration Using a Resistivity Counter (Year 2 of 3)

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Prepared for:
Pacific Salmon Commission

March 2019

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Citation: Yuan, B. and S. Folks. 2019. Bessette Creek Coho Enumeration Using a Resistivity Counter (Year 2 of 3). Prepared for Pacific Salmon Commission, Southern Fund Committee. Okanagan National Alliance, Westbank, BC.

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1.0 INTRODUCTION

1.1 Project Background

Bessette Creek Coho Salmon is part of the South Thompson conservation unit (CU) and one of many small populations that contribute to the Threatened Interior Fraser Coho Management Unit (IFCMU; COSEWIC 2016). 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 is on average 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). In recent years, the use of resistivity counters as an alternate, automated method of enumeration resulted in higher quality escapement estimates. Escapements in Bessette Creek 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 (caused by 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 detect fish in turbid conditions, and can remain running for extended periods of time. A resistivity counter was operated on Bessette Creek during the 2017 and 2018 Coho escapement season. This report summarizes year 2 results of a 3-year operation that aims to calibrate this method with existing escapement estimates via streamwalk surveys.

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 a resistivity counter. A resistivity counter will be operated concurrently with stream-walk surveys during Coho spawning season over three years. At the end of the three-year project, a calibration relationship will be established between the two methods of enumeration, which will then be applied to historic data. This data will assist in evaluating the status of Bessette Coho populations, measuring their productivity patterns, applying escapement goals, and evaluating recovery potential.

2.0 METHODS

2.1 Location

Bessette Creek is a tributary of the Middle Shuswap River, with its mouth located 12 km NE of Lumby, BC. The Bessette Creek watershed is 795 km^2 in area and includes three main tributaries: Harris, Duteau and Creighton creeks. In addition to Coho Salmon, the watershed provides habitat for other fish species, such as Chinook and Kokanee salmon and Rainbow Trout. Although Sockeye salmon are rarely present in the Bessette Creek watershed, they were observed in 2018, which coincided with their 4-year peak spawning cycle.

A resistivity counter and flat pad sensors were installed in Bessette Creek at a location 6 km NE of Lumby, BC (Figure 1) from September 26 to November 30 in 2017, and September 26 to December 5 in 2018. At this site, the stream is approximately 12 m wide with a mean 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.

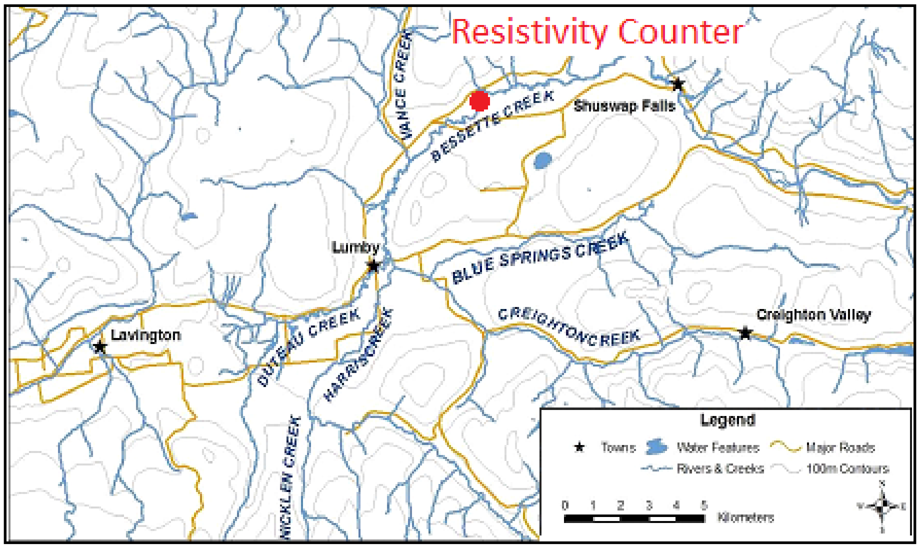

Figure 1: Location of resistivity counter on Bessette Creek.

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

2.2 Resistivity Counter

The Logie 2100C resistivity counter consists of two components. The electronic unit (computer that contains the algorithm) that is deployed onshore and the flat pad sensors (2.44 m by 0.635 m), which each house three electrodes, that are deployed in the river. 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 the flat pad sensors is continuously measured. When an object passes over the electrodes, it displaces water around it and thus a change in resistance is detected. If the object spans two electrodes simultaneously, an event is recorded. Each event 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 and correct for algorithm errors. 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 user defined 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.

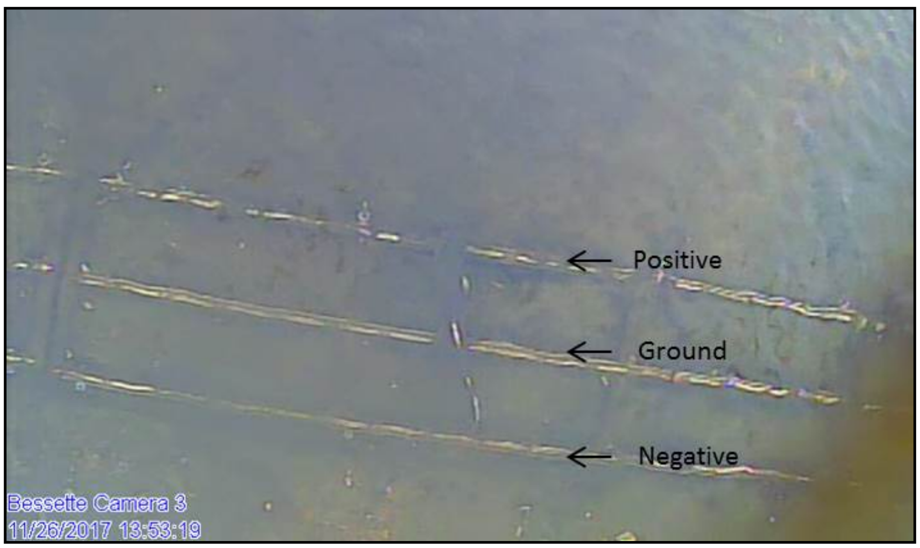

Figure 3: Video screenshot of upstream migrating Coho salmon over resistivity panel in Bessette Creek, BC.

Four flat pad sensors were installed in 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. The remaining stream margins were 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.

In 2018, to increase ease of fish detection during video review, white plastic strips were installed beneath the flat pad sensors to increase image contrast (Figure 5).

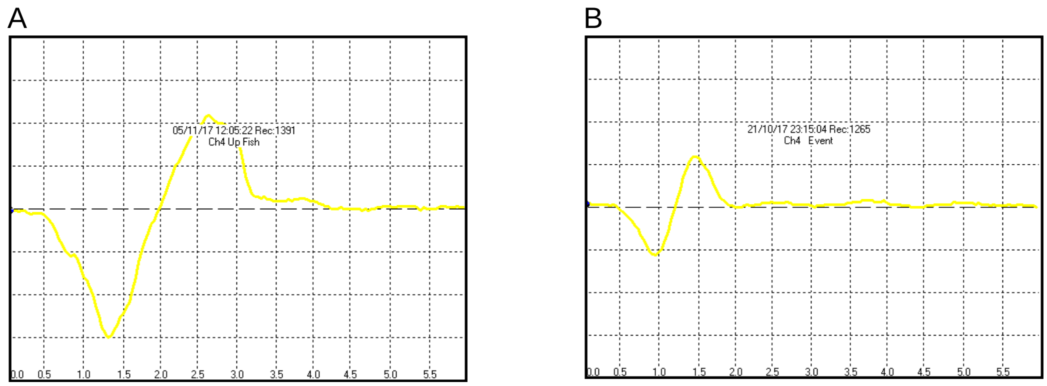

Figure 4: Graphical trace data for resistivity counter at Bessette Creek, BC: A) correct counter assignment of a Coho Salmon upstream movement, and B) incorrect counter assignment of a Coho Salmon upstream movement as unclassified event.

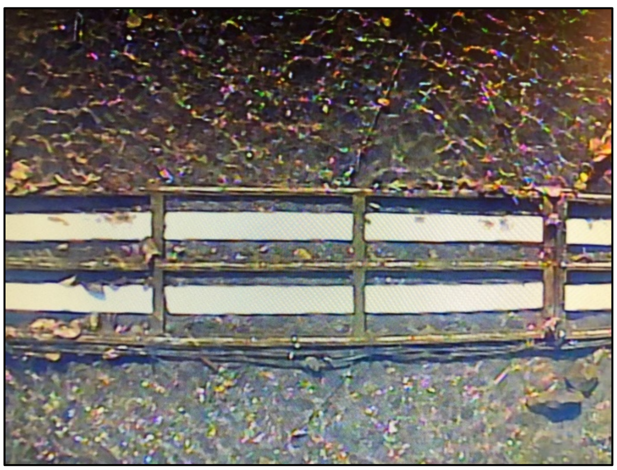

Figure 5. Flat pad sensors with white plastic stripping installed underneath to aid in fish detection during video review.

2.3 Analysis

Graphical trace data were visually assessed and compared to the counter algorithm assignment of each record. When trace data indicated the record was incorrectly assigned, a note was made in the event's record. To confirm the validity of each misidentified event, along with all other correctly-assigned fish movement records, targeted video validation was conducted by reviewing video camera footage at the time of these records. Data recorded included channel number, video start and end time, and video duration. If a Coho was present, the direction of movement, the onscreen length of the fish, and the onscreen width of the resistivity panel were also recorded.

To capture counter inaccuracies, including fish movements that were not detected, 10-15% of all video during Coho Salmon migration was reviewed (Ramos-Espinoza 2017, InStream Fisheries Research, pers. comm.). Power outages resulted in periods with no video footage in both years (Table 1). Random 5-15 min video clips were reviewed for all panels until a minimum of 10% of the available video footage (not including blackout periods) was reviewed. When previously undetected Coho were identified during random validation, data on the video time, duration, direction of movement, and lengths were recorded. The number of Coho that were undetected by the counter was then extrapolated from 10-15% of the video period to the entire unwatched video period.

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

$$L = l * W / w$$

where l is the onscreen fish length, W is the known panel width, and w is the onscreen panel width. A linear regression between fish length and PSS was graphed and the R^2 value calculated to estimate the strength of relationship, and ultimately, determine the usefulness of PSS in identifying fish species.

To determine how effective the resistivity counter was at detecting Coho movements, counter accuracy (q) was calculated as,

$$q = (Fc/Fv) * 100$$

where Fc is the number of fish movements detected from the resistivity counter, and Fv is the number of fish movements validated from the video in addition to the extrapolated number of movements missed by the counter following random video validation. Note that q was calculated separately for upstream counts and downstream counts.

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, 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 in operation from late September to late November/early December. However, analysis did not start until mid-October to align with the onset of Coho runs. In 2017, the analysis period was October 15 to November 30. In 2018, the analysis period was October 9 to December 4. The analysis period began earlier in 2018 due to earlier returns, and extended to a later date due to constraints related to scheduling field crews. Table 1 summarizes the duration of available video for both project years along with periods of video blackout due to power outages. 10.06% of the video was reviewed in 2017 and 10.03% of the video was reviewed in 2018.

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.

Year		Dates From	To	Days	Minutes
2017	Overall	October 15	November 30	38.41	55,309
	Video Down	October 15	October 19	6.34	9,135
		October 29	November 1	3.33	4,796
2018	Overall	October 9	December 4	52.22	75,200
	Video Down	November 2	November 5	3.07	4,422
		November 21	November 23	1.71	2,461

3.0 RESULTS

3.1 Run Timing

In 2017, 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.

In 2018, the first video validated Coho Salmon was observed on October 11 and the last video validated Chinook Salmon was observed on October 23. Despite having video footage during this overlapping period, night time species identification proved difficult, and was further complicated by the presence of Sockeye Salmon which were observed from October 9 to November 1.

In 2017, nearly all upstream movements for Coho occurred between sunset and sunrise (Figure 6). This supports the notion that Coho may be hard to detect during the daytime escapement survey walks, possibly leading to incorrectly low escapement estimates. In 2018, a greater proportion of upstream movements occurred during daytime, although the majority migrated between sunset and sunrise.

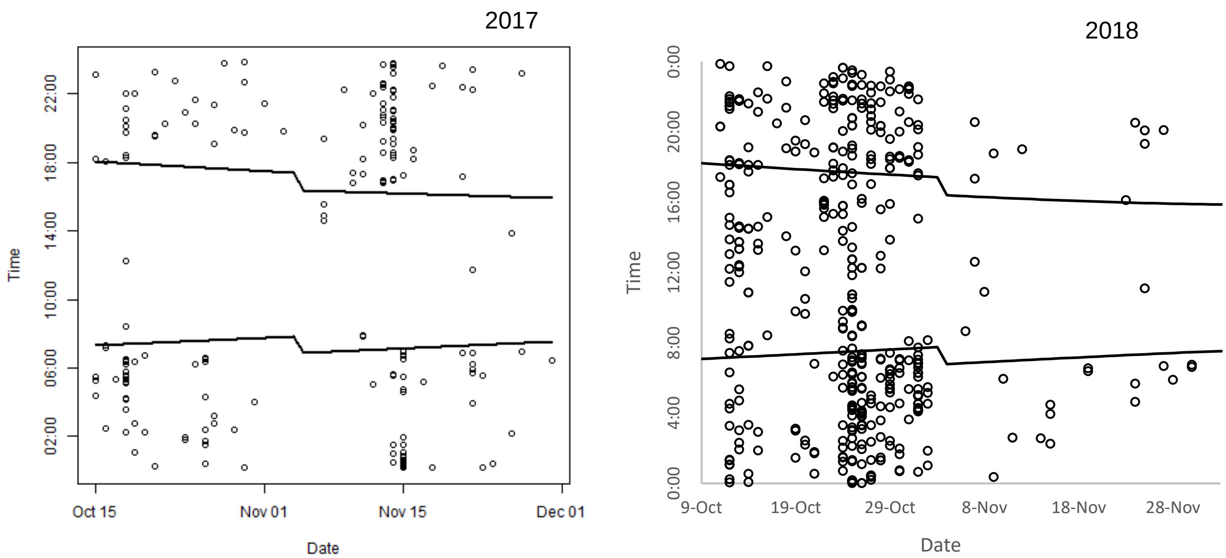

Figure 6: Time of day that upstream migrating Coho Salmon were detected by resistivity counter in Bessette Creek, BC in 2017 (left) and 2018 (right). Daily sunrise and sunset indicated by black horizontal lines.

In 2017, the overall return of Coho peaked in mid-November, with a large proportion of adults returning from November 11 to 16. A large pulse of fish was also detected on October 18 by the counter (Figure 7). Peak returns in 2018 occurred earlier, with a large proportion of individuals returning between October 24th and November 3. An earlier pulse was also detected in 2018 between October 9 and 13.

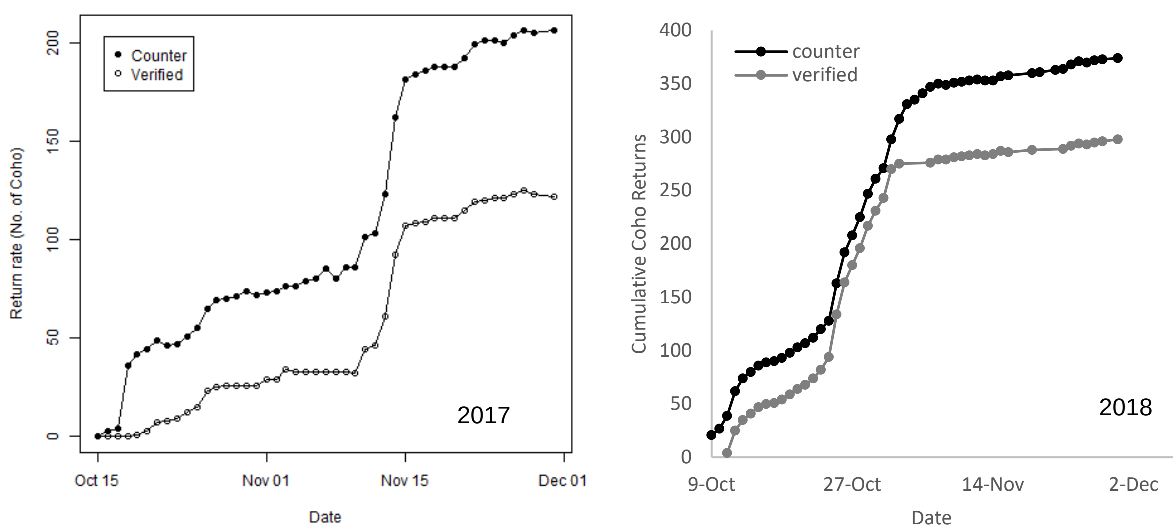

Figure 7: Cumulative Coho returns at Bessette Creek, BC in 2017 (left) and 2018 (right), as net daily upstream movements, estimated by resistivity counter (Counter) and those detections which were verified through video validation (Verified).

3.2 Fish Movements

<u>2017</u>

In 2017, the counter classified 298 fish movements, 47 of which were visually identified as non-Coho movements (Whitefish, otter, Chinook salmon, or false positives where no fish was observed; Table 2). The remaining 251 fish movements were either validated by video to be Coho, or were assumed to be Coho when video validation was not possible. Fifty-nine of the 251 detections occurred during a power outage when no video was available (Table 3), and 46 could not be verified due to obstructions of view (eg. ice, glare on water surface, spider on lens, heavy precipitation). The 251 movements were comprised of 223 upstream and 28 downstream movements, giving a net upstream migration of 195 Coho Salmon.

Table 2: Counter detection movements verified as non-Coho events from video validation in 2017.

	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

Table 3: Summary of resistivity counter events in Bessette Creek during the Coho migration period in 2017 (October 15 - November 30) and while the video system was down. Counter logged fish movement upstream (U) and downstream (D), and net movement represents 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

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 217 undetected Coho movements (Table 4).

Table 4: The extrapolation of Coho Salmon in Bessette Creek which were undetected by the resistivity counter in 2017.

Channel	Video Counts Not Detected by Counter		Video			Extrapolated		
	D	U	Watched (mins)	Total (mins)	%	D	U	Total
1	0	0	5,489.00	55,308.85	9.92	0	0	0
2	0	1	5,516.52	55,308.85	9.97	0	10	10
3	1	1	5,605.72	55,308.85	10.14	10	10	20
4	7	12	5,645.82	55,308.85	10.21	69	118	187
Total	8	14	22,257.05	221,235.4	10.06	79	138	217

2018

In 2018, the counter classified 872 fish movements, 198 of which were visually identified as non-Coho movements (Whitefish, Chinook salmon, Sockeye salmon, otter, or false positives where no fish was observed;

Table 5). The remaining 674 movements were either video validated as Coho or assumed to be Coho when no video was available. There were two power outages in 2018, resulting in 37 detections that had no video (Table 6). An additional 52 could not be video-verified due to obstructions to vision. Fourty-eight detections were verified by video but the species could not be confidently identified due to overlaps in run timing.

Table 5: Counter detection movements verified as non-Coho events from video validation in 2018.

	D	U	Total
No fish observed	1	2	3
Whitefish	9	7	16
Otter	0	1	1
Chinook	48	93	141
Sockeye	18	19	37
Total	75	122	198

Table 6: Summary of resistivity counter events in Bessette Creek during the Coho migration period in 2018 (October 9 – December 4) and while the video system was down. Counter logged fish movement upstream (U) and downstream (D), and net movement represents U-D.

	Dates	Counter Events			
		D	U	Total	Net
Video Down	November 2 – 5	0	34	34	34
	November 21 – 23	1	2	3	1
Overall		150	524	674	374

Video validation identified 565 Coho movements, 537 corresponding with counter detections, and 29 which 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 286 undetected Coho movements (Table 7).

Table 7: The extrapolation of Coho Salmon in Bessette Creek which were undetected by the resistivity counter in 2018.

	Video Counts Not Detected by Counter		Video			Extrapolated		
Channel	D	U	Watched (mins)	Total (mins)	%	D	U	Total
1	1	1	7,511.75	75,200	9.99	10	10	20
2	1	4	7,497.78	75,200	9.97	10	40	50
3	4	1	7,493.73	75,200	9.97	40	10	50
4	9	8	7,671.12	75,200	10.20	88	78	166
Total	15	14	30,174.38	300,800	10.03	148	138	286

3.3 Counter Accuracy

The overall counter accuracy in 2017 was lower than anticipated (67%; Table 8), and was largely impacted by the high number of extrapolated fish (217) 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 8: Counter accuracy in 2017 expressed as the number of Coho detected by the resistivity counter divided by the number of Coho detected by video validation (including the extrapolated number of missed Coho movements).

	No. of Coho detected						Accuracy		
	Counter			Video (including extrapolated false negatives)					
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	12	12	1.00	0.75	0.83
3	7	70	77	11	38	49	0.64	1.84	1.57
4	18	136	154	82	218	300	0.22	0.62	0.51
Total	28	223	251	94	269	363	0.30	0.83	0.69

Counter accuracy in 2018 was higher than 2017 (82%; Table 9) as the counter detected many more fish in 2018 while the extrapolated number of fish missed by the counter did not increase by much. Similar to 2017, accuracy was lower for downstream movements, and lowest for panel 4. Most Coho detections occurred in panel 4.

Table 9: Counter accuracy in 2018 expressed as the number of Coho detected by the resistivity counter divided by the number of Coho detected by video validation (including the extrapolated number of missed Coho movements).

	No. of Coho detected								
	Counter			Video (including extrapolated false negatives)			Accuracy		
Channel	D	U	Total	D	U	Total	D	U	Total
1	19	58	77	25	46	71	0.73	1.26	1.07
2	28	86	144	30	108	138	0.93	0.80	0.83
3	29	89	118	66	87	153	0.44	1.02	0.77
4	74	291	365	146	314	460	0.51	0.93	0.79
Total	150	524	674	267	555	822	0.56	0.94	0.82

3.4 Escapement Estimate

In 2017, up and downstream counter estimates of Coho salmon totaled 223 and 28 respectively, but when corrected for counter accuracy the estimate increased 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.

In 2018, up and downstream counter estimates of Coho salmon totaled 524 and 150, respectively. When corrected for counter accuracy, these numbers changed to 555 upstream and 268 downstream movements. This gives an escapement estimate of 266 fish for 2018.

3.5 Length-Peak Signal Size Relationship

The average length of the measured Coho Salmon was 62.88 ± 4.85 cm in 2017 and 63.89 ± 12.15 cm in 2018. The relationship between fish length and peak signal size was very weak across both years, with R^2 values ranging from 0.005 to 0.010 (Figure 8).

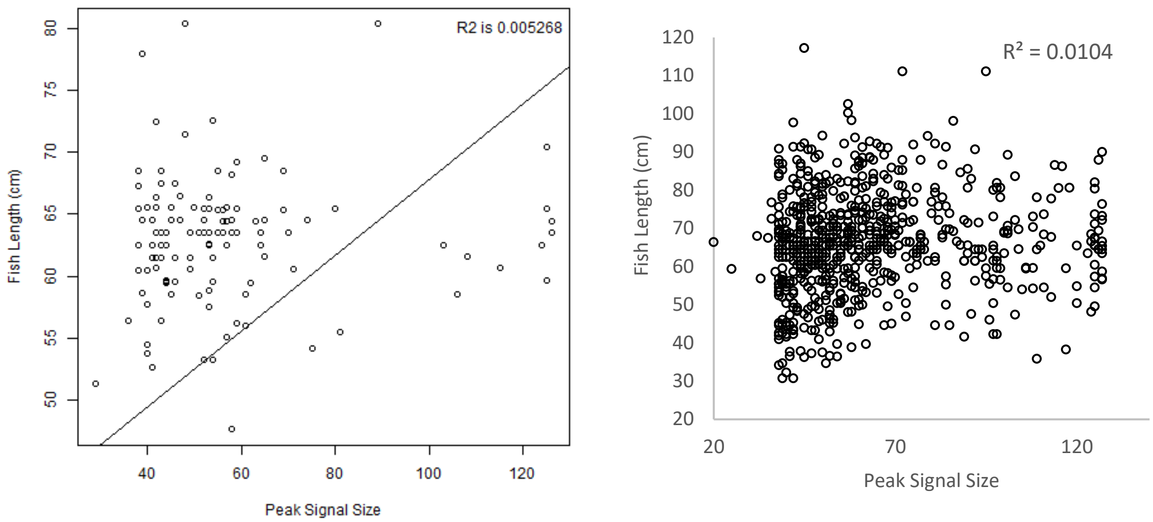

Figure 8: Regression analysis of peak signal size and fish length in 2017 (left) and 2018 (right).

4.0 DISCUSSION AND RECOMMENDATIONS

Across both project years, the electronic counter was able to detect a large number of fish movements and produced a relatively clean dataset free of an excessive number of false positives or events. Video loss, particularly during periods where Chinook and Coho migrations overlap could have lead to reduced accuracy of the analysis.

Counter accuracy was lower than anticipated in 2017 and was largely influenced by the high extrapolation value for undetected Coho. During this year, only three Coho in panels 1, 2 and 3 were visually detected in the video and undetected by the counter. These single detection events are rare 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%. In 2018, the accuracy of the counter increased to 82% overall. However, this increase is largely due to the higher returns in 2018 resulting in a 2.7-fold increase in fish detected. Meanwhile, the total extrapolated number of missed fish only increased by 1.3-fold. If the number of false negatives remain fairly constant, counter accuracy could decrease once again during low return years.

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 in 2017, which is nearly double that of the resistivity counter, 175. In 2018, stream walks and AUC calculation estimated escapement to be 317 Coho, while the counter estimate was 266. 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 in both years (217 in 2017 and 286 in 2018). 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, particularly in channels 3 and 4. A large proportion of extrapolated values were downstream movements (37% in 2017, 52% in 2018), suggesting the counter has particular difficulty picking up these movements. Often times, downstream movements are much quicker, which could explain this pattern.

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 many of the Coho movements occurring between sunset and sunrise. During the 2018 season, Chinook were observed as late as October 22, and Sockeye were observed until November 1. This made species identification at night particularly challenging. The combination of obstructions, propensity to migrate at night, and overlapping migration periods prevents video validation to provide certainty in all situations. This introduces a presence/not-detected exercise, with certainty only being applied when a fish is visualized in daylight.

In 2017, the majority of the fish passed the counter during five days in mid-November, a period of time which coincided with a drop in temperature and increased discharge. That year had a particularly dry summer and fall, with water levels in Bessette Creek being below normal. Therefore, return timing could have been driven by increases in water levels. In 2018, a bulk of the returning adults passed the counter from October 24 to November 3, which preceded a multi-day precipitation event beginning on November 2. It would appear that water levels were not a driving factor in the returning timing of this year's run.

Channel 4 accounted for a large proportion 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 sensitive.

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.

- A decision rule framework should be put in place to aid species identification when visual identification is difficult. This framework should consider size, time of day, and date as possible decision rules.

5.0 REFERENCES

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