ESCAPEMENT OF WILD COHO SALMON TO THE LILLOOET RIVER, 2019

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LIST OF ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations are used in this report:

APE	average percent error
ARIS	Adaptive Resolution Imaging Sonar
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CU	Conservation Unit
CV	coefficient of variation
CWT	coded wire tag
DFO	Fisheries and Oceans Canada
DNA	deoxyribonucleic acid
ER	exploitation rate
FOV	field-of-view
IFR	Interior Fraser River
LFFA	Lower Fraser Fisheries Alliance
LFR	Lower Fraser River
MU	Management Unit
PIT	passive integrated transponder
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
SCMP	Southern Coho Management Plan
SD	standard deviation
WSP	Wild Salmon Policy

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EXECUTIVE SUMMARY

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We estimated escapement of wild Coho Salmon (*Oncorhynchus kisutch*) to the Lillooet River between 18 October 2019 and 30 November 2019 using an Adaptive Resolution Imaging Sonar (ARIS) 1200. This project was the first to attempt to estimate aggregate escapement of Coho Salmon to the Lillooet River and by association the Lillooet River Coho Salmon Conservation Unit.

The ARIS was installed in the Lillooet River mainstem approximately 40 km upstream of the outflow at Harrison Lake, and immediately below Rogers Creek. Here, the Lillooet River was approximately 50 m across and defined by laminar flow with neither underwater obstruction, nor significant turbulence. The distant half of the river experienced more rapid flows than the near side. Imaging files were recorded in discrete 10-minute files. To better enable accurate measurement of fish length and to establish preferred migration paths of fish, the first thirty minutes of every hour recorded the near field view (0−25.0 m) and the latter thirty minutes recorded the distant half (25.1–50.0 m). Fish greater than 40 cm nose fork length were assumed to be adult Coho Salmon.

Daily escapement estimates peaked early in the 6-week sampling period with an estimated 228 Coho Salmon passing the site on 19 October. Daily estimates were shown to generally decrease through the remainder of the sampling period to 15 fish on 27 November. The total escapement estimate for Coho Salmon in the Lillooet River during the sampling period was 2,124 with an estimated 95% confidence interval of $\pm$ 276 fish ($\pm$ 13%). This is an underestimate of total escapement as the operational period did not capture the early or peak migration, assuming the run-timing curve approximates a normal distribution.

Results from this study indicate that the sampling site on the Lillooet River at Rogers Creek is an effective sampling location for estimating Coho Salmon escapement using imaging sonar methods. However, considering escapement estimates declined after the installation date, ideally the ARIS would be in place prior to the beginning of the migration allowing for assessment of the initial stages of the run and subsequent peaks and declines.

INTRODUCTION

The Lillooet River and its tributaries, draining the southern Coast Mountains in British Columbia and flowing through the lands of the Líl̓wat Nation, provides significant habitat for Coho Salmon (*Oncorhynchus kisutch*) to spawn (Noble et al. 2015). Some of this habitat is assessed annually by the Líl̓wat Nation which conducts escapement surveys of Coho Salmon throughout the Upper and Lower Lillooet River. Despite these efforts, there is no aggregate escapement estimate available for Lillooet River Coho Salmon as surveys do not cover all tributaries and there is no agreed upon method to in-fill the non-surveyed portion. This presents a challenge for resource managers as the Lillooet River watershed is identified as a Conservation Unit (CU) (DFO 2005) and is also included in the Lower Fraser River Management Unit (LFR MU) – the unit upon which fishery and international agreements are managed. Despite the geographic, genetic, cultural and management significance, the Lillooet CU is data deficient and lacks any actionable information resource managers would typically utilize to sustainably manage stocks or assess status as required under the Wild Salmon Policy (WSP) and/or the Pacific Salmon Treaty (PST).

Inconsistent, and sometimes absent, annual funding and a lack of resources to develop a Coho Salmon centric assessment program have resulted in Fisheries and Oceans Canada (hereafter DFO) being unable to generate an estimate of Coho Salmon escapement to the Lillooet River CU or the larger Lower Fraser River Management Unit (LFR MU) from observed data. The absence of reliable escapement estimates for Coho Salmon in the LFR MU and its three component Conservation Units (Lillooet, Boundary Bay and Lower Fraser) represents a critical information gap for Southern Boundary Coho Salmon Management. Despite more than a decade of stream specific Coho Salmon escapement estimates within the Lillooet CU, DFO does not have an acceptable way of using these estimates to generate a CU specific aggregate escapement estimate.

The absence of an escapement estimate to the LFR MU limits the ability of DFO to achieve its responsibilities described in the Southern Coho Management Plan (SCMP), including to "maintain capabilities and programs as necessary to conduct stock assessments …", and identifying status of "each MU originating in their rivers…". The lack of escapement estimates for Coho Salmon to the LFR MU is a serious impediment to achieving these said objectives. Further, specific acceptable exploitation rate ranges are described in the PST for MUs and are dependant on status. Currently, the Lower Fraser Coho MU is managed under the assumption of 'low' status and exploitation rate (ER) is capped at 20%. However, estimating exploitation rates of LFR MU Coho requires an escapement estimate. The lack of data for the LFR MU also complicates management of the Interior Fraser River Coho Management Unit (IFR MU), a COSEWIC-listed species, specifically that IFR MU exploitation rate estimates are directly dependant on escapement estimates of LFR MU Coho Salmon such that underestimating escapement to the LFR MU results in overestimates of IFR MU ERs and vice-versa. Generating an escapement estimate of Coho Salmon to the LFR MU is of critical importance and is identified as the top priority for Coho Salmon by the Coho Technical Committee.

All three CUs within the LFR MU lack an escapement estimate, however a current project between DFO, the Lower Fraser Fisheries Alliance (LFFA) and LGL Limited is being piloted to

estimate escapement to the LFR MU (Arbeider et al. 2020). This pilot is multi-faceted and integrates data from a variety of sources including a sampling program of returning adult Coho Salmon on the Lower Fraser River, coded wire tag (CWT) data from Nicomen and Chilliwack rivers, DNA from the sampling program and passive integrated transponder (PIT) tag data from the Chilliwack River. However, for the project to work as designed, an escapement estimate of Coho Salmon to the Lillooet River CU is required as there are neither CWT stocks originating from the Lillooet nor acceptable stream escapement projects that could be utilized.

Coho Salmon returning to the Lillooet CU must transit through the Lower Lillooet River, thus providing the unique potential for a census-style assessment for much of the CU. Funding from the PSC in 2018 enabled LGL Limited, Johnson Fisheries Science, and the Líl̓wat Nation to identify a site near Rogers Creek (Figure 1) where digital imaging technology, specifically an Adaptive Resolution Imaging Sonar (ARIS) 1200, could be installed to assess escapement of Coho Salmon to the Lillooet CU (Johnson et al. 2019). In 2019, the PSC provided funds to assess the feasibility of using an ARIS to assess abundance of migrating Coho Salmon during a six-week period with the specific objectives of:

1. Setup and operate an ARIS on the Lillooet River to enumerate Coho Salmon migrants during a six-week sampling period in October and November 2019;
2. Train fisheries technicians with the Líl̓wat Nation regarding operation and maintenance of the ARIS and review of the sonar data;
3. Characterize run-timing and analyze count data to produce escapement estimates for Coho Salmon present during the 2019 sampling period; and
4. Confirm Rogers Creek is an appropriate location for the ARIS.

METHODS

Coho Salmon escapement was assessed using an ARIS 1200 unit deployed in the Lillooet River mainstem just below the mouth of Rogers Creek (Figure 1). This site was assessed in 2018 as the most suitable location for sampling with imaging sonar given the relatively narrow wetted width of the river at the location at that time (approximately 50 m), absence of highly turbulent flows or large boulders and ease of access from the Lillooet River Forest Service Road (Johnson et al. 2019).

Data Collection

The ARIS 1200 was deployed and operational 24 hours a day from 18 October through 30 November 2019. The system consisted of the sonar head, data transmission cable, ARIS command module, Ethernet cable, and laptop computer loaded with ARIScope (Sound Metrics Inc.) data acquisition software. The system was powered through an inverter using a bank of six 6-volt batteries wired in series (three pairs) and with all pairs joined in parallel. The battery bank was charged up daily using a portable Honda 2000 generator maintained by onsite technicians. All electronic components were housed in a weather-proof shed-like enclosure located above the elevation of the high-water line (Figure 2).

The ARIS 1200 sonar head was fastened to an aluminum H-mount which was placed on the substrate approximately 2 m from the bank and secured with sandbags and heavy cotton rope

tethered to shore (Figure 2). The sonar head was placed 0.2 m above the substrate, aimed with a heading of 247° toward the opposite bank with a pitch angle of -9°. The sampling area across the river was divided into two separate sample volumes: the near-field zone (from 0.7 m to 20.4 m in range) and far-field zone (from 21.0 m to 41.8 m in range) (Figure 3). The near-field zone was characterized by relatively low to moderate laminar flow whereas the far-field zone was observed to have relatively moderate to high flows with some turbulence.

All data were collected using the system frequency of 0.7 MHz and data were recorded in 10-minute duration data files. ARIScope was configured to collect near-field zone data for the first three 10-minute periods for each hour and far-field zone data for the last three 10-minute periods for each hour. Data files were collected directly onto 3-TB external hard drives and each day technicians swapped out external hard drives and backed up the data to additional hard drives.

Data Processing

Data files were reviewed and processed using ARISFish (Sound Metrics Inc.) software and a subsampling scheme was employed to optimize data processing effort (Lilja et al. 2008). Subsampling for near-field zone data involved randomly selecting two 10-minute data files per hour for review. Subsampling for far-field zone data involved randomly selecting one 10-minute data file within each four-hour time block per day (blocks defined as hours 0 through 3, 4 through 7, 8 through 11, 12 through 15, 16 through 19, and 20 through 23) for review. The decision to undertake less intensive processing effort for far-field zone data was based on preliminary data review that indicated 100% of the fish observed were passing through the near-field zone.

Data processing entailed opening the data files with ARISFish and presenting the data in both echogram and raw imagery formats. An echogram is a visual representation of an entire image file compressed so that each pixel along the horizontal axis represents a single frame. Fish that swim across the field-of-view (FOV) show up as traces, and these traces indicate the location of fish to be processed. Echogram mode allows for examination of large portions of the data file at once (as opposed to having to review entire files in raw imagery mode) increasing the efficiency of the review process. The raw imagery format presents the data in streaming form against the 29°FOV. Though the ARIS samples a three-dimensional volume that includes a 14° 'thickness' component, the data are limited to two dimensions as the 'thickness' component is spatially compressed.

When a fish trace was observed, the trace was framed with the cursor to prompt that portion of the file to be replayed in imagery mode. In imagery mode the total length of the observed fish was then estimated using the software's sizing tool. If the fish was shown to have an estimated total length of $\geq$ 40 cm and was observed to move through the FOV the fish was tallied on the data sheet and the fish's direction of travel (upstream or downstream) was noted. The 40 cm size threshold for determining whether or not a fish was counted as a migrant was based on preliminary data review which indicated fish smaller than 40 cm were typically not actively moving through the FOV and were likely resident trout.

Assumptions

There were two primary assumptions regarding the sonar-based fish counts:

1. All fish that met the size and migratory criteria included in this assessment were Coho Salmon. This assumption is based on Coho Salmon run timing information to tributaries of the Lillooet River and personal communication with Líl̓wat Fisheries staff with reference to their knowledge of Lillooet River run timing and experience handling and measuring salmonids.
2. No fish avoided detection by passing in the shallow water area behind the ARIS.

Training of Líl̓wat Nation Technicians

Líl̓wat Nation fisheries technicians were trained regarding operation and maintenance of the ARIS 1200 system during the setup period (17 and 18 October 2019) just prior to the start of data collection. Specific tasks discussed during the training session included maintenance and charging protocols for the battery bank used to power the system, swapping out and backing up data hard drives, and recognition of and troubleshooting problems that may arise. Additional training was conducted in late October and early November 2019 via telephone conference to discuss data processing protocols.

Escapement Estimation and Data Analysis

Hourly count data from ARIS sampling were used to estimate the net upstream flux (fish per unit time) of Coho Salmon passing through the ensonified volume using the following model (Xie et al. 2002):

$$N = U - D \quad (1)$$

Where *N* is the net upstream flux, *U* is the actively migrating fish heading upstream and *D* is the actively migrating fish heading downstream. For non-migratory resident fish, the model assumes there is equal probability of upstream or downstream movement through the sample volume, and therefore *U* = *D* for resident fish. The model relates only to actively migrating fish so in order to exclude post-spawned moribund fish from the escapement estimates, the post-spawned fish must be removed from the downstream estimates.

The daily number of fish (y) that satisfy size and movement criteria during day i were estimated as:

$$\hat{y}_i = \frac{24}{h_i} \sum \hat{y}_{ij} \quad (2)$$

Where h_i is the number of hours during which fish passage was estimated during day *i*, and $\hat{y}_{ij}$ is hourly fish passage during hour *j* of day *i*, and is estimated as:

$$\hat{y}_{ij} = \frac{60}{m_{ij}} c_{ij} \quad (3)$$

Where

m_{ij} is the number of minutes sampled during hour *j* of day *i*, and

c_{ij} is the number of fish satisfying size criteria during hour *j* of day *i*.

Precision (repeatability of a count between different individuals for the same data file) of ARIS counts was assessed using the coefficient of variation (*CV*) and average percent error (*APE*) as per Cronkite et al. (2006) where:

$$CV = \sqrt{\frac{\sum_{i=1}^{R}(X_{ij} - \bar{X}_j)^2}{\bar{X}_j^2}} \text{ x } 100 \quad (4)$$

$$APE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij} - \bar{X}_j|}{\bar{X}_j}\right] \text{ x } 100 \quad (5)$$

And *N* is the number of events counted by *R* observers, X_{ij} is the i^{th} count of the j^{th} event and X_j is the average count of the j^{th} event. *APE* as presented above is an index of the repeatability of counts across the entire data set, whereas *CV* is a measure of the variability in counts of a particular file among observers.

The variance caused by temporal expansion was estimated using the following sample-variance estimator as per Eggers et al. (1995) and Cronkite et al. (2006):

$$Var\,(\hat{Y}) = N^2\left(\frac{1-f}{n}\right)\sum_{i=2}^{N}\frac{(y_1 - y_{i-1})^2}{2(N-1)} \quad (6)$$

Where y_i is the estimated number of fish passing through the sample volume during hour *i*, *N* is the total number of one-hour sample periods, *n* is the total sampled time in hours, and *f* is the sample fraction (*n/N*). The estimate of total variance for the upstream escapement estimate is equal to the sum of the sample variance component ($Var\,(\hat{Y})$) and the average percent error (*APE*) variance and expressed as the standard deviation (*SD*) for the total count:

$$SD_{TotalCount} = \sqrt{Var\left(\hat{Y}\right) + Var\left(\hat{Y}_{APE}\right)} \quad (7)$$

This *SD* is in respect to numbers of fish for the total count and the 95% confidence reported is calculated by multiplying the *SD* by $\pm$ 1.96 for normal distributions of data (Zar 1984).

RESULTS AND DISCUSSION

Sample Effort and Data Quality

Data were collected continuously from 18 October through 30 November 2019. During this period, the ARIS system remained functional and recording each hour with only two exceptions: two complete hours of data (1000 on 20 October and 0900 on 9 November) were not recorded when the process of swapping out external hard drives exceeded the typical time (about two minutes) it took to complete that process. The Líl̓wat Fisheries technicians did an exceptional job maintaining the system and managing data collection throughout the sampling period.

Sampling effort was unexpectedly altered to a small degree due to an intermittent software issue that affected the timer-based recording of data files with respect to sampling the far-field zone. As stated in the methods section above the ARIScope software was programed to collect near-field zone data in the first three 10-minute periods per hour and far-field zone data in the last three 10-minute periods per hour. Upon processing and reviewing the data set we found that occasionally instead of the last three 10-minute file periods per hour recording data from the far-field zone, these files actually recorded and contained near-field zone data. However, as no fish were observed transiting through the far field in any other file, this software issue was considered a non-issue from the perspective of enumerating Coho Salmon.

Data quality (i.e., ability to discern structural elements of the substrate and detect fish and debris throughout the fields-of-view) remained high throughout much of the sampling period. However, there were two periods in which flows decreased to the point where the Lillooet River water level dropped and became too low to effectively sample. This became apparent in the ARIS imagery when substrate features were no longer or intermittently visible resulting when sampling beams were unable to form due to insufficient water levels. These periods occurred on 16 November from 0600 through 1200 hours, and on 28 November from 0400 through the end of the study on 30 November at 2300 hours.

Coho Salmon Run-timing and Population Estimate

Daily Coho Salmon escapement estimates for the Lillooet River during the 6-week sample period in 2019 are presented in Figure 4. The daily distribution of counts indicates that the 2019 sampling period did not represent the entire Coho Salmon migration period, and as such the results reported here should be considered an assessment of only a portion of the Coho Salmon population in the Lillooet River. Given the general pattern of declining daily counts over time, Figure 4 indicates the 2019 sampling period captured the tail end of the migration period. Daily escapement estimates peaked early in the 6-week sampling period with an estimated 228 Coho Salmon passing the site on 19 October. Daily estimates were shown to generally decrease through the remainder of the sampling period with a couple of minor increases on 24 October (177 fish) and 4 and 5 November (102 fish) before declining to 15 fish on 27 November. Coho Salmon migration may have continued past 27 November but given the low river level conditions during the last few days of the study that precluded data collection the actual date in which Coho Salmon migration was completed is uncertain.

The net upstream flux model used to estimate Coho Salmon escapement relates only to fish that are actively migrating, therefore post-spawned moribund fish must be excluded from the downstream term of the flux model equation. The timing in which removal of post-spawned fish from the downstream estimates was to begin was assessed by examining the proportion of daily downstream counts relative to daily net upstream counts (Figure 5). The percentage of downstream counts was shown to increase to 50% on 8 November and remain fairly high through the remainder of the study. The downstream-moving fish observed from 8 November through the remainder of the study period were assumed to be post-spawned moribund fish and were removed from the daily counts and excluded in the calculation of the net upstream counts.

The total escapement point estimate for Coho Salmon in the Lillooet River during the sampling period was 2,124 with an estimated 95% confidence interval of + 276 fish (+ 13%). This confidence interval reflects errors associated with the repeatability of counts (precision) and temporal sub-sampling (representativeness of the sampling). The repeatability of counts using the average percent error (APE) is discussed in the Inter-reviewer Error section; this error contributed less than + 0.1% to the overall error. The temporal sub-sampling error contributed + 13% to the overall error.

Lateral Distribution

The assessment of lateral distributions of Coho Salmon observations in the Lillooet River was not a focus of the 2019 study. For individual fish passage events, detections at range were not reported. However, given that two discrete portions of the river (near-field and far-field zones) were sampled throughout the study period lateral distribution of fish detections can be assessed in a general sense. All observed fish were detected within the near-field zone, and reviewers stated anecdotally that most of the detections occurred within six meters in range from the ARIS. Flow conditions at the site indicated much lower flows along the shore within the near-field zone as compared to further out in the near-field zone as well as in the far-field zone. Assuming that migrating fish tend to follow flow lines that maximize swimming efficiency and minimize energy expenditure, the results reported here regarding migrants hugging the near shore where the lowest flows occur would be expected.

Size Estimation

The measuring tool feature in the ARISFish software was used to estimate the total length of observed fish to separate migrating Coho Salmon from resident fish species. A size threshold of < 40 cm was used to define resident fish and so fish $\geq$ 40 cm were then classified as migrating Coho Salmon. These classifications were based on discussions with Líl̓wat Nation members experienced with handling and measuring fish as well as preliminary data analysis assessing migratory behavior relative to estimated total length. Though the software measuring tool can be used as a surrogate for estimating fish length it is a rather coarse technique when considering the variability in length measurements of a given individual fish that result from differing estimates across different frame images of the same fish. Additionally, there were a number of examples observed in the 2019 data whereby fish length could not be estimated when fish passed immediately in front of the ARIS and their total length exceeded the narrow FOV presented that close to the sonar. In those instances, the fish were clearly > 40 cm and so

were classified as Coho Salmon and tallied in the count but estimated total length was not reported. Despite these limitations in size estimation the estimated total lengths can nonetheless be used to describe in general terms size distributions of Coho Salmon throughout the sampling period. The mean daily estimated size of Coho Salmon migrants observed in the Lillooet River in 2019 (Figure 6) shows that typically the average size ranged from 50 to 62 cm, with a slight increase later in the study with a peak of 65 cm on 27 November.

Hourly Distribution

Upstream counts of Coho salmon were higher during daytime hours as compared to nighttime hours (Figure 7). The period from 1000 through 1800 hours indicated higher relative upstream movement than other hours, with each hour in this period exceeding 5% of the total count. Peak hourly proportional counts occurred during the 1400 and 1700 hours with 8.8% and 7.7% of passage, respectively. Proportional counts generally decreased each hour after 1800 hours through the evening and into the early morning hours with a low of 0.4% occurring during the 0600 hour.

Inter-reviewer Error

Inter-reviewer error was assessed based on a data set of 74 randomly selected 10-minute files reviewed by multiple observers (Table 1). The net upstream counts tallied among the files within the data set ranged from a minimum of 0 fish to a maximum of 3 fish. The average percent error was calculated to be 14% which indicates that repeated independent counts of the ARIS data sets would be expected to produce the same count 86% of the time for net upstream migrating Coho Salmon. The CV, representing average error between observers, was 20%.

Tributary Stream Survey Estimates

Rogers Creek is the most preferred location from an operational standpoint, however there a number of known Coho Salmon bearing streams downstream of Rogers Creek (e.g., Sloquet and Crazy Creek), the spawning abundances of which would not be enumerated by the ARIS. Thus, any escapement estimate generated by the observations with the ARIS would be an underestimate of total Coho Salmon escapement to the Lillooet CU. However, some of these Lower Lillooet River streams are surveyed by the Líl̓wat Nation and escapement estimates could be generated and added to the ARIS estimate to reflect total escapement more accurately.

Annually, the Líl̓wat Nation conducts stream surveys to assess the spawning abundance of Coho Salmon in select tributaries of the Upper and Lower Lillooet watershed. In 2019 surveys were conducted in the Upper Lillooet on thirteen streams, seven of which were observed to have actively spawning Coho Salmon (Alena Creek, Birkenhead River, Green River, Pemberton Creek, Poole Creek, Ryan River and Sampson Creek). In the Lower Lillooet River, six tributaries (Crazy Creek, Gowan Creek, Old Courthouse, Port Douglas, and the Sloquet and Tipella rivers) were similarly assessed and spawning Coho Salmon were observed in all of them (M. Bruce, pers. comm.).

These streams do not account for all Coho Salmon bearing streams in the Lillooet watershed, nor do they provide estimates of total escapement to each tributary or the CU, however they do provide some data with which to explore, if only qualitatively, a few results of this project.

Specifically, the Lower Lillooet tributary data provides a ballpark estimate of the number of Coho Salmon that spawn below Rogers Creek (estimated 276 in 2019, M. Bruce pers. comm.), and the Upper Lillooet data can be used to assess the efficacy of the ARIS such that observed Coho Salmon in the tributaries should be less than the observed Coho Salmon migrating past the ARIS. In 2019, 805 Coho Salmon were observed spawning in the Upper Lillooet, less than the 2,124 Coho Salmon estimated to have passed the ARIS, indicating that the ARIS was sufficient in monitoring passage, which is contrary to our conclusion that the peak migration was missed due to the timing of operations. Here, it is important to note that the 805 is observed (not estimated) salmon, thus the comparison is only casually comparable until estimated escapement to each tributary is available. Further, upon review of the timing of first and last observations to the Birkenhead River (5 November and 27 December, respectively) and Poole Creek (15 November and 29 November, respectively) we can confirm the ARIS was operational throughout this period and would have enumerated these Coho Salmon should they have passed the ARIS. However, given the results of the ARIS provided herein, it appears that these fish migrated into the Upper Lillooet prior to the ARIS becoming operational. Having passed the ARIS prior to operation, fish likely would have held and 'ripened' in Lillooet Lake, for example, prior to entering the tributaries.

CONCLUSIONS AND RECOMMENDATIONS

Results from the 2019 study indicate that the sampling site on the Lillooet River immediately below the mouth of Rogers Creek is an effective sampling location for estimating Coho Salmon escapement using imaging sonar methods. The physical conditions of the river at that location, including relatively narrow width, absence of large woody debris or boulders that could obstruct sonar sampling, and flow apportionment whereby much lower relative flows occur near the river bank where the sonar system is located (and as a result where the fish are most likely to migrate) all contribute to the efficacy of the site. Additionally, ease of access to the location allows for Líl̓wat fisheries technicians to readily get to the site for daily maintenance and data management of the sonar system.

Though the 2019 assessment did show that the Rogers Creek site was proven to be an effective sonar sampling location, the study was not without its shortcomings. The major limitation was the timing of the sampling period. The ARIS system was deployed and operational starting on 18 October. Daily escapement estimates shown in Figure 4 indicate that the Coho Salmon migration was well underway at that point in time. Ideally the ARIS would be in place prior to the beginning of the migration allowing for assessment of the initial stages of the run and subsequent peaks and declines. The assumption in 2019 was that the two-week window around the presumed peak of the migration would be captured using a six-week sampling period starting in mid-October. That assumption was violated as the peak period in the Coho Salmon migration appears to have occurred earlier than expected. As a consequence, the escapement abundance reported herein have limited value for management implications, but can inform future escapement work such that the data is of higher value to management. Specifically, that the ARIS should be operational earlier, by the end of September.

To address study limitations and to continue to improve our sampling methods we provide the following recommendations regarding future studies using ARIS to monitor Coho Salmon and develop escapement estimates in the Lillooet River:

1. Begin ARIS data collection in mid-September to capture the initial stages of the Coho Salmon migration;
2. Extend the sampling period to eight weeks to ensure peak migration periods are captured and potentially capture the entire migration period; and
3. Develop methods to assess species apportionment in order to test the assumption that all migrating fish observed with ARIS are indeed Coho Salmon.

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TABLES

Table 1. Net upstream fish counts for ARIS data files used to assess the repeatability of counts between observers.

	File	Observer				File	Observer		
Date	Start Time	1	2	Mean	Date	Start Time	1	2	Mean
19-Oct	1900	0	0	0.0	29-Oct	1920	0	0	0.0
19-Oct	1910	0	0	0.0	29-Oct	2210	0	0	0.0
19-Oct	2300	0	0	0.0	29-Oct	2220	0	0	0.0
19-Oct	2310	0	0	0.0	30-Oct	1100	2	2	2.0
22-Oct	1210	0	0	0.0	30-Oct	1110	1	1	1.0
22-Oct	1220	0	1	0.5	30-Oct	1410	0	0	0.0
22-Oct	2000	0	0	0.0	30-Oct	1420	0	0	0.0
22-Oct	2010	0	1	0.5	30-Oct	1500	1	1	1.0
22-Oct	2300	0	0	0.0	30-Oct	1510	0	0	0.0
22-Oct	2310	0	0	0.0	30-Oct	1910	1	0	0.5
23-Oct	1200	2	0	1.0	30-Oct	1920	0	0	0.0
23-Oct	1210	1	1	1.0	30-Oct	2110	1	0	0.5
23-Oct	1310	2	2	2.0	30-Oct	2120	1	1	1.0
23-Oct	1320	0	0	0.0	30-Oct	2300	0	0	0.0
23-Oct	1600	0	0	0.0	30-Oct	2310	0	0	0.0
23-Oct	1620	1	1	1.0	31-Oct	0110	0	0	0.0
23-Oct	2300	0	0	0.0	31-Oct	0120	0	0	0.0
23-Oct	2310	0	0	0.0	31-Oct	0700	0	0	0.0
24-Oct	0200	0	0	0.0	31-Oct	0710	0	1	0.5
24-Oct	0210	0	0	0.0	31-Oct	1510	0	0	0.0
24-Oct	0610	0	0	0.0	31-Oct	1520	2	2	2.0
24-Oct	0620	0	0	0.0	31-Oct	1710	0	0	0.0
24-Oct	1300	2	2	2.0	31-Oct	1720	0	0	0.0
24-Oct	1320	1	1	1.0	01-Nov	0310	0	0	0.0
25-Oct	2100	0	0	0.0	01-Nov	0320	0	0	0.0
25-Oct	2110	0	0	0.0	01-Nov	0900	0	0	0.0
26-Oct	1200	1	3	2.0	01-Nov	0910	0	0	0.0
26-Oct	1210	0	0	0.0	01-Nov	1400	2	1	1.5
26-Oct	1700	1	1	1.0	01-Nov	1420	1	1	1.0
26-Oct	1710	0	1	0.5	01-Nov	2310	0	0	0.0
29-Oct	1200	1	0	0.5	01-Nov	2320	0	0	0.0
29-Oct	1210	3	1	2.0	03-Nov	0310	1	0	0.5
29-Oct	1610	2	2	2.0	03-Nov	0320	0	0	0.0
29-Oct	1620	1	1	1.0	03-Nov	0610	0	0	0.0
29-Oct	1700	1	1	1.0	03-Nov	0620	0	0	0.0
29-Oct	1720	0	0	0.0	03-Nov	2110	0	0	0.0
29-Oct	1910	2	1	1.5	03-Nov	2120	0	0	0.0

FIGURES

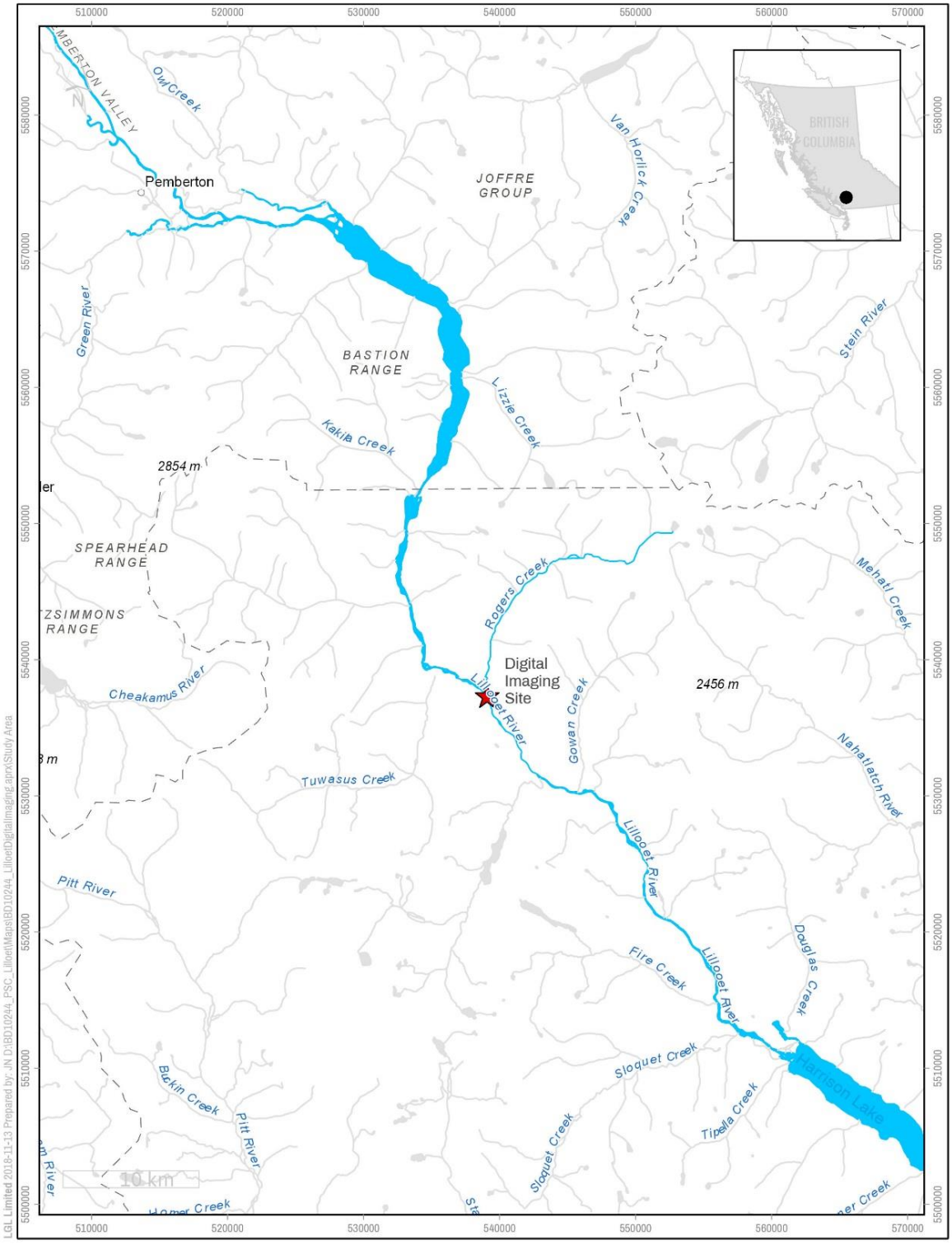

Figure 1. Map of the Lillooet Coho CU and identification of Rogers Creek ARIS site.

Figure 2. Photographs of the H-mount used to deploy the ARIS 1200 in the Lillooet River just below the mouth of Rogers Creek (left) and the portable shed used to house the batteries and electronic components used to operate the ARIS system (right).

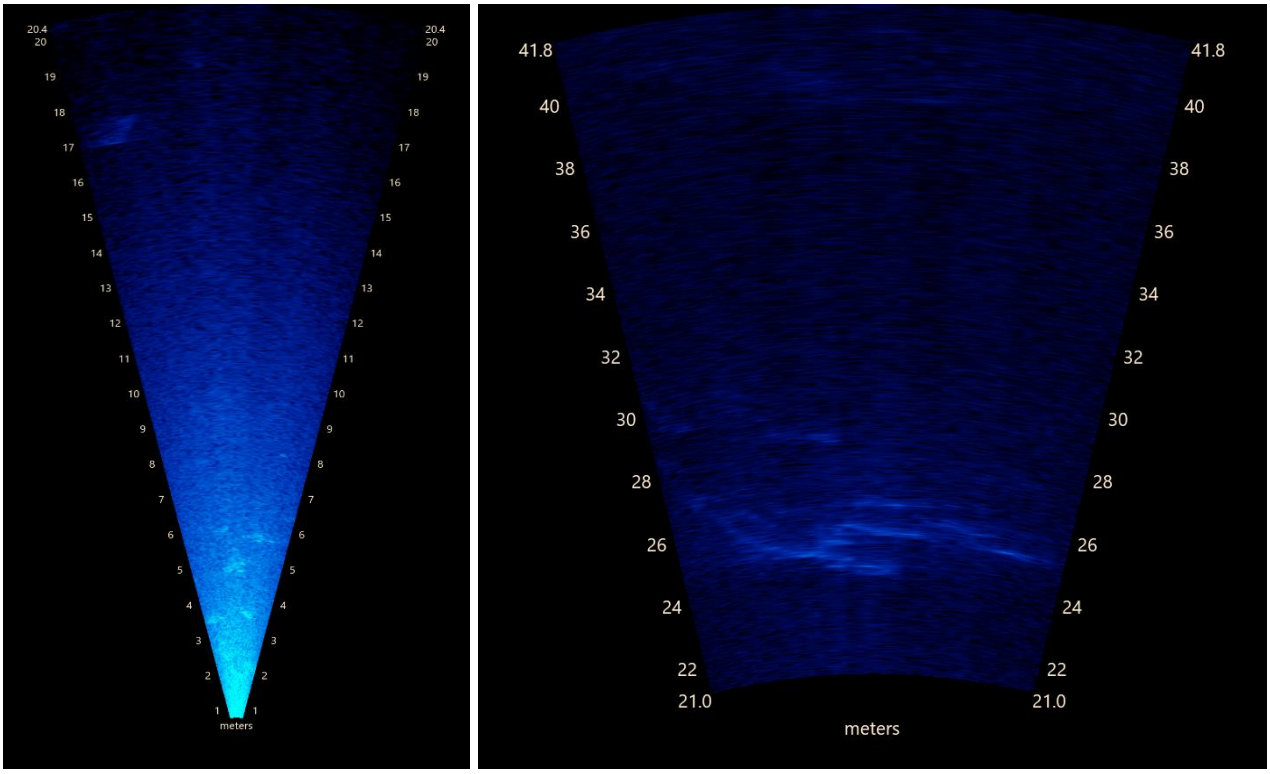

Figure 3. Screen shots taken of still ARIS imagery showing the FOV for the near-field zone (left) and far-field zone (right). Brighter features within the fields-of-view represent cobble and boulder substrate.

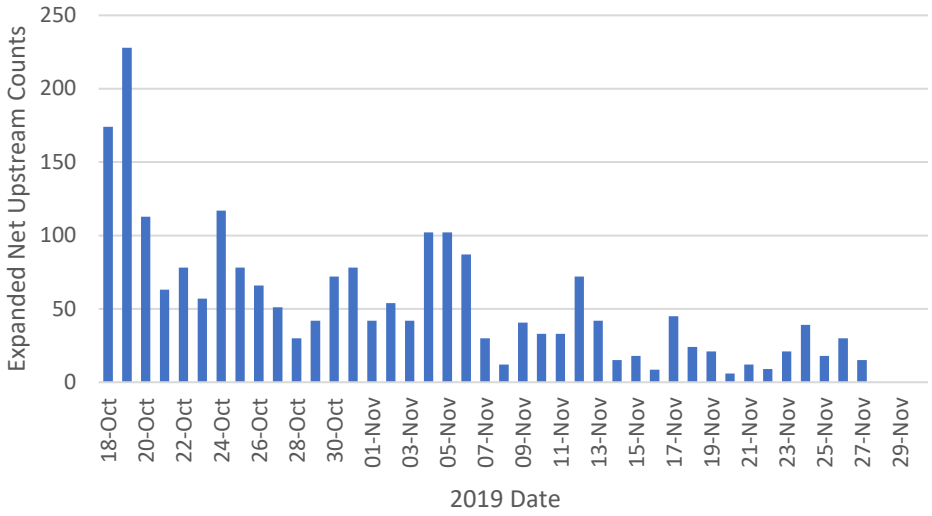

Figure 4. Daily expanded net upstream counts of Coho Salmon migrating past the ARIS site on the Lillooet River in 2019. Note: Operational on 29 November 2019, but no data collected.

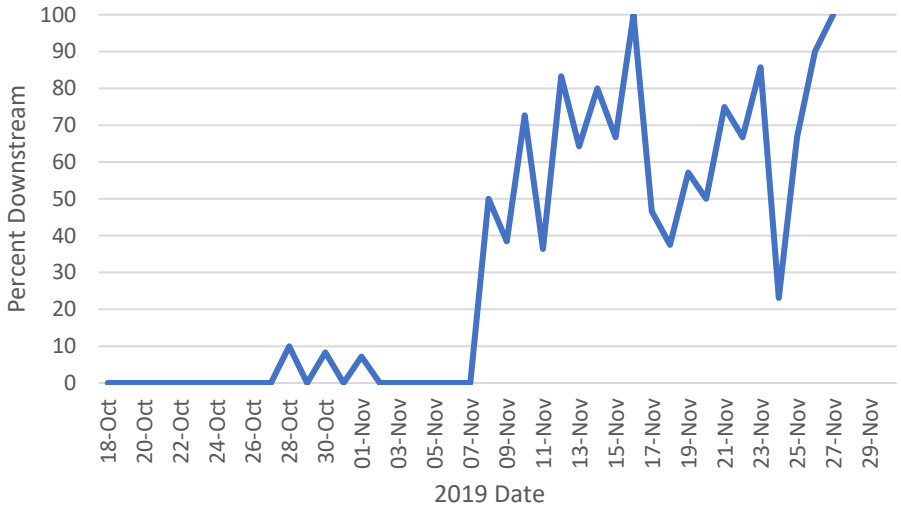

Figure 5. Percentage of daily downstream counts of Coho Salmon at the ARIS site on the Lillooet River in 2019.Note: Operational on 29 November 2019, but no data collected.

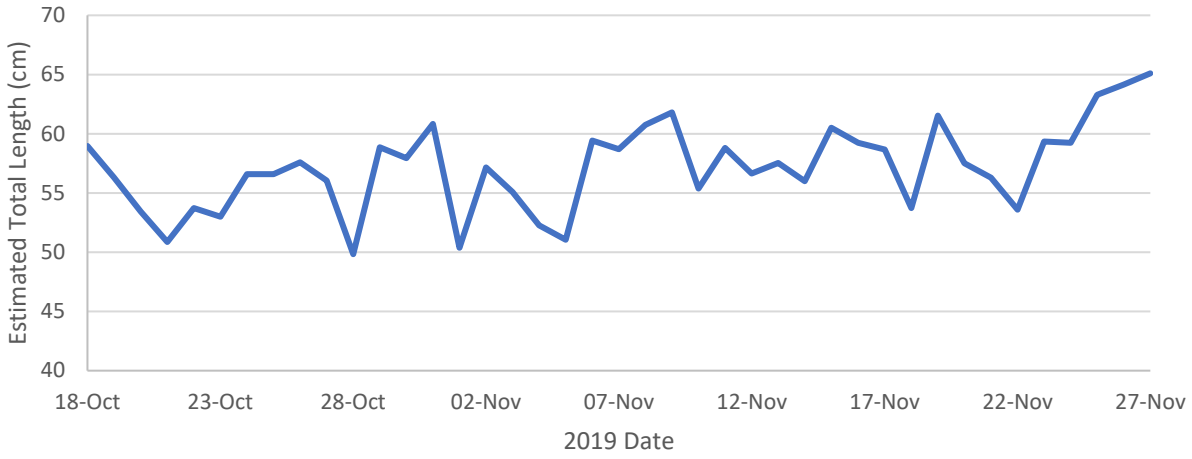

Figure 6. Mean daily estimated total length of Coho Salmon migrating past the ARIS site on the Lillooet River in 2019.

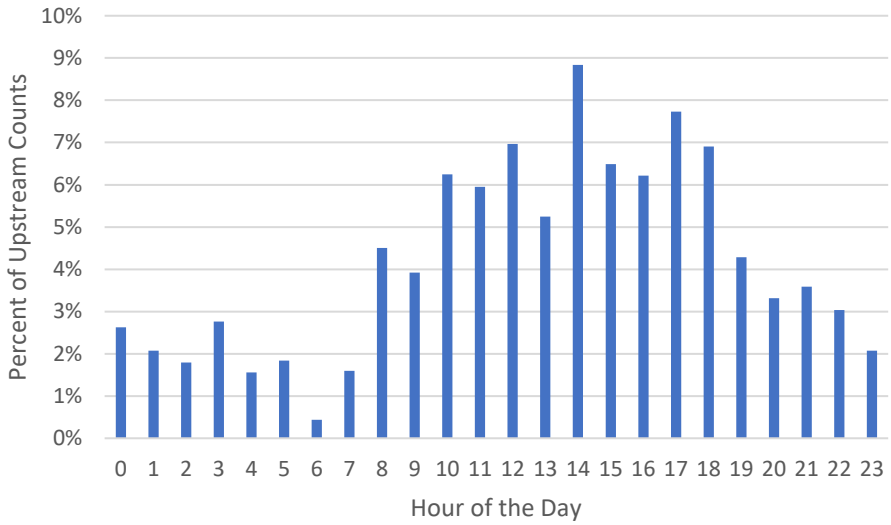

Figure 7. Hourly distribution of upstream counts of Coho salmon migrating past the ARIS site on the Lillooet River in 2019.