2017 Chinook Salmon Sonar Enumeration on the Big Salmon River

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ABSTRACT

A multiple beam sonar unit was used to enumerate the Chinook salmon escapement to the Big Salmon River in 2017. The sonar was operated on the Big Salmon River for its thirteenth year at the same site used since 2005. Sonar operation began on July 16 and continued without significant interruption through August 20. A total escapement of 5,672 Chinook salmon was estimated to have passed the sonar site in 2017. The first Chinook salmon passing the Big Salmon sonar station was observed on July 16, the first day of operations. The peak daily count of 432 fish occurred on July 31, when 47% of the run had passed the sonar site. On August 10 90% of the run had passed the station. Based on the 2017 Big Salmon sonar count and above border escapement estimates from the Eagle sonar project, the Big Salmon run comprised approximately 8.3% of the total above border escapement. A total of 87 Chinook carcass samples were collected between Aug 9 and Aug 26 over approximately 145 km of the Big Salmon River system. Age, length, sex, location and spawning success data was obtained from the samples.

INTRODUCTION

The 2017 Big Salmon River sonar project marks the thirteenth year Chinook salmon enumeration has been conducted on this system by Metla Environmental Inc. (MEI). The DIDSON (Dual frequency Identification Sonar) and ARIS (Adaptive Resolution Imaging Sonar) units used on the Big Salmon and other escapement enumeration projects have been found to be reliable and to provide accurate counts of migrating salmon (Enzhofer et al. 2010, Holmes et al. 2006, Mercer & Wilson 2006 - 2017). Due to high seasonal flows and wilderness recreation use of the Big Salmon River system, the utilization of traditional salmon weir techniques on this river is not feasible. For these reasons a multiple beam sonar was selected as a low impact, non-intrusive method of accurately enumerating annual Chinook escapements into the system. The use of sonar allows for enumeration of migrating Chinook salmon while minimizing negative impacts on fish behaviour and providing un-restricted recreational use of the river. This report is a summary of the results of the 2017 project.

The goal of the program is to provide stock assessment information that will enhance the ability of salmon management agencies to manage Yukon River Chinook salmon. Quantifying Chinook escapement into upper Yukon River index streams allows for independent (from Eagle sonar project estimates) assessment of total above border Chinook escapements. Using accurate Chinook escapement enumeration of select tributaries combined with genetic stock information (GSI), it is possible to generate upper Yukon River Chinook spawning escapement estimates within quantified statistical parameters.

In addition to the sonar operation, carcass sampling was conducted to obtain age, sex and length data from the 2017 Big Salmon Chinook escapement. This information provides important biological baseline data on the health of the stock as well as information used in constructing future pre-season run forecasts.

In 2015 a juvenile chinook mark/recapture and outmigration study was initiated by Fisheries and Oceans Canada (DFO) on the Big Salmon River system. This study was continued in 2017. The existing Big Salmon sonar camp has been used as a base for the project. In addition, personnel associated with the sonar program have assisted with the juvenile assessment project. Information on juvenile production and life history in conjunction with adult escapement information will assist with interpretation of stock recruitment models and could contribute to the management of Canadian-origin Yukon River Chinook salmon stocks.

Based on the 2005 – 2016 sonar operations, the Big Salmon River has been shown to be a significant contributor to upper Yukon River Chinook production. The 2005 -2016 average Big Salmon sonar count is 5,507 (range 1,329 to 10,071). These counts represented an average of 10.2% of the total average upper Yukon River Chinook spawning escapement estimate for these years (JTC 2017).

Study Area

The Big Salmon River flows in a north-westerly direction from the headwaters at Quiet and Big Salmon lakes to its confluence with the Yukon River (Figure 1). The river and its tributaries drain an area of approximately 6,760 km^2, predominantly from the Big Salmon Range of the

Pelly Mountains. Major tributaries of the Big Salmon River include the North Big Salmon River and the South Big Salmon River. The Big Salmon River can be accessed by boat either from Quiet Lake on the South Canol Road, from the Yukon River on the Robert Campbell and Klondike Highways, or from Lake Laberge via the Thirty Mile and Yukon rivers. The sonar site is at a remote location, approximately 130 air kilometers from Whitehorse. It is accessible by either boat or float plane.

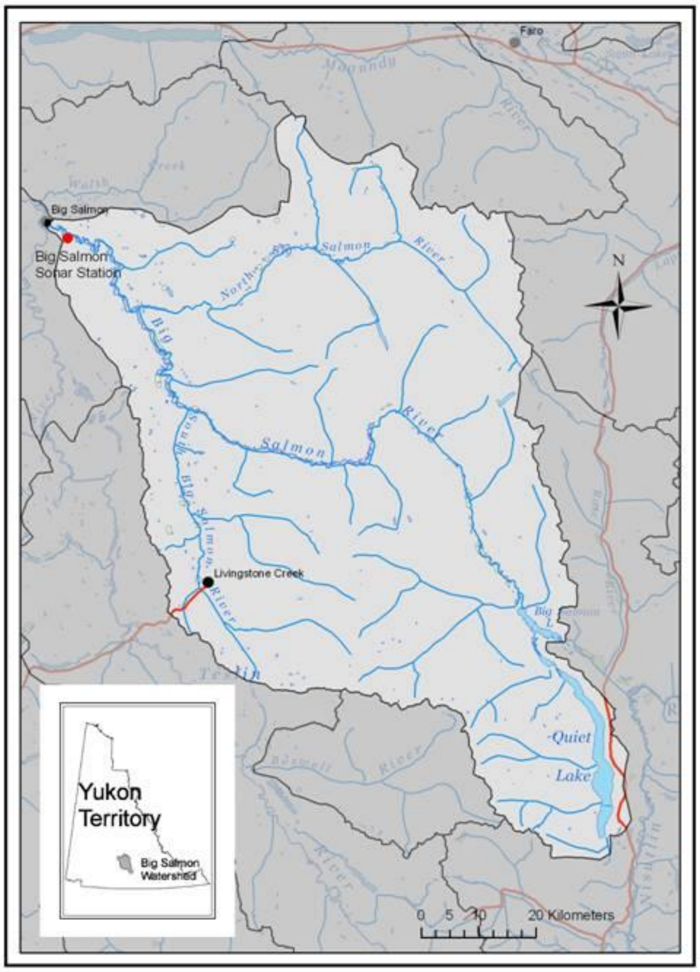

Figure 1. Big Salmon River Watershed and location of the 2017 Big Salmon sonar station.

Objectives

The objectives of the 2017 Big Salmon River sonar project were:

1. Obtain an accurate count of the 2017 Chinook salmon escapement in the Big Salmon River.

2. Obtain age-sex-length (ASL) data from as many post-spawned Chinook as possible with a target goal of 5% of the total run. In addition document egg retention of female spawners and the principal recovery locations of spawned out fish.

3. Support the proposed 2017 Big Salmon River Juvenile Chinook Out-migrant Assessment Study.

METHODS

Site selection

Sonar operations were set up at the same site used since 2005. This site, located approximately 1.5 km upstream from the confluence with the Yukon River (Figure 1), was initially selected for the following reasons:

- It is a sufficient distance upstream of the mouth to avoid straying or milling Chinook salmon destined for other headwater spawning sites.
- The site is in a relatively straight section of the river and far enough downstream from any bends in the river so that recreational boaters using the river have a clear view of the in-stream structures.
- The river flow is laminar and swift enough to preclude milling or 'holding' behaviour by migrating fish.
- Bottom substrates consist of gravel and cobble evenly distributed along the width of the river.
- The stream bottom profile allows for complete ensonification of the water column.
- The site is accessible by boat and floatplane.

The physical characteristics of the river at this site have not changed over the 13 years of sonar operation. It is anticipated that this site will continue to be used as long as the sonar program operates.

Camp and Sonar Station Set-up

Supplies and crew were initially transported from Whitehorse to a pullout along the Robert Campbell Highway 3 km downstream of Little Salmon Village. Subsequent camp access, crew changes, and delivery of supplies were accomplished by riverboat and floatplane from Whitehorse. Set-up of the sonar station was initiated on July 16 and was operational by 18:00 the same day. The sonar unit was placed next to the south bank at the site used in previous sonar operations.

Diversion Fence Construction

Partial fence structures were placed in the river to divert migrating Chinook salmon into a 36 m migration corridor in the center of the river (Figure 2). These were placed in the river on July 6 and 7, approximately 10 days ahead of scheduled sonar operation to take advantage of lower water levels. The fence structures were constructed as in previous years (Mercer & Wilson 2017) using conduit panels and metal tripods.

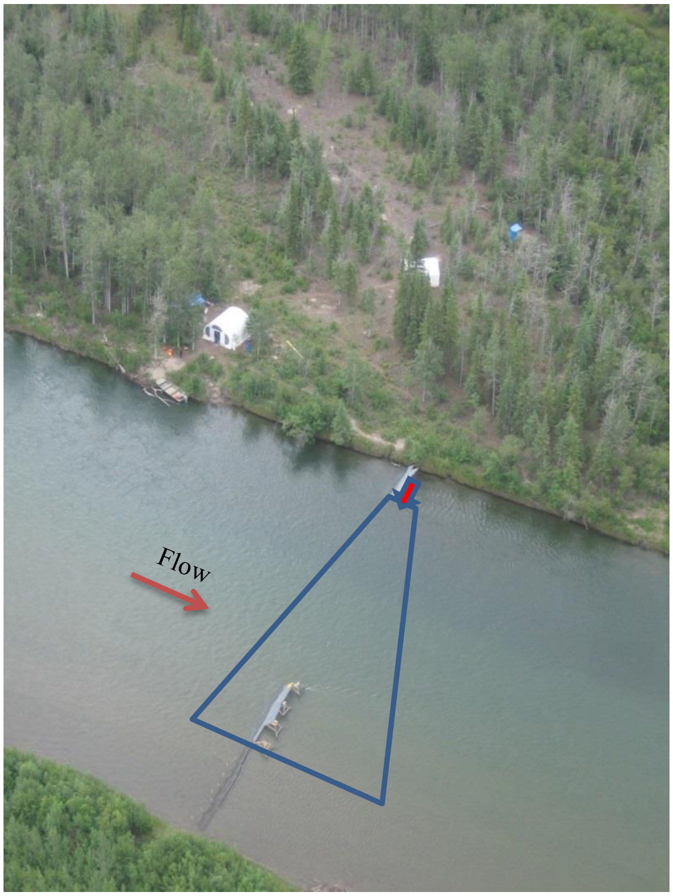

Figure 2. Aerial view of sonar station camp and partial weirs, (photo from 2010 project).
Blue outline denotes ensonified portion of the river.

River Profile

A boat mounted Biosonics DTX split beam sonar, aimed 90° down from the surface, was used to obtain a cross section profile of the river bottom at the sonar site. Data was collected from three bank to bank transects of the river. These transects were located 5m upstream, at the center and 5m downstream of the anticipated sonar beam. The bottom profile was similar for all three transects. The cross section profile where the sonar was deployed is presented in Figure 3. The cross section profile of the river bottom has remained relatively unchanged since the project started in 2005.

ARIS Sonar and Software Configuration

The sonar unit was placed next to the south bank at the same location used in previous sonar operations (Figures 4). The sonar unit was mounted on an adjustable stand constructed of 2-inch steel galvanized pipe and placed. The stand consisted of two T-shaped legs 120 cm in height connected by a 90 cm crossbar. The sonar unit was bolted to a steel plate suspended from the cross bar that was connected to the stand with adjustable fittings (Kee Klamps™). The adjustable clamps allowed the sonar unit to be raised or lowered according to fluctuating water levels as well as enabling rotation of the transducer lens to adjust the beam angle.

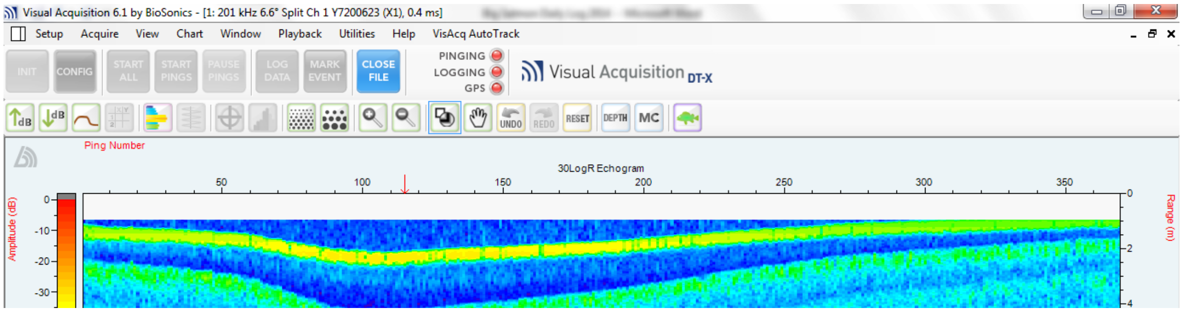

Figure 3. Cross section profile of Big Salmon River at sonar site using a Biosonics DTX split beam echo-sounder.
Note: Top of yellow line is river bottom, thalweg = 1.97 m. Transect view looking down river. The near field of the transducer prevents readings at depths less than 1m as indicated by the white band.

The sonar system was powered by a battery bank of five – 12 volt gel cell batteries connected in parallel to create a 12 volt power source. The battery bank was charged by six 80 watt solar panels and supplemented by a battery charger powered by a 2.0 kW generator. An 800 watt inverter was used to obtain 110 volt AC from the batteries to supply continuous power for the computers and the sonar unit as well as domestic power for the camp. An uninterruptible power supply (UPS) was used to protect the equipment from power surges and occasional power interruptions. As well an alarm system was installed on the recording computer to alert personnel to power interruptions.

The ARIS sonar with a standard lens produces an ensonified field 29° wide in the horizontal plane and 12° in the vertical plane. An 8° concentrator lens was used for the 2017 project. This lens reduces the vertical ensonified field from 14° to 8°, resulting in an increase in the resolution of the target images. The ARIS transducer lens was positioned at a depth of approximately 12 cm below the surface of the river and angled downward approximately 3º from horizontal resulting in the ensonified field of view remaining parallel to the surface of the river.

Using an 8° lens on a sonar unit deployed horizontally results in a beam depth of 1.05 m at a distance of 7.5 m from the sonar. A table, using simple trigonometry formulae, enabled the sonar crew to determine the beam depth for given water depths and sonar window start lengths. Care was taken to insure the sonar beam contacted the river bottom before the end of the deflection fence to insure the entire migration corridor was ensonified.

For optimal resolution of the ensonified targets within the migration corridor the following ARIS sonar settings were used: a) Low frequency (1.1 Mhz), b) 96 sub-beam array, c) Frame rate of 4 frames/sec. and d) Samples per beam set at 2000. The computer equipment used to interface with the sonar consisted of two workstation laptop computers and one HDMI 25 inch video monitor. The computers used I-7 processors, 256 GB solid state hard drives and 16 GB of RAM. This processing capability allowed the technicians to review the files with continuous uninterrupted recording of the data. A third computer was used as a standby machine and for the internet connection.

Sonar Data Collection

The sonar data was collected continuously over the course of the project and stored automatically in pre-programmed, 20 minute date stamped files using the ARIScope software. This resulted in the accumulation of 72 files over a 24 hour period. The files were stored on the recording laptop computer and transferred each day to a 5 TB external hard drive. Each 20 minute file required approximately 250 Mb of hard disc space. It is MEI policy to maintain the ARIScope files on the external hard drive for a minimum of 3 years after the project is completed.

The ARISFish software program was used for reviewing the recorded files and inputting of data. File review typically occurred the day following recording. All 72 files from each day were reviewed. Files were reviewed using a combination of the sonar view platform and echogram view of each file. When the examiner identified a target on the echogram the sonar view was used to observe and measure the fish when required. To optimize target detection in both sonar and echogram view, the background subtraction feature was used to remove the static images such as the river bottom and weir structures. ARISFish software inputs the targets selected by the reviewer into a comma-separated values (CSV) file. Data from the CSV file was inputted into an excel spreadsheet incorporating the counts from each file into hourly and daily counts as well as upstream and downstream movements. Total daily fish counts were derived from the net upstream passage of fish.

Figure 4. Sonar transducer unit and mounting stand in position (2011 Photo).

The target measurement feature of the ARISFish software was used when required to estimate the size of the observed fish. All fish 50 cm and larger were categorized as Chinook. Fish moving downstream identified as live Chinook were subtracted from each file total. It is assumed Chinook migrating downstream were strays. Straying of migrating salmon is not unusual and temporary[1] straying has been documented in telemetry studies of Yukon River Chinook (Eiler et al. 2006). The number of assumed strays detected is typically low and in 2017 amounted to 81 fish or 1.4% of the total run.

Short interruptions in data collection due to equipment maintenance, power interruptions and other technical difficulties are inevitable. All stoppages or gaps in recording coverage were documented. Potentially missed fish were added to the counts by interpolation based on the mean

[1] Radio tagged Chinook were documented entering a tributary and subsequently retreating to the mainstem river and continuing their migration further up the system. Since the sonar station is located 1.5 km upstream from the confluence of the Yukon River the presence of straying Chinook could be expected.

number of fish per hour counted 12 hours before and after the outage. If complete files were missed the Chinook passage was estimated by interpolation of the average file count over the 12 hour period before and after the missing sample event as follows:

$$P_m = \frac{X_a + X_b}{2}$$

Where m is mth missing value, X_a is the mean file count prior to the missing sample event and X_b is the mean file count of the sample after the missing file(s). The interpolated counts were included in the total daily counts reported over the course of the project.

Precision of Fish Counts

It is the practice in some salmon enumeration sonar projects, particularly those with high rates of daily passage, to review and count salmon in a sub-set of recorded data and apply an expansion factor to obtain a total estimate of fish passage. The variance associated with this expansion method can be quantified and incorporated into the total fish passage estimate (Enzenhofer et al., 2010). For the Big Salmon sonar project, all recorded files were reviewed in their entirety so there was no variance associated with the expansion of a sub-set of a file data.

The precision of the Chinook counts was measured by double reviewing a sub-set of all the files recorded. Precision in this case refers to the repeatability of a count between different individuals for the same data file. Files for review were randomly selected from each day of sonar operation. The re-count from each file was recorded for comparison with the original.

The average percent error (APE) method was used to quantify the repeatability (precision) of counts, particularly those counts with high fish passage rates (Enzenhofer *et. al*, 2010). This formula is expressed as:

$$APE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{\left|X_{ij} - \overline{X}_j\right|}{\overline{X}_j}\right]\times 100$$

where N is the number of events counted by R observers, Xij is the ith count of the jth event and Xj is the average count of the jth event.

Because of the relatively low number of fish per hour in most of the Big Salmon sonar files, the percent error could be over-estimated. For example, if the first counter observed 2 upstream fish and the second counter missed one, the APE would be as high as 33%. This is due to the leverage that small numerical differences in low counts have on the overall calculation of APE. For this reason, the average percent error for this project was calculated using files with fish counts ≥ 5 fish/ file.

As well as calculating APE, a sample variance estimator based on the absolute difference between readers was used to quantify the correlation of the counts and the net variability between readers.

Range Distribution

Targets identified as Chinook using the ARISFish software recorded the distance (m) from the sonar for each target selected and inputted into the CSV file. This provided data to construct a range frequency histogram illustrating the cross sectional pattern of migrating Chinook.

Species identification and target testing

An ARIS 1800 sonar with high resolution settings was deployed for 73 hours concurrently with a LR DIDSON sonar. This was done to obtain accurate measurements of a sub-set of the fish passing the station. The ARIS 1800 sonar was deployed 5 m upstream of the LR DIDSON sonar from July 31at 14:00 through August 4 at 11:20. Fish passing through the beams of each of the sonars would be identifiable by the time of passage and the distance from the sonar. The ARIS sonar was configured with a window length of 16 m, a frame rate of 6 frames/second, a 2000 sample rate and a frequency of 1.8 Mhz. These settings resulted in the capture of high resolution images by the ARIS sonar. All fish targets ≥ 50 cm were measured[2] and marked using ARISFish software. ARISFish records data such as time, frame, fish size and range from a fish marked in the sonar view into a .csv format file. The data from each 20 minute file was exported into a master excel spreadsheet after each file was reviewed.

Fish length measurements using a LR DIDSON with a window length of 40 m are not considered accurate (Burwen et. al. 2010; Tuser et al. 2014). Work conducted by MEI at other sonar projects has indicated that it is possible to obtain high resolution images and measurements of fish using an ARIS sonar with the aforementioned settings (Mercer 2017). This work indicated that an ARIS sonar with the above settings produces a mean error of length measurement of 3.1 cm (95% CI +/- 4.9 cm). The purpose of obtaining a subset of accurate Chinook length measurements was to: a) Determine if the fish that were identified as Chinook using the high resolution ARIS images were also identified as Chinook using the LR DIDSON sonar, and b) To archive length frequency data for future use in determining age structure of Big Salmon Chinook.

Carcass Pitch

Access to Chinook spawning areas on the river was via a riverboat powered by a 60 hp outboard jet. Carcass pitch efforts extended from the camp approximately 145 river kilometers to a point located 20 km downstream from Big Salmon Lake.

The carcass pitch involved collecting dead and moribund Chinook and sampling each fish for age, length and sex (ASL). Length measurements (fork length, mid-eye to fork and post orbital to hyperal) were recorded to the nearest 0.5 cm. Five scales were taken from each fish and placed on scale cards for age determination. All sampling data and scale cards were submitted to DFO Whitehorse. Scale age analysis was conducted by the sclerochronology lab, Pacific Biological Station, Nanaimo, British Columbia.

In addition to collection of ASL data, information was collected on the egg retention of the sampled females. The principal locations of the recovered carcasses and moribund fish were also recorded.

[2] Depending on the number of viable frames captured up to 10 separate measurements could be taken for an individual fish in order to select the best image and largest measurement.

RESULTS

Chinook Salmon Counts

The 2017 Big Salmon Chinook run timing was earlier than the previous 12 year average for this stock (Figure 5). The first Chinook salmon was observed on July 16, on the first day of operations. The peak daily count of 432 fish occurred on July 31, at which date 47% of the estimated run had passed the sonar station. The run reached 50% passage on August 1 and ninety percent of the run had passed the station by August 10. Daily and cumulative counts are presented in Appendix 1 and Figure 5.

A total of 5,551 targets identified as Chinook salmon was counted past the sonar station from July 16 through to August 20. Short interruptions in sonar recording due to maintenance or power interruptions resulted in a total of 11 hrs, 13 min recording loss. A total of 152 fish was interpolated for these periods. Because the sonar was removed before the run was completely over, an estimate was obtained of the number of Chinook that passed the station after sonar operations were stopped. This was done through regression analysis of the previous 10 days of the sonar counts based on the logarithmic regression $y = -37.95\ln(x) + 109.22$. This extrapolation added 121 fish to bring the total count to 5,672.

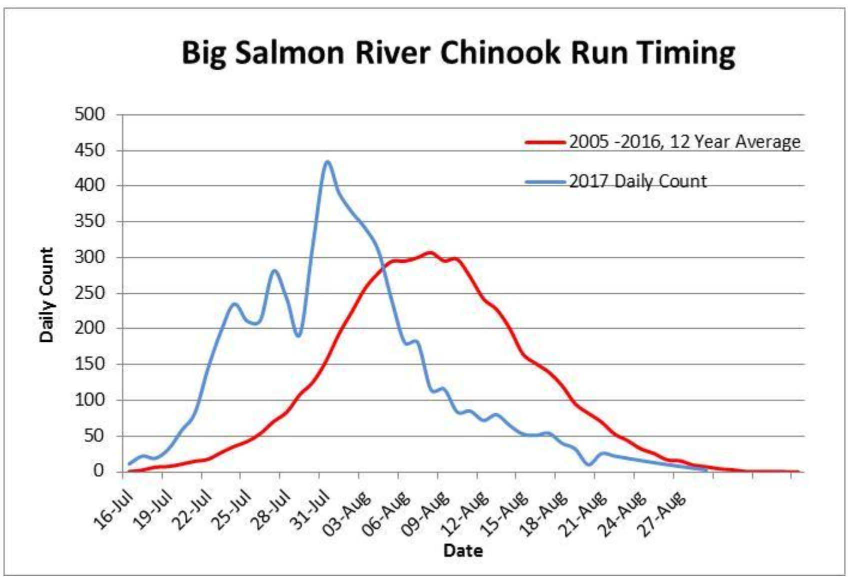

Figure 5. Daily counts of Chinook salmon passing the Big Salmon River sonar station in 2017 and average daily counts 2005 through 2016.

The 2017 Big Salmon Chinook sonar count was similar to the 2005 – 2017 average of 5,507 (Figure 6, Appendix 2).

Precision of Counts

Of the 2,490 sonar files recorded and analysed, a total of 103 (4.2%) was reviewed by a second observer (Table 1). Of the 103files reviewed, 7 files (5.8%) exhibited a discrepancy in the total target count between readers. Of the 7 files that exhibited an inconsistency between readers, an additional 6 fish were observed and 1 fish missed in the reviews.   This yields a net gain of 5 fish for the 103 files that were reviewed representing 2.3% of the fish counted in the first iteration.

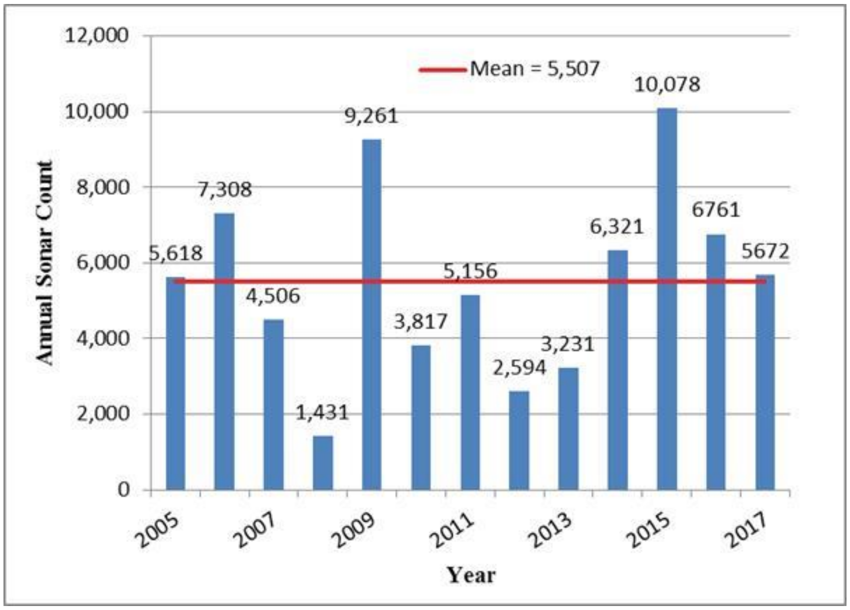

Figure 6.   Annual sonar counts for Big Salmon sonar project 2005 – 2017.

Table 1. Double reviewed files and calculated difference between counts.

	Count	**%**
Total files recorded during project	2,490	
Total files double reviewed	103	4.1%
Total fish counted first iteration	213	
Total fish counted first iteration	219	
Total files with + divergence	6	5.8%
Total files with - divergence	1	1.0%
Total Files with divergence	7	6.8%
Net difference in target count	5	2.3%

The average percent error was calculated for 13 reviewed files that had fish counts ≥ 5 fish/file. The average percent error for this subset was 0.06%. Figure 7 illustrates the relationship between counts of 2 different file readers using daily pooled original (reader 1) and reviewed files (reader 2). The Pearson correlation between the separate file reviewers = 0.99, (R (11) $p<0.001$).

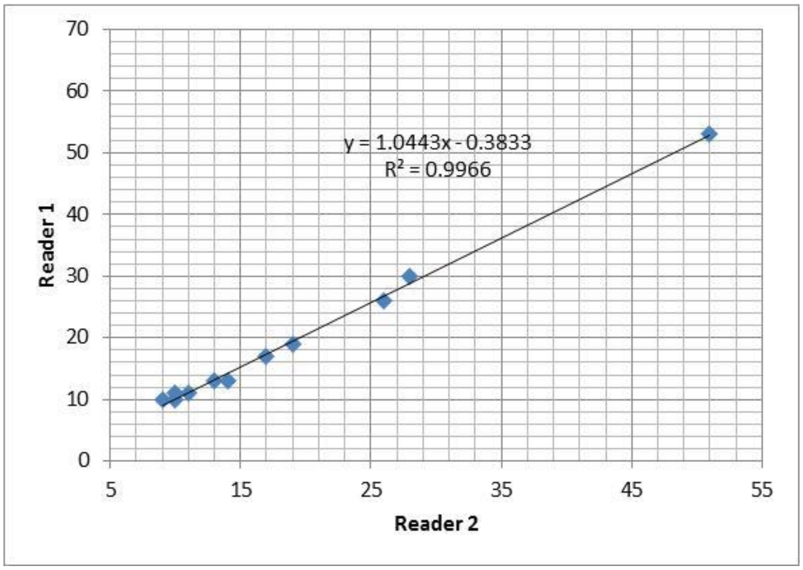

Figure 7. Linear regression between daily pooled sonar file Chinook counts examined by two separate readers.
Note: Data points are daily pooled initial file counts (y axis) and reviewed file counts (x axis).

Range Distribution

The cross section pattern of migrating Chinook at the sonar site in 2017 is presented in Figure 8.[3] As occurred in previous years (Mercer & Wilson 2017) the largest proportion of fish migrated near the south bank in deeper water at a distance of 5-20 meters from the sonar. In 2017 more Chinook were observed passing at the 33-36 m range than in previous years and are likely fish deflected by west bank weir.

Species Identification

A total of 618 fish passing the station between 15:40 on July 31 and 04:20 on August 4 was detected and measured using high resolution ARIS sonar imagery. This subset represented 46% of the 1,111 Chinook counted past the station by the concurrently operating LR DIDSON sonar. The lengths of these fish ranged from 50 cm to 110 cm. A length frequency histogram of this subset is illustrated in Appendix 4.

Carcass Pitch

A total of 87 dead or moribund Chinook was recovered during the carcass pitch. Mean length and age data is presented in Table 2. Of the fish sampled, 45 (51.7%) were female and 42 (48.3%) were male. The mean fork length (MEF) of females and males sampled was 816 mm and 736 mm, respectively. Complete age data was determined from 61 of the Chinook sampled; the remaining 26 samples yielded partial or no ages due to regenerate scales. Females were predominately age-6 (1.4) (37%) and males predominantly age-5 (1.3) (24%). The length frequency of Chinook sampled is presented in appendix 4.

[3] The distribution observed from sonar data may not reflect the natural in-river migration pattern at this location as the weir structures channel the fish into the 36 m wide corridor.

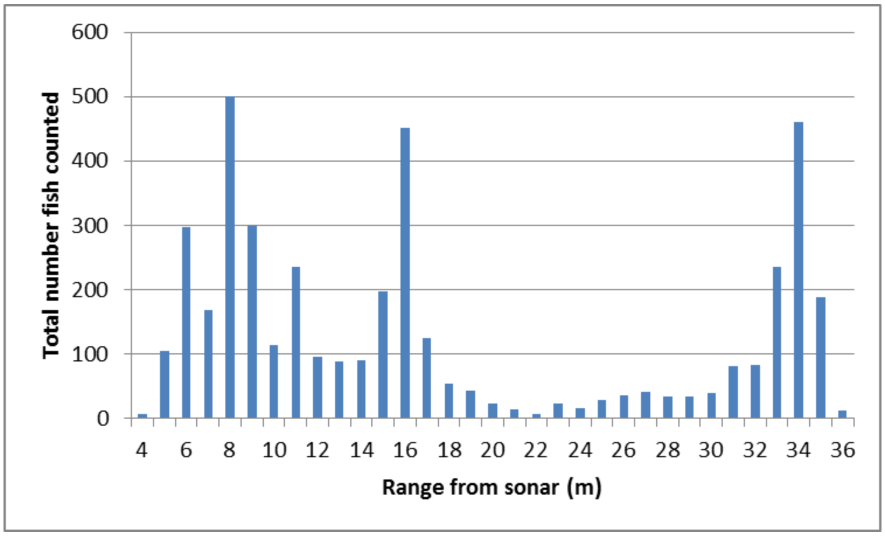

Figure 8. 2017 Big Salmon River Chinook range/frequency in cross section profile.
Note: The 0 – 5m range from the sonar has a deflection fence in place.

Table 2. Age, length, and sex of Chinook sampled from the Big Salmon River, 2017.

SEX	AGE	Mean MEF (mm)	Count	%
Female	1.3	773	4	5%
	1.4	817	29	37%
	M3	750	1	1%
	M4	825	9	11%
Female total			43	54%
Male	1.1	420	1	1%
	1.2	575	1	1%
	1.3	729	19	24%
	1.4	834	7	9%
	M2	637	3	4%
	M3	780	1	1%
	M4	835	4	5%
Male total			36	46%
Total			79	100%

Of the 44 females examined (in which egg retention could be determined), 15 (34.1%) were not fully spawned out. Of the females not fully spawned out, 10 were found to have 50% or more egg retention. Complete age, length and sex data as well as egg retention and principal recovery locations are presented in Appendix 5 (b).

DISCUSSION

The 2017 Big Salmon sonar project was successful in enumerating the Chinook salmon passing the station throughout the course of the run. Other than the 11 hours and 13 minutes when the sonar was not operating due to maintenance and power issues no significant problems were encountered with the sonar and related equipment. Water levels at the sonar station were considered average with no high water events affecting the sonar operation (Appendix 3).

A high degree of precision was observed between reviewers. The precision between reviewers was higher than the previous 3 years and may be due to the experienced technicians engaged on the project. As occurred in the past 3 years, the reviewed file counts resulted in a net gain of fish. This would suggest that the 2017sonar count could be biased low by approximately 2% of the total count as a result of missed fish.

Obtaining accurate measurements of a sub-set of the Big Salmon Chinook could provide additional information on the age class of the escapement into the system. Mixture modeling techniques have been developed to quantify age and species composition of fish stocks using multiple beam sonar (Key et al. 2016, Gurney et al. 2014). Accurate length frequency data has been collected in 2016 and 2017. It is recommended these techniques be explored if the Big Salmon program continues. The ARIS sonar measurements of Chinook encompassed a wider range than the Chinook sampled from the carcass pitch (Appendix 4). This is likely due to the smaller carcass pitch sample set.

The ARIS sonar is considered the second generation of multiple beam sonars manufactured by Sound Metrics Corporation. The use of an ARIS 1800 sonar and ARISFish software provides better downrange resolution of the fish targets and increases efficiency when reviewing the data. It is recommended the ARIS sonar be used on this project rather than the LR DIDSON.

The 2017 Eagle sonar project on the Yukon River downstream of the Canada/U.S. border yielded a total count of 73,313 Chinook. The above border spawning escapement[4] estimate was 68,315 (JTC 2017, preliminary). Based on the Big Salmon and Eagle Chinook sonar counts, the Big Salmon stock contributed 8.3% of the total above border Chinook escapement in 2017.

Genetic stock identification (GSI) samples were obtained at the Eagle sonar site using drift gillnets. The GSI data provides information on the proportional stock composition of the total above border Yukon River Chinook escapement. The 2017 un-weighted contribution of the Big Salmon River stock to the total Chinook above border escapement based on analysis of the GSI samples was 8.5%, (SD 1.5%) (DFO Whitehorse unpublished data). The 2017 sonar and GSI data correlate well. Appendices 6 and 7 illustrate the relationship between the Eagle sonar counts and the Big Salmon sonar counts from 2005 through 2017. As expected there is a correlation between the annual Big Salmon sonar counts and the JTC above border escapement estimates (Pearson corr. =.82, R (11) $p<0.001$).

The 2017 carcass pitch component of the project was planned with an extension of the carcass pitch period by approximately 4 days over that of previous years. The expansion of the carcass pitch effort was initiated to reduce the level of sampling bias associated with carcass sampling (Mercer and Wilson 2017). Because of high water conditions during the carcass pitch the number of samples collected was lower than anticipated and the collection period was terminated earlier than planned.

An ongoing DFO juvenile Chinook salmon research project was again based at the Big Salmon sonar site in 2017. During the operation of the sonar project one of the sonar technicians assisted

[4] Spawning escapement is the Eagle sonar count minus the catches in the U.S. upstream of the sonar station and in the Canadian fisheries.

on the juvenile Chinook project. This did not unduly affect sonar operations and if both projects are conducted again in 2018 a similar arrangement could be made.

ACKNOWLEDGEMENTS

Several people contributed to the successful operation of the 2017 Big Salmon River sonar project. David McDonald and Christine Bylenga were the sonar technicians and conducted the carcass pitch. Sara Preiksaitis assisted with file review and with the juvenile Chinook research project. Norma Barnard assisted with weir installation. The project was funded by the Yukon River Restoration and Enhancement Fund.

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Appendix 1. 2017 daily and cumulative counts of Chinook salmon at the Big Salmon River sonar site.

DATE	DAILY COUNT	CUMULATIVE	COMMENTS
16-Jul	11	11	Sonar begins recording at 1800h
17-Jul	22	33	
18-Jul	19	52	
19-Jul	32	84	
20-Jul	58	142	
21-Jul	82	224	
22-Jul	144	368	
23-Jul	197	565	
24-Jul	235	800	
25-Jul	211	1011	
26-Jul	212	1223	
27-Jul	281	1504	
28-Jul	243	1747	
29-Jul	192	1939	
30-Jul	317	2256	
31-Jul	432	2688	peak daily count
01-Aug	390	3078	
02-Aug	363	3441	
03-Aug	341	3782	
04-Aug	309	4091	
05-Aug	241	4332	
06-Aug	181	4513	
07-Aug	181	4694	
08-Aug	115	4809	
09-Aug	116	4925	
10-Aug	84	5009	
11-Aug	85	5094	
12-Aug	72	5166	
13-Aug	80	5246	
14-Aug	65	5311	
15-Aug	53	5364	
16-Aug	51	5415	
17-Aug	54	5469	
18-Aug	40	5509	
19-Aug	32	5541	Last full day of recording
20-Aug	10	5551	
21-Aug	26	5577	
22-Aug	22	5599	
23-Aug	19	5618	
24-Aug	16	5633	
25-Aug	13	5646	
26-Aug	10	5657	
27-Aug	8	5664	
28-Aug	5	5669	
29-Aug	3	5672	Final estimate based on interpolation

Note: shaded area denotes interpolated counts

Appendix 2. Daily and average Chinook counts in the Big Salmon River, 2005-2017.

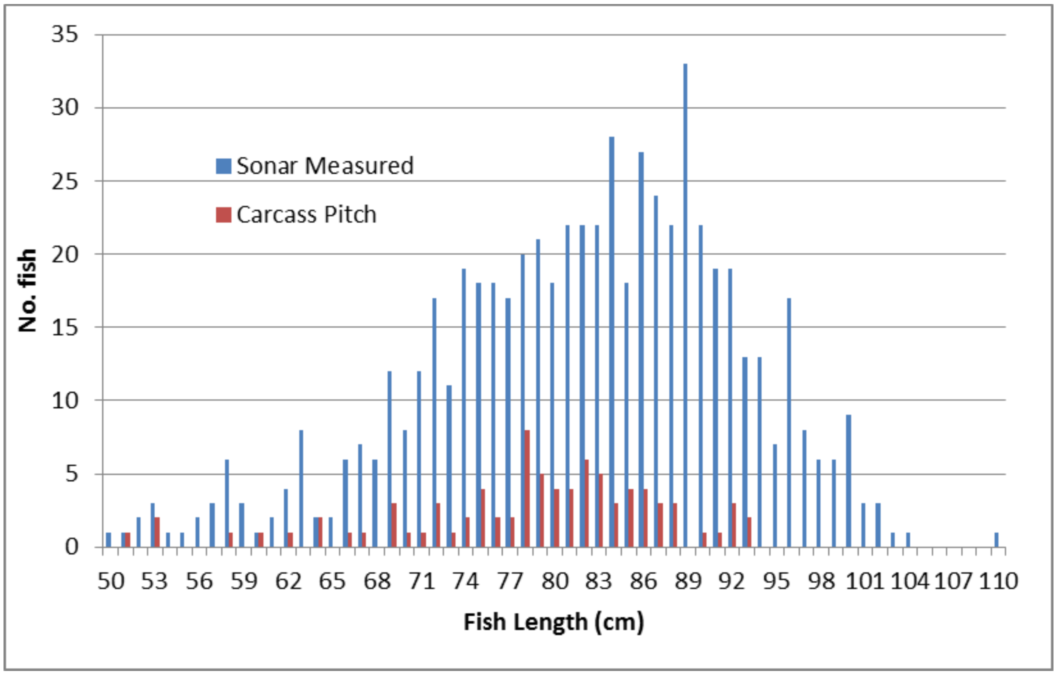
DATE	Daily Count 2005	Daily Count 2006	Daily Count 2007	Daily Count 2008	Daily Count 2009	Daily Count 2010	Daily Count 2011	Daily Count 2012	Daily Count 2013	Daily Count 2014	Daily Count 2015	Daily Count 2016	Daily Count 2017	Daily Average
11-Jul										2		3		**3**
12-Jul										18		11		**15**
13-Jul	0									52		27		**26**
14-Jul	0									52		36		**29**
15-Jul	2	1								64	5	57		**26**
16-Jul	12	0	2	0					0	90	17	56	11	**21**
17-Jul	13	1	0	0			2		0	115	25	56	22	**23**
18-Jul	23	0	2	0	0		7	0	0	170	39	82	19	**29**
19-Jul	13	0	5	1	11		13	0	0	199	72	113	32	**38**
20-Jul	23	1	5	0	22	0	15	0	0	236	81	126	58	**44**
21-Jul	36	3	7	0	47	7	24	0	1	229	117	171	82	**56**
22-Jul	58	8	11	0	68	14	24	0	1	284	148	226	144	**76**
23-Jul	92	11	18	1	85	12	43	0	2	345	217	174	197	**92**
24-Jul	130	21	26	2	135	7	44	0	4	343	312	271	235	**118**
25-Jul	158	20	52	1	201	12	50	1	3	356	411	240	211	**132**
26-Jul	204	53	88	3	226	14	56	1	11	372	538	292	212	**159**
27-Jul	219	95	153	5	346	27	105	1	25	421	494	428	281	**200**
28-Jul	287	146	237	9	498	46	160	3	44	307	531	430	243	**226**
29-Jul	290	230	287	9	532	83	192	15	86	380	588	394	192	**252**
30-Jul	299	321	337	29	594	123	218	12	83	330	586	409	317	**281**
31-Jul	279	368	400	21	808	141	218	23	150	256	492	377	432	**305**
01-Aug	333	357	435	23	578	159	260	62	196	207	568	362	390	**302**
02-Aug	346	379	331	18	715	182	313	76	220	207	485	329	363	**305**
03-Aug	303	358	304	16	725	216	417	138	264	192	441	309	341	**310**
04-Aug	292	413	258	31	595	226	426	156	262	190	451	245	309	**296**
05-Aug	331	496	210	51	559	215	396	196	261	170	452	235	241	**293**
06-Aug	214	490	178	55	452	221	400	228	225	120	469	222	181	**266**
07-Aug	188	464	147	78	364	227	317	192	191	114	449	177	181	**238**
08-Aug	232	464	59	61	295	242	294	235	195	96	397	161	115	**219**
09-Aug	234	360	74	70	270	248	243	183	156	68	348	157	116	**194**
10-Aug	203	349	90	98	209	183	160	154	132	61	246	101	84	**159**
11-Aug	124	348	82	122	183	207	170	106	134	50	217	77	85	**147**
12-Aug	126	324	98	107	146	174	143	130	113	46	187	79	72	**134**
13-Aug	125	243	77	109	118	181	100	110	101	25	201	58	80	**118**
14-Aug	72	196	74	89	117	134	85	81	77	30	126	63	65	**93**
15-Aug	57	180	66	78	65	114	89	80	65	24	113	52	53	**80**
16-Aug	40	172	56	70	55	82	63	94	57	24	91	33	51	**68**
17-Aug	53	104	40	49	63	80	35	70	34	17	65	26	54	**53**
18-Aug	47	69	64	45	55	53	20	50	32	15	54	20	40	**43**
19-Aug	35	87	37	17	43	40	18	44	21	14	28	10	32	**33**
20-Aug	29	59	47	18	35	24	21	38	28	11	10	18	10	**27**
21-Aug	26	45	11	15	28	18	11	27	20	9	7	15	26	**20**
22-Aug	19	50	16	16	14	38	2	19	10	6		12	22	**19**
23-Aug	17	12	23	9	4	24	2	19	14	3		9	19	**13**
24-Aug	13	10	17	2		20		14	11	1		6	16	**11**
25-Aug	9		14	1		17		9	6			4	13	**9**
26-Aug	6		14			6		6	4			2	10	**7**
27-Aug	4		13					5	2				8	**6**
28-Aug	2		11					3	1				5	**4**
29-Aug			9					2					3	**5**
30-Aug			8					1						**5**
31-Aug			6											**6**
01-Sep			4											**4**
02-Sep			3											**3**
TOTAL:	**5618**	**7308**	**4506**	**1329**	**9261**	**3817**	**5156**	**2584**	**3242**	**6321**	**10078**	**6761**	**5672**	

Note: Stippled areas are interpolated counts. Shaded areas denote start and end of sonar recording

Appendix 3. 2017 Big Salmon River water conditions.

DATE	TIME	WATER TEMP. (ºC)	WATER LEVEL (cm)
17-Jul	9:00	11	-
18-Jul	9:00	11	70
19-Jul	9:00	11	73
20-Jul	9:00	12	73
21-Jul	9:00	12	67
22-Jul	9:00	13	58
23-Jul	9:00	13	54
24-Jul	9:00	13	50
25-Jul	9:00	14	47
26-Jul	9:00	14	56
27-Jul	9:00	13	42
28-Jul	9:00	12	45
29-Jul	9:00	12	74
30-Jul	9:00	12	71
31-Jul	9:00	11	63
01-Aug	9:00	13	60
02-Aug	9:00	12	56
03-Aug	9:00	12	52
04-Aug	9:00	13	48
05-Aug	9:00	13	45
06-Aug	9:00	13	42
07-Aug	9:00	13	40
08-Aug	9:00	14	38
09-Aug	9:00	13	35
10-Aug	9:00	14	32
11-Aug	9:00	14	30
12-Aug	9:00	13	28
13-Aug	9:00	13	25
14-Aug	9:00	13	25
15-Aug	9:00	12	27
16-Aug	9:00	10	29
17-Aug	9:00	11	27
18-Aug	9:00	10	23
19-Aug	9:00	10	25
20-Aug	9:00	9	26
21-Aug	9:00	-	28
22-Aug	9:00	-	26
23-Aug	9:00	-	70
24-Aug	9:00	-	73
25-Aug	9:00	-	73
26-Aug	9:00	-	67

Appendix 4. Length frequency histogram of sampled Big Salmon Chinook from carcass pitch (Fork Length) and ARIS sonar derived measurements (total length).



Appendix 5 (a). Age, sex, and length of sampled Chinook on the Big Salmon River, 2017.

DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *	LOCATION
9-Aug	1	F	30	930	840	735	14	sonar site
16-Aug	2	F	0	825	760	660	14	sonar site
18-Aug	3	F	0	965	875	760	M4	sonar site
22-Aug	4	M		860	770	675	14	1
22-Aug	5	F	0	910	830	730	14	1
22-Aug	6	F	95	850	770	690	14	1
22-Aug	7	M		930	820	725	M4	2
22-Aug	8	M		1040	915	790	M4	2
22-Aug	9	M		795	715	625	13	2
22-Aug	10	F	75	920	845	745	14	2
22-Aug	11	M		1040	910	790	14	2
22-Aug	12	M		980	865	745	14	2
22-Aug	13	M		1000	875	740	13	2
22-Aug	14	F	10	880	800	700	14	2
22-Aug	15	M		810	720	625	14	2
22-Aug	16	M		1075	940	830	1F	2
22-Aug	17	F	100	975	880	810	14	2
22-Aug	18	F	100	910	815	750	14	2
22-Aug	19	M		890	780	705	M3	2
22-Aug	20	F	100	1010	920	830	no age	2
22-Aug	21	F	0	990	900	810	14	2
22-Aug	22	F	10	945	855	760	M4	2
22-Aug	23	M		970	870	780	14	2
23-Aug	24	F	100	935	850	740	14	3
23-Aug	25	F	100	890	810	710	M4	3
23-Aug	26	M		740	655	575	13	3
23-Aug	27	M		965	830	730	13	3
23-Aug	28	M		810	715	630	13	3
23-Aug	29	F	100	930	850	770	14	3
23-Aug	30	F	100	910	830	745	14	3
23-Aug	31	M		880	775	670	13	4
23-Aug	32	M		965	840	730	13	4
23-Aug	33	M		855	760	670	1F	4
23-Aug	34	M		840	745	645	13	4
23-Aug	35	M		640	575	495	12	5
23-Aug	36	M		710	640	570	13	5
23-Aug	37	M		1050	920	800	14	5
23-Aug	38	F	100	860	780	705	14	5
23-Aug	39	F	100	930	835	740	14	5
23-Aug	40	F	100	875	790	690	14	5
23-Aug	41	M		860	745	650	13	5

DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *	LOCATION
24-Aug	42	F	100	860	780	695	14	6
24-Aug	43	F	100	885	810	720	14	6
24-Aug	44	M		585	530	450	13	6
24-Aug	45	F	100	895	815	730	M4	6
24-Aug	46	M		670	605	525	M2	6
24-Aug	47	M		765	690	595	no age	6
24-Aug	48	M		840	750	660	M4	7
24-Aug	49	M		970	860	760	13	7
24-Aug	50	F	100	920	830	740	M4	7
24-Aug	51	M		860	780	675	14	8
24-Aug	52	M		745	670	580	1F	8
24-Aug	53	M		590	530	465	13	8
25-Aug	54	M		760	685	605	13	9
25-Aug	55	F	100	930	830	760	14	9
25-Aug	56	F	N/A	1040	940	830	14	9
25-Aug	57	F	100	880	805	710	M4	9
25-Aug	58	F	50	900	820	725	14	9
25-Aug	59	M		800	690	640	M2	9
25-Aug	60	M		700	630	550	1F	9
25-Aug	61	M		710	635	560	13	9
25-Aug	62	M		830	735	660	13	9
25-Aug	63	F	90	865	785	700	14	10
25-Aug	64	F	100	880	800	710	M4	10
25-Aug	65	F	100	925	850	750	M4	10
25-Aug	66	F	90	790	725	645	13	10
25-Aug	67	M		970	855	755	M4	10
25-Aug	68	F	100	860	780	700	13	11
25-Aug	69	F	100	820	740	660	14	11
26-Aug	70	M		570	510	440	no age	12
26-Aug	71	F	100	860	785	710	M4	12
26-Aug	72	M		460	420	365	11	12
26-Aug	73	F	100	955	870	775	14	12
26-Aug	74	F	50	880	800	700	14	12
26-Aug	75	F	100	905	820	730	14	12
26-Aug	76	F	25	815	750	660	M3	12
26-Aug	77	F	100	880	795	705	13	12
26-Aug	78	F	100	835	765	670	14	12
26-Aug	79	F	100	895	815	725	1F	12
26-Aug	80	F	100	880	785	715	14	12
26-Aug	81	M		880	780	695	13	12
26-Aug	82	F	100	890	810	720	14	13
26-Aug	83	F	0	855	775	680	14	13
26-Aug	84	M		795	710	640	13	13
26-Aug	85	M		960	860	770	13	13

DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *	LOCATION
26-Aug	86	F	95	870	790	705	13	13
26-Aug	87	M		680	615	540	M2	13

*European age format; e.g. 1.3 denotes a 5 year old fish with 1+ years freshwater residence and 3 years marine residence

No age = scales regenerate (center is missing from scale) or resorbed (growth at scale margin is missing)
M = Marine stage
F = Freshwater stage
N/A = Partially decomposed or consumed, no assessment.
NM = no measurement obtained due to partial decomposition

Appendix 5 (b). Primary locations of sampled carcasses and moribund fish recovered on the Big Salmon River, 2017.

Recovery Site	* GPS Coordinates
sonar site	N 61˚ 52' 44.2"
	W 134˚ 53' 24.9"
1	N 61˚ 35' 41.8"
	W 133˚ 49' 06.6"
2	N 61˚ 41' 47.1"
	W 134˚ 31' 19.1"
3	N 61˚ 41' 00.1"
	W 134˚ 30' 27.6"
4	N 61˚ 39' 43.3"
	W 134˚ 31' 32.1"
5	N 61˚ 37' 00.8"
	W 134˚ 29' 05.2"
6	N 61˚ 31' 48.3"
	W 134˚ 02' 18.0"
7	N 61˚ 35' 38.6"
	W 133˚ 41' 41.1"
8	N 61˚ 36' 53.5"
	W 133˚ 45' 18.7"
9	N 61˚ 33' 41.1"
	W 134˚ 18' 20.4"
10	N 61˚ 36' 52.8"
	W 134˚ 28' 37.0"
11	N 61˚ 37' 00.8"
	W 134˚ 29' 05.2"
12	N 61˚ 39' 33.0"
	W 134˚ 30' 08.0"
13	between site 12 and sonar camp

Appendix 6. Estimated proportion of Big Salmon River Chinook and Yukon River Chinook border escapement, 2002 through 2017.

Year	Method	Estimated % proportion of border escapement based on telemetry or GSI sampling	Big Salmon sonar count	Border escapement based on Eagle sonar count or mark/recapture	Border escapement [d] based on Big Salmon sonar count and GSI stock proportion
2002	Telemetry	9.2	n/a	n/a	n/a
2003	Telemetry	15.1	n/a	n/a	n/a
2004	Telemetry	10.0	n/a	n/a	n/a
2005	Fishwheel GSI Sampling	10.8	5,618	67,985 [c]	52,019
2006	Fishwheel GSI Sampling	9.7	7,308	62,630 [c]	75,340
2007	Fishwheel GSI Sampling	10.6	4,506	34,904 [b]	42,509
2008	Fishwheel GSI Sampling	9.3	1,431	33,883 [b]	15,387
2009	Gillnet GSI Sampling	16.9	9,261	65,278 [b]	54,799
2010	Gillnet GSI Sampling	11.7	3,817	32,010 [b]	32,624
2011	Gillnet GSI Sampling	9.2	5,156	50,780 [a]	56,043
2012	Gillnet GSI Sampling	6.7	2,594	32,658 [a]	38,104
2013	Gillnet GSI Sampling	6.6	3,239	28,669	49,136
2014	Gillnet GSI Sampling	2.4	6,321	63,331	263,375
2015	Gillnet GSI Sampling	9.7	10,078	82,674	103,896
2016	Gillnet GSI Sampling	9.0	6,762	68,798	75,122
2017	Gillnet GSI Sampling	8.5	5,672	68,315	66,729
Mean		11.3	5.717	54,618	61,757
Std. Dev.		3	2,341	17,418	65,681

[a] Eagle sonar above border spawning escapement estimate (DFO Whitehorse, unpublished data).
[b] Eagle sonar estimate (JTC 2012 and Unpublished DFO Whitehorse data).
[c] Mark/recapture estimate (JTC 2012).
[d] Point estimate
Sources: Osborne et al. 2003; Mercer and Eiler 2004; Mercer 2005; JTC reports 2005 through 2012; unpublished DFO Whitehorse data.

Appendix 7. Big Salmon sonar counts and the JTC above border escapement estimates based on Eagle sonar counts, 2005 – 2017.