2018 Big Salmon River Chinook Salmon Sonar Enumeration Project

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ABSTRACT

A multiple beam sonar unit was used to enumerate the Chinook salmon escapement to the Big Salmon River in 2018. The sonar was operated on the Big Salmon River for its fourteenth year at the same site used since 2005. Sonar operation began on July 15 and continued without interruption through August 21. A total escapement of 5,159 Chinook salmon was estimated to have passed the sonar site in 2018. The first Chinook salmon passing the Big Salmon sonar station was observed on July 15, the first day of operations. Fifty percent of the run had passed the sonar by August 3 and 90% by August 15. Based on the 2018 Big Salmon sonar count and above border escapement estimates from the Eagle sonar project, the Big Salmon run comprised approximately 9.5% of the total above border Chinook Salmon escapement. A total of 201 Chinook carcass samples were collected between Aug 22 and Aug 25 over approximately 145 km of the Big Salmon River system. Age, length and sex data was obtained from the samples.

INTRODUCTION

The 2018 Big Salmon River sonar project marks the fourteenth year that Chinook salmon (*Oncorhynchus tshawytscha***)** enumeration has been conducted on this system by Metla Environmental Inc. (MEI). The multiple beam sonar units used by the Big Salmon River Chinook enumeration program, as well as many other salmon 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, Key et al. 2016, Mercer & Wilson 2006 - 2018). 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. 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 2018 project.

The overall goal of the Big Salmon Chinook program is to provide stock assessment information that will improve the ability of Canadian and U.S. salmon management agencies to manage Yukon River Chinook salmon. Quantifying Chinook escapement into upper Yukon River index streams allows for an 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 2018 Big Salmon Chinook escapement. This information provides important ongoing 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 2018. 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 – 2017 sonar operations, the Big Salmon River has been shown to be a significant contributor to upper Yukon River Chinook production. The 2005 -2017 average Big Salmon sonar count is 5,512 (range 1,329 to 10,078). 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.

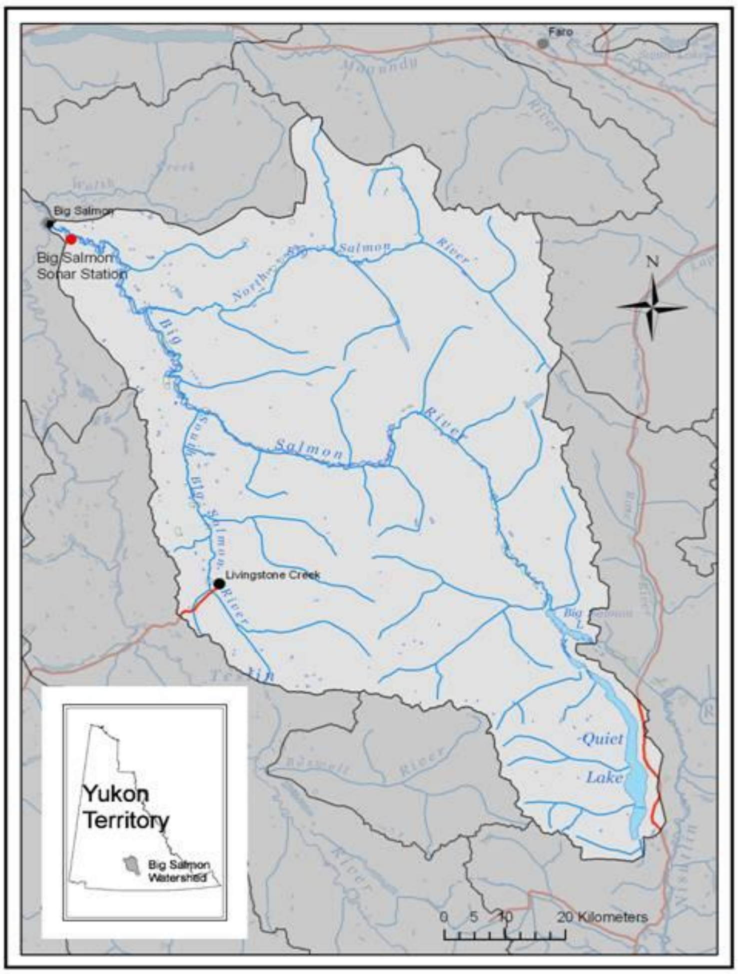

Figure 1. Big Salmon River Watershed and location of the 2018 Big Salmon sonar station.

Objectives

The objectives of the 2018 Big Salmon River sonar project were:

1. Obtain an accurate count of the 2018 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 2018 Big Salmon River Juvenile Chinook Out-migrant Assessment Study.

METHODS

Site selection

Sonar operations were set up at the same site on the lower Big Salmon River 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 14 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 mobilized from Whitehorse, YT. This entailed driving to a boat launch site on the Yukon River situated 3 km downstream of Little Salmon Village on the Robert Campbell Highway. From the boat launch a riverboat was used to access the sonar station site. Subsequent camp access, crew changes, and delivery of supplies were accomplished by riverboat and floatplane from Whitehorse. Mobilization to the sonar station was initiated on July 14. The sonar apparatus was operational beginning 15:00 on July 15.

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 2. The cross section profile of the river bottom at the sonar station has remained relatively unchanged since the project started in 2005. However the sonar location in 2018 was moved 2 m downstream relative to the previous year's location. This site had a bottom profile the most conducive to complete ensonification of the water column.

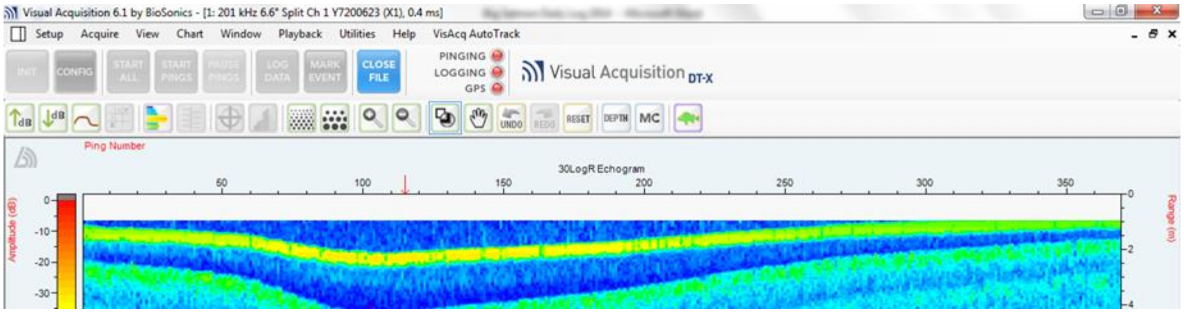

Figure 2. Cross section profile of Big Salmon River at sonar site using a Biosonics DTX split beam echo-sounder.
Note: Top of yellow line is river bottom, thalweg = 1.97 m. Transect view looking down river. The near field of the transducer prevents readings at depths less than 1m as indicated by the white band.

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 3). The weir was constructed using conduit panels and metal tripods that were stored on site. The fences were constructed as detailed in previous years reports (Mercer & Wilson 2018).

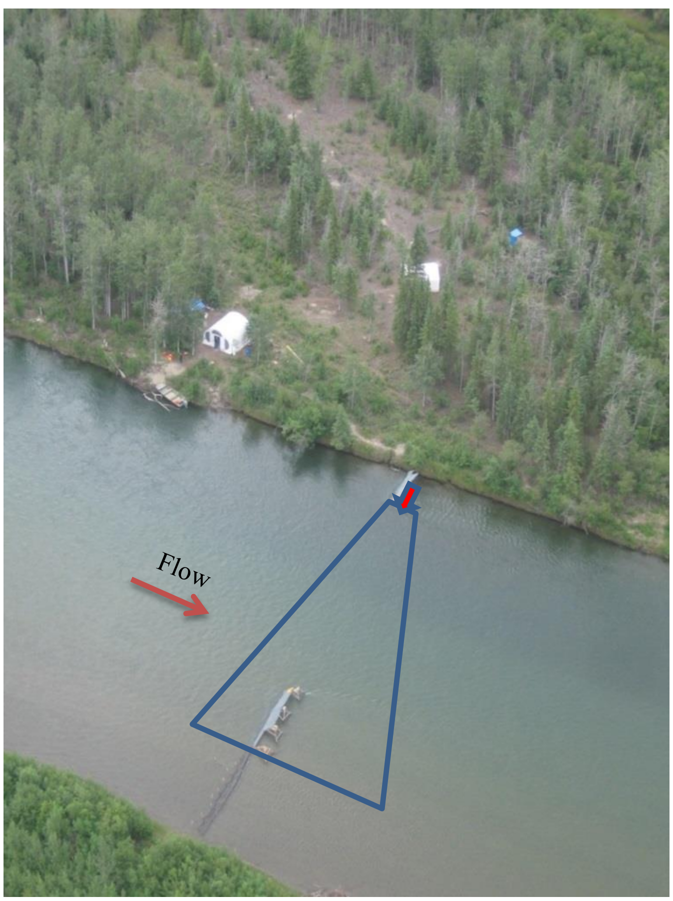

Figure 3. Aerial view of sonar station camp and partial weirs, (photo from 2010 project).
Blue outline denotes ensonified portion of the river.

__ARIS 1800 Sonar, Placement and Software Configuration__

An ARIS model 1800 sonar, manufactured by Sound Metrics Corporation, was used for the 2018 Big Salmon sonar project. This sonar belongs to MEI and was an in-kind contribution to the 2018 project. Sound Metrics are currently the primary manufacturers of multi-beam sonars employed for enumerating migrating salmon in riverine environments.

The DIDSON sonar was the first sonar developed by Sound Metrics. The ARIS (Adaptive Resolution Imaging Sonar) sonar is considered the second generation of multiple beam sonars manufactured by Sound Metrics Corporation. While the underlying beam-forming techniques involving the use of acoustic lenses are similar for both units, significant refinements to the ARIS hardware and software as well as specialized fish counting and measuring software make it a more versatile and user friendly platform for detecting and counting migrating salmon (Key et al. 2016). With DIDSON the number of image samples (pixels) is fixed at 512. Moreover, the DIDSON window length parameter can only be set at the discrete values (2.5M, 5M, 10M etc.). ARIS images can attain a finer downrange resolution than DIDSON. With the ARIS sonar, the number of samples in a beam is operator controlled and is variable from 128 to a maximum of 4,000 samples (pixels). In addition the ARIS window length is user selectable. This allows the user to increase the number of samples per beam to compensate for the reduced resolution associated with increased window length. A LR DIDSON sonar was also on-site for the 2018 project as a backup unit.

The sonar unit was placed next to the south bank as depicted in Figures 3 and 4. The sonar unit was mounted on an adjustable stand constructed of 2-inch steel galvanized pipe. 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 4. Sonar transducer unit and mounting stand in position (2011 Photo).

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 14° in the vertical plane. An 8° concentrator lens was used for the 2018 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 and 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 Chinook 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 SSHD plus a 1TB HDD and 16 GB of RAM. This processing capability allowed the technicians to read the files concurrent 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 reading the recorded files and the inputting of data. File reading typically occurred the day following recording. All 72 files from each day were read. Files were read 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 reader 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. The target measurement feature of the ARISFish software was used when required to estimate the size of the observed fish and when required to differentiate Chinook salmon from resident fish species. 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 proportion of suspected straying Chinook at the sonar site is typically very low (< 2%).

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 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 read and count salmon from a sub-set of recorded data files 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 reviewing a sub-set of all the files recorded and read. Precision in this case refers to the repeatability of a count between different individuals for the same data file or aggregate of data files. Files for review were randomly selected from 16 days of sonar operation, over the periods July 25 through July 30 and August 3 through August11, inclusive. The re-count from each reviewed file was recorded for comparison with the original.

The Coefficient of Variation (CV) 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:

$$CV = \sqrt{\frac{\sum_{i=1}^{R} (X_{ij} - \overline{X}_j)^2}{\overline{X}_j^{\,2}}} \times 100$$

[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.

where 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 counted per hour in most of the Big Salmon sonar files, the CV values could be distorted. For example, if the first counter observed 2 upstream fish and the second counter observed one, the CV would be as high as 50%. This is due to the leverage that small numerical differences in low counts have on the overall calculation of CV. For this reason, the CV for this project was calculated using reviewed files with fish counts ≥ 5 fish/ file.

As well as calculating CV, 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. To do this the relationship was plotted between counts of 2 different file readers using original daily aggregate file counts (reader 1) and reviewed aggregate file counts (reader 2).

Range Distribution

The ARISFish software recorded the distance (m) from the sonar for each target selected and marked as a Chinook salmon. This range value was inputted into the CSV file. This provided data to construct a range frequency histogram illustrating the cross sectional distribution of migrating 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 sonar station to a point approximately 120 river kilometers upstream.

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.

RESULTS

Chinook Salmon Counts

The 2018 Big Salmon River Chinook run timing was similar to the previous 13 year average for this stock (Figure 5). The first Chinook salmon was observed on July 15, on the first day of operations. The run reached 50% passage on August 3 and 90% of the run had passed the station by August 15. Daily and cumulative counts are presented in Appendix 1 and Figure 5.

A total of 5,053 targets identified as Chinook salmon was counted past the sonar station from July 15 through to August 21. The sonar was operated continually and no stoppages were recorded during the 2018 project. Because sonar operation stopped 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 using the final 18 days of the sonar counts based on the logarithmic regression y = -110.1ln(x) + 354.69. This extrapolation added 106 fish to bring the total count to 5,159. A total of 8 Chinook salmon (0.16% of the total escapement) was recorded moving downstream during the 2018 project.

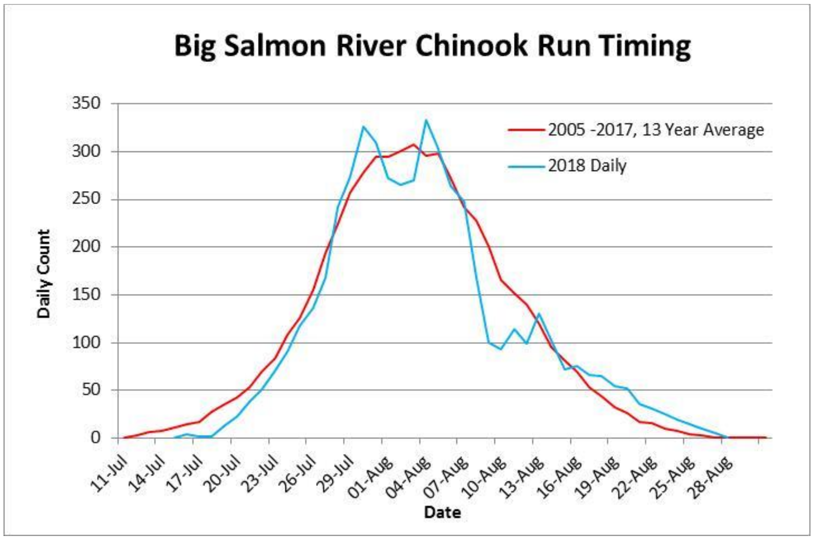

Figure 5. Daily counts of Chinook salmon passing the Big Salmon River sonar station in 2018 and average daily counts 2005 through 2017.

The 2018 Big Salmon Chinook sonar count 5,159 was comparable to the 2005 – 2017 average of 5,512 (Figure 6, Appendix 2).

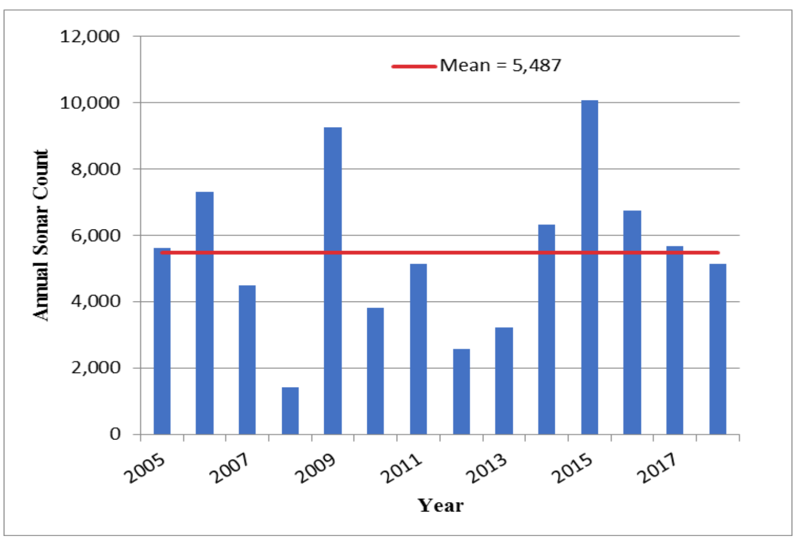

Figure 6.   Annual sonar counts for Big Salmon sonar project 2005 – 2018.

Precision of Counts

Of the 2,655 sonar files recorded and analysed, a total of 96 (3.6%) was reviewed by a second reader (Table 1). Of the 96 files reviewed, 22 files (22.9%) exhibited a discrepancy in the total target count between readers. Of the 22 files that exhibited an inconsistency between readers, additional fish were identified in 14 files and 8 files had the Chinook count reduced (Appendix 3). This yields a net gain of 3 fish for the 96 files that were reviewed representing 0.9% of the 320 fish counted in the first iteration.

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

	Count	%
Total files recorded during project	2,655	
Total files double reviewed	96	3.6%
Total fish counted first iteration	320	
Total fish counted second iteration	323	
Total files with + divergence	14	14.6%
Total files with - divergence	8	8.3%
Total Files with divergence	22	22.9%
Net difference in target count	3	0.9%

The CV was calculated for reviewed files that had fish counts ≥ 5 fish/file. The CV for this subset was 6.9%.

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 = 0.98, (R (14) p<0.001).

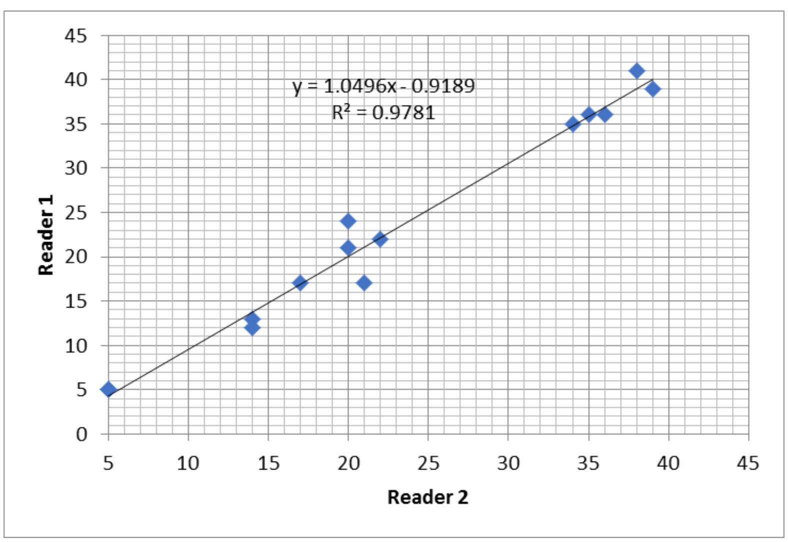

Figure 7. Linear regression between daily pooled sonar file Chinook counts examined by two separate readers.
Note: Data points are daily pooled initial file counts (y axis) and reviewed file counts (x axis).

Range Distribution

The cross section pattern of migrating Chinook at the sonar site in 2018 is presented in Figure 8.[2] As occurred in some previous years there was a bi-modal range distribution. There were peak distributions at approximately 6 meters and 19 meters from the sonar. The higher number observed at 6 meters was likely a function of the deflection weir moving south bank oriented fish around the fence. The peak at 19 m demarks the thalweg of the river. The cross sectional range distribution of Chinook at the sonar site varies inter-annually, likely as a result of prevailing water levels.

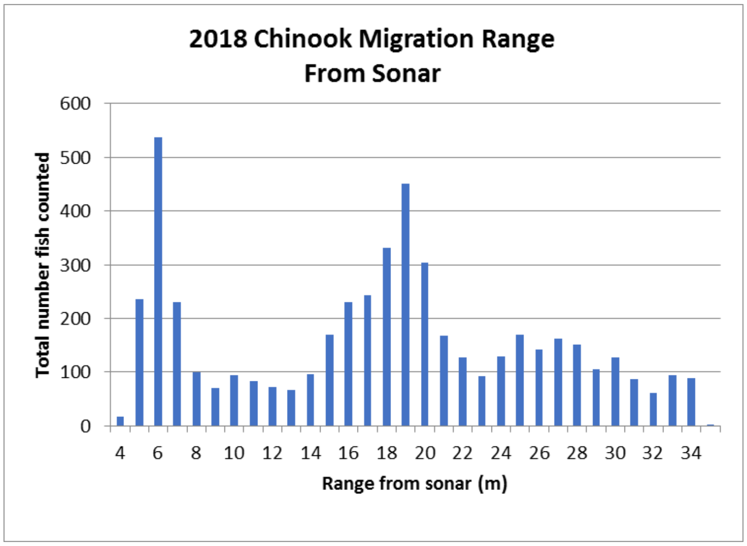

Figure 8. 2018 Big Salmon River Chinook range/frequency in cross section profile.
Note: The 0 – 5m range from the sonar has a deflection fence in place.

Table 2. Age, length, and sex of Chinook sampled from the Big Salmon River, 2018.

SEX	AGE	Mean MEF (mm)	Count	%
Female	1.2	605	1	0.5%
	1.3	788	28	14.4%
	1.4	821	66	34.0%
	1.5	852	5	2.6%
	M3	779	7	3.6%
	M4	841	17	8.8%
	M5	890	1	0.5%
Female total			125	64.4%
Male	1.2	622	5	2.6%
	1.3	735	30	15.5%
	1.4	841	18	9.3%
	1.5	980	1	0.5%
	M3	809	5	2.6%
	M4	829	10	5.2%
Male total			69	35.6%
Total			194	100.0%

[2] 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 from an 80 m wide into a 36 m wide corridor.

Carcass Pitch

A total of 201 dead or moribund Chinook was recovered during the carcass pitch. Mean length and age data is presented in Table 2 above. Of the total, 128 (64%) fish were female and 73 (36%) fish were male. Complete age data was determined from 154 of the Chinook sampled; the remaining 47 samples yielded partial or no ages due to regenerate scales. Females were predominately age-6 (1.4) (34%) and males predominantly age-5 (1.3) (15%). Complete age, length and sex data are presented in Appendix 4.

DISCUSSION

The 2018 Big Salmon sonar project was successful in enumerating the Chinook salmon passing the sonar station throughout the course of the run. No significant technical problems were encountered with the sonar and related equipment. The sonar recorded continuously over the course of the project with no interruptions. Water levels at the sonar station were considered average with no extreme high water events affecting the sonar operation (Appendix 5). A high water event occurred on August 10 through 12 that resulted in significant accumulations of woody debris that could not be safely removed until after the water level subsided.

There was a high degree of precision between file readers for both single file counts and daily aggregate counts. As occurred in past years, the reviewed file aggregate counts resulted in a net gain of fish. This is a result of there being a higher probability a file reader will miss a target rather than mark and count a non-existent target. This would suggest that the 2018 sonar count could be biased low. This low bias could be approximately 0.9% of the total 2018 sonar count as indicated by the results of the file review precision data.

The ARIS sonar is considered the second generation of multiple beam sonars manufactured by Sound Metrics Corporation. The ARIS 1800 sonar and ARISFish software provides better downrange resolution of the fish targets and increases efficiency when reviewing the data compared to the DIDSON sonar. It is recommended the ARIS sonar continue to be used on this project rather than the LR DIDSON previously used from 2005 through 2015. The ARISfish software also reduces the workload of the file readers which allows one member of the sonar crew to assist with the concurrent DFO juvenile Chinook research project.

The 2018 Eagle sonar project on the Yukon River downstream of the Canada/U.S. border yielded a total count of 57,893 Chinook. The above border spawning escapement[3] estimate was 54,474 (JTC 2018, preliminary). Based on the Big Salmon and Eagle Chinook sonar counts, the Big Salmon stock contributed 9.5% of the total above border Chinook escapement in 2018. A comparison of Big Salmon River Chinook sonar counts and the JTC above border Chinook escapement estimates based on Eagle sonar counts, (2005 – 2018) is illustrated in Appendix 6. There is a positive relationship between Eagle sonar escapement estimates and the Big Salmon sonar counts, with a Pearson correlation of 0.82, (R (14) $p<0.001$).

Genetic stock identification (GSI) samples were obtained at the Eagle sonar site in 2018 using drift gillnets. The GSI data provides information on the proportional stock composition of the

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

total above border Yukon River Chinook escapement, including the Big Salmon River. The 2018 GSI data has not been analyzed at the time of this report preparation.

An ongoing DFO juvenile Chinook salmon research project was again based at the Big Salmon River sonar site in 2018. During the operation of the sonar project one of the MEI sonar technicians assisted on the juvenile Chinook project. This did not unduly affect sonar operations and if both projects are conducted again in 2019 a similar arrangement could be made.

ACKNOWLEDGEMENTS

Several people contributed to the successful operation of the 2018 Big Salmon River sonar project. Austin Schroeder, Carolyn Knapper and Robert Gransden were the sonar technicians on the project. David McDonald assisted with the carcass pitch. The project was funded by the Yukon River Restoration and Enhancement Fund. DFO funded the age analysis of the carcass samples.

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Appendix 1. 2018 daily and cumulative counts of Chinook salmon at the Big Salmon River sonar site.

DATE	DAILY COUNT	CUMULATIVE	COMMENTS
15-Jul	1	1	Sonar begins recording at 1500h
16-Jul	4	5	
17-Jul	2	7	
18-Jul	2	9	
19-Jul	13	22	
20-Jul	23	45	
21-Jul	38	83	
22-Jul	51	134	
23-Jul	71	205	
24-Jul	91	296	
25-Jul	118	414	
26-Jul	136	550	
27-Jul	168	718	
28-Jul	242	960	
29-Jul	273	1233	
30-Jul	326	1559	
31-Jul	310	1869	
01-Aug	272	2141	
02-Aug	265	2406	
03-Aug	270	2676	
04-Aug	333	3009	peak daily count
05-Aug	303	3312	
06-Aug	264	3576	
07-Aug	248	3824	
08-Aug	168	3992	
09-Aug	100	4092	
10-Aug	93	4185	
11-Aug	114	4299	
12-Aug	99	4398	
13-Aug	131	4529	
14-Aug	103	4632	
15-Aug	72	4704	
16-Aug	76	4780	
17-Aug	66	4846	
18-Aug	65	4911	
19-Aug	54	4965	
20-Aug	52	5017	
21-Aug	36	5053	Last full day of recording
22-Aug	31	5084	
23-Aug	25	5109	
24-Aug	20	5129	
25-Aug	15	5143	
26-Aug	10	5153	
27-Aug	5	5158	
28-Aug	1	5159	Final estimate based on extrapolation

Note: Shaded area denotes extrapolated daily counts.

Appendix 2. Daily and average Chinook counts in the Big Salmon River, 2005-2018.

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 Count 2018	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		1	**22**
16-Jul	12	0	2	0					0	90	17	56	11	4	**19**
17-Jul	13	1	0	0			2		0	115	25	56	22	2	**21**
18-Jul	23	0	2	0	0		7	0	0	170	39	82	19	2	**26**
19-Jul	13	0	5	1	11		13	0	0	199	72	113	32	13	**36**
20-Jul	23	1	5	0	22	0	15	0	0	236	81	126	58	23	**42**
21-Jul	36	3	7	0	47	7	24	0	1	229	117	171	82	38	**54**
22-Jul	58	8	11	0	68	14	24	0	1	284	148	226	144	51	**74**
23-Jul	92	11	18	1	85	12	43	0	2	345	217	174	197	71	**91**
24-Jul	130	21	26	2	135	7	44	0	4	343	312	271	235	91	**116**
25-Jul	158	20	52	1	201	12	50	1	3	356	411	240	211	118	**131**
26-Jul	204	53	88	3	226	14	56	1	11	372	538	292	212	136	**158**
27-Jul	219	95	153	5	346	27	105	1	25	421	494	428	281	168	**198**
28-Jul	287	146	237	9	498	46	160	3	44	307	531	430	243	242	**227**
29-Jul	290	230	287	9	532	83	192	15	86	380	588	394	192	273	**254**
30-Jul	299	321	337	29	594	123	218	12	83	330	586	409	317	326	**285**
31-Jul	279	368	400	21	808	141	218	23	150	256	492	377	432	310	**305**
01-Aug	333	357	435	23	578	159	260	62	196	207	568	362	390	272	**300**
02-Aug	346	379	331	18	715	182	313	76	220	207	485	329	363	265	**302**
03-Aug	303	358	304	16	725	216	417	138	264	192	441	309	341	270	**307**
04-Aug	292	413	258	31	595	226	426	156	262	190	451	245	309	333	**299**
05-Aug	331	496	210	51	559	215	396	196	261	170	452	235	241	303	**294**
06-Aug	214	490	178	55	452	221	400	228	225	120	469	222	181	264	**266**
07-Aug	188	464	147	78	364	227	317	192	191	114	449	177	181	248	**238**
08-Aug	232	464	59	61	295	242	294	235	195	96	397	161	115	168	**215**
09-Aug	234	360	74	70	270	248	243	183	156	68	348	157	116	100	**188**
10-Aug	203	349	90	98	209	183	160	154	132	61	246	101	84	93	**155**
11-Aug	124	348	82	122	183	207	170	106	134	50	217	77	85	114	**144**
12-Aug	126	324	98	107	146	174	143	130	113	46	187	79	72	99	**132**
13-Aug	125	243	77	109	118	181	100	110	101	25	201	58	80	131	**119**
14-Aug	72	196	74	89	117	134	85	81	77	30	126	63	65	103	**94**
15-Aug	57	180	66	78	65	114	89	80	65	24	113	52	53	72	**79**
16-Aug	40	172	56	70	55	82	63	94	57	24	91	33	51	76	**69**
17-Aug	53	104	40	49	63	80	35	70	34	17	65	26	54	66	**54**
18-Aug	47	69	64	45	55	53	20	50	32	15	54	20	40	65	**45**
19-Aug	35	87	37	17	43	40	18	44	21	14	28	10	32	54	**34**
20-Aug	29	59	47	18	35	24	21	38	28	11	10	18	10	52	**29**
21-Aug	26	45	11	15	28	18	11	27	20	9	7	15	26	36	**21**
22-Aug	19	50	16	16	14	38	2	19	10	6		12	22	31	**20**
23-Aug	17	12	23	9	4	24	2	19	14	3		9	19	25	**14**
24-Aug	13	10	17	2		20		14	11	1		6	16	20	**12**
25-Aug	9		14	1		17		9	6			4	13	15	**10**
26-Aug	6		14			6		6	4			2	10	10	**7**
27-Aug	4		13					5	2				8	5	**6**
28-Aug	2		11					3	1				5	1	**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**	**5159**	**5487**

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

Appendix 3. Precision of counts by two ARISfish file reviewers.

Reviewed File Number	Fish counted by reader #1	Fish counted by reader #2	Difference	Reviewed File Number	Fish counted by reader #1	Fish counted by reader #2	Difference
1	4	4	0	49	2	2	0
2	16	16	0	50	2	2	0
3	7	7	0	51	0	0	0
4	0	0	0	52	6	5	-1
5	3	3	0	53	1	1	0
6	2	2	0	54	2	2	0
7	2	2	0	55	1	0	-1
8	2	2	0	56	0	0	0
9	4	4	0	57	1	2	1
10	5	6	1	58	2	2	0
11	6	7	1	59	3	3	0
12	4	4	0	60	3	3	0
13	7	8	1	61	6	6	0
14	2	2	0	62	1	1	0
15	4	4	0	63	3	1	-2
16	6	6	0	64	3	4	1
17	4	4	0	65	0	0	0
18	7	8	1	66	0	0	0
19	5	5	0	67	0	0	0
20	0	0	0	68	5	5	0
21	15	15	0	69	0	0	0
22	4	4	0	70	0	0	0
23	1	1	0	71	2	2	0
24	3	2	-1	72	0	0	0
25	0	0	0	73	0	0	0
26	1	1	0	74	3	3	0
27	3	3	0	75	0	0	0
28	1	1	0	76	7	7	0
29	0	0	0	77	7	7	0
30	5	5	0	78	1	1	0
31	1	0	-1	79	2	2	0
32	3	3	0	80	0	0	0
33	12	12	0	81	9	9	0
34	0	0	0	82	5	6	1
35	3	3	0	83	0	0	0
36	5	5	0	84	6	6	0
37	5	6	1	85	1	2	1
38	1	1	0	86	6	5	-1
39	3	3	0	87	2	1	-1
40	6	6	0	88	9	**9**	0
41	2	3	1	89	3	0	-3
42	1	2	1	90	1	1	0
43	0	0	0	91	5	5	0
44	1	2	1	92	2	2	0
45	0	0	0	93	2	2	0
46	3	4	1	94	3	3	0
47	9	9	0	95	5	5	0
48	4	4	0	96	16	17	1
				Total	**320**	**323**	**3**

Appendix 4. Age, sex, and length of sampled Chinook on the Big Salmon River, 2018.

DATE	FISH #	SEX	FL (mm)	MEF (mm)	POHL (mm)	AGE *
22-Aug	1	M	825	735	625	
22-Aug	2	F	855	785	670	14
22-Aug	3	F	910	830	720	14
22-Aug	4	M	965	855	745	14
22-Aug	5	F	930	855	750	13
22-Aug	6	F	820	740	660	M3
22-Aug	7	F	890	820	725	M4
23-Aug	8	M	1055	935	820	14
23-Aug	9	F	760	690	630	13
23-Aug	10	F	870	795	715	no age
23-Aug	11	F	930	840	770	M4
23-Aug	12	F	925	845	755	14
23-Aug	13	F	890	825	730	14
23-Aug	14	M	800	720	640	13
23-Aug	15	M	910	815	710	13
23-Aug	16	M	920	825	720	M4
23-Aug	17	F	870	800	700	M4
23-Aug	18	F	880	805	705	14
23-Aug	19	F	835	760	670	M4
23-Aug	20	F	895	820	720	M4
23-Aug	21	F	910	835	725	15
23-Aug	22	M	830	745	655	M4
23-Aug	23	F	900	820	730	13
23-Aug	24	F	865	795	695	14
23-Aug	25	F	850	765	670	14
23-Aug	26	F	900	820	735	14
23-Aug	27	F	875	790	705	13
23-Aug	28	M	830	755	665	14
23-Aug	29	F	910	830	745	14
23-Aug	30	F	930	845	745	14
23-Aug	31	F	880	800	710	14
23-Aug	32	M	1010	900	775	14
23-Aug	33	M	890	780	670	13
23-Aug	34	F	930	860	765	14
23-Aug	35	F	940	855	750	13
23-Aug	36	F	660	605	525	12
23-Aug	37	M	995	890	785	M4
23-Aug	38	M	810	735	650	13
23-Aug	39	F	950	860	755	14
23-Aug	40	M	685	605	535	13
23-Aug	41	F	960	870	770	14
23-Aug	42	M	990	885	770	13
23-Aug	43	F	865	790	690	14
23-Aug	44	M	965	865	765	14
23-Aug	45	F	810	740	670	14
23-Aug	46	F	920	840	740	14
23-Aug	47	M	820	730	635	13
23-Aug	48	F	865	785	685	14
23-Aug	49	M	1020	890	765	14
23-Aug	50	F	880	805	705	14
23-Aug	51	M	720	650	565	12

DATE	FISH #	SEX	FL (mm)	MEF (mm)	POHL (mm)	AGE *
23-Aug	52	M	750	675	585	12
23-Aug	53	F	880	810	710	M3
23-Aug	54	F	920	830	710	14
23-Aug	55	F	750	685	605	13
23-Aug	56	F	910	830	750	M4
23-Aug	57	M	955	860	750	13
24-Aug	58	F	980	895	795	14
24-Aug	59	F	910	825	735	M3
24-Aug	60	M	940	845	730	14
24-Aug	61	F	880	805	710	14
24-Aug	62	M	875	790	685	M4
24-Aug	63	M	940	845	725	14
24-Aug	64	F	980	895	795	14
24-Aug	65	M	800	720	625	13
24-Aug	66	F	890	810	715	14
24-Aug	67	F	890	820	725	14
24-Aug	68	M	910	820	715	14
24-Aug	69	F	960	880	780	14
24-Aug	70	M	1015	900	780	M4
24-Aug	71	F	895	830	720	14
24-Aug	72	F	905	825	735	14
24-Aug	73	F	950	860	770	14
24-Aug	74	F	910	835	725	no age
24-Aug	75	M	870	775	695	14
24-Aug	76	F	940	850	760	14
24-Aug	77	F	805	730	650	M3
24-Aug	78	M	580	525	460	12
24-Aug	79	M	920	805	700	M3
24-Aug	80	M	1000	885	785	14
24-Aug	81	F	930	850	735	13
24-Aug	82	F	905	830	730	14
24-Aug	83	F	960	870	770	14
24-Aug	84	F	940	850	750	14
24-Aug	85	M	855	670	580	13
24-Aug	86	M	785	705	600	13
24-Aug	87	F	960	870	765	no age
24-Aug	88	F	900	820	720	14
24-Aug	89	F	890	780	680	13
24-Aug	90	F	930	845	745	15
24-Aug	91	M	840	750	655	13
24-Aug	92	M	945	830	705	M3
24-Aug	93	F	985	890	780	M5
24-Aug	94	M	705	630	535	13
24-Aug	95	F	870	790	705	14
24-Aug	96	M	905	820	720	14
24-Aug	97	F	1030	935	830	M4
24-Aug	98	F	915	845	750	14
24-Aug	99	F	760	690	605	13
24-Aug	100	F	880	805	710	M4
24-Aug	101	M	800	710	620	13
24-Aug	102	F	930	855	765	13
24-Aug	103	F	900	830	730	14
24-Aug	104	F	790	715	640	13
24-Aug	105	M	830	750	655	12
24-Aug	106	M	860	760	675	M4

DATE	FISH #	SEX	FL (mm)	MEF (mm)	POHL (mm)	AGE *
24-Aug	107	M	760	690	610	M3
24-Aug	108	F	945	860	760	13
24-Aug	109	M	725	660	585	1F
24-Aug	110	M	1100	980	850	15
24-Aug	111	M	750	680	585	13
24-Aug	112	F	1000	905	800	M4
24-Aug	113	F	870	790	700	14
24-Aug	114	M	920	830	725	M3
24-Aug	115	F	1010	915	810	M4
24-Aug	116	F	900	820	720	14
24-Aug	117	M	990	885	760	14
24-Aug	118	F	930	855	750	14
24-Aug	119	F	785	720	630	13
24-Aug	120	M	890	805	705	13
24-Aug	121	F	855	775	680	13
24-Aug	122	M	845	750	655	13
24-Aug	123	F	840	770	685	M3
24-Aug	124	M	960	870	750	14
24-Aug	125	F	850	775	690	M3
24-Aug	126	F	900	820	725	14
24-Aug	127	M	560	510	440	12
24-Aug	128	F	915	835	745	14
24-Aug	129	F	890	815	700	14
24-Aug	130	F	950	875	780	14
24-Aug	131	M	945	835	725	M4
24-Aug	132	F	970	870	780	M4
24-Aug	133	F	830	770	670	14
24-Aug	134	F	910	820	750	14
24-Aug	135	F	780	715	635	13
24-Aug	136	M	1045	925	790	14
24-Aug	137	F	850	785	690	14
24-Aug	138	F	880	805	715	13
24-Aug	139	F	865	785	690	14
24-Aug	140	F	925	845	755	14
24-Aug	141	M	890	785	695	13
24-Aug	142	F	970	890	775	13
24-Aug	143	M	800	705	610	13
24-Aug	144	M	1030	925	800	no age
24-Aug	145	F	910	835	745	15
24-Aug	146	M	895	795	685	13
24-Aug	147	F	885	800	705	14
24-Aug	148	M	780	710	600	13
24-Aug	149	F	875	805	720	13
24-Aug	150	F	885	800	720	14
25-Aug	151	M	1010	890	775	M3
25-Aug	152	F	930	840	745	13
25-Aug	153	F	850	775	675	14
25-Aug	154	F	810	740	655	13
25-Aug	155	M	1035	915	810	M4
25-Aug	156	F	975	885	785	M4
25-Aug	157	M	740	660	575	13
25-Aug	158	M	1030	905	790	M4
25-Aug	159	M	860	775	685	14
25-Aug	160	M	885	795	680	13
25-Aug	161	F	890	810	730	14

DATE	FISH #	SEX	FL (mm)	MEF (mm)	POHL (mm)	AGE *
25-Aug	162	F	980	895	805	15
25-Aug	163	M	780	700	600	14
25-Aug	164	F	865	790	700	14
25-Aug	165	F	960	875	780	14
25-Aug	166	F	805	735	650	13
25-Aug	167	M	870	780	680	13
25-Aug	168	M	870	800	700	14
25-Aug	169	M	800	720	620	M4
25-Aug	170	F	890	815	720	14
25-Aug	171	F	870	795	690	M4
25-Aug	172	F	900	825	710	13
25-Aug	173	F	885	805	715	14
25-Aug	174	M	840	760	675	13
25-Aug	175	F	840	770	685	M4
25-Aug	176	F	920	845	740	14
25-Aug	177	M	775	700	610	13
25-Aug	178	F	895	820	725	14
25-Aug	179	M	745	670	570	13
25-Aug	180	M	920	820	710	No age
25-Aug	181	F	940	860	750	14
25-Aug	182	F	875	800	705	14
25-Aug	183	F	950	870	760	13
25-Aug	184	M	660	585	515	13
25-Aug	185	F	785	715	635	14
25-Aug	186	F	870	790	690	14
25-Aug	187	F	865	790	700	13
25-Aug	188	F	980	885	770	13
25-Aug	189	F	845	770	690	13
25-Aug	190	M	760	680	585	13
25-Aug	191	F	790	720	630	13
25-Aug	192	F	885	810	720	M4
25-Aug	193	F	880	805	695	14
25-Aug	194	F	930	850	725	15
25-Aug	195	F	1020	925	815	M4
25-Aug	196	F	920	840	735	14
25-Aug	197	F	885	800	715	M3
25-Aug	198	F	825	745	655	13
25-Aug	199	F	890	820	720	M4
25-Aug	200	M	995	880	775	13
25-Aug	201	F	880	790	690	14

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

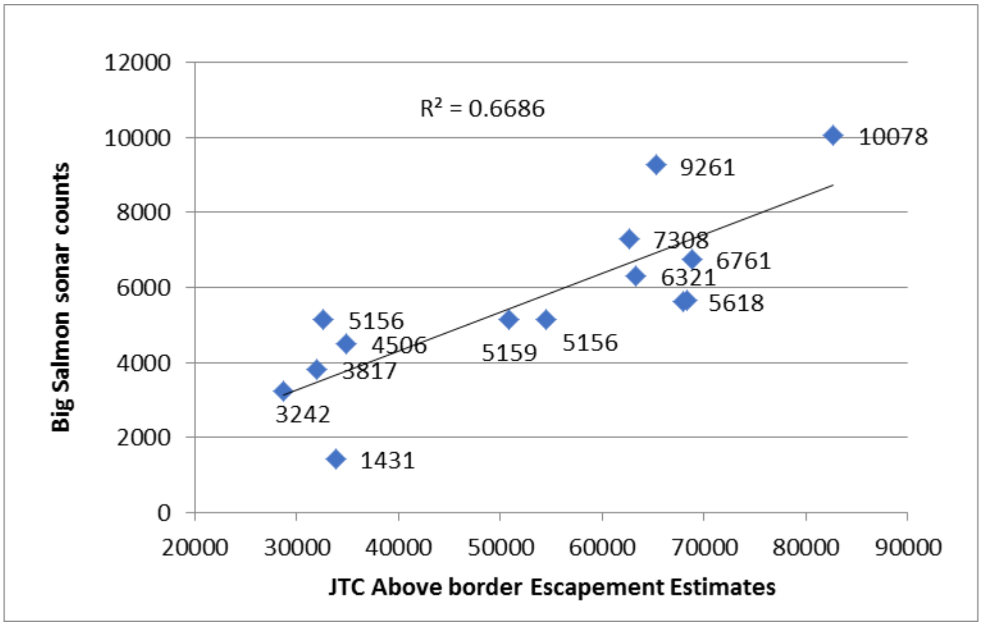
No age = scales regenerate (center is missing from scale) or resorbed (growth at scale margin is missing)
M = Marine stage
F = Freshwater stage

Appendix 5. 2018 Big Salmon River environmental conditions.

DATE	AIR TEMP. (ºC)	WATER TEMP. (ºC)	WATER LEVEL (cm)	COMMENTS
16-Jul	10.0	10.0	56	Foggy AM
17-Jul	10.0	11.0	55	sunny
18-Jul	9.5	10.0	57	
19-Jul	5.0	10.0	56	cloudy AM, sunny PM
20-Jul	10.0	11.0	57	sunny, hot
21-Jul	11.0	11.5	54	sunny, hazy, hot
22-Jul	10.0	12.0	50	sunny, hazy, hot
23-Jul	12.0	13.0	47	sunny, hot
24-Jul	11.0	14.0	44	sunny, hot
25-Jul	13.0	13.5	41	sunny, hot
26-Jul	14.0	14.0	39	sunny, hot
27-Jul	15.0	14.5	37	sunny, hot
28-Jul	12.0	16.0	35	sunny, hot
29-Jul	14.0	16.0	34	mostly sunny evening shower
30-Jul	9.0	16.0	32	sunny, hot
31-Jul	13.0	15.0	31	sun and cloud mix
01-Aug	12.0	16.0	29	Smoky
02-Aug	8.0	15.0	28	overcast
03-Aug	13.0	14.0	27	Rain
04-Aug	14.0	14.0	26	Rain
05-Aug	13.0	14.0	25	Rain
06-Aug	12.0	14.0	25	Overcast
07-Aug	11.0	12.5	29	Rain
08-Aug	12.5	11.5	41	Overcast
09-Aug	9.0	11.0	63	sunny, below 0 overnight
10-Aug	7.5	10.0	88	sun and cloud mix
11-Aug	6.0	9.0	101	PM rain and wind
12-Aug	9.0	9.5	94	
13-Aug	13.0	10.5	76	partially cloudy, river very turbid
14-Aug	10.0	11.0	70	partially cloudy, river clearing
15-Aug	8.5	10.0	76	partially cloudy with light rain
16-Aug	9.0	9.5	75	sun with some clouds
17-Aug	6.5	9.0	69	sun with a few clouds
18-Aug	8.0	9.0	67	Overcast with some sunny periods
19-Aug	4.5	8.5	65	Overcast
20-Aug	6.0	9.0	59	Foggy AM
21-Aug	10.0	10.0	55	sunny

Note: Environmental conditions recorded at 0900h daily

Appendix 6. Comparison of Big Salmon River Chinook sonar counts and the JTC above border Chinook escapement estimates based on Eagle sonar counts, 2005 – 2018.



Note: The value labels are the yearly Big Salmon Chinook sonar counts.