2019 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 2019. The sonar was operated on the Big Salmon River for its fifteenth year at the same site used since 2005. Sonar operation began on July 14 and continued without interruption through August 21. A total escapement of 3,874 Chinook salmon was estimated to have passed the sonar site in 2019. The first Chinook salmon passing the Big Salmon sonar station was observed on July 14, the first day of operations. Fifty percent of the run had passed the sonar by August 5 and 90% by August 14. Based on the 2019 Big Salmon sonar count and above border escapement estimates from the Eagle sonar project, the Big Salmon run comprised approximately 9.3% of the total above border Chinook Salmon escapement. A total of 105 Chinook carcass samples was 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 2019 Big Salmon River sonar project marks the fifteenth year that Chinook salmon (*Oncorhynchus tshawytscha*) enumeration has been conducted on this system by Metla Environmental Inc. (MEI). This report is a summary of the results of the 2019 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 2019 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.

A four year juvenile Chinook salmon study was conducted by DFO on the Big Salmon system between 2015 and 2018. The Big Salmon sonar camp belonging to MEI was used as a base for the juvenile Chinook study over those years. The Big Salmon sonar project will continue to provide supportive data quantifying the adult returns from previous years of the juvenile Chinook out-migrant study. The juvenile out-migrant study corroborates the JTC Research objective of developing scientifically-based escapement objectives for Canadian-origin salmon. Continued provision of annual Chinook escapement estimates into the Big Salmon system will be an integral component of the data required to complete the juvenile Chinook study.

Based on the 2005 – 2019 sonar operations, the Big Salmon River has been shown to be a significant contributor to upper Yukon River Chinook production. The 2005 -2018 average Big Salmon sonar count is 5,487 (range 1,329 to 10,078). These counts represented an average of 10.2% (range 8.3% - 15.8%) of the total average upper Yukon River Chinook spawning escapement estimate for these years (JTC 2019).

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.

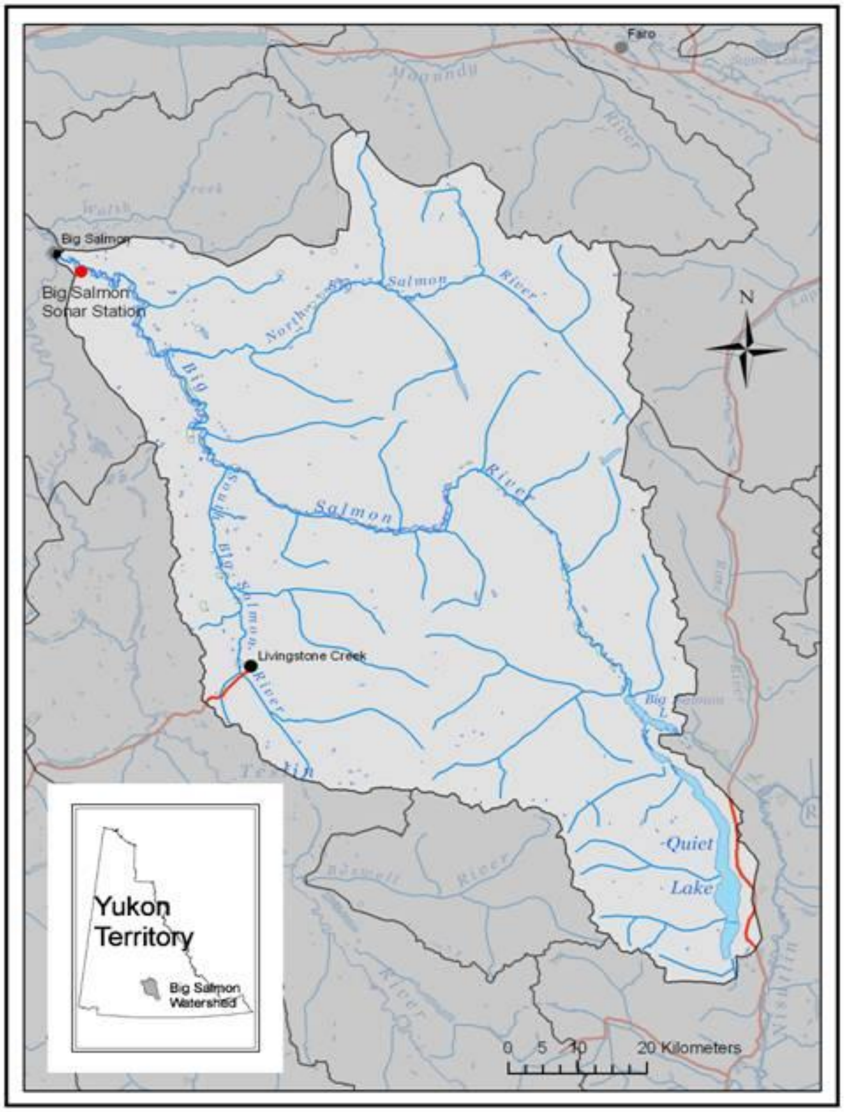


Figure 1. Big Salmon River Watershed and location of the 2019 Big Salmon sonar station.

Objectives

The objectives of the 2019 Big Salmon River sonar project were:

1. To provide an accurate count of the total Chinook salmon escapement in the Big Salmon River using a multiple beam sonar unit.

2. To conduct a carcass pitch on the Big Salmon River to obtain age-sex-length (ASL) data from as many post-spawned Chinook as possible with a target goal of 5% of the total run.

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 15 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 13. The sonar apparatus was operational beginning 18:00 on July 14.

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. This site had a bottom profile the most conducive to complete ensonification of the water column.

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 2019).

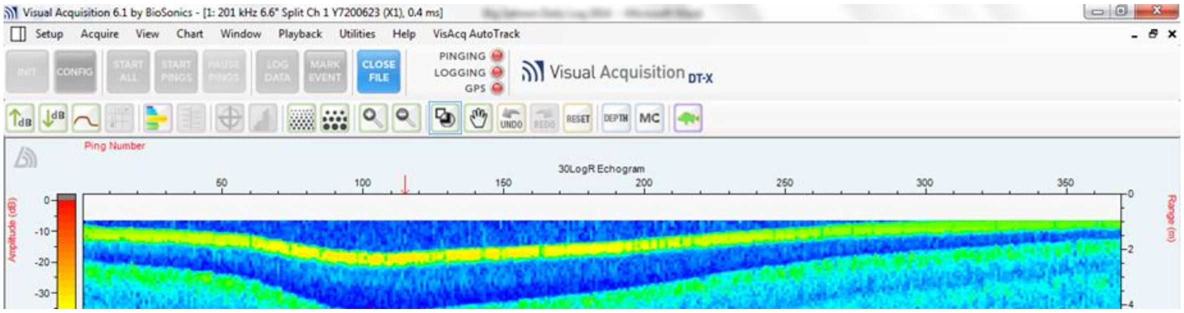


Figure 2. Cross section profile of Big Salmon River at sonar site using a Biosonics DTX split beam echo-sounder.
Note: Top of yellow line is river bottom, thalweg = 1.97 m. Transect view looking down river. The near field of the transducer prevents readings at depths less than 1m as indicated by the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

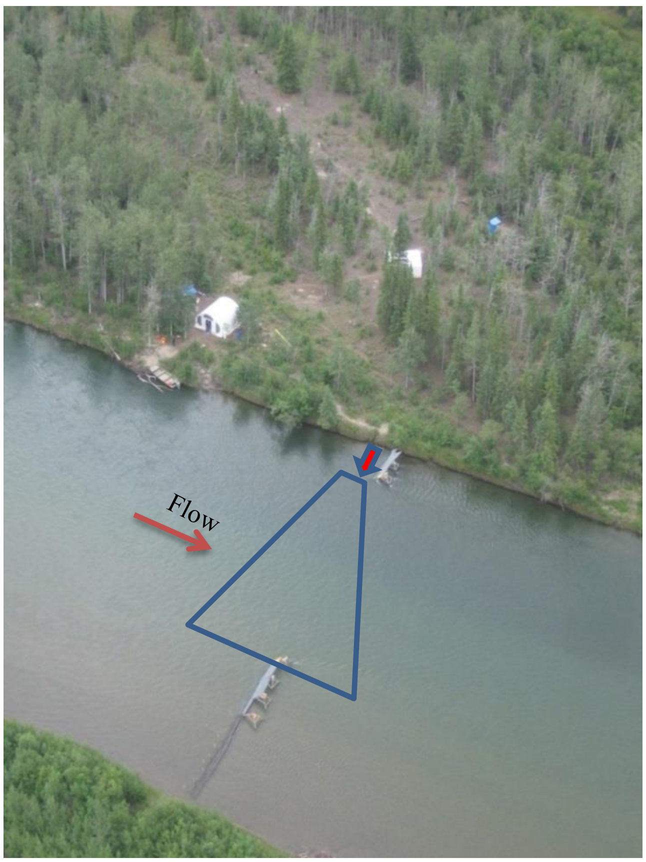


Figure 3. Aerial view of sonar station camp and partial weirs, (photo from 2010 project).
Blue outline denotes ensonified portion of the river.

ARIS 1800 Sonar, Placement and Software Configuration

An ARIS model 1800 sonar, owned by MEI and manufactured by Sound Metrics Corporation, was used for the 2019 Big Salmon sonar project. Sound Metrics are currently the primary manufacturers of multi-beam sonars employed for enumerating migrating salmon in riverine environments.

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 (Figure 4). 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.

The sonar unit was placed in the river 1.5m upstream of the south bank diversion fence and remained in this position for the duration of the project. 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 2019 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. Daily adjustments to the sonar aiming configuration were performed in response to fluctuating water levels.

Figure 4. Sonar transducer unit and mounting stand.

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 or data transmission interruptions.

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.

[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.

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 14 days of sonar operation, over the periods July 25 through August 6, 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:

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

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 only files that had a total Chinook count of 7 fish or higher were used to determine the precision of counts.

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 accomplish 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 145 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 hypural) were recorded to the nearest 0.5 cm. Five scales were taken from each fish and placed on scale cards for age determination. Information was collected on the egg retention of the sampled females. 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 2019 Big Salmon River Chinook run timing was within the range of the previous 14 year average for this stock (Figure 5). The first Chinook salmon was observed on July 14, on the first day of operations. The run reached 50% passage on August 5 and 90% of the run had passed the station by August 14. Daily and cumulative counts are presented in Appendix 1 and Figure 5.

A total of 3,865 targets identified as Chinook salmon was counted past the sonar station from July 14 through to August 21. Short interruptions in sonar recording due to maintenance or power interruptions resulted in a total of 1 hr, 45 min recording loss. 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 12 days of the sonar counts and the polynomial y=0.396x2 - 17.78x + 172.95. This extrapolation added 9 fish to bring the total count to 3,874. A total of 24 Chinook salmon (0.6% of the total escapement) was recorded moving downstream during the 2019 project.

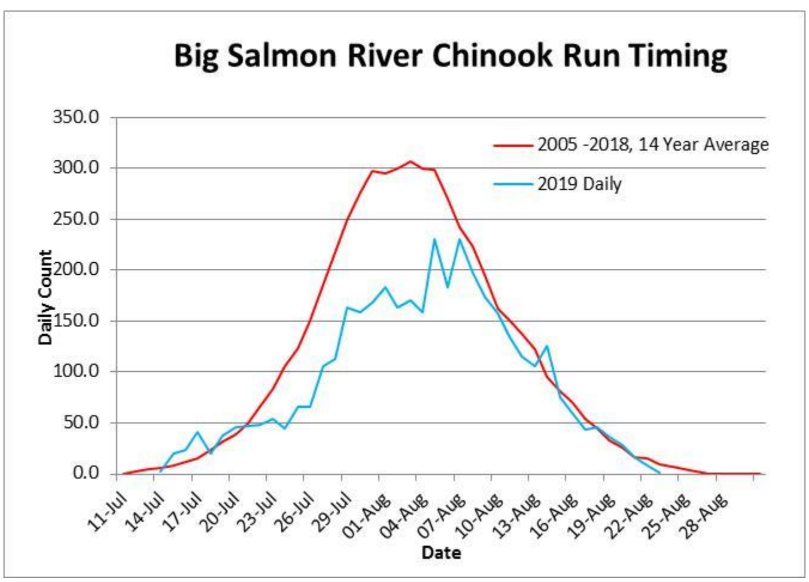


Figure 5. Daily counts of Chinook salmon passing the Big Salmon River sonar station in 2019 and average daily counts 2005 through 2018.

The 2019 Big Salmon Chinook sonar count of 3,874 was below (28%) the 2005 – 2018 average of 5,398 (Figure 6, Appendix 2).

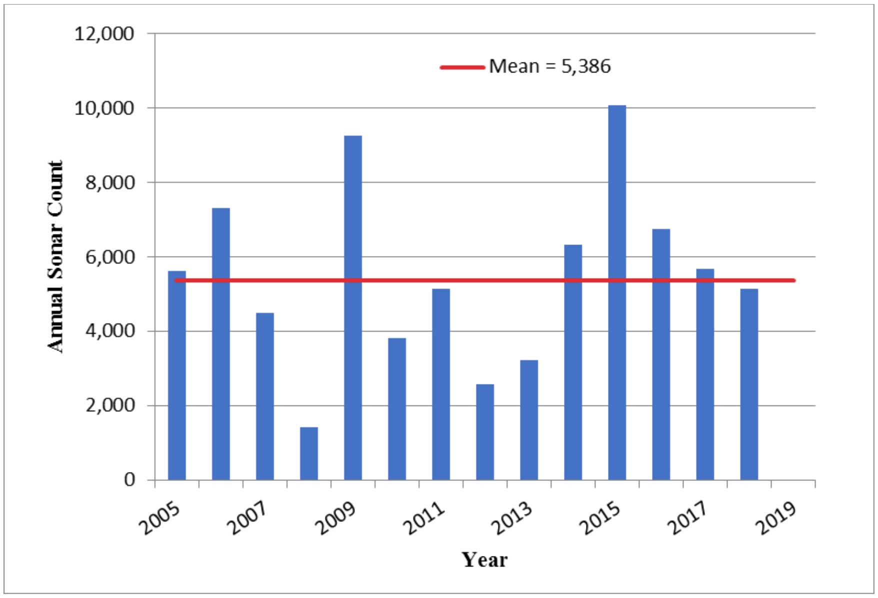


Figure 6. Annual sonar counts for Big Salmon sonar project 2005 – 2019.

Precision of Counts

Of the 2,790 sonar files recorded and analysed, a total of 36 was reviewed by a second reader (Table 1). A total of 290 fish was counted in the 36 files by the first reviewer. Of the 36 files reviewed by a second reader, 6 files (16%) exhibited a discrepancy in the count between readers (Appendix 3). Three files had one additional fish each and 3 files yielded 3 less fish. There was no net difference between the total number of fish counted in the first iteration and the subsequent review.

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

	Count	**%**
Total files recorded during project	2,790	
Total files double reviewed	36	1.2%
Total fish counted first iteration	290	
Total fish counted second iteration	290	
Total files with + divergence	3	8.3%
Total files with - divergence	3	8.3%
Total Files with divergence	6	22.9%
Net difference in target count	0	0%

The CV was calculated for all reviewed files. The CV for this subset was 9.9%.

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 = 0.96, (R 36; p<0.001).

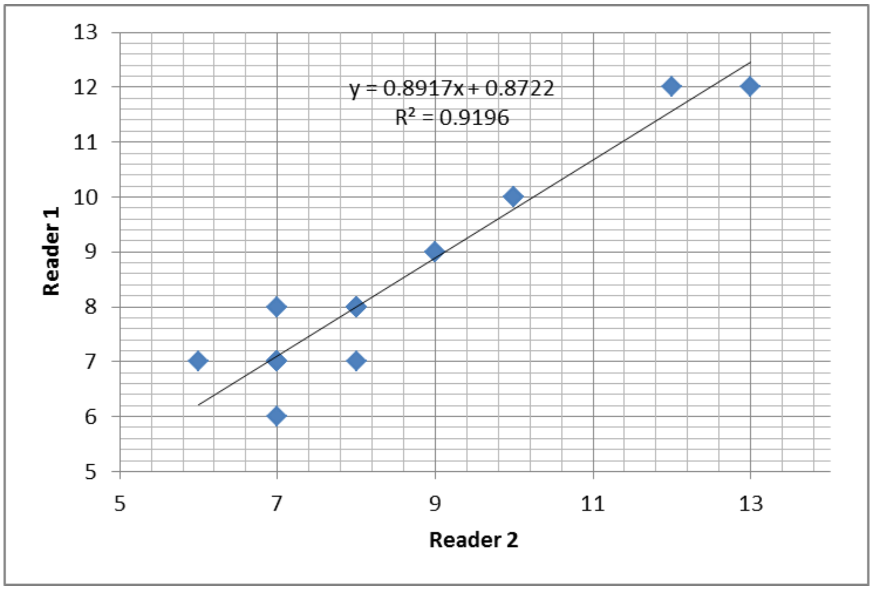


Figure 7. Linear regression between daily pooled sonar file Chinook counts examined by two separate readers.
Note: Data points are daily pooled initial file counts (y axis) and reviewed file counts (x axis).

Range Distribution

The cross section pattern of migrating Chinook at the sonar site in 2019 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.

Carcass Pitch

The carcass pitch was conducted from August 22 through to August 25. A total of 105 dead or moribund Chinook was recovered. Mean length and age data is presented in Table 2. Of the total, 67 (64%) fish were female and 38 (36%) fish were male. Complete age data was determined from 84 of the Chinook sampled; the remaining 21 samples yielded partial or no ages due to regenerate scales. Females were predominately age-6 (1.4) (35%) and males predominantly age-5 (1.3) (14%). Complete age, length and sex data are presented in Appendix 4.

[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.

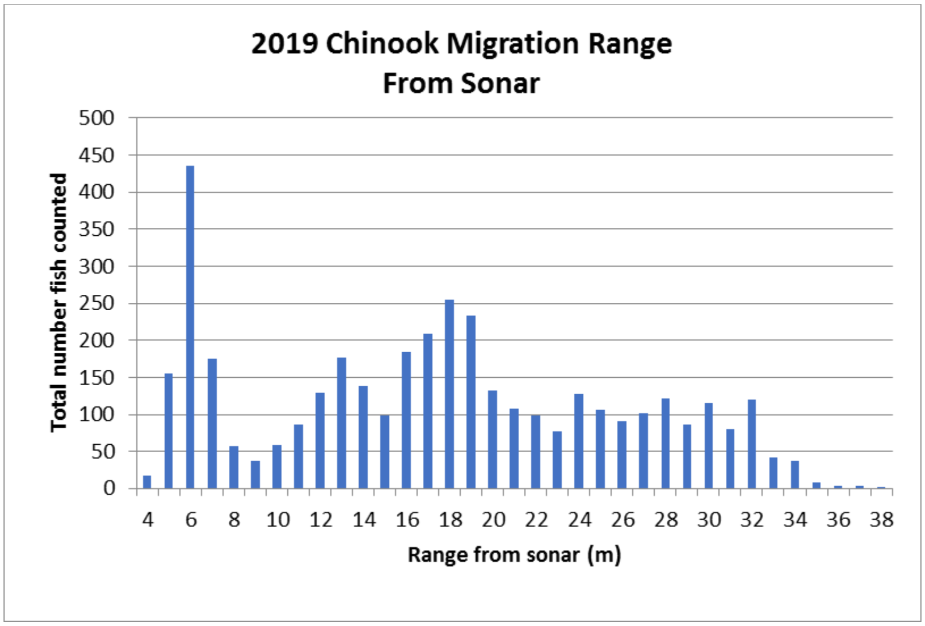


Figure 8. 2019 Big Salmon River Chinook range/frequency in cross section profile.
Note: The 0 – 4m range from the sonar has a deflection fence in place.

Table 2. Age, length, and sex of Chinook sampled from the Big Salmon River, 2019.

SEX	AGE	Mean MEF (mm)	Count	%
Female	1.3	811	9	8%
	1.4	830	42	35%
	1.5	865	1	1%
	M2	790	1	1%
	M3	819	5	4%
	M4	855	4	3%
	M5	920	1	1%
Female total			63	53%
Male	1.1	510	1	1%
	1.3	712	17	14%
	1.4	806	14	12%
	M2	600	2	2%
	M3	695	2	2%
	M4	720	1	1%
Male total			37	31%
Total			100	84%

DISCUSSION

The 2019 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 significant interruptions. Water levels at the sonar station were considered average with no extreme high water events affecting the sonar operation (Appendix 5).

There was a high degree of precision between file readers for all files reviewed. The total count of the fish in the double reviewed files (290) was identical between reviewers

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 2019 Eagle sonar project on the Yukon River downstream of the Canada/U.S. border yielded a total count of 45,560 Chinook. The above border spawning escapement[3] estimate was 41,786 (DFO Whitehorse, unpublished data). Based on the Big Salmon and Eagle Chinook sonar counts, the Big Salmon stock contributed 9.3% of the total above border Chinook escapement in 2019. A comparison of Big Salmon River Chinook sonar counts and the JTC above border Chinook escapement estimates based on Eagle sonar counts (2005 – 2019) 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) $p<0.001$).

A DFO juvenile Chinook salmon research project was conducted on the Big Salmon River from 2014 through 2018. The adult salmon returns from this period are expected to occur through to 2023. Annual Big Salmon sonar Chinook escapement estimates would continue to contribute to this juvenile Chinook research project.

[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.

ACKNOWLEDGEMENTS

Several people contributed to the successful operation of the 2019 Big Salmon River sonar project. Carolyn Knapper and Nicholas Starr were the sonar technicians on the project. Robert Gransden 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.

REFERENCES

Eiler, J.H., R. Spencer, J.J. Pella, and M.M. Masuda. 2006. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River Basin 2004. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-AFSC-165.

Enzenhofer, H.J., Cronkite, G.M.W., and Holmes, J.A. 2010. Application of DIDSON imaging sonar at Qualark Creek on the Fraser River for enumeration of adult pacific salmon: An operational manual. Can. Tech. Rep. Fish. Aquat. Sci. 2869: iv + 37 p.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2019. Yukon River salmon 2018 season summary and 2019 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A19-01, Anchorage.

Mercer B. and J. Wilson, years 2006 - 2019. Chinook Salmon Sonar Enumeration on the Big Salmon River. CRE project 41-xx, Unpublished reports for the Yukon River Panel.

Appendix 1. 2019 daily and cumulative counts of Chinook salmon at the Big Salmon River sonar site.

DATE	DAILY COUNT	CUMULATIVE	COMMENTS
14-Jul	2	2	Weir complete at 18:00 hrs. Partial Daily Count
15-Jul	20	22	
16-Jul	24	46	
17-Jul	41	87	
18-Jul	20	107	
19-Jul	38	145	
20-Jul	46	191	
21-Jul	47	238	
22-Jul	48	286	
23-Jul	54	340	
24-Jul	45	385	
25-Jul	66	451	
26-Jul	66	517	
27-Jul	106	623	
28-Jul	113	736	
29-Jul	164	900	
30-Jul	159	1059	
31-Jul	168	1227	
01-Aug	183	1410	
02-Aug	164	1574	
03-Aug	170	1744	
04-Aug	159	1903	
05-Aug	230	2133	peak daily count
06-Aug	184	2317	
07-Aug	230	2547	
08-Aug	198	2745	
09-Aug	174	2919	
10-Aug	158	3077	
11-Aug	134	3211	
12-Aug	115	3326	
13-Aug	106	3432	
14-Aug	126	3558	
15-Aug	75	3633	
16-Aug	60	3693	
17-Aug	44	3737	
18-Aug	46	3783	
19-Aug	37	3820	
20-Aug	28	3848	
21-Aug	17	3865	Last full day of recording
22-Aug	8	3873	
23-Aug	1	3874	Final estimate based on extrapolation

Yellow cells denote daily extrapolated counts based on the previous 12 days of sonar counts using the polynomial equation: $y=0.396x^2-17.78x+172.95$

Appendix 2. Daily and average Chinook counts in the Big Salmon River, 2005-2019.

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 Count 2019	Daily Average
11-Jul										2		3				**3**
12-Jul										18		11				**15**
13-Jul	0									52		27				**26**
14-Jul	0									52		36			2	**23**
15-Jul	2	1								64	5	57		1	20	**21**
16-Jul	12	0	2	0					0	90	17	56	11	4	24	**20**
17-Jul	13	1	0	0			2		0	115	25	56	22	2	41	**23**
18-Jul	23	0	2	0	0		7	0	0	170	39	82	19	2	20	**26**
19-Jul	13	0	5	1	11		13	0	0	199	72	113	32	13	38	**36**
20-Jul	23	1	5	0	22	0	15	0	0	236	81	126	58	23	46	**42**
21-Jul	36	3	7	0	47	7	24	0	1	229	117	171	82	38	47	**54**
22-Jul	58	8	11	0	68	14	24	0	1	284	148	226	144	51	48	**72**
23-Jul	92	11	18	1	85	12	43	0	2	345	217	174	197	71	54	**88**
24-Jul	130	21	26	2	135	7	44	0	4	343	312	271	235	91	45	**111**
25-Jul	158	20	52	1	201	12	50	1	3	356	411	240	211	118	66	**127**
26-Jul	204	53	88	3	226	14	56	1	11	372	538	292	212	136	66	**151**
27-Jul	219	95	153	5	346	27	105	1	25	421	494	428	281	168	106	**192**
28-Jul	287	146	237	9	498	46	160	3	44	307	531	430	243	242	113	**220**
29-Jul	290	230	287	9	532	83	192	15	86	380	588	394	192	273	164	**248**
30-Jul	299	321	337	29	594	123	218	12	83	330	586	409	317	326	159	**276**
31-Jul	279	368	400	21	808	141	218	23	150	256	492	377	432	310	168	**296**
01-Aug	333	357	435	23	578	159	260	62	196	207	568	362	390	272	183	**292**
02-Aug	346	379	331	18	715	182	313	76	220	207	485	329	363	265	164	**293**
03-Aug	303	358	304	16	725	216	417	138	264	192	441	309	341	270	170	**298**
04-Aug	292	413	258	31	595	226	426	156	262	190	451	245	309	333	159	**290**
05-Aug	331	496	210	51	559	215	396	196	261	170	452	235	241	303	230	**290**
06-Aug	214	490	178	55	452	221	400	228	225	120	469	222	181	264	184	**260**
07-Aug	188	464	147	78	364	227	317	192	191	114	449	177	181	248	230	**238**
08-Aug	232	464	59	61	295	242	294	235	195	96	397	161	115	168	198	**214**
09-Aug	234	360	74	70	270	248	243	183	156	68	348	157	116	100	174	**187**
10-Aug	203	349	90	98	209	183	160	154	132	61	246	101	84	93	158	**155**
11-Aug	124	348	82	122	183	207	170	106	134	50	217	77	85	114	134	**144**
12-Aug	126	324	98	107	146	174	143	130	113	46	187	79	72	99	115	**131**
13-Aug	125	243	77	109	118	181	100	110	101	25	201	58	80	131	106	**118**
14-Aug	72	196	74	89	117	134	85	81	77	30	126	63	65	103	126	**96**
15-Aug	57	180	66	78	65	114	89	80	65	24	113	52	53	72	75	**79**
16-Aug	40	172	56	70	55	82	63	94	57	24	91	33	51	76	60	**68**
17-Aug	53	104	40	49	63	80	35	70	34	17	65	26	54	66	44	**53**
18-Aug	47	69	64	45	55	53	20	50	32	15	54	20	40	65	46	**45**
19-Aug	35	87	37	17	43	40	18	44	21	14	28	10	32	54	37	**34**
20-Aug	29	59	47	18	35	24	21	38	28	11	10	18	10	52	28	**29**
21-Aug	26	45	11	15	28	18	11	27	20	9	7	15	26	36	17	**21**
22-Aug	19	50	16	16	14	38	2	19	10	6		12	22	31	8	**19**
23-Aug	17	12	23	9	4	24	2	19	14	3		9	19	25	1	**13**
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**	**3874**	**5379**

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.

File #	Reviewer #1	Reviewer #2	Difference
1	7	8	1
2	7	7	0
3	8	8	0
4	7	8	1
5	7	7	0
6	8	8	0
7	8	8	0
8	10	10	0
9	8	8	0
10	9	9	0
11	8	8	0
12	7	7	0
13	10	10	0
14	9	9	0
15	12	12	0
16	13	12	-1
17	8	8	0
18	8	8	0
19	8	7	-1
20	10	10	0
21	7	7	0
22	8	8	0
23	7	7	0
24	6	7	1
25	7	7	0
26	7	7	0
27	7	7	0
28	7	7	0
29	7	7	0
30	8	8	0
31	8	8	0
32	9	9	0
33	7	7	0
34	8	8	0
35	8	8	0
36	7	6	-1
Total	**290**	**290**	**0**

Appendix 4. Age, sex, and length of sampled Chinook on the Big Salmon River, 2019.

DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *
22-Aug	1	M		1015	880	780	1.4
22-Aug	2	F	100%	800	740	660	1.4
22-Aug	3	F	100%	950	870	765	1.3
22-Aug	4	M		685	620	540	1.3
22-Aug	5	M		875	775	685	1.3
22-Aug	6	F	N/A	910	830	745	1.3
22-Aug	7	F	0%	870	790	700	M2
22-Aug	8	M		770	690	610	1.3
22-Aug	9	F	N/A	920	840	750	1.4
22-Aug	10	F	100%	970	885	790	1.4
22-Aug	11	F	100%	925	850	750	1.4
22-Aug	12	F	100%	940	850	760	M4
22-Aug	13	M		560	510	445	1.1
22-Aug	14	F	N/A	875	800	710	M3
23-Aug	15	M		870	770	670	M3
23-Aug	16	M		1050	930	815	no age
23-Aug	17	M		760	675	590	1.4
23-Aug	18	F	100%	930	860	770	1.4
23-Aug	19	F	100%	920	830	735	no age
23-Aug	20	M		640	585	530	1.3
23-Aug	21	M		775	690	600	1.3
23-Aug	22	M		780	700	620	1.4
23-Aug	23	M		750	660	585	M2
23-Aug	24	F	10%	830	760	670	1.4
23-Aug	25	M		830	740	650	1.4
23-Aug	26	M		800	720	635	M4
23-Aug	27	F	100%	850	770	680	1.3
23-Aug	28	M		680	620	550	M3
23-Aug	29	M		760	680	600	1.3
23-Aug	30	F	100%	930	830	750	1.3
23-Aug	31	F	100%	990	890	810	1.4
23-Aug	32	F	100%	890	820	730	1.4
23-Aug	33	F	100%	950	865	770	1.5
23-Aug	34	F	100%	920	840	750	1.3
23-Aug	35	F	100%	960	880	780	1.4
23-Aug	36	F	10%	915	820	745	M3
23-Aug	37	F	100%	950	865	775	M3
23-Aug	38	F	100%	880	810	720	1.4
23-Aug	39	M		940	835	730	1.4
23-Aug	40	F	100%	880	815	720	1.4
23-Aug	41	F	N/A	895	815	700	1.4
23-Aug	42	M		910	810	710	1.4
23-Aug	43	M		730	660	570	1.3
23-Aug	44	M		1010	895	790	1.4
23-Aug	45	M		830	750	660	1.3
23-Aug	46	M		590	540	470	M2
23-Aug	47	F	100%	895	815	730	no age
23-Aug	48	M		1000	870	760	1.4
23-Aug	49	F	100%	910	830	755	1.4
23-Aug	50	M		920	830	735	1.4

DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *
23-Aug	51	F	100%	945	860	775	M4
23-Aug	52	F	100%	900	815	740	1.4
23-Aug	53	M		780	700	630	1.4
23-Aug	54	F	100%	890	810	715	M3
23-Aug	55	F	100%	1015	920	840	M5
23-Aug	56	F	100%	895	810	720	1.3
23-Aug	57	M		795	710	620	1.3
23-Aug	58	F	100%	950	865	775	1.4
23-Aug	59	M		1015	905	795	1.4
24-Aug	60	F	N/A	950	870	770	1.4
24-Aug	61	F	100%	955	880	785	1.4
24-Aug	62	F	100%	980	900	810	M4
24-Aug	63	F	100%	915	840	750	1.4
24-Aug	64	F	10%	820	755	665	1.3
24-Aug	65	F	100%	940	860	775	1.4
24-Aug	66	M		940	830	710	1.3
24-Aug	67	M		760	670	590	1.3
24-Aug	68	M		650	590	515	1.3
24-Aug	69	F	100%	865	800	720	M3
24-Aug	70	M		805	725	620	1.3
24-Aug	71	F	N/A	1010	930	830	1.4
24-Aug	72	M		755	665	580	1.3
24-Aug	73	F	10%	860	795	705	1.4
24-Aug	74	F	100%	980	890	800	1.4
24-Aug	75	F	N/A	850	800	710	1.4
24-Aug	76	F	100%	870	790	710	1.3
24-Aug	77	F	100%	900	820	720	1.4
24-Aug	78	M		880	780	690	1.4
24-Aug	79	M		960	840	740	1.4
24-Aug	80	M		1050	910	815	1.3
24-Aug	81	F	N/A	920	845	750	1.4
24-Aug	82	F	N/A	970	905	810	1F
25-Aug	83	M		830	740	650	1.3
25-Aug	84	F	100%	870	790	705	1.4
25-Aug	85	F	50%	850	780	690	1.4
25-Aug	86	F	0%	900	820	730	1F
25-Aug	87	F	100%	920	840	740	1.4
25-Aug	88	F	10%	940	860	775	1.4
25-Aug	89	F	100%	950	860	760	1.4
25-Aug	90	F	100%	900	820	730	1.4
25-Aug	91	F	100%	910	830	730	1.4
25-Aug	92	F	100%	900	820	740	1.4
25-Aug	93	F	N/A	880	800	715	1.4
25-Aug	94	F	100%	880	800	710	1.3
25-Aug	95	F	100%	900	825	730	1.4
25-Aug	96	M		925	820	720	1.3
25-Aug	97	F	100%	890	815	740	1.4
25-Aug	98	F	100%	930	850	755	1.4
25-Aug	99	F	100%	890	810	730	M4
25-Aug	100	F	80%	825	750	680	1.4

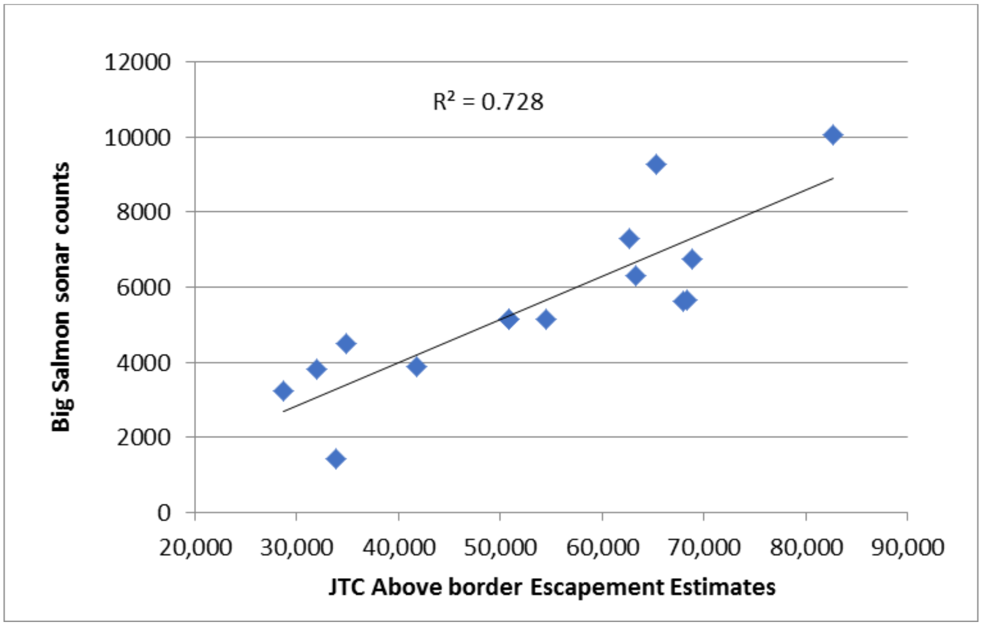
DATE	FISH #	SEX	% SPAWNED	FL (mm)	MEF (mm)	POHL (mm)	AGE *
25-Aug	101	F	100%	890	810	720	1.4
25-Aug	102	F	100%	835	760	680	1.4
25-Aug	103	F	50%	860	790	700	1.4
25-Aug	104	F	100%	950	860	765	1.4
25-Aug	105	M		930	820	720	1.4

*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.

Appendix 5. 2019 Big Salmon River Environmental Conditions – Recorded at 0900h Daily

DATE	AIR TEMP. (ºC)	WATER TEMP. (ºC)	WATER LEVEL (cm)	COMMENTS
14-Jul	10.0	14.0		Sunny in am, cloudy and showers after 16:00
15-Jul	7.0	14.0		Sunny in am.
16-Jul	10.0	14.0		partial clouds
17-Jul	10.0	14.0		partial clouds
18-Jul	12.0	14.0		warm, partial clouds, threatening thunder in eve
19-Jul	14.0	14.0	36	light drizzle turning to rain in the evening
20-Jul	12.0	14.0	38	cloudy morning
21-Jul	12.0	14.0	41	heavy rain in the morning until late afternoon
22-Jul	12.0	14.0	45	cloudy morning, no rain
23-Jul	12.0	14.0	50	cloudy morning, series of short rains
24-Jul	8.0	13.5	52	Cloudy morning, no rain
25-Jul	10.0	13.5	50	Sunny, partial clouds
26-Jul	13.0	13.5	48	Sunny, partial clouds
27-Jul	13.0	13.0	46	Sunny, partial clouds
28-Jul	12.0	13.0	44	Cloudy
29-Jul	10.5	12.0	44	cloudy
30-Jul	12.0	12.0	50	sunny with some clouds, light rain in evening
31-Jul	9.0	12.0	50	Sunny, partial clouds
01-Aug	9.0	12.5	46	Sunny, partial clouds, light rain in eve
02-Aug	9.0	12.5	44	cloudy
03-Aug	14.0	13.0	42	sunny and hot
04-Aug	10.0	14.5	38	overcast with some clouds
05-Aug	15.0	14.5	38	overcast light rain
06-Aug	10.0	13.5	37	overcast, rain
07-Aug	11.5	13.5	37	partial sun and cloud
08-Aug	5.0	12.0	38	sunny and cool
09-Aug	4.0	11.0	37	sunny and cool
10-Aug	7.0	11.0	36	partial clouds, light rain
11-Aug	7.0	11.0	34	rainy, windy and cool
12-Aug	7.0	11.0	33	partial cloud, cool
13-Aug	7.0	11.0	32	light rain, cool
14-Aug	12.0	12.0	32	rain and cool
15-Aug	10.0	11.5	35	rain and cool
16-Aug	7.0	11.0	39	rain
17-Aug	5.0	10.5	45	sunny and cool
18-Aug	4.0	9.0	73	sunny and cool
19-Aug	4.0	8.0	65	sunny and cool
20-Aug	1.0	8.0	65	sunny and cool

Appendix 6. Comparison of Big Salmon River Chinook sonar counts and the JTC above border Chinook escapement estimates based on Eagle sonar counts, 2005 – 2019.



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