2015 CHINOOK SALMON SONAR ENUMERATION ON THE BIG SALMON RIVER

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Prepared for: The Yukon River Panel
Restoration and Enhancement Fund

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

A long range dual frequency identification sonar (DIDSON) was used to enumerate the Chinook salmon escapement to the Big Salmon River in 2015. The sonar was operated on the Big Salmon River for its eleventh year at the same site used for the 2005 through 2014 projects. Sonar operation began on July 15 and continued through to August 20. A total of 10,078 targets identified as Chinook salmon was counted during the period of operation; the highest sonar count since the inception of the program. The 2015 Big Salmon Chinook count was twice the previous 10-year average of 4,924 Chinook. The first Chinook salmon passing the Big Salmon sonar station was observed on July 15, the first day of operations. The peak daily count of 588 fish occurred on July 29, at which date 36% of the estimated run had passed the sonar station. Approximately 90% of the run had passed the station by August 11. Genetic stock identification sampling conducted at the Eagle sonar indicated the Big Salmon River stock group comprised 9.7% (s.d. = 1.7) of upper Yukon River Chinook salmon escapement in 2015. Based on the Big Salmon sonar count and above border escapement estimates from the Eagle sonar project the Big Salmon run comprised approximately 12.2% of the total above border escapement.

Carcass samples were collected between Aug 23 and Aug 25 over approximately 145 km of the Big Salmon River system; yielding 133 Chinook salmon samples. Of the total, 84 (63%) were female and 49 (37%) were male. The mean MEF length of females and males sampled was 828 mm and 764 mm, respectively. All sampling data and scale cards were submitted to DFO Whitehorse stock assessment; scales were subsequently read by the Pacific Biological Station fish ageing lab. Complete age data was determined from 97 of the Chinook sampled; the remaining 36 samples yielded partial or no ages due to regenerate scales. The dominant age class of females was age-6 (41%) and males, age-5 (14%).

INTRODUCTION

The 2015 Big Salmon sonar project marks the eleventh year Chinook enumeration has been conducted on this system. The DIDSON 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 - 2015). Due to high flows and wilderness recreation use of the Big Salmon system, the utilization of traditional salmon weir techniques on this river is not feasible. For these reasons the DIDSON sonar was selected as a low impact, non-intrusive method of accurately enumerating annual Chinook escapements to the Big Salmon River 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 2015 project.

Based on the 2005 – 2015 sonar operations, the Big Salmon River has been shown to be a significant contributor to upper Yukon River Chinook production. The 2005 -2014 average Big Salmon sonar count is 4,924 (range 1,329 to 9,261). These counts represented an average of 10.2% of the total average upper Yukon River Chinook spawning escapement estimate for these years (JTC 2015).

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 2015 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 conducted by Fisheries and Oceans Canada (DFO) on the Big Salmon River system. One of the goals of the project was to begin to develop a baseline of juvenile Chinook outmigration timing and abundance in a river with monitored adult returns. Information on juvenile production and life history will assist with interpretation of stock recruitment models and could contribute to the restoration and management of Canadian-origin Chinook salmon stocks. The existing Big Salmon sonar camp was used as a base for the project. In addition, personnel associated with the sonar program assisted with the juvenile assessment project over the course of its operation.

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.

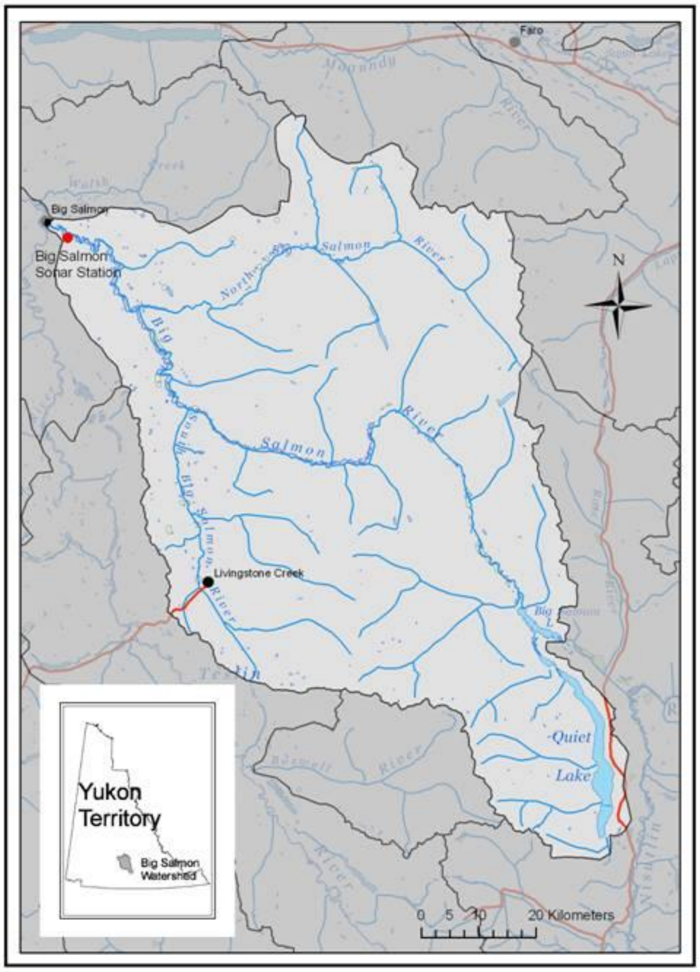

Figure 1. Big Salmon River Watershed and location of the 2015 Big Salmon sonar station.

Objectives

The objectives of the 2015 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 high resolution DIDSON 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.

In addition, document egg retention of female spawners and principal recovery locations of spawned out fish.

3. Provide material, logistical and technical support to a DFO initiated juvenile Chinook assessment project.

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 11 years of sonar operation. It is anticipated that this site will continue to be used as long as the sonar program operates.

Permits

An application was submitted in 2005 to Transport Canada (Marine Branch), Navigable Waters Protection for approval to install partial fish diversion fences in a navigable waterway. Approval was granted for ongoing annual sonar operations as described in the original application.

Camp and Sonar Station Set-up

Project mobilization began on July 12. Initial access to the project site and transportation of associated equipment and supplies was by boat from Little Salmon Village. Other supplies and personnel were transported from Whitehorse via floatplane. Subsequent camp access, crew changes, and delivery of supplies and fuel were accomplished either by riverboat or floatplane.

A five year licence of occupation was granted to the contractor in 2009 by the Yukon Territorial Government Lands Branch for the sonar camp (lower Big Salmon River, N 61°52' 45'', W 134° 53' 08''). This licence was renewed in 2014. This precluded the requirement of annual land use permits and allowed for the construction of upgraded and more permanent facilities at this site. As occurred in 2014 the camp was comprised of two wall tents and one cabin. The cabin was used primarily for storage and the tents were used for accommodation and to house the sonar and computer equipment.

Diversion Fence Construction

At the onset of the project, fence structures were placed in the river to divert shoreline migrating Chinook salmon into a 36 m migration corridor in the center of the river (Figure 2). Fence structures were constructed as in previous years using conduit panels and metal tripods stored on site. Placement of the fence structures was completed by July 15.

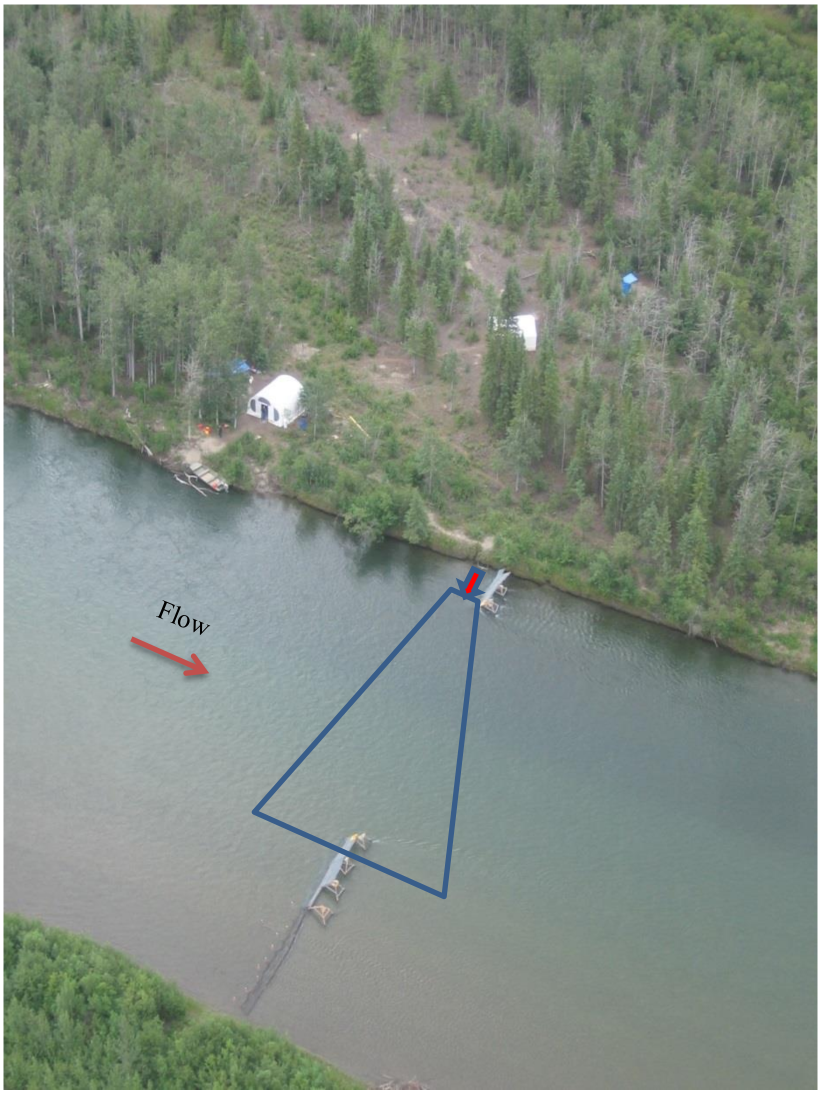

Figure 2. Aerial view of sonar station camp and partial weirs, (photo from 2010 project). Blue outline denotes ensonified portion of the river.

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 DIDSON sonar beams. 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.

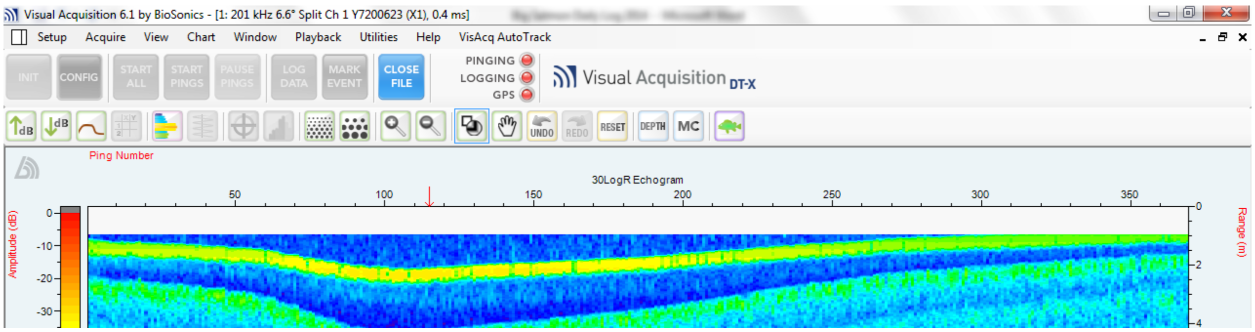

Figure 3. Cross section profile of Big Salmon River at sonar site using a Biosonics DTX split beam echo-sounder.
Note: Top of yellow line is river bottom, thalweg = 1.97 m. Transect view looking down river. The near field of the transducer prevents readings at depths less than 1m as indicated by the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

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. 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 and enabled 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 one set of 6 – 6 volt gel cell batteries connected in two parallel circuits to create a 12 volt power source. The battery banks were charged by six 80 watt solar panels and a backup 2.0 kW generator. A rotating solar panel platform allowed the panels to be manually rotated to directly face the sun thereby increasing the efficiency of the solar panel array. An 800 watt inverter was used to obtain 110 volt AC from the batteries to supply power for the computers and the sonar unit.

A concentrator lens has been attached to the sonar unit during its operation since 2009. This lens reduces the vertical ensonified field from 14° to 8° resulting in an increase in the resolution of the target images. The DIDSON sonar produces an ensonified field 29° wide in the horizontal plane. The DIDSON 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. The average water levels encountered in 2015 allowed for use of the concentrator lens throughout the project. 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.

Once the sonar was in place and positioned, the primary sonar unit settings and software were configured. The receiver gain was set at –40 dB, the window start at 5.86 m, window length at 40 m, and auto frequency enabled for the duration of the project. The recording frame rate was typically set at 4 frames per second, which was the highest frame rate the computers could process with a window length setting of 40 m. Two laptop computers were used for the project, one recording the DIDSON files and one for reviewing the files. All files were saved and placed on a 2 TB external hard drive.

Sonar Data Collection

Sonar recording began on July 15 and continued until August 20. Sonar data was collected continuously and stored automatically in pre-programmed, 20 minute date stamped files. This resulted in an accumulation of 72 files over a 24 hour period. These files were subsequently reviewed the following day and stored on the active PC as well as backed up on the external hard drive.

To optimize target detection during file review, the background subtraction feature was used to remove static images such as the river bottom and weir structures. The intensity (brightness) was set at 40 dB and threshold (sensitivity) at 3dB. The playback speed depended on the preference and experience of the observer, but was generally set between 40 and 50 frames per second, approximately 8 to 10 times the recording rate. When necessary, the recording was stopped when a fish was observed and replayed at a slower rate for positive identification. Chinook salmon images were visually counted using a hand counter and the total count from each file was entered into an excel spreadsheet. A record of each 20 minute file count as well as hourly, daily and cumulative counts was collected throughout the project.

The target measurement feature of the DIDSON software was used when required to estimate the size of the observed fish. All fish 50 cm and larger were categorized as Chinook. The smallest sampled Big Salmon Chinook during the 2015 carcass pitch was 56.0 cm. The largest target categorized as a resident fish based on size and swimming behaviour was approximately 30 cm. 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 2015 amounted to 143 fish or 1.4% of the total run.

As in previous years short interruptions in data collection due to equipment malfunctions, power failures and other technical difficulties are inevitable. The number of chinook passing the sonar station during data collection interruptions was estimated and applied by using the mean hourly fish passage 12 hours before and 12 hours after the interruption. The interpolated counts were included in the total daily counts reported over the course of the project.

Precision of Fish Counts

It is standard practice in salmon enumeration sonar projects to review 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; Crane and Dunbar 2007, 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 file 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. In 2015 a total of 352 (13%) of all the sonar files were reviewed by a second observer. 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.

However, 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 because of 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.

[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.

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

Cross Section Distribution

The position of each Chinook observed within the cross section profile of the river was recorded in 5 m increments. This provided a range frequency histogram illustrating the cross sectional pattern of migrating Chinook.

Carcass Pitch

The carcass pitch which was scheduled to begin on August 20 was delayed due to flood conditions which occurred after a period of heavy rains. An extended trip upriver was made on August 23 through to August 25, when water levels had subsided. 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 the first logjam located 20 km downstream from Big Salmon Lake.

The carcass pitch involved collecting dead and moribund Chinook using a spear and sampling each fish. Carcass sampling consisted of collecting five scales per fish and placing them in prescribed scale cards. The sex and three length measurements (fork, mid-eye-fork and post-orbital hypural) (to the nearest 0.5cm) were also recorded for each recovered fish.

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.

RESULTS

Chinook Salmon Counts

The 2015 Big Salmon Chinook run timing was similar to the previous 10 year average for this stock. The first Chinook salmon was observed on July 15, on the first day of operations. The peak daily count of 588 fish occurred on July 29, at which date 36% of the estimated run had passed the sonar station. The run reached 50% passage on August 1, two days earlier than the previous 10 year average. Ninety percent of the run had passed the station by August 11 which was two days earlier than the 10 year average. Daily and cumulative counts are presented in Appendix 1 and Figure 5.

A total of 10,071 targets identified as Chinook salmon was counted past the sonar station from July 15 through to August 20. Because the sonar was removed before the run was totally complete, an extrapolation was used to estimate the number of Chinook that passed after sonar operations were stopped. This was done by extrapolation of the previous 12 days of the sonar counts based on the polynomial regression $y = 1.4221x^2 - 45.669x + 360.32$. This extrapolation added 7 fish to bring the total count to 10,078.

Short interruptions in sonar recording due to maintenance or power interruptions resulted in a total of 9 hours and 48 minutes recording loss over the course of the project. A total of 47 fish was interpolated for this period. In addition, 11 hours of recorded data from August 9 was lost due to technical issues with an external hard drive. A total of 170 Chinook was estimated for this period. The total interpolated Chinook count over the course of the 2015 project was 217 fish.

The 2015 daily counts exhibited a normal distribution somewhat skewed to the earlier portion of the run with the peak approximately 4 days earlier than average (Figure 5). Daily counts from 2005 through 2015 are illustrated in Figure 6 and listed in Appendix 2.

Precision of Fish Counts

Of the 2,654 sonar files recorded and analysed, a total of 352 (13.3%) was reviewed by a second observer (Table 1). Of the 352 files reviewed, a total of 22 files (6.3%) exhibited a discrepancy between readers. Of the 22 files that exhibited inconsistencies between readers, an additional 19 fish were observed by the reviewer and 11 fish missed by the reviewer. This yields a net gain of 8 fish for the 352 files that were reviewed (0.6% of fish counted in first iteration). Expansion of the net gain in this subset of files to cover the total number of files recorded would result in a possible total of 60 Chinook that may not have been observed or correctly identified and therefore not counted.

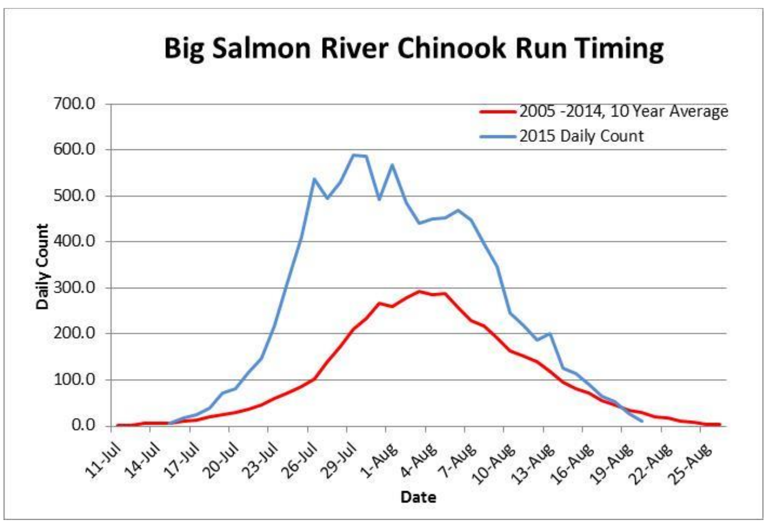

Figure 5. Daily counts of Chinook salmon passing the Big Salmon River sonar station in 2015 and 2005 through 2014.

Figure 7 illustrates the relationship between counts of 2 different file readers using daily pooled original (reader 1) and reviewed files (reader 2). Linear regression between readers showed variation between counts, but overall the correlation is high (R^2= 0.99).

The average percent error (APE) was calculated for the 29 reviewed files that had fish counts ≥ 5 fish/file. The APE for this subset was 0.21%.

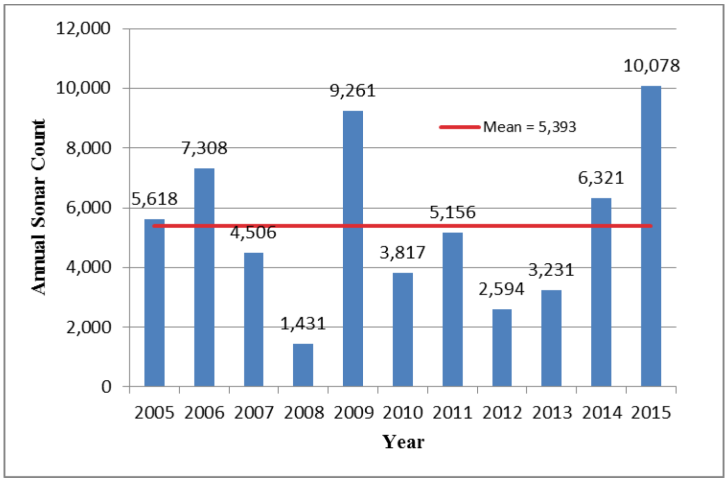

Figure 6. Annual sonar counts for Big Salmon sonar project 2005 – 2015.

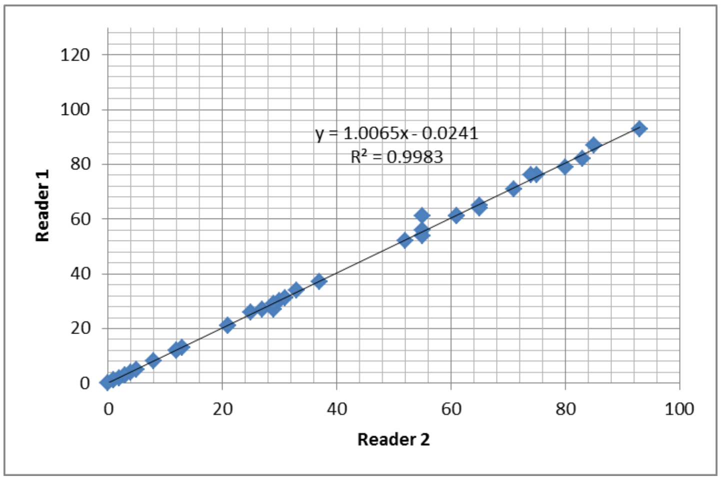

Figure 7. Linear regression between daily pooled sonar file counts that had been analysed by 2 different readers.

Note: Data points are daily pooled initial file counts (y axis) and reviewed file counts (x axis).

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

	Count	**%**
Total files recorded during project	2,654	
Total files double reviewed	352	13.3%
Total fish counted first iteration	1377	
Total files with + variance	12	3.4%
Total files with - variance	10	2.8%
Total Files with variance	22	6.3%
Total plus fish	19	5.4%
Total minus fish	-11	-3.1%
Net difference	8	0.6%

Cross Section Distribution

The cross sectional distribution pattern of migrating Chinook at the sonar site over the period 2011 – 2015 is presented in Figure 8.[2] As occurred in previous years the largest proportion of fish migrated near the south bank in deeper water at a distance of 15-20 meters from the sonar. The water levels experienced in 2015 were considered average which may account for the typical migration pattern. The water levels and temperatures recorded during the project are listed in Appendix 3.

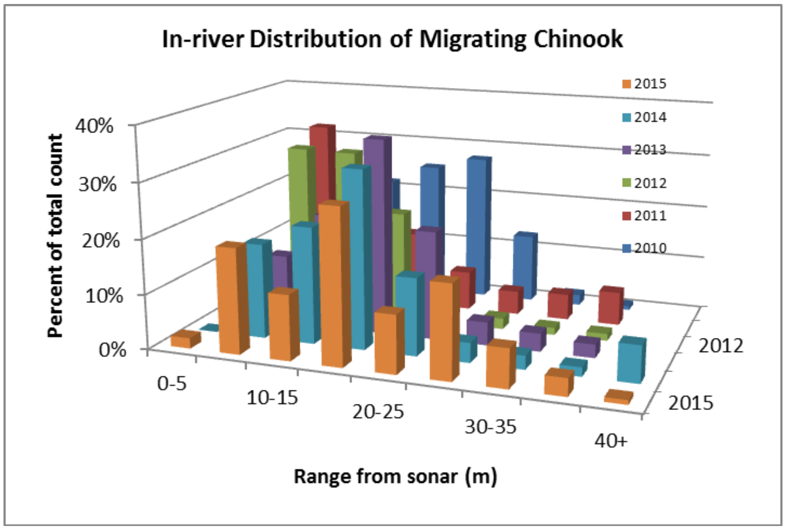

Figure 8. 2010 - 2015 Big Salmon River Chinook range/frequency in cross section profile.
Note: The 0 – 7m range from the sonar has a deflection fence in place.

Carcass Pitch

A total of 133 dead or moribund Chinook was recovered during the carcass pitch. Of the fish sampled, 84 (63%) were female and 49 (37%) were male. The mean mid-eye fork length (MEF) of females and males sampled was 828 mm and 764 mm, respectively. The length frequency of Chinook sampled is presented in Figure 9. Complete age data[3] was determined from 97 of the Chinook sampled; the remaining 36 samples yielded partial or no ages due to regenerate scales. Age-6 (1.4) [4] was the dominant age class of females (41%), followed by age-5 (1.3) (7%). Of the males, age 5 (1.3) was the dominant age class (14%) followed by ages 6 (1.4) (11%) and 4 (1.2) (3%). Mean length and age data is presented in Table 2.

The egg retention of sampled dead and moribund female Chinook was low. Of the 81 females examined,[5] five (6.2%) were not fully spawned out. The estimated egg retention in these five fish ranged from 10% – 40%. Complete age, length and sex data as well as egg retention and principal recovery locations are presented in Appendix 4.

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[2] It should be noted the distribution likely does not reflect the typical in-river migration pattern as the weir structures channel the fish into the 36 m wide opening.
[3] Scale age analysis was conducted for DFO Whitehorse by the Pacific Biological Station, sclerochronology lab in Nanaimo, British Columbia.
[4] European age format; e.g. 1.3 denotes a 5 year old fish with 1+ years freshwater residence and 3 years marine residence.
[5] No assessment for egg retention was possible for 3 females examined due to partial decomposition or predation.

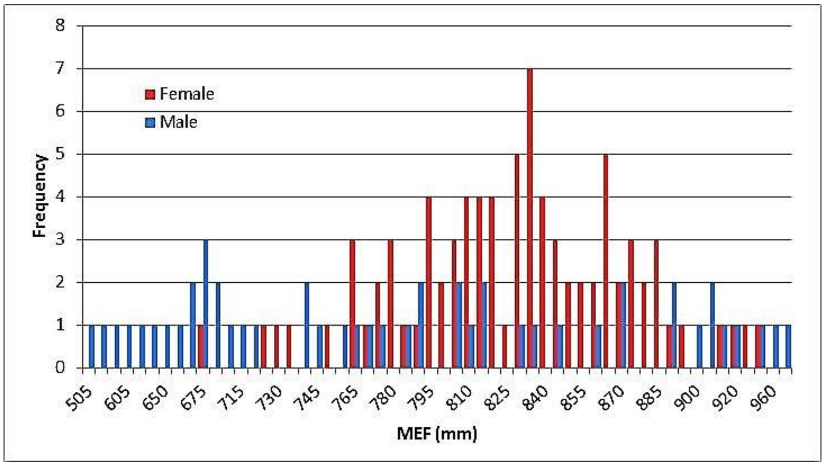

Figure 9. Length/frequency histogram of Big Salmon Chinook sampled in 2015.

Table 2. Age, length, and sex of Chinook sampled from the Big Salmon River, 2015.

SEX	AGE	Mean MEF	Count	%
Female	1.3	751	9	7%
	1.4	839	52	41%
	M4	833	21	17%
Female total		828	82	65%
Male	1.2	552	4	3%
	1.3	701	18	14%
	1.4	880	14	11%
	M3	742	3	2%
	M4	877	5	4%
Male total		764	44	35%
Total		808	126	100%

DISCUSSION

The 2015 Big Salmon sonar project was successful in enumerating the Chinook salmon passing the station. There is a high level of confidence the sonar count accurately reflected the Chinook escapement into the system. Water levels were moderate (below average) throughout the project until August 19 when a period of heavy rains resulted in rapidly rising water levels. By August 21 the river was in flood condition after water levels had risen 110 cm. Overall the weir structures remained in place during the flood events and the migration corridor of 36 m was maintained. However there was considerable damage done to some of the weir structure. The damaged parts of the structure will have to be repaired if the project is conducted in 2016.

The DIDSON sonar unit and related power and computer equipment functioned well throughout the project. Although every effort is made to achieve continuous data collection, short interruptions due to maintenance, power interruptions or other technical difficulties are expected in this type of project.

The counts of files reviewed by a second person exhibited a high level of concordance between both reviewers[6]. Repeated counts of the files were observed to produce the same counts 94% of the time for the 352 files reviewed. Average percent error of all the reviewed files was low (0.21%). As occurred in 2014, the reviewed Chinook counts resulted in a net gain of fish for those files reviewed (Mercer and Wilson 2015). This would indicate that sonar counts could be biased low by a factor of approximately 0.6% of the total count due to missed fish. The variability between readers was not factored into the daily counts and the resultant potentially missed fish (60 Chinook total) were not added to the total sonar count.

The 2015 Eagle sonar project on the Yukon River downstream of the Canada/U.S. border yielded a total count of 84,031 Chinook. The above border spawning escapement[7] estimate was 82,674 Chinook salmon (DFO Whitehorse unpublished data 2016). Based on both the Big Salmon and Eagle Chinook sonar counts, the Big Salmon stock contributed 12.2% of the total above border Chinook escapement in 2015.

Genetic stock identification (GSI) samples were also obtained at the Eagle sonar site using drift nets. The GSI data provides information on the stock composition of the total above border Chinook escapement. The 2015 un-weighted contribution of the Big Salmon River stock to the total Chinook above border escapement based on analysis of the GSI samples was 9.7%, (SD 1.7%) (DFO Whitehorse unpublished data). The 2015 proportional contribution of the Big Salmon River stock to the Chinook above border escapement based on analysis of the GSI samples was within the range observed from 2005 through 2014 (mean 9.4%; range 2.4% - 16.9%). Three years of radio telemetry studies (2002-2004) indicated the Big Salmon contribution to the total above border Chinook escapement averaged 11.4% (range 9.2% – 15.1%; Appendix 5).

Appendix 6 illustrates the relationship between the Eagle sonar counts and the Big Salmon sonar counts from 2005 through 2015. As expected there is a relationship between the annual Big Salmon sonar counts and JTC above border escapement estimates. However, to date the relationship is non-significant (R^2= 0.72); but is bettering with each year of additional data. Therefore neither the 2005 – 2015 Big Salmon nor Eagle sonar counts can yet be used as reliable proxy indices for the relative run strength of these stocks.

An independent above border Chinook escapement estimate can be obtained by expansion of the Big Salmon sonar count using the 2015 Big Salmon GSI stock proportion. Using this method yields an above border escapement estimate of 103,896 (95% CI: 88,404 – 129,205). This estimate range is higher than the escapement estimate (82,674) based on the Eagle sonar counts. Over the period 2005 – 2015 there has been no significant correlation between the Big Salmon Chinook sonar counts and the calculated Big Salmon escapement estimates derived from the Eagle sonar count and GSI proportions (R^2= 0.28). This has been discussed in previous reports (Mercer and Wilson, 2015). In addition, there is no significant relationship between actual Big Salmon sonar counts and estimated Big Salmon escapements calculated from Eagle sonar counts and GSI data (Appendix 7).

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[6] Precision in this case refers to the repeatability of a count between different individuals reading the same sonar file.
[7] Spawning escapement is the Eagle sonar count minus the catches in the U.S. above the sonar station and in the Canadian fisheries.

More years of data and the elimination of suspected outlier years may increase the predictive precision of using GSI data to estimate Chinook stock groups. The Big Salmon stock is a relatively small component of the total above border escapement. Using the GSI method with aggregate stocks (e.g.Teslin plus Big Salmon stocks) has been demonstrated to yield somewhat better results (Mercer 2016).

The 2015 carcass pitch component of the project was planned to be extended by approximately 6 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. This potential sampling bias has been discussed at length in previous reports (Mercer and Wilson 2015; Mears and Dubois, 2009; Zou 2002). Due to the flood conditions encountered, the carcass pitch was truncated because the flood event scoured the system of spawning and moribund Chinook. When water levels receded an extensive single carcass pitch excursion yielded only 133 ASL samples. The few remaining Chinook observed during this carcass pitch led the crew to believe a second extended sampling excursion would yield a low number of ASL samples and would not warrant the effort.

The Big Salmon program has been ongoing for 11 consecutive years. There is value in maintaining an upper Yukon Chinook escapement monitoring project that provides accurate data over a long time series. The rationale for continuing this project is:

- It has proven to be a viable and consistent means of obtaining accurate escapement counts as well as age, sex and length data of Chinook salmon returning to the Big Salmon River.
- The Big Salmon stock comprises, on average, approximately 11% of the total upper Yukon Chinook escapement; the fourth highest stock composition behind the Yukon Mainstem, the Pelly and the Teslin systems.
- There is now one full generation of escapement data for the Big Salmon stock. Continuation of the project will provide ensuing recruitment information on those escapements. The development of biologically based escapement goals is typically based on stock recruitment modelling. These models are based on escapement estimates incorporating an extended time series. The importance of long time series and continuous data sets related to escapement monitoring cannot be over emphasized. The data from this project has been an investment for the YRP and management agencies.
- Quantified Big Salmon Chinook escapement coupled with GSI stock composition data can provide an independent annual estimate of the total above border Chinook spawning escapement as well as provide information on the precision of the GSI stock proportions.

In 2015, a DFO study on juvenile Chinook salmon was initiated on the Big Salmon system. This study was conducted between May 12 and August 16. The Big Salmon sonar camp belonging to Metla Environmental was used as a base for the study. During the operation of the sonar project one of the sonar technicians assisted on the DFO juvenile Chinook project when time permitted. This did not unduly affect sonar operations and if both projects are conducted again in 2016 a similar arrangement could be made.

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Appendix 1. 2015 daily and cumulative counts of Chinook salmon at the Big Salmon River sonar site.

DATE	DAILY COUNT	CUMULATIVE	COMMENTS
Jul-15	5	5	Sonar recording starts at 1600h
Jul-16	17	22	
Jul-17	25	47	
Jul-18	39	86	
Jul-19	72	158	
Jul-20	81	239	
Jul-21	117	356	
Jul-22	148	504	
Jul-23	217	721	
Jul-24	312	1033	
Jul-25	411	1444	
Jul-26	538	1982	
Jul-27	494	2476	
Jul-28	531	3007	
Jul-29	588	3595	peak daily count
Jul-30	586	4181	
Jul-31	492	4673	
Aug-1	568	5241	
Aug-2	485	5726	
Aug-3	441	6167	
Aug-4	451	6618	
Aug-5	452	7070	
Aug-6	469	7539	
Aug-7	449	7988	
Aug-8	397	8385	
Aug-9	348	8733	
Aug-10	246	8979	
Aug-11	217	9196	
Aug-12	187	9383	
Aug-13	201	9584	
Aug-14	126	9710	
Aug-15	113	9823	
Aug-16	91	9914	
Aug-17	65	9979	
Aug-18	54	10033	
Aug-19	28	10061	
Aug-20	10	10071	sonar recorded 24 hrs on Aug 20
Aug-21			sonar removed

Appendix 2. Daily and average Chinook counts in the Big Salmon River, 2005-2015.

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 Average
11-Jul										2		**2**
12-Jul										18		**18**
13-Jul	0									52		**26**
14-Jul	0									52		**26**
15-Jul	2	1								64	5	**18**
16-Jul	12	0	2	0					0	90	17	**17**
17-Jul	13	1	0	0			2		0	115	25	**19**
18-Jul	23	0	2	0	0		7	0	0	170	39	**22**
19-Jul	13	0	5	1	11		13	0	0	199	72	**27**
20-Jul	23	1	5	0	22	0	15	0	0	236	81	**30**
21-Jul	36	3	7	0	47	7	24	0	1	229	117	**35**
22-Jul	58	8	11	0	68	14	24	0	1	284	148	**47**
23-Jul	92	11	18	1	85	12	43	0	2	345	217	**61**
24-Jul	130	21	26	2	135	7	44	0	4	343	312	**71**
25-Jul	158	20	52	1	201	12	50	1	3	356	411	**85**
26-Jul	204	53	88	3	226	14	56	1	11	372	538	**103**
27-Jul	219	95	153	5	346	27	105	1	25	421	494	**140**
28-Jul	287	146	237	9	498	46	160	3	44	307	531	**174**
29-Jul	290	230	287	9	532	83	192	15	86	380	588	**210**
30-Jul	299	321	337	29	594	123	218	12	83	330	586	**235**
31-Jul	279	368	400	21	808	141	218	23	150	256	492	**266**
01-Aug	333	357	435	23	578	159	260	62	196	207	568	**261**
02-Aug	346	379	331	18	715	182	313	76	220	207	485	**279**
03-Aug	303	358	304	16	725	216	417	138	264	192	441	**293**
04-Aug	292	413	258	31	595	226	426	156	262	190	451	**285**
05-Aug	331	496	210	51	559	215	396	196	261	170	452	**289**
06-Aug	214	490	178	55	452	221	400	228	225	120	469	**258**
07-Aug	188	464	147	78	364	227	317	192	191	114	449	**228**
08-Aug	232	464	59	61	295	242	294	235	195	96	397	**217**
09-Aug	234	360	74	70	270	248	243	183	156	68	348	**191**
10-Aug	203	349	90	98	209	183	160	154	132	61	246	**164**
11-Aug	124	348	82	122	183	207	170	106	134	50	217	**153**
12-Aug	126	324	98	107	146	174	143	130	113	46	187	**141**
13-Aug	125	243	77	109	118	181	100	110	101	25	201	**119**
14-Aug	72	196	74	89	117	134	85	81	77	30	126	**96**
15-Aug	57	180	66	78	65	114	89	80	65	24	113	**82**
16-Aug	40	172	56	70	55	82	63	94	57	24	91	**71**
17-Aug	53	104	40	49	63	80	35	70	34	17	65	**55**
18-Aug	47	69	64	45	55	53	20	50	32	15	54	**45**
19-Aug	35	87	37	17	43	40	18	44	21	14	28	**36**
20-Aug	29	59	47	18	35	24	21	38	28	11	10	**31**
21-Aug	26	45	11	15	28	18	11	27	20	9	7	**21**
22-Aug	19	50	16	16	14	38	2	19	10	6		**19**
23-Aug	17	12	23	9	4	24	2	19	14	3		**13**
24-Aug	13	10	17	2		20		14	11	1		**11**
25-Aug	9		14	1		17		9	6			**9**
26-Aug	6		14			6		6	4			**7**
27-Aug	4		13					5	2			**6**
28-Aug	2		11					3	1			**4**
29-Aug			9					2				**6**
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**	**5384**

Note: Stippled values were obtained through extrapolation of counts. Shaded areas denote start and end of sonar recording

Appendix 3. 2015 Big Salmon River water and weather conditions.

DATE	TIME	AIR TEMP. (ºC)	WATER TEMP. (ºC)	WATER LEVEL (cm)	COMMENTS
15-Jul	08h45	9.0	11.0	61	Mostly sunny in A.M, thunderstorms in afternoon, clearing in evening
16-Jul	09h00	8.0	11.0	60	Mostly sunny
17-Jul	08h35	12.0	11.0	56	100% cloud cover in morning, 50% by noon
18-Jul	08h35	11.0	11.0	51	Mix sun and cloud in morning
19-Jul	09h30	11.0	11.0	48	Mix sun and cloud in morning
20-Jul	08h30	10.0	11.0	44	Mostly sun, some cloud in morning
21-Jul	08h30	9.0	11.0	40	Mostly sunny in A.M, thunderstorms in afternoon, clearing in evening
22-Jul	09h30	9.0	11.0	41	Mostly sun, some cloud in morning
23-Jul	08h45	10.0	11.0	41	Mostly sun, some cloud in morning
24-Jul	08h50	10.0	11.0	40	Mostly sunny in A.M, thunderstorms in afternoon, clearing in evening
25-Jul	08h30	8.0	11.0	43	mostly cloudy in morning
26-Jul	09h10	9.0	11.0	40	mostly cloudy in morning
27-Jul	09h00	13.0	12.0	36	mostly cloudy, clearing in evening
28-Jul	09h10	11.0	12.0	34	cloudy
29-Jul	09h00	10.0	11.0	35	cloudy
30-Jul	09h05	11.0	11.0	35	cloudy
31-Jul	08h50	4.0	10.0	32	sunny, cloudy in evening
01-Aug	09h00	7.0	11.0	29	mostly sunny
02-Aug	08h45	8.0	11.0	30	cloudy
03-Aug	08h50	5.0	10.0	35	mainly sunny
04-Aug	08h50	7.0	11.0	32	mainly sunny
05-Aug	08h50	11.0	13.0	27	sun and cloud
06-Aug	09h05	15.0	13.0	24	cloudy
07-Aug	08h50	10.0	12.0	23	cloudy
08-Aug	09h15	5.0	11.0	25	foggy morning, sunny afternoon
09-Aug	09h35	8.0	11.0	22	sunny
10-Aug	10h05	13.0	11.0	19	cloudy
11-Aug	10h25	12.0	11.0	18	cloudy
12-Aug	09h30	14.0	11.0	19	cloudy, rain
13-Aug	11h40	10.0	11.0	22	sun and cloud
14-Aug	10h25	9.0	10.0	20	mainly sunny
15-Aug	09h30	5.0	10.0	17	cloudy
16-Aug	09h30	8.0	10.0	14	cloudy
17-Aug	09h30	8.0	10.0	12	showers
18-Aug	09h30	12.0	11.0	13	rain and showers
19-Aug	10h00	9.0	10.0	32	rain and showers
20-Aug	8h00	6.0	9.0	81	showers, clearing to mix of sun and cloud
21-Aug	9h00	4.0	9.0	114	foggy morning, sunny afternoon

Appendix 4 (a). Age, sex, and length of sampled Chinook on the Big Salmon River, 2015.

DATE	FISH #	SEX	% Spawned (Females)	FL (mm)	MEF (mm)	POHL (mm)	AGE*	Recovery Site
16-Aug	1	M		NR	650	565	1.3	10
23-Aug	2	M		975	860	735	1.4	1
23-Aug	3	M		875	790	685	1.4	1
23-Aug	4	M		910	805	695	1.3	1
23-Aug	5	M		1030	910	820	1.4	1
23-Aug	6	M		795	715	625	1.2	1
23-Aug	7	M		1035	890	780	1.4	1
23-Aug	8	F	100	860	790	710	1.4	1
23-Aug	9	M		605	550	480	1.2	1
23-Aug	10	M		770	675	595	no age	1
23-Aug	11	M		1050	915	800	1.4	1
23-Aug	12	M		810	720	635	1.3	1
23-Aug	13	M		925	815	710	1.4	1
23-Aug	14	F	100	970	875	775	1.4	2
23-Aug	15	M		860	760	670	1F	2
23-Aug	16	M		880	785	670	1.3	2
23-Aug	17	F	100	900	820	720	M4	2
23-Aug	18	M		985	870	770	M4	2
23-Aug	19	M		730	660	575	1.3	2
23-Aug	20	M		860	770	675	1.3	2
23-Aug	21	F	100	1005	925	825	1.4	2
23-Aug	22	F	100	845	775	680	1.4	2
23-Aug	23	F	100	815	725	640	1.3	2
23-Aug	24	M		1030	920	790	1.4	2
23-Aug	25	M		955	845	745	1.4	2
23-Aug	26	F	100	795	735	640	1.3	2
23-Aug	27	F	100	920	855	755	1.4	2
23-Aug	28	F	100	835	765	680	M4	2
23-Aug	29	M		745	675	575	1.3	3
23-Aug	30	M		705	640	550	1.3	3
23-Aug	31	M		1125	980	840	1.4	3
23-Aug	32	F	100	845	780	680	1.4	3
23-Aug	33	F	100	915	830	730	1.4	3
23-Aug	34	F	100	1035	935	815	M4	3
23-Aug	35	F	100	900	815	720	1.4	3
23-Aug	36	M		975	870	755	1.3	3
23-Aug	37	F	100	920	835	730	1.4	3
23-Aug	38	F	100	935	860	750	1.4	3
23-Aug	39	F	100	795	730	645	1.3	3
23-Aug	40	M		775	695	600	1.3	3
23-Aug	41	F	100	895	810	715	1.4	3
23-Aug	42	M		940	830	725	1.4	3
23-Aug	43	M		875	790	680	M3	3
23-Aug	44	F	100	910	830	725	M4	3
23-Aug	45	F	100	820	750	670	1.3	4
23-Aug	46	F	100	900	805	715	1.4	4
23-Aug	47	F	100	895	830	740	1.4	4
23-Aug	48	F	100	885	805	730	M4	4
23-Aug	49	F	90	925	845	770	1.4	4
23-Aug	50	M		910	810	725	M4	4

DATE	FISH #	SEX	% Spawned (Females)	FL (mm)	MEF (mm)	POHL (mm)	AGE*	Recovery Site
23-Aug	51	F	100	920	845	750	M4	4
23-Aug	52	F	100	935	865	780	no age	4
23-Aug	53	F	100	970	885	790	1.4	4
23-Aug	54	F	100	865	795	705	M4	4
23-Aug	55	F	100	895	785	690	1.4	4
23-Aug	56	F	100	920	840	740	1.4	4
23-Aug	57	F	80	965	885	775	1.4	4
23-Aug	58	F	N/A	920	835	725	M4	4
23-Aug	59	F	100	1020	920	830	1.4	4
23-Aug	60	M		665	605	540	1.3	4
23-Aug	61	M		1110	960	840	M4	5
23-Aug	62	F	100	885	800	715	1.4	5
23-Aug	63	M		1025	890	765	1.4	5
23-Aug	64	F	100	925	840	745	M4	5
23-Aug	65	F	100	865	780	695	1.4	5
23-Aug	66	F	100	880	800	705	M4	5
23-Aug	67	F	100	750	675	585	1.3	5
23-Aug	68	M		685	620	530	1.3	5
24-Aug	69	F	100	890	810	725	M4	6
24-Aug	70	F	100	900	815	715	1.4	6
24-Aug	71	F	100	920	830	735	1.4	6
24-Aug	72	F	100	980	885	785	1.4	6
24-Aug	73	M		870	775	685	M3	6
24-Aug	74	F	100	960	875	780	1.4	6
24-Aug	75	F	100	920	840	745	1.4	6
24-Aug	76	F	100	850	770	690	M4	6
24-Aug	77	F	75	870	795	710	M4	6
24-Aug	78	F	100	920	835	740	1.4	6
24-Aug	79	F	100	945	865	760	1.4	6
24-Aug	80	M		675	600	525	1.2	7
24-Aug	81	F	100	955	865	760	1.4	7
24-Aug	82	F	100	975	890	795	1.4	7
24-Aug	83	F	100	930	850	755	1.4	7
24-Aug	84	F	100	880	810	715	M4	7
24-Aug	85	F	100	920	835	735	1.4	7
24-Aug	86	F	100	905	820	725	1.4	7
24-Aug	87	F	100	945	865	750	1.4	7
24-Aug	88	F	100	840	765	660	1.3	7
24-Aug	89	F	100	900	820	720	1.4	7
24-Aug	90	M		935	835	720	M4	7
24-Aug	91	F	100	935	850	750	1.4	7
24-Aug	92	M		825	740	645	1.3	7
24-Aug	93	F	100	915	840	730	no age	7
24-Aug	94	F	60	880	810	720	1.4	8
24-Aug	95	M		905	805	720	1F	8
24-Aug	96	F	100	990	895	780	M4	8
24-Aug	97	F	100	955	875	775	1.4	8
24-Aug	98	F	N/A	860	795	705	1.4	8
24-Aug	99	M		760	680	600	1.3	8
24-Aug	100	M		1025	910	790	M4	8

DATE	FISH #	SEX	% Spawned (Females)	FL (mm)	MEF (mm)	POHL (mm)	AGE*	Recovery Site
24-Aug	101	F	100	1010	915	810	M4	8
24-Aug	102	F	100	840	765	670	1.3	8
24-Aug	103	F	100	925	835	735	1.3	8
24-Aug	104	F	100	850	780	690	1.3	8
24-Aug	105	F	100	945	880	770	1.4	8
24-Aug	106	M		1060	935	810	1.4	8
24-Aug	107	F	100	870	795	705	1.4	8
24-Aug	108	M		830	745	640	no age	8
24-Aug	109	F	100	960	880	775	1.4	8
24-Aug	110	F	100	915	835	730	1.4	8
24-Aug	111	F	100	935	845	750	1.4	8
24-Aug	112	M		730	655	565	1.3	8
24-Aug	113	F	100	955	865	760	M4	8
24-Aug	114	F	70	845	775	680	1.4	8
24-Aug	115	M		760	680	580	1.3	9
24-Aug	116	F	100	960	870	755	M4	9
24-Aug	117	F	100	900	815	725	1.4	9
24-Aug	118	F	100	940	855	745	M4	9
24-Aug	119	M		1025	900	785	1.4	9
24-Aug	120	F	N/A	915	830	730	M4	9
24-Aug	121	F	100	870	805	700	1.4	9
24-Aug	122	F	100	910	820	720	1.4	9
24-Aug	123	M		755	675	580	1.3	9
24-Aug	124	M		830	740	640	1.3	9
24-Aug	125	F	100	970	870	760	1.4	9
24-Aug	126	F	100	885	815	710	M4	9
24-Aug	127	F	100	940	860	755	1.4	9
24-Aug	128	M		855	765	660	1.4	9
24-Aug	129	F	100	895	825	725	1.4	9
24-Aug	130	F	100	920	835	725	1.4	9
25-Aug	131	M		560	505	440	1.2	10
25-Aug	132	M		905	815	700	no age	10
25-Aug	133	M		740	660	555	M3	10

*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 4 (b). Primary locations of sampled carcasses and moribund fish recovered on the Big Salmon River, 2015.

Recovery Site	*** GPS Coordinates**
1	N 61 41.518'
	W 134 30.188'
2	Not recorded
3	N 61 38.417'
	W 134 30.486'
4	N 61 36.685'
	W 134 26.429'
5	N 61 36.156'
	W 134 22.854'
6	N 61 32.735'
	W 134 12.150'
7	N 61 31.712'
	W 133 58.579'
8	N 61 31.924'
	W 133 52.560'
9	N 61 35.942'
	W 133 48.534'
10	N 61 52.45'
	W 134 53.08'

Appendix 5. Estimated proportion of Big Salmon River Chinook and Yukon River Chinook border escapement, 2002 through 2015.

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
Mean		11.3	4,770	45,422	61,757
Std. Dev.		3	2,278	15,259	65,681

[a] Eagle sonar above border spawning escapement estimate (DFO Whitehorse, unpublished data).

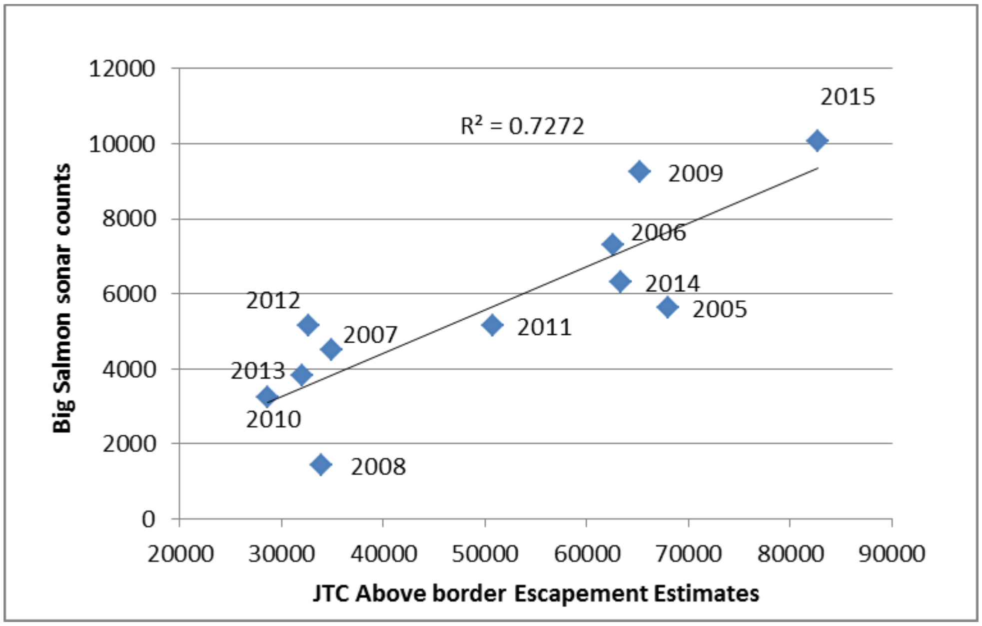
[b] Eagle sonar estimate (JTC 2012 and Unpublished DFO Whitehorse data).

[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 6. Big Salmon sonar counts and the JTC above border escapement estimates based on Eagle sonar counts, 2005 – 2015.



Appendix 7. Big Salmon Chinook sonar counts and Big Salmon Chinook escapement estimates based on Eagle sonar counts and GSI data, 2005 – 2015.