2011 CHINOOK SALMON SONAR ENUMERATION ON THE BIG SALMON RIVER

CRE-41-11

Prepared for: The Yukon River Panel
Restoration and Enhancement Fund

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ABSTRACT

A long range dual frequency identification sonar was used to enumerate the Chinook salmon escapement to the Big Salmon River in 2011, as well as determine associated run timing and diel migration patterns. This was the seventh year of sonar operation at this site. The sonar was operated on the Big Salmon River at the same site used for the 2005 through 2010 projects, approximately 1.5 km upstream of the confluence of the Yukon River. The camp and sonar station set-up was initiated on July 15. Sonar operation began on July 17 and operated continuously through to August 23. A total of 5,156 targets identified as Chinook salmon was counted during the period of operation. This was slightly below the six year average of 5,307 in this system and represented 10.2% of the upper Yukon River spawning escapement estimate of 50,780. The first Chinook salmon was observed on July 17. The peak daily count of 426 fish occurred on August 4, at which time 50% of the run had passed the sonar station; 90% of the run had passed the station on August 12. A carcass pitch was conducted over approximately 120 km of the Big Salmon River, yielding 271 sampled Chinook. Of these, 174 (64%) were female and 97 (36%) were male. The mean fork length of females and males sampled was 857.4 mm and 796.6 mm, respectively. The DFO scale lab determined ages from 219 Chinook sampled. Age-6 (77.6%) was the dominant age class, followed by age-5 fish (15.1%). Age-4 and age-7 fish represented 2.7% and 4.6% of the sample, respectively.

INTRODUCTION

A project to enumerate the Chinook salmon escapement into the Big Salmon River drainage was initiated in 2005 using a DIDSON™ (Dual frequency Identification SONAR). The 2011 project is the seventh year sonar enumeration has been conducted on this system. The DIDSON units have been found to be reliable, do not require extensive operator training, and provide accurate counts of migrating salmon (Enzhofer et al. 2010, Holmes et al. 2006, Mercer & Wilson 2006 - 2010). Due to high flow rates and wilderness recreation utilization of the Big Salmon River, the use of traditional salmon weir techniques on this river is not feasible. For these reasons the DIDSON sonar was considered as a relatively low impact, non-intrusive method of 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.

Based on the 2005 – 2010 sonar operations, the Big Salmon River has been shown to be a significant contributor to upper Yukon River Chinook production. From 2005 through 2010 the Big Salmon River sonar counts were 5,618, 7,308, 4,506, 1,431, 9,261 and 3,817. These counts represented 10.8%, 9.7%, 10.6%, 9.3%, 16.9% and 11.7% of the total upper Yukon River spawning escapement point estimate for these years (JTC 2011).

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 Pilot station and Eagle sonar project estimates) assessment of total above border Chinook escapements. Accurate Chinook escapement enumeration of select tributaries combined with GSI sampling information collected at the Eagle sonar project increases the accuracy of the post season upper Yukon River Chinook run re-construction.

In conjunction with sonar enumeration, carcass sampling was conducted to obtain age, sex and length data from the 2011 Big Salmon Chinook escapement. This information provides important biological baseline data on the health of the stocks as well as information used in constructing future sibling based pre-season run forecasts.

A proposal to continue sonar operations and a Chinook dead pitch on the Big Salmon River was submitted by J. Wilson and Associates to the Yukon River Panel Restoration and Enhancement (R&E) fund in January 2011. The proposal was accepted and financial support was received from the R&E fund. This report is a summary of the 2011 project.

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 along the 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 approximately 130 air kilometers from Whitehorse.

Objectives

The objectives of the 2011 Big Salmon River sonar project were:

1. To operate a sonar station on the Big Salmon River to enumerate the Chinook salmon escapement and obtain information on run timing and diel migration patterns.

2. To conduct spawning ground sampling for age-sex-length data from post-spawn fish.

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 characteristics of the river at this site have not changed for the past 7 years of sonar operation. It is anticipated that this site will continue be used as long as the sonar program operates.

Permits

A five year licence of occupation (with option of renewal) was granted in 2009 by the Yukon Territorial Government (YTG) Lands Branch for the sonar camp on the lower Big Salmon River. This precluded the requirement of annual land use permits and allowed for the construction of upgraded and more permanent facilities at this site. 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.

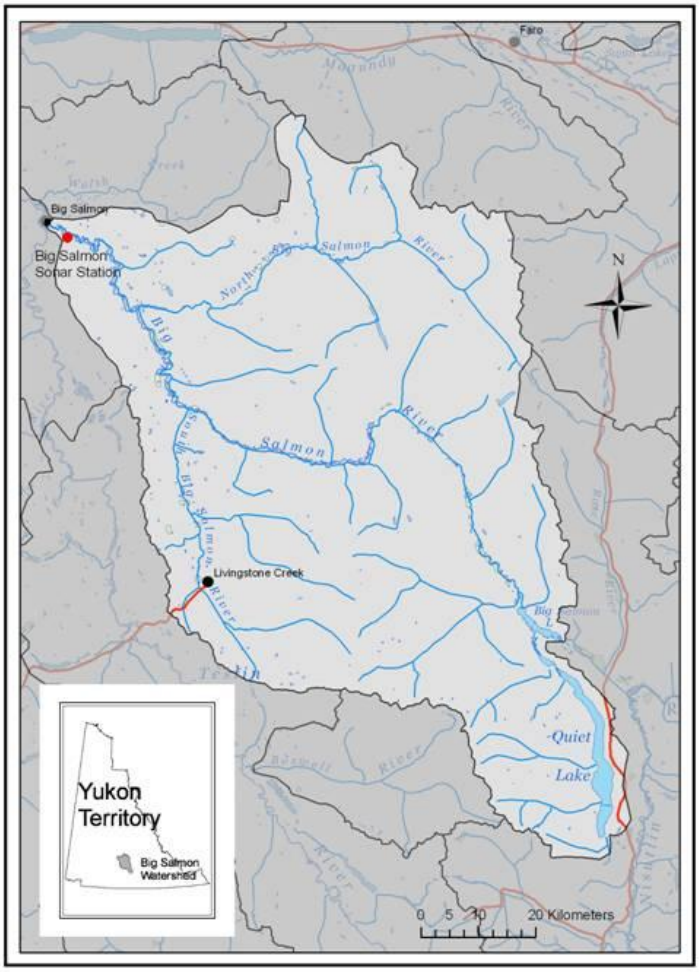

Figure 1. Big Salmon River Watershed and location of the 2011 Big Salmon sonar station.

Camp and Sonar Station Set-up

Construction of the camp and sonar station was initiated on July 15. Equipment and supplies were transported by truck from Whitehorse and loaded onto a boat and floatplane at Little Salmon Village for transport to the site. Subsequent camp access, crew changes, and delivery of supplies were accomplished either by riverboat or floatplane.

As in previous years, the camp was comprised of two wall tents: one to house a kitchen/eating area and computer station and another for sleeping quarters. The kitchen and computer station was located 6 m from the south bank of the river and constructed using a 5m x 5m “weatherall” free standing wall tent placed on a plywood platform. The sleeping quarters was situated 30 m from the south bank and constructed using a 14’ X 16’ canvas wall tent placed on a plywood platform and wooden frame (Figure 2).

Weir construction

Two weir structures were constructed on either side of the river to divert shoreline migrating Chinook salmon into a 36 m migration corridor in the center of the river (Figure 2). Weir structures were constructed as in previous years using conduit panels and metal tripods stored on site (Figures 3 and 4).

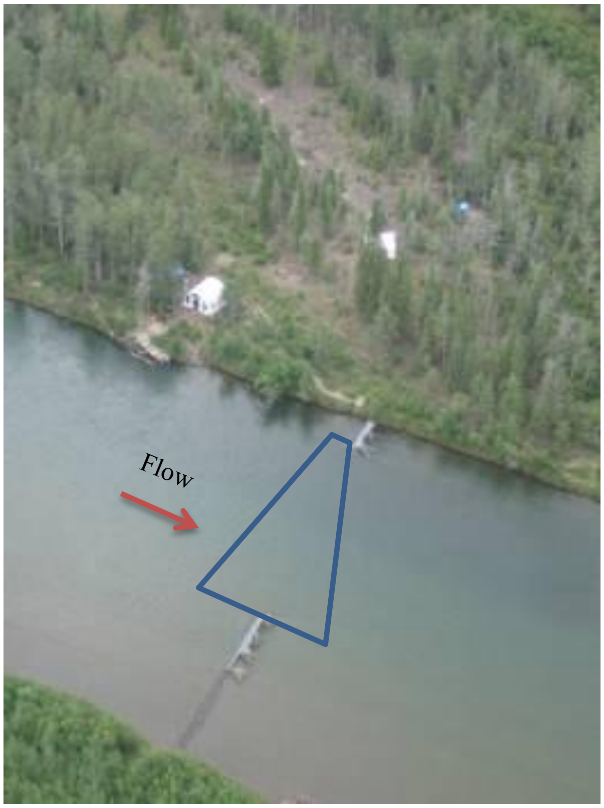

Figure 2. Aerial view of sonar station camp and partial weirs, (photo from 2006 project).
Blue outline denotes ensonified portion of the river.

Sonar and Computer Software Configuration

The configuration of the DIDSON sonar unit was similar to that used in previous years at this site. The unit was mounted on an adjustable stand constructed of 2-inch steel galvanized pipe similar in design to those used at other DIDSON sonar projects (Galbreath and Barber 2005). The stand consisted of two T-shaped legs 120 cm in height connected by a 90 cm crossbar (Figure 5). The sonar unit was bolted to a steel plate suspended from the cross bar that was connected to the stand with adjustable fittings (Kee Klamps™). The adjustable clamps allowed the sonar unit to be raised or lowered according to fluctuating water levels as well as enabling rotation of the transducer lens to adjust the beam angle.

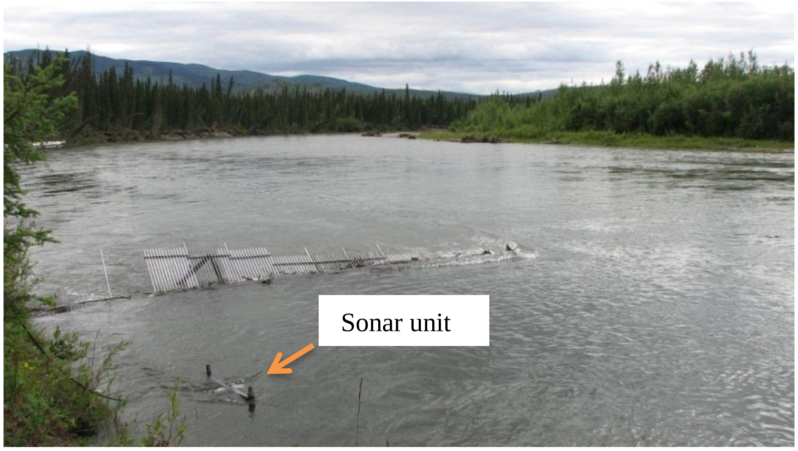

Figure 3. Sonar transducer unit and mounting stand in position.

Figure 4. Construction of partial weir on south side of river.

Figure 5. Sonar transducer unit and mounting stand.

An 8° concentrator lens used in 2009 and 2010 was again used for the 2011 project. The 8° concentrator lens reduces the vertical ensonified field from 14° to 8°. The reduced field size increases the acoustic energy reflected from the targets in the field and reduces interference from surface and bottom reverberation. This results in an increase in the resolution of all target images and more importantly increases the resolution and detection of targets in the outer range of the ensonified area where reflected acoustic energy is lower.

The mounted sonar unit and stand was placed next to the south bank immediately upstream of the diversion fence in approximately 1.0 m of water (Figure 3). The “feet” of the stand were secured to the stream bottom using sandbags. A 6 mm stainless steel safety cable was affixed to the sonar unit and fastened to a buried anchor onshore.

The DIDSON sonar produces an ensonified field 29° wide in the horizontal plane and with the concentrator lens, 8° deep in the vertical 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 the surface of the river (Figure 6).

Due to the high water levels encountered during portions of the 2011 project it was necessary to tilt the sonar unit on the horizontal plane to ensure the entire near shore water column was ensonified. 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. Since the water depth at a distance of 7.5 m from the sonar unit reached a maximum of 1.5 m, it was necessary during certain periods of the project to tilt the sonar to increase the depth of the ensonified vertical plane. A table was prepared using simple trigonometry formulae to enable the sonar operators to determine the sonar tilt requirements for given water depths and sonar window start lengths (Appendix 2). The maximum tilt of the sonar did not exceed 10° from horizontal.

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. Threshold settings were set at 3 dB and intensity at 40 dB. 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 backup 500 GB external hard drive

The sonar system was powered by two sets of 6 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. 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 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.

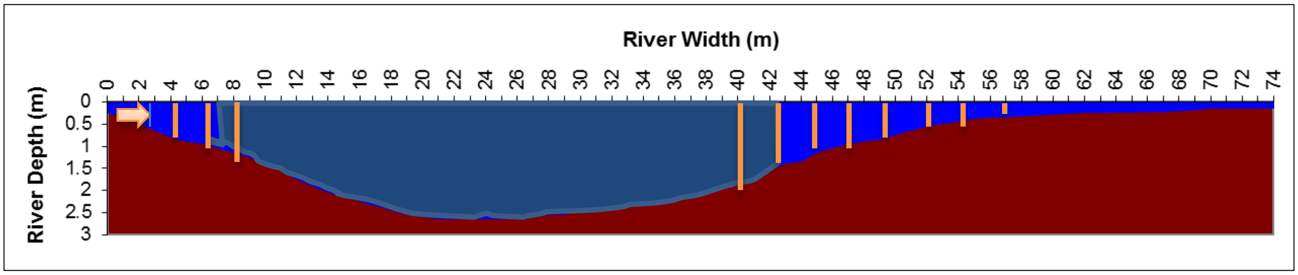

Figure 6. Schematic diagram of river cross section profile and sonar and weir configuration. Orange bars denote weir structures and dark blue the ensonified portion of the water column. Note: Not to scale.

Sonar Data Collection

After the weir structure and sonar unit was installed, 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 maintained throughout the run.

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 2011 dead pitch was 52 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 2011 amounted to 116 or 2.2% of the total run.

[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.

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 upper reaches of the Big Salmon River were accessed using a 6.0 m open skiff powered by a 60 hp outboard jet motor. The crew made two extended trips upriver on August 21 through 24 and August 26 through 28 searching for spent Chinook and carcasses. Carcass pitch efforts extended from the camp approximately 120 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 mid-eye-fork and post-orbital hypural lengths (to the nearest 0.5cm) were also recorded for each recovered fish.

RESULTS

Chinook Salmon Counts

The first Chinook salmon was observed on July 17 at 19:40. The peak passage was on August 4, and 90% of the run had passed the station on August 12. Daily and cumulative counts are presented in Appendix 1. A total of 5,156 targets identified as Chinook salmon was counted past the sonar station from July 17 through to August 23. The daily counts exhibited a normal distribution. The run timing in 2011 was similar to the average run timing observed in the previous 6 years (Figure 7). Daily counts from 2005 through 2011 are in Appendix 5.

Diel Migration

As occurred in previous years at this site, there was no significant diel migration pattern observed in the 2011 Chinook salmon migration in the Big Salmon River (Single factor ANOVA, tested for homogeneity of variance: $df=23$, $F=0.41$, $F_{crit.} = 1.54$, $\alpha=0.05$, $p=0.99$) (Figure 8). The average of the previous 6 years of 24 hour temporal migration data has shown the collective mean hourly variance decreasing. This suggests that with successive years of diel migration data no distinct diel pattern will be observed.

Cross Section Distribution

The distribution pattern of the migrating Chinook as detected by the sonar is presented in Figure 9. The largest proportion of fish was located in the deeper water near the south bank at a

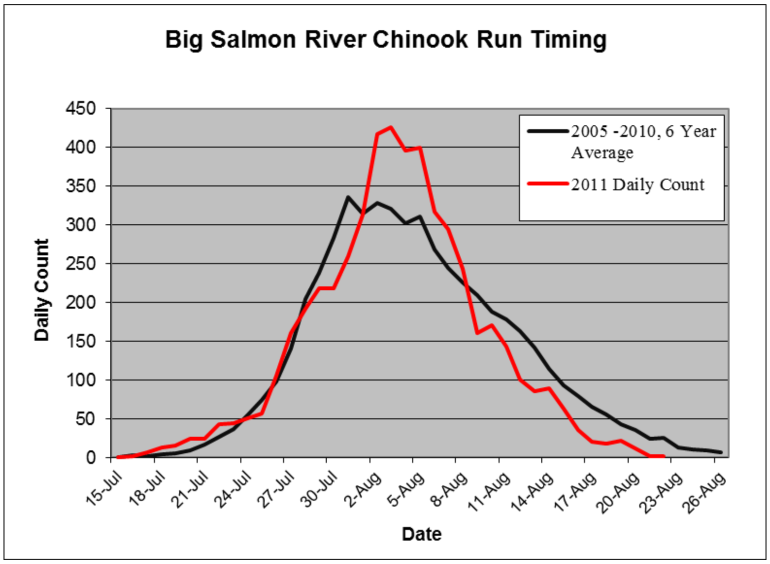

Figure 7. Daily counts of Chinook salmon passing the Big Salmon River sonar station in 2005 through 2011.

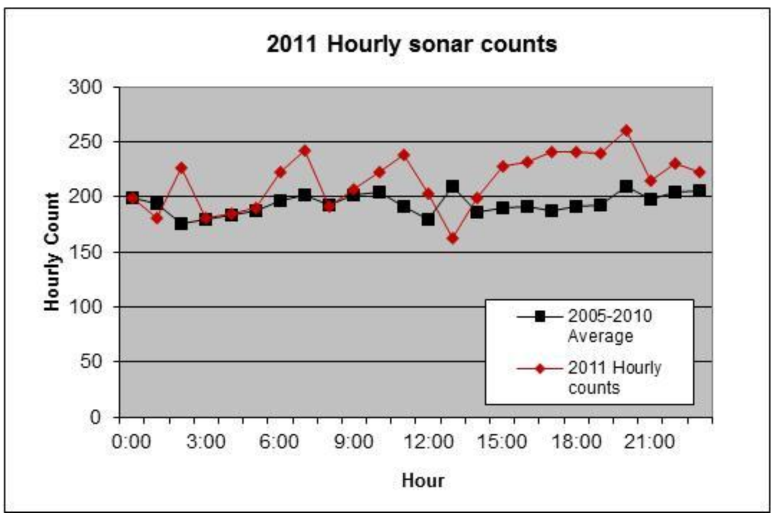

Figure 8. Total hourly counts of Chinook salmon passing the Big Salmon River sonar station in 2011 and the 2005 – 2011 average.

distance of 10-20 meters from the sonar. This distribution likely does not reflect the typical in-river migration pattern as the weir structures channel the fish into the 36 m wide opening. The distribution pattern observed in 2011 differs significantly from the pattern observed in 2010. The cause for this difference is unknown.

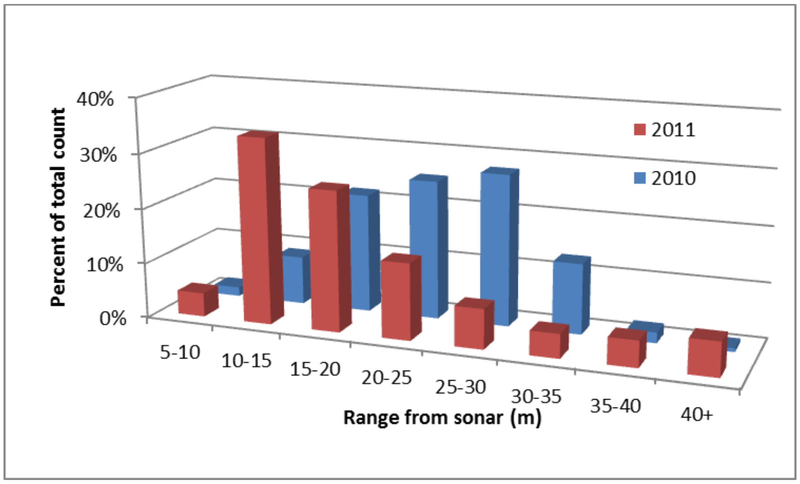

Figure 9. 2011 Big Salmon River Chinook range/frequency in cross section profile.

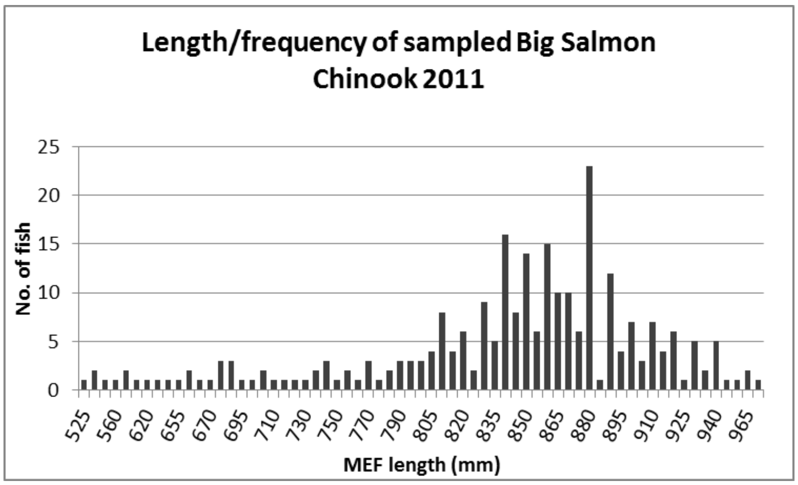

Figure 10. Length/frequency histogram of Big Salmon Chinook sampled in 2011.

Above border Chinook spawning escapement estimates

The 2011 Eagle sonar project on the Yukon River downstream of the Canada/U.S. border yielded a spawning escapement[2] estimate of 50,780 Chinook salmon (DFO Whitehorse unpublished data 2012). Genetic stock identification (GSI) samples were also obtained at this site using drift nets. The GSI data provides information on the proportional contribution of identified stocks to the total above border Chinook escapement. The 2011 mean weighted proportional contribution of the Big Salmon River stock to the Chinook border escapement based on analysis of the GSI samples was 9.2%, (DFO Whitehorse unpublished data). Using Big Salmon sonar counts and the proportion of Big Salmon origin stock derived from the GSI sampling, the 2011 expanded Chinook border escapement estimate would be 56,043 (Table 1). The 2011 Big Salmon Chinook

[2] Spawning escapement is the Eagle sonar count minus the catches in the U.S. above the sonar station and in the Canadian fisheries.

contribution to the above border Chinook escapement based on GSI sampling (9.2%) is at the low end of the range observed from previous telemetry studies and GSI sampling over the period 2002 through 2010.

Table 1. Estimated proportion of Big Salmon River Chinook and Yukon River Chinook border escapement, 2002 through 2011.

Year	Method	Estimated % proportion of border escapement based on telemetry or GSI sampling	Big Salmon sonar count	Escapement based on Eagle sonar count or mark/recapture	Escapement 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
Mean		11.3	5,300	49,639	46,960
Std. Dev.		2.4	2,319	14,771	17,717

[a] Preliminary Eagle sonar above border spawning escapement estimate (DFO Whitehorse, unpublished data).
[b] Eagle sonar estimate (JTC 2010).
[c] Mark/recapture estimate (JTC 2010).
Sources: Osborne et al. 2003; Mercer and Eiler 2004; Mercer 2005; JTC reports 2005 through 2010; unpublished DFO Whitehorse data.

Carcass Pitch

A total of 271 dead or moribund Chinook was recovered during the carcass pitch. Of these, 174 (64%) were female and 97 (36%) were male. Age, length and sex data are summarized in Table 2. The mean mid-eye fork length of females and males sampled was 857.4 mm and 796.6 mm, respectively. Complete age data[3] was determined from 219 of the Chinook sampled; the remaining 52 samples yielded partial ages or no ages due to regenerate scales. Due to caudal fin deterioration matched age and fork lengths were obtained from only 212 fish. Age-6 (1.4) was

[3] Scale age analysis was conducted for DFO Whitehorse by the Pacific Biological Station, fish ageing lab in Nanaimo, British Columbia.

the predominant age class comprising 77.6% of the sample, followed by age-5 (1.3) [4] fish (15.1%). Age-4 (1.2) and age-7 (1.5) represented 2.7% and 4.6%, respectively. Complete age, length and sex data are presented in Appendix 4.

Table 2. Age, length, and sex of Chinook sampled from the Big Salmon River, 2011.

SEX	AGE	Data	Total	Percent
Female	1.3	Average of MEF (mm)	810	
		Count of AGE	7	3%
	1.4	Average of MEF (mm)	857	
		Count of AGE	118	56%
	1.5	Average of MEF (mm)	912	
		Count of AGE	9	4%
Female Average of MEF (mm)			858	
Female Count of AGE			134	63%
Male	1.2	Average of MEF (mm)	577	
		Count of AGE	6	3%
	1.3	Average of MEF (mm)	721	
		Count of AGE	24	11%
	1.4	Average of MEF (mm)	867	
		Count of AGE	46	22%
	1.5	Average of MEF (mm)	940	
		Count of AGE	1	0%
Male Average of MEF (mm)			800	
Male Count of AGE			77	36%
Total Average of MEF (mm)			836	394%
Total Count of AGE			212	100%

DISCUSSION

There were no significant operational problems encountered during the 2011 sonar project. Both weir structures functioned well during the high water events which occurred and the migration corridor of 36 m was maintained throughout the sonar operation. Three interruptions in recording due to computer/power problems resulted in a total down time of 5 hours over the course of the project. Chinook counts during these outages were obtained by inferring counts per hour from the 24 hour counts before and after the outage.

The Chinook border escapement of 56,043 derived from the Big Salmon sonar counts and the proportional contribution of the Big Salmon River stock based on GSI samples was higher than the preliminary Eagle sonar spawning escapement estimate of 50,780 Chinook salmon. The difference between the Big Salmon GSI/sonar based estimate and the Eagle sonar estimate is within the range of variance observed in the GSI determined stock proportion (mean 9.2%; std. dev. 2.4%).

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

As occurred in previous years, the daily sonar counts in 2011 exhibited a normal distribution with few targets detected at the beginning and end of the run. This suggests the probability is low that other co-migrating fish species mis-identified as Chinook are present in the system when the sonar is in operation. Resident fish species (as well as other aquatic organisms such as waterfowl and beaver) are readily distinguished from migrating Chinook based on size, form, and behaviour. Due to similar migratory behaviour and size overlap with smaller Chinook, the only likely species that could be confused with Chinook are Chum salmon. The presence of co-migrating fall Chum salmon entering the system at the end of the Chinook migration period would be problematic and would decrease the accuracy of the Chinook escapement estimate. However, the presence of Chum salmon has not been documented in the Big Salmon system (DFO Whitehorse FISS database) and none have been observed during the seven years of carcass recovery. Test fishing at the Eagle sonar station from 2007 through 2009 captured the first Chum Salmon on August 8, 9, and 19 respectively (Crane and Dunbar, 2009 and 2011). This suggests the Big Salmon Chinook run would typically be complete before any fall Chum could potentially arrive in the system.

Chinook post spawning mortality may result in an asymmetric die off with one sex dying, on average, sooner than the other. If sampling is not done throughout the die off period the samples collected may not be representative of the population structure. Efforts were made to obtain ASL samples representative of the total escapement but it is not known if the samples collected were representative of the aggregate escapement. The planning for the first carcass recovery trip in 2011 was based on run timing in 2011 and previous years. Each carcass recovery effort involves a 3-4 day, 240 km round trip. For reasons of economy, efficient use of personnel, and to maximize the number of samples obtained, the carcass sampling is timed to coincide with the period of maximum die off.

In 2010, construction of a cabin was initiated at the sonar site to replace the wall tents used in previous years. The cabin was clad to weather at the end of the 2011 season which enabled secure storage of some camp equipment on site. Completion of the cabin is expected during the 2012 season. This structure will reduce the logistical constraints of freighting and storage, mitigate the potential damage from high water events, and provide more comfortable and secure accommodation for personnel and equipment.

The Big Salmon program has been ongoing for seven consecutive years and 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. In addition, the Big Salmon escapement information coupled with GSI data provides an independent annual estimate of the total above border Chinook salmon spawning escapement. The Big Salmon sonar project is recognized as having value as a long term ongoing Yukon Chinook stock assessment tool. Currently, funding and project approval is granted on an annual basis. If the Yukon River Panel accepts this program has long term value it would be of benefit if the project were granted multiple year funding status. This would allow for better long range planning, retention of experienced personnel, and could result in overall cost savings as equipment and rentals could be amortized over a longer period.

ACKNOWLEDGEMENTS

Several people contributed to the 2011 Big Salmon River sonar project. Jim Mercer and David McDonald worked as technicians on the project and played an especially valuable role during camp and cabin construction and demobilization and freighting of materials. The carcass pitch was ably conducted by David McDonald and Bob Gransden.

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Appendix 1. 2011 daily and cumulative counts of Chinook salmon at the Big Salmon River sonar site.

DATE	DAILY COUNT	CUMULATIVE	SONAR OPERATION TIME/COMMENTS
July 17	2	2	Sonar starts recording at 18:20
18	7	9	
19	13	22	Sonar inoperative for 1.5 hrs due to unexpected PC shutdown.
20	15	37	
21	24	61	
22	24	85	
23	43	128	
24	44	172	
25	50	222	
26	56	278	
27	105	383	
28	160	543	
29	192	735	
30	218	953	
31	218	1171	
August 1	260	1431	
2	313	1744	
3	417	2161	
4	426	2587	
5	396	2983	Sonar shut down for 1.5 hrs while testing wireless equipment, count expanded from 380 to 396.
6	400	3383	
7	317	3700	
8	294	3994	
9	243	4237	
10	160	4397	
11	170	4567	
12	143	4710	Sonar inoperative for 2 hrs due to unexpected PC shutdown, count expanded from 131 to 143.
13	100	4810	
14	85	4895	
15	89	4984	
16	63	5047	
17	35	5082	
18	20	5102	
19	18	5120	
20	21	5141	
21	11	5152	
22	2	5154	
23	2	5156	Sonar pulled at 18:20

Appendix 2. Sonar beam depth at tilt angles 0° – 45° and with start window lengths 6.67m and 7.5m.

8 Degree Lens								
Horizontal Beam			6.67 m start window			7.5 m start window		
Distance From Sonar (m)	Depth of Beam (m)	Width of Beam (m)	Tilt Degree @ 6.67m from sonar	Depth Added (m)	TOTAL DEPTH @ 6.67m (m)	Tilt Degree @ 7.5m from sonar	Depth Added (m)	TOTAL DEPTH @ 7.5m (m)
2.00	0.28	1.03	1.00	0.06	0.99	1.00	0.07	1.00
3.00	0.42	1.55	2.00	0.12	1.05	2.00	0.14	1.07
4.00	0.56	2.07	3.00	0.18	1.11	3.00	0.20	1.13
5.00	0.70	2.59	4.00	0.24	1.17	4.00	0.27	1.20
6.00	0.84	3.10	5.00	0.30	1.23	5.00	0.34	1.27
6.67	0.93	3.45	6.00	0.36	1.29	6.00	0.41	1.34
7.00	0.98	3.62	7.00	0.42	1.35	7.00	0.48	1.41
7.50	1.05	3.88	8.00	0.48	1.41	8.00	0.55	1.48
8.00	1.12	4.14	9.00	0.55	1.48	9.00	0.61	1.54
9.00	1.26	4.66	10.00	0.61	1.54	10.00	0.68	1.61
10.00	1.40	5.17	11.00	0.67	1.60	11.00	0.75	1.68
11.00	1.54	5.69	12.00	0.73	1.66	12.00	0.82	1.75
12.00	1.68	6.21	13.00	0.80	1.73	13.00	0.90	1.83
13.00	1.82	6.72	14.00	0.86	1.79	14.00	0.97	1.90
14.00	1.96	7.24	15.00	0.92	1.85	15.00	1.04	1.97
15.00	2.10	7.76	16.00	0.99	1.92	16.00	1.11	2.04
16.00	2.24	8.28	17.00	1.05	1.98	17.00	1.19	2.12
17.00	2.38	8.79	18.00	1.12	2.05	18.00	1.26	2.19
18.00	2.52	9.31	19.00	1.19	2.12	19.00	1.34	2.27
19.00	2.66	9.83	20.00	1.26	2.19	20.00	1.41	2.34
20.00	2.80	10.34	21.00	1.32	2.25	21.00	1.49	2.42
21.00	2.94	10.86	22.00	1.39	2.32	22.00	1.57	2.50
22.00	3.08	11.38	23.00	1.46	2.39	23.00	1.65	2.58
23.00	3.22	11.90	24.00	1.54	2.47	24.00	1.73	2.66
24.00	3.36	12.41	25.00	1.61	2.54	25.00	1.81	2.74
25.00	3.50	12.93	26.00	1.68	2.61	26.00	1.89	2.82
26.00	3.64	13.45	27.00	1.76	2.69	27.00	1.98	2.91
27.00	3.78	13.97	28.00	1.83	2.76	28.00	2.06	2.99
28.00	3.92	14.48	29.00	1.91	2.84	29.00	2.15	3.08
29.00	4.06	15.00	30.00	1.99	2.92	30.00	2.24	3.17
30.00	4.20	15.52	31.00	2.07	3.00	31.00	2.33	3.26
31.00	4.34	16.03	32.00	2.16	3.09	32.00	2.42	3.35
32.00	4.48	16.55	33.00	2.24	3.17	33.00	2.52	3.45
33.00	4.62	17.07	34.00	2.33	3.26	34.00	2.62	3.55
34.00	4.76	17.59	35.00	2.42	3.35	35.00	2.72	3.65
35.00	4.89	18.10	36.00	2.51	3.44	36.00	2.82	3.75
36.00	5.03	18.62	37.00	2.60	3.53	37.00	2.92	3.85
37.00	5.17	19.14	38.00	2.70	3.63	38.00	3.03	3.96
38.00	5.31	19.65	39.00	2.79	3.72	39.00	3.14	4.07
39.00	5.45	20.17	40.00	2.89	3.82	40.00	3.26	4.19
40.00	5.59	20.69	41.00	3.00	3.93	41.00	3.37	4.30
41.00	5.73	21.21	42.00	3.11	4.04	42.00	3.49	4.42
42.00	5.87	21.72	43.00	3.22	4.15	43.00	3.62	4.55
43.00	6.01	22.24	44.00	3.33	4.26	44.00	3.75	4.68
44.00	6.15	22.76	45.00	3.45	4.38	45.00	3.88	4.81
45.00	6.29	23.28						

Appendix 3. 2011 Big Salmon River water and weather conditions.

DATE	TIME	AIR TEMP. (ºC)	WATER TEMP. (ºC)	WATER LEVEL (cm)	COMMENTS
23-Jul	10:00 AM	13.0	13.0		
24-Jul	1:00 PM	14.0	13.0	67cm	
25-Jul	10:00 AM	12.0	12.0	71cm	Sunny with little cloud
26-Jul	9:00 AM	8.0	13.0	76cm	Sunny with little cloud
27-Jul	9:00 AM	13.0	13.0	69cm	70 % cloud, warm day
28-Jul	9:00 AM	13.0	14.0	64cm	Sunny and clear, warm
29-Jul	9:00 AM	9.0	14.0	61cm	Clear cool morning
30-Jul	9:00 AM	13.0	15.0	59cm	20% cloud, mostly sunny warm day
31-Jul	10:00 AM	14.0	15.0	56cm	Overcast but warm
01-Aug	10:00 AM	15.0	15.0	55cm	Clear sunny day
02-Aug	9:00 AM	15.0	15.0	53cm	Warm day, some cloud, not overly hot
03-Aug	10:00 AM	12.0	15.0	51cm	Clear blue day
04-Aug	10:00 AM	14.0	15.0	49cm	Clear day with bright sun, hot
05-Aug	9:00 AM	17.0	16.0	48cm	Overcast cloudy day, warm
06-Aug	9:00 AM	14.0	16.0	46cm	Overcast and windy
07-Aug	10:00 AM	13.0	15.0	45cm	Mixed cloud and blue sky
08-Aug	10:00 AM	10.0	13.0	45cm	Overcast and rainy
09-Aug	9:00 AM	9.0	13.0	45cm	Overcast and rainy
10-Aug	9:00 AM	12.0	13.0	46cm	Cool morning with mixed cloud
11-Aug	10:00 AM	14.0	13.0	44cm	Clear blue sky, some wind
12-Aug	9:00 AM	5.0	11.0	44cm	Cold morning, blue sky
13-Aug	9:00 AM	10.0	11.0	44.5cm	Clear cool morning
14-Aug	10:00 AM	13.0	12.0	42cm	Overcast and grey
15-Aug	9:00 AM	11.0	14.0	40cm	Clear sunny day, blue sky
16-Aug	8:00 AM	8.0	13.0	38cm	Clear sunny day, blue sky
17-Aug	10:00 AM	13.0	14.0	37cm	Clear sunny day, blue sky
18-Aug	10:00 AM	12.0	13.0	35.5cm	Overcast grey day, sprinkles of rain in morning
19-Aug	8:00 AM	6.0	13.0	41cm	Rainy overcast day, no sun
20-Aug	9:00 AM	8.0	11.0	49cm	80% cloud, patches of clear sky
21-Aug	9:00 AM	3.0	10.0	60cm	Overcast cool morning
22-Aug	9:00 AM	5.0	10.0	57cm	Overcast cool morning
23-Aug	9:00 AM	5.0	10.0	53cm	Cold morning, some clear sky
24-Aug	9:00 AM	6.0	10.0	51cm	Cold morning, overcast
25-Aug	9:00 AM	5.0	10.0	51cm	Cold morning, cloudy sky, some light patches
26-Aug	9:00 AM	4.0	9.0	52cm	Cool morning but clear patches, will be sunny

Appendix 4. Age, sex, and length of sampled Chinook on the Big Salmon River, 2011.

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
21-Aug	1	M	565	495	1.3
21-Aug	2	M	900	790	1.4
21-Aug	3	M	740	640	M3
21-Aug	4	F	840	740	1.4
21-Aug	5	M	NA	600	1.4
21-Aug	6	M	910	800	1.4
22-Aug	7	M	710	610	1.3
22-Aug	8	F	NA	795	1.4
22-Aug	9	F	820	710	1.4
22-Aug	10	F	805	700	1.4
22-Aug	11	F	890	790	1.4
22-Aug	12	F	NA	780	1.4
22-Aug	13	F	NA	735	1.4
22-Aug	14	F	870	770	1.4
22-Aug	15	M	740	640	1.3
22-Aug	16	F	940	850	M4
22-Aug	17	F	850	765	1.4
22-Aug	18	M	860	740	M4
22-Aug	19	F	855	760	1.4
22-Aug	20	M	NA	765	RG
22-Aug	21	F	920	820	1.4
22-Aug	22	F	840	750	1.4
22-Aug	23	F	880	790	1.4
22-Aug	24	F	850	755	1.4
22-Aug	25	F	700	605	1.3
22-Aug	26	F	890	785	1.4
22-Aug	27	M	660	570	1.3
22-Aug	28	M	830	745	1.4
22-Aug	29	M	855	740	1.4
22-Aug	30	F	870	760	M4
22-Aug	31	F	NA	710	1.3
22-Aug	32	M	725	640	1.3
22-Aug	33	F	860	770	1.4
22-Aug	34	F	830	730	1.4
22-Aug	35	F	780	705	M4
22-Aug	36	M	840	725	1.4
22-Aug	37	M	760	670	1.3
22-Aug	38	M	875	760	1.4
22-Aug	39	M	775	660	1.4
22-Aug	40	F	845	750	1.4
22-Aug	41	M	540	460	1.2
22-Aug	42	F	805	715	1.4
22-Aug	43	F	890	785	1.5
22-Aug	44	F	865	770	M4
22-Aug	45	M	935	820	1.4
22-Aug	46	F	895	800	1.4
22-Aug	47	F	880	770	1.4

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
22-Aug	48	F	740	655	1.4
22-Aug	49	M	NM	650	1.4
22-Aug	50	M	660	575	1.4
22-Aug	51	F	NM	770	M5
22-Aug	52	M	545	480	1.4
22-Aug	53	M	660	570	1.4
23-Aug	54	F	775	695	1.4
23-Aug	55	M	665	585	1.4
23-Aug	56	F	870	765	1.4
23-Aug	57	M	800	700	1.4
23-Aug	58	M	1005	870	M4
23-Aug	59	F	875	775	1.4
23-Aug	60	F	850	755	1.3
23-Aug	61	F	900	795	1.3
23-Aug	62	M	910	800	1.5
23-Aug	63	F	910	810	1.4
23-Aug	64	M	770	680	1.4
23-Aug	65	M	730	635	1.3
23-Aug	66	M	705	620	M4
23-Aug	67	M	780	690	1.4
23-Aug	68	F	740	655	1.4
23-Aug	69	M	730	635	1.4
23-Aug	70	M	625	545	1.3
23-Aug	71	M	860	760	1.4
23-Aug	72	F	845	760	1.4
23-Aug	73	M	NM	580	M3
23-Aug	74	F	845	740	1.5
23-Aug	75	F	840	740	1.4
23-Aug	76	F	915	805	1.5
23-Aug	77	F	900	790	M4
23-Aug	78	F	910	790	1.4
23-Aug	79	F	835	725	M4
23-Aug	80	M	880	790	1.4
23-Aug	81	M	950	820	M4
23-Aug	82	F	810	720	1.4
23-Aug	83	F	830	730	1.4
23-Aug	84	F	880	780	1.4
23-Aug	85	M	930	800	1.4
23-Aug	86	M	555	485	1.3
23-Aug	87	M	715	635	1.2
23-Aug	88	F	880	775	1.4
23-Aug	89	F	930	830	1.4
23-Aug	90	F	875	775	1.3
23-Aug	91	F	750	670	1.4
23-Aug	92	F	860	760	1.4
23-Aug	93	F	855	760	1.3
23-Aug	94	F	845	760	M4
23-Aug	95	F	860	750	1.4
23-Aug	96	M	690	600	1.4
23-Aug	97	M	830	720	1.3

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
23-Aug	98	M	915	790	1.4
23-Aug	99	F	880	770	1.4
23-Aug	100	F	870	770	1.4
23-Aug	101	M	680	600	1.3
23-Aug	102	M	NA	670	1.4
24-Aug	103	M	930	800	1.4
26-Aug	104	M	810	700	1.3
26-Aug	105	M	730	635	1.3
26-Aug	106	F	880	800	1.4
26-Aug	107	M	810	710	1.4
26-Aug	108	F	870	780	1.4
26-Aug	109	M	820	725	M4
26-Aug	110	F	905	810	1.4
26-Aug	111	M	920	785	1.4
26-Aug	112	M	670	580	1.3
26-Aug	113	F	925	780	1.4
26-Aug	114	F	900	795	1.4
26-Aug	115	M	690	590	1.3
26-Aug	116	M	665	590	1.3
26-Aug	117	F	915	800	1.5
26-Aug	118	F	860	750	M4
26-Aug	119	F	870	770	1.4
26-Aug	120	M	865	740	1.4
26-Aug	121	F	810	720	1.4
26-Aug	122	F	880	790	1.4
26-Aug	123	F	840	750	1.4
26-Aug	124	F	850	760	M4
26-Aug	125	M	610	530	1.2
26-Aug	126	F	845	750	1.4
26-Aug	127	F	895	790	M4
26-Aug	128	M	525	460	1.2
26-Aug	129	M	850	740	1.4
26-Aug	130	F	815	725	M4
26-Aug	131	F	930	825	M5
26-Aug	132	F	810	730	1.4
26-Aug	133	M	770	670	1.4
26-Aug	134	F	850	760	1.4
26-Aug	135	M	830	720	1.4
26-Aug	136	F	890	785	1.4
26-Aug	137	M	880	755	1.4
26-Aug	138	F	840	745	M4
26-Aug	139	F	735	645	1.3
26-Aug	140	M	920	800	1.4
26-Aug	141	M	900	780	1.4
26-Aug	142	F	880	790	1.5
26-Aug	143	F	880	780	M5
26-Aug	144	F	735	640	1.4
26-Aug	145	F	840	730	1.4
26-Aug	146	M	920	810	1.4
26-Aug	147	F	850	760	1.4

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
26-Aug	148	M	780	675	1.4
26-Aug	149	F	845	750	M4
26-Aug	150	M	770	680	1.4
26-Aug	151	F	865	760	M4
26-Aug	152	F	860	750	1.4
26-Aug	153	M	890	790	1.4
26-Aug	154	M	880	760	1.4
26-Aug	155	F	865	770	1.4
26-Aug	156	F	815	715	1F
26-Aug	157	F	865	765	M4
26-Aug	158	F	NA	760	1.4
26-Aug	159	F	870	775	1.4
26-Aug	160	M	705	600	1.3
26-Aug	161	M	965	835	1.4
26-Aug	162	F	880	780	M4
26-Aug	163	F	885	780	1.4
26-Aug	164	F	895	790	1.4
26-Aug	165	F	845	750	1.4
26-Aug	166	M	560	490	1.2
26-Aug	167	M	860	740	1.4
26-Aug	168	F	860	750	M4
26-Aug	169	F	795	710	1.4
26-Aug	170	M	695	600	1.3
27-Aug	171	F	820	730	1.4
27-Aug	172	F	880	780	M4
27-Aug	173	M	835	720	1.4
27-Aug	174	M	765	665	1.3
27-Aug	175	M	890	780	1.4
27-Aug	176	F	825	730	M4
27-Aug	177	F	890	790	1.4
27-Aug	178	M	890	780	M3
27-Aug	179	F	895	785	1.5
27-Aug	180	M	740	620	1.4
27-Aug	181	M	810	710	1.3
27-Aug	182	F	850	760	1.4
27-Aug	183	M	910	780	1.4
27-Aug	184	F	920	820	1.4
27-Aug	185	F	815	725	1.4
27-Aug	186	F	810	720	1.4
27-Aug	187	M	805	700	M4
27-Aug	188	F	930	820	M4
27-Aug	189	F	870	770	1.4
27-Aug	190	F	NA	720	M4
27-Aug	191	F	800	710	1.3
27-Aug	192	F	890	790	1.4
27-Aug	193	F	905	800	1.5
27-Aug	194	F	805	710	M4
27-Aug	195	F	880	770	1.4
27-Aug	196	M	940	820	1.3
27-Aug	197	M	860	755	M3

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
27-Aug	198	F	850	760	1.4
27-Aug	199	F	795	700	M3
27-Aug	200	F	840	760	1.4
27-Aug	201	M	655	550	M3
27-Aug	202	F	840	740	1.4
27-Aug	203	F	840	740	M4
27-Aug	204	M	835	715	M4
27-Aug	205	M	690	600	M3
27-Aug	206	F	880	770	1.4
27-Aug	207	F	840	750	1.4
27-Aug	208	M	940	810	1.4
27-Aug	209	F	890	790	1.4
27-Aug	210	F	890	765	1.4
27-Aug	211	F	880	770	1.4
27-Aug	212	F	820	710	1.4
27-Aug	213	F	875	760	1.4
27-Aug	214	F	800	700	1.4
27-Aug	215	M	860	750	1.4
27-Aug	216	F	940	830	1.4
27-Aug	217	F	840	745	1.4
27-Aug	218	F	850	750	1.4
27-Aug	219	F	910	790	1.4
27-Aug	220	M	610	530	1.2
27-Aug	221	F	835	740	1.4
27-Aug	222	F	815	720	1.4
27-Aug	223	M	620	530	M3
27-Aug	224	F	820	720	1.4
27-Aug	225	F	855	760	1.4
27-Aug	226	M	860	740	1.4
27-Aug	227	F	845	740	1.4
27-Aug	228	M	640	550	M3
27-Aug	229	F	795	700	1.4
27-Aug	230	F	840	750	RG
27-Aug	231	F	870	780	1.4
27-Aug	232	F	810	720	1.4
27-Aug	233	F	790	700	1F
27-Aug	234	M	820	710	1.4
27-Aug	235	M	915	800	1.4
27-Aug	236	F	860	755	1.4
27-Aug	237	F	840	740	1.4
27-Aug	238	M	680	590	1.3
27-Aug	239	M	625	540	1.4
27-Aug	240	F	875	780	RG
27-Aug	241	F	760	660	M3
27-Aug	242	M	905	780	M4
27-Aug	243	F	855	750	1.4
27-Aug	244	F	910	800	1.4
27-Aug	245	F	865	770	1.4
27-Aug	246	F	870	770	1.4
28-Aug	247	M	880	760	M4

DATE	FISH #	SEX	MEF (mm)	POHL (mm)	AGE
28-Aug	248	M	680	580	1.3
28-Aug	249	F	845	735	1.4
28-Aug	250	M	830	735	1.3
28-Aug	251	M	880	750	1.4
28-Aug	252	F	830	710	RG
28-Aug	253	M	920	795	1.4
28-Aug	254	F	850	730	M4
28-Aug	255	F	910	815	1.4
28-Aug	256	F	865	770	1.4
28-Aug	257	F	835	735	1.4
28-Aug	258	M	790	670	1.4
28-Aug	259	F	850	755	1.4
28-Aug	260	F	875	770	1.4
28-Aug	261	M	955	830	1.4
28-Aug	262	F	1000	890	1.5
28-Aug	263	F	910	810	1.4
28-Aug	264	F	880	790	1.3
28-Aug	265	F	865	770	1.4
28-Aug	266	F	880	780	1.5
28-Aug	267	F	770	675	1.4
28-Aug	268	F	850	745	1.4
28-Aug	269	M	900	795	1.4
28-Aug	270	F	865	770	1.4
28-Aug	271	F	880	780	1.4
28-Aug	248	M	680	580	1.3
28-Aug	249	F	845	735	1.4
28-Aug	250	M	830	735	1.3
28-Aug	251	M	880	750	1.4
28-Aug	252	F	830	710	RG
28-Aug	253	M	920	795	1.4
28-Aug	254	F	850	730	M4
28-Aug	255	F	910	815	1.4
28-Aug	256	F	865	770	1.4
28-Aug	257	F	835	735	1.4
28-Aug	258	M	790	670	1.4
28-Aug	259	F	850	755	1.4
28-Aug	260	F	875	770	1.4
28-Aug	261	M	955	830	1.4
28-Aug	262	F	1000	890	1.5
28-Aug	263	F	910	810	1.4
28-Aug	264	F	880	790	1.3
28-Aug	265	F	865	770	1.4
28-Aug	266	F	880	780	1.5
28-Aug	267	F	770	675	1.4
28-Aug	268	F	850	745	1.4
28-Aug	269	M	900	795	1.4
28-Aug	270	F	865	770	1.4
28-Aug	271	F	880	780	1.4

Appendix 5. Daily and average Chinook counts in the Big Salmon River, 2005-2011.

DATE	Daily Count 2005	Daily Count 2006	Daily Count 2007	Daily Count 2008	Daily Count 2009	Daily Count 2010	Daily Count 2011	Daily Average
13-Jul	0							**0**
14-Jul	0							**0**
15-Jul	2	1						**2**
16-Jul	12	0	2	0				**4**
17-Jul	13	1	0	0			2	**3**
18-Jul	23	0	2	0	0		7	**5**
19-Jul	13	0	5	1	11		13	**7**
20-Jul	23	1	5	0	22	0	15	**9**
21-Jul	36	3	7	0	47	7	24	**18**
22-Jul	58	8	11	0	68	14	24	**26**
23-Jul	92	11	18	1	85	12	43	**37**
24-Jul	130	21	26	2	135	7	44	**52**
25-Jul	158	20	52	1	201	12	50	**71**
26-Jul	204	53	88	3	226	14	56	**92**
27-Jul	219	95	153	5	346	27	105	**136**
28-Jul	287	146	237	9	498	46	160	**198**
29-Jul	290	230	287	9	532	83	192	**232**
30-Jul	299	321	337	29	594	123	218	**274**
31-Jul	279	368	400	21	808	141	218	**319**
01-Aug	333	357	435	23	578	159	260	**306**
02-Aug	346	379	331	18	715	182	313	**326**
03-Aug	303	358	304	16	725	216	417	**334**
04-Aug	292	413	258	31	595	226	426	**320**
05-Aug	331	496	210	51	559	215	396	**323**
06-Aug	214	490	178	55	452	221	400	**287**
07-Aug	188	464	147	78	364	227	317	**255**
08-Aug	232	464	59	61	295	242	294	**235**
09-Aug	234	360	74	70	270	248	243	**214**
10-Aug	203	349	90	98	209	183	160	**185**
11-Aug	124	348	82	122	183	207	170	**177**
12-Aug	126	324	98	107	146	174	143	**160**
13-Aug	125	243	77	109	118	181	100	**136**
14-Aug	72	196	74	89	117	134	85	**110**
15-Aug	57	180	66	78	65	114	89	**93**
16-Aug	40	172	56	70	55	82	63	**77**
17-Aug	53	104	40	49	63	80	35	**61**
18-Aug	47	69	64	45	55	53	20	**50**
19-Aug	35	87	37	17	43	40	18	**40**
20-Aug	29	59	47	18	35	24	21	**33**
21-Aug	26	45	11	15	28	18	11	**22**
22-Aug	19	50	16	16	14	38	2	**22**
23-Aug	17	12	23	9	4	24	2	**13**
24-Aug	13	10	17	2		20		**12**
25-Aug	9		14	1		17		**10**
26-Aug	6		14			6		**9**
27-Aug	4		13					**9**
28-Aug	2		11					**7**
29-Aug			9					**9**
30-Aug			8					**8**
31-Aug			6					**6**
01-Sep			4					**4**
02-Sep			3					**3**
TOTAL:	**5618**	**7308**	**4506**	**1329**	**9261**	**3817**	**5156**	