U.S. Fish & Wildlife Service

Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2012

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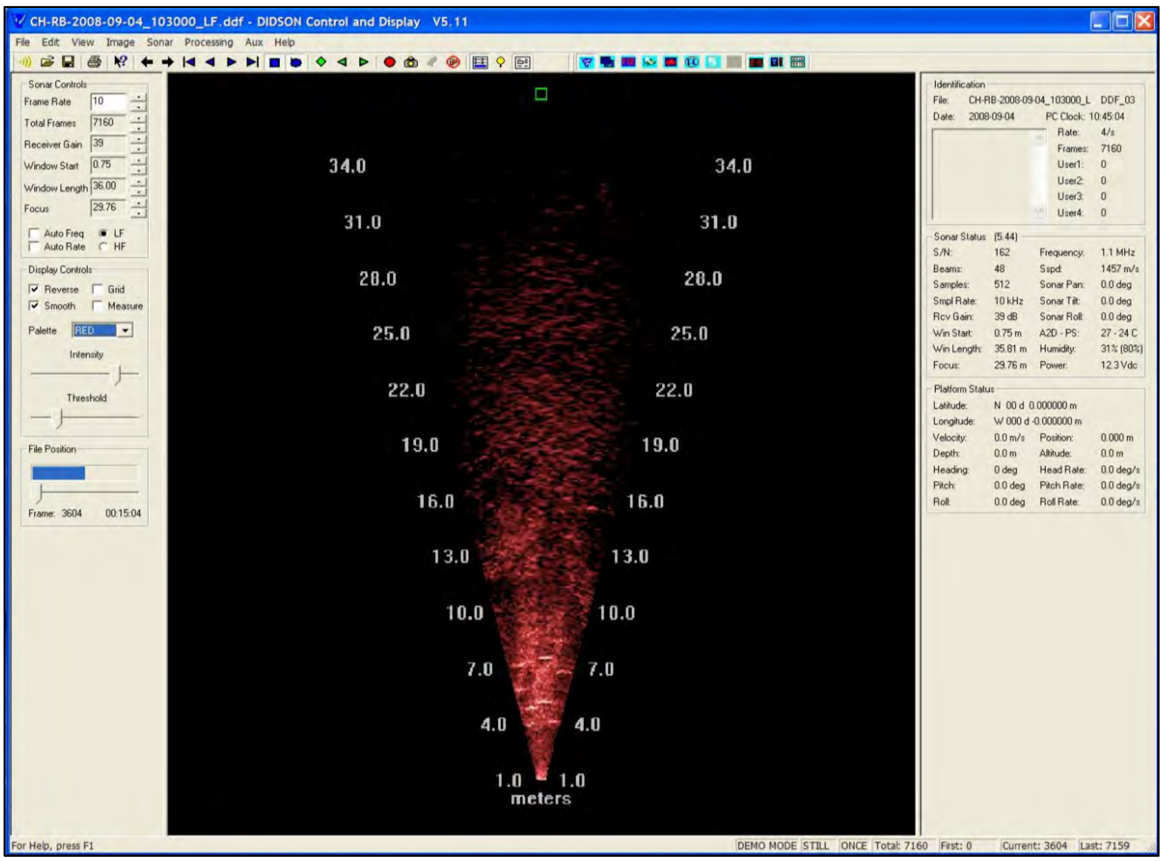

Fairbanks Fish and Wildlife Field Office
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Cover: Image of DIDSON control and display software showing fish in display between 4 and 7 m range.

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Jeffery L. Melegari

Abstract

During 2012, Dual Frequency Identification Sonar (DIDSON) was used to assess the population abundance of adult fall chum salmon *Oncorhynchus keta* in the Chandalar River, a tributary of the Yukon River. Operations began on August 8 and continued until September 29, which was three days later than the usual end date of the project. Of the 2,544 h (1,272 h on each bank) of time available during the sample period 2,239.9 h of data were collected, with 177,090 upriver swimming fish enumerated. After adjustments were made for missed time, the fall chum salmon passage estimate for 2012 was 197,931. This passage estimate is considered conservative because it only includes fish that passed during the dates of sonar operation and within the ensonified portion of the river. The passage on the first day of counting was 670 upriver swimming chum salmon. The passage on the final day of counting was 2,758 upriver chum salmon. The first quartile, mid-point, and third quartile passage dates were August 31, September 11, and September 18, respectively. Fish target positional data suggests that most fish were within the detection range of the DIDSON. Most fish were shore-oriented, and few were observed near the outer range limits of the ensonified zone.

Introduction

Accurate salmon escapement counts on Yukon River tributaries are important for informing and assessing annual harvest management decisions, predicting run strength based on brood year returns, and monitoring long-term population trends. Weirs, counting towers, mark-recapture programs, ground surveys, and hydroacoustics are used to obtain escapement estimates of specific Yukon River salmon stocks (Bergstrom et al. 2001).

The Yukon River drainage encompasses 854,700 km^2 and is among the largest producers of wild Chinook salmon *Oncorhynchus tschawytscha* and chum salmon *O. keta* in North America (Daum and Osborne 1995). The salmon resources of this unique river support important subsistence and commercial fisheries throughout the drainage. The U.S. Fish and Wildlife Service (USFWS), through Section 302 of the Alaska National Interest Lands Conservation Act, has a responsibility to ensure that salmon populations within federal conservation units are conserved in their natural diversity, international treaty obligations are met, and subsistence opportunities are maintained. Accurate spawning escapement estimates for major salmon stocks in the drainage is an important component for addressing these mandates. The fall chum salmon population in the Chandalar River is one of the largest in the Yukon River drainage and is an important wildlife and subsistence resource.

The use of fixed-location hydroacoustics to count migrating salmon in Alaska began during the early 1960s and provided counts in rivers where limited visibility or sample volume precluded other sampling techniques (Gaudet 1990). A five-year study from 1986 to 1990 using fixed-

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location Bendix salmon counters to enumerate adult fall chum salmon in the Chandalar River was conducted by the USFWS. The annual Bendix sonar counts of fall chum salmon during that period averaged 58,628 fish, with a range of 33,619 to 78,631 fish (Appendix 1). The early "Bendix salmon counters" were not acoustically calibrated, used factory-set echo-counting criteria to determine fish counts, had limited acoustic range (<33 m), and could not determine the direction of target travel (upriver or downriver). Due to these technological limitations, it is now suspected that the Bendix sonar yielded very conservative estimates of fall chum salmon passage on the Chandalar River.

A study was initiated in 1994 to reassess the Chandalar River fall chum population status using newly developed split-beam sonar technology. This sonar system was acoustically calibrated, had user-defined echo-tracking techniques to count fish, and an extended acoustic range (>100 m). The split-beam sonar also provided three-dimensional positioning for each returning echo, allowing the determination of direction of travel and swimming behavior for each passing target (Daum and Osborne 1998). Operations during 1994 were used to develop site-specific procedures and methods, evaluate site characteristics, and describe possible data collection biases, even though activities ended prematurely due to flooding (Daum and Osborne 1995). In 1995, daily and seasonal estimates of fall chum salmon passage were calculated post season and *in situ* target strength evaluations were collected (Daum and Osborne 1996).

Experimentation to evaluate DIDSON technology (Dual Frequency Identification Sonar), for enumeration of fall chum salmon in the Chandalar River was initiated in 2004 and continued through 2006. DIDSON offers several advantages over the previous sonar technologies used on the Chandalar River. These include deployment over a wider range of site conditions, production of a more straightforward visual image, reduction of training requirements for technicians due to more intuitive operation and image interpretation, easier setup and deployment, and the potential for increased capacity for species determination under some conditions. The primary limitations of DIDSON, relative to split-beam sonar, include limited range capabilities, lack of vertical position data, and larger data files requiring large hard drives to store or archive data. During the evaluation period, up to three DIDSONs were set up at different locations, both adjacent to the split-beam sonar, and at independent locations. Conclusions from these evaluations indicate that DIDSON is well suited to enumerate fall chum salmon on the Chandalar River. Therefore, DIDSON has been used to enumerate fall chum salmon on the Chandalar River since 2007.

Objectives of the Chandalar River sonar project have consistently been to: (1) provide daily in-season counts of Chandalar River fall chum salmon to fishery managers; (2) estimate annual passage of fall chum salmon; and (3) describe annual variability in run size and timing. Since 1996, the project has provided daily in-season counts to managers and a total estimate of passage post season. Sonar passage estimates from 1995 to 2011 averaged 189,653 fish and ranged from 65,894 to 496,484 fish (Appendix 1).

Additionally, carcass sampling for age sex and length data has been conducted at fall chum salmon spawning grounds upstream of the community of Venetie on the Chandalar River during some years, however funding was unavailable during 2012.

Study Area

The Chandalar River is a fifth-order tributary of the Yukon River and drains the southern slopes of the Brooks Range. It consists of three major branches, the East, Middle, and North Forks

(Figure 1). Principal water sources include rainfall, snowmelt, and to a lesser extent, melt water from small glaciers, and perennial springs (Craig and Wells 1975). Summer water turbidity is highly variable, depending on rainfall. The region has a continental subarctic climate characterized by the most extreme temperatures in the state, -41.7°C to 37.8°C (U.S. Department of the Interior 1964). Precipitation ranges from 15 to 33 cm annually with the greater amount falling between May and September. The river is typically ice-free by early June and freeze-up occurs in late September to early October.

The lower 19 km of the Chandalar River is influenced by a series of slough systems connected to the Yukon River. River banks are typically steep and covered with overhanging vegetation and downed trees caused by active bank erosion. Gravel bars are absent in this area and the bottom substrate is primarily sand and silt. Water velocities are generally less than 0.75 m/s. Approximately 21 to 22.5 km upriver from its confluence with the Yukon River, the Chandalar River is confined to a single channel with steep cut-banks alternating with large gravel bars. Substrate in this area primarily ranges from small gravel to cobble with some sand/silt in slow current areas. Upriver from this area, the river becomes braided with many islands and multiple channels. The sonar study area located at river kilometer (rkm) 21.5 was previously described by Daum et al. (1992; Figure 2).

The DIDSON deployment locations were 150 to 200 m downriver from the sites where the split-beam was deployed in previous years. The left bank site (facing downriver) has a bottom slope of approximately 5° out to approximately 40 m where it flattens out (Figure 3). On the right bank the bottom slopes at approximately 7° out to approximately 27 m before it flattens out. Substrate on both banks consists of mainly large gravel. Overall river width at the site is approximately 140 m, and varies depending on water level.

Methods

Water Quality Monitoring

A staff gauge was installed upstream of the right bank sonar to measure daily water levels. Water levels were calibrated using a benchmark established on the right bank in 1989. An Onset Hobo Pro v2 temperature logger collected water temperature throughout the season, and one was left on site to collect data throughout the winter. Data from the Onset Hobo temperature loggers are not presented in this report. A YSI Professional Plus Multiprobe (Yellow Springs, Ohio) was used to collect water temperature, conductivity, dissolved oxygen, and pH data, twice daily at approximately 0800 hours and 2100 hours near the right bank sonar deployment location. Additionally a YSI model 6920V2 sonde was deployed from August 2 to September 28 to collect temperature, conductivity, dissolved oxygen, pH, and turbidity data hourly. Data from the Pro-Plus was used primarily to provide in-season information to project biologists and managers, and the sonde data is presented in this report.

Site Selection and Sonar Deployment

A sonar deployment site for each bank was selected from cross-sectional river profiles of the area (Figure 3), developed using a Lowrance (Tulsa, Oklahoma) HDS-7 depth sounder–GPS. Requirements for site selection included: (1) single channel; (2) uniform non-turbulent flow; (3) gradually sloping bottom gradient without sudden inflections; (4) absence of structure or debris that could impede fish detection; (5) location downriver from known salmon spawning areas; and (6) active fish migration past the site (no milling behavior).

The Sound Metrics DIDSON system (Lake Forest Park, Washington) is a high frequency 12° X 29° multiple beam sonar (Belcher et al. 2001; 2002). Standard and long range models are currently in use. The standard DIDSON operates at frequencies of 1.8 or 1.1 MHz and has an effective range for confidently enumerating fall chum salmon on the Chandalar River of approximately 30 m, based on detection of known targets drifted through the sonar beam, and on analysis of fish data. The long range model operates at frequencies of 1.2 MHz or 700 KHz with an effective range of approximately 60 m. DIDSON specifications are available in the DIDSON operation manual V5.25 (Sound Metrics Corp. 2010). The DIDSON units were deployed at fixed locations in the river and communicated with laptop computers for control and data management.

The long range DIDSON was deployed on the left bank, and the standard range DIDSON was used on the right bank. Both DIDSON models were operated in the low frequency mode (1.1 MHz for the standard range and 700 KHz for the long range). Partial weirs were installed approximately 1 m downriver of each DIDSON to direct fish through the beams. The left bank DIDSON had a window start setting of 0.83 m, and a window length settings of 40.01 m, and the right bank had a window start setting of 0.77 m, and a window length settings of 18.54 m. Both DIDSONs began operation on August 8 during 2012. During previous years the left bank DIDSON window length setting was 70 m, however since we began using DIDSONs in 2007, on average 96.4% of the upstream swimming fish counted were within 40 m of the sonar. Reducing the range to 40 m would increase the efficiency of analyzing data and counting fish from the DIDSON images as well as increase the downrange resolution. During 2010 side by side counts of fish within the first 20 m of the long range (~70 m window length) DIDSON and counts from a standard range (~20 m window length) DIDSON were compared. Although variable, the comparison indicated that over the entire season approximately 3.5% of fish in the first 20 m of the long range DIDSON were missed, presumably due to the decreased resolution with a window length setting of 70 m (Melegari 2011). Thus, while reducing the range to 40 m would miss the few fish (average of 3.6% of the total) that have historically passed beyond 40 m it will concurrently reduce the potential of missing fish at closer ranges, where most fish travel. Therefore, switching to 40 m would have a negligible impact on the final passage estimate, while increasing efficiency of data analysis.

The DIDSON units were oriented perpendicular to river flow and mounted to aluminum frames with brackets allowing manual adjustments to vertical and horizontal aim. The aim was adjusted by verifying the detection of targets (liter plastic bottle half filled with steel shot) placed on the river bottom at varying ranges within the ensonified area and drifted through the ensonified area from a boat.

A wireless network was installed for the left bank so all DIDSON communications, data acquisition, and analysis could occur at a single data tent located on the right bank next to the camp. This remote communications network consisted of two D-Link® DWL-2100AP wireless access points, one connected to the DIDSON on the left bank, and the other, connected to the receiving computer on the right bank. A D-Link® ANT24-1800 outdoor directional panel antenna was attached to each access point using an outdoor low loss RF cable.

Sonar Data Collection and Analysis

In the data tent, a wired network was set up for each DIDSON to facilitate data collection and analysis. Each of these data networks consisted of a gigabit Ethernet switch, two laptop computers, and a 500 gigabyte Ethernet hard disk. One computer was used to control and communicate with the DIDSON, and save the collected data to files on the Ethernet hard disk. The second computer was used to analyze the data and manage files.

The sonar systems were operated continuously 24 hours per day, except during intermittent periods for maintenance, repairs, aim adjustments, or relocating the DIDSON as water levels changed. The collected data were saved to files at 30 minute intervals. Data were analyzed using the DIDSON control and display software (version 5.25.32; Sound Metrics Corp. 2010). Data files were examined in the echogram view and when a potential target was encountered it was further evaluated by reviewing that section of data in the normal image view to verify the target was a fish and to determine direction of travel. Data from these files were then exported to ASCII files, which were compiled and summarized using a Microsoft Excel Visual Basic for Applications macro developed by the author.

Count adjustments were made for time lapses in data acquisition. Partial hourly counts (≥ 15 and < 60 minutes) were standardized to 1 hour, using the formula:

$$E_h = (60 / T_h) \bullet C_h. \qquad (1)$$

Where E_h = estimated hourly upriver count for hour h, T_h = number of minutes sampled in hour h, and C_h = upriver count during the sampled time during hour h. Counts for hours with < 15 minutes were discarded and treated as missing hours.

Fish counts from missing hours were estimated from seasonal mean hourly passage rates. Mean hourly passage rates were calculated from days with 24 h of continuous data. Hourly passage rates (fish passing during each hour) were determined for all hours in each day. These hourly passage rates were expressed as proportions (%) of the daily count so high-passage days did not bias results. Then mean passage rates (%) by hour were calculated for the season. During the season missing hours were estimated using the averaged mean hourly rates from all previous seasons. During post season analysis missing hours were re-estimated using seasonal mean hourly passage rates calculated for the 2012 season. Estimated fish counts for missing hours were calculated, using

$$E_d = \sum R_{di} / (100 - \sum R_{di}) \bullet T_d. \qquad (2)$$

where E_d = estimated upriver fish count for missing hours in day d, R_{di} = mean hourly passage rate (%) for each missing hour i in day d, and T_d = adjusted upriver fish count for non-missing hours in day d.

Daily upriver fish passage estimates for each bank were calculated by summing all hourly estimates for that day. For the season, total passage was calculated by summing all daily estimates. Hourly fish passage rates for each bank were plotted for the season and examined for diel patterns. Range distributions of fish targets were evaluated to assess the likelihood of fish passing beyond the detection range of the DIDSON.

Video monitoring

During 2012 an underwater video monitoring system, similar to that used in previous years (Osborne and Melegari 2006; Melegari and Osborne 2007; Melegari 2012), was deployed off the right bank to monitor a portion of the ensonified area. This system was used to collect species presence data. The system consisted of four 1/3" HAD CCD underwater video cameras, a four channel DVR (EverFocus EVECOR2644F1), and an ultra-high resolution monitor (Samsung

SASM1722). All four cameras were attached to a single steel rod spaced 0.75 m apart, to create an array. The area of coverage was approximately 3.5 m wide x 0.5 m high at 1 m from the array. The camera array was positioned along the upstream edge of the sonar beam looking downstream into the beam. Video was recorded throughout the day when lighting was sufficient. At the beginning of the season 13 hours per day were reviewed, and as daylight length shortened the review time was decreased to 11 hours per day by the end of the season.

Results

Water Quality Monitoring

Calibrated water levels ranged from approximately 1.8 to 3.4 m, and averaged 2.4 m throughout the season. Water temperatures ranged from 3.4°C to 14.8°C and averaged 9.6°C (Figure 4; Appendix 2). The other water quality data collected with the YSI sonde are available in Appendix 2.

Site Selection and Sonar Deployment

Several cross sectional profiles were recorded on each bank near the identified deployment locations and the DIDSONs were deployed where the bottom profiles were considered best for counting fish with the DIDSONs (Figure 3). These locations have remained approximately the same since we switched to DIDSON, since minimal changes in physical conditions have been observed at the locations between years.

Sonar Data Collection and Analysis

Sonar operations began on August 8, 2012 and continued through September 29, ending three days later than normal due to a large pulse of fish late in the run. Acoustic data were collected for 2,239.9 hours, and 180,690 total fish were counted (Table 1). Upriver swimming fish accounted for 98% (177,090) of the total counted. On the left bank, 1,114.9 hours (88% of the potential 1,272 hours) were monitored, with 125.2 hours missed due to high water and 31.9 hours missed due to intermittent disruptions to the remote communications network, generator refueling, relocating the DIDSON, and maintenance or repairs. On the right bank, 1,125.0 h (88% of the potential 1,272 hours) were monitored, with 113.0 hours missed due to high water and 34.0 hours missed due to maintenance or repairs. Upriver fish counts were 57,332 for the left bank and 119,758 for the right bank.

After adjusting for missed time, the estimated fall chum salmon passage for 2012 was 197,931 (Table 2). The left bank estimate was 67,731 accounting for 34% of the total. The right bank estimate was 130,200, accounting for 66% of the total. The adjusted count was 670 upriver swimming fish on the first day of sonar operation (0.3% of the total), and 2,758 fish on the final day of counting (1.4% of the total). The run was bimodal, with peak daily passages occurring on August 31 and September 18 (Figure 5). The first quartile of the run occurred on August 31, the mid-point on September 11 and the third quartile on September 20.

Hourly passage rates (number of fish passing during each hour expressed as a proportion of the daily count) of upriver fish during 2012, showed a strong diel pattern on the left bank, and a slight diel pattern on the right bank. These patterns displayed higher passage rates during late night (left bank) or early morning hours (right bank; Figure 6).

Upriver migrating chum salmon were shore-oriented and most fish were well within the range of acoustic detection for both banks (Figures 7 and 8). More than 95% of upriver swimming fish were within 13 m on the left bank, and 12 m on the right bank. Downriver swimming fish, while also shore oriented, were slightly more dispersed across the full detection range of the DIDSONs.

Video monitoring

Video monitoring began August 23 and continued through September 22. Visibility varied with water clarity and light levels, ranging from approximately 0.0 to 1.5 m, but usually in the lower half of this range. Similar to 2011, 2012 was a relatively high water year with reduced visibility for most of the season. Additionally, from Sept 4 to 14 video monitoring was suspended due to high water and turbidity. Approximately 230 hours of video were reviewed; during which 11,012 upstream swimming fish were observed (only 11 downstream fish were observed). Of these 11,012 fish, 10,963 (99.6%) were identified as chum salmon, 5 as northern pike, 2 as burbot, 2 as suckers, and 38 were unable to be identified.

Discussion

Site Selection and Sonar Deployment

Proper aim of the sonar is a primary concern, however the wide beam angles of DIDSON and the ability to enumerate fish when the beams are hitting the substrate, make small precise adjustments to aim less critical than with the split-beam system. Additionally, the intuitive images provided by the DIDSON allow for a quick, confident evaluation of the aim and aiming adjustments. This allows us to forego the use of remote controlled underwater rotators and aim the DIDSONs manually. Manual adjustment of the aim has worked well, using two way radios to facilitate communication between the DIDSON operator and the person adjusting the aim. Furthermore, by not using the rotators the power requirement of the systems is reduced.

Few problems with the remote communications network were encountered and were primarily limited to brief interruptions to the connection. Data were collected at one frame per second on the left bank with the long range DIDSON and the remote communications network. One frame per second was considered sufficient to capture fall chum salmon migrating upriver past the site. This is supported by the data, in which nearly all fish were captured in several frames. If substantial numbers of fish were being missed because the frame rate was too low, then more fish would be expected to be “nearly missed”, or captured in only one or two frames.

Sonar Data Collection and Analysis

Run timing appeared normal early in the run, with the first quarter point of passage on August 31, only one day later than average (1995-2010, excluding 2009 when the project terminated early). However, the run was bimodal, with a substantial lull in passage during the middle of the season and an increase in passage late in the run. This resulted in the midpoint of passage being September 11, four days later than average, and the third quarter point was September 20, six days later than average. Considering that the estimated passage on the last day was 1.4% of the cumulative, it is probable the actual quarter point dates for the run are slightly later than calculated. Preliminary data from other fall chum salmon projects indicate similar patterns in run timing during 2012 (ADF&G unpublished data). The project was extended three days beyond the normal shut down day of September 26 to capture as much of the late pulse of fish as feasible.

The 2012 passage estimate of 197,931 fish is near average (104% of the historical average) (Figure 9). Preliminary data from other Yukon River drainage fall chum salmon enumeration projects during 2012 also indicate near or above average escapements (ADF&G unpublished data).

The Chandalar River sonar passage estimate is a conservative estimate because it does not include fish that passed before or after sonar operation (e.g., passage on the final day of operations was still 1.4% of the total). Additionally, while chum salmon are generally shore and bottom oriented during migration, which is supported by our data, it is likely that some fish passed undetected outside of the ensonified zone.

The observed diel patterns in upriver fish passage were similar to patterns seen during previous years (Daum and Osborne 1998; Melegari and Osborne 2007; Figure 6). During most years, the left bank has had a strong diel pattern, while the right bank generally displays a weaker, or no diel pattern. Also of note is the general pattern of the peak daily passage rate occurring later in the morning on the right bank then on the left, which is also common during previous years.

During 2012, the right bank accounted for 66% of the total passage, which is similar to the trend observed in previous years. The trend of higher counts on the right bank has been observed during all years of operation with split-beam or DIDSON (Appendix 1), however the ratio of right bank to left bank has been variable. An interesting phenomenon observed during 2012 was, as water level rose, this ratio decreased and even reversed just before the level rose high enough to interrupt counting; then the ratio returned to “normal” as the water dropped after counting was reinitiated. Since these water levels were very high relative to those normally seen, and because counting with the older split beam sonar would have been interrupted at lower water levels than the DIDSON we have not been able maintain operations under similar conditions in the past. Thus, we have not observed this in the past.

Fish range data collected with the DIDSONs were similar to previous years and suggests that most upriver swimming fish passing the sonar site were well within the ensonified zone. Upriver swimming fish were found close to shore with few fish near the range limits of acoustic detection. This shore orientation is consistent with previous behavioral observations of upriver-migrating fall chum salmon on the Chandalar (Osborne and Melegari 2006), Sheenjek (Barton 1995), and main-stem Yukon rivers (Johnston et al. 1993). During 2012 the range of the left bank DIDSON was reduced to 40 m from 70 m that was used during previous years. Less than 1% of the fish counted were beyond 25 m, which is similar to previous years. This, along with the historical range distributions and the improved down range resolution gained by reducing the range, support the assertion that the change had an inconsequential impact on the passage estimate.

Unlike split-beam sonar, DIDSON does not obtain vertical position data. However, the larger vertical angle of the DIDSON’s beams (12° vs. 2.1° and 4.8° used with the split-beam on the Chandalar River) reduced the potential of fish passing above or below the beams. This is further supported by the DIDSON data, in which surface waves were usually detected on windy days, and the river bottom was normally visible throughout the range.

Video monitoring

The relatively high water and associated turbidity levels resulted in marginal performance of the video monitoring, as observed in 2011. However, the video data corroborates previous data indicating that the vast majority of fish passing the sight during sonar operations are chum salmon. It is notable that in some years both video monitoring and seining yielded higher proportions of least cisco in the samples (Osborne and Melegari 2006; Melegari and Osborne 2007). This could indicate that least cisco abundance, run timing, or both, is highly variable. Additionally, low visibility levels may have reduced the ability to detect smaller sized fish that were not very close to the cameras. However, even with reduced visibility if substantial numbers of least cisco were present we should have detected some of them.

Conclusions

The DIDSON performed well overall, and only minimal time was missed due to high water during the season. Less down time resulted in fewer adjustments to raw counts, which should correspond to more accurate passage estimates.

Video monitoring and beach seining have been used to evaluate sonar performance and the presence of non-target species. Both methods are greatly impacted by water conditions and only provide qualitative data. However, they do provide beneficial information with minimal additional cost. Video monitoring should be implemented during future years, as conditions allow, and should be focused on times of higher passage, during morning and evening hours with sufficient lighting levels. Beach seining is labor intensive and often produces minimal catches, but can provide some useful data when video monitoring cannot be used.

Annual sonar enumeration of fall chum salmon in the Chandalar River is a vital component for effectively managing the complex mixed stock subsistence and commercial fisheries in the Yukon River. The Chandalar River fall chum salmon stock is crucial to the total Yukon River fall chum salmon run and is important to users throughout the drainage. Daily in-season counts and post-season passage estimates provide important escapement information to managers and users of this resource, allowing better informed management decisions and evaluation of past actions. This project is an important component in assessing the lower river abundance estimate proportioned by mixed stock genetic analysis. Additionally, this project has provided accurate population status and trend data over an 18-year time series. These time series data will become increasingly important as stressors such as climate change, disease, selective harvest, and overall demand on the fisheries and resources in the Yukon River drainage continue to increase.

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Table 1. — Hydroacoustic data collected via DIDSON at the Chandalar River, Alaska 2012

Date	Left bank			Right bank			Combined		
	Sample time (h)	Upriver count	Downriver count	Sample time (h)	Upriver count	Downriver count	Sample time (h)	Upriver count	Downriver count
8-Aug	23.98	303	1	23.98	367	5	47.96	670	6
9-Aug	23.98	297	9	23.98	372	7	47.96	669	16
10-Aug	23.98	250	8	23.98	423	8	47.96	673	16
11-Aug	23.97	222	4	23.98	437	15	47.95	659	19
12-Aug	23.97	182	5	19.84	379	4	43.81	561	9
13-Aug	23.98	177	11	23.98	463	8	47.96	640	19
14-Aug	23.98	213	9	23.87	573	5	47.85	786	14
15-Aug	23.97	227	6	23.98	660	5	47.95	887	11
16-Aug	23.98	282	10	23.98	705	8	47.96	987	18
17-Aug	23.40	189	6	23.98	1,018	8	47.38	1,207	14
18-Aug	23.98	221	9	23.98	873	3	47.96	1,094	12
19-Aug	23.98	306	7	23.98	1,085	7	47.96	1,391	14
20-Aug	23.98	424	5	23.98	1,306	7	47.96	1,730	12
21-Aug	22.69	325	6	22.68	1,577	7	45.37	1,902	13
22-Aug	23.98	337	6	23.98	1,776	14	47.96	2,113	20
23-Aug	23.97	490	6	23.98	2,508	19	47.95	2,998	25
24-Aug	23.98	686	7	23.98	3,359	17	47.96	4,045	24
25-Aug	23.98	951	14	23.98	2,905	4	47.96	3,856	18
26-Aug	23.97	1,076	9	23.98	2,410	11	47.95	3,486	20
27-Aug	23.98	1,375	2	23.98	2,726	12	47.96	4,101	14
28-Aug	23.98	1,153	7	23.98	3,253	20	47.96	4,406	27
29-Aug	23.98	1,420	7	23.98	2,930	22	47.96	4,350	29
30-Aug	23.98	1,597	6	23.98	4,322	28	47.96	5,919	34
31-Aug	23.98	1,798	8	23.98	5,606	12	47.96	7,404	20
1-Sep	23.98	1,596	12	23.98	4,134	19	47.96	5,730	31
2-Sep	23.98	1,472	5	23.98	3,745	72	47.96	5,217	77
3-Sep	23.98	1,697	9	23.98	3,339	101	47.96	5,036	110
4-Sep	23.98	2,720	5	23.98	2,655	9	47.96	5,375	14
5-Sep	23.98	2,091	4	23.98	2,221	12	47.96	4,312	16
6-Sep	23.98	2,115	5	23.98	1,893	27	47.96	4,008	32
7-Sep	12.99	1,182	2	12.99	554	26	25.98	1,736	28
8-Sep	0.00	—	—	0.00	—	—	0.00	—	—
9-Sep	0.00	—	—	0.00	—	—	0.00	—	—
10-Sep	0.00	—	—	0.00	—	—	0.00	—	—
11-Sep	5.83	430	3	6.49	326	8	12.32	756	11
12-Sep	23.98	1,330	15	23.98	1,652	92	47.96	2,982	107
13-Sep	23.98	1,247	13	23.98	2,047	109	47.96	3,294	122
14-Sep	23.97	1,693	21	23.98	2,766	72	47.95	4,459	93
15-Sep	23.96	1,828	10	23.98	3,009	65	47.94	4,837	75
16-Sep	23.98	1,977	9	23.98	4,024	103	47.96	6,001	112
17-Sep	23.98	3,937	23	23.98	5,686	91	47.96	9,623	114
18-Sep	23.98	3,107	14	23.98	5,544	97	47.96	8,651	111
19-Sep	23.98	2,571	20	23.98	4,516	266	47.96	7,087	286
20-Sep	23.98	2,581	27	23.98	5,412	167	47.96	7,993	194
21-Sep	23.98	2,297	18	23.98	6,339	62	47.96	8,636	80
22-Sep	23.97	2,032	92	23.98	4,183	467	47.95	6,215	559
23-Sep	0.00	—	—	11.49	1,319	87	11.49	1,319	87
24-Sep	6.99	456	7	8.49	1,410	27	15.48	1,866	34
25-Sep	23.98	1,180	28	23.98	2,854	107	47.96	4,034	135
26-Sep	23.98	936	158	23.98	2,472	117	47.96	3,408	275
27-Sep	23.98	895	103	23.98	2,375	94	47.96	3,270	197
28-Sep	23.98	1,004	74	23.98	2,271	110	47.96	3,275	184
29-Sep	11.99	457	23	11.99	979	69	23.98	1,436	92
Totals	1,114.94	57,332	868	1,125.00	119,758	2,732	2,239.94	177,090	3,600

Table 2. — Daily fall chum salmon upriver passage estimates at the Chandalar River, Alaska 2012.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative %
8-Aug	303	367	670	670	0.34
9-Aug	297	372	669	1,339	0.68
10-Aug	250	423	673	2,012	1.02
11-Aug	222	437	659	2,671	1.35
12-Aug	182	460[a]	642	3,313	1.67
13-Aug	177	463	640	3,953	2.00
14-Aug	213	575	788	4,741	2.40
15-Aug	227	661	888	5,629	2.84
16-Aug	282	706	988	6,617	3.34
17-Aug	196	1,019	1,215	7,832	3.96
18-Aug	221	874	1,095	8,927	4.51
19-Aug	306	1,086	1,392	10,319	5.21
20-Aug	424	1,307	1,731	12,050	6.09
21-Aug	327[a]	1,671[a]	1,998	14,048	7.10
22-Aug	337	1,777	2,114	16,162	8.17
23-Aug	490	2,510	3,000	19,162	9.68
24-Aug	687	3,362	4,049	23,211	11.73
25-Aug	952	2,907	3,859	27,070	13.68
26-Aug	1,077	2,412	3,489	30,559	15.44
27-Aug	1,376	2,728	4,104	34,663	17.51
28-Aug	1,154	3,256	4,410	39,073	19.74
29-Aug	1,421	2,932	4,353	43,426	21.94
30-Aug	1,598	4,326	5,924	49,350	24.93
31-Aug	1,799	5,611	7,410	56,760	28.68
1-Sep	1,597	4,137	5,734	62,494	31.57
2-Sep	1,473	3,748	5,221	67,715	34.21
3-Sep	1,698	3,342	5,040	72,755	36.76
4-Sep	2,722	2,657	5,379	78,134	39.48
5-Sep	2,093	2,223	4,316	82,450	41.66
6-Sep	2,117	1,895	4,012	86,462	43.68
7-Sep	2,131[a]	992[a]	3,123	89,585	45.26
8-Sep	1,971[b]	1,072[b]	3,043	92,628	46.80
9-Sep	1,811[b]	1,152[b]	2,963	95,591	48.30
10-Sep	1,651[b]	1,231[b]	2,882	98,473	49.75
11-Sep	1,491[b]	1,311[a]	2,802	101,275	51.17
12-Sep	1,331	1,653	2,984	104,259	52.67
13-Sep	1,248	2,049	3,297	107,556	54.34
14-Sep	1,695	2,768	4,463	112,019	56.59
15-Sep	1,831	3,012	4,843	116,862	59.04
16-Sep	1,979	4,027	6,006	122,868	62.08
17-Sep	3,940	5,691	9,631	132,499	66.94
18-Sep	3,110	5,549	8,659	141,158	71.32
19-Sep	2,573	4,520	7,093	148,251	74.90
20-Sep	2,583	5,417	8,000	156,251	78.94
21-Sep	2,299	6,344	8,643	164,894	83.31
22-Sep	2,034	4,186	6,220	171,114	86.45
23-Sep	1,664[b]	2,754[a]	4,418	175,532	88.68
24-Sep	1,294[a]	4,348[a]	5,642	181,174	91.53
25-Sep	1,181	2,856	4,037	185,211	93.57
26-Sep	937	2,474	3,411	188,622	95.30
27-Sep	896	2,377	3,273	191,895	96.95
28-Sep	1,005	2,273	3,278	195,173	98.61
29-Sep	858[a]	1,900[a]	2,758	197,931	100.00
Totals	67,731	130,200	197,931		

[a] Partial daily count, missing hours estimated using mean hourly frequencies.
[b] Sonar was inoperable due to high water, counts interpolated

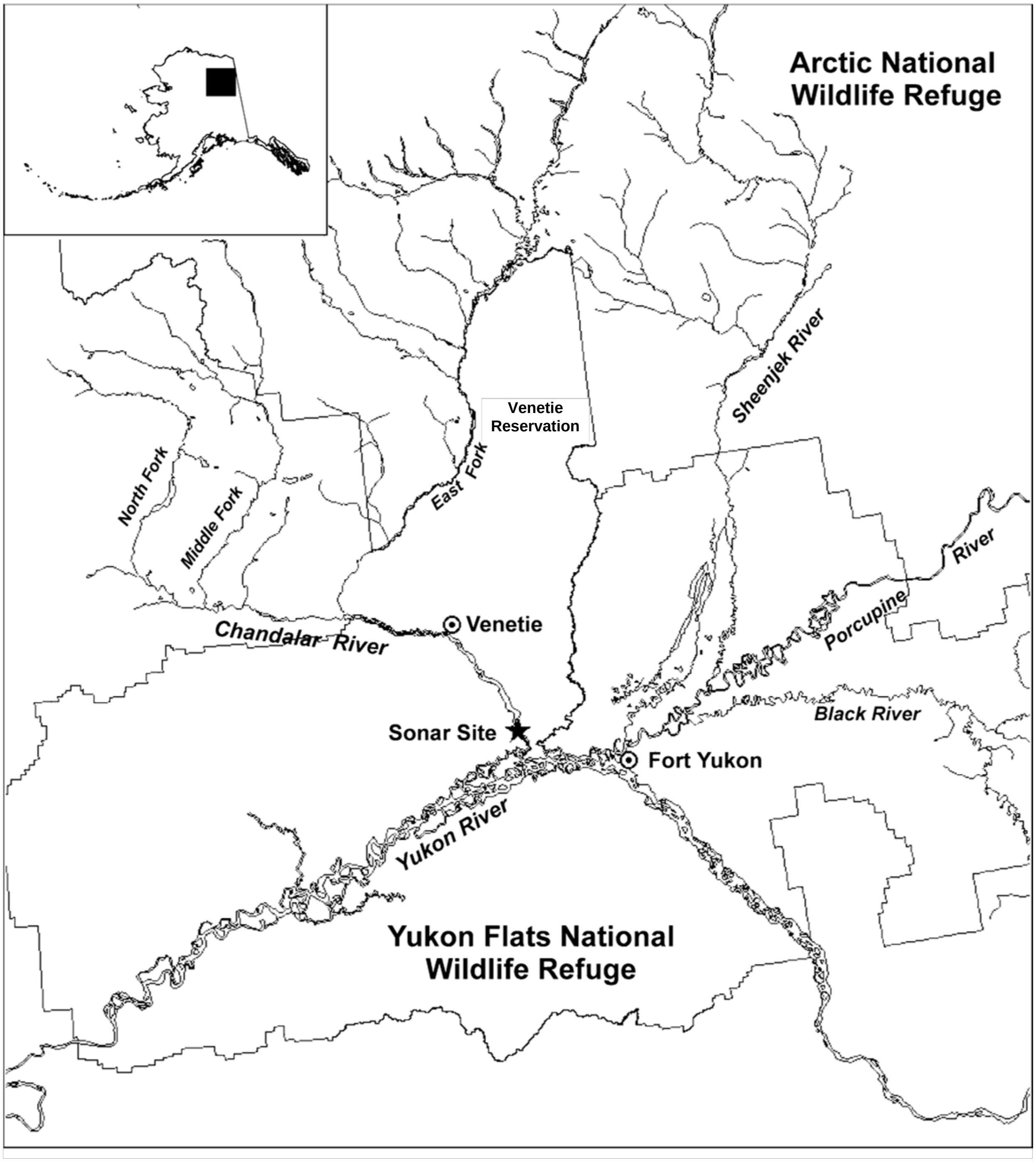

Figure 1. — Chandalar River sonar site and major tributaries of the Yukon River near the U.S.-Canada border.

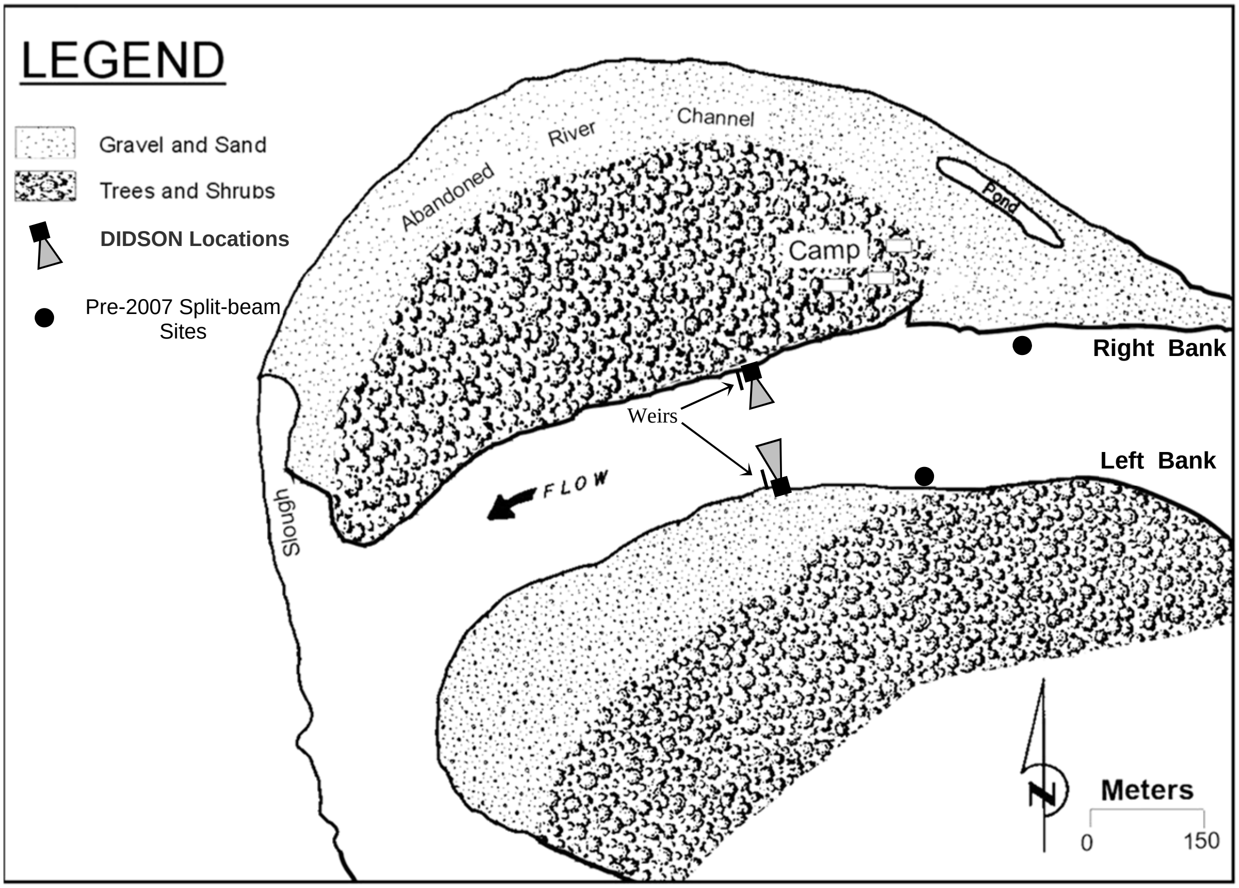

Figure 2. — Site map of Chandalar River sonar facilities.

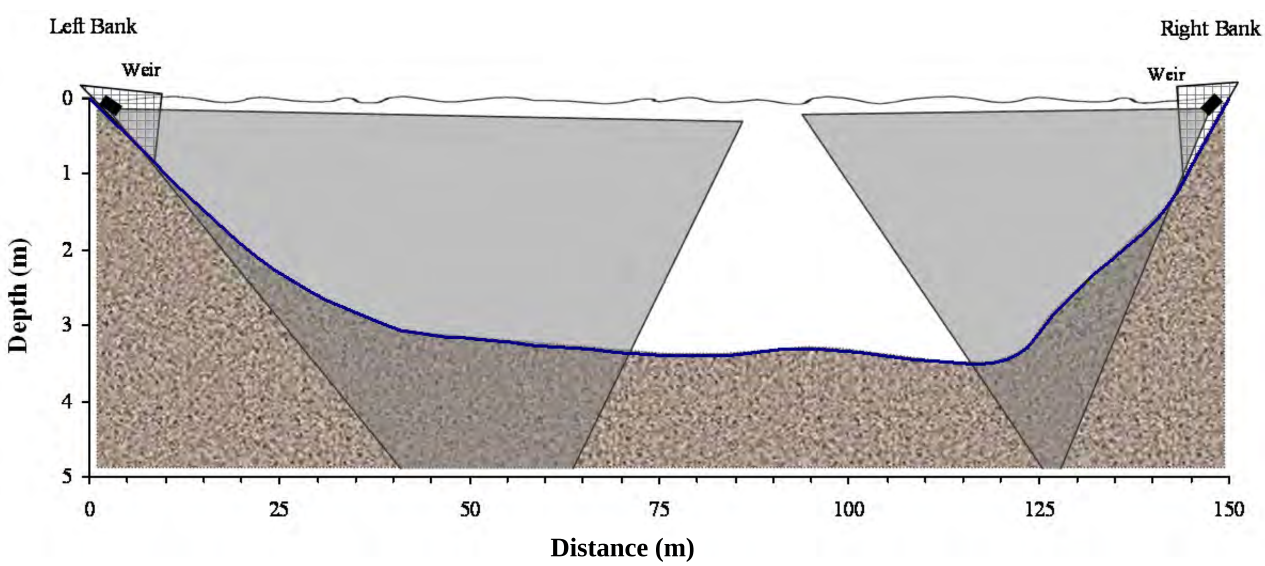

Figure 3. — River channel profile and approximated ensonified zones during 2009 for the left and right bank sonar sites, Chandalar River. Little change has been detected in channel profile from 2008 to 2012. Note: different axis scales are used to enhance readability.

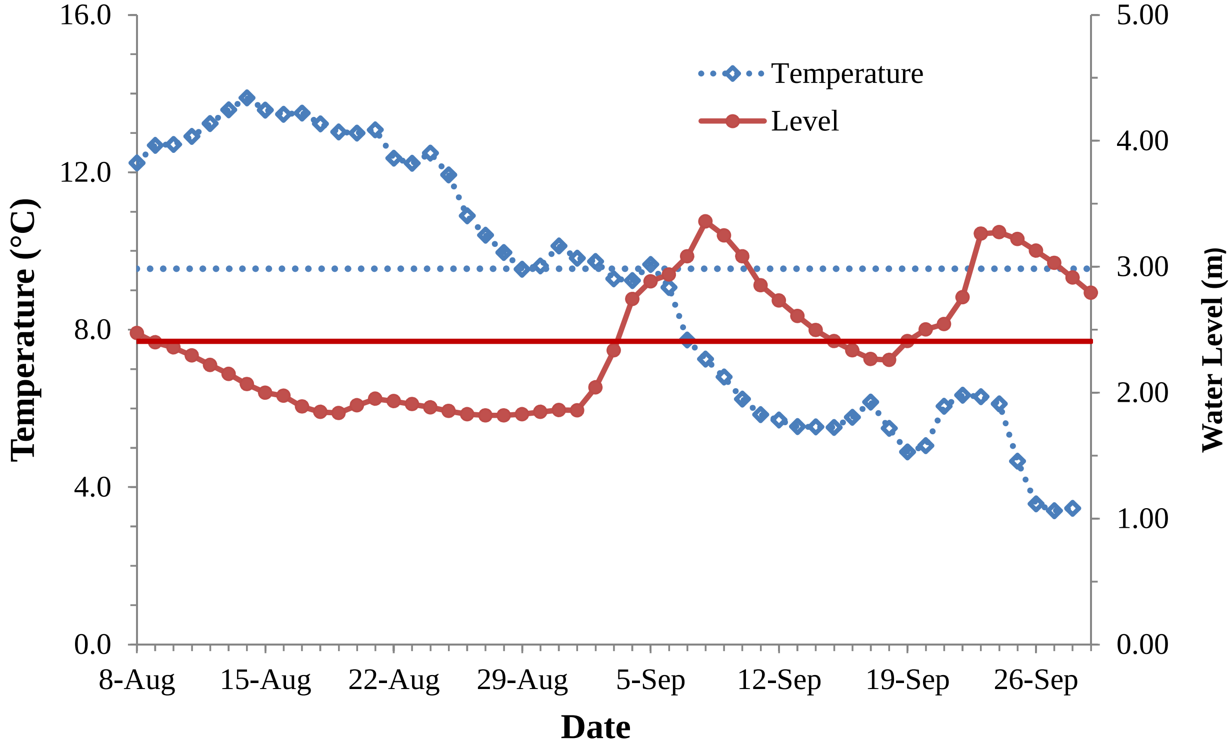

Figure 4. — Average daily water temperature and calibrated daily water level from Chandalar River sonar site, 2012. Temperature is the daily average of hourly measurements from YSI sonde. Straight horizontal lines indicate seasonal averages.

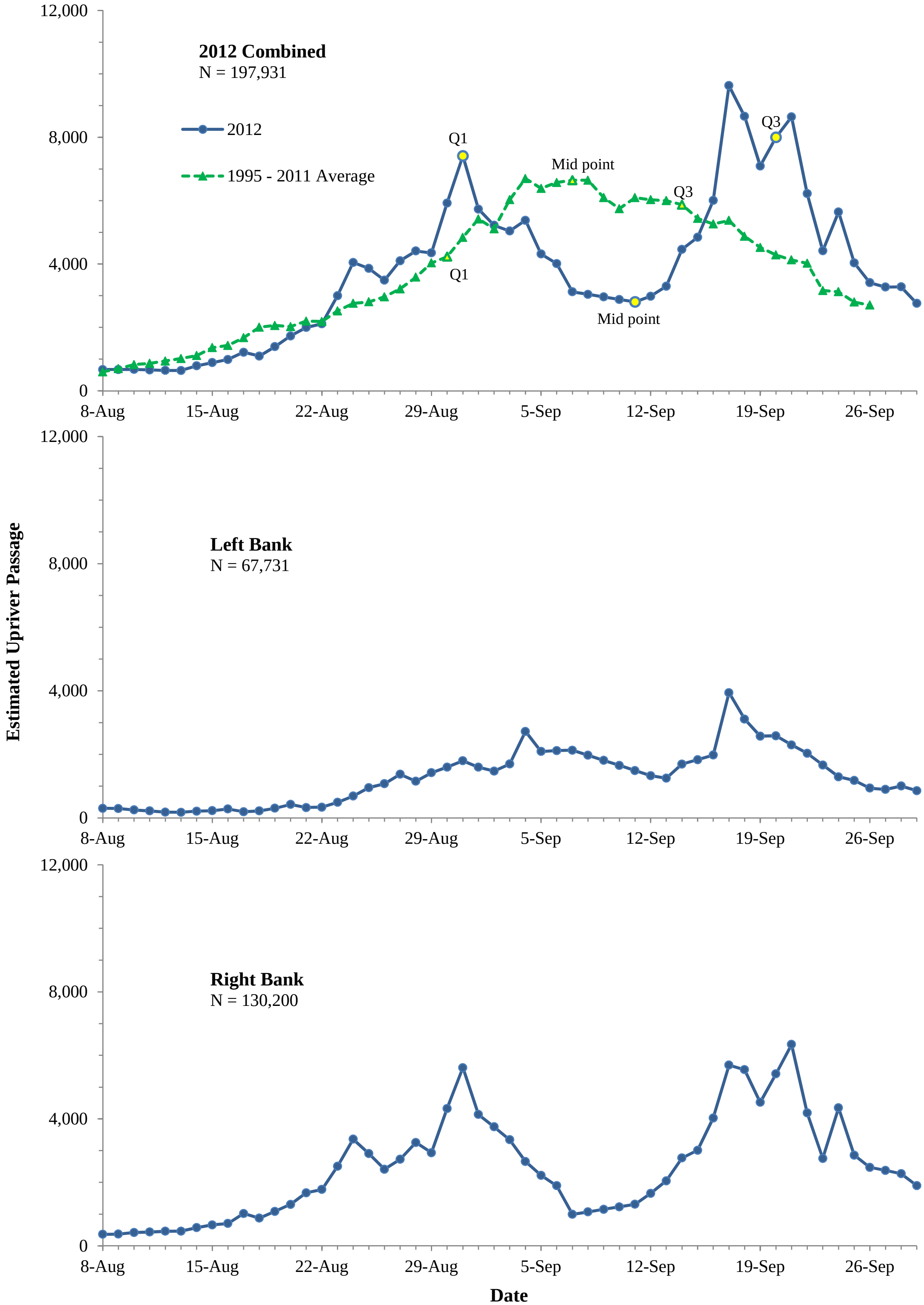

Figure 5 — Estimated passage of upriver swimming fall chum salmon by bank and combined, Chandalar River, 2012. Highlighted points in the top graph indicate the 1st quarter, mid, and 3rd quarter points of passage.
* Average does not include data from 2009 because the project was ended early before the majority of the run normally passes.

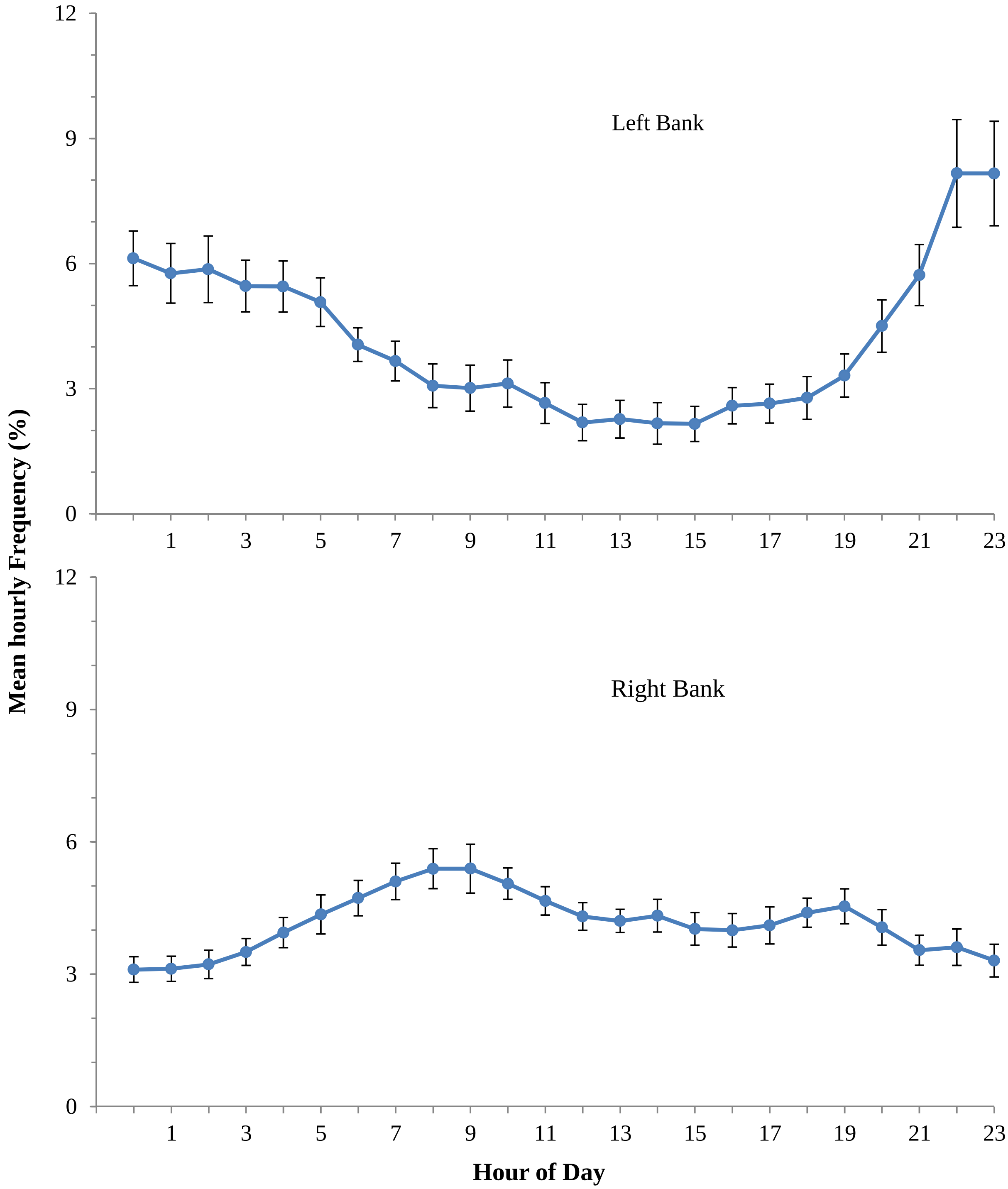

Figure 6. — Mean (±2 SE) hourly frequency of upriver swimming fall chum salmon, Chandalar River, 2012. Hourly frequency is the hourly passage expressed as a percent of the total daily count. Results include 45 complete days of 24-hour data on the left bank and 44 days on the right bank.

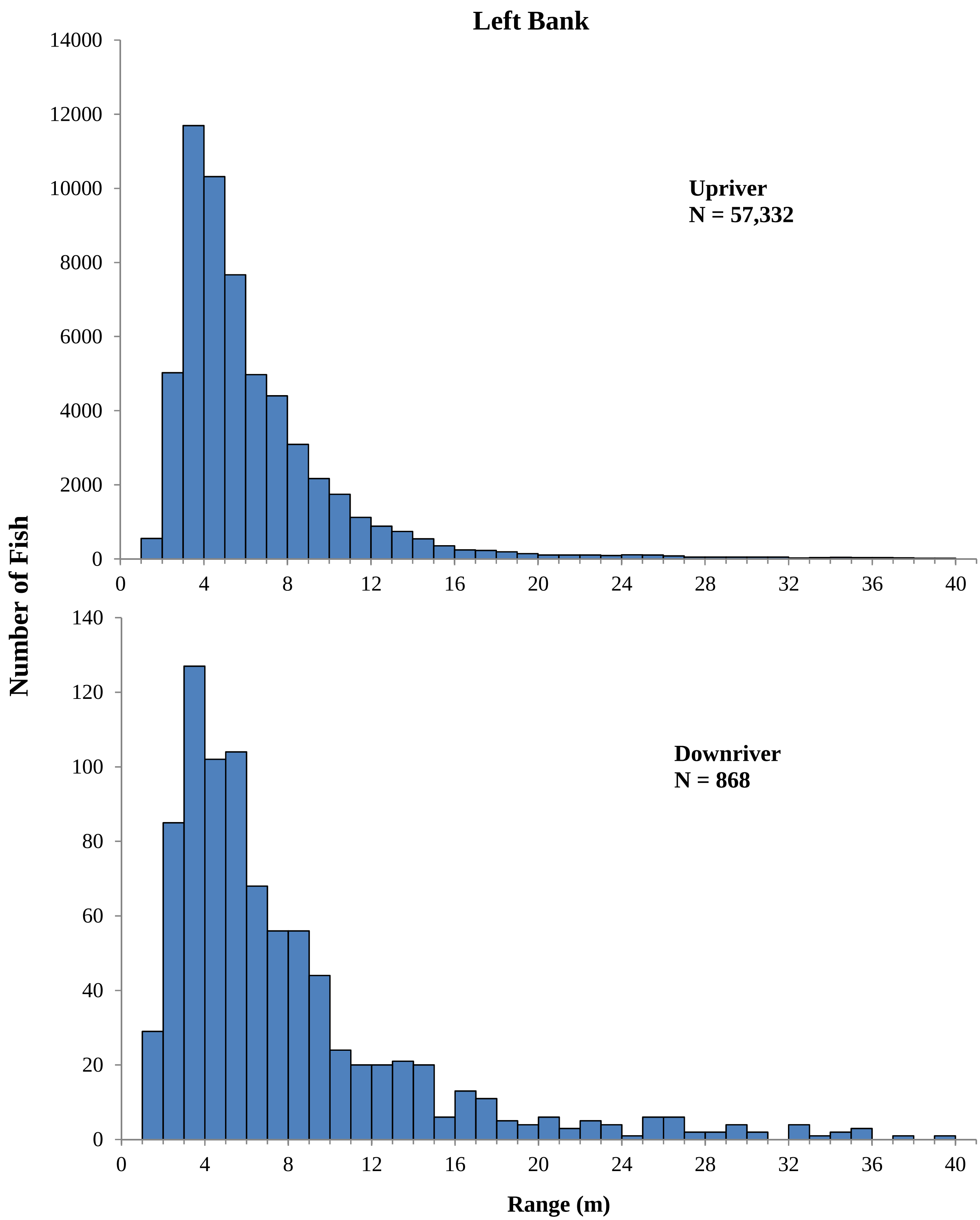

Figure 7. — Range (horizontal distance from DIDSON) distribution of upriver and downriver swimming fish, from hydroacoustic data collected on the left bank Chandalar River, August 8 to September 29, 2012. Note different Y-axis scales on top and bottom graphs.

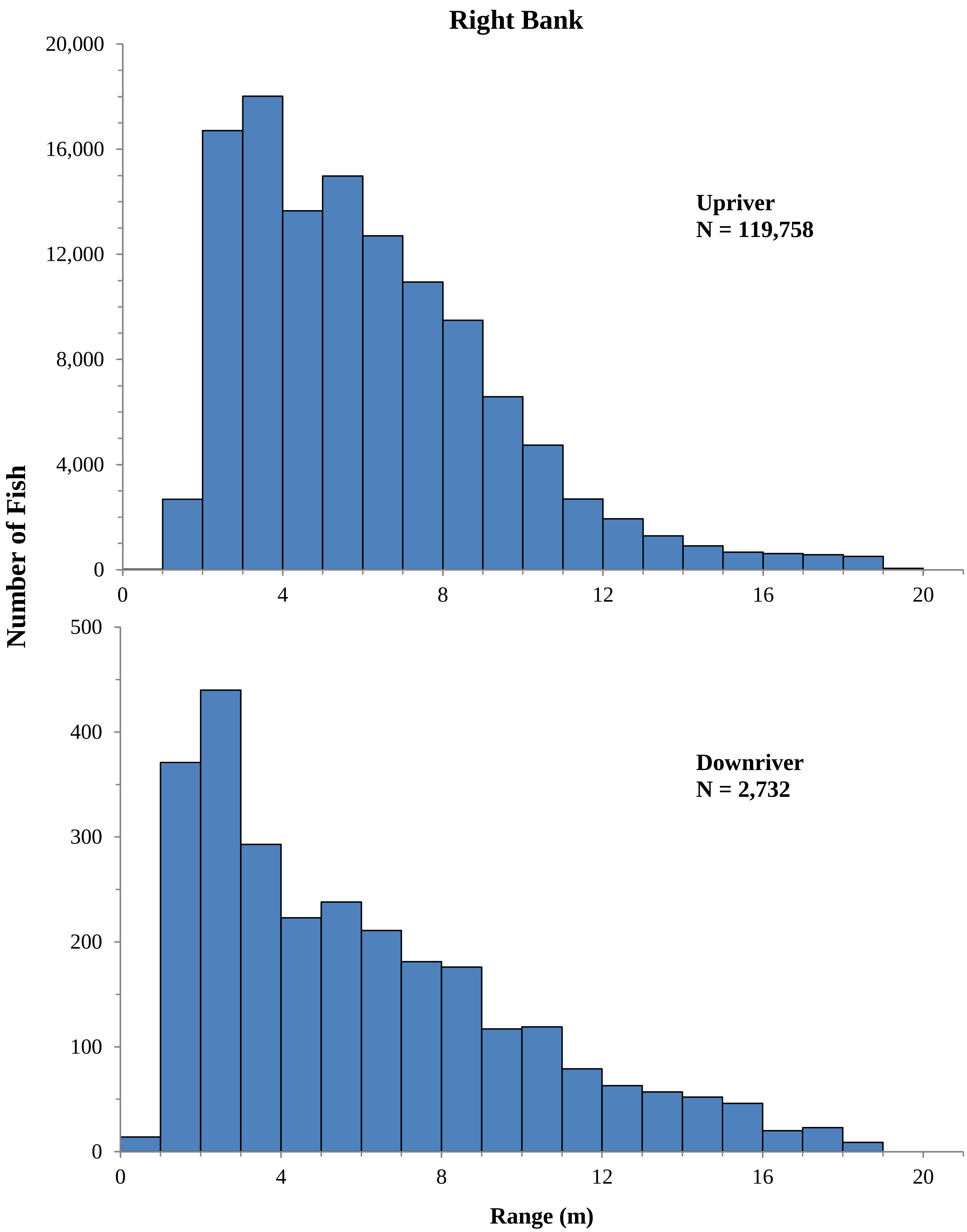

Figure 8. — Range (horizontal distance from DIDSON) distribution of upriver and downriver swimming fish, from hydroacoustic data collected on the right bank Chandalar River, August 8 to September 29, 2012. Note different Y-axis scales on top and bottom graphs.

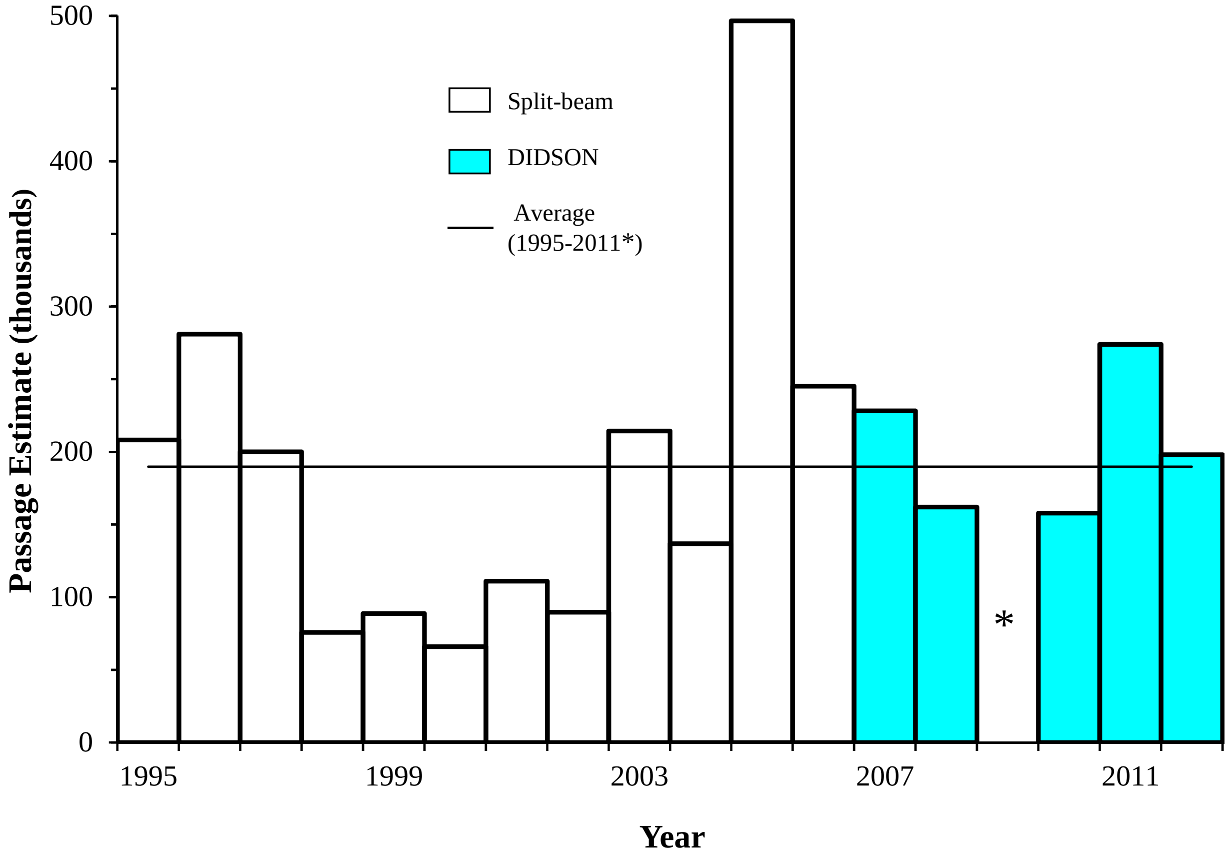

Figure 9. — Annual passage estimates (in thousands of fish) of fall chum salmon from sonar counts on the Chandalar River, 1995 to 2012. The horizontal line indicates the average of 1995 to 2011 passage estimates. * Average does not include data from 2009, because the project was ended early before the majority of the run normally passes.

Appendix 1. — Historical fall chum salmon passage estimates from sonar counts on the Chandalar River, Alaska.

		Passage estimate		
Year	Sonar type	Left bank	Right bank	Combined
1987	Bendix	36,089	16,327	52,416
1988	Bendix	20,516	13,103	33,619
1989	Bendix	36,495	32,666	69,161
1990	Bendix	24,635	53,996	78,631
1995[a]	Split-beam	116,074	164,925	280,999
1996	Split-beam	75,630	132,540	208,170
1997	Split-beam	65,471	134,403	199,874
1998	Split-beam	31,676	44,135	75,811
1999	Split-beam	38,091	50,571	88,662
2000	Split-beam	16,420	49,474	65,894
2001	Split-beam	20,299	90,672	110,971
2002	Split-beam	24,188	65,392	89,580
2003	Split-beam	68,825	145,591	214,416
2004	Split-beam	29,851	106,852	136,703
2005	Split-beam	159,937	336,547	496,484
2006	Split-beam	63,123	181,967	245,090
2007	DIDSON	31,193	196,862	228,055
2008	DIDSON	22,261	139,763	162,024
2009[b]	DIDSON	1,314	4,861	6,175
2010	DIDSON	38,539	119,205	157,744
2011	DIDSON	76,638	197,327	273,965
2012	DIDSON	67,731	130,200	197,931

[a] Estimates calculated post season.
[b] Incomplete counts, operations stopped before the majority of the run normally passes.

Appendix 2. — Water level and water quality data, collected with a YSI sonde at the Chandalar River sonar project, 2012. Daily values are averages of hourly readings.

Date	Level[a] (m)	Temperature (°C)	Specific conductance (µS/cm)	pH	Turbidity (NTU)	DO	
						mg/L	(% saturation)
8-Aug	2.47	12.24	326.8	8.24	19.9	10.42	98.2
9-Aug	2.40	12.69	326.9	8.23	13.9	10.37	98.7
10-Aug	2.36	12.71	330.1	8.24	12.8	10.35	98.7
11-Aug	2.30	12.91	332.9	8.23	9.9	10.32	98.8
12-Aug	2.22	13.24	335.1	8.23	7.3	10.26	98.9
13-Aug	2.15	13.59	336.0	8.23	6.5	10.14	98.6
14-Aug	2.07	13.89	336.4	8.22	5.8	10.02	98.1
15-Aug	2.00	13.58	336.1	8.21	5.3	10.01	97.3
16-Aug	1.98	13.48	335.7	8.21	5.6	10.05	97.4
17-Aug	1.89	13.51	335.4	8.23	6.0	9.99	96.9
18-Aug	1.85	13.23	335.5	8.23	5.9	10.05	97.0
19-Aug	1.84	13.03	336.2	8.22	5.3	10.06	96.6
20-Aug	1.90	13.00	338.6	8.22	5.3	10.15	97.4
21-Aug	1.95	13.08	339.6	8.24	5.6	10.23	98.3
22-Aug	1.93	12.36	338.3	8.23	4.7	10.41	98.4
23-Aug	1.91	12.23	338.2	8.22	4.0	10.39	97.9
24-Aug	1.88	12.49	338.8	8.21	3.5	10.26	97.4
25-Aug	1.85	11.93	338.8	8.22	4.2	10.38	97.2
26-Aug	1.83	10.89	338.2	8.22	3.8	10.60	96.9
27-Aug	1.82	10.40	336.5	8.20	3.4	10.69	96.7
28-Aug	1.82	9.96	335.6	8.20	3.2	10.92	97.8
29-Aug	1.83	9.54	336.1	8.20	3.2	11.09	98.3
30-Aug	1.85	9.62	334.1	8.18	3.2	11.05	98.1
31-Aug	1.86	10.13	333.0	8.18	2.8	10.89	97.8
1-Sep	1.86	9.82	335.0	8.18	3.8	10.89	97.2
2-Sep	2.04	9.74	323.2	8.17	6.5	10.98	97.7
3-Sep	2.34	9.30	316.8	8.14	20.0	11.09	97.7
4-Sep	2.74	9.25	309.2	8.11	40.7	11.19	98.4
5-Sep	2.88	9.66	314.0	8.14	41.5	11.02	97.8
6-Sep	2.94	9.08	318.8	8.16	34.2	11.14	97.6
7-Sep	3.08	7.74	317.4	8.14	51.3	11.60	98.4
8-Sep	3.36	7.26	317.1	8.11	55.9	11.81	99.0
9-Sep	3.25	6.80	329.4	8.12	36.5	11.88	98.5
10-Sep	3.08	6.24	334.5	8.13	22.7	12.10	98.9
11-Sep	2.85	5.84	336.8	8.13	16.5	12.20	98.7
12-Sep	2.73	5.70	337.5	8.15	11.8	12.16	98.1
13-Sep	2.61	5.54	338.3	8.15	9.3	12.17	97.8
14-Sep	2.50	5.53	338.4	8.14	7.7	12.15	97.6
15-Sep	2.41	5.52	338.2	8.15	6.7	12.14	97.5
16-Sep	2.33	5.78	336.8	8.15	5.9	12.03	97.2
17-Sep	2.27	6.16	335.1	8.16	6.0	11.85	96.7
18-Sep	2.26	5.49	333.0	8.17	5.0	12.05	96.7
19-Sep	2.41	4.90	328.8	8.15	6.9	12.36	97.6
20-Sep	2.50	5.05	331.4	8.15	8.6	12.38	98.2
21-Sep	2.55	6.06	325.0	8.14	9.0	12.14	98.8
22-Sep	2.76	6.34	306.8	8.11	18.9	12.05	98.7
23-Sep	3.26	6.30	282.3	8.06	43.0	12.05	98.4
24-Sep	3.27	6.12	290.4	8.09	28.9	12.04	98.0
25-Sep	3.22	4.66	298.6	8.12	19.8	12.49	98.0
26-Sep	3.13	3.57	309.3	8.13	16.2	12.84	97.9
27-Sep	3.03	3.40	318.8	8.15	13.7	12.75	96.8
28-Sep	2.91	3.46	323.8	8.14	10.0	12.68	96.4
29-Sep	2.79						
Average	2.41	9.55	331.7	8.18	14.07	11.10	97.83
Min	1.82	3.40	278.0	8.04	2.60	9.52	95.10
Max	3.36	14.82	399.6	8.27	66.20	12.90	100.70

[a] Water level is calibrated to 1989 levels using a benchmark on shore.

Appendix 3. — Historical daily and cumulative fall chum salmon passage estimates from sonar counts on the Chandalar River. Highlighted cells indicated the midpoint of the run, and the boxes indicate the quarter points.

	1995		1996		1997		1998		1999	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
8-Aug	1,172	1,172	517	517	619	619	90	90	149	149
9-Aug	928	2,100	341	858	522	1,141	152	242	128	277
10-Aug	861	2,961	323	1,181	682	1,823	215	457	123	400
11-Aug	856	3,817	262	1,443	435	2,258	189	646	119	519
12-Aug	1,269	5,086	356	1,799	752	3,010	162	808	114	633
13-Aug	1,327	6,413	628	2,427	729	3,739	119	927	203	836
14-Aug	1,600	8,013	928	3,355	723	4,462	270	1,197	214	1,050
15-Aug	1,876	9,889	1,209	4,564	838	5,300	395	1,592	368	1,418
16-Aug	1,761	11,650	1,743	6,307	619	5,919	235	1,827	561	1,979
17-Aug	1,672	13,322	2,633	8,940	639	6,558	160	1,987	1,032	3,011
18-Aug	1,741	15,063	3,523	12,463	423	6,981	158	2,145	1,232	4,243
19-Aug	1,851	16,914	4,413	16,876	388	7,369	151	2,296	1,985	6,228
20-Aug	2,297	19,211	5,302	22,178	365	7,734	139	2,435	2,269	8,497
21-Aug	2,729	21,940	6,085	28,263	540	8,274	141	2,576	2,372	10,869
22-Aug	1,988	23,928	6,449	34,712	793	9,067	168	2,744	2,227	13,096
23-Aug	2,596	26,524	7,132	41,844	1,617	10,684	273	3,017	3,266	16,362
24-Aug	6,893	33,417	5,996	47,840	2,263	12,947	318	3,335	3,052	19,414
25-Aug	8,540	41,957	5,165	53,005	3,125	16,072	400	3,735	2,854	22,268
26-Aug	9,666	51,623	6,469	59,474	3,458	19,530	421	4,156	3,679	25,947
27-Aug	6,388	58,011	7,750	67,224	6,103	25,633	486	4,642	3,635	29,582
28-Aug	7,723	65,734	7,572	74,796	5,942	31,575	330	4,972	3,928	33,510
29-Aug	6,842	72,576	6,834	81,630	7,217	38,792	273	5,245	2,961	36,471
30-Aug	8,212	80,788	6,677	88,307	6,661	45,453	651	5,896	2,022	38,493
31-Aug	11,146	91,934	6,737	95,044	6,020	51,473	917	6,813	2,034	40,527
1-Sep	7,229	99,163	7,233	102,277	5,123	56,596	1,230	8,043	1,754	42,281
2-Sep	8,390	107,553	7,982	110,259	4,509	61,105	1,321	9,364	1,974	44,255
3-Sep	8,708	116,261	9,500	119,759	9,720	70,825	1,455	10,819	2,444	46,699
4-Sep	6,136	122,397	7,572	127,331	10,468	81,293	1,379	12,198	2,571	49,270
5-Sep	4,308	126,705	5,837	133,168	13,069	94,362	1,505	13,703	3,716	52,986
6-Sep	3,991	130,696	6,086	139,254	15,951	110,313	1,630	15,333	4,767	57,753
7-Sep	5,354	136,050	6,132	145,386	15,420	125,733	1,675	17,008	3,965	61,718
8-Sep	5,795	141,845	8,090	153,476	12,953	138,686	1,824	18,832	2,775	64,493
9-Sep	3,859	145,704	9,847	163,323	8,872	147,558	2,128	20,960	1,743	66,236
10-Sep	5,087	150,791	9,422	172,745	7,602	155,160	2,429	23,389	1,417	67,653
11-Sep	3,825	154,616	9,870	182,615	5,458	160,618	2,503	25,892	1,227	68,880
12-Sep	3,728	158,344	9,263	191,878	4,660	165,278	2,512	28,404	1,195	70,075
13-Sep	5,764	164,108	10,708	202,586	4,109	169,387	2,723	31,127	1,238	71,313
14-Sep	3,672	167,780	10,095	212,681	3,956	173,343	2,524	33,651	1,363	72,676
15-Sep	3,739	171,519	9,527	222,208	3,900	177,243	2,273	35,924	1,133	73,809
16-Sep	6,104	177,623	8,324	230,532	4,124	181,367	2,747	38,671	1,357	75,166
17-Sep	7,063	184,686	8,439	238,971	4,264	185,631	4,999	43,670	1,340	76,506
18-Sep	5,089	189,775	8,274	247,245	3,656	189,287	5,935	49,605	1,352	77,858
19-Sep	5,819	195,594	8,086	255,331	3,513	192,800	4,731	54,336	1,332	79,190
20-Sep	4,186	199,780	7,836	263,167	2,320	195,120	4,401	58,737	1,510	80,700
21-Sep	4,086	203,866	9,605	272,772	2,428	197,548	4,053	62,790	1,324	82,024
22-Sep	4,304	208,170	8,227	280,999	2,326	199,874	3,329	66,119	1,628	83,652
23-Sep							2,738	68,857	1,490	85,142
24-Sep							2,498	71,355	1,362	86,504
25-Sep							2,336	73,691	1,112	87,616
26-Sep							2,103	75,794	1,046	88,662
27-Sep										
28-Sep										
29-Sep										

Appendix 3. — Continued.

	2000		2001		2002		2003		2004	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
8-Aug	226	226	454	454	216	216	310	310	880	880
9-Aug	232	458	368	822	665	881	395	705	907	1,787
10-Aug	222	680	355	1,177	774	1,655	449	1,154	995	2,782
11-Aug	260	940	317	1,494	600	2,255	872	2,026	991	3,773
12-Aug	200	1,140	385	1,879	905	3,160	894	2,920	1,077	4,850
13-Aug	238	1,378	322	2,201	569	3,729	792	3,712	1,031	5,881
14-Aug	264	1,642	626	2,827	270	3,999	1,193	4,905	921	6,802
15-Aug	216	1,858	969	3,796	623	4,622	1,598	6,503	888	7,690
16-Aug	240	2,098	1,270	5,066	691	5,313	1,980	8,483	1,016	8,706
17-Aug	500	2,598	1,561	6,627	772	6,085	3,551	12,035	1,193	9,899
18-Aug	451	3,049	7,024	13,651	641	6,726	3,747	15,781	1,350	11,249
19-Aug	460	3,509	5,108	18,759	959	7,685	3,294	19,076	1,374	12,623
20-Aug	665	4,174	3,164	21,923	683	8,368	3,015	22,091	1,610	14,233
21-Aug	621	4,795	2,576	24,499	469	8,837	4,363	26,454	1,488	15,721
22-Aug	706	5,501	2,279	26,778	481	9,318	5,789	32,243	1,230	16,951
23-Aug	591	6,092	2,902	29,680	604	9,922	6,427	38,671	1,555	18,506
24-Aug	2,270	8,362	2,744	32,424	700	10,622	5,237	43,908	981	19,487
25-Aug	1,616	9,978	2,630	35,054	721	11,343	4,537	48,445	787	20,274
26-Aug	1,231	11,209	2,272	37,326	1,074	12,417	3,992	52,436	699	20,973
27-Aug	1,051	12,260	2,282	39,608	1,260	13,677	5,073	57,509	738	21,711
28-Aug	1,742	14,002	1,940	41,548	1,644	15,321	6,170	63,680	1,602	23,313
29-Aug	1,598	15,600	2,728	44,276	2,230	17,551	7,896	71,576	2,485	25,798
30-Aug	1,303	16,903	2,066	46,342	1,722	19,273	7,980	79,556	2,622	28,420
31-Aug	1,943	18,846	2,359	48,701	2,790	22,063	7,828	87,384	3,985	32,405
1-Sep	2,601	21,447	2,307	51,008	2,541	24,604	7,639	95,023	5,247	37,652
2-Sep	1,981	23,428	2,575	53,583	2,281	26,885	6,812	101,834	4,910	42,562
3-Sep	2,021	25,449	2,478	56,061	1,977	28,862	7,357	109,191	5,953	48,515
4-Sep	2,159	27,608	3,421	59,482	2,038	30,900	10,955	120,146	7,167	55,682
5-Sep	2,150	29,758	3,540	63,022	1,389	32,289	8,978	129,124	4,438	60,120
6-Sep	2,262	32,020	3,086	66,108	1,458	33,747	7,050	136,174	5,357	65,477
7-Sep	1,902	33,922	4,437	70,545	1,530	35,277	4,667	140,842	6,344	71,821
8-Sep	1,983	35,905	3,860	74,405	1,780	37,057	3,387	144,229	6,053	77,874
9-Sep	1,650	37,555	3,746	78,151	1,857	38,914	3,899	148,127	5,308	83,182
10-Sep	1,791	39,346	4,176	82,327	1,981	40,895	5,659	153,786	4,473	87,655
11-Sep	1,921	41,267	3,108	85,435	2,922	43,817	4,856	158,642	5,415	93,070
12-Sep	1,484	42,751	3,311	88,746	2,830	46,647	4,329	162,972	5,491	98,561
13-Sep	1,496	44,247	3,107	91,853	3,410	50,057	3,954	166,926	6,525	105,086
14-Sep	1,517	45,764	2,320	94,173	4,112	54,169	3,795	170,721	5,741	110,827
15-Sep	1,160	46,924	2,208	96,381	4,145	58,314	4,520	175,241	4,055	114,882
16-Sep	1,292	48,216	2,165	98,546	4,152	62,466	4,789	180,030	2,515	117,397
17-Sep	1,225	49,441	2,173	100,719	3,671	66,137	6,049	186,079	1,669	119,066
18-Sep	1,409	50,850	1,696	102,415	4,033	70,170	3,565	189,644	2,280	121,346
19-Sep	1,289	52,139	1,525	103,940	3,490	73,660	2,307	191,951	2,731	124,077
20-Sep	1,690	53,829	1,530	105,470	3,356	77,016	3,592	195,543	2,765	126,842
21-Sep	1,765	55,594	1,293	106,763	2,846	79,862	5,551	201,094	3,401	130,243
22-Sep	1,607	57,201	1,203	107,966	2,174	82,036	3,430	204,524	6,845	137,088
23-Sep	1,113	58,314	1,201	109,167	2,077	84,113	3,047	207,571		
24-Sep	1,280	59,594	786	109,953	2,095	86,208	2,466	210,037		
25-Sep	1,665	61,259	578	110,531	1,904	88,112	2,590	212,627		
26-Sep	1,340	62,599	440	110,971	1,735	89,847	1,801	214,428		
27-Sep										
28-Sep										
29-Sep										

Appendix 3. — Continued, (no data for 2009, when the project was terminated early, before the majority of the run began).

	2005		2006		2007		2008		2010	
Date	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum
8-Aug	2,819	2,819	570	570	269	269	521	521	173	173
9-Aug	4,117	6,936	526	1,096	375	644	673	1,194	130	303
10-Aug	5,235	12,171	625	1,721	551	1,195	717	1,911	258	561
11-Aug	5,899	18,070	589	2,310	553	1,748	662	2,573	386	947
12-Aug	5,214	23,284	751	3,061	628	2,376	877	3,450	514	1,461
13-Aug	5,972	29,256	871	3,932	504	2,880	1,332	4,782	641	2,102
14-Aug	6,252	35,508	1,074	5,006	522	3,402	1,008	5,790	769	2,871
15-Aug	5,923	41,431	2,960	7,966	553	3,955	1,136	6,926	897	3,768
16-Aug	6,893	48,324	1,785	9,751	572	4,527	1,054	7,980	1,025	4,793
17-Aug	7,154	55,478	1,082	10,833	674	5,201	1,321	9,301	1,152	5,945
18-Aug	5,245	60,723	1,276	12,109	786	5,987	1,099	10,400	1,381	7,326
19-Aug	6,233	66,956	1,646	13,755	591	6,578	862	11,262	1,562	8,888
20-Aug	5,820	72,776	1,931	15,686	496	7,074	755	12,017	1,865	10,753
21-Aug	6,479	79,255	2,216	17,902	454	7,528	967	12,984	1,468	12,221
22-Aug	5,303	84,558	2,501	20,403	437	7,965	819	13,803	1,596	13,817
23-Aug	5,217	89,775	2,786	23,189	419	8,384	939	14,742	1,509	15,326
24-Aug	4,495	94,270	3,071	26,260	427	8,811	1,006	15,748	1,893	17,219
25-Aug	4,707	98,977	3,356	29,616	408	9,219	1,158	16,906	2,096	19,315
26-Aug	3,572	102,549	3,641	33,257	336	9,555	1,799	18,705	2,179	21,494
27-Aug	4,798	107,347	3,926	37,183	381	9,936	2,318	21,023	2,055	23,549
28-Aug	5,510	112,857	4,501	41,684	417	10,353	2,424	23,447	2,310	25,859
29-Aug	6,186	119,043	6,160	47,844	458	10,811	4,259	27,706	2,392	28,251
30-Aug	8,162	127,205	8,420	56,264	476	11,287	4,596	32,302	1,926	30,177
31-Aug	7,608	134,813	11,266	67,530	556	11,843	5,376	37,678	2,046	32,223
1-Sep	18,372	153,185	11,041	78,571	897	12,740	6,184	43,862	1,937	34,160
2-Sep	12,774	165,959	11,815	90,386	994	13,734	6,440	50,302	1,883	36,043
3-Sep	17,290	183,249	10,819	101,205	1,658	15,392	7,210	57,512	1,847	37,890
4-Sep	23,630	206,879	9,762	110,967	2,965	18,357	8,411	65,923	1,816	39,706
5-Sep	25,251	232,130	7,091	118,058	5,086	23,443	7,530	73,453	1,914	41,620
6-Sep	24,374	256,504	6,522	124,580	6,739	30,182	6,979	80,432	2,330	43,950
7-Sep	22,788	279,292	5,744	130,324	9,676	39,858	6,814	87,246	3,224	47,174
8-Sep	22,831	302,123	5,675	135,999	13,137	52,995	5,439	92,685	4,058	51,232
9-Sep	18,256	320,379	6,336	142,335	14,952	67,947	4,535	97,220	4,501	55,733
10-Sep	12,488	332,867	5,886	148,221	14,571	82,518	3,982	101,202	5,183	60,916
11-Sep	16,035	348,902	6,569	154,790	17,754	100,272	3,624	104,826	6,330	67,246
12-Sep	17,056	365,958	6,412	161,202	17,067	117,339	3,765	108,591	7,344	74,590
13-Sep	12,242	378,200	7,176	168,378	15,931	133,270	3,501	112,092	8,106	82,696
14-Sep	12,973	391,173	8,324	176,702	16,398	149,668	3,189	115,281	8,103	90,799
15-Sep	11,966	403,139	8,440	185,142	13,399	163,067	2,851	118,132	8,255	99,054
16-Sep	8,848	411,987	8,721	193,863	12,772	175,839	3,215	121,347	7,820	106,874
17-Sep	8,511	420,498	8,082	201,945	11,374	187,213	3,626	124,973	8,160	115,034
18-Sep	9,271	429,769	8,499	210,444	6,934	194,147	4,107	129,080	7,028	122,062
19-Sep	9,435	439,204	6,805	217,249	5,690	199,837	4,085	133,165	6,991	129,053
20-Sep	8,485	447,689	6,362	223,611	4,644	204,481	5,082	138,247	6,538	135,591
21-Sep	6,875	454,564	4,977	228,588	3,598	208,079	4,008	142,255	6,154	141,745
22-Sep	9,396	463,960	3,931	232,519	3,364	211,443	4,108	146,363	4,459	146,204
23-Sep	8,033	471,993	3,997	236,516	4,102	215,545	3,660	150,023	3,337	149,541
24-Sep	9,513	481,506	3,315	239,831	4,099	219,644	4,145	154,168	2,804	152,345
25-Sep	7,086	488,592	2,740	242,571	4,316	223,960	3,630	157,798	2,854	155,199
26-Sep	7,892	496,484	2,519	245,090	4,095	228,055	4,226	162,024	2,545	157,744
27-Sep										
28-Sep										
29-Sep										

Appendix 3. — Continued.

	2011		2012	
Date	Daily	Cum	Daily	Cum
8-Aug			670	670
9-Aug	481	481	669	1,339
10-Aug	760	1,241	673	2,012
11-Aug	835	2,076	659	2,671
12-Aug	840	2,916	642	3,313
13-Aug	813	3,729	640	3,953
14-Aug	729	4,458	788	4,741
15-Aug	693	5,151	888	5,629
16-Aug	786	5,937	988	6,617
17-Aug	1,153	7,090	1,215	7,832
18-Aug	1,349	8,439	1,095	8,927
19-Aug	1,819	10,258	1,392	10,319
20-Aug	1,638	11,896	1,731	12,050
21-Aug	1,081	12,977	1,998	14,048
22-Aug	1,237	14,214	2,114	16,162
23-Aug	1,384	15,598	3,000	19,162
24-Aug	1,331	16,929	4,049	23,211
25-Aug	1,360	18,289	3,859	27,070
26-Aug	1,840	20,129	3,489	30,559
27-Aug	2,971	23,100	4,104	34,663
28-Aug	4,527	27,627	4,410	39,073
29-Aug	5,985	33,612	4,353	43,426
30-Aug	7,672	41,284	5,924	49,350
31-Aug	9,218	50,502	7,410	56,760
1-Sep	9,918	60,420	5,734	62,494
2-Sep	10,228	70,648	5,221	67,715
3-Sep	11,965	82,613	5,040	72,755
4-Sep	11,836	94,449	5,379	78,134
5-Sep	11,185	105,634	4,316	82,450
6-Sep	10,787	116,421	4,012	86,462
7-Sep	7,711	124,132	3,123	89,585
8-Sep	9,406	133,538	3,043	92,628
9-Sep	10,524	144,062	2,963	95,591
10-Sep	8,010	152,072	2,882	98,473
11-Sep	6,554	158,626	2,802	101,275
12-Sep	6,809	165,435	2,984	104,259
13-Sep	7,486	172,921	3,297	107,556
14-Sep	7,132	180,053	4,463	112,019
15-Sep	7,458	187,511	4,843	116,862
16-Sep	7,256	194,767	6,006	122,868
17-Sep	8,123	202,890	9,631	132,499
18-Sep	7,914	210,804	8,659	141,158
19-Sep	8,773	219,577	7,093	148,251
20-Sep	8,789	228,366	8,000	156,251
21-Sep	7,772	236,138	8,643	164,894
22-Sep	8,487	244,625	6,220	171,114
23-Sep	8,395	253,020	4,418	175,532
24-Sep	7,369	260,389	5,642	181,174
25-Sep	7,269	267,658	4,037	185,211
26-Sep	6,307	273,965	3,411	188,622
27-Sep			3,273	191,895
28-Sep			3,278	195,173
29-Sep			2,758	197,931

Appendix 4. — Historical age and sex of fall chum salmon carcasses sampled on spawning grounds in the Chandalar River, Alaska. Vertebrae were aged by Alaska Department of Fish and Game, unknown age indicates the number of samples that could not be aged and were not included in age calculations.

Year		Sample size	Unknown age	Age (brood year) n (%)				
2006				0.2 (2003)	0.3 (2002)	0.4 (2001)	0.5 (2000)	0.6 (1999)
	Female	72(41%)	0 (0%)	8 (11%)	45 (63%)	16 (22%)	3 (4%)	0 (0%)
	Male	103(59%)	0 (0%)	6 (6%)	69 (67%)	28 (27%)	0 (0%)	0 (0%)
	Total	175(100%)	0 (0%)	14 (8%)	114 (65%)	44 (25%)	3 (2%)	0 (0%)
2008				0.2 (2005)	0.3 (2004)	0.4 (2003)	0.5 (2002)	0.6 (2001)
	Female	102(56%)	2 (2%)	4 (4%)	45 (44%)	41 (40%)	7 (7%)	3 (3%)
	Male	79(44%)	1 (1%)	2 (3%)	28 (35%)	42 (53%)	6 (8%)	0 (0%)
	Total	181(100%)	3 (2%)	6 (3%)	73 (41%)	83 (47%)	13 (7%)	3 (2%)
2009				0.2 (2006)	0.3 (2005)	0.4 (2004)	0.5 (2003)	0.6 (2002)
	Female	104(58%)	0 (0%)	10 (10%)	70 (67%)	23 (22%)	1 (1%)	0 (0%)
	Male	76(42%)	0 (0%)	6 (8%)	43 (57%)	23 (30%)	3 (4%)	1 (1%)
	Total	180(100%)	0 (0%)	16 (9%)	113 (63%)	46 (26%)	4 (2%)	1 (<1%)
2010				0.2 (2007)	0.3 (2006)	0.4 (2005)	0.5 (2004)	0.6 (2003)
	Female	124(70%)	0 (0%)	30 (24%)	70 (56%)	19 (15%)	4 (3%)	1 (1%)
	Male	53(30%)	0 (0%)	7 (13%)	33 (62%)	11 (21%)	2 (4%)	0 (0%)
	Total	177(100%)	0 (0%)	37 (21%)	103 (58%)	30 (17%)	6 (3%)	1 (<1%)
2011				0.2 (2008)	0.3 (2007)	0.4 (2006)	0.5 (2005)	0.6 (2004)
	Female	277 (51%)	6 (2%)	4 (1%)	161 (59%)	92 (34%)	14 (5%)	0 (0%)
	Male	263 (49%)	3 (1%)	3 (1%)	116 (45%)	126 (48%)	15 (6%)	0 (0%)
	Total	540 (100%)	9 (2%)	7 (1%)	277 (52%)	218 (41%)	29 (5%)	0 (0%)

Appendix 5 — Historical length-at-age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska.

		Female					Male				
			Mid-eye to fork length (mm)					Mid-eye to fork length (mm)			
Year	Age	N	Mean	SE	Median	Range	N	Mean	SE	Median	Range
2006											
	0.2	8	542	13.2	540	480-590	6	573	15.6	585	510-620
	0.3	45	551	3.5	550	500-600	69	583	3.8	580	500-655
	0.4	16	564	5.6	560	530-600	28	604	6.1	600	550-660
	0.5	3	607	18.6	–	570-630	–	–	–	–	–
	0.6	0	–	–	–	–	–	–	–	–	–
	Total	72					103				
2008											
	0.2	4	543	19.3	545	500-580	2	540	10	540	530-550
	0.3	45	552	3.3	550	510-610	28	575	5.9	570	520-640
	0.4	41	578	4.0	580	530-630	42	608	4.3	605	560-700
	0.5	7	560	11.1	560	520-610	6	595	4.3	595	580-610
	0.6	3	593	8.8	590	580-610	0	–	–	–	–
	Total	100					78				
2009											
	0.2	10	553	8.8	555	505-590	6	575	14.1	585	510-610
	0.3	70	557	2.9	558	500-600	43	584	4.3	580	540-650
	0.4	23	565	6.6	570	470-620	23	615	4.8	620	560-660
	0.5	1	590	–	590	–	3	607	16.7	590	590-640
	0.6	0	–	–	–	–	1	660	–	660	–
	Total	104					76				
2010											
	0.2	30	545	4.6	543	490-610	7	599	6.6	600	575-630
	0.3	70	558	3.2	560	500-650	33	605	7.7	610	530-720
	0.4	19	568	8.2	570	500-630	11	586	12.1	580	540-670
	0.5	4	585	11.9	585	560-610	2	595	15.0	595	580-610
	0.6	1	630	–	630	–	0	–	–	–	–
	Total	124					53				
2011											
	0.2	4	531	11.4	530	505-560	3	558	25.9	535	530-610
	0.3	161	562	2.2	560	500-670	116	600	2.9	605	510-660
	0.4	92	582	2.7	580	505-645	126	614	2.3	615	555-695
	0.5	14	594	8.7	588	550-650	15	612	10.3	620	530-695
	0.6	0	–	–	–	–	0	–	–	–	–
	Total	271					260				