U.S. Fish & Wildlife Service

Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2011

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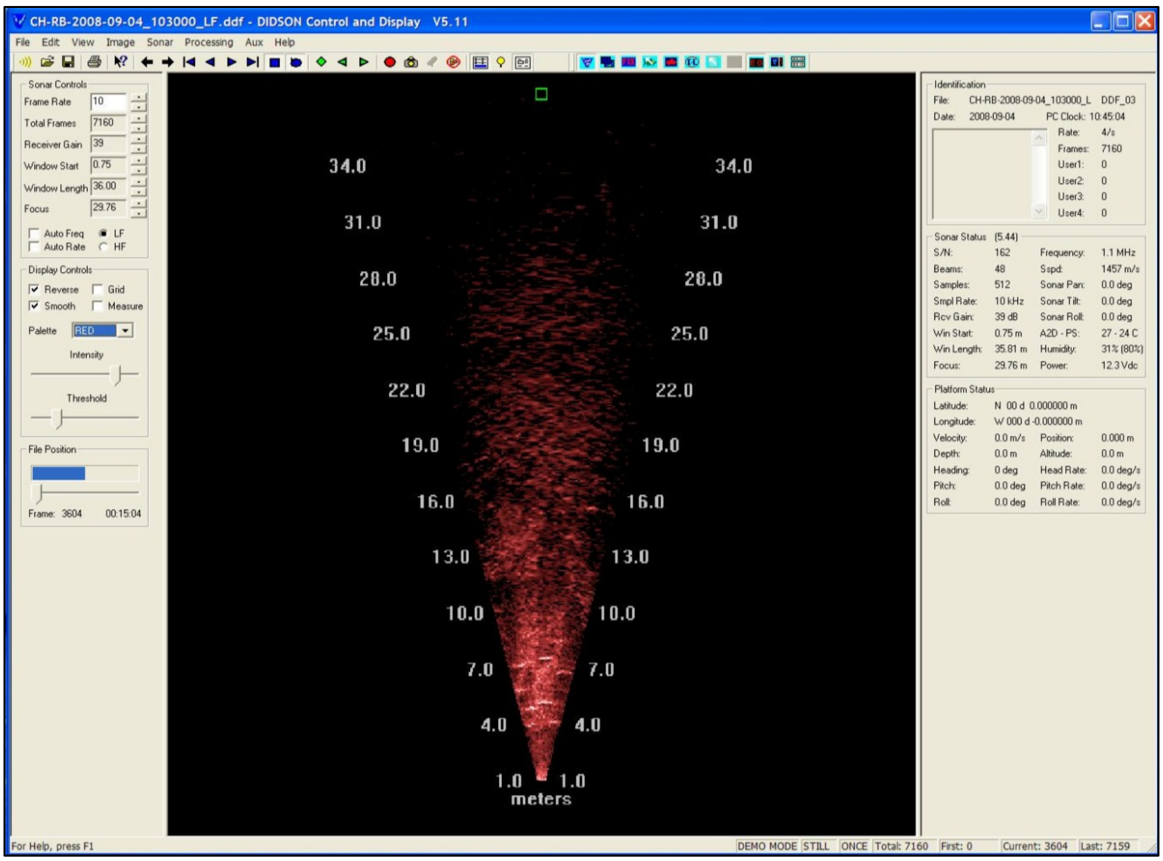

Fairbanks Fish and Wildlife Field Office
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Cover: Image of DIDSON control and display software showing fish in display between 4 and 7 m range.

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Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2011

Jeffery L. Melegari

Abstract

During the 2011season, 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 9, and continued until September 26. Of the 2,400 h (1,200 h on each bank) of time available during the targeted sample period (Aug. 8 – Sept. 26), 2,263.6 h of data were collected, with 267,546 upriver swimming fish enumerated. After adjustments were made for missed time, the fall chum salmon passage estimate for 2011 was 273,965. This passage estimate is considered conservative because it only included 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 481 upriver chum salmon. The passage on the final day of counting was 6,307 upriver chum salmon. The first quartile, median, and third quartile passage dates were September 2, 9, and 18 respectively. Fish target positional data suggested that most fish were within the detection range of the DIDSON with most fish being shore-oriented, and few fish observed near the outer range limits of the ensonified zone.

Introduction

Accurate salmon escapement counts on Yukon River tributaries are important for assessing the results of 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 methods 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 the salmon populations within federal conservation units, including National Wildlife Refuge lands, are conserved in their natural diversity, international treaty obligations are met, and subsistence opportunities are maintained. Accurate spawning escapement estimates for the major salmon stocks in the drainage is one 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. Their use 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-location Bendix salmon counters to enumerate adult fall chum salmon in the

Author: Jeffery L. Melegari is a fish biologist with the U.S. Fish and Wildlife Service. The author can be contacted at Fairbanks Fish and Wildlife Field Office, 101 12th Ave. Room 110, Fairbanks, Alaska 99701; or Jeff_Melegari@fws.gov.

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, they used factory-set echo-counting criteria to determine fish counts, they 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 system yielded very conservative estimates of actual 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 operational 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). Beginning in 1996 the project has provided daily in-season counts to managers.

Experimentation to evaluate the more recently developed DIDSON technology (Dual Frequency Identification Sonar), for enumeration of fall chum salmon in the Chandalar River was initiated in 2004 and continued through 2006. The DIDSON was found to offer 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 the more intuitive operation and image interpretation, easier setup and deployment, and the potential to have increased capacity for species determination under some conditions. The major limitations of DIDSON, relative to split-beam sonar, include a more limited range capability, 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 indicated that the DIDSON was 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 remained consistent and have 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 – 2010 averaged 184,032, ranging from 65,894 to 496,484 fish (Appendix 1).

Additionally, carcass sampling has been conducted at the fall chum salmon spawning grounds upstream of the community of Venetie on the Chandalar River since 2006 (excluding 2007). This sampling effort has been conducted to collect biological information (Age, Sex, and Length) on the fall chum salmon, which are not sampled at the sonar site. Funding support for this effort has been provided by the Yukon River Salmon Research and Management Fund (R&M).

Study Area

The Chandalar River is a fifth-order tributary of the Yukon River draining 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 km 21.5 was previously described by Daum et al. (1992; Figure 2).

The DIDSON deployment locations were 150 - 200 m downriver from the sites where the split-beam was deployed in previous years. The left bank site (left determined while 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. A YSI Professional Plus Multiprobe (Yellow Springs, Ohio) was used to collect water temperature, conductivity, dissolved oxygen, and pH, twice daily at approximately 08:00 and 21:00 near the right bank sonar deployment location.

Site Selection and Sonar Deployment

A deployment site for each bank was selected from cross-sectional river profiles of the area (Figure 3), which were 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 the detection of known targets drifted through the sonar, 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 V5.11 (Sound Metrics Corp. 2007). The DIDSON units were deployed in 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 and 700 KHz for the long range). Partial weirs were installed approximately 1 m downriver of each DIDSON to direct fish through the beams. Both DIDSONs had a window start setting of 0.75 m, and window length settings were 20 m and 70 m on right and left banks respectively. Both DIDSONs began operation on August 9 during 2011.

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 placing targets (liter plastic bottles half filled with lead shot) on the river bottom at varying ranges within the ensonified area, and drifting targets through the ensonified area from a boat and verifying that the targets were detected by the sonar.

A wireless network was installed for the left bank so all DIDSON communications, data acquisition, and analysis could occur at a single data tent location 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 in 30 minute intervals. Data were analyzed using the DIDSON control and display software (version 5.11; Sound Metrics Corp. 2007). Data files were examined in echogram view and when a potential target was encountered it was further evaluated by reviewing that section of data in normal view to verify that the target was a fish and 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 mean hourly passage rates from all previous years during the season. During post season analysis counts from missing hours were recalculated from mean hourly passage rates from the 2011 season. Mean hourly passage rates were calculated from days with 24 h of continuous data. Hourly passage rates (fish/h) were calculated 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. 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 2011 an underwater video monitoring system, similar to that used in previous years (Osborne and Melegari 2006; Melegari and Osborne 2007), 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 0.75m 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. For the first week of video monitoring (August 21-28) the entire daylight period was reviewed, however due to available resources and logistics 6-8 h were reviewed per day throughout the rest of the season. This time was evenly split between the first 3-4 h with adequate light in the morning, and the last 3-4 h with adequate light in the evening. These time periods were chosen to coincide with the times that normally experience the highest sonar counts.

ASL Data Collection

Sex, length, and vertebrae for aging were collected from fall chum salmon carcasses on the spawning grounds over three trips. Sampling dates were: collection 1= September 28, collection 2= October 11-12, and collection 3= October 22. Samples were collected from the same site during collections 1 and 3 (site 1=N 67° 03.937′ W 146° 56.974′); while samples were collected from two sites during collection 2 (site 1 and site 2=N 67° 06.144′ W 147° 07.019′). In past years, a single trip was used to collect samples; however, three trips were scheduled during 2011 to investigate possible sampling biases. Due to reporting deadlines, and time needed to age the vertebrae, results from the analysis of these data for possible bias will be included in a future R&M report (project #RM-03-11).

A helicopter was used to survey the spawning area for concentrations of spawned out fish. Upon location of concentrations of spawned out fish, all dead or dying fish near the shoreline at that site were sampled to reduce possible sampling bias. The exception was during trip 2 when some live fish were snagged to accommodate collecting genetic samples. Fish were measured to the nearest 5 millimeters, mid-eye to the fork of the tail (METF). The sex of specimens was determined by external morphology, or by dissection of the carcass and visual identification of reproductive organs if sex was not obvious from external morphology. Vertebrae were collected, cleaned, and provided to the Alaska Department of Fish and Game for aging.

Results

Water Quality Monitoring

Calibrated water levels ranged from approximately 1.98 to 3.16 m, and averaged 2.43 m throughout the season. Water temperatures ranged from 3.8 to 13.1 °C and averaged 9.7 °C (Figure 4; Appendix 2). The other water chemistry data collected with the YSI Professional Plus Multiprobe 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

During 2011, sonar operations began on August 9, a day later than planned, and continued through September 26. Acoustic data were collected for 2,263.6 hours, and 271,163 fish were counted (Table 1). Of these, 267,546 (99% of the total fish counted) were upriver swimming fish. On the left bank, 1,138.8 h (95% of the planned 1,200 h) were monitored, with 61.2 hours missed due to intermittent disruptions to the remote communications network, generator refueling, relocating the DIDSON, and maintenance/repairs. On the right bank, 1,124.8 h (94% of the planned 1,200 h) were monitored, with 75.2 hours missed due to maintenance/repairs. Upriver fish counts were 74,835 and 192,711 for the left and right banks, respectively.

After adjusting for the missed time, the estimated fall chum salmon passage for 2011 was 273,965 (Table 2). The left bank estimate was 76,638 accounting for 28% of the total. The right bank estimate was 197,327, accounting for 72% of the total. The adjusted count was 481 upriver fish on the first day of sonar operation (0.2% of the total), and 6,307 fish on the final day of counting (2.3% of the total). Peak daily passage occurred on September 3 (Figure 5). The first quartile of the run occurred on September 2, the mid-point on September 9 and the third quartile on September 18.

During 2011, hourly passage rates (number of fish passing during each hour expressed as a proportion of the daily count) of upriver fish showed a strong diel pattern on the left bank, and a slight 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 fish were within 14 m on the left bank, and 11 m on the right bank. Downriver fish, while still shore oriented, were slightly more dispersed across the full detection range of the DIDSONs.

Video monitoring

Video monitoring began on August 21 and continued through September 22. Image quality and visibility (maximum range) of the cameras was poorer than expected from previous years' experience. Visibility varied with changes in water clarity and light levels, ranging from approximately 0.5-1.5 m, but usually in the lower half of this range. This resulted in a larger number of fish, relative to previous years, that were seen only as silhouettes or "shadows", and thus were unable to be positively identified to species. Approximately 257 hours of video were reviewed, during which 13,343 fish were observed. Of these 13,343 fish 1,873 (14%) were unable to be identified. Of the 11,470 fish that were identified, 11,448 (99.8%) were identified as chum salmon, 13 (0.1%) were identified as northern pike, and 9 (0.1%) were identified as whitefish spp.

ASL Data Collection

During 2011, samples were collected from 180 carcasses during each of the three collections, for a total of 540 samples. Overall, samples were collected from 277 females and 263 males, resulting in an overall sample sex ratio of 51% female, which was similar to previous years (Table 3; Appendix 4). Sex ratios (percent female) of samples for each individual trip were 53%, 43%, and 58% for collections 1, 2, and 3 respectively. Vertebrae were cleaned and sent to the Alaska Department of Fish and Game to be aged. Ages were determined for 531 (98%) of the samples (Table 3). There were two primary age classes in the samples, 0.3, and 0.4, from brood years 2007 and 2006 respectively. Age class 0.3 was predominant overall, accounting for 52% of the combined samples, with values of 57%, 41%, and 59% for collections 1, 2, and 3 respectively. Age class 0.4 accounted for 41% of the combined samples, and accounted for 38%, 49%, and 37% of the samples for collections 1, 2, and 3 respectively. Other age classes present were 0.5 from brood year 2005, accounting for 5% of the combined samples, and 0.2 from brood year 2008, which accounted for 2% of the combined samples. The female samples were predominantly age class 0.3 (59%; ranging from 48% to 64% for the individual collections) followed by age class 0.4 (34%; ranging from 30% to 43% for the individual collections). Male samples were more evenly distributed between age classes 0.3 and 0.4, with 0.4 being slightly predominant (48%; ranging from 45% to 53% for the individual collections) followed by age class 0.3 (45%; ranging from 35% to 51% for the individual collections). Female samples ranged from 500 to 670 mm METF and males ranged from 510 to 695 mm METF (Table 4). For length-at-age measurements, mean lengths of male fish were generally larger than females. Additional analysis of the age, sex, and length data will be conducted and will be presented in the R&M report.

Discussion

Site Selection and Sonar Deployment

The greater tolerance for site conditions of the DIDSON relative to the split-beam sonar previously used on this project has allowed operations to continue over a wider range of water levels than possible with the split-beam. This tolerance has also allowed selection of locations that are more stable, but which may not meet some of the other requirements for a good split-beam site, resulting in less variation in conditions at the site from year to year.

Proper aim of the sonar remains a primary concern; however, the wider beam angles of the DIDSON and the ability to continue enumeration of fish while the beams are hitting the substrate, make small precise adjustments to aim less critical than with the split-beam system. Additionally, the images provided by the DIDSON allow for a quicker, more confident evaluation of the aim and aiming adjustments than with the split-beam sonar. This has allowed us to forego the use of the remote controlled underwater rotators that were used with the split-beam sonar and aim the DIDSONs manually. Manual adjustment of the aim has worked well, with two way radios used to facilitate communication between the DIDSON operator and the person adjusting the aim. Furthermore, not using the rotators has reduced the power requirements of the system.

Few problems with the remote communications network were encountered and were primarily limited to brief interruptions to the connection. Maximum achievable frame rates, however, were slightly more limited with the remote communications network than with hard wiring. Data were collected at one frame per second on the left bank with the long range DIDSON and the remote communications network. During previous years and under similar conditions, we were able to operate the long range DIDSON at three to four frames per second when hard wired. However, 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 not being detected because the frame rate was too low, then more fish would be expected to be almost missed, or captured in only one or two frames. During 2011 some problems were encountered with limited frame rates on the right bank DIDSON for much of the season. Maximum achievable frame rates were limited to one to two frames per second, when in previous years with the same setup and components we consistently obtained four to five frames per second. Post season maintenance/troubleshooting by Sound Metrics Corporation indicated that an impedance issue with the connector on the DIDSON was most likely responsible. However, as with the left bank, nearly all fish were captured in several frames, indicating that this frame rate was sufficient to capture fall chum salmon migrating upriver past the site.

Sonar Data Collection and Analysis

Run timing during 2011 in the Chandalar River was slightly later than average. The first quarter passage date, September 2 was two days later than the historical average (1995 – 2010, excluding 2009 when project terminated early). Also, both the mid-point, September 10, and the third quarter passage date, September 18, were three days later than the historical average. Considering that the estimated passage on the last day was 2.3% of the cumulative, it is probable that the actual quarter point dates for the run are slightly later than the dates indicated. Preliminary data from other fall chum salmon projects in the upper Yukon River drainage also indicate that run timing was 2-5 days later than normal (JTC 2012). Attempting to extend the project beyond the normal shut down day of September 26 this season was unfeasible due to logistic constraints and weather conditions.

The 2011 passage estimate of 273,965 fish is 149% of the historical average (Figure 9), and is the third largest passage estimate to date. Preliminary data from other Yukon River drainage fall chum salmon enumeration projects during 2011 indicate above average escapements at nearly all projects (JTC 2012).

Generally, the Chandalar River sonar passage estimate is a conservative estimate. This is because counts did not include fish that passed before or after the sonar was in operation, e.g.

passage on the final day of operations was still 2.3% of the total. Additionally, while chum salmon are generally considered shore and bottom oriented during migration, which is supported by our data that suggest most fish passed well within the ensonified zone, it is likely that a small number of 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 sometimes an undistinguishable 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. The fact that these similar patterns were observed at the new DIDSON locations, where the physical conditions of the river on the right bank closely resemble those of the old split-beam left bank location, highlights the complexity of behaviors in migrating fish, and indicates that factors other than in-river physical conditions at the sonar site may be influencing the diel patterns.

During 2011, the right bank accounted for 72% of the total passage. This is similar to that observed in previous years. The pattern of right bank counts being higher has been observed during all years of operation with split-beam or DIDSON (Appendix 1), however, the differences have tended to be greater in more recent years This could be due to natural variation, or changing river conditions. Also, there appeared to be a larger jump when the project first switched to DIDSON leading to the hypothesis that this larger change could be due to the relocation of the site 150 - 200 m down river. A sand/gravel bar extends into the river from the right bank between the new downriver site and the previous site. This bar could be affecting migration patterns, causing fish to crossover between the new and old sites, and thus a larger proportion of the fish may be migrating on the right bank at this location. However, during the last two – three years the differences between bank passages have been closer to what was seen the last few years of split-beam operation.

Fish range data collected with the DIDSONs were similar to data collected during previous years and suggested that most upriver swimming fish passing the sonar site were well within the ensonified zone. Upriver 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). Unlike the split-beam sonar, the DIDSON does not obtain vertical position data. However, the much 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, where surface waves were usually detected on windy days, and the river bottom was normally visible throughout most or all of the range.

Video monitoring

Performance of the video monitoring system was lower than what was expected based on experience from previous years, despite having newer, and what is believed to be better quality equipment. While actual measurements of water turbidity were not taken, general observations throughout the season suggested that turbidity during 2011 was higher than during other years when video was used. This would account for the reduced performance. Even with the higher proportion of unidentifiable fish in 2011, the video data does support previous data indicating that the vast majority of fish passing the sight during sonar operations are chum salmon. One item of note is that in some previous years both video monitoring and seining yielded higher proportions of least cisco in the samples (Osborne and Melegari 2006; Melegari and Osborne 2007). While not conclusive, this could be an indication that least cisco abundance and/or run timing is highly variable.

Conclusions

The DIDSON performed well overall, and no major blocks of time were missed 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 very little additional cost. Video monitoring should be implemented during future years as conditions allow, and should be focused to coincide with times of higher passage, during morning and evening hours with sufficient lighting levels. The beach seining is labor intensive and often produces minimal catches, but could still 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 a crucial stock component of 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 a 17 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 2011.

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
9-Aug	5.29	82	0	3.87	30	0	9.16	112	0
10-Aug	23.98	466	3	16.44	198	2	40.42	664	5
11-Aug	23.98	486	10	23.49	346	1	47.47	832	11
12-Aug	23.62	368	20	23.53	459	8	47.15	827	28
13-Aug	23.98	340	47	23.96	472	4	47.94	812	51
14-Aug	23.98	286	15	23.95	442	1	47.93	728	16
15-Aug	23.96	179	14	23.96	513	2	47.92	692	16
16-Aug	23.98	206	10	23.95	579	3	47.93	785	13
17-Aug	23.36	282	3	22.79	836	9	46.15	1,118	12
18-Aug	23.98	333	4	23.97	1,015	1	47.95	1,348	5
19-Aug	23.98	380	11	23.97	1,437	5	47.95	1,817	16
20-Aug	23.98	440	3	23.96	1,196	15	47.94	1,636	18
21-Aug	23.98	346	6	23.95	733	12	47.93	1,079	18
22-Aug	23.98	292	6	23.95	943	10	47.93	1,235	16
23-Aug	23.98	326	4	23.95	1,056	10	47.93	1,382	14
24-Aug	23.98	272	5	23.95	1,057	7	47.93	1,329	12
25-Aug	22.48	293	1	22.76	1,010	7	45.24	1,303	8
26-Aug	23.98	428	3	23.97	1,410	12	47.95	1,838	15
27-Aug	23.98	614	7	23.97	2,353	14	47.95	2,967	21
28-Aug	23.98	822	12	23.97	3,699	8	47.95	4,521	20
29-Aug	23.97	1,129	12	23.96	4,846	25	47.93	5,975	37
30-Aug	22.98	1,194	15	23.97	6,437	13	46.95	7,631	28
31-Aug	23.98	1,345	10	23.97	7,863	20	47.95	9,208	30
1-Sep	23.98	1,452	12	23.97	8,454	25	47.95	9,906	37
2-Sep	23.98	1,342	12	23.97	8,874	19	47.95	10,216	31
3-Sep	23.98	1,919	15	23.96	10,027	12	47.94	11,946	27
4-Sep	23.98	1,730	22	22.63	9,383	20	46.61	11,113	42
5-Sep	23.98	1,805	27	21.83	8,598	33	45.81	10,403	60
6-Sep	23.98	1,529	34	23.97	9,245	35	47.95	10,774	69
7-Sep	23.98	1,319	24	23.97	6,381	53	47.95	7,700	77
8-Sep	23.98	2,557	41	23.96	6,836	66	47.94	9,393	107
9-Sep	23.98	3,832	8	23.96	6,679	67	47.94	10,511	75
10-Sep	23.96	3,735	9	23.95	4,259	51	47.91	7,994	60
11-Sep	23.98	2,692	18	23.97	3,855	66	47.95	6,547	84
12-Sep	23.98	2,240	23	23.97	4,561	59	47.95	6,801	82
13-Sep	23.98	2,063	24	23.97	5,413	53	47.95	7,476	77
14-Sep	23.98	1,767	6	20.73	4,693	106	44.71	6,460	112
15-Sep	23.98	1,951	11	23.98	5,500	199	47.96	7,451	210
16-Sep	23.98	1,936	12	23.98	5,314	162	47.96	7,250	174
17-Sep	23.98	2,627	17	23.98	5,489	277	47.96	8,116	294
18-Sep	23.98	2,488	13	23.98	5,419	205	47.96	7,907	218
19-Sep	23.98	3,174	10	23.98	5,591	201	47.96	8,765	211
20-Sep	23.98	3,705	2	23.98	5,077	72	47.96	8,782	74
21-Sep	23.98	4,219	9	23.98	3,546	193	47.96	7,765	202
22-Sep	23.98	3,799	0	23.98	4,681	193	47.96	8,480	193
23-Sep	23.98	3,415	1	23.98	4,973	235	47.96	8,388	236
24-Sep	21.98	2,613	1	23.98	4,363	162	45.96	6,976	163
25-Sep	23.98	2,824	1	23.98	4,439	176	47.96	7,263	177
26-Sep	11.98	1,193	0	11.99	2,131	115	23.97	3,324	115
Totals	1,138.80	74,835	573	1,124.79	192,711	3,044	2,263.59	267,546	3,617

Table 2. — Daily fall chum salmon upriver passage estimates at the Chandalar River, Alaska 2011.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative %
9-Aug	303[a]	178[a]	481	481	0.2
10-Aug	466	294[a]	760	1,241	0.5
11-Aug	486	349	835	2,076	0.8
12-Aug	372	468	840	2,916	1.1
13-Aug	340	473	813	3,729	1.4
14-Aug	286	443	729	4,458	1.6
15-Aug	179	514	693	5,151	1.9
16-Aug	206	580	786	5,937	2.2
17-Aug	285	868	1,153	7,090	2.6
18-Aug	333	1,016	1,349	8,439	3.1
19-Aug	380	1,439	1,819	10,258	3.7
20-Aug	440	1,198	1,638	11,896	4.3
21-Aug	346	735	1,081	12,977	4.7
22-Aug	292	945	1,237	14,214	5.2
23-Aug	326	1,058	1,384	15,598	5.7
24-Aug	272	1,059	1,331	16,929	6.2
25-Aug	300[a]	1,060[a]	1,360	18,289	6.7
26-Aug	428	1,412	1,840	20,129	7.3
27-Aug	615	2,356	2,971	23,100	8.4
28-Aug	823	3,704	4,527	27,627	10.1
29-Aug	1,131	4,854	5,985	33,612	12.3
30-Aug	1,226[a]	6,446	7,672	41,284	15.1
31-Aug	1,346	7,872	9,218	50,502	18.4
1-Sep	1,453	8,465	9,918	60,420	22.1
2-Sep	1,343	8,885	10,228	70,648	25.8
3-Sep	1,921	10,044	11,965	82,613	30.2
4-Sep	1,731	10,105	11,836	94,449	34.5
5-Sep	1,807	9,378[a]	11,185	105,634	38.6
6-Sep	1,530	9,257	10,787	116,421	42.5
7-Sep	1,320	6,391	7,711	124,132	45.3
8-Sep	2,559	6,847	9,406	133,538	48.7
9-Sep	3,835	6,689	10,524	144,062	52.6
10-Sep	3,743	4,267	8,010	152,072	55.5
11-Sep	2,694	3,860	6,554	158,626	57.9
12-Sep	2,242	4,567	6,809	165,435	60.4
13-Sep	2,065	5,421	7,486	172,921	63.1
14-Sep	1,768	5,364[a]	7,132	180,053	65.7
15-Sep	1,953	5,505	7,458	187,511	68.4
16-Sep	1,938	5,318	7,256	194,767	71.1
17-Sep	2,629	5,494	8,123	202,890	74.1
18-Sep	2,490	5,424	7,914	210,804	76.9
19-Sep	3,177	5,596	8,773	219,577	80.1
20-Sep	3,708	5,081	8,789	228,366	83.4
21-Sep	4,223	3,549	7,772	236,138	86.2
22-Sep	3,802	4,685	8,487	244,625	89.3
23-Sep	3,418	4,977	8,395	253,020	92.4
24-Sep	3,002[a]	4,367	7,369	260,389	95.0
25-Sep	2,826	4,443	7,269	267,658	97.7
26-Sep	2,280[a]	4,027[a]	6,307	273,965	100.0
Totals	76,638	197,327	273,965		

[a] Partial daily count, missing hours estimated using mean hourly frequencies.

Table 3. — Age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska, 2011. Vertebrae were aged by Alaska Department of Fish and Game, unknown age indicates numbers of samples that could not be aged and were not included in age calculations.

				Brood year and age			
				2008	2007	2006	2005
Sample dates		Sample size	Unknown age	0.2	0.3	0.4	0.5
Sept. 28	Female	95 (53%)	4 (5%)	1 (1%)	58 (64%)	27 (30%)	5 (5%)
	Male	85 (47%)	1 (1%)	2 (2%)	42 (50%)	39 (46%)	1 (1%)
	Total	180 (100%)	5 (3%)	3 (2%)	100 (57%)	66 (38%)	6 (3%)
Oct. 11-12	Female	77 (43%)	0 (0%)	1 (1%)	37 (48%)	33 (43%)	6 (8%)
	Male	103 (57%)	1 (1%)	0 (0%)	36 (35%)	54 (53%)	12 (12%)
	Total	180 (100%)	1(<1%)	1 (<1%)	73 (41%)	87 (49%)	18 (10%)
Oct. 22	Female	105 (58%)	2 (2%)	2 (2%)	66 (64%)	32 (31%)	3 (3%)
	Male	75 (42%)	1 (1%)	1 (1%)	38 (51%)	33 (45%)	2 (3%)
	Total	180 (100%)	3 (2%)	3 (2%)	104 (59%)	65 (37%)	5 (3%)
Combined	Female	277 (51%)	6 (2%)	4 (1%)	161 (59%)	92 (34%)	14 (5%)
	Male	263 (49%)	3 (1%)	3 (1%)	116 (45%)	126 (48%)	15 (6%)
	Total	540 (100%)	9 (2%)	7 (1%)	277 (52%)	218 (41%)	29 (5%)

Table 4. — Length at age of female and male fall chum salmon carcasses sampled on Chandalar River spawning grounds, Alaska, 2011.

		Female					Male				
			Mid-eye to fork length (mm)					Mid-eye to fork length (mm)			
Sample dates	Age	N	Mean	SE	Median	Range	N	Mean	SE	Median	Range
Sept 28	0.2	1	525	—	—	—	2	573	37.5	573	535-610
	0.3	58	570	4.2	568	515-670	42	601	4.5	605	510-660
	0.4	27	587	4.6	585	545-640	39	606	3.7	610	560-650
	0.5	5	587	13.8	585	550-635	1	600	—	—	—
	Total	91					84				
Oct 11-12	0.2	1	535	—	—	—	0	—	—	—	—
	0.3	37	561	4.1	560	505-615	36	604	5.1	608	530-660
	0.4	33	587	5.2	595	505-645	54	623	3.2	625	575-685
	0.5	6	606	15.6	615	555-650	12	622	10.1	625	565-695
	Total	77					102				
Oct 22	0.2	2	533	27.5	533	505-560	1	530	—	—	—
	0.3	66	556	3.1	558	500-610	38	595	5.2	600	510-650
	0.4	32	573	4.0	573	525-615	33	608	4.9	605	555-695
	0.5	3	582	13.0	580	560-605	2	558	27.5	558	530-585
	Total	103					74				
Combined	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
	Total	271					260				

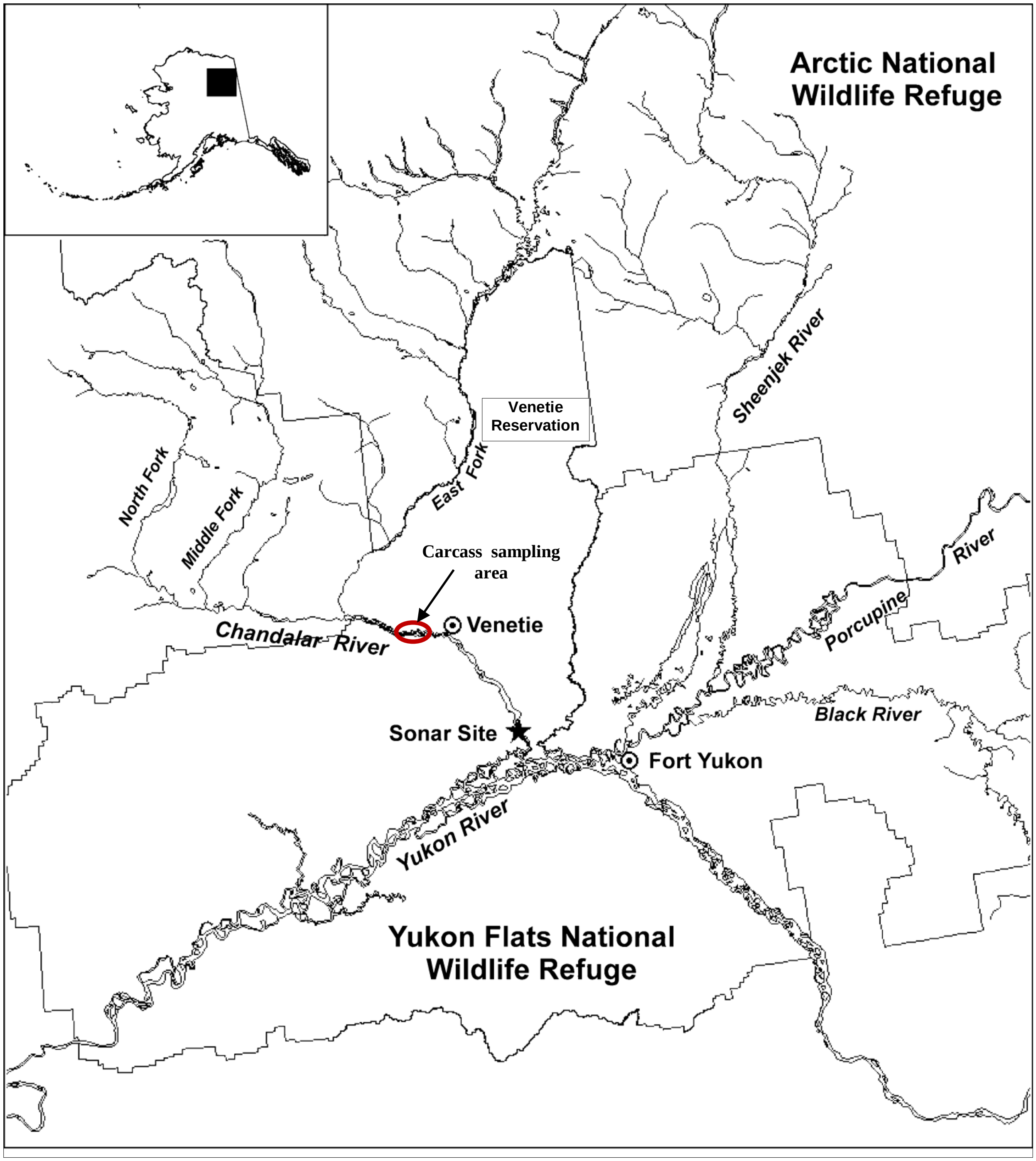

Figure 1. — Chandalar River sonar site, carcass sampling area, and major tributaries of the Yukon River near U.S.-Canada border.

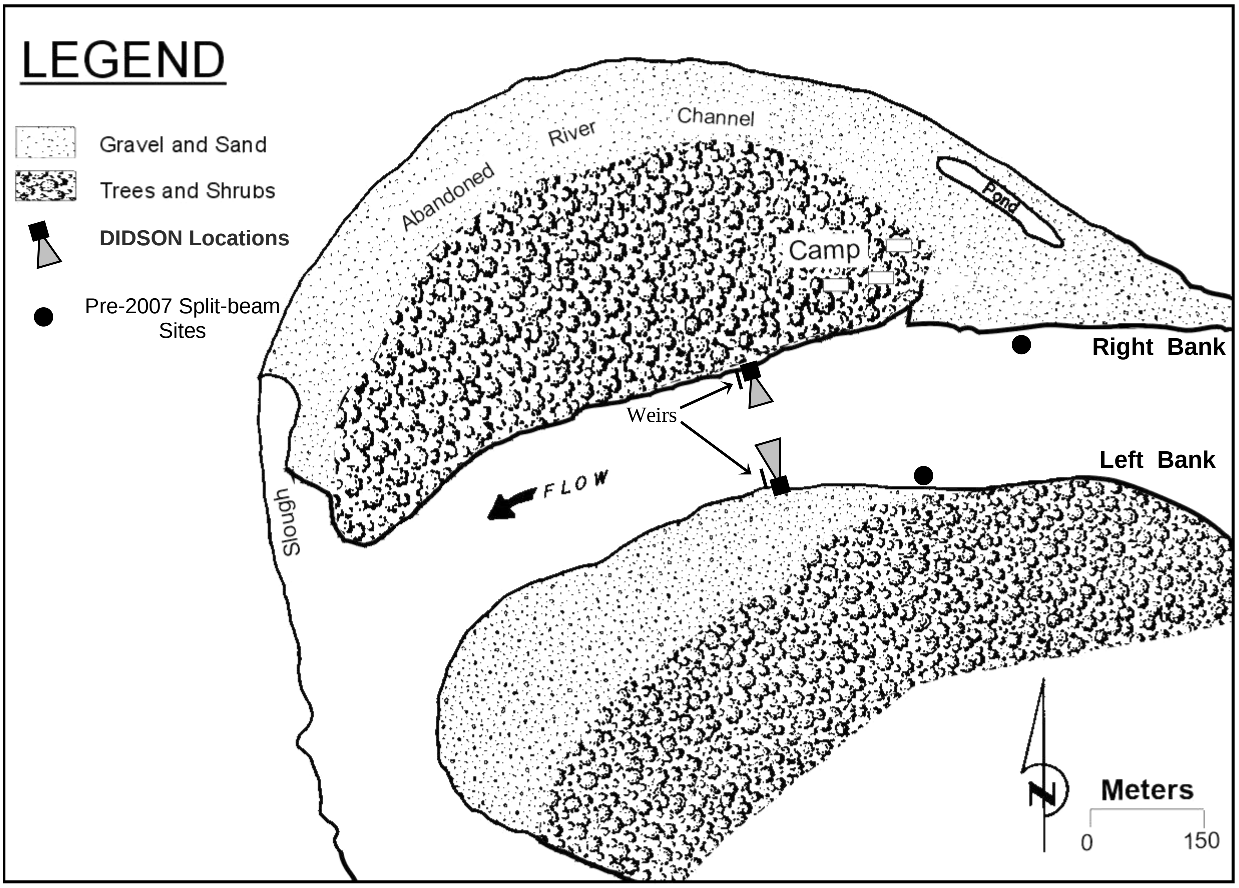

Figure 2. — Site map of Chandalar River sonar facilities.

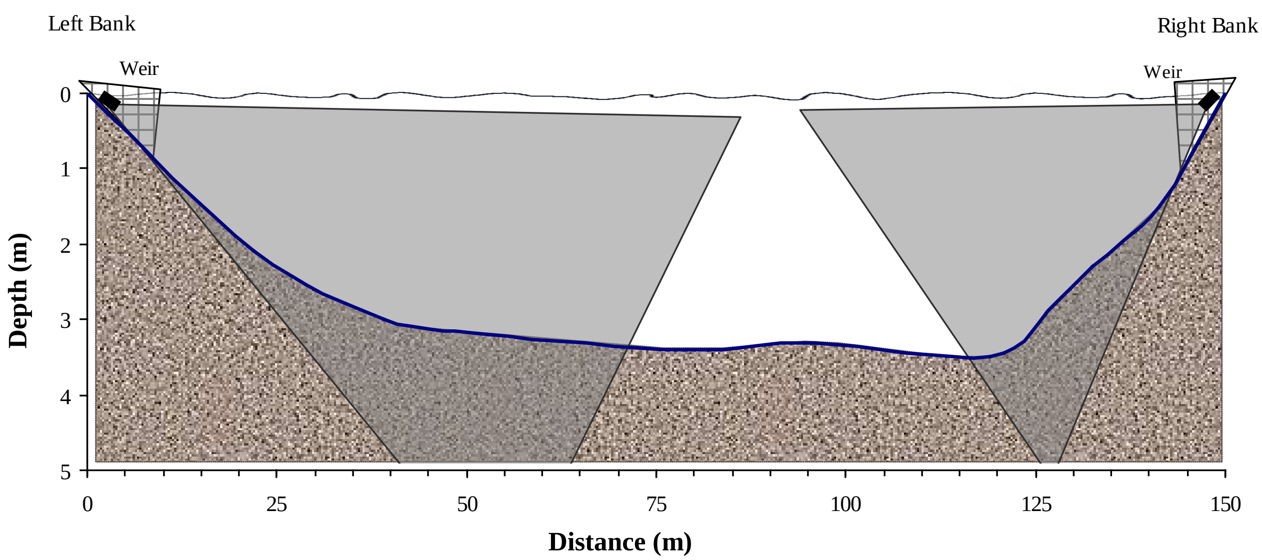

Figure 3. — River channel profile and approximated ensonified zones for the left and right bank sonar sites, Chandalar River, 2009. Very little change has been detected in channel profile from 2008 - 2011. Note: different axis scales are used to enhance readability.

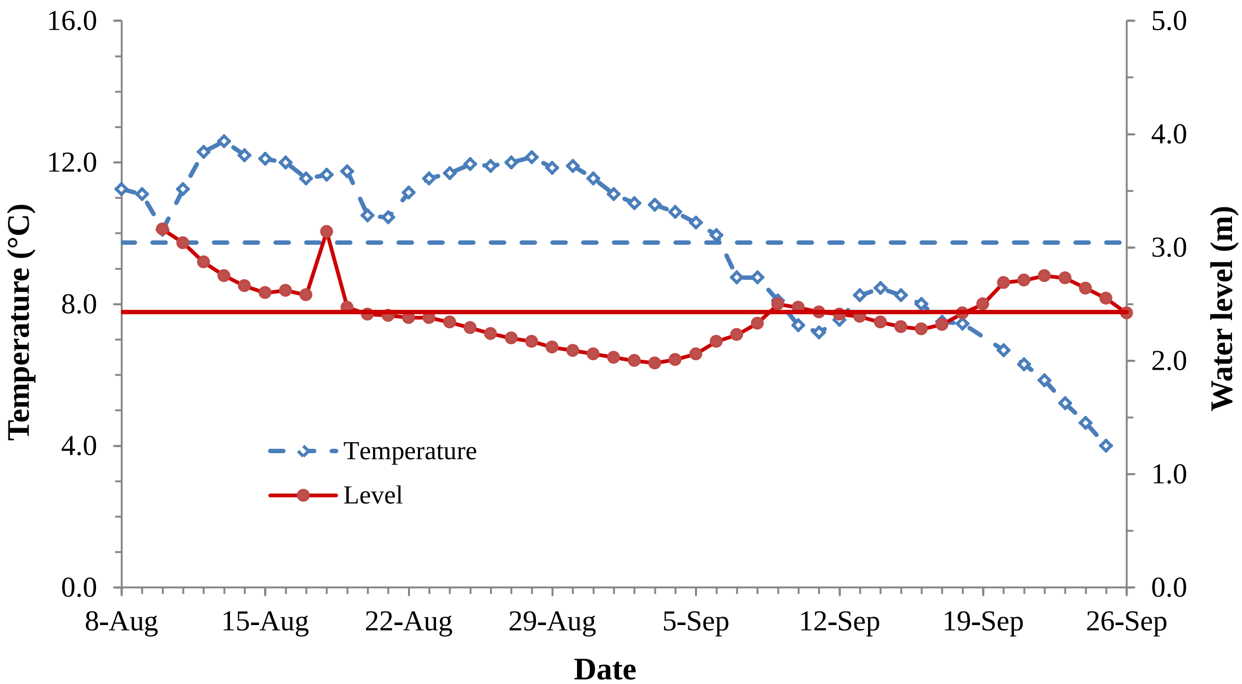

Figure 4. — Average daily water temperature and calibrated water level data from Chandalar River sonar site, 2011. Temperature is the average of two daily measurements (morning and evening measurements). Straight horizontal lines indicate seasonal averages.

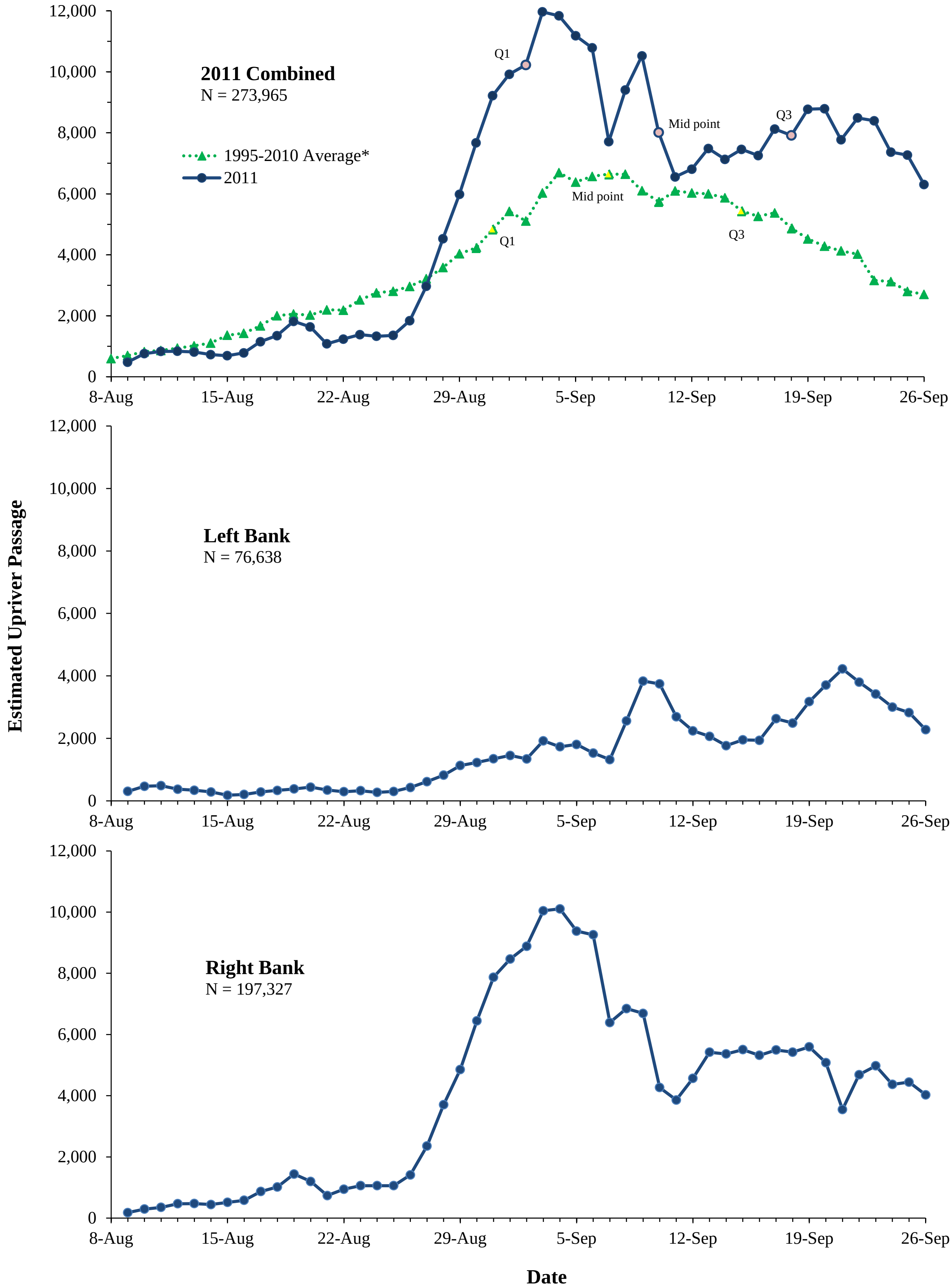

Figure 5 — Estimated passage of upriver swimming fall chum salmon by bank and combined, Chandalar River, 2011. Highlighted data points in the top graph indicate the 1st quarter, mid, and 3rd quarter points of passage.
* Average does not include data from 2009, since the project was ended early before the majority of the run normally passes.

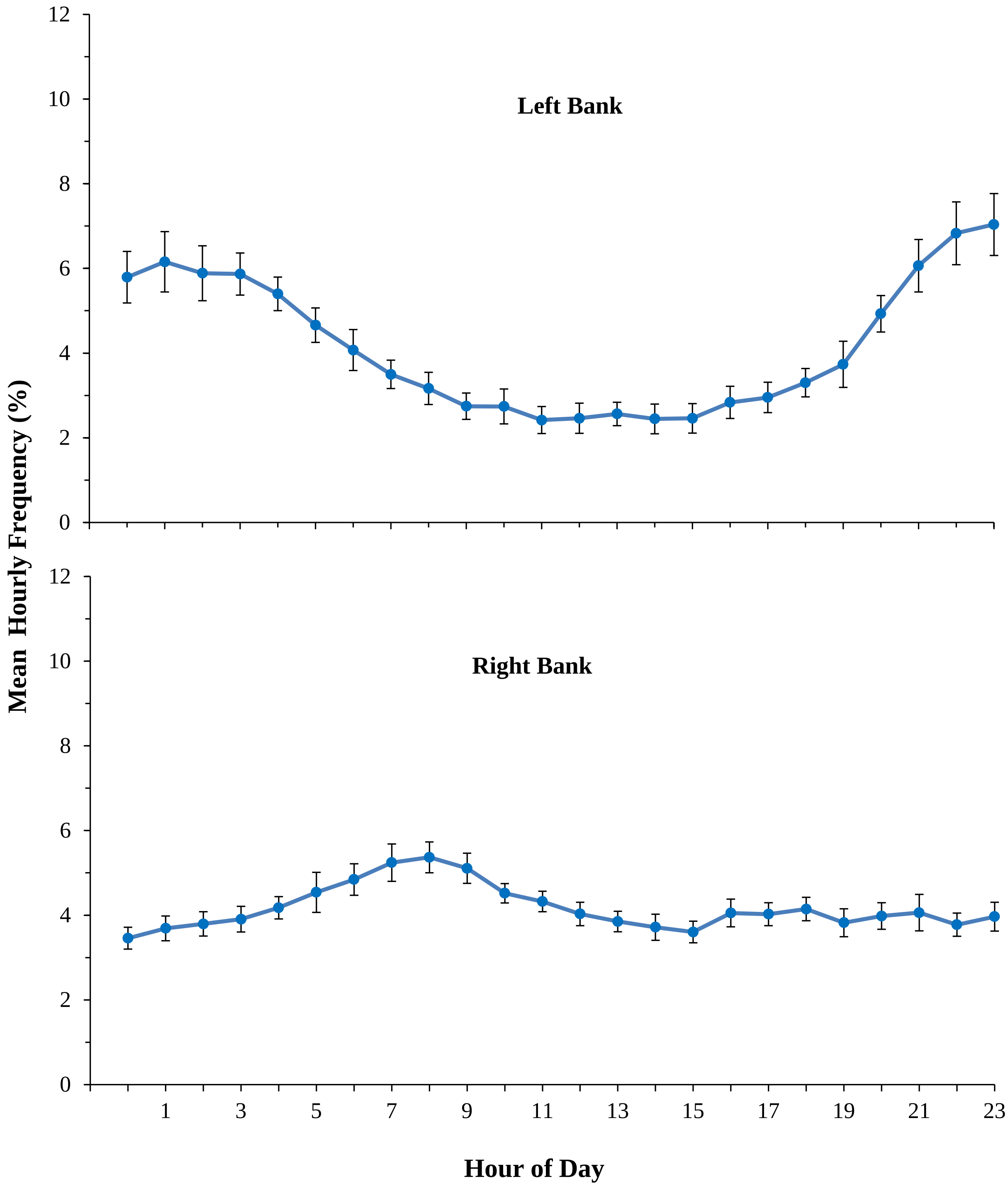

Figure 6. — Mean (±2 SE) hourly frequency of upriver swimming fall chum salmon, Chandalar River, 2011. Hourly frequency is the hourly passage expressed as a percent of the total daily count. Data from 44 complete days of 24 hour data on the left bank and 43 days on the right bank.

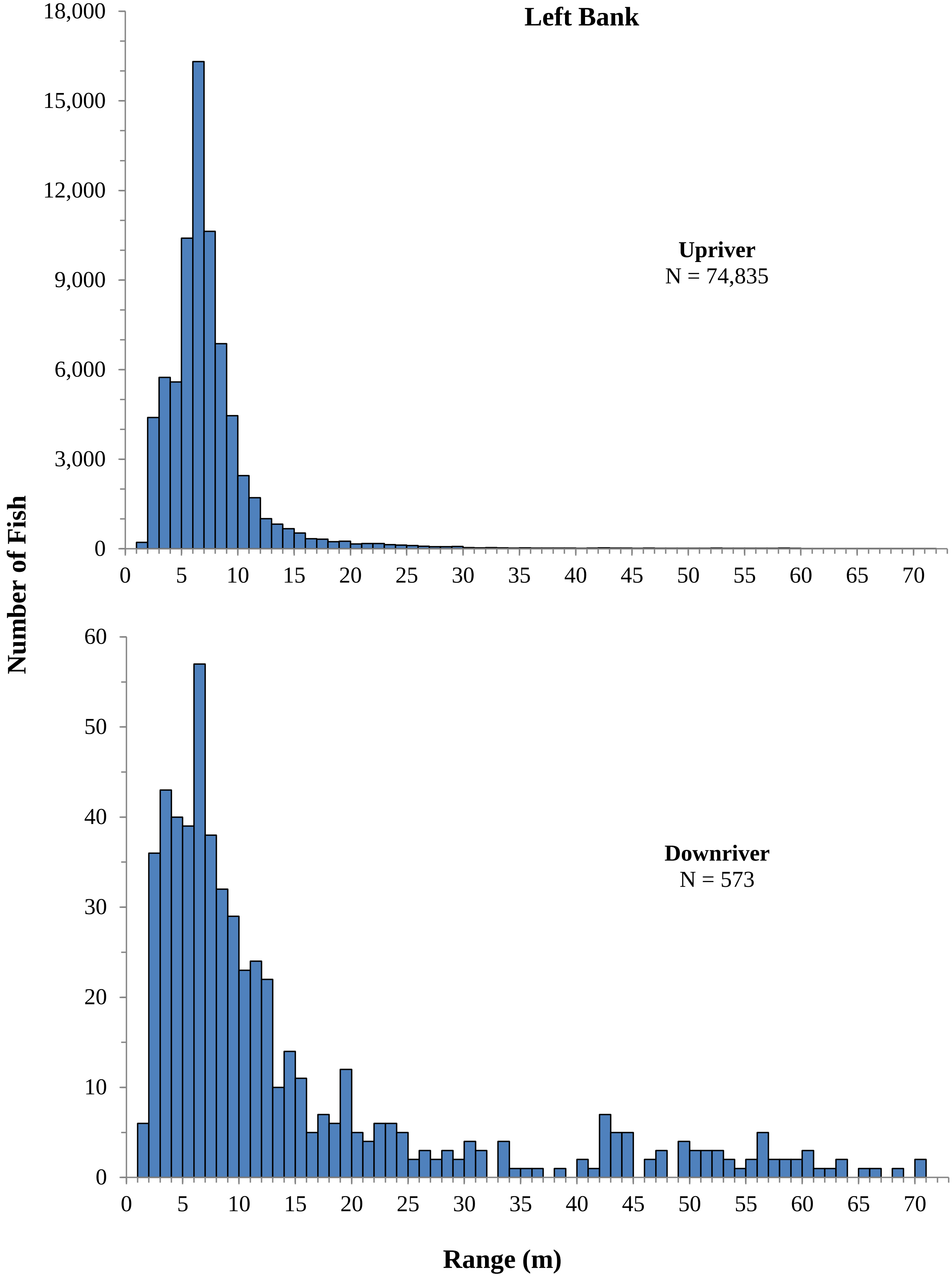

Figure 7. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the left bank Chandalar River, August 9 to September 26, 2011. Note different Y-axis scales.

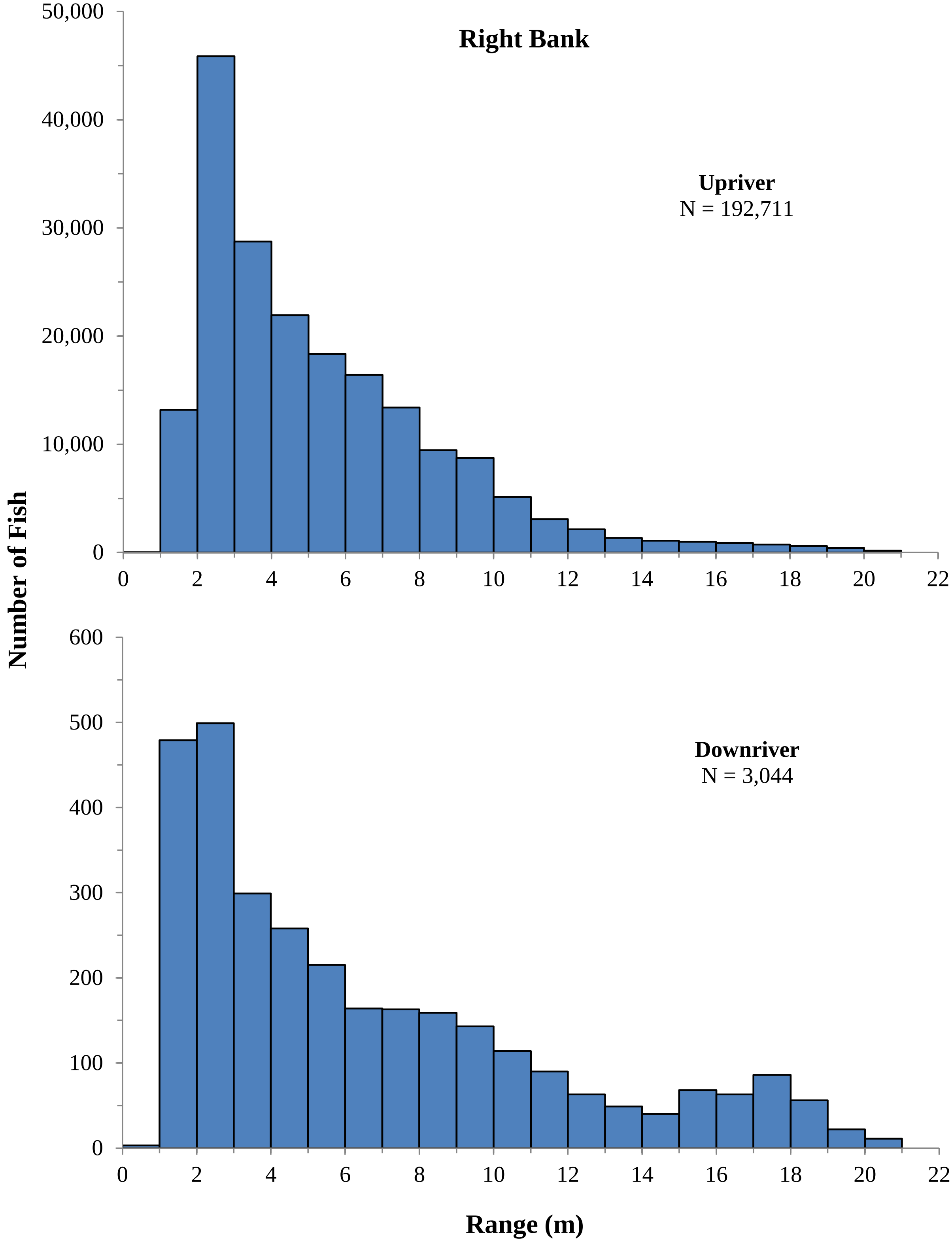

Figure 8. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the right bank Chandalar River, August 9 to September 26, 2011. Note different Y-axis scales.

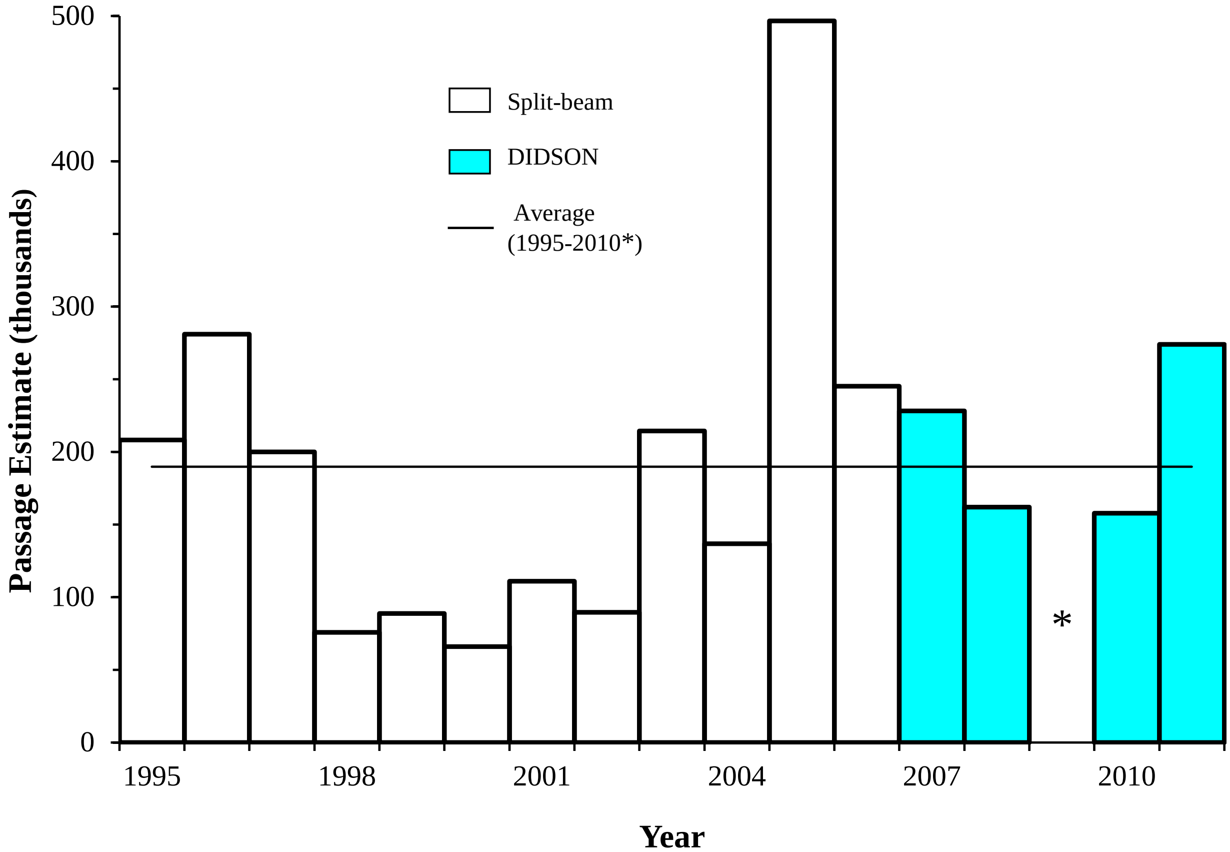

Figure 9. — Annual passage estimates (in thousands of fish) of fall chum salmon from sonar counts on the Chandalar River, 1995 - 2011. The horizontal line indicates the average of 1995-2010 passage estimates. * Average does not include data from 2009, since the project was ended early before the majority 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

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

Appendix 2. — Water quality data collected at the Chandalar River Sonar project, 2011.

		Temperature (°C)		Conductivity (µS/cm²)		DO (mg/l)		PH	
Date	Level[a] (m)	AM	PM	AM	PM	AM	PM	AM	PM
8-Aug		11.0	11.5	299.3	304.4	10.41	10.96	8.43	8.63
9-Aug		10.6	11.6	291.1	298.8	10.66	11.81	8.52	8.61
10-Aug	3.16	10.2	10.0	303.2	305.7	10.57	11.01	8.54	8.70
11-Aug	3.04	11.7	10.8	302.0	303.7	10.43	10.34	8.46	8.61
12-Aug	2.87	11.9	12.7	306.9	310.0	10.00	9.56	8.46	8.37
13-Aug	2.75	12.3	12.9	312.2	316.7	9.69	10.00	8.42	8.41
14-Aug	2.66	12.1	12.3	308.1	308.8	9.84	10.01	8.53	8.34
15-Aug	2.60	11.7	12.5	305.9	310.0	9.66	10.05	8.33	8.44
16-Aug	2.62	11.7	12.3	300.2	301.3	10.06	10.06	8.44	8.37
17-Aug	2.58	11.1	12.0	290.4	300.5	9.74	9.96	8.45	8.41
18-Aug	3.14	11.2	12.1	296.1	306.4	9.95	10.01	8.52	8.47
19-Aug	2.47	11.6	11.9	301.3	304.7	9.69	9.92	8.66	8.52
20-Aug	2.41	10.7	10.3	299.4	296.9	10.20	9.99	8.45	8.49
21-Aug	2.40	9.9	11.0	294.4	304.6	10.22	10.43	8.48	7.98
22-Aug	2.38	10.9	11.4	304.4	300.4	10.62	8.84	8.26	8.60
23-Aug	2.38	11.0	12.1	—	322.7	9.80	9.80	—	8.21
24-Aug	2.34	11.5	11.9	318.6	306.6	10.02	9.96	8.21	8.33
25-Aug	2.29	11.4	12.5	—	—	9.76	10.22	8.15	8.11
26-Aug	2.24	11.2	12.6	315.9	327.0	9.50	10.04	8.23	8.25
27-Aug	2.20	11.5	12.5	307.6	328.0	9.88	9.85	8.31	8.09
28-Aug	2.17	11.2	13.1	321.4	324.5	10.02	10.10	8.16	8.23
29-Aug	2.12	11.5	12.2	318.5	326.5	10.13	11.31	8.19	8.30
30-Aug	2.09	11.2	12.6	313.1	327.8	9.80	9.89	8.21	8.15
31-Aug	2.06	11.4	11.7	317.1	321.2	9.41	9.40	8.19	8.28
1-Sep	2.03	11.0	11.2	301.6	315.7	9.66	9.85	8.31	8.28
2-Sep	2.00	10.4	11.3	308.5	312.9	9.63	9.95	8.20	8.24
3-Sep	1.98	10.6	11.0	310.7	310.4	9.32	9.76	8.31	8.19
4-Sep	2.01	10.3	10.9	306.4	309.5	9.34	9.87	8.22	8.21
5-Sep	2.06	10.2	10.4	309.8	311.7	9.33	9.76	8.25	8.33
6-Sep	2.17	10.1	9.8	316.4	307.6	9.42	10.08	8.27	8.61
7-Sep	2.23	8.5	9.0	282.6	286.4	10.76	10.79	8.54	8.52
8-Sep	2.33	8.4	9.1	277.4	285.8	10.80	10.23	8.58	8.44
9-Sep	2.50	8.3	7.9	273.2	270.8	10.71	10.72	8.38	8.62
10-Sep	2.47	—	7.4	—	270.5	—	11.45	—	8.50
11-Sep	2.43	7.0	7.4	272.8	279.1	11.11	11.40	8.46	8.47
12-Sep	2.41	7.1	8.0	278.9	289.7	10.80	11.21	7.80	—
13-Sep	2.39	7.7	8.8	290.9	304.7	10.84	10.80	8.17	8.23
14-Sep	2.34	8.1	8.8	301.6	309.6	11.04	11.07	8.28	8.42
15-Sep	2.30	8.4	8.1	303.1	301.2	10.95	11.01	8.50	8.60
16-Sep	2.28	7.8	8.2	307.2	305.1	10.84	11.08	8.31	8.52
17-Sep	2.32	7.5	7.5	297.1	290.6	10.78	10.84	8.59	8.65
18-Sep	2.42	7.0	7.9	279.7	288.3	10.93	10.72	8.55	8.56
19-Sep	2.50	—	—	—	—	—	—	—	—
20-Sep	2.69	6.9	6.5	291.4	301.2	10.82	10.73	8.40	8.55
21-Sep	2.71	n/a	6.3	—	265.7	—	11.29	—	8.46
22-Sep	2.75	5.7	6.0	262.5	266.5	11.16	11.81	8.48	8.55
23-Sep	2.73	5.2	n/a	264.4	—	11.24	—	8.76	—
24-Sep	2.64	4.6	4.7	264.0	266.4	11.41	11.68	8.68	8.60
25-Sep	2.55	4.2	3.8	272.4	262.0	11.23	11.89	8.59	8.59
26-Sep	2.42	—	—	—	—	—	—	—	—
Average	2.43	9.7	10.2	297.8	302.3	10.27	10.47	8.39	8.42
Min	1.98	4.2	3.8	262.5	262.0	9.32	8.84	7.80	7.98
Max	3.16	12.3	13.1	321.4	328.0	11.41	11.89	8.76	8.77

[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.

	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

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		

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

Appendix 4. — Historical age and sex of fall chum salmon carcasses sampled on the spawning grounds in the Chandalar River, Alaska. Vertebrae were aged by Alaska Department of Fish and Game, unknown age indicates numbers 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%)

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				