U.S. Fish & Wildlife Service

Abundance and Run Timing of Adult Fall Chum Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2013

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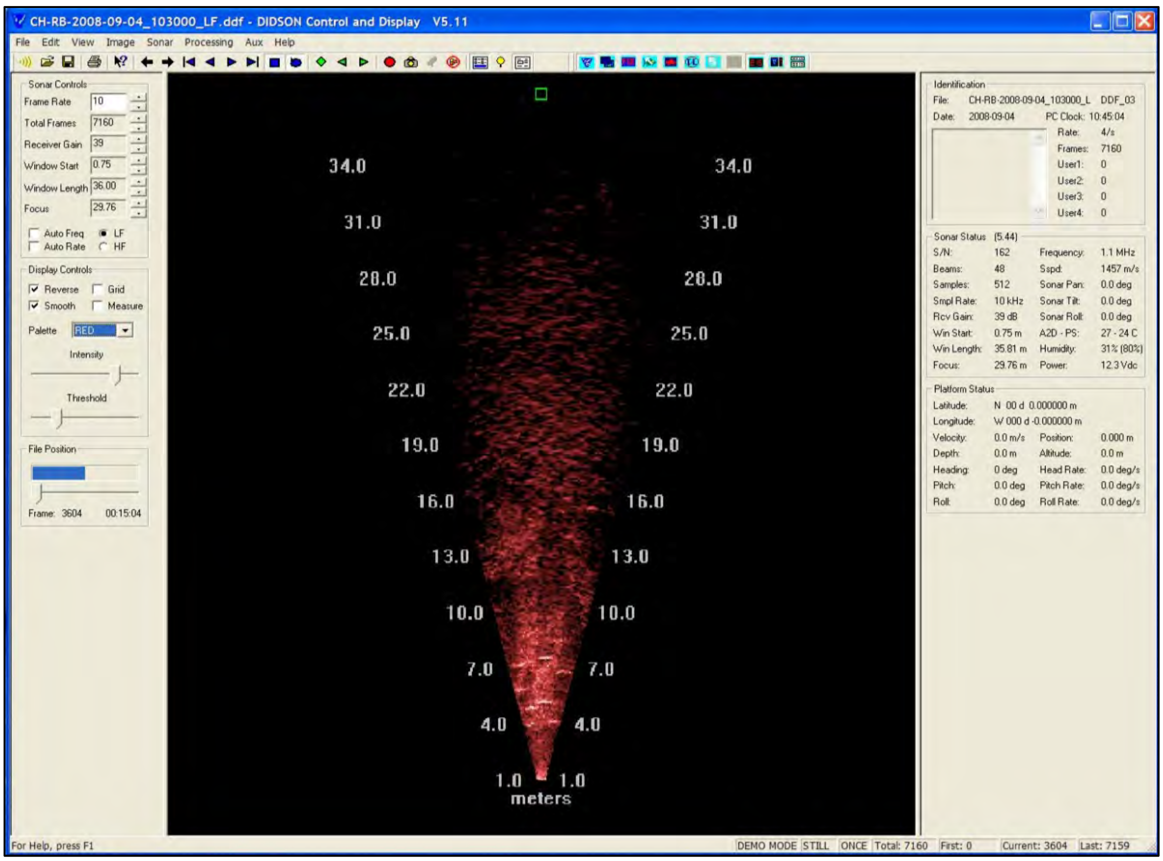

Fairbanks Fish and Wildlife Field Office
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Cover: Image of DIDSON control and display software showing fish in display between 4 and 7 m range.

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Jeffery L. Melegari

Abstract

During 2013, 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 26. Of the 2,400 hours (1,200 hours on each bank) of time available during the sample period 2,341.3 hours of data were collected, with 222,318 upriver swimming fish enumerated. After adjustments were made for missed time, the fall chum salmon passage estimate for 2013 was 227,145. 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 1,134 upriver swimming chum salmon. The passage on the final day of counting was 6,647 upriver swimming chum salmon. The first quartile passage date was September 6, the mid-point September 14, and the third quartile was September 19. 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 5 year study from 1986 to 1990 using fixed-location Bendix side scanning sonar salmon counters to enumerate adult fall chum salmon in the

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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 A). These early Bendix sonar 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 salmon 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). Fall chum salmon enumeration with the split-beam sonar continued through 2006.

Experimentation to evaluate DIDSON (Dual Frequency Identification Sonar) technology from Sound Metrics (Lake Forest Park, Washington), 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 easily interpreted 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 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 2012 averaged 190,140 fish and ranged from 65,894 to 496,484 fish (Appendix A).

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 (Appendix B); however funding was unavailable during 2013.

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 typically occurs in 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 left bank (facing downriver) DIDSON site has a bottom slope of approximately 5° out to approximately 40 m where it flattens out (Figure 3). On the right bank site 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 varied from approximately 140 m to 155 m during the season, 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. Additionally, a YSI model 6920V2 sonde was deployed from June 13 to September 29 to collect temperature (°C), conductivity (µS/cm), dissolved oxygen (mg/L and % saturation), pH, and turbidity (NTU) data every 15 minutes.

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 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 migrating fish through the beams. The left bank DIDSON had a window start setting of 0.83 m, and a window length setting of 40.01 m, and the right bank had a window start setting of 0.77 m, and a window length setting of 18.54 m. Both DIDSONs began operation on August 8 during 2013. During previous years the left bank DIDSON window length setting was 70 m, however, since we began using DIDSONs in 2007, an average of 96.4% of the upstream swimming fish counted were within 40 m of the DIDSON. 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 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 would 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 radio frequency 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:

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

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 less than 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 hours 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 2013 season. Estimated fish counts for missing hours were calculated, using

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

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 2013 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 (hole accumulation diode) CCD (charge-coupled device) underwater video cameras, a four channel digital video recorder (EverFocus EVECOR2644F1), and an ultra-high resolution monitor (Samsung SASM1722). All four cameras were attached to a single steel rod and were 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. However, no data were reviewed due primarily to the low proportions of other species seen in the past and the lack of any indication from the sonar data that this was different during 2013; and to a much lesser degree, logistic demands related to the furlough of government employees during much of October.

Results

Water Quality Monitoring

Calibrated water levels ranged from approximately 1.4 to 2.7 m, and averaged 1.8 m throughout the season. Water temperatures, recorded with the YSI sonde during sonar operations, ranged from 1.9°C to 16.7°C and averaged 8.7°C (Figure 4). Water quality data collected with the YSI sonde from June 13 to September 29 are presented in Appendix C.

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). The same approximate locations have been used since we switched to DIDSON, given that minimal changes in physical conditions have been observed at the locations between years.

Sonar Data Collection and Analysis

Sonar operations began on August 8, 2013, and continued through September 26. Acoustic data were collected for 2,341.3 hours, and 225,804 total fish were counted (Table 1). Upriver swimming fish accounted for 98.5% (222,318) of the total counted. On the left bank, 1,173.2 hours (98% of the potential 1,200 hours) were monitored, with 26.8 hours missed due to repositioning the DIDSON as water levels changed, as well as intermittent maintenance or repairs. On the right bank, 1,168.1 hours (97% of the potential 1,200 hours) were monitored, with 31.9 hours missed due to repositioning the DIDSON as water levels changed, as well as intermittent maintenance or repairs. Upriver fish counts were 54,567 for the left bank and 167,751 for the right bank.

After adjusting for missed time, the estimated fall chum salmon passage for 2013 was 227,145 (Table 2; Appendix D). The left bank estimate was 56,073 accounting for 25% of the total. The right bank estimate was 171,072 accounting for 75% of the total. The adjusted count was 1,134 upriver swimming fish on the first day of sonar operation (0.5% of the total), and 6,647 fish on the final day of counting (2.9% of the total). Peak daily passage occurred on September 13 (Figure 5). The first quartile of the run occurred on September 6, the mid-point on September 14, and the third quartile on September 19.

Hourly counts (number of fish counted during each hour expressed as a proportion of the daily count) of upriver swimming fish during 2013, showed a strong diel pattern on the left bank, and a slight diel pattern on the right bank. These patterns displayed higher counts during late night (left bank) or early morning hours (right bank; Figure 6).

Upriver swimming chum salmon were shore-oriented and most were within the range of acoustic detection for both banks (Figures 7 and 8). More than 95% of upriver swimming fish were within 19 m on the left bank, and 14 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

While video cameras were deployed and video was recorded, none of the video was reviewed due primarily to the low proportions of other species seen in the past and the lack of any indication from the sonar data that this was different during 2013. To a much lesser degree, there were also logistic demands related to the furlough of government employees during much of October.

Discussion

Site Selection and Sonar Deployment

Almost no changes in bottom profiles at the deployment sites were seen again in 2013. This has allowed for consistent deployment, data collection, and analysis.

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 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 was slightly later than average, with both the first quarter point of passage (September 6) and the midpoint (September 14) 6 days later than average (1995-2012, excluding 2009 when the project terminated early), and the third quarter point (September 19) 4 days later than average. Considering that the estimated passage on the last day was 2.9% of the cumulative, it is probable the actual quarter point dates for the run were slightly later than calculated. Preliminary data from other fall chum salmon projects indicate similar patterns in run timing during 2013 (JTC 2014).

The 2013 passage estimate of 227,145 fish is 119% of the historical average (Figure 9). Preliminary data from other Yukon River drainage fall chum salmon enumeration projects during 2013 also indicate above average escapements (JTC 2014).

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 2.9% 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 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 2013, the right bank accounted for 75% 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 (Appendices A); however, the ratio of right bank to left bank has been variable. In recent years, using DIDSON, enumeration has been able to continue at higher water levels than possible with the split-beam sonar. Observations during higher water levels have shown some tendency for the right bank to left bank ratio to decrease during high water.

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 only a few fish found 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 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.

Conclusions

The DIDSONs performed well overall, and only minimal time was missed due to maintenance and repositioning the DIDSONs as water levels changed 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 additional information with minimal additional cost. Video monitoring should be used 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 could provide some useful data when video monitoring cannot be used or if there was some increased concern about the presence of non-target species.

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 for 19 years. These time series data will become more 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 2013.

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	23.97	140	15	23.99	993	8	47.96	1,133	23
9-Aug	23.97	85	8	23.98	967	12	47.95	1,052	20
10-Aug	23.97	85	8	23.98	942	12	47.95	1,027	20
11-Aug	23.98	109	11	23.98	920	7	47.96	1,029	18
12-Aug	23.97	95	9	23.98	858	15	47.95	953	24
13-Aug	23.98	122	11	23.98	949	20	47.96	1,071	31
14-Aug	23.98	143	15	16.15	562	14	40.13	705	29
15-Aug	23.98	151	6	23.98	839	8	47.96	990	14
16-Aug	23.98	127	9	23.98	884	5	47.96	1,011	14
17-Aug	23.97	135	5	23.98	736	5	47.95	871	10
18-Aug	23.96	177	5	23.98	1,032	6	47.94	1,209	11
19-Aug	23.98	241	13	23.98	1,101	6	47.96	1,342	19
20-Aug	23.98	396	11	23.98	944	11	47.96	1,340	22
21-Aug	23.46	398	13	22.20	586	18	45.66	984	31
22-Aug	23.98	1,158	10	21.85	753	15	45.83	1,911	25
23-Aug	14.22	877	2	22.73	732	18	36.95	1,609	20
24-Aug	23.98	1,400	4	23.98	949	17	47.96	2,349	21
25-Aug	23.98	857	14	23.98	1,061	20	47.96	1,918	34
26-Aug	22.98	712	19	23.24	887	18	46.22	1,599	37
27-Aug	23.98	717	18	23.98	1,021	14	47.96	1,738	32
28-Aug	23.98	841	14	23.98	1,489	14	47.96	2,330	28
29-Aug	23.98	1,177	6	23.98	1,778	26	47.96	2,955	32
30-Aug	23.98	1,365	11	23.98	2,549	13	47.96	3,914	24
31-Aug	23.47	1,029	8	18.78	1,282	42	42.25	2,311	50
1-Sep	22.79	863	11	23.98	1,729	33	46.77	2,592	44
2-Sep	23.97	1,096	14	23.98	1,819	24	47.95	2,915	38
3-Sep	23.98	828	10	23.98	2,472	23	47.96	3,300	33
4-Sep	23.98	797	10	23.98	2,409	18	47.96	3,206	28
5-Sep	23.98	692	9	23.98	3,185	22	47.96	3,877	31
6-Sep	23.98	1,051	8	23.98	2,341	19	47.96	3,392	27
7-Sep	23.98	1,217	13	23.98	2,563	9	47.96	3,780	22
8-Sep	23.98	1,181	15	23.98	3,148	16	47.96	4,329	31
9-Sep	23.98	1,778	13	23.98	3,829	19	47.96	5,607	32
10-Sep	23.98	1,636	17	23.98	5,864	34	47.96	7,500	51
11-Sep	23.98	1,816	14	23.98	7,245	8	47.96	9,061	22
12-Sep	23.96	1,690	10	23.98	9,456	11	47.94	11,146	21
13-Sep	23.98	2,000	13	23.98	10,676	17	47.96	12,676	30
14-Sep	23.98	1,753	9	23.98	9,279	11	47.96	11,032	20
15-Sep	23.97	1,853	21	23.98	8,242	17	47.95	10,095	38
16-Sep	23.97	1,798	26	23.98	8,793	11	47.95	10,591	37
17-Sep	23.97	2,161	61	23.98	6,420	48	47.95	8,581	109
18-Sep	23.97	2,826	161	23.98	4,697	139	47.95	7,523	300
19-Sep	23.48	3,056	137	23.98	7,321	127	47.46	10,377	264
20-Sep	23.76	2,623	64	23.98	7,542	70	47.74	10,165	134
21-Sep	23.98	1,808	87	23.98	4,466	75	47.96	6,274	162
22-Sep	23.98	1,985	160	23.98	5,606	123	47.96	7,591	283
23-Sep	23.98	1,681	206	23.98	7,047	202	47.96	8,728	408
24-Sep	23.98	1,241	67	23.98	7,157	81	47.96	8,398	148
25-Sep	23.98	1,831	151	23.98	6,515	122	47.96	8,346	273
26-Sep	11.99	769	75	11.99	3,116	81	23.98	3,885	156
Totals	1173.17	54,567	1,627	1,168.09	167,751	1,704	2,341.26	222,318	3,331

Table 2. — Daily fall chum salmon upriver passage estimates at the Chandalar River, Alaska 2013.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative %
8-Aug	140	994	1,134	1,134	0.50%
9-Aug	85	968	1,053	2,187	0.96%
10-Aug	85	943	1,028	3,215	1.42%
11-Aug	109	921	1,030	4,245	1.87%
12-Aug	95	859	954	5,199	2.29%
13-Aug	122	950	1,072	6,271	2.76%
14-Aug	143	950[a]	1,093	7,364	3.24%
15-Aug	151	840	991	8,355	3.68%
16-Aug	127	885	1,012	9,367	4.12%
17-Aug	135	737	872	10,239	4.51%
18-Aug	177	1,033	1,210	11,449	5.04%
19-Aug	241	1,102	1,343	12,792	5.63%
20-Aug	396	945	1,341	14,133	6.22%
21-Aug	404	621[a]	1,025	15,158	6.67%
22-Aug	1,159	841[a]	2,000	17,158	7.55%
23-Aug	1,680[a]	783[a]	2,463	19,621	8.64%
24-Aug	1,401	950	2,351	21,972	9.67%
25-Aug	858	1,062	1,920	23,892	10.52%
26-Aug	728	914	1,642	25,534	11.24%
27-Aug	718	1,022	1,740	27,274	12.01%
28-Aug	842	1,490	2,332	29,606	13.03%
29-Aug	1,178	1,779	2,957	32,563	14.34%
30-Aug	1,366	2,551	3,917	36,480	16.06%
31-Aug	1,031	1,542[a]	2,573	39,053	17.19%
1-Sep	1,019	1,730	2,749	41,802	18.40%
2-Sep	1,097	1,821	2,918	44,720	19.69%
3-Sep	829	2,474	3,303	48,023	21.14%
4-Sep	798	2,411	3,209	51,232	22.55%
5-Sep	693	3,188	3,881	55,113	24.26%
6-Sep	1,052	2,343	3,395	58,508	25.76%
7-Sep	1,218	2,565	3,783	62,291	27.42%
8-Sep	1,182	3,151	4,333	66,624	29.33%
9-Sep	1,780	3,832	5,612	72,236	31.80%
10-Sep	1,637	5,869	7,506	79,742	35.11%
11-Sep	1,818	7,251	9,069	88,811	39.10%
12-Sep	1,693	9,464	11,157	99,968	44.01%
13-Sep	2,002	10,685	12,687	112,655	49.60%
14-Sep	1,755	9,287	11,042	123,697	54.46%
15-Sep	1,855	8,249	10,104	133,801	58.91%
16-Sep	1,800	8,800	10,600	144,401	63.57%
17-Sep	2,163	6,425	8,588	152,989	67.35%
18-Sep	2,829	4,701	7,530	160,519	70.67%
19-Sep	3,097	7,327	10,424	170,943	75.26%
20-Sep	2,636	7,548	10,184	181,127	79.74%
21-Sep	1,810	4,470	6,280	187,407	82.51%
22-Sep	1,987	5,611	7,598	195,005	85.85%
23-Sep	1,682	7,053	8,735	203,740	89.70%
24-Sep	1,242	7,163	8,405	212,145	93.40%
25-Sep	1,833	6,520	8,353	220,498	97.07%
26-Sep	1,195[a]	5,452[a]	6,647	227,145	100.00%
Totals	56,073	171,072	227,145		

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

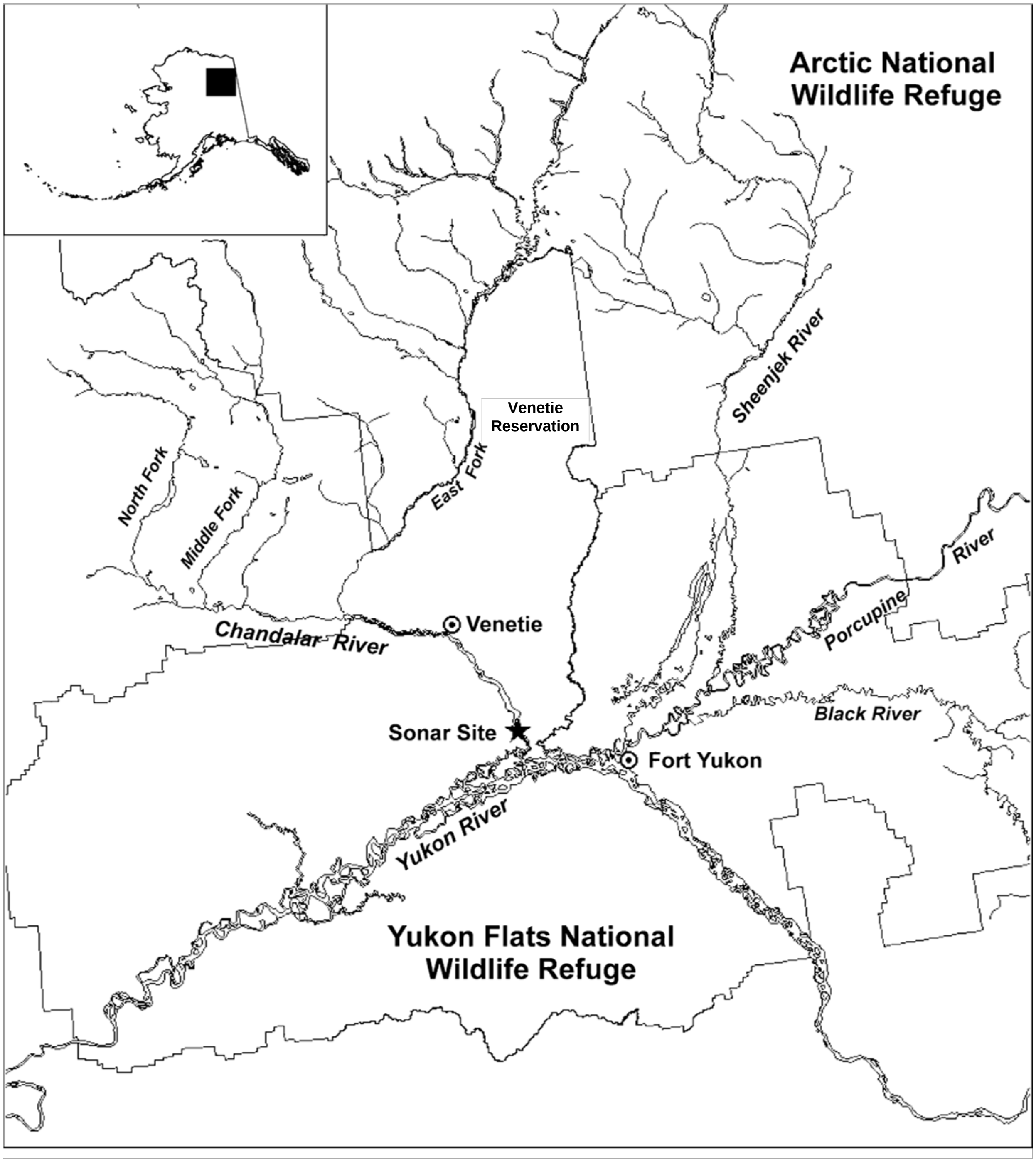

Figure 1. — Chandalar River sonar site and major tributaries of the Yukon River near the U.S.-Canada border.

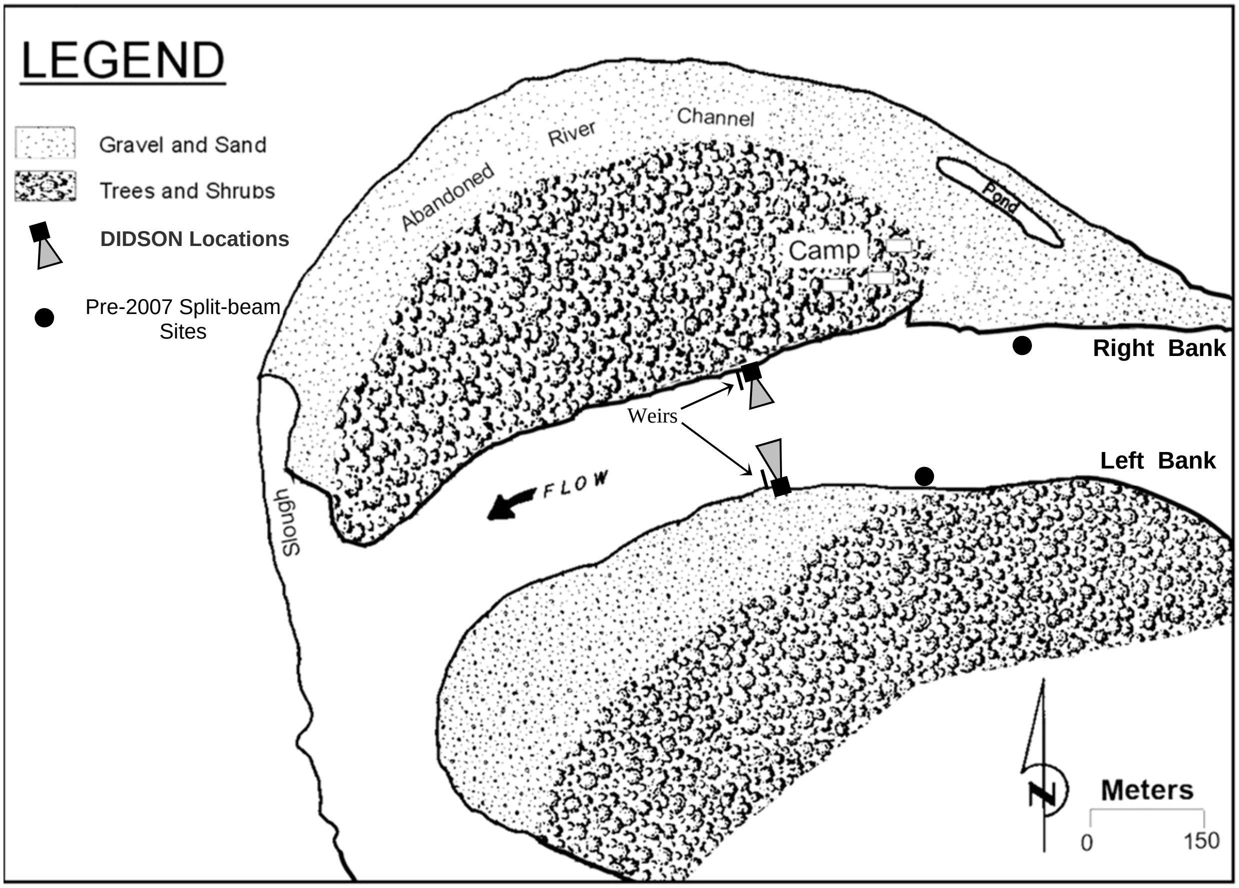

Figure 2. — Site map of Chandalar River sonar facilities.

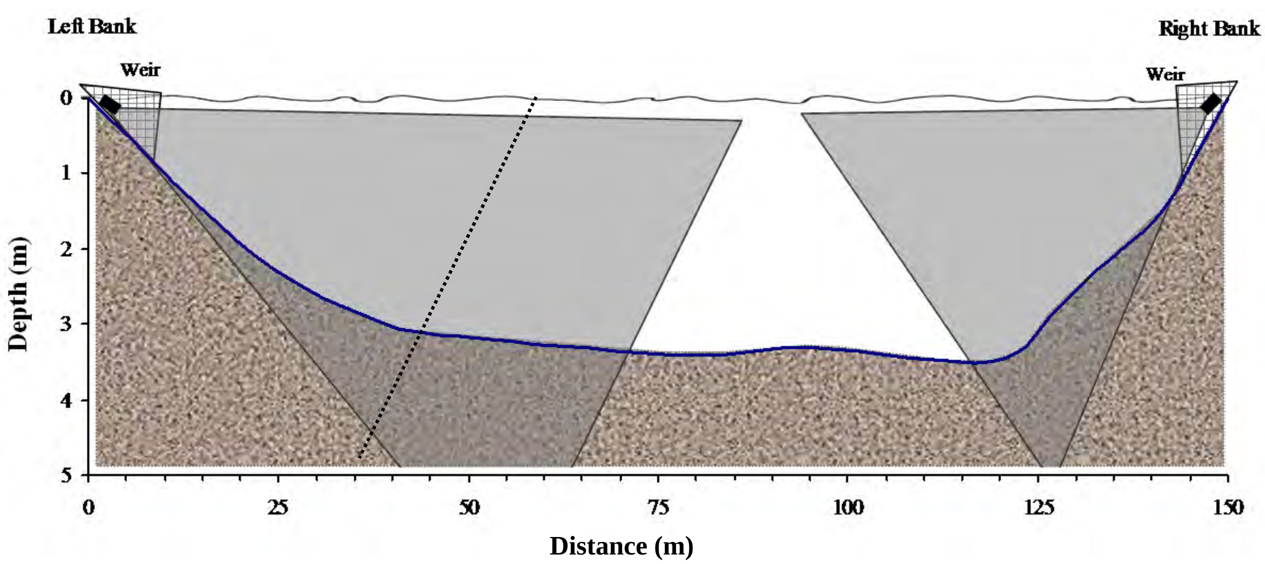

Figure 3. — River channel profile and approximated ensonified zones during 2009 for the left and right bank sonar sites, Chandalar River. Dotted line on left bank indicates the approximate limit of the ensonified zone with the range reduced to 40 m. Little change has been detected in channel profile from 2008 to 2013. Note: different axis scales are used to enhance readability.

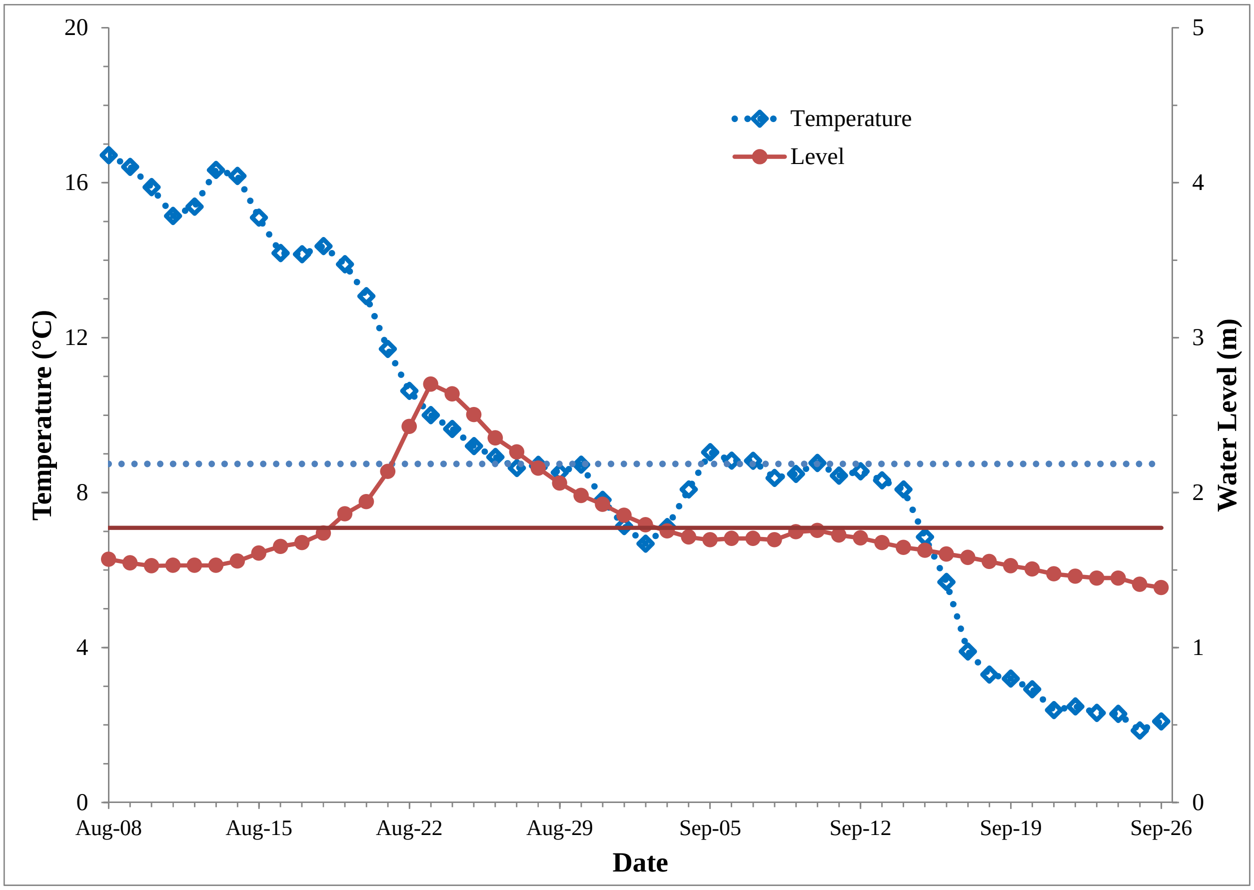

Figure 4. — Average daily water temperatures and calibrated daily water levels from the Chandalar River sonar site, 2013. Temperature is the daily average of readings taken at 15 minute intervals with a YSI sonde. Straight horizontal lines indicate seasonal averages.

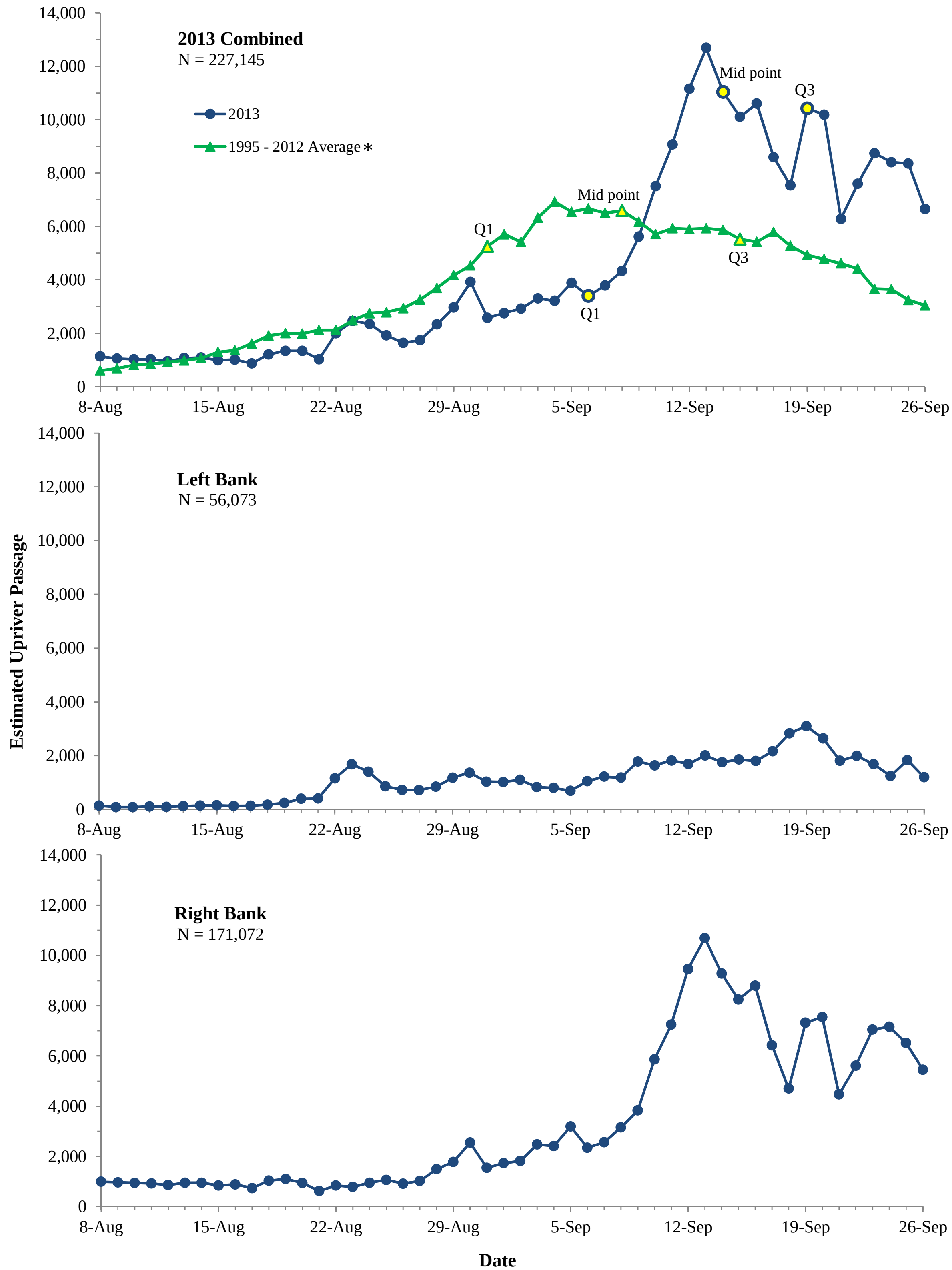

Figure 5 — Estimated passage of upriver swimming fall chum salmon by bank and combined, Chandalar River, 2013. Highlighted points in the top graph indicate the 1st quarter, mid, and 3rd quarter points of passage.
* Average does not include data from 2009 because the project was ended early before the majority of the run normally passes.

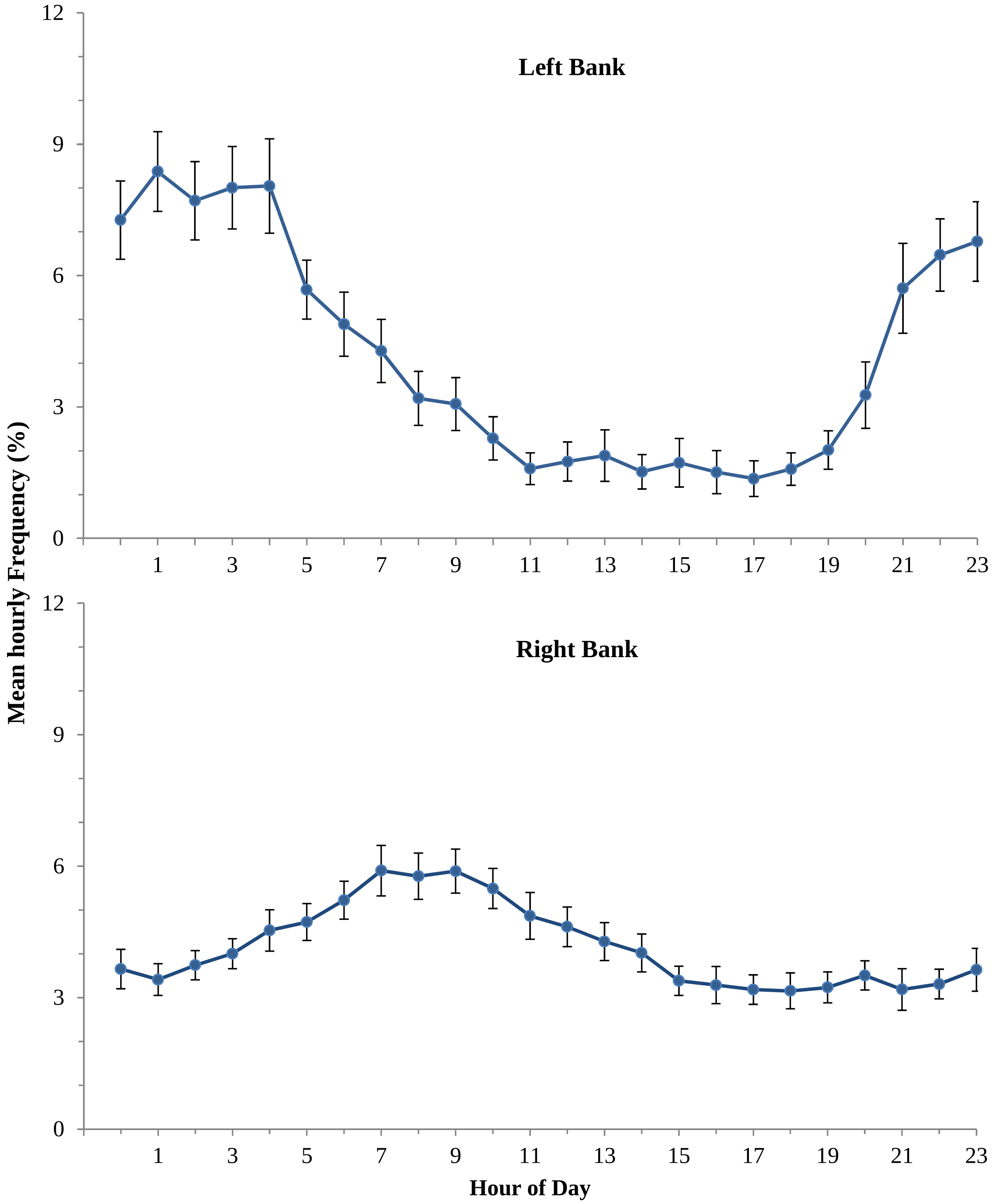

Figure 6. — Mean (±2 SE) hourly frequency of upriver swimming fall chum salmon, Chandalar River, 2013. Hourly frequency is the hourly passage expressed as a percent of the total daily count. Results include 48 complete days of 24-hour data on the left bank and 44 days on the right bank.

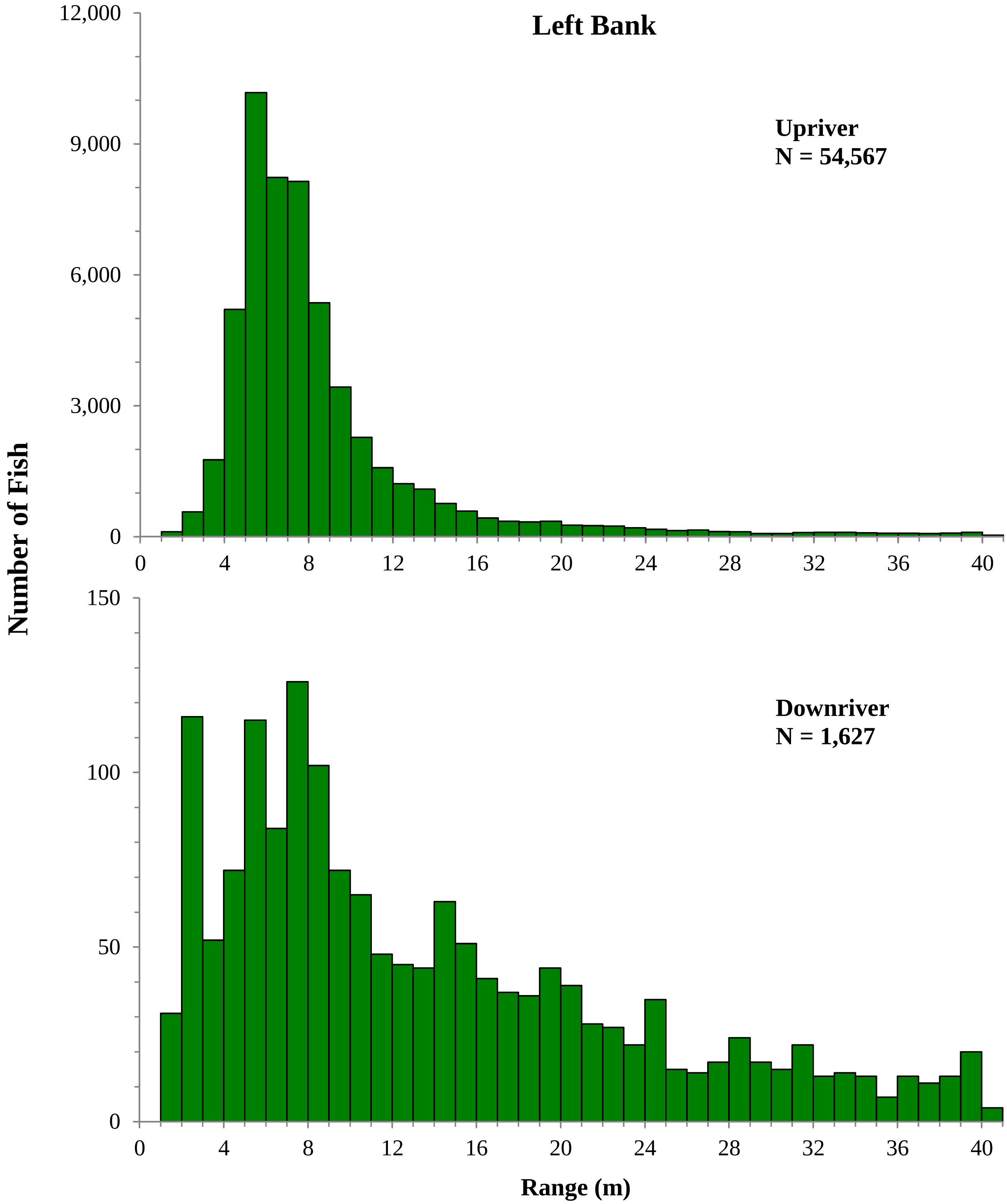

Figure 7. — Range (horizontal distance from DIDSON) distribution of upriver and downriver swimming fish, from hydroacoustic data collected on the left bank Chandalar River, August 8 to September 26, 2013. Note different Y-axis scales on top and bottom graphs.

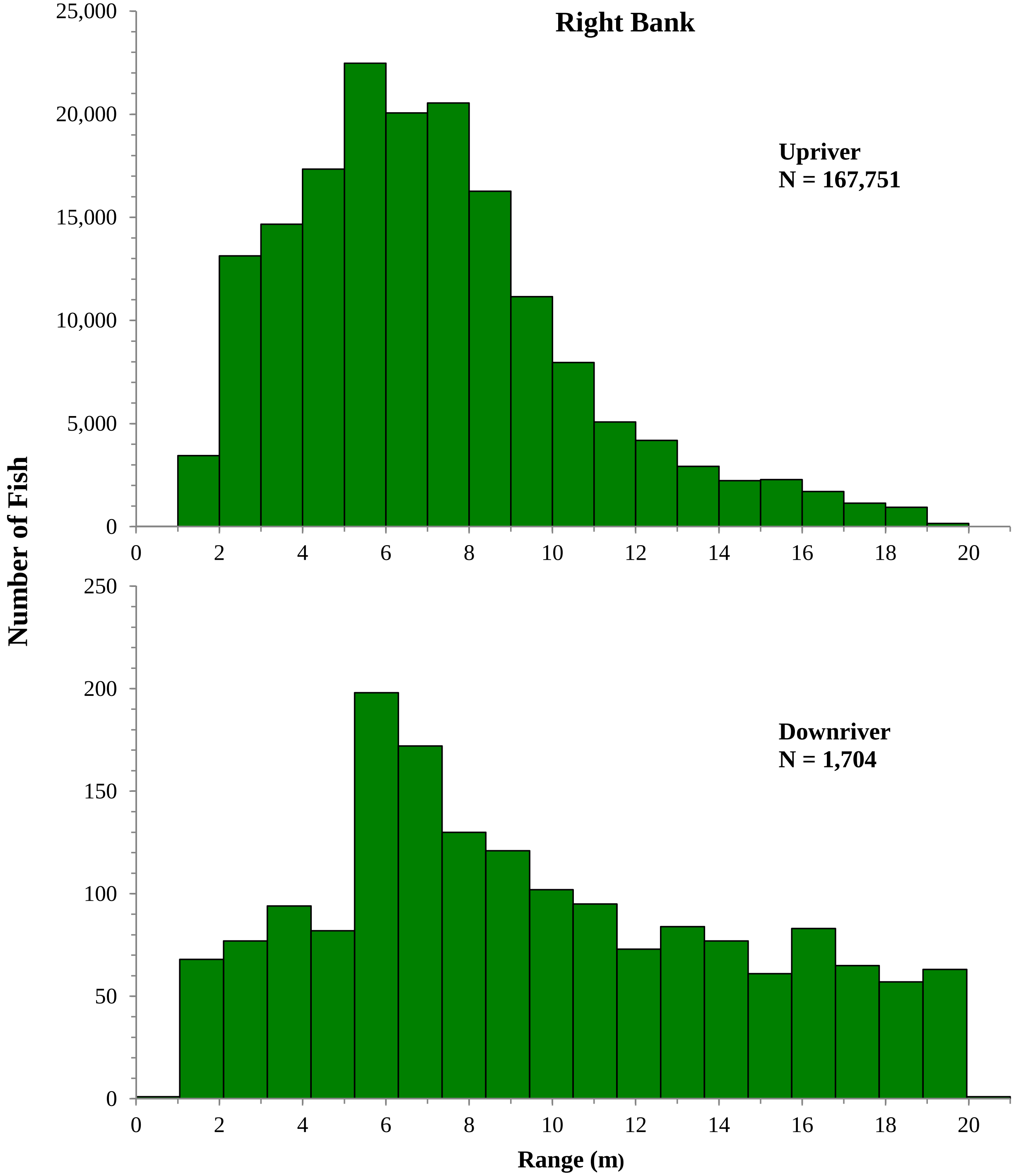

Figure 8. — Range (horizontal distance from DIDSON) distribution of upriver and downriver swimming fish, from hydroacoustic data collected on the right bank Chandalar River, August 8 to September 26, 2013. Note different Y-axis scales on top and bottom graphs.

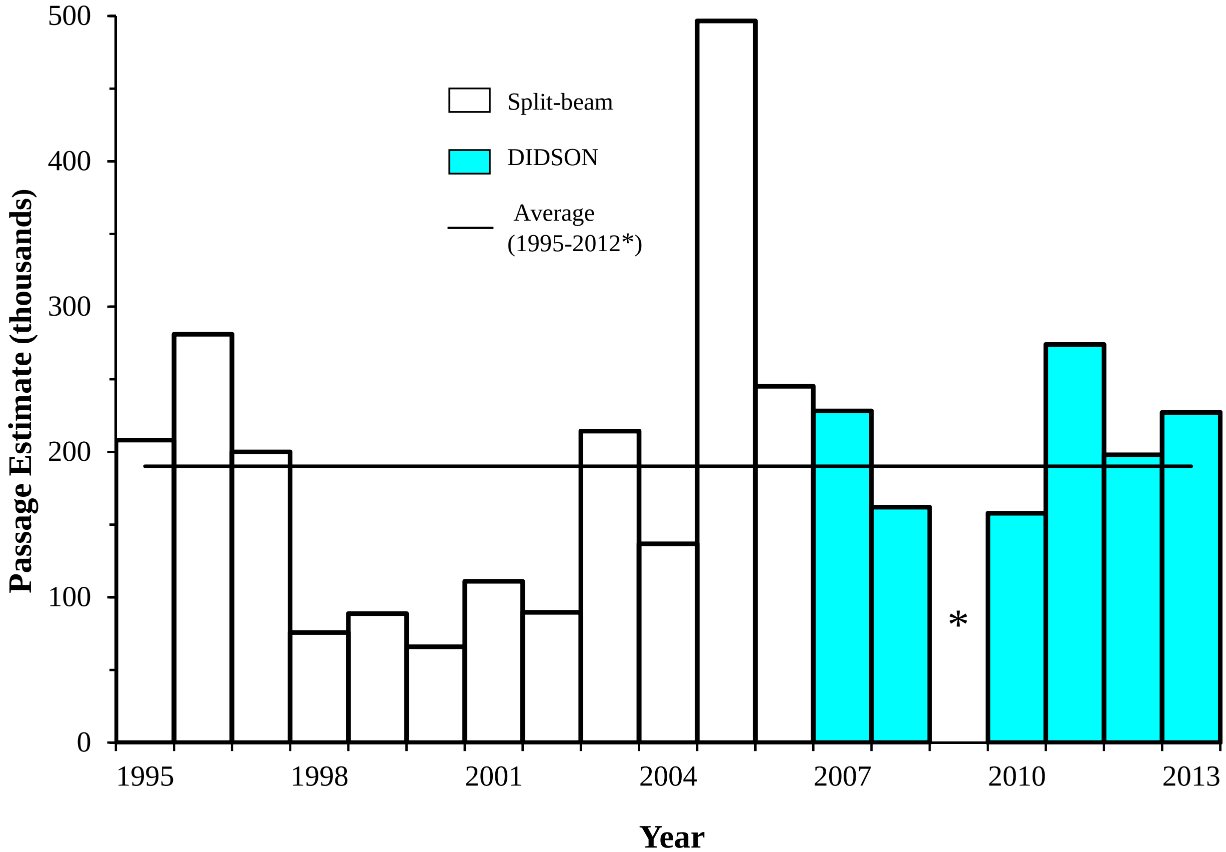

Figure 9. — Annual passage estimates (in thousands of fish) of fall chum salmon from sonar counts on the Chandalar River, 1995 to 2013. The horizontal line indicates the average of 1995 to 2012 passage estimates. * Average does not include data from 2009, because the project was ended early before the majority of the run normally passes.

Appendix A. Historical Passage

Table A.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
2013	DIDSON	56,073	171,072	227,145

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

Appendix B. Age, Sex, and Length Data

Table B.1. — 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%)

Table B.2. — 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				

Appendix C. Staff Gauge and Sonde Data

Table C.1. — Water level (via staff gauge data), and water quality data collected with a YSI sonde at the Chandalar River sonar project, 2013. Daily water quality values are averages of readings taken at 15 minute intervals.

Date	Level[a] (m)	Temperature (°C)	Specific conductance (μS/cm)	pH	Turbidity (NTU)	DO	
						mg/L	(% saturation)
13-Jun	—	11.77	253.2	7.86	38.1	10.6	98.0
14-Jun	—	13.41	255.1	7.88	30.7	10.2	97.6
15-Jun	—	14.47	258.7	7.91	26.6	9.9	97.4
16-Jun	—	15.31	266.3	7.94	34.1	9.9	98.5
17-Jun	—	15.39	257.1	7.95	58.6	9.9	98.6
18-Jun	—	15.44	247.3	7.95	86.3	9.9	98.7
19-Jun	—	15.87	238.4	7.94	200.1	9.7	98.1
20-Jun	—	16.24	236.2	7.94	159.4	9.6	97.3
21-Jun	—	16.18	244.3	7.95	78.0	9.4	96.1
22-Jun	—	16.06	249.0	7.98	66.5	9.5	96.9
23-Jun	—	15.82	239.6	7.96	96.5	9.6	97.2
24-Jun	—	15.80	240.1	7.94	142.6	9.6	97.1
25-Jun	—	15.91	251.1	7.97	161.5	9.6	97.3
26-Jun	—	16.28	253.6	7.98	90.1	9.5	97.1
27-Jun	—	17.09	260.3	7.98	53.5	9.3	96.4
28-Jun	—	17.64	268.7	8.01	30.7	9.2	96.7
29-Jun	—	17.13	273.1	8.02	26.6	9.3	96.2
30-Jun	—	16.88	279.2	8.01	25.2	9.3	96.1
1-Jul	—	17.34	291.6	8.02	21.4	9.1	95.3
2-Jul	—	16.79	296.2	8.03	18.8	9.2	94.4
3-Jul	—	15.85	294.2	8.05	15.4	9.5	95.8
4-Jul	—	15.75	287.5	8.05	12.1	9.6	96.5
5-Jul	—	14.95	286.9	8.07	24.5	9.8	97.4
6-Jul	—	15.15	276.0	8.07	58.7	9.9	98.1
7-Jul	—	14.53	268.0	8.05	55.0	9.8	96.1
8-Jul	—	13.76	273.2	8.04	27.2	9.8	94.4
9-Jul	—	13.73	278.6	8.02	14.6	9.9	95.2
10-Jul	—	13.46	272.9	8.02	58.2	10.1	96.6
11-Jul	—	12.09	259.1	7.98	289.2	10.6	98.5
12-Jul	—	13.38	273.5	7.98	224.2	10.3	98.3
13-Jul	—	14.81	283.6	8.00	86.9	9.9	97.6
14-Jul	—	16.17	295.6	8.00	39.9	9.5	96.8
15-Jul	—	17.01	305.4	8.02	22.8	9.3	96.0
16-Jul	—	16.78	311.7	8.05	15.7	9.3	95.9
17-Jul	—	16.30	314.8	8.06	13.4	9.4	96.0
18-Jul	—	16.04	317.7	8.06	10.7	9.5	96.0
19-Jul	—	16.35	320.1	8.05	8.3	9.4	95.7
20-Jul	—	15.91	318.3	8.08	9.3	9.5	96.3
21-Jul	—	15.57	310.3	8.09	14.6	9.7	97.1
22-Jul	—	15.67	304.7	8.08	31.7	9.7	98.1
23-Jul	—	15.63	296.2	8.06	70.3	9.8	98.4
24-Jul	—	15.96	292.3	8.06	68.6	9.6	97.6
25-Jul	—	15.82	300.0	8.06	37.7	9.6	96.9
26-Jul	—	15.24	309.6	8.05	18.5	9.7	96.8
27-Jul	—	15.62	316.7	8.05	12.3	9.6	96.9
28-Jul	—	16.32	321.4	8.05	9.4	9.5	96.8
29-Jul	—	16.48	322.6	8.07	8.3	9.4	96.6
30-Jul	—	16.38	324.1	8.07	6.9	9.5	96.7
31-Jul	—	16.45	327.8	8.08	8.5	9.4	96.7
1-Aug	—	16.57	327.0	8.06	8.4	9.4	96.2
2-Aug	—	16.59	329.5	8.05	7.2	9.3	95.4
3-Aug	—	16.70	346.8	8.05	6.3	9.2	94.5
4-Aug	—	16.36	380.8	8.09	5.3	9.3	95.1
5-Aug	—	15.77	380.5	8.09	4.8	9.5	95.6
6-Aug	—	15.63	380.4	8.09	4.0	9.6	96.1
7-Aug	—	16.26	380.6	8.11	4.2	9.4	96.3

Table C.1. — Continued

Date	Level[a] (m)	Temperature (°C)	Specific conductance (μS/cm)	pH	Turbidity (NTU)	DO mg/L	DO (% saturation)
8-Aug	1.57	16.71	380.1	8.10	3.5	9.2	95.2
9-Aug	1.55	16.41	380.3	8.10	2.9	9.2	94.4
10-Aug	1.53	15.89	380.8	8.10	2.7	9.4	94.7
11-Aug	1.53	15.15	380.6	8.10	2.4	9.7	96.1
12-Aug	1.53	15.39	381.4	8.10	2.0	9.7	96.9
13-Aug	1.53	16.33	382.1	8.10	1.7	9.5	96.9
14-Aug	1.56	16.17	381.2	8.10	2.1	9.4	95.9
15-Aug	1.61	15.10	383.5	8.11	2.8	9.6	95.5
16-Aug	1.65	14.19	384.5	8.12	3.3	9.8	95.8
17-Aug	1.68	14.15	385.3	8.11	3.4	9.9	96.1
18-Aug	1.74	14.36	384.4	8.12	4.2	9.8	96.3
19-Aug	1.86	13.90	375.9	8.13	7.6	9.9	95.9
20-Aug	1.94	13.08	365.6	8.13	9.5	10.1	96.0
21-Aug	2.14	11.71	355.2	8.12	14.8	10.5	97.2
22-Aug	2.43	10.63	335.0	8.10	41.7	10.8	97.5
23-Aug	2.70	10.00	321.1	8.09	47.2	11.0	97.2
24-Aug	2.64	9.65	317.7	8.10	26.8	11.1	97.5
25-Aug	2.50	9.20	320.5	8.10	16.2	11.2	97.6
26-Aug	2.35	8.92	323.5	8.10	10.8	11.3	97.5
27-Aug	2.26	8.64	325.9	8.10	7.9	11.3	97.2
28-Aug	2.16	8.72	327.9	8.08	6.1	11.2	96.3
29-Aug	2.06	8.52	328.5	8.08	5.3	11.2	96.0
30-Aug	1.98	8.72	328.5	8.08	5.2	11.2	96.3
31-Aug	1.92	7.81	328.0	8.09	16.6	11.5	96.5
1-Sep	1.85	7.13	328.0	8.08	4.6	11.7	96.7
2-Sep	1.79	6.68	329.2	8.07	4.6	11.7	96.1
3-Sep	1.75	7.11	329.7	8.07	8.2	11.5	95.4
4-Sep	1.71	8.09	329.3	8.07	5.7	11.3	95.5
5-Sep	1.69	9.04	329.9	8.08	4.8	11.1	96.4
6-Sep	1.70	8.83	328.8	8.08	2.6	11.2	96.8
7-Sep	1.70	8.82	325.2	8.07	3.5	11.1	96.1
8-Sep	1.69	8.38	324.4	8.08	4.9	11.2	95.8
9-Sep	1.75	8.48	321.3	8.07	4.5	11.4	97.1
10-Sep	1.76	8.77	314.8	8.06	6.0	11.3	96.9
11-Sep	1.73	8.44	314.0	8.04	4.4	11.2	95.8
12-Sep	1.71	8.55	313.9	8.06	1.8	11.3	96.8
13-Sep	1.68	8.31	315.8	8.05	1.7	11.3	96.2
14-Sep	1.65	8.08	317.7	8.06	2.0	11.4	96.5
15-Sep	1.63	6.85	319.4	8.06	2.0	11.7	96.5
16-Sep	1.60	5.69	319.7	8.06	2.3	12.1	96.5
17-Sep	1.58	3.90	321.6	8.07	2.5	12.5	95.4
18-Sep	1.55	3.30	323.2	8.05	3.1	12.7	95.3
19-Sep	1.53	3.19	325.2	8.04	3.8	12.7	94.6
20-Sep	1.51	2.92	326.0	8.04	3.6	12.7	94.1
21-Sep	1.48	2.39	326.1	8.05	4.5	12.7	93.1
22-Sep	1.46	2.48	327.3	8.04	5.1	12.8	93.9
23-Sep	1.45	2.31	328.3	8.05	5.7	13.0	94.8
24-Sep	1.45	2.29	329.5	8.05	6.4	13.1	95.6
25-Sep	1.41	1.86	329.5	8.05	7.4	13.2	95.2
26-Sep	1.39	2.09	328.2	8.04	5.6	13.1	95.3
27-Sep	—	2.76	327.2	8.05	3.3	12.9	95.3
28-Sep	—	3.51	327.1	8.06	3.4	12.6	94.9
29-Sep	—	3.74	326.9	8.08	4.2	12.6	95.6
Average	1.77	12.30	314.8	8.05	28.7	10.4	96.4
Min	1.39	1.69	233.43	7.85	1.35	9.02	91.91
Max	2.70	18.4	386.65	8.15	1119.27	13.26	100.00

[a] Water level data was collected with a staff gage during sonar operations only, and has been calibrated to 1989 levels using a benchmark on shore.

Appendix D. Historical Daily and Cumulative Counts

Table D.1. — Historical daily and cumulative fall chum salmon passage estimates from sonar counts on the Chandalar River. Highlighted cells indicate 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										

Table D.1. — 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										

Table D.1. — 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										

Table D.1. — Continued.

	2011		2012		2013	
Date	Daily	Cum	Daily	Cum	Daily	Cum
8-Aug			670	670	1,134	1,134
9-Aug	481	481	669	1,339	1,053	2,187
10-Aug	760	1,241	673	2,012	1,028	3,215
11-Aug	835	2,076	659	2,671	1,030	4,245
12-Aug	840	2,916	642	3,313	954	5,199
13-Aug	813	3,729	640	3,953	1,072	6,271
14-Aug	729	4,458	788	4,741	1,093	7,364
15-Aug	693	5,151	888	5,629	991	8,355
16-Aug	786	5,937	988	6,617	1,012	9,367
17-Aug	1,153	7,090	1,215	7,832	872	10,239
18-Aug	1,349	8,439	1,095	8,927	1,210	11,449
19-Aug	1,819	10,258	1,392	10,319	1,343	12,792
20-Aug	1,638	11,896	1,731	12,050	1,341	14,133
21-Aug	1,081	12,977	1,998	14,048	1,025	15,158
22-Aug	1,237	14,214	2,114	16,162	2,000	17,158
23-Aug	1,384	15,598	3,000	19,162	2,463	19,621
24-Aug	1,331	16,929	4,049	23,211	2,351	21,972
25-Aug	1,360	18,289	3,859	27,070	1,920	23,892
26-Aug	1,840	20,129	3,489	30,559	1,642	25,534
27-Aug	2,971	23,100	4,104	34,663	1,740	27,274
28-Aug	4,527	27,627	4,410	39,073	2,332	29,606
29-Aug	5,985	33,612	4,353	43,426	2,957	32,563
30-Aug	7,672	41,284	5,924	49,350	3,917	36,480
31-Aug	9,218	50,502	7,410	56,760	2,573	39,053
1-Sep	9,918	60,420	5,734	62,494	2,749	41,802
2-Sep	10,228	70,648	5,221	67,715	2,918	44,720
3-Sep	11,965	82,613	5,040	72,755	3,303	48,023
4-Sep	11,836	94,449	5,379	78,134	3,209	51,232
5-Sep	11,185	105,634	4,316	82,450	3,881	55,113
6-Sep	10,787	116,421	4,012	86,462	3,395	58,508
7-Sep	7,711	124,132	3,123	89,585	3,783	62,291
8-Sep	9,406	133,538	3,043	92,628	4,333	66,624
9-Sep	10,524	144,062	2,963	95,591	5,612	72,236
10-Sep	8,010	152,072	2,882	98,473	7,506	79,742
11-Sep	6,554	158,626	2,802	101,275	9,069	88,811
12-Sep	6,809	165,435	2,984	104,259	11,157	99,968
13-Sep	7,486	172,921	3,297	107,556	12,687	112,655
14-Sep	7,132	180,053	4,463	112,019	11,042	123,697
15-Sep	7,458	187,511	4,843	116,862	10,104	133,801
16-Sep	7,256	194,767	6,006	122,868	10,600	144,401
17-Sep	8,123	202,890	9,631	132,499	8,588	152,989
18-Sep	7,914	210,804	8,659	141,158	7,530	160,519
19-Sep	8,773	219,577	7,093	148,251	10,424	170,943
20-Sep	8,789	228,366	8,000	156,251	10,184	181,127
21-Sep	7,772	236,138	8,643	164,894	6,280	187,407
22-Sep	8,487	244,625	6,220	171,114	7,598	195,005
23-Sep	8,395	253,020	4,418	175,532	8,735	203,740
24-Sep	7,369	260,389	5,642	181,174	8,405	212,145
25-Sep	7,269	267,658	4,037	185,211	8,353	220,498
26-Sep	6,307	273,965	3,411	188,622	6,647	227,145
27-Sep			3,273	191,895		
28-Sep			3,278	195,173		
29-Sep			2,758	197,931		