U.S. Fish & Wildlife Service

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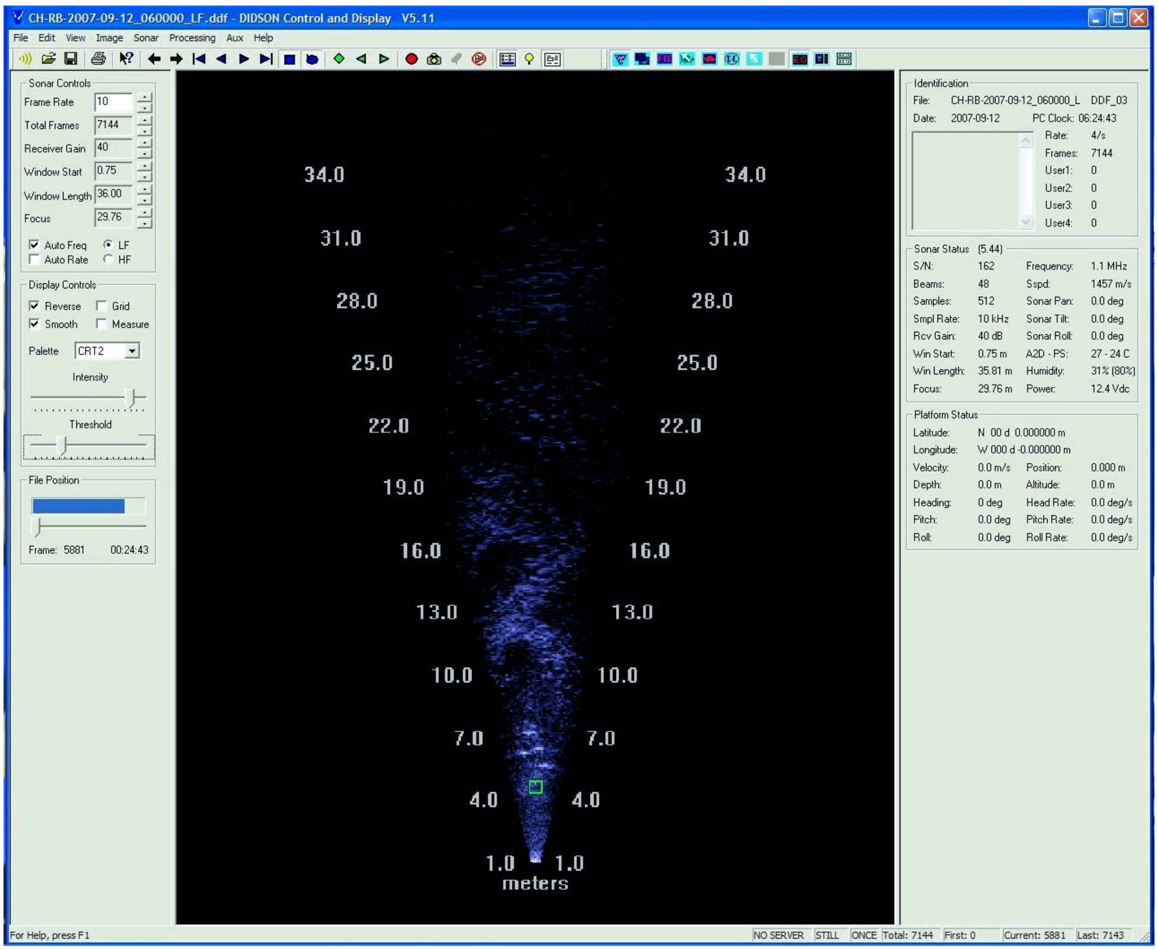

Fairbanks Fish and Wildlife Field Office
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Cover: Image of DIDSON control and display software showing four fish in display near 7 m range.

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Jeffery L. Melegari

Abstract

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. For 1995 through 2006 split-beam sonar was used to provide annual passage estimates and daily in-season counts at this location. From 2004 through 2006 DIDSON was operated, on an experimental basis, concurrently with split-beam sonar, and 2007 was the first year of operations with only DIDSON. DIDSON operations began on August 8 and continued through September 26 2007. Of the available 2,400 hours of sample time during the season (1,200 on each bank) 2,277 hours of data were collected, with 223,465 upriver swimming fish enumerated. After adjustments for missed time, the fall chum salmon passage estimate for 2007 was 228,055. This estimate represents a conservative estimate of total passage because it only included fish that passed during the dates of sonar operation. The passage rate on the first day of counting was 269 upriver chum salmon. The passage rate on the final day of counting was 4,095 upriver chum salmon. The first quartile, median, and third quartile passage dates were September 9, 12, and 16 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 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. An important component of these mandates is to provide accurate spawning escapement estimates for the major salmon stocks in the drainage. 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.

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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). These early "Bendix salmon counters" were not acoustically calibrated, used factory-set echo-counting criteria to determine fish counts, had limited acoustic range (< 33 m), and could not determine direction of target travel (upriver or downriver). From 1986 to 1990, the USFWS used fixed-location, Bendix salmon counters to enumerate adult fall chum salmon in the Chandalar River. The results of this study revealed that the Chandalar River fall chum salmon stock was one of the largest populations of fall chum salmon in the entire Yukon River drainage. Annual Bendix sonar counts of fall chum salmon during this period averaged 58,628 fish, with a range of 33,619 to 78,631 fish (Appendix 1). It is now suspected that technological limitations of the Bendix sonar system yielded very conservative estimates of actual salmon passage.

In 1992, the first riverine application of split-beam sonar technology was used to monitor upriver migrations of mainstream Yukon River salmon (Johnston et al. 1993). This sonar system was acoustically calibrated, had user-defined echo-tracking techniques to count fish, and had 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).

A study was initiated in 1994 to reassess the Chandalar River fall chum population status using newly developed, split-beam hydroacoustics. Although prematurely ended due to flooding operations during 1994 were used to develop site-specific operational methods, evaluate site characteristics, and describe possible data collection biases (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). Since 1996, the project has provided daily in-season counts to managers and a total estimate of passage post season. Split-beam sonar passage estimates during this time averaged 184,388, ranging from 65,894 to 496,484 fish (Appendix 1).

A more recently developed sonar technology, Dual Frequency Identification Sonar (DIDSON) offers advantages over the split-beam sonar. These advantages are: deployment over a wider range of site conditions; production of a more straightforward visual image; requires less training for technicians due the more intuitive image interpretation and operation; 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 large data files requiring large hard drives to store or archive data. Experimentation to evaluate DIDSON for enumeration of fall chum salmon in the Chandalar River began in 2004 and continued through 2006. During this time, up to three DIDSONs were set up at several locations, including along side the split-beam sonar, and at their own locations. Conclusions from these evaluations indicated that the DIDSON was well suited to enumerate fall chum salmon on the Chandalar River. More detailed analysis of these data to assist managers and researchers in better understanding and interpreting abundance estimates generated from the different technologies is ongoing and will be documented in a future report.

DIDSON was used to enumerate fall chum salmon on the Chandalar River in 2007. The objectives of the project remained the same as when split-beam sonar was used: (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.

Study Area

The Chandalar River is a fifth-order tributary of the Yukon River, draining from the southern slopes of the Brooks Range. It consists of three major branches: 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° 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. Twenty-one 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 150 m, depending on water level.

Methods

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 from a chart recording depth sounder with an 8° transducer mounted below a boat's hull. 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 DIDSON system, developed by University of Washington's Applied Physics Laboratory (APL) is a high frequency, 12° X 29° multiple beam sonar (Belcher et al. 2001; 2002). Two models are available. 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. The long range version operates at frequencies of 1.2 MHz or 700 KHz with 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.

A long range DIDSON was deployed on the left bank and a 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 the DIDSONs to direct fish through the beams. The right bank DIDSON began operation on August 8. The left bank DIDSON was not fully operational until August 10.

The DIDSON units were mounted to aluminum frames with brackets allowing manual adjustments to vertical and horizontal aim. The DIDSONs were oriented perpendicular to river flow. 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. 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, configured as a client, 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.

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 saved 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 24 hours per day, except for 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 periods. 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 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. A staff gauge was used to record changes in water level throughout the season.

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:

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

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. 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.

Missing daily counts from the first two days on left bank were estimated from the counts from the right bank using the ratio estimator method (Cochran 1977). Left bank counts were estimated using the ratios of left bank to right bank counts from the first five days after both banks became fully operational.

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

Results

Site Selection and Sonar Deployment

Several cross sectional profiles were recorded on each bank near the identified deployment locations and the DIDSONs were deployed at the river bottom profiles considered best for counting fish with the DIDSONs (Figure 3). Counting began on August 8 and continued through September 26 on the right bank. Due to initial difficulties with the setup and performance of the remote communications network, counting did not begin until August 10 on the left bank and continued through September 26. After the difficulties were resolved, the left bank wireless performed well except for a slightly lower maximum frame rate limitation than experienced when wired, and occasional short term, usually self correcting, interruptions to the wireless connection. Neither one of these conditions substantially impacted the effectiveness of the DIDSON.

Data Collection and Analysis

During the 2007 season, 2,277 hours of acoustic data were collected and 227,246 fish were counted (Table 1). Of these 223,465 (98% of the total fish counted) were upriver swimming fish. On the left bank, 1,095 h (91% of the possible 1,200 h) were monitored, with the first two days missed due to problems with the remote communications network and 57 h missed for maintenance/repairs. On the right bank, 1,181 h (98% of the possible 1,200 h) were monitored, with 19 h missed for maintenance/repairs. Upriver fish counts were 28,259 and 195,206 for the left and right banks, respectively.

After adjusting for the missed time, the estimated fall chum salmon passage for 2007 was 228,055 (Table 2). The left bank estimate was 31,193, accounting for 14% of the total. The right bank estimate was 196,862, accounting for 86% of the total. These estimates are conservative because counts did not include fish that passed before or after the sonar was operated. The adjusted count was 269 upriver fish on the first day of sonar operation (0.1% of the total), and 4,095 fish on the final day of counting (1.8% of the total). Peak daily passage occurred during September 11 (Figure 4). The first quartile of the run occurred during September 9, the median during September 12, and the third quartile during September 16.

During 2007, hourly passage rates of upriver fish showed a strong diel pattern on the left bank, with higher passage rates during late night/early morning hours (Figure 5). For the right bank, no substantial diel pattern was shown.

Upriver migrating chum salmon were shore-oriented and most fish were well within the range of acoustic detection for both banks (Figures 6 and 7). More than 90% of upriver fish were within 11 m of the DIDSONs on both banks. Downriver fish, while still shore oriented, were slightly more dispersed across the full detection range of the DIDSONs.

Discussion

Site Selection and Sonar Deployment

The ability of the DIDSON to be deployed under slightly less stringent site conditions than required for the split-beam sonar allowed the counting sites to be relocated downriver from the split-beam sites. The right bank location at this site is much more amenable to operations at different water levels than the previous right bank site used with the split-beam sonar. As a result, operations were able to be maintained for the entire season without any interruptions due to high water. At the previous right bank site, an average (1995 - 2006) of 14 days per year was missed due to high water. River conditions were high during the beginning of the 2007 season, which would have delayed deployment of the split-beam sonar at the previous right bank location for 1-2 weeks, but did not affect DIDSON deployment at the new site.

Foregoing the use of the remote underwater rotators, which were used with the split-beam sonar, and aiming the DIDSONs manually worked well. While proper aim is still a major concern, 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. Furthermore, not using the rotators reduces the power requirements of the system.

Few problems with the remote communications network were encountered after the initial setup and were limited to primarily brief, self-correcting 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 two frames 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 3 - 4 frames per second when hard wired. However, two frames 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.

Data Collection and Analysis

Run timing during 2007 in the Chandalar River was later than average. The median passage date of September 12 was 6 days later than the average for 1995 - 2006. The first quartile passage date, September 9, occurred 11 days later than the average for 1995 - 2006. Preliminary data from other fall chum salmon projects in the Yukon River drainage also suggest later than average run timing (Alaska Department of Fish and Game unpublished data).

The 2007 passage estimate of 228,055 fish was 124% of the average from 1995 - 2006, and was the fourth highest estimate to date (Figure 8). Preliminary data from other fall chum salmon enumeration projects in the upper Yukon River drainage during 2007 were variable, ranging from below to above average (Alaska Department of Fish and Game unpublished data). Some of these estimates may have been impacted by the later than average run timing, where, potentially, a larger proportion of fish may have passed after cessation of the project than would have during a year with average timing.

The observed presence/absence of diel patterns in upriver fish passage were similar to patterns seen during previous years (Daum and Osborne 1998; Osborne and Melegari 2006). During most years, the left bank has had a strong diel pattern, while the right bank generally displays a weaker, or no, diel pattern. The fact that these similar patterns were observed at the new locations, where the physical conditions of the river on the right bank more closely resemble those of the old split-beam left bank location, indicates that factors other than in-river physical conditions may be influencing the diel patterns.

The pattern of right bank counts being higher than left bank counts has been observed during all years of split-beam operation (Appendix 1). However, the difference during 2007 was greater than other years. Right bank counts accounted for 86% of the total in 2007, while the average (1995 - 2006) proportion of the total that was counted on right bank was 69% (range 57 - 81%). This could be due to natural variation, or changing river conditions. The differences in counts during recent years of the project have generally tended to be larger and a little more variable than during the earlier years of the project. Another possible reason for the larger differences in counts could be the relocation of the site 150 – 200 m down river. A larger proportion of the fish may be migrating on the right bank at this location. There is a sand/gravel bar that 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.

Fish range data collected with the DIDSONs were similar to data collected during previous years with the split-beam sonar and suggested that most upriver fish passing the sonar site were 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 mainstem 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.

Conclusions / Recommendations

The DIDSON performed well and allowed operation during high water that would have delayed split-beam deployment. Less down time resulted in fewer adjustments to raw counts, which should correspond to more accurate passage estimates. With this ability to maintain DIDSON operations at the new locations during high water levels that would have interrupted operations at the past split-beam sites, precision of future estimates should also increase.

In the past, video monitoring and beach seining have been used with the split-beam sonar to evaluate sonar performance and the presence of non-target species. In 2007, neither evaluation method was used. This allowed operations to focus on the best implementation of counting with DIDSON, integration of wireless technology, and working towards integrating solar power stations. In addition, both methods of sampling to determine species presence are greatly impacted by water conditions and may only provide qualitative data. However, they do provide beneficial information with little to no additional costs, and should be implemented during future years as conditions allow.

Annual sonar enumeration of fall chum salmon in the Chandalar River is an important component for effectively managing Yukon River fisheries and should continue. The Chandalar River fall chum salmon stock is a key 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. 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 13 year time series. Time series data such as these will become increasingly important for investigating the impacts of climate change on fisheries in the Yukon River drainage.

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Table 1. — Hydroacoustic data collected at the Chandalar River, 2007. * indicate days where data were not collected due to wireless network problems.

	Left bank			Right bank			Combined		
Date	Sample time (h)	Upriver count	Downriver count	Sample time (h)	Upriver count	Downriver count	Sample time (h)	Upriver count	Downriver count
8-Aug	0.00*			23.35	186	8	23.35	186	8
9-Aug	0.00*			21.93	234	1	21.93	234	1
10-Aug	10.90	82	4	20.03	282	8	30.93	364	12
11-Aug	22.98	167	11	23.98	365	8	46.96	532	19
12-Aug	23.97	162	15	23.99	466	5	47.96	628	20
13-Aug	23.98	144	8	23.98	360	9	47.96	504	17
14-Aug	22.98	132	4	23.99	372	21	46.97	504	25
15-Aug	23.84	152	3	23.99	399	25	47.83	551	28
16-Aug	23.98	105	9	23.99	467	11	47.97	572	20
17-Aug	23.98	180	13	23.99	494	13	47.97	674	26
18-Aug	23.98	208	8	23.99	578	30	47.97	786	38
19-Aug	23.98	151	11	23.99	440	13	47.97	591	24
20-Aug	23.98	139	6	23.99	357	7	47.97	496	13
21-Aug	23.98	127	3	23.99	327	1	47.97	454	4
22-Aug	23.87	79	8	23.99	358	13	47.86	437	21
23-Aug	23.98	83	5	23.99	336	17	47.97	419	22
24-Aug	23.98	58	2	23.99	369	16	47.97	427	18
25-Aug	23.98	69	4	23.99	339	11	47.97	408	15
26-Aug	23.98	50	7	23.99	286	12	47.97	336	19
27-Aug	23.83	55	11	23.99	326	20	47.82	381	31
28-Aug	22.98	55	11	23.99	361	10	46.97	416	21
29-Aug	23.98	38	7	23.99	420	9	47.97	458	16
30-Aug	22.87	62	7	23.99	410	8	46.86	472	15
31-Aug	22.44	65	14	23.99	484	19	46.43	549	33
1-Sep	23.98	100	13	23.99	797	8	47.97	897	21
2-Sep	23.89	71	10	23.98	922	11	47.87	993	21
3-Sep	23.98	127	10	23.99	1,530	54	47.97	1,657	64
4-Sep	19.57	230	7	23.99	2,674	23	43.56	2,904	30
5-Sep	23.86	499	11	23.99	4,584	46	47.85	5,083	57
6-Sep	23.98	867	18	23.99	5,868	9	47.97	6,735	27
7-Sep	23.98	1,474	20	23.99	8,196	26	47.97	9,670	46
8-Sep	23.98	2,982	10	23.99	10,147	17	47.97	13,129	27
9-Sep	15.99	2,107	6	23.99	11,346	53	39.98	13,453	59
10-Sep	23.98	984	26	23.99	13,578	39	47.97	14,562	65
11-Sep	23.98	1,419	20	23.99	16,325	63	47.97	17,744	83
12-Sep	23.98	2,458	21	23.99	14,599	31	47.97	17,057	52
13-Sep	23.98	1,045	22	23.99	14,877	54	47.97	15,922	76
14-Sep	21.25	1,770	13	23.99	14,454	30	45.24	16,224	43
15-Sep	23.98	1,529	21	23.99	11,861	53	47.97	13,390	74
16-Sep	15.28	777	23	23.99	11,487	51	39.27	12,264	74
17-Sep	23.98	1,414	46	23.99	9,953	43	47.97	11,367	89
18-Sep	23.18	708	77	23.99	6,195	72	47.17	6,903	149
19-Sep	23.97	1,037	88	23.99	4,649	93	47.96	5,686	181
20-Sep	23.98	758	56	23.99	3,883	86	47.97	4,641	142
21-Sep	23.97	563	53	23.99	3,032	95	47.96	3,595	148
22-Sep	23.97	436	92	23.99	2,925	229	47.96	3,361	321
23-Sep	23.98	479	72	23.99	3,621	156	47.97	4,100	228
24-Sep	23.98	688	170	23.99	3,408	237	47.97	4,096	407
25-Sep	23.98	910	267	23.99	3,403	404	47.97	4,313	671
26-Sep	12.39	464	45	12.39	1,876	115	24.78	2,340	160
Totals	1,095.44	28,259	1,388	1,181.21	195,206	2,393	2,276.65	223,465	3,781

Table 2. — Daily upriver passage estimates at the Chandalar River, 2007. * indicate data estimated from opposite bank using ratio estimator.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative %
8-Aug	78*	191	269	269	0.12
9-Aug	109*	266	375	644	0.28
10-Aug	223	328	551	1,195	0.52
11-Aug	188	365	553	1,748	0.77
12-Aug	162	466	628	2,376	1.04
13-Aug	144	360	504	2,880	1.26
14-Aug	150	372	522	3,402	1.49
15-Aug	154	399	553	3,955	1.73
16-Aug	105	467	572	4,527	1.99
17-Aug	180	494	674	5,201	2.28
18-Aug	208	578	786	5,987	2.63
19-Aug	151	440	591	6,578	2.88
20-Aug	139	357	496	7,074	3.10
21-Aug	127	327	454	7,528	3.30
22-Aug	79	358	437	7,965	3.49
23-Aug	83	336	419	8,384	3.68
24-Aug	58	369	427	8,811	3.86
25-Aug	69	339	408	9,219	4.04
26-Aug	50	286	336	9,555	4.19
27-Aug	55	326	381	9,936	4.36
28-Aug	56	361	417	10,353	4.54
29-Aug	38	420	458	10,811	4.74
30-Aug	66	410	476	11,287	4.95
31-Aug	72	484	556	11,843	5.19
1-Sep	100	797	897	12,740	5.59
2-Sep	71	923	994	13,734	6.02
3-Sep	127	1,531	1,658	15,392	6.75
4-Sep	290	2,675	2,965	18,357	8.05
5-Sep	499	4,587	5,086	23,443	10.28
6-Sep	868	5,871	6,739	30,182	13.23
7-Sep	1,475	8,201	9,676	39,858	17.48
8-Sep	2,984	10,153	13,137	52,995	23.24
9-Sep	3,600	11,352	14,952	67,947	29.79
10-Sep	985	13,586	14,571	82,518	36.18
11-Sep	1,420	16,334	17,754	100,272	43.97
12-Sep	2,460	14,607	17,067	117,339	51.45
13-Sep	1,046	14,885	15,931	133,270	58.44
14-Sep	1,936	14,462	16,398	149,668	65.63
15-Sep	1,531	11,868	13,399	163,067	71.50
16-Sep	1,279	11,493	12,772	175,839	77.10
17-Sep	1,415	9,959	11,374	187,213	82.09
18-Sep	736	6,198	6,934	194,147	85.13
19-Sep	1,038	4,652	5,690	199,837	87.63
20-Sep	759	3,885	4,644	204,481	89.66
21-Sep	564	3,034	3,598	208,079	91.24
22-Sep	437	2,927	3,364	211,443	92.72
23-Sep	479	3,623	4,102	215,545	94.51
24-Sep	689	3,410	4,099	219,644	96.31
25-Sep	911	3,405	4,316	223,960	98.20
26-Sep	750	3,345	4,095	228,055	100.00
Totals	31,193	196,862	228,055		

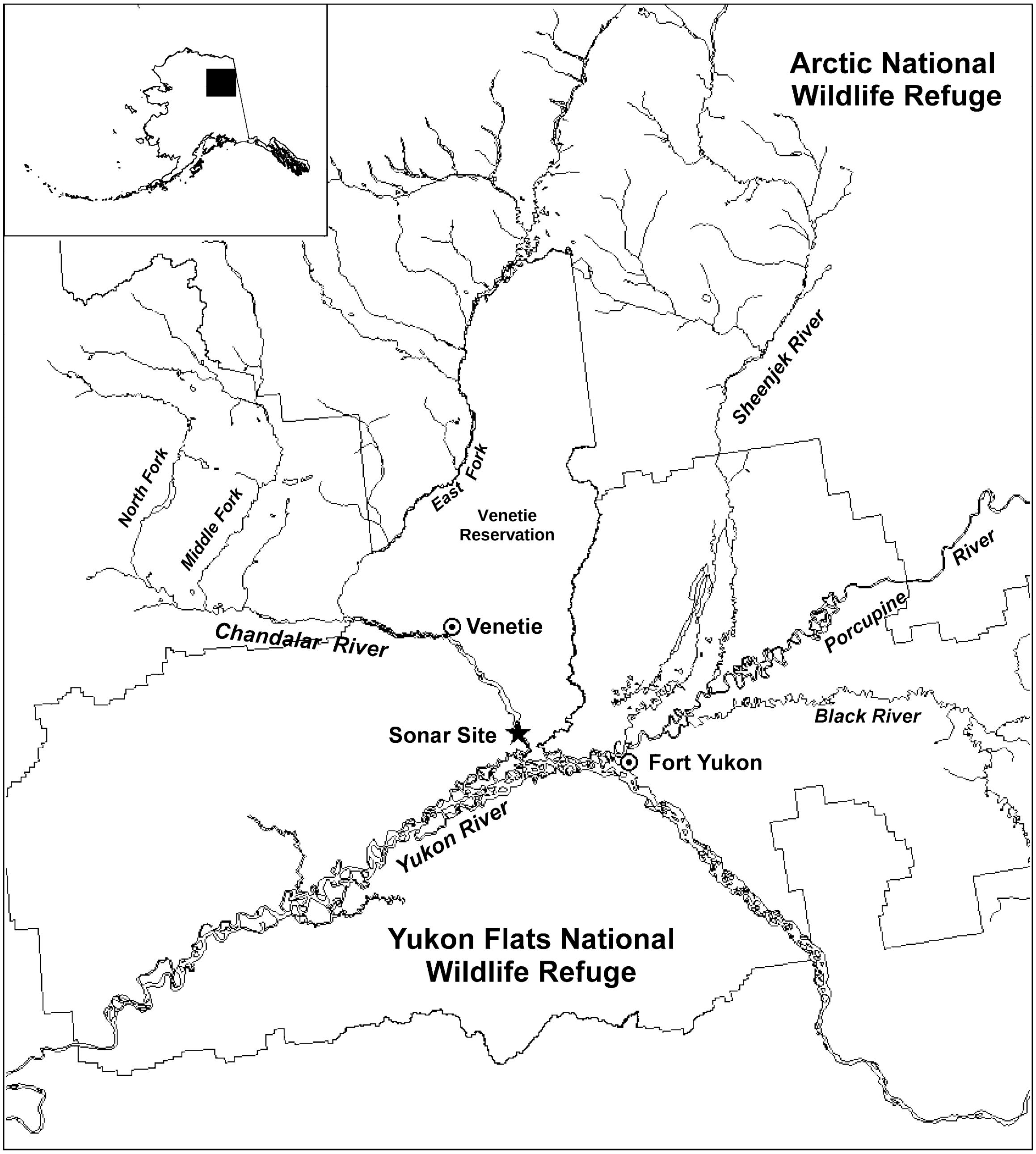

Figure 1. — Sonar site and major tributaries of the Yukon River near U.S. Canada border.

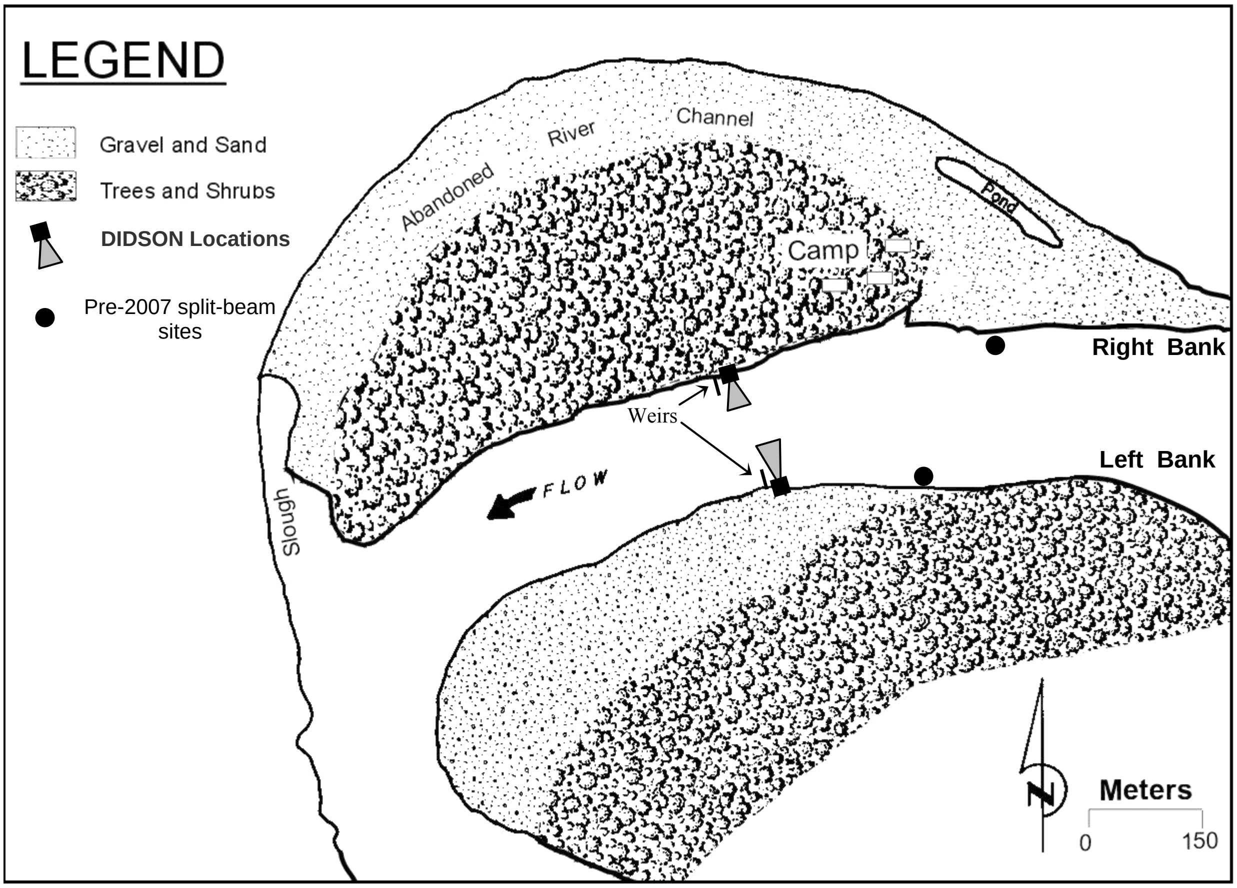

Figure 2. — Site map of Chandalar River sonar facilities.

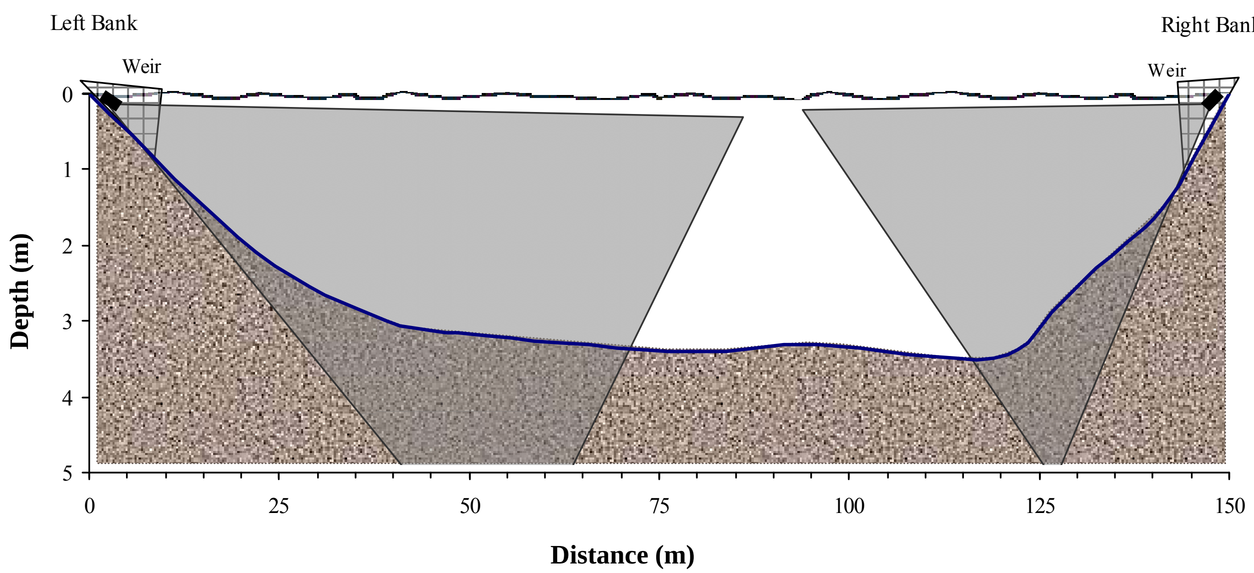

Figure 3. — River channel profile and approximated ensonified zones for the left and right bank sonar sites, Chandalar River, 2007. Different axis scales are used to enhance readability.

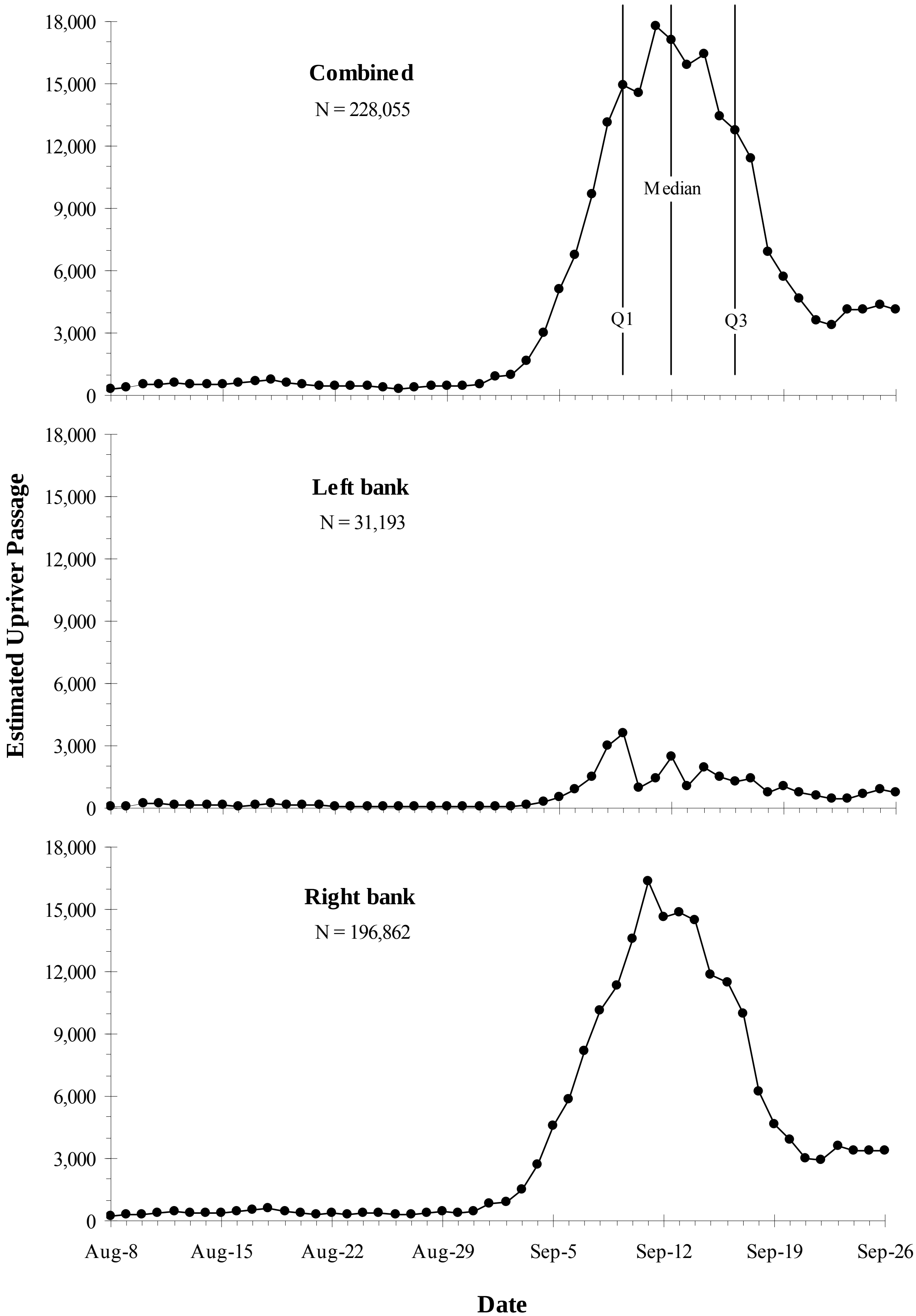

Figure 4. — Estimated passage of upriver fall chum salmon by bank and combined, Chandalar River, 2007. Daily counts were estimated using the ratio estimator method for the first 2 days on the left bank. Vertical lines in top graph indicate the 1st quartile, median, and 3rd quartile passage dates.

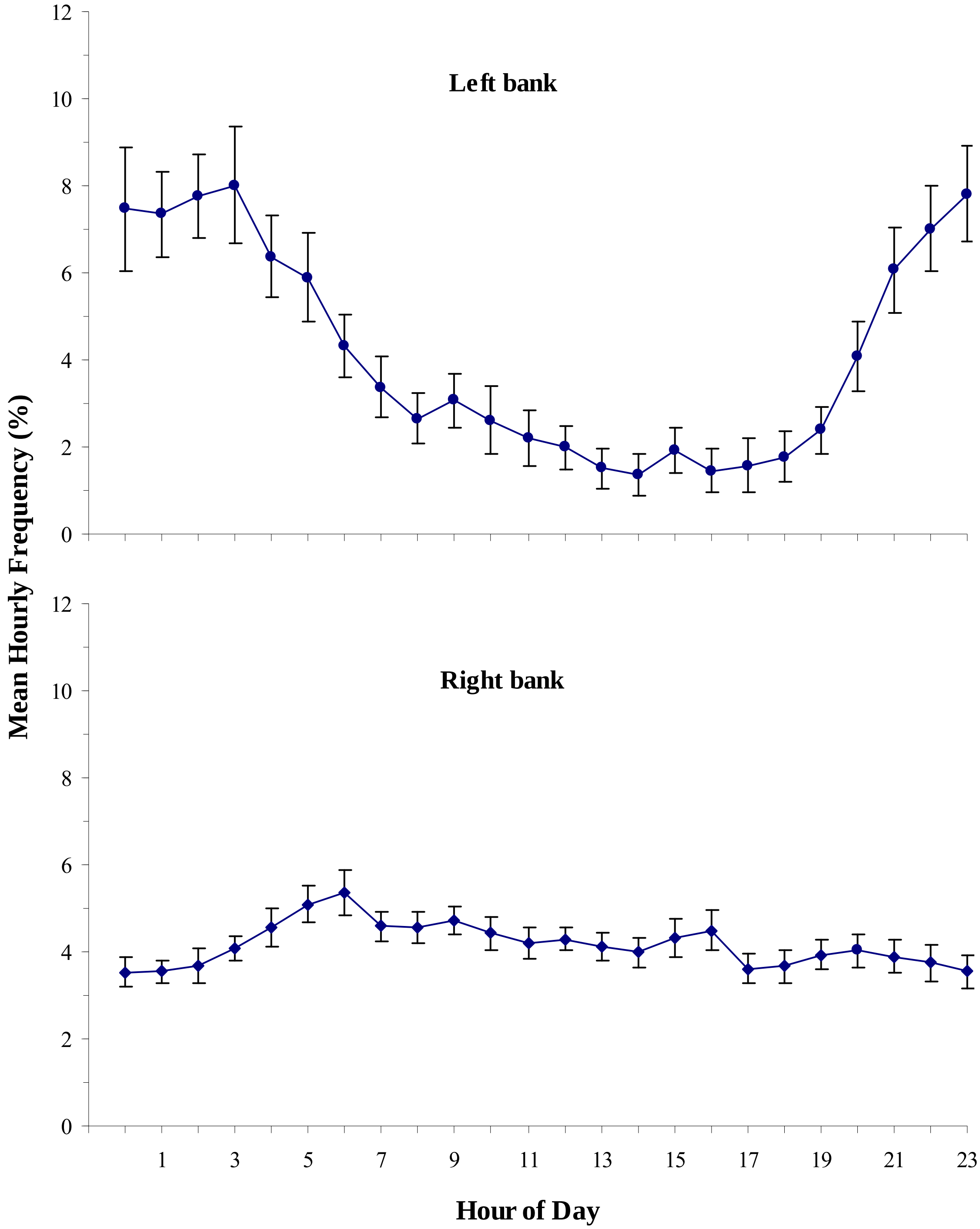

Figure 5. — Mean (±2 SE) hourly frequency of upriver fish, Chandalar River, 2007. Data from 38 complete days of 24 hour data on the left bank and 49 days on the right bank.

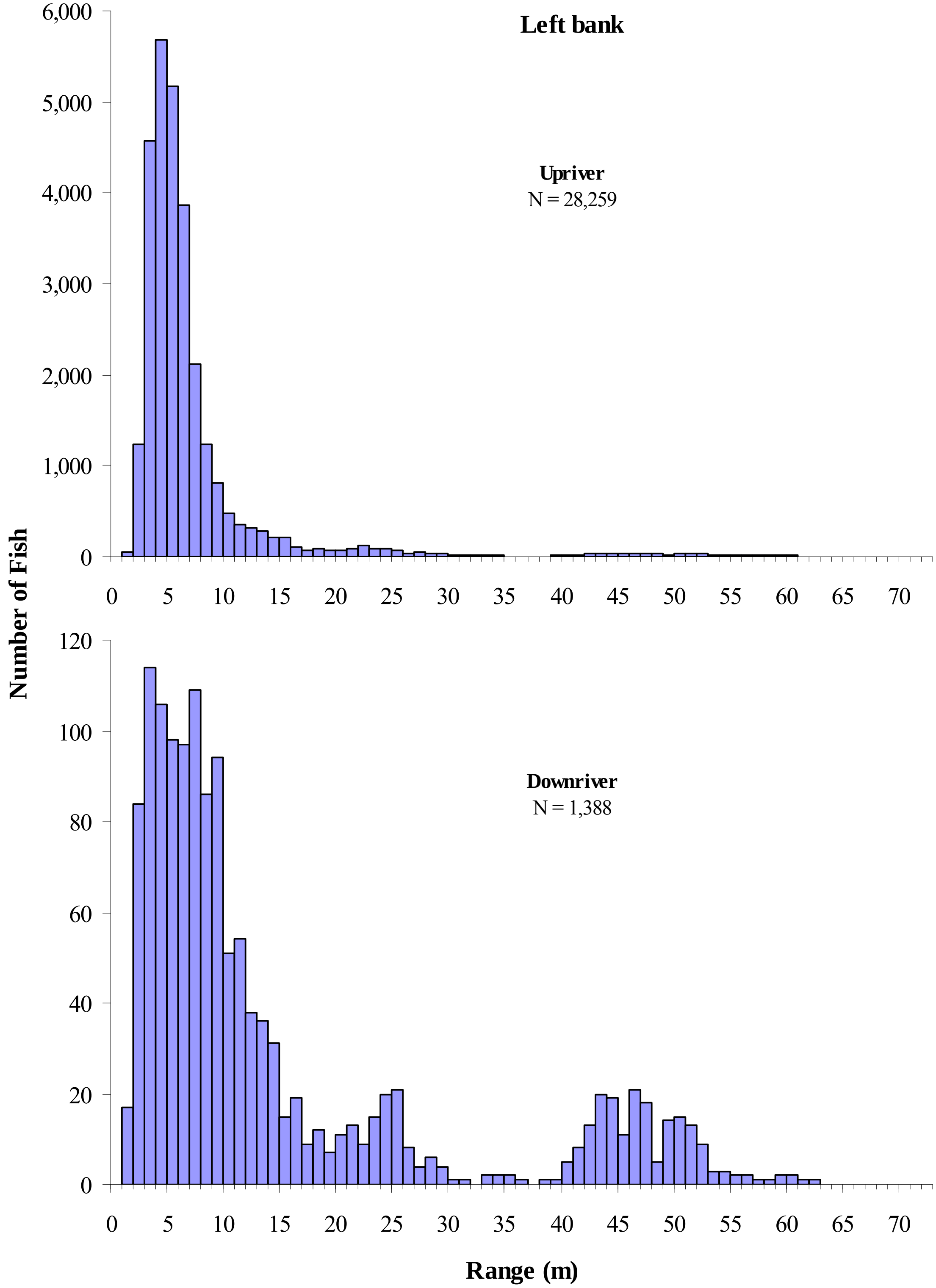

Figure 6. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the left bank Chandalar River, August 10 to September 26, 2007. Note different Y-axis scales.

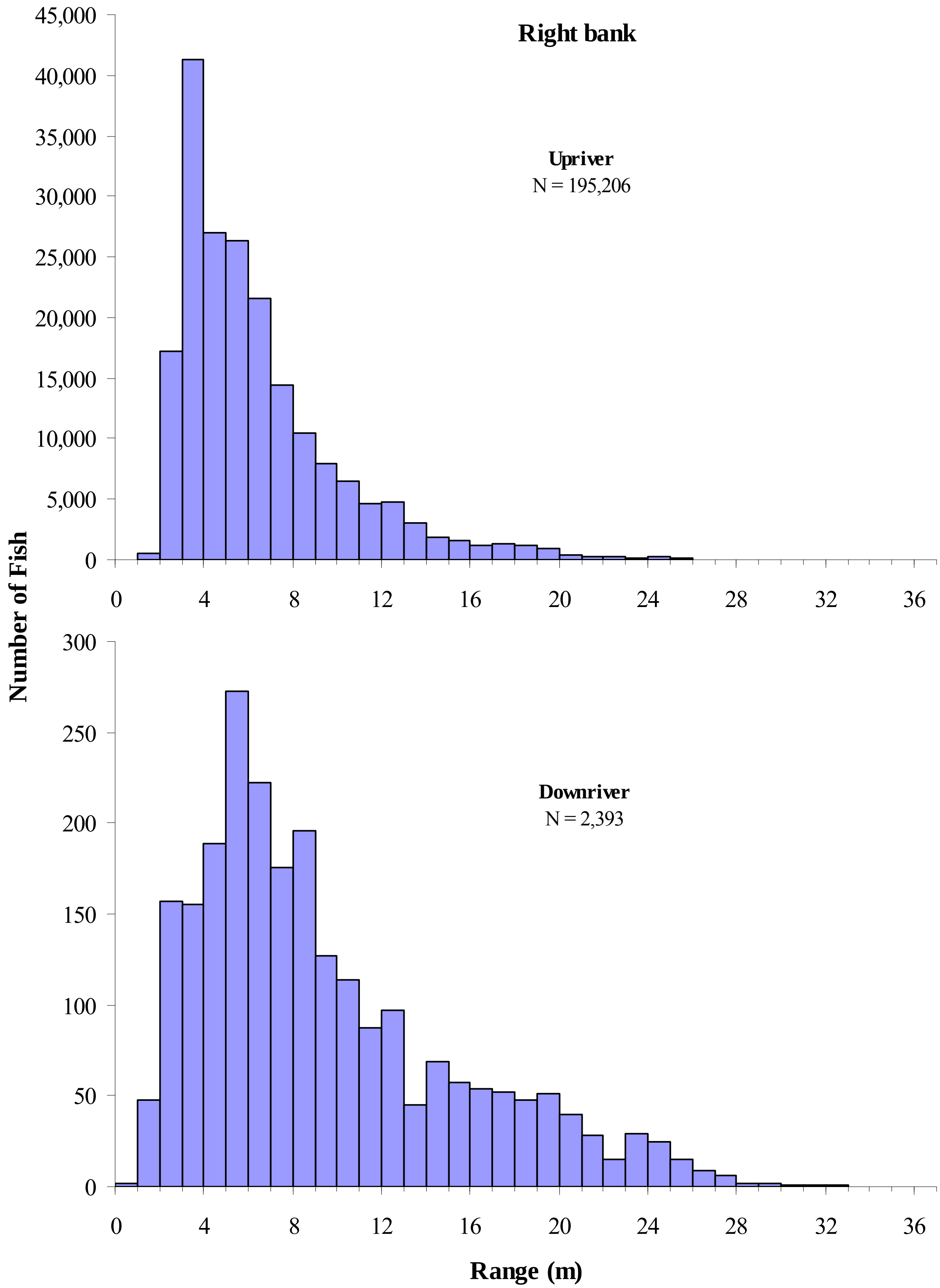

Figure 7. — Range (horizontal distance from DIDSON) distribution of upriver and downriver fish, from hydroacoustic data collected on the right bank Chandalar River, August 8 to September 26, 2007. . Note different Y-axis scales.

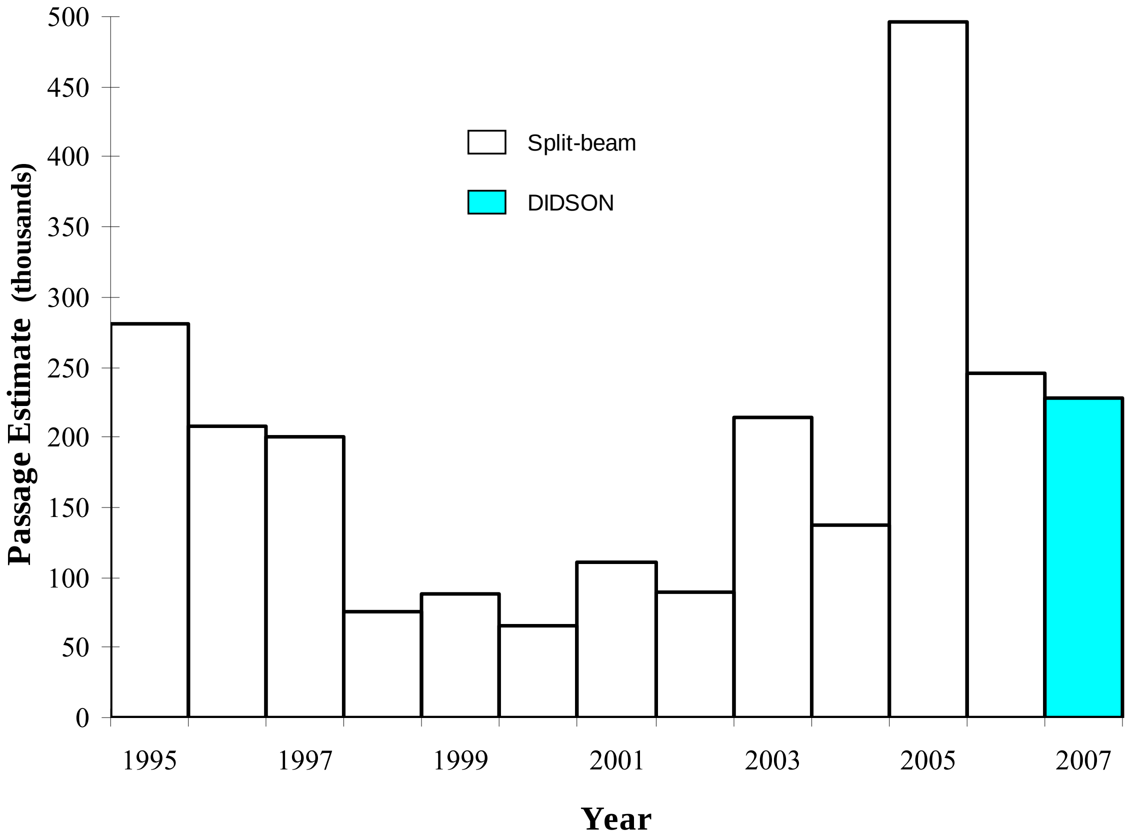

Figure 8. — Annual passage estimates (in thousands of fish) of fall chum salmon from sonar counts on the Chandalar River, 1995 - 2007.

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	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

Appendix 2. — Water staff gauge readings taken at the Chandalar River Sonar project, 2007.

Date	Gauge height	Date	Gauge height
8/8/2007	5.5	9/2/2007	4.28
8/9/2007	5.66	9/3/2007	4.2
8/10/2007	5.32	9/4/2007	4.06
8/11/2007	4.74	9/5/2007	4.06
8/12/2007	4.31	9/6/2007	4.02
8/13/2007	3.8	9/7/2007	3.94
8/14/2007	5.85	9/8/2007	3.89
8/15/2007	5.63	9/9/2007	3.83
8/16/2007	5.59	9/10/2007	3.79
8/17/2007	5.86	9/11/2007	3.78
8/18/2007	6.24	9/12/2007	3.75
8/19/2007	6.38	9/13/2007	3.72
8/20/2007	6.5	9/14/2007	3.7
8/21/2007	6.35	9/15/2007	3.7
8/22/2007	6.1	9/16/2007	3.84
8/23/2007	5.85	9/17/2007	NA
8/24/2007	5.63	9/18/2007	3.92
8/25/2007	5.44	9/19/2007	3.98
8/26/2007	5.25	9/20/2007	4.1
8/27/2007	5.06	9/21/2007	4.08
8/28/2007	4.89	9/22/2007	3.89
8/29/2007	4.73	9/23/2007	3.88
8/30/2007	4.59	9/24/2007	3.72
8/31/2007	4.46	9/25/2007	3.6
9/1/2007	4.36		