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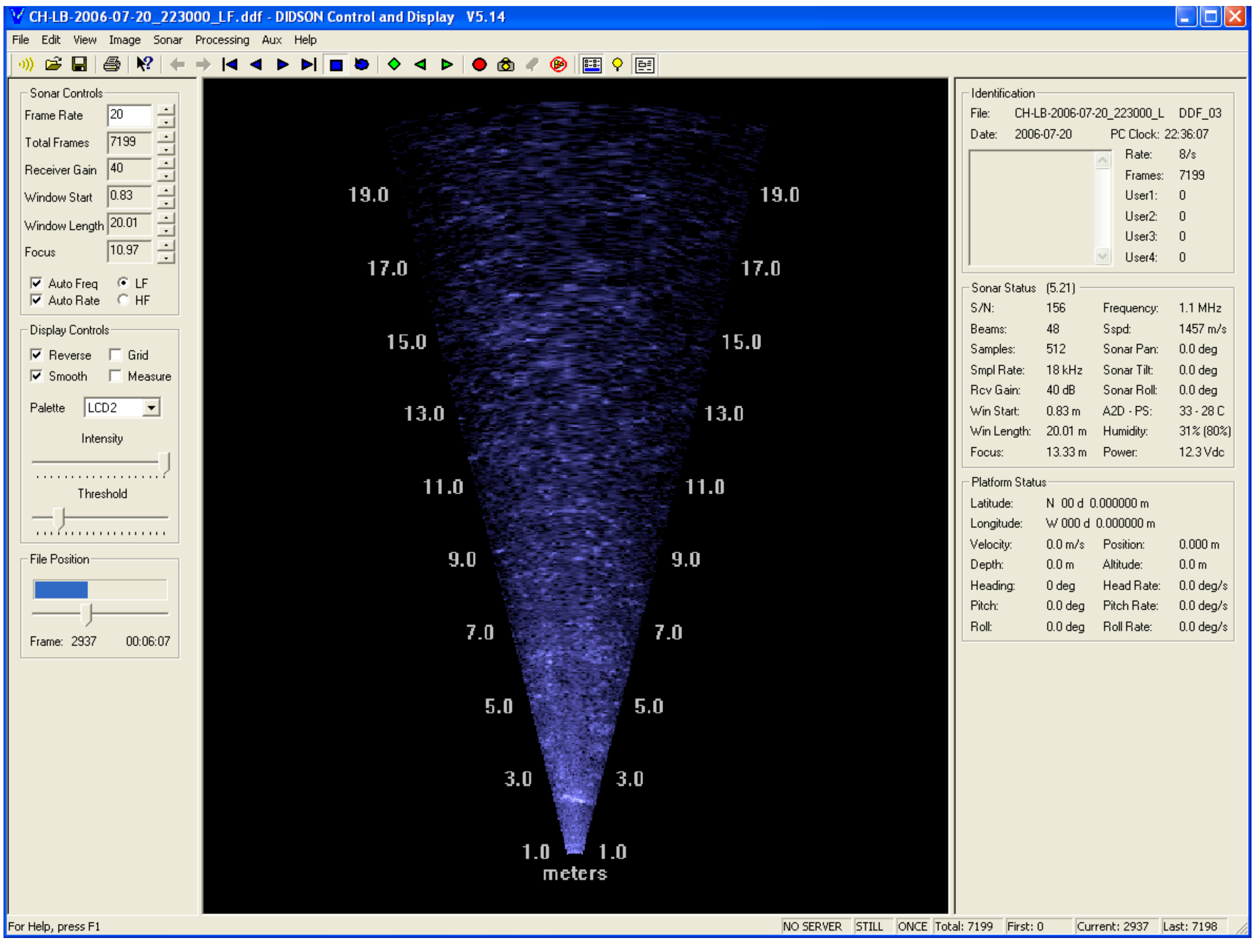

Fairbanks Fish and Wildlife Field Office
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Evaluation of Sonar for Enumeration of Chinook Salmon in the Chandalar River, Yukon Flats National Wildlife Refuge, Alaska, 2004 - 2006

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Abstract

We evaluated the potential for using fixed-location sonar to estimate Chinook salmon *Oncorhynchus tshawytscha* abundance in the Chandalar River, Alaska. Two types of sonar were evaluated: Dual Frequency Identification Sonar and split-beam sonar. Site evaluation was completed during 2004. During 2005, 1,433 hours (64% of the possible hours) of DIDSON data were collected, resulting in an upriver swimming fish count of 5,591. During 2006, 1,372 hours (75% of the possible hours) of data were collected with split-beam sonar, and 1,527 hours (84% of the possible hours) with DIDSON, providing two independent counts of upriver swimming fish, 13,822 for split-beam sonar and 32,609 for DIDSON. The majority of the missed time during both years was a result of high water. Fish were shore oriented. Hourly passage rates of upriver fish showed a diel pattern at most of the deployment locations, with more fish passing in the morning and evening hours. Beach seining and gill netting indicated that chum salmon *O. keta* and Chinook salmon were present in the river during July. We were unable to distinguish between the different salmon species present using DIDSON or split-beam sonar; therefore, we were unable to obtain an accurate estimate of Chinook salmon abundance.

Introduction

The Yukon River flows 3,700 km through Canada and Alaska, draining an area of roughly 854,700 km^2 (Daum and Osborne 1995; Vania et al. 2002). The Yukon River contains all five North American species of Pacific salmon *Oncorhynchus* spp., and is one of the largest producers of wild Chinook salmon *O. tshawytscha* in North America. The Chandalar River is a major tributary to the upper Yukon River, draining roughly 29,000 km^2, and flowing south 460 km from the Brooks Range through the Yukon Flats National Wildlife Refuge. The Chandalar River supports three species of Pacific salmon, with chum salmon *O. keta* being the most abundant, followed by Chinook salmon, and coho salmon *O. kisutch*.

Two distinct races of chum salmon, summer and fall, are present in the Yukon River and many of its tributaries. Fall chum salmon, which account for the majority of the chum salmon returning to the Chandalar River, begin arriving in late July/early August (Melegari and Osborne 2007). Summer chum salmon, while not as abundant, have been intermittently observed in the Chandalar River and were recorded in the river during a telemetry feasibility study during July 1987 (USFWS, unpublished data). While Chinook salmon are known to spawn in the Chandalar River, their actual abundance is unknown.

Chinook salmon, and other salmon species, support important subsistence and commercial fisheries throughout the drainage. Chinook salmon populations in the Yukon River experienced weak returns beginning in 1998, with the 2000 run the lowest on record (Lingnau and Bergstrom 2003). Population declines during this time period led to harvest restrictions, fishery closures,

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and spawning escapements that were below management goals (Kruse 1998). Returns showed improvement beginning in 2001 and continuing through 2005 (JTC 2006). In-season fisheries managers' interest in the abundance of Chinook salmon in the Chandalar River increased when telemetry data from a basin-wide Chinook salmon radio tagging project initiated in 2002 (Eiler et al. 2004) suggested that more Chinook salmon may spawn in the Chandalar River than previously thought.

An accurate assessment of the abundance of Chinook salmon in the Chandalar River would assist with the management of subsistence and commercial harvests in the Yukon River. The large size of the Chandalar River, low visibility caused by turbid water, and fluctuating flows preclude many sampling techniques commonly used to estimate daily fish passage, such as weirs or counting towers. Under such conditions sonar can often be used to estimate fish passage and the Fairbanks Fish and Wildlife Field Office has been enumerating fall chum salmon on the Chandalar River using split-beam sonar since 1994.

A multi-year study (2004 - 2006) evaluating the feasibility of enumerating Chinook salmon using sonar was conducted. Although split-beam sonar has been used successfully on the Chandalar River, a newer sonar technology, Dual Frequency Identification Sonar (DIDSON) has been developed (Belcher et al. 2001; Belcher et al. 2002), and was used for this study. DIDSON offers advantages over the split-beam sonar, including: deployment over a wider range of site conditions; a more straightforward visual image is produced; less training for technicians is required; 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.

The objectives of the study were to: (1) locate and evaluate potential sites for DIDSON deployment, (2) install and operate DIDSON units at the sites identified, (3) evaluate the ability to count fish throughout the variable river conditions during the entire Chinook salmon run at the selected sites and, (4) evaluate the potential to differentiate Chinook salmon from other species. After the 2005 season, the objectives were modified to include evaluating the feasibility of using split-beam sonar as well as DIDSON. The goal of the project remained to evaluate the ability to enumerate Chinook salmon, and not to evaluate the reasons for the differences of the counts produced by the different technologies.

Study Area

The Chandalar River is a fifth-order tributary of the Yukon River (Strahler 1957), with headwaters in the southern slopes of the Brooks Range. It consists of three major branches: East, Middle, and North Forks (Figure 1). The lower 19 km of the Chandalar River is influenced by a series of slough systems connected to the Yukon River. Upriver of this area, 21 to 22.5 km from its confluence with the Yukon River, the Chandalar River is confined to a single channel with alternating cut-banks and large gravel bars. Beyond 22.5 km, the river becomes braided with multiple channels. The split-beam sonar project has operated at 21.5 km of the Chandalar River (at approximately N66° 42' 2", W146° 2' 30") since 1994 to enumerate fall chum salmon (Figure 1).

The ongoing chum salmon split-beam sonar site was assumed to be unfavorable for enumerating Chinook salmon with DIDSON due to the river width at that site. DIDSON has limited range and Chinook salmon tend to swim in deeper water (Burwen et al. 1995; Miller et al. 2004) farther offshore than chum salmon (Melegari and Osborne 2007). In 2005, we selected a DIDSON site approximately 300 - 400 m upriver of the ongoing split-beam sonar site, where the river is divided into two channels by an island (Figure 2). The left channel (facing downriver) was approximately 30 m wide when surveyed (water flow was moderate to low at the time of survey), and the right channel was 80 - 90 m wide. Faster current in these narrower channels led to unforeseen problems during high water. Therefore, in 2006, the DIDSON units were relocated and operated at or near the established fall chum salmon split-beam sonar locations (Osborne and Melegari 2006).

Methods

Sonar Equipment and Deployment

In 2004, several sites were investigated for potential deployment of DIDSON near the vicinity of the established fall chum salmon split-beam sonar enumeration study site (Daum and Osborne 1999). Site requirements included: location below known spawning areas; the absence of turbulent flow; gradual sloping bottom profile without sudden inflections; a lack of large obstructions that would impede fish detection; and channel width narrow enough to allow as complete coverage as possible with DIDSON. Potential sites were evaluated by taking width measurements of the channel(s) with a laser rangefinder and by recording river bottom profiles. Bottom profiles were recorded by completing transects perpendicular to the flow with a Lowrance X16 chart recording depth sounder. Several profiles were recorded at each deployment location and the sonar units were deployed at the river bottom profiles considered best for counting fish with the sonar. Transects were completed each year before deployment to detect any changes in the river bottom profiles.

The DIDSON system is a high frequency, 12° X 29° multiple beam sonar developed by the University of Washington’s Applied Physics Laboratory (APL) (Belcher et al. 2001; Belcher et al. 2002). Two models are available. The standard DIDSON operates at frequencies of 1.8 or 1.1 MHz and for our application has an effective range of approximately 30 m. The long range version operates at frequencies of 1.2 MHz or 700 kHz with an effective range of 50 - 60 m. During this project both DIDSON models were operated in the low frequency mode (1.1 MHz for the standard, and 700 kHz for the long range). DIDSON specifications are available in Appendices 1 and 2 and the DIDSON operation manual V5.02 (APL 2006). The DIDSON units were deployed in fixed locations in the river, and communicated with laptop computers for control and data management.

The split-beam sonar systems consisted of two Hydroacoustic Technology, Inc. (HTI) 200-kHz split-beam echo sounders/processors with elliptical-beam transducers (4.8° x 10.8° on the left bank, and 2.1° x 9.7° on the right bank). Each system included a 150 m transducer cable, chart recorder, oscilloscope, and data analysis computer. Specific component descriptions and operations are detailed in HTI manuals (HTI 1994a, 1994b). Setup, operations, and all sonar settings were the same as those used during the fall chum salmon enumeration project (Daum and Osborne 1998; Melegari and Osborne 2007).

The DIDSON units and split-beam transducers were mounted to aluminum frames with remote controlled duel axis underwater rotators and were oriented perpendicular to river flow. The rotators allow vertical and horizontal adjustments for aiming. Due to the bottom orientation of migrating salmon, beams were aimed or fitted as close as possible to the river bottom to prevent fish passing undetected by swimming below the beams. 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 verifying that the targets were detected by the sonar. Horizontal aim was checked by "sweeping" the transducer/DIDSON across the target with the rotator, and/or drifting targets through the beams.

Three DIDSONs, two standard and one long range, were used during 2005. Two DIDSONs were installed on the island, one monitoring the left channel, and the long range DIDSON monitoring a portion of the right channel. The third was installed on the right bank across from and slightly upriver of the long range DIDSON (Figure 2). The left channel DIDSON began counting on June 30, and both the right bank and right channel began counting on July 1. Partial weirs were installed to direct fish through the beams.

Split-beam sonar systems were used in addition to DIDSONs during the 2006 Chinook salmon run. The split-beam sonar systems were operated at their established fall chum salmon locations. Operations began on the left bank on July 1 and the right bank operations were delayed until July 9, due to high water. One DIDSON was deployed at the established fall chum salmon split-beam sonar left bank site next to the split-beam sonar and began counting on July 1, and the other DIDSON was deployed at a site on the right bank approximately 150 m below the established fall chum salmon split-beam sonar site (Figure 2).

Data Collection and Analysis

The sonar systems were operated 24 hours per day, except for intermittent periods for maintenance or repairs, and during high water. DIDSON data were collected in 15 minute sample periods and saved to files on external hard drives. Two drives were used with each DIDSON unit and were rotated daily between the DIDSON location and camp where the data were analyzed. Data were analyzed using the DIDSON control and display software (version 4.53). Data files were examined in echogram view. Potential targets were further evaluated by playing that section of data in normal view to verify the target was a fish and direction of travel. Data from these files were exported to ASCII files, which were compiled and summarized using a Microsoft excel Visual Basic for Applications macro. Split-beam sonar data were collected and analyzed using the same software (Trakman) and protocols as used during the fall chum salmon enumeration project (Daum and Osborne 1998; Melegari and Osborne 2007).

Species Evaluation

The ability to distinguish between fish species being detected is necessary in a sonar project where multiple species are present and the objective is to enumerate a specific species. This can be straightforward if the different species are isolated either spatially or temporally. When this is not the case, distinguishing between the different species with the sonar becomes increasingly difficult or impossible as the differences in size, shape, and/or behavior decrease. Chinook salmon and chum salmon are known to be present for some of the same time period and possess considerable overlap in size and shape. Also, considerable overlap in behavior and spatial distributions of these species was expected.

Beach seines as well as set and drift gill nets were deployed to identify what species were present during sonar operation. The beach seines used were 90.0 m x 3.7 m with 2.5 cm stretch mesh. Gill nets were 18.3 m x 3.0 m with 15.0 cm stretch mesh during 2005, and 18.3 m x 3.0 m with 11.4 cm, 15.0 cm, and 21.0 cm stretch mesh during 2006. Only set gill netting was conducted during 2006 due to the numerous snags throughout most of the river that impeded drift netting during 2005. All gill net sets were monitored continually for the duration of the set in an effort to minimize stress to captured fish. Catch per unit effort (CPUE) was calculated as number of fish caught per hour. High water and turbidity precluded the use of video cameras for species validation (Osborne and Melegari 2001) during 2005 and 2006.

Our efforts focused on using DIDSON to attempt to distinguish species with sonar because previous experience with the split-beam sonar indicated that confidently differentiating species that do not have significant differences in size, behavior and/or spatial distributions has been problematic. The DIDSON data were evaluated for patterns in diel or range distributions, or distinguishable size groupings that could be indicative of different species. Any discerned patterns were compared to net catches.

Results

Sonar Equipment and Deployment

During 2004, several sites were explored and a location which met the criteria was chosen where the river is divided into two channels by an island. This site was chosen because we believed the narrower channels would allow more complete coverage with the DIDSON.

Enumeration began on July 1, 2005. Water levels and current began increasing soon after deployment, resulting in an inability to keep the aluminum frames and DIDSON units firmly anchored. Due to the high water, operations were interrupted at the right bank site after July 3. Right channel and left channel operations were interrupted after July 4 and July 5 respectively. The right channel and left channel were redeployed on July 7. The right bank location was not redeployed until July 16. The aluminum frames and DIDSON units were displaced by the current and had to be repositioned two other times during the season. The right channel location ceased operations on July 25 due to equipment malfunction. The left channel and the right bank DIDSON units were operated until July 31.

Maintaining partial weirs to direct fish through the beams was difficult in the faster current. Therefore, operations were often conducted with limited or no diversion weirs or without the ability to evaluate the effectiveness of the offshore end of the weirs.

In 2006, all sonar units began operation on July 1, except the right bank split-beam sonar, which was unable to be installed until July 9 because of high water. A second period of high water interrupted right bank split-beam sonar operations from July 16 - 24. Right bank DIDSON operations were interrupted due to a failed power supply from July 10 - 14.

Data Collection and Analysis

2005 Season — For the season, 1,433 hours of data (only 64% of the 2,232 possible hours) were collected at all three locations with DIDSON. This resulted in enumeration of 5,591 upriver swimming fish (Table 1; Figure 3). Seventeen full days (408 hours) were missed due to high water. Equipment malfunctions interrupted operations for the final 6 days (144 hours) of the season at the right channel location.

Upriver fish counted with the DIDSON were generally shore oriented, with 78% of all upriver fish within 10 m of the DIDSON units (Figure 4). This trend was greatest at the left channel site, with 90% of upriver fish within 10 m of the DIDSON. For both the right bank and right channel locations, range distributions appeared more dispersed earlier in the season. Weekly range distributions showed no variation for the left channel location.

A diel pattern showing increased counts during night and early morning hours was evident at the right bank and right channel locations, but was less distinguishable at the left channel location (Figure 5).

2006 Season — For the season, 1,372 hours of data were collected with split-beam sonar (Table 2), and 1,527 hours were collected with DIDSON (Table 3), representing 75% and 84% respectively, of the total available hours (from July 1 to August 7). This resulted in enumeration of 13,822 and 32,609 upriver swimming fish for split-beam sonar and DIDSON, respectively (Figure 6).

For split-beam sonar, the left bank was operational for 99% of the season and the right bank for 51%. A total of 17 full days (408 hours) at the right bank was missed due to high water (Table 2). Additionally, partial hours missed due to high water, maintenance, relocating the sonar as water levels changed, or equipment malfunctions totaled 6.34 hours at the left bank and 37.45 hours at right bank. The first eight days (July 1 through July 8) of counting were missed at the right bank (Figure 6).

Upriver fish counted with the split-beam sonar were generally shore oriented, with 90% of upriver fish within 10 m of the left bank transducer and 24 m of the right bank transducer (Figure 7). No discernable trends in range distributions were detected throughout the season at either of the split-beam sonar sites. A diel pattern showing increased counts during night and early morning hours was evident at the left bank but no clear diel pattern was present at the right bank location (Figure 8).

The DIDSONs were operational for 91% and 77% of the season for the left and right banks, respectively. Five full days (120 hours) were missed due to failure of a power supply at the right bank. Additionally, time missed due to maintenance, relocating the sonar as water levels changed, or other equipment malfunctions totaled 83 hours at left bank and 93 hours at the right bank.

Upriver fish counted with the DIDSON were shore oriented, with more than 92% of upriver fish within 10 m of the DIDSON units at both sites (Figure 9). No discernable trends or changes in range distributions were detected throughout the season at either of the DIDSON sites.

Hourly passage rates of upriver fish showed a diel pattern with increased counts during night and early morning hours on the left bank. However, no discernable pattern was evident on the right bank (Figure 10).

Species Evaluation

2005 Season — Conditions for netting were generally poor due to the increased current associated with high water. Additionally, the abundance of submerged logs and snags, and limited room for boat maneuvering contributed to making seining and drift gill netting ineffective near the DIDSON deployment locations. Therefore, netting near the DIDSON sites was discontinued, but some netting was conducted below the fall chum salmon site in a location known to be relatively free of snags. Set netting was conducted at the lower end of the island and at two other locations where we previously captured Chinook salmon to collect genetic samples in 2003 (USFWS, unpublished data).

A total of 28 hours of set net time was completed with no fish being caught (Table 4). Drifts with gill nets were of short duration (2 - 6 minutes), often ending when the net became snagged.

Thirteen drifts were made with the gill net, resulting in no fish being captured, and 12 seine hauls produced no fish during this time period.

2006 Season — Conditions for netting, while better than 2005, were again generally poor due to high water. Seining or drift netting were not conducted. However, increased effort was focused on set gill nets, with 244 hours of sampling time being expended (Table 4). Totals of 48 Chinook salmon (seasonal CPUE = 0.20) and 66 chum salmon (seasonal CPUE = 0.27) were captured. Daily chum salmon CPUE began increasing during the last week of July for both the 11.4 cm and 15 cm mesh nets (Figure 11). Additional species captured in the nets included five humpback whitefish *Coregonus pidschian* and one sheefish *Stenodus leucichthys*.

Discussion

The main goal of this project was to evaluate the potential of sonar for enumeration of Chinook salmon. We successfully deployed DIDSON and split-beam sonar and enumerated fish during the Chinook salmon run. However, the overlap of Chinook salmon and chum salmon during this time, and the inability to distinguish between the two species using sonar, makes it unfeasible to accurately obtain abundance information for either species. Additionally, the amount of time the sonar systems were not operating due to high water, which is likely during this time of the season, presents another obstacle to enumerating Chinook salmon in the Chandalar River.

Site Evaluation and Selection

2005 Season — The river bottom at all three deployment locations was free of any abrupt inflections or large objects that would impede the fish detection ability of the DIDSON. The debris at the far bank of the left channel was near the range limit of the DIDSON and was generally small enough that it was assumed to have a negligible affect on detection ability. River currents, while strong were not turbulent, so fish milling or holding behavior was unlikely. Data show most fish moved steadily through the beam, which supports this hypothesis.

Selecting a site with two narrower channels helped achieve more inclusive coverage of the river; however, there were still some areas not ensonified. Within the left channel, woody debris and brush along the cut bank on the far side made it difficult to evaluate the maximum range in the field. Post season analysis of DIDSON placement, range settings, and distribution of counted targets suggest that approximately 2 - 5 m along the far shore may not have been sampled. On the right channel, only 20 m near the center of the channel was not ensonified. The narrower channels resulted in faster currents and the effects of high water events were amplified. These amplified effects were the main reason for changing site locations in 2006.

2006 Season — Split-beam sonar systems were deployed at the same locations of past deployments for enumerating fall chum salmon (Melegari and Osborne 2007). Performance of the sonar and physical conditions at these locations were as expected from past experience. The right bank DIDSON was deployed at a location downriver of the established split-beam sonar location. This downriver location was previously evaluated as an alternate location for deploying split-beam sonar. While this location may have been marginal for split-beam sonar use, the less stringent site requirements of the DIDSON allowed for successful deployment and enumeration here.

Each DIDSON ensonified about 20 m, leaving approximately 70 - 80 m of the middle of the river unmonitored. However, our data indicate that few salmon use this area of the river for migration. The range distribution data (Figure 9) show that nearly all fish traveled within 10 m of the shore with few fish near the outer limits of the range. If large numbers of fish were migrating up the middle of the river, more fish would be expected to be counted at the farthest ranges.

The right bank DIDSON was approximately 150 m downriver of the left bank DIDSON; and the thalweg changes from being closer to the left bank at the left bank site to being closer to the right bank at the right bank DIDSON site, raising questions of the potential of fish crossing over from one bank to the other between the sites. While the lack of fish at the outer range limits suggests that crossover is minimal, it should be addressed if a long term enumeration project were to be initiated using these two locations.

Data Collection and Analysis

Our data indicate that chum salmon and Chinook salmon are present in the Chandalar River during July. Furthermore, chum salmon may constitute a major proportion of sonar counts, impeding the ability to accurately count Chinook salmon. Based on the condition of chum salmon (degree of coloration, spawning condition, overall condition) captured during netting, fish from both runs of chum salmon are present in the Chandalar River during July. The number of summer chum salmon that spawn in the Chandalar River is assumed to be small and variable. The fall chum salmon run is generally thought to start near the beginning of August. First day counts (August 8 for all years) from 12 years of the fall chum salmon split-beam sonar have ranged from 100 to 2,800.

A fish wheel/video CPUE project was conducted on the main stem Yukon River in an area called the Rapids approximately 404 km downriver of the mouth of the Chandalar River. Using average travel times from tagging data and chum salmon CPUE data from the Rapids video CPUE project for 2005 (Zuray 2005), chum salmon were estimated to begin arriving on the Chandalar River near July 13, with more substantial numbers arriving shortly thereafter. DIDSON counts from the Chandalar River indicate small increases in counts after July 13 at the right and left channel locations and a substantial increase at the right bank location after July 22, consistent with the estimated arrival times. During 2006, chum salmon CPUE data from the Rapids video CPUE project on the Yukon River (Zuray 2006) indicated chum salmon should begin arriving at the Chandalar River on approximately July 16, with more significant numbers arriving around July 26. Sonar counts at the Chandalar River around July 16 were impacted by high water on the right bank, making comparison to Rapids CPUE data less clear. However, available counts showed a steady increasing trend beginning the second week of July.

Species Evaluation

Netting CPUE data indicate that there is an overlap in the timing of the Chinook salmon and chum salmon runs on the Chandalar River (Figure 11). The presence of both species necessitates the ability to distinguish between them with the sonar to accurately enumerate either species.

Analysis of the data did not yield conclusive evidence to assist in distinguishing the species counted with the DIDSON. During 2005, the range distributions of fish at the right bank and right channel locations from earlier in the season were more dispersed than those from later in the season. However, since no such pattern existed at the 2005 left channel location, or any of the locations during 2006, the observed trend was more likely due to coincidence or some other factor, rather than a change in species composition. Except for a grouping of fish that were obviously smaller than salmon, there were no distinguishable size groupings. This, along with the substantial overlap in size ranges of Chinook salmon and fall chum salmon, indicate that the DIDSON is not suitable to differentiate these two species at these sites.

Conclusions

While fish in the Chandalar River can be enumerated using sonar during July, the presence and overlap of runs of Chinook salmon and chum salmon makes it unfeasible to accurately obtain abundance information for either species. Additionally, higher water levels during this time of year increase the likelihood of down-time, further reducing the efficacy of enumerating salmon at this time.

The technology and methods for species discrimination that have been examined to date seem unlikely to provide an accurate means of separating Chinook salmon from chum salmon under present conditions on the Chandalar River. However, species discrimination using acoustics is an ongoing area of study that may be improved in the future.

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Table 1. — DIDSON hydroacoustic data collected from the Chandalar River, 2005.

	Right bank		Right channel		Left channel		Combined	
Date	Sample time (h)	Upriver count	Sample time (h)	Upriver count	Sample time (h)	Upriver count	Sample time (h)	Upriver count
Jul-1	8.69	3	8.94	1	23.93	30	41.56	34
2	23.93	7	23.93	7	22.93	22	70.79	36
3	12.58	3	17.72	4	24.00	14	54.3	21
4	0.00*	-	0.00*	-	8.00	4	8.00	4
5	0.00*	-	0.00*	-	0.00*	-	0.00*	-
6	0.00*	-	0.00*	-	0.00*	-	0.00*	-
7	0.00*	-	8.00	5	8.93	11	16.93	16
8	0.00*	-	23.97	35	10.56	7	34.53	42
9	0.00*	-	23.81	35	23.83	30	47.64	65
10	0.00*	-	23.84	34	23.75	16	47.59	50
11	0.00*	-	23.97	30	11.23	11	35.2	41
12	0.00*	-	23.86	52	9.52	19	33.38	71
13	0.00*	-	23.66	32	23.81	31	47.47	63
14	0.00*	-	17.89	29	22.67	70	40.56	99
15	0.00*	-	8.47	24	23.71	210	32.18	234
16	11.80	63	23.84	62	23.58	229	59.22	354
17	23.96	108	23.85	50	23.77	181	71.58	339
18	23.20	63	23.96	60	23.94	118	71.10	241
19	23.95	89	23.95	46	23.93	174	71.83	309
20	23.75	157	23.94	30	23.75	163	71.44	350
21	17.76	85	23.96	19	23.95	75	65.67	179
22	11.85	30	23.83	20	23.77	71	59.45	121
23	23.84	86	23.94	30	23.96	57	71.74	173
24	23.57	142	23.95	30	24.00	63	71.52	235
25	23.96	216	9.35	14	23.89	42	57.20	272
26	22.98	250	0.00†	-	23.95	57	46.93	307
27	23.87	324	0.00†	-	23.82	38	47.69	362
28	23.96	397	0.00†	-	23.97	42	47.93	439
29	16.44	357	0.00†	-	23.96	78	40.40	435
30	11.61	263	0.00†	-	23.97	100	35.58	363
31	9.90	241	0.00†	-	23.96	95	33.86	336
Total	361.60	2,884	452.63	649	619.04	2,058	1,433.27	5,591

* Sonar not operational due to high water.
† Sonar not operational due to equipment problems.

Table 2. — Split-beam sonar hydroacoustic data collected from the Chandalar River, 2006.

	Left bank		Right bank		Combined	
Date	Sample time (h)	Upriver count	Sample time (h)	Upriver count	Sample time (h)	Upriver count
Jul-1	22.80	4	0.00*	-	22.80	4
Jul-2	23.92	4	0.00*	-	23.92	4
Jul-3	23.24	11	0.00*	-	23.24	11
Jul-4	23.90	12	0.00*	-	23.90	12
Jul-5	23.75	23	0.00*	-	23.75	23
Jul-6	24.00	26	0.00*	-	24.00	26
Jul-7	23.92	22	0.00*	-	23.92	22
Jul-8	24.00	30	0.00*	-	24.00	30
Jul-9	23.96	40	10.91	115	34.87	155
Jul-10	23.98	69	23.98	139	47.96	208
Jul-11	23.96	70	23.98	251	47.94	321
Jul-12	23.96	73	23.96	254	47.92	327
Jul-13	23.78	89	23.98	264	47.76	353
Jul-14	23.94	90	23.00	255	46.94	345
Jul-15	23.94	110	14.39	235	38.33	345
Jul-16	23.96	115	0.00*	-	23.96	115
Jul-17	23.23	49	0.00*	-	23.23	49
Jul-18	23.20	80	0.00*	-	23.20	80
Jul-19	24.00	146	0.00*	-	24.00	146
Jul-20	22.98	215	0.00*	-	22.98	215
Jul-21	23.90	241	0.00*	-	23.90	241
Jul-22	24.00	211	0.00*	-	24.00	211
Jul-23	24.00	258	0.00*	-	24.00	258
Jul-24	24.00	206	0.00*	-	24.00	206
Jul-25	24.00	195	10.78	214	34.78	409
Jul-26	23.64	191	23.96	449	47.60	640
Jul-27	23.98	173	23.98	433	47.96	606
Jul-28	23.87	161	23.96	461	47.83	622
Jul-29	24.00	224	23.98	410	47.98	634
Jul-30	23.98	297	24.00	481	47.98	778
Jul-31	23.98	230	23.98	623	47.96	853
Aug-1	23.98	195	24.00	628	47.98	823
Aug-2	24.00	292	23.96	669	47.96	961
Aug-3	23.96	249	23.98	560	47.94	809
Aug-4	23.97	318	24.00	556	47.97	874
Aug-5	23.98	351	23.81	438	47.79	789
Aug-6	24.00	326	24.00	305	48.00	631
Aug-7	24.00	337	23.96	349	47.96	686
Total	905.66	5,733	466.55	8,089	1,372.21	13,822

* Sonar not operational due to high water.

Table 3. — DIDSON hydroacoustic data collected from the Chandalar River, 2006.

	Left bank		Right bank		Combined	
Date	Sample time (h)	Upriver count	Sample time (h)	Upriver count	Sample time (h)	Upriver count
Jul-1	22.78	21	23.29	14	46.07	35
Jul-2	18.70	20	20.76	11	39.47	31
Jul-3	22.91	41	19.52	60	42.44	101
Jul-4	23.37	86	23.61	115	46.98	201
Jul-5	23.43	81	16.19	48	39.61	129
Jul-6	23.04	47	23.12	45	46.15	92
Jul-7	23.59	48	16.95	27	40.55	75
Jul-8	22.26	47	23.64	79	45.91	126
Jul-9	21.36	107	0.87	3	22.22	110
Jul-10	23.57	177	0.00*	-	23.57	177
Jul-11	23.37	172	0.00*	-	23.37	172
Jul-12	23.55	143	0.00*	-	23.55	143
Jul-13	23.30	143	0.00*	-	23.30	143
Jul-14	23.65	141	0.00*	-	23.65	141
Jul-15	22.30	165	8.39	157	30.69	322
Jul-16	23.68	248	23.52	570	47.20	818
Jul-17	22.93	275	23.75	609	46.67	884
Jul-18	21.58	321	22.90	660	44.48	981
Jul-19	22.72	468	23.57	872	46.29	1,340
Jul-20	23.49	555	23.68	1,006	47.17	1,561
Jul-21	23.49	511	23.90	1,064	47.39	1,575
Jul-22	21.92	399	20.03	851	41.95	1,250
Jul-23	7.16	121	23.78	906	30.94	1,027
Jul-24	11.83	190	15.30	634	27.13	824
Jul-25	23.55	350	23.88	1,140	47.43	1,490
Jul-26	23.53	358	13.36	672	36.89	1,030
Jul-27	23.55	390	23.65	1,195	47.20	1,585
Jul-28	23.03	339	23.78	1,078	46.81	1,417
Jul-29	23.49	304	23.70	1,014	47.19	1,318
Jul-30	22.58	366	23.72	1,034	46.30	1,400
Jul-31	21.86	243	23.78	1,192	45.64	1,435
Aug-1	20.21	222	23.47	1,068	43.68	1,290
Aug-2	15.90	231	23.73	1,179	39.63	1,410
Aug-3	23.70	304	23.59	1,048	47.30	1,352
Aug-4	23.40	394	23.73	1,345	47.13	1,739
Aug-5	22.26	459	23.76	1,363	46.02	1,822
Aug-6	18.18	400	23.70	1,080	41.89	1,480
Aug-7	23.56	469	23.85	1,114	47.41	1,583
Total	828.78	9,356	698.48	23,253	1,527.26	32,609

* Sonar not operational due equipment failure.

Table 4. — Seasonal data from netting on the Chandalar River, 2005 - 2006.

Net	Effort	Chinook catch	Chinook CPUE	Chum catch	Chum CPUE	Other catch
2005						
15 cm mesh, set	28[a]	0	0[a]	0	0[a]	0
15 cm mesh, drift	13[b]	0	0[b]	0	0[b]	0
seine	12[c]	0	0[c]	0	0[c]	0
2006						
11.4 cm mesh, set	99.25[a]	16	0.16[a]	26	0.26[a]	5 Humpback whitefish
15 cm mesh, set	110.25[a]	25	0.23[a]	37	0.34[a]	1 Sheefish
21 cm mesh, set	34.75[a]	7	0.20[a]	3	0.09[a]	
Total	244.25[a]	48	0.20[a]	66	0.27[a]	

[a] Effort for set nets = hours, CPUE = fish per hour.
[b] Effort for drift nets = number of drifts, CPUE = fish per drift.
[c] Effort for seine = number of hauls, CPUE = fish per haul.

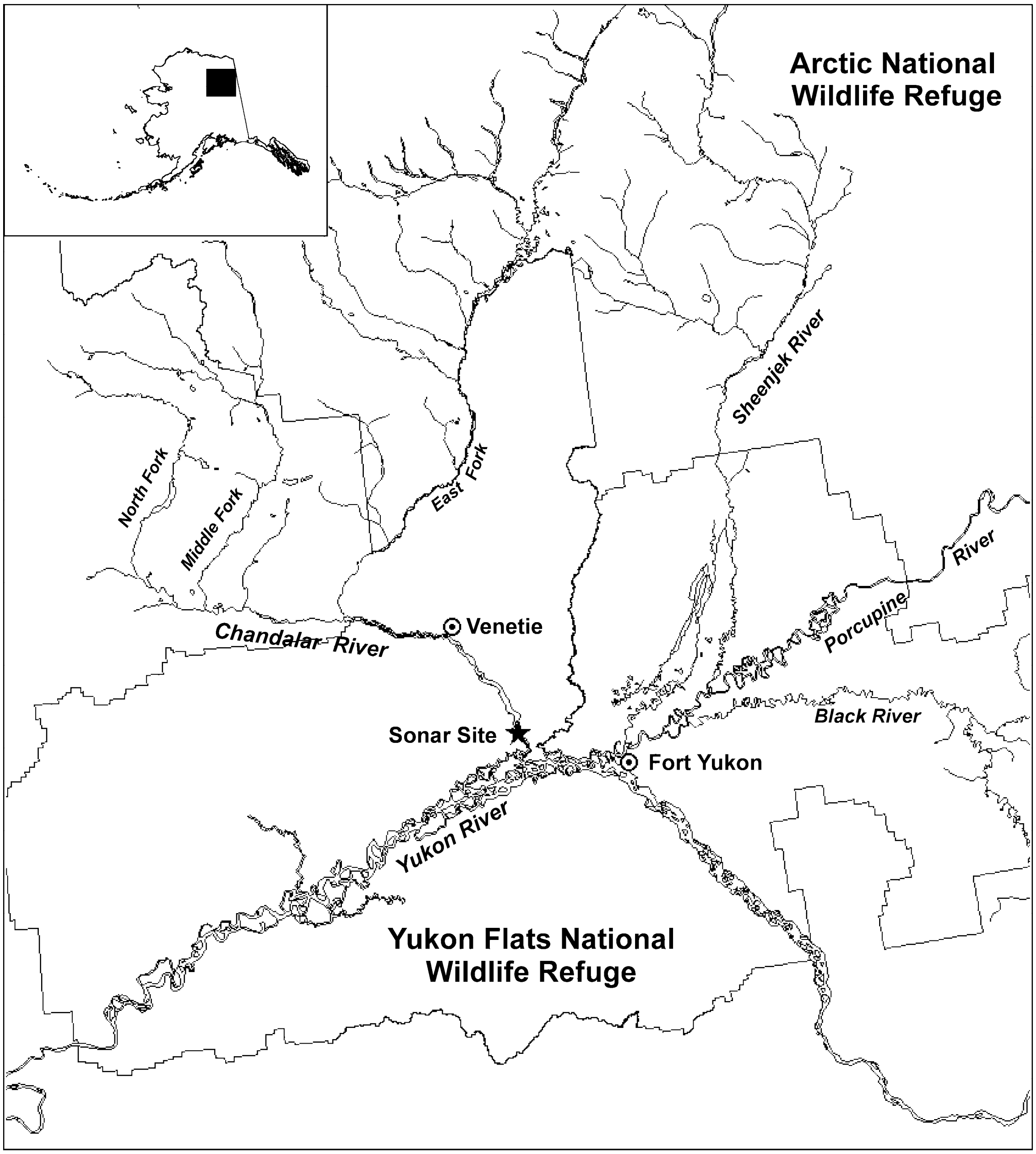

Figure 1. — Sonar site and nearby tributaries of the Yukon River.

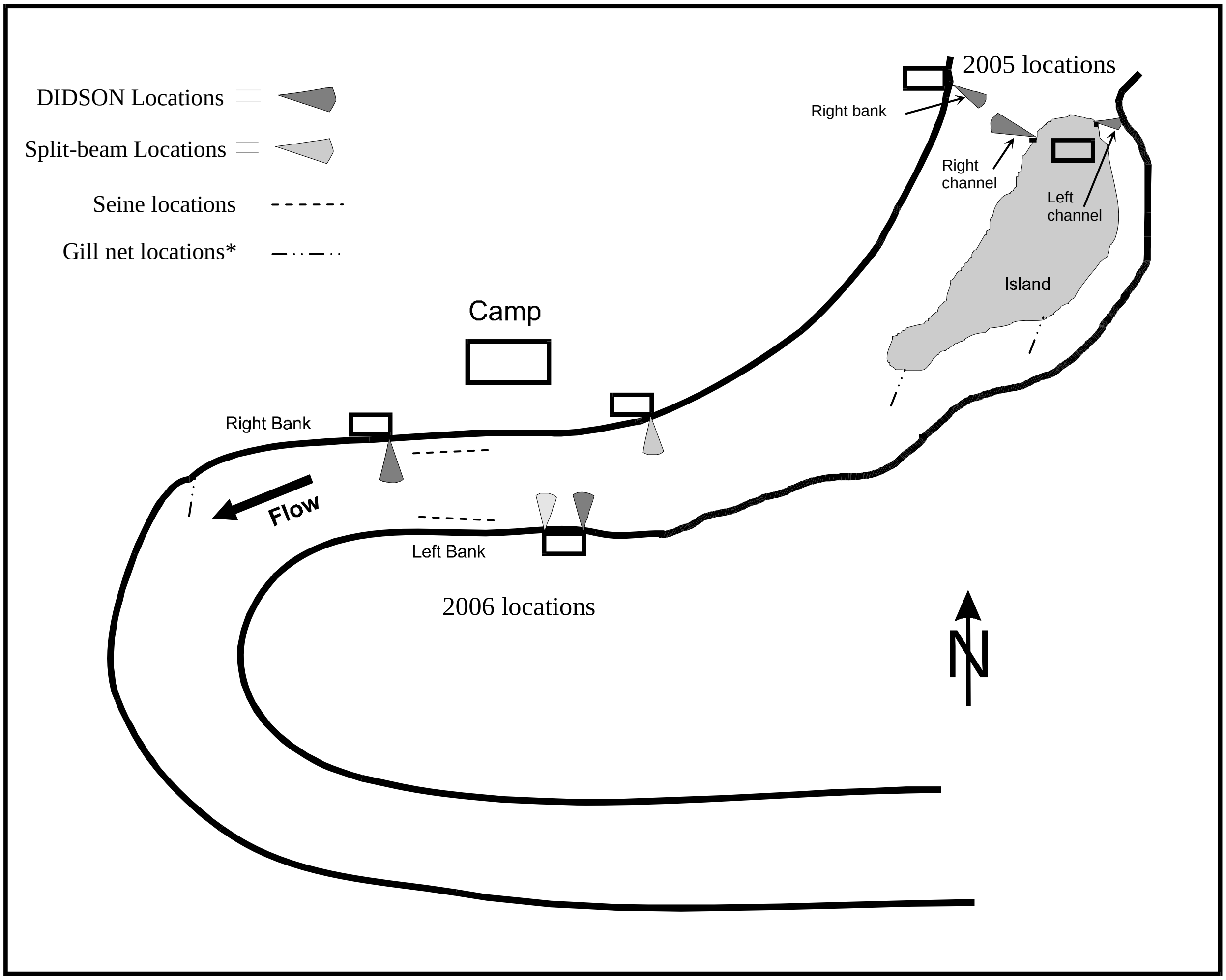

Figure 2. — Site map of Chandalar River Sonar operations, 2005-2006. Sonar graphics indicate locations only and do not represent actual beam size or coverage. * Not all gill net locations are on this map, several locations upriver and downriver were also used.

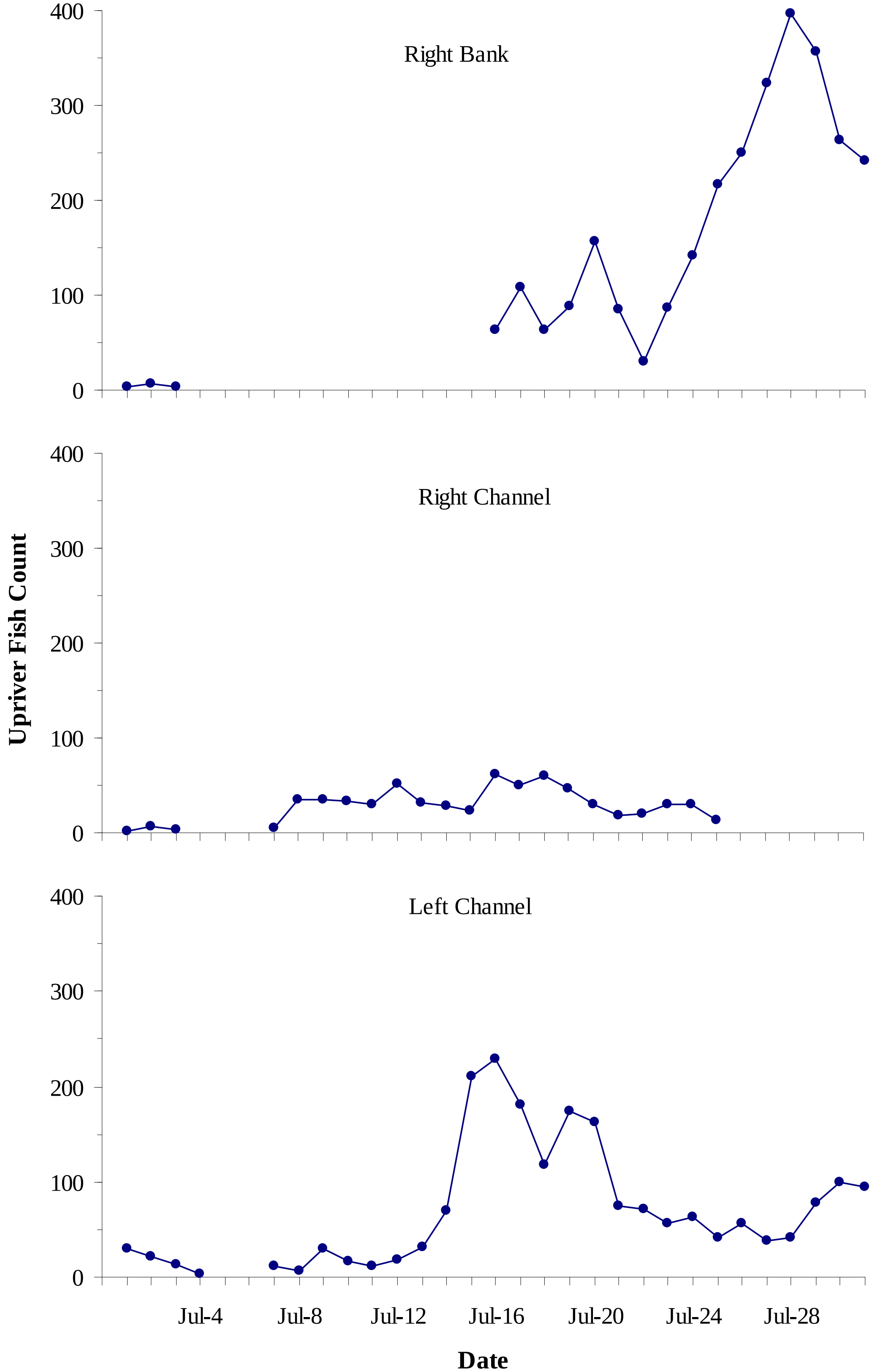

Figure 3. — Daily upriver fish counts from DIDSONs, Chandalar River, 2005.

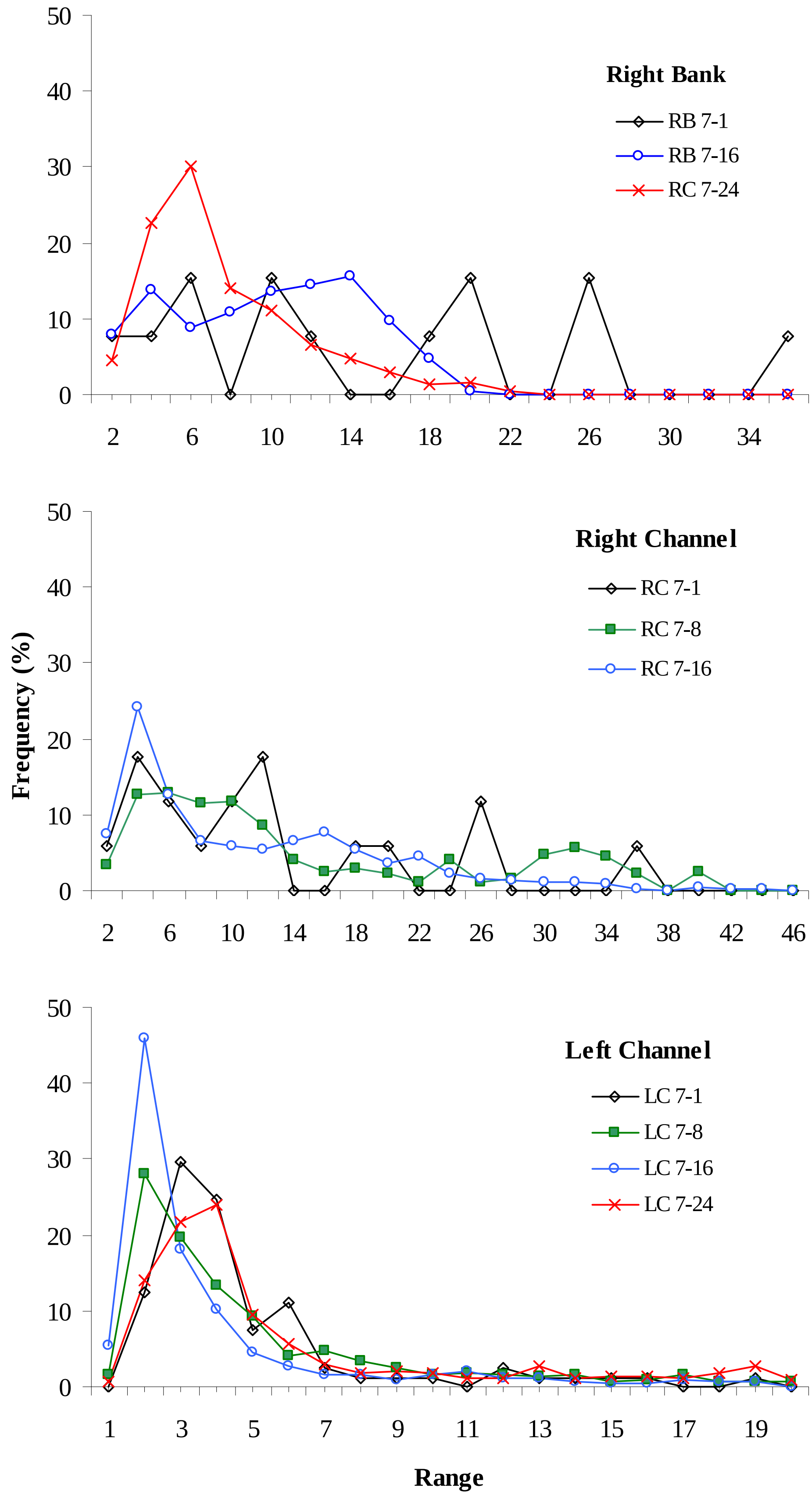

Figure 4. — Range (horizontal distance from DIDSON) distribution of upriver fish, by week Chandalar River, 2005. The dates represent the beginning day of each week. The missing weeks at the right bank and the right channel locations are due to down time from high water.

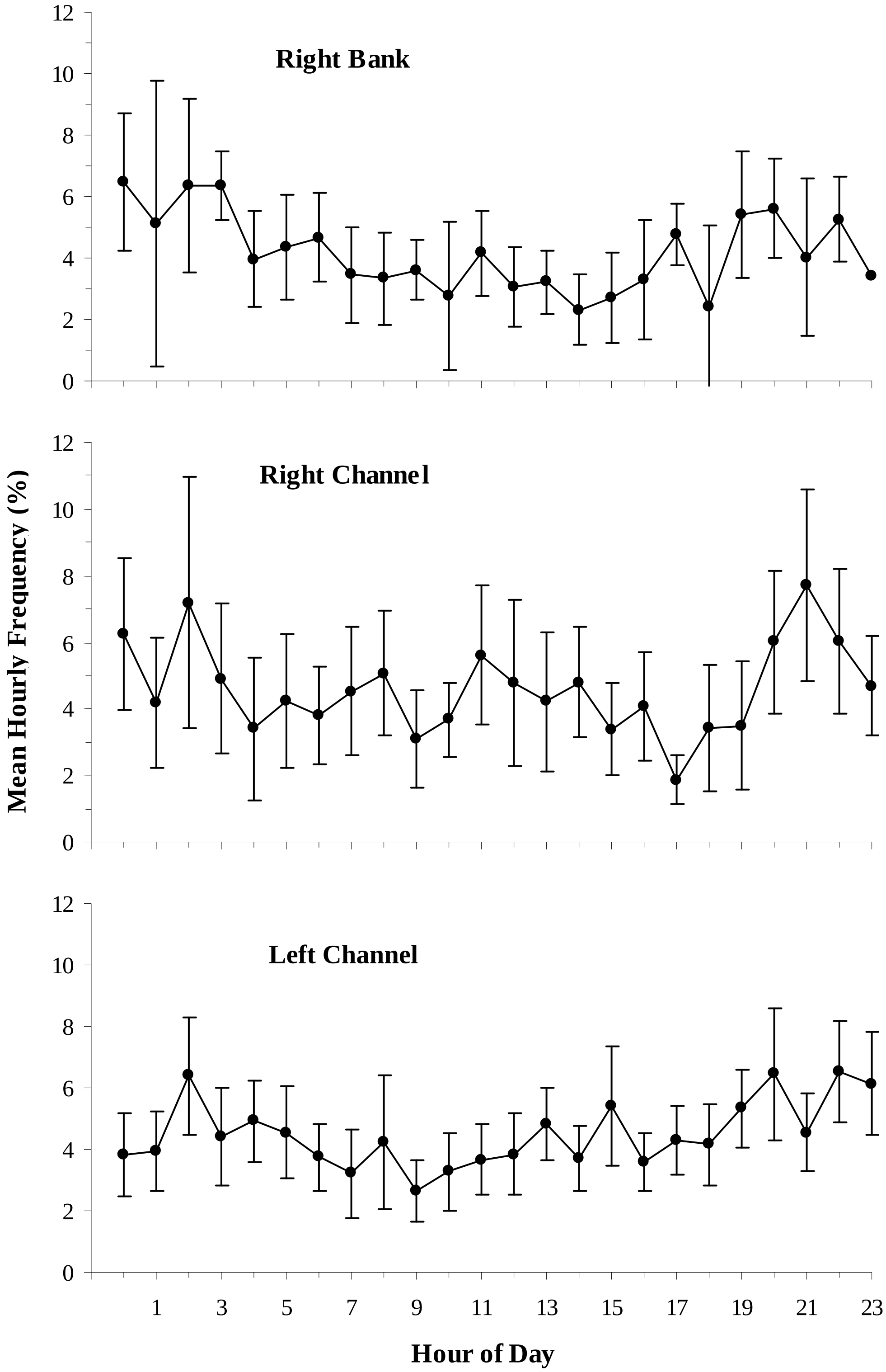

Figure 5. — Mean (±2SE) hourly frequency of upriver fish in the Chandalar River, 2005. Data from 10 days of continuous 24 hour data on the right bank, 16 days on the right channel, and 22 days on the left bank.

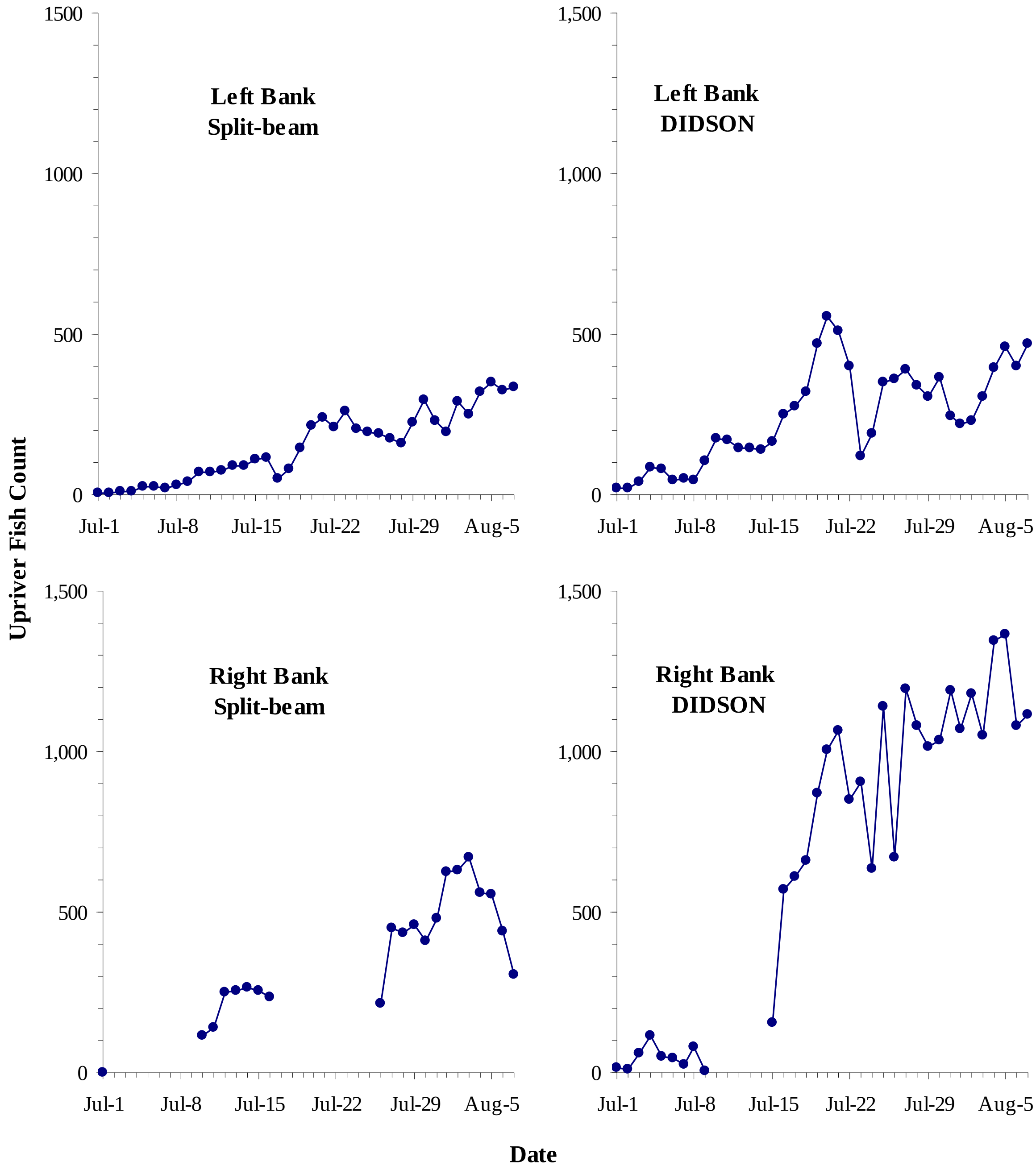

Figure 6. — Daily upriver fish counts from DIDSON and split-beam sonar, Chandalar River, 2006.

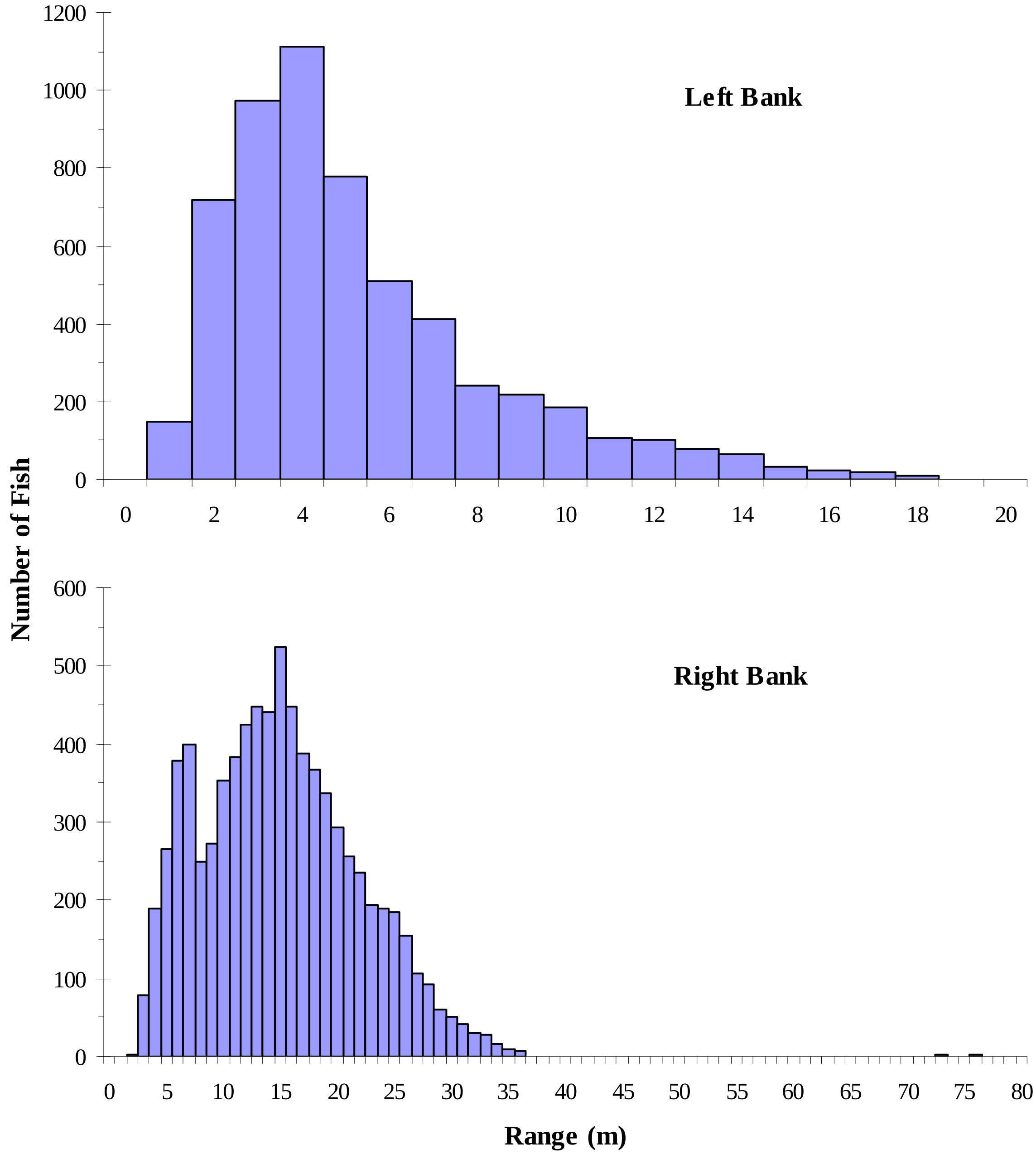

Figure 7. — Range (horizontal distance from transducer) distribution of upriver fish enumerated with split-beam sonar on the Chandalar River, 2006.

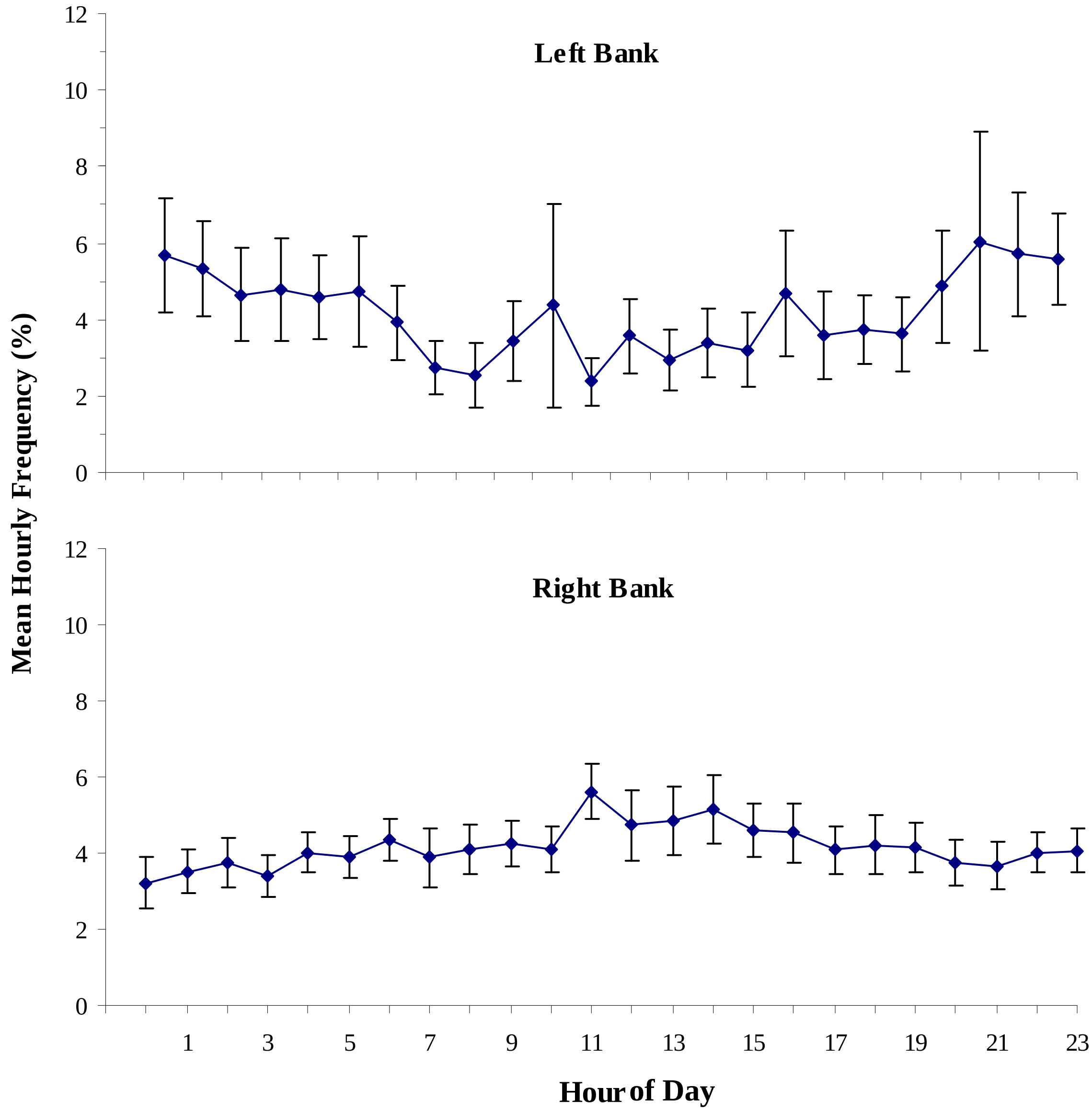

Figure 8. — Mean (±2SE) hourly frequency of upriver fish counted with split-beam on the Chandalar river, 2006. Data from 37 days of continuous data on the left bank and 18 days on the right bank.

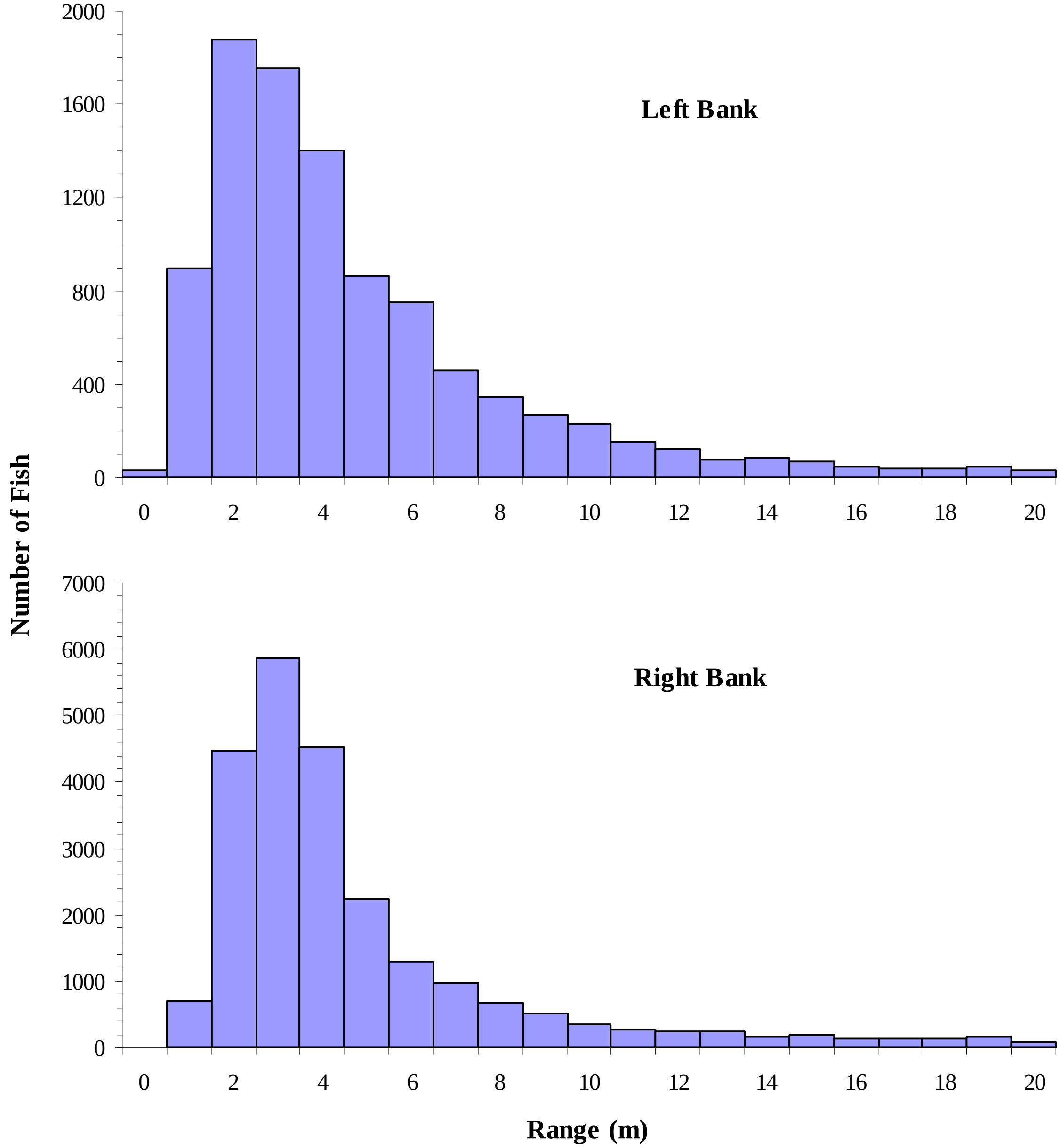

Figure 9. — Range (horizontal distance from DIDSON) distribution of upriver fish enumerated with DIDSON on the Chandalar River, 2006.

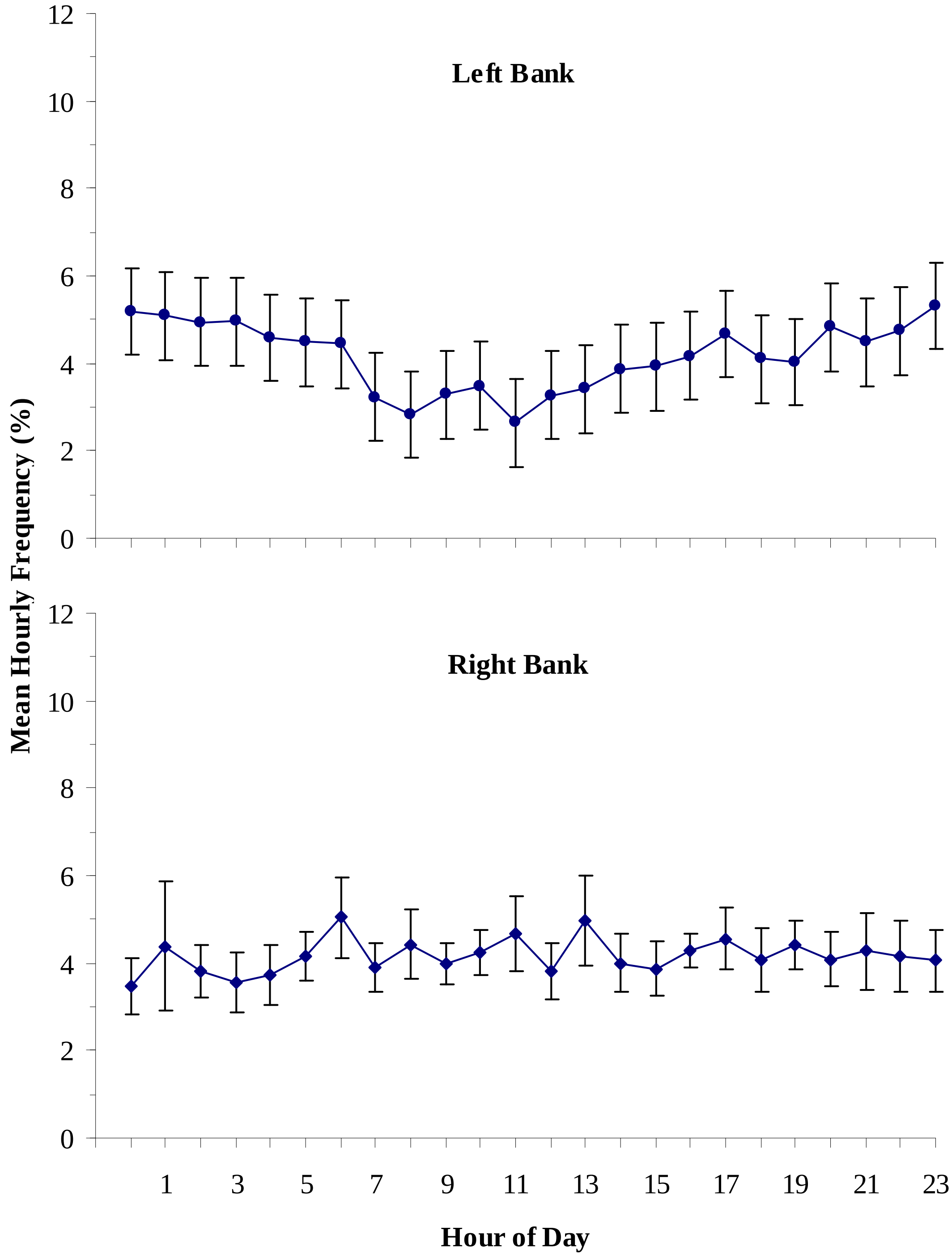

Figure 10. — Mean (±2SE) hourly frequency of upriver fish counted with DIDSON on the Chandalar River, 2006. Data from 25 days of continuous data on the left bank and 24 days on the right bank.

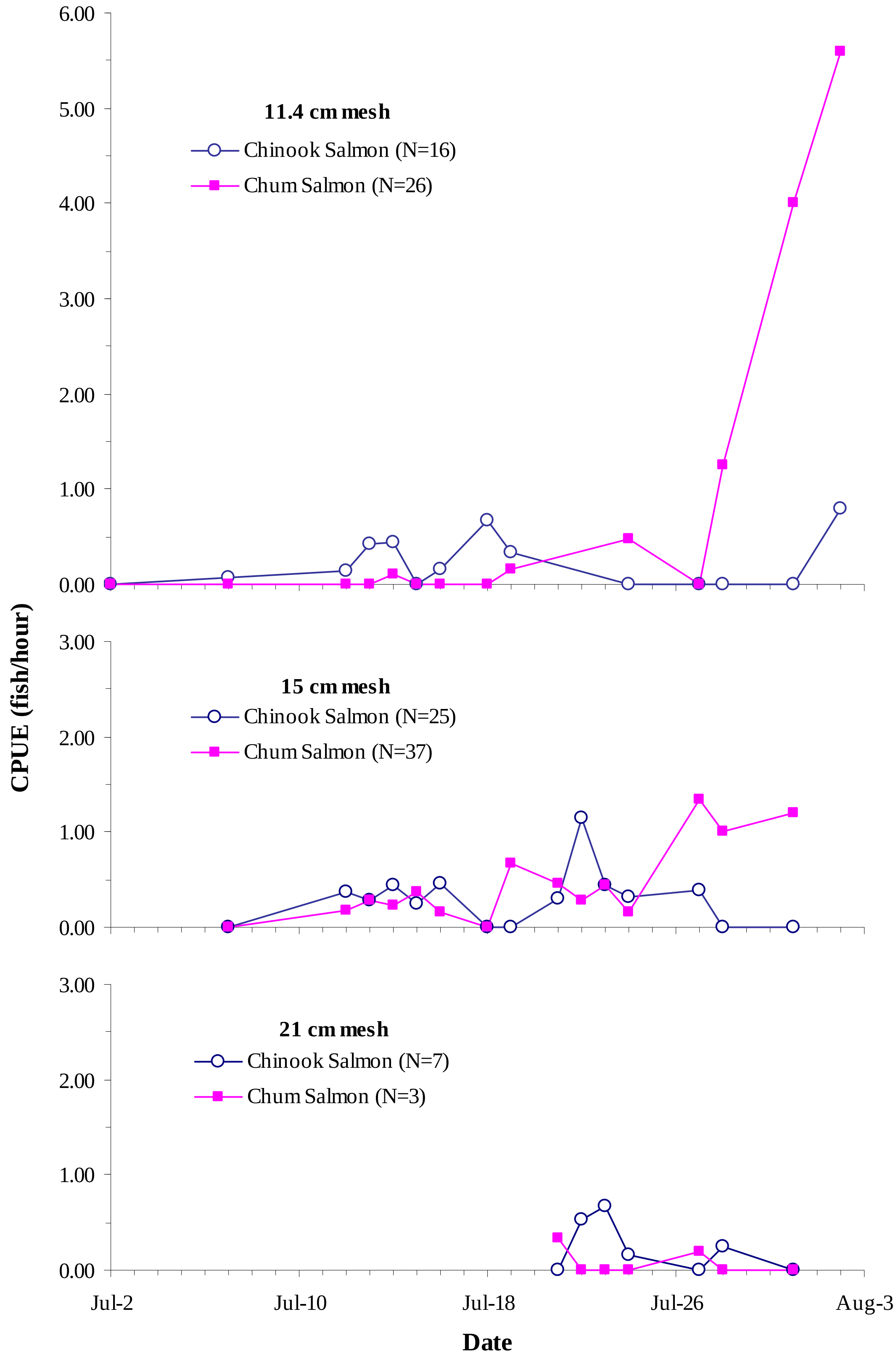

Figure 11. — Daily CPUE for salmon captured with set gill nets on the Chandalar River, 2006.

Appendix 1. — Technical specifications for the Dual Frequency Identification Sonar (taken from DIDSON operation manual)

DIDSON-S (Standard Version)

<u>*Detection Mode*</u>

Operating frequency	1 MHz (1.0 MHz < SN16)
Beamwidth (two-way)	0.4° H by 12° V
Number of beams	48
Source level (average)	202 dB re 1 μPa at 1 m
Standard range settings	
window start	0.75m to 23.25m in 0.75m intervals
window length	4.5m, 9m, 18m, 36m
range bin size relative to window length:	8mm, 17mm, 35mm, 70mm
pulse length relative to window length:	16μs, 32μs, 64μs, 128μs
Extended range settings	
window start	0.84m to 26.04m in 0.84m intervals
window length	5m, 10m, 20m, 40m
range bin size relative to window length:	10mm, 20mm, 40mm, 80mm
pulse length relative to window length:	18μs, 36μs, 72μs, 144μs

<u>*Identification Mode*</u>

Operating frequency	1.8 MHz
Beamwidth (two-way)	0.3° H by 12 ° V
Number of beams	96
Source level (average)	206 dB re 1 μPa at 1 m
Standard range settings	
start range	0.38m to 11.63m in 0.38m steps
window length	1.13m, 2.25m, 4.5m, 9m
Range bin size relative to window length:	2.2mm 4.4mm, 9mm, 18mm
pulse length relative to window length:	4μs, 8μs, 16μs, 32μs
Extended Range settings	
start range	0.42m to 13.02m in 0.42m steps
window length	1.25 m, 2. 5 m, 5 m, 10 m
range bin size relative to window length:	2.5mm 5mm, 10mm, 20mm
pulse length relative to window length:	4.5μs, 9μs, 18μs, 36μs

<u>*Both Modes*</u>

Max frame rate (window length dependent)	4-21 frames/s
Field-of-view	29°
Remote focus	1 m to max range
Power consumption	30 Watts typical
Weight in air (DC option)	7.0 kg (15.4 lb.)
Weight in water (DC option)	0.61 kg neg. (1.33 lb.)
Dimensions	30.7 cm by 20.6 cm by 17.1 cm
Depth rating	152 m (500 feet)
Control	Ethernet
Display up-link	Ethernet or NTSC Video
Maximum cable length	(100BaseT option) 61 m (200 feet)
Maximum cable length	(Thinnet option) 152 m (500 feet)
Maximum cable length (Patton option)	1220 m (4000 feet) (with local power)
Topside requirements:	Windows (95, 98, Me, NT, 2000, XP), Ethernet card, Video monitor (optional)

Appendix 2. — Technical specifications for the Dual Frequency Identification Sonar (taken from DIDSON operation manual)

DIDSON-LR (Long Range DIDSON)

Detection Mode	
Operating frequency	0.700 MHz
Beamwidth (two-way)	0.8° H by 12° V
Number of beams	48
Range settings	
window start	0.75 m to 23.25 m in 0.75-m intervals
window length	9 m, 18 m, 36 m, 72 m
Range bin size relative to window length:	17 mm, 35 mm, 70 mm, 140 mm
Pulse length relative to window length:	23µs, 46µs, 92µs, 184 µs
Identification Mode	
Operating frequency	1.2 MHz
Beamwidth (two-way)	0.5° H by 12 ° V
Number of beams	48
Range settings	
start range	0.38 m to 11.63 m in 0.38-m steps
window length	2.25 m, 4.5 m, 9 m, 18 m
Range bin size relative to window length:	4.4 mm, 9 mm, 18 mm, 36 mm
Pulse length relative to window length:	7µs, 13µs, 27µs, 54 µs
Both Modes	
Max frame rate (window length dependent)	2-10 frames/s
Field-of-view	29°
Remote focus	1 m to max range
Power consumption	30 Watts typical
Weight in air (DC option)	7.0 kg (15.4 lb.)
Weight in water (DC option)	0.61 kg neg. (1.33 lb.)
Dimensions	30.7 cm by 20.6 cm by 17.1 cm
Depth rating	152 m (500 feet)
Control	Ethernet