Use of Split-beam Sonar to Enumerate Chandalar River Fall Chum Salmon, 2000

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ABSTRACT

A fixed-location, split-beam hydroacoustic study was initiated in 1994 to assess the population status of adult fall chum salmon *Oncorhynchus keta* in the Chandalar River, a tributary of the Yukon River. Annual escapement estimates have been made since 1995 and daily in-season counts have been provided since 1996. This report presents the results for the 2000 season and describes the annual variability in run size and timing. Elliptical-beam transducers were installed on opposite banks of the river and aimed perpendicular to the current. Sonar operation began on August 8 and continued through September 26. High water during August 8-17 and August 23-29 resulted in 15 days of missed sampling on the right bank.

A total of 1,956 hours of digital echo processor data were collected, resulting in 54,128 fish manually tracked. Upstream-traveling fish accounted for 97.5% of the total tracked targets. The median number of acquired echoes per upstream fish was 26 on the left bank and 21 on the right bank. Downstream fish had medians of 17 echoes per fish on the left bank and 35 echoes per fish on the right bank. An estimated 65,894 ± 4,992 (95% confidence interval) fall chum salmon migrated upriver past the sonar from August 8 through September 26, 2000. Right bank accounted for 75% of the total estimated escapement. The count represented a conservative estimate of total escapement because it only included fish that passed during sonar operation. The 2000 count was 39% of the 1995-1999 average of 170,703 fish. The passage rate was 526 upstream fish on the first day of counting (0.8% of the total estimated count) and 1,340 fish on the final day (2% of the total). The peak daily count of 2,601 fish occurred on September 1. Both the median passage date (September 5) and the first quartile passage date (August 28) occurred on the same date as the averages of the years 1995-1997 and 1999. The 1998 run was not included in annual run timing averages since it was 11 days later in both median and first quartile passage dates. In 2000, hourly passage rates of upstream fish were higher during late night/early morning hours.

Migrating chum salmon were shore-oriented and traveled close to the river bottom. Downstream fish exhibited a wider spatial distribution than upstream fish. Positional data suggested that most fish were detected by the sonar because few targets were observed near the vertical or outer range limits of acoustic detection. Target strength distributions, spatial positioning, and chart/tracked fish comparisons corroborated the assumption that few fish were missed due to the voltage threshold settings used for processing acoustic data.

An underwater video camera was used to investigate the appearance of atypical traces. This investigation revealed the presence of schools of least cisco *Coregonus sardinella*. Approximately 60 hours of video were compared to corresponding sonar data, to determine that the atypical traces were least cisco. Subtraction of the atypical traces from the sonar data during this part of the season resulted in the removal of approximately 11,000 fish from our preliminary in-season estimate and provides the final fall chum salmon estimate of 65,894. All data presented in this report do not include least cisco unless specifically noted.

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INTRODUCTION

Accurate salmon escapement counts on Yukon River tributaries are important for assessing annual harvest management guidelines, 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 total escapement estimates of specific Yukon River salmon stocks (Bergstrom et al. 1999).

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. 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 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 providing accurate spawning escapement estimates for the major salmon stocks in the drainage.

In limited use in Alaska since the early 1960s (Gaudet 1990), fixed-location hydroacoustics provided counts of migrating adult salmon in rivers where other sampling techniques were not feasible, i.e., limited by visibility or sample volume. 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 (upstream or downstream). In 1992, the first riverine application of split-beam sonar technology was used to monitor upstream migrations of mainstem 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 1998b).

From 1986 to 1990, the USFWS used fixed-location, Bendix salmon counters to enumerate adult fall chum salmon escapement in the Chandalar River, located on the Yukon Flats National Wildlife Refuge (Daum et al. 1992). 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 sonar counts during this period averaged 58,628 fish, ranging from 33,619 to 78,631.

Because Chandalar River fall chum salmon are important as a wildlife and subsistence resource, and in view of the declining trend of some Yukon River salmon stocks (Bergstrom et al. 1995), a study was initiated in 1994 to reassess the population status using newly developed, split-beam hydroacoustics. Overall project objectives were to:

1) provide daily in-season counts of Chandalar River fall chum salmon to fishery managers;
2) estimate annual spawning escapement; and
3) describe annual variability in run size and timing.

The initial year, 1994, although prematurely ended due to flooding, was used to develop site-specific operational methods, evaluate site characteristics, and describe possible data collection biases (Daum and Osborne 1995). During 1995, daily and seasonal estimates of spawning escapement were calculated post-season and *in situ* target strength evaluations were collected (Daum and Osborne 1996). The 1995 escapement estimate of 280,999 chum salmon was the highest on record (Appendix 1). In 1996, the project became fully operational (Osborne and Daum 1997). Daily passage rates were tallied in-season with a post-season escapement estimate of 208,170 fish (Appendix 2). In 1997, the escapement estimate was 199,874 fall chum salmon (Appendix 3), the highest escapement of all monitored populations in the Yukon River drainage for that year (Daum and Osborne 1998a). The 1998 estimate was 75,811 fish, only 33% of the 1995-1997 average (Appendix 4; Daum and Osborne 1999). The estimate for 1999 was 88,662, only 46% of the 1995-1998 average (Appendix 5; Daum and Osborne 2000). This report presents the escapement information from the 2000 season and describes annual variability in run size and timing.

During the later part of the 2000 season, an underwater video camera was used to investigate the appearance of atypical sonar traces. This investigation revealed least cisco. Post season comparison of video images and sonar data led to retracking of some files to exclude these atypical traces. Unless specifically noted, all data presented in this report are from data sets where these atypical traces have been removed.

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, meltwater 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 upstream 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. Upstream from this area, the river becomes braided with many islands and multiple channels.

The sonar site, located at River Kilometer 21.5, was previously described by Daum et al. (1992; Figure 2). Requirements for site selection included: 1) single channel; 2) uniform non-turbulent flow; 3) gradually sloping bottom gradient; 4) absence of highly reflective river substrate; 5) location downriver from known salmon spawning areas; and 6) active fish migration past the site (no milling behavior). A transducer deployment site for each bank was selected from cross-sectional river profiles constructed of the area (Figure 3), using a chart recording depth sounder and an 8° transducer mounted below a boat's hull. Transducer deployment locations were similar to previous years. The left bank site, looking downstream, had a steeper bottom gradient and higher water velocity than the right bank. River bottom slopes were approximately 7.6° on the left bank and 2.4° on the right bank. River substrate consisted of small rounded cobble/gravel on the left bank and sand/silt on the right bank. During the 2000 season, river width at the site averaged 136 m (ranging from 126 to 156 m) and maximum depth averaged 4.2 m (ranging from 3.5 to 4.5 m). In-season water levels were lower than most previous years. Water temperature decreased from 13 to 4°C as the season progressed. Daily water conductivity measurements were discontinued in 1999 because of the consistent readings from past years (ranging from 220 to 320 :S/cm). Specific methodology for constructing cross-sectional river profiles and measuring daily water elevation and temperature can be found in Osborne and Daum (1997).

METHODS

Data Collection

Fixed-location, split-beam hydroacoustics was used to monitor the upstream migration of adult fall chum salmon in the Chandalar River. Systems were installed on opposite river banks to optimize sonar beam coverage of the river's cross-sectional area. Sonar operations began August 8 and continued through September 26. During two periods of high water (August 8 - 17 and August 23 - 29), the right bank sonar missed 15 days of sampling.

<u>Equipment description</u>

Two Hydroacoustic Technology, Inc. (HTI) split-beam systems were used throughout the study. Each system consisted of a 200-kHz split-beam echo sounder, digital echo processor, elliptical-beam transducer, 150 m transducer cable, chart recorder, oscilloscope, and data analysis computer with optical disk drives and network capabilities. Specific component descriptions and operations are detailed in HTI manuals (HTI 1994a, 1994b). A Remote Ocean Systems underwater rotator was attached to the transducer housing to facilitate remote aiming. For each bank, sonar equipment was housed in a portable shelter and powered by a 3.5 kW gasoline-powered generator. Frequency modulation hardware (FM slide) was installed in the right bank echo sounder to reduce background noise levels (Ehrenberg 1995).

A complete system calibration was performed pre-season by HTI (HTI 1999, 2000) using the comparison method referenced in Urick (1983), along with on-axis standard target measurements from a 38.1 mm tungsten carbide sphere (Foote and MacLennan 1984). During the season, *in situ* calibration data were collected using the standard target to insure that the system electronics were functioning properly. All on-axis, *in situ* calibrations were less than 3.8 dB of factory calibrated values.

Echo sounder settings

Echo sounder settings differed between banks. Left bank settings were: 10 dB_W transmit power; ! 3 dB_V total receiver gain; $40\log_{10}(R)$ time-varied gain function, where *R* = target range (m); 0.2 ms pulse width; and 10 pings/s ping rate. Right bank settings, using FM slide, were: 25 dB_W transmit power; ! 18 dB_V total receiver gain; $40\log_{10}(R)$ time-varied gain function; 0.18 ms pulse width (compressed); and 6.25 pings/s ping rate. Echo sounder settings were influenced by background noise levels and signal cross-talk.

Data acquisition

The digital echo processor and digital chart recorder were used to record hydroacoustic data. The digital echo processor receives output from the echo sounder, processes and stores acoustic data, and provides real-time screen displays of fish passing through the beam. The processor was run concurrently with the echo sounder except during short periods used for transducer aiming and generator maintenance. Processor-produced data files were created once per hour. Files included only returning echoes that met user-controlled pulse width, angle off-axis (vertical and horizontal), signal strength threshold, and range criteria (Table 1). A detailed description of file contents can be found in Johnston et al. (1993) and HTI (1994b). On both banks, the vertical angle off-axis criteria were increased beyond the half-power beam widths so echoes from fish traveling very close to the river bottom were accepted into the echo processor data file. Throughout the season, target strength threshold values were set at -40 dB on-axis for both banks. The on-axis target strength threshold was set 10 dB lower than that predicted from Love's equation (Love 1977) for the smallest chum salmon in the Chandalar River (50 cm in length; Daum et al. 1992) to insure that passing fish were not being missed because of acoustic size or off-axis position. During high-noise events, the threshold was increased up to -34 dB on-axis for data collected at far ranges. For the season, average peak amplitude noise levels varied from -66 to -48 dB for the left bank and -57 to -39 dB for the right bank. Noise increased with distance from the transducer. The maximum acquisition range (distance from the transducer) changed throughout the season on the left bank, primarily due to transducer redeployment as water levels varied. The left bank acquisition range changed from 12 to 18 m; the final 12 m distance to the thalweg was not ensonified due to an inflection in the river bottom. Right bank beam coverage was 75 m throughout the season, with approximately 15 m left unensonified due to reverberation from the irregular bottom. Changes to processor settings were recorded in hourly files and log books. Networking between the echo sounder, echo processor, and analysis computer allowed daily file backup and data analysis without interrupting real-time data collection.

Digital chart recordings were collected for 2 h/d throughout the season and run concurrently with the digital echo processor. Unlike digital echo processor data files, chart recordings were not filtered by pulse width or angle off-axis criteria. On the left bank, target strength threshold settings were kept constant for the season at -40 dB. For the right bank, the setting varied between -40 and -34 dB due to high noise levels. The maximum acquisition range for chart recordings was increased approximately 4 m beyond the echo processor settings to insure that fish were not traveling beyond the range of the echo processor. Fish counts from charts were compared to tracked fish counts from the processed data to confirm that fish were not being missed due to the echo acceptance criteria settings of the processor, i.e., pulse width, angle off-axis, range, or target strength threshold. All chart recorder settings and changes were recorded on real-time echograms and in log books.

Transducer deployment

Elliptical-beam transducers (one per bank) were used throughout the 2000 season. Elliptical beams maximize sampling volume for targets moving horizontally in the water column (migrating fish) while maintaining a small vertical angle fitted to shallow water conditions (as in rivers). The half-power beam widths (measured at !3 dB down the acoustic axis) were 4.8 by 10.8° on the left bank and 2.1 by 9.7° on the right bank. The transducers had low side-lobes which allowed the beam to be aimed close to the river bottom (!16.3 dB for the left bank and !23.6 dB for the right bank, measured on a one-way beam pattern plot).

The transducers and remote-controlled rotators were mounted on frames and deployed at depths of 0.6-1.5 m (see Daum and Osborne 1999 for specific description of pod assembly). Transducers were oriented perpendicular to river flow and positioned as close to the river bottom as substrate and contour allowed, usually within 5 cm of the bottom. Before deployment, the transducer face was washed with soap solution to remove foreign matter and air bubbles that could affect performance. The transducer assembly was moved inshore or offshore during the season as water level changed. A wire fence weir (5 x 10 cm mesh) was installed 1 m downstream and extended past calculated near-field values (MacLennan and Simmonds 1992) for each transducer, 1.3 m on the left bank and 7.2 m on the right bank. Fish moving upstream and close to shore would encounter the weir, be forced offshore, and then pass through the sonar beam.

Transducers were aimed using dual-axis remote rotators allowing vertical and horizontal adjustments. Precise aiming was critical because most fish traveled close to the bottom. During aiming, a target was used to align the lower edge of the beam with the river bottom. Chart recordings, oscilloscope readings, and real-time positional displays of passing fish from the digital echo processor were used to monitor transducer aiming. The low acoustic reflectivity of right bank substrate (silt and sand) allowed the right bank transducer to be aimed slightly into the bottom, enhancing detection of bottom-oriented fish. Bottom coverage was verified by dragging a target through the beam at various ranges. Whenever the transducer assembly was moved, proper beam orientation was checked by horizontally sweeping the beam across a stationary standard target suspended in the water column. All changes in transducer aiming and redeployment were recorded in log books.

Acoustic Data Verification and Fish Tracking

Prior to acoustic data analyses, all hourly files from the digital echo processor were examined for completeness and data integrity. Subsequently, data files were processed through target-tracking software (HTI Trakman software, version 1.31a). Echoes from boat motors, acoustic noise, and rocks were excluded from the database. Boat motor and acoustic noise echoes were visually identified by the random nature they displayed on software-produced echograms. Returning echoes from rocks exhibited a stationary bottom position in the beam with no movement in the upstream or downstream direction. Suspected fish targets, represented by a series of contiguous echoes, were examined for upstream or downstream directional progression and written to hourly files. A description of tracked fish files (**.ech* and **.fsh* files) can be found in Johnston et al. (1993) and HTI (1994b). All targets in these tracked fish files were classified as fish, although some downstream debris could not be differentiated from downstream fish. Fish were grouped into upstream and downstream categories based on direction of travel values reported in the tracked fish files. If the total distance traveled in the upstream/downstream direction was < 0.1 m, that target was deleted from the data set.

During previous years, all upstream-swimming fish were assumed to be chum salmon based on five previous seasons of gill net (30.5 m long, 3.7 m deep, with stretch mesh sizes of 11.4 and 14.9 cm) catches consisting of more than 99% chum salmon (Daum and Osborne 1996). However, during 2000 while investigating the appearance of atypical sonar traces, schools of least cisco were detected with an underwater video camera. Approximately 60 hours of video were recorded.

During post-season analysis, the fish in these video images were compared to the corresponding sonar traces. This allowed identification of sonar trace patterns that were indicative of schools of least cisco. All data files were examined for the presence of these traces, beginning at the end of the season and working backwards. Data files that contained these trace patterns were retracked to remove least cisco from the counts.

For each bank, hourly sample times, upstream/downstream tracked fish counts, and average number of acquired echoes per fish were calculated. Only tracked fish data were used in all subsequent analyses contained in this report.

Acoustic Data Analyses

<u>Escapement estimate and run timing</u>

Daily and seasonal estimates of upstream fish passage were calculated from the hourly tracked fish files. Time lapses in data acquisition (see Methods, Data Collection) required adjusting tracked fish counts before the daily and seasonal totals were calculated. Count adjustments were made for partial hours, missing hours, and missing days. Partial hourly counts ($\geq$ 15 and < 60 min) were standardized to 1 h, using

$$E_h = (60 / T_h) \cdot C_h, \quad (1)$$

where E_h = estimated hourly upstream count for hour h, T_h = number of minutes sampled in hour h, and C_h = tracked upstream count during the sampled time in hour h. Counts from hours with sample times < 15 minutes were discarded and treated as missing hours.

Fish counts from missing hours were extrapolated from seasonal mean hourly passage rates. Seasonal mean hourly passage rates were calculated from days with 24 h of continuous data (31 days on the right bank, and 45 days on the left bank). First, 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

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

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

Daily upstream fish counts for each bank were calculated by summing all hourly counts for that day. During the high-water events, 15 missing daily counts from the right bank were extrapolated from left bank counts using the ratio estimator method and associated variance calculation (Cochran 1977; Eggers et al. 1995). For the season, total escapement was calculated by summing all estimated daily counts. Also, hourly fish passage rates for each bank were plotted for the season and examined for diel patterns.

<u>Spatial distribution of tracked fish</u>

Fish position data provided an assessment of the likelihood of failing to detect fish that pass above, below, or beyond the detection range of the sonar beam. Also, spatial information furnishes insight into behavioral differences between upstream and downstream-swimming fish. The spatial positions of individually tracked fish were described in two dimensions, distance offshore from the transducer (range) and vertical position in the acoustic beam. Median range values and vertical position in meters were calculated for all tracked fish (upstream and downstream). Median vertical positions of tracked fish were converted to angle off-axis measurements before analyses, using

$$V_a = \text{arcsine}\,(V_d / R_d), \quad (3)$$

where V_a = vertical median angle off-axis (°), V_d = median vertical distance off-axis (m), R_d = median distance from transducer (m). For each bank, range and vertical distributions of upstream and downstream fish were plotted for the season.

<u>Target strength distribution of tracked fish</u>

Acoustic target strength data may be useful in differentiating fish species according to size, filtering out small debris, and assessing sampling bias due to voltage threshold settings. Mean target strength values for each fish were calculated. Target strength distributions of upstream and downstream fish by bank were plotted for the season. Mean target strengths of upstream and downstream fish by bank and between banks were compared using a two-sample *t* test for means with unequal variances (Zar 1984).

RESULTS

Acoustic Data Verification and Fish Tracking

During the 2000 season, 1,956 hours of acoustic data were collected and 54,128 fish were manually tracked (Tables 2 and 3). Upstream-traveling fish accounted for 97.5% of the total tracked targets. On the left bank, 97% of the season was monitored. Approximately 66% of the season was sampled on right bank, with 15 days missed during high water. The median number of acquired echoes per upstream fish was 26 on the left bank (range of 4-372) and 21 on the right bank (range of 4-528). Downstream fish had medians of 17 echoes per fish on the left bank (range of 4-154) and 35 echoes per fish on the right bank (range of 4-408).

Approximately 60 hours of underwater video were compared to corresponding sonar data to identify those traces indicative of whitefish schools. After reviewing the data, we were able to distinguish traces from medium and large groups of least cisco from those of chum salmon, which were primarily in small groups. However, we were unable to confidently differentiate traces from single or groups of a few least cisco from chum salmon. Reviewing sonar data files revealed that traces that were attributed to least cisco began during the first week of September on both banks. Therefore, we retracked data files from September 1 to the end of the season. After retracking, approximately 11,000 traces that were attributed to whitefish were removed from our preliminary count.

Acoustic Data Analyses

<u>Escapement estimate and run timing</u>

The adjusted 2000 fall chum salmon escapement estimate for the Chandalar River was 65,894 upstream fish ± 4,992 (95% confidence interval; Table 4). The right bank accounted for 75% of the total escapement. The seasonal count represented a conservative estimate of total escapement because counts did not include fish that passed before or after the sonar was operated. The passage rate was 526 upstream fish on the first day of sonar operation (0.8% of the total seasonal count), and 1,340 fish on the final day of counting (2% of the total). Daily counts were more than 2,000 fish/d for 6 of the 50 counting days. The 2000 count was only 39% of the 1995-1999 average of 170,703 fish (Figure 4).

The peak daily count of 2,601 fish occurred on September 1 (Figure 4). Both the median passage date (September 5) and the first quartile passage date (August 28) occurred on the same date as the averages for the years 1995-1997 and 1999. The 1998 run was not included in annual run timing averages since it was substantially later than in other years, i.e.,11 days later in both median and first quartile passage dates (Figure 4).

Of the final adjusted upstream count of 65,894 fall chum salmon, 82% were actually tracked (54,128 fish). Missing days made up the largest block of estimated counts (Figure 5). The right bank missed 15 days due to high-water events during August 8-16 and August 24-29. This represented 30% of the entire 50-day sampling period on the right bank. The left bank did not miss any days during the entire season. Counts were also estimated for 72 missing hours for the season, 45 on the right bank, and 27 on the left bank. Count adjustments for partial hours made

DISCUSSION

Acoustic Data and Estimate

The low returns of 1998 and 1999 continued into 2000. During 2000, the Chandalar River had the lowest escapement of fall chum salmon since split-beam sonar enumeration began in 1995 (Figure 13). The 2000 count of 65,894 fish was only 29% of the average annual returns during the high-escapement years, 1995-1997. Also, escapements to other major spawning grounds in the upper Yukon River drainage dropped substantially from the 1994-1997 levels (Bergstrom et al. 2001; B. Borba, Alaska Dept. of Fish and Game, personal communication). During five of the last six years, the Chandalar River has had the highest escapement estimate of all monitored fall chum spawning streams in the upper Yukon River drainage. The 2000 Chandalar River estimate was 45% of the combined total of the upper Yukon River enumeration projects (i.e., Chandalar R., Sheenjek R., Fishing Branch R., and Canadian mainstem of Yukon R.).

The precision of the 2000 Chandalar River escapement estimate varied between banks. On the left bank, acoustic data were collected for 97% of the season and few adjustments were made to the actual tracked fish count (97% of the left bank's final count was actually tracked). The right bank was monitored 66% of the season, and tracked fish represented 75% of the right bank's total adjusted count. The largest potential source of error was in estimating daily right bank counts for the 15 missing 24-h periods due to high water. The ratio of right bank to left bank daily counts from the non-missing days was used to extrapolate the missing right bank counts (Figure 14). The left and right bank daily counts were highly correlated for the first half of the season (12 non-missing days), ($r = 0.88$, $P < 0.001$). The ratio estimator was used for the missing days, which occurred during this time period. In addition, the 95% confidence interval around the missing-days estimate was within 7.6 % of the total seasonal count. Fish position data suggested that most upstream fish passing the sonar site were within the ensonified zone during the 2000 season. As in the previous five years, upstream fish were found close to shore and near the bottom. Few fish were found near the vertical or outer range limits of acoustic detection. Chart counts from echogram recordings provided additional evidence that few fish passed beyond the acquisition range. As in 1999, the non-linear, near-shore bottom contour on right bank in 2000 required aiming the transducer in a more downward-looking aspect than in previous years to attain complete bottom coverage near the transducer. This, in turn, raised the acoustical position of fish at far ranges since the lower edge of the beam was down in the sand/silt substrate (Figure 3). The shore/bottom orientation exhibited by Chandalar River chum salmon was consistent with previous behavioral observations of upstream-migrating fall chum salmon on the Sheenjek (Barton 1995) and mainstem Yukon rivers (Johnston et al. 1993).

To insure that acoustic data were not biased, the voltage threshold was set at -40 dB for most of the 2000 season which was substantially lower (10 dB) than predicted target strength values for fish of chum salmon length (Love 1977). Due to high-noise events, the voltage threshold on the right bank was increased to -34 dB beyond a range of approximately 10 m for 11 days, and beyond 24 m for 13 days. This could cause biased target strength values and undercounting of fish past these ranges. However, most upstream fish had target strengths substantially above the elevated threshold setting (Figure 12) and the majority of fish were close to shore (Figure 8). Daily comparisons of chart counts to the electronic data set confirmed that few fish were missed at the elevated voltage threshold settings. In addition, fish traces at far ranges were closely scrutinized while upstream targets were visually tracked to verify that off-axis echoes were being collected. This evidence supports the assumption that few fish were missed during periods of elevated voltage threshold settings.

Least Cisco Evaluation

Since gill net sampling of fish during previous years suggested that over 99% of passing fish were chum salmon (Daum and Osborne 1998a), it was assumed that all fish detected by sonar in the river were chum salmon. However, the appearance of atypical traces and identification of these traces as least cisco in 2000 leads to the presumption that the Chandalar River may support a multi-species run of fish during at least part of the chum salmon migration. This would require that appropriate amendments be made to future sonar operations.

While sonar is capable of identifying that fish are present in an ensonified area, it is rarely possible to determine size or species of fish (Gunderson 1993). Ideally, species of fish can be differentiated by unique echo patterns resulting from their swimming or schooling behavior. Burwen and Bosch (1996) used signal strength and distance from shore criteria to focus on passing chinook salmon, the species of interest in the Kenai River. Through sampling programs, chinook salmon were recognized to prefer deeper water farther from shore than sockeye salmon that were also passing upstream. While imperfect, the methods removed most of the non-chinook salmon from the counts and provided a useful escapement number for management purposes.

The data collected during 2000 from the Chandalar River suggested that the majority of least cisco pass the site in relatively large schools, while chum salmon pass mostly as singles, pairs, or small groups. Other characteristics of sonar traces generated by least cisco include length (number of echos in a trace) and density of traces (number of traces in a group of targets) and more variable position in the beam. Other characteristics such as diel patterns (higher counts in the morning or evening hours) exhibited by least cisco may also be useful for determining species.

Through identification of sonar signature traces, large schools of least cisco were separated from chum salmon. However, a more detailed investigation is necessary to increase the confidence of these determinations. Recommendations for future investigations include: (1) increased video monitoring, (2) sampling with beach seine, and (3) radio telemetry. Video monitoring with an array of cameras synchronized with the sonar should continue. This would allow monitoring a specific portion of the sonar beam and a better understanding of the relationship between passing fish and their corresponding traces. Also, it may provide for initial indication that least cisco or other non-target species are present. Sampling with a beach seine to determine timing and relative abundance of least cisco or other species, provides the least selective sampling method for species, size, or sex information, and will not cause mortality inherent in gillnet sampling (Hayes et al. 1996). Radio telemetry could be employed to help determine the destination and intent (spawning, feeding, or overwintering) of least cisco. This information could help predict or identify future changes or patterns in least cisco migration that could affect sonar counts of chum salmon.

Right Bank Relocation

The traditional site on the right bank for transducer deployment is located on the upriver side of a large gravel/sand/silt bar just down-river from a steep cut bank that is eroding. The river bottom here has a slope of approximately 2.4° and consists of sand and silt. This bottom type absorbs sound, resulting in little or no returning acoustic signal, that makes aiming the sonar difficult.

The consistent linear appearance of the bottom on the right bank (1994-1997) had changed for 1998-2000. The bottom became bumpy and uneven past 57 m offshore, due to sediment deposited from severe bank erosion during an early summer flood in 1998.

Additionally, the sonar at this site has to be shut down during high water events. As the river level rises, water floods back onto the shallow sloped shoreline leaving no room to deploy the transducer. Right bank sample time has been considerably less than the left bank due to down-time from high water events. From 1997 to 2000, the right bank missed an average of 21 sampling days due to high water. Thirty-three days were missed in 1998, representing 66% of the entire 50 days counting period.

Given these problems, a potential new site on the right bank approximately 300 meters down river from the original site was mapped during the 2000 field season. This site had a similar bathymetry (6° slope) and substrate type (round cobble) as on left bank. Future operations should include testing the suitability of this location using spare sonar components.

Annual sonar enumeration of fall chum salmon in the Chandalar River should continue into the future, based on its significant contribution to the total run of Yukon River fall chum salmon and the importance of the stock to subsistence users throughout the drainage. Daily in-season counts and post-season escapement estimates will be provided to managers. Large numbers of salmon and software limitations cause data verification and manual fish tracking to continue to be labor intensive. Considerable time would be saved if an automatic tracking system was developed that provided accurate counts of upstream-traveling fish in the Chandalar River. Until that time, manual tracking of fish targets will be necessary to ensure data integrity and count accuracy.

ACKNOWLEDGMENTS

Special appreciation is extended to the people who participated in the sixth year of this project, and who are largely responsible for its success: C. Gewin and G. Hoffman for field assistance; S. Johnston for technical assistance; R. Simmons for project review; and D. Daum and J. Adams for editorial review.

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TABLE 1.— Echo acceptance criteria used for digital echo processing, Chandalar River, 2000. Range values represent the variation in individual settings during the season.

Bank	Pulse width (ms) at !6 dB	Vertical angle off-axis (°)	Horizontal angle off-axis (°)	Voltage Threshold (dB)	Range (m)
Left	0.10 to 0.38	!3.61 to 2.41	!5.42 to 5.42	!40[a]	12 to 18
Right	0.00 to 0.38	!1.50 to 1.50	!4.87 to 4.87	!40[a]	75

[a] During high noise events, voltage threshold was increased up to -34 dB at far ranges.

TABLE 2.— Hydroacoustic data collected from the left bank, Chandalar River, 2000.

Date	Sample time (h)	Upstream count	Downstream count	Total count
Aug 8	15.38	60	1	61
9	24.00	116	3	119
10	23.48	111	1	112
11	24.00	130	9	139
12	24.00	100	5	105
13	24.00	119	10	129
14	24.00	132	10	142
15	24.00	108	5	113
16	24.00	120	4	124
17	23.74	125	10	135
18	24.00	118	5	123
19	24.00	109	4	113
20	24.00	205	7	212
21	24.00	176	2	178
22	24.00	203	7	210
23	24.00	216	11	227
24	22.28	582	8	590
25	24.00	449	2	451
26	24.00	342	6	348
27	24.00	292	4	296
28	23.97	483	10	493
29	24.00	444	21	465
30	24.00	452	10	462
31	24.00	417	21	438
Sept 1	23.86	655	2	657
2	23.86	449	4	453
3	24.00	463	6	469
4	23.19	340	5	345
5	23.99	359	5	364
6	24.00	370	1	371
7	24.00	243	2	245
8	24.00	282	2	284
9	24.00	276	10	286
10	24.00	266	14	280
11	24.00	424	13	437
12	24.00	275	16	291
13	24.00	254	11	265
14	23.84	352	20	372
15	23.85	229	32	261
16	24.00	299	25	324
17	23.86	420	34	454
18	23.07	429	66	495
19	23.58	464	51	515
20	23.72	507	35	542
21	24.00	644	29	673
22	24.00	457	35	492
23	21.57	425	21	446
24	19.89	421	24	445
25	24.00	685	5	690
26	12.13	292	4	296
Total	1,167.26	15,889	648	16,537

TABLE 3.— Hydroacoustic data collected from the right bank, Chandalar River, 2000. Asterisks represent days when sampling did not occur due to high water.

Date	Sample time (h)	Upstream count	Downstream count	Total count
Aug 8 *	0	—	—	—
9 *	0	—	—	—
10 *	0	—	—	—
11 *	0	—	—	—
12 *	0	—	—	—
13 *	0	—	—	—
14 *	0	—	—	—
15 *	0	—	—	—
16 *	0	—	—	—
17	7.00	87	12	99
18	24.00	333	14	347
19	24.00	351	11	362
20	24.00	460	19	479
21	24.00	445	12	457
22	24.00	503	20	523
23	19.98	316	8	324
24 *	0	—	—	—
25 *	0	—	—	—
26 *	0	—	—	—
27 *	0	—	—	—
28 *	0	—	—	—
29 *	0	—	—	—
30	24.00	851	9	860
31	24.00	1,526	21	1,547
Sept 1	24.00	1,943	31	1,974
2	24.00	1,531	12	1,543
3	24.00	1,558	30	1,588
4	24.00	1,816	36	1,852
5	23.99	1,790	31	1,821
6	23.97	1,888	30	1,918
7	22.25	1,543	38	1,581
8	24.00	1,701	50	1,751
9	24.00	1,374	53	1,427
10	23.17	1,456	26	1,482
11	23.84	1,485	45	1,530
12	23.64	1,190	38	1,228
13	24.00	1,242	22	1,264
14	23.95	1,163	12	1,175
15	24.00	929	7	936
16	22.61	925	8	933
17	23.60	786	13	799
18	23.92	974	16	990
19	23.95	820	7	827
20	23.02	1,168	13	1,181
21	23.62	1,114	13	1,127
22	22.28	1,067	24	1,091
23	15.29	354	10	364
24	22.55	651	10	661
25	23.85	976	11	987
26	11.85	547	16	563
Total	788.33	36,863	728	37,591

TABLE 4.— Daily adjusted fall chum salmon count, Chandalar River, 2000. Asterisks denote daily count estimated by ratio estimator method (*).

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	131	395 *	526	526	0.80
9	116	350 *	466	992	1.51
10	111	334 *	445	1,437	2.18
11	130	392 *	522	1,959	2.97
12	100	301 *	401	2,360	3.58
13	119	359 *	478	2,838	4.31
14	132	398 *	530	3,368	5.11
15	108	325 *	433	3,801	5.77
16	120	362 *	482	4,283	6.50
17	126	374	500	4,783	7.26
18	118	333	451	5,234	7.94
19	109	351	460	5,694	8.64
20	205	460	665	6,359	9.65
21	176	445	621	6,980	10.59
22	203	503	706	7,686	11.66
23	216	375	591	8,277	12.56
24	635	1,913 *	2,548	10,825	16.43
25	449	1,353 *	1,802	12,627	19.16
26	342	1,030 *	1,372	13,999	21.24
27	292	880 *	1,172	15,171	23.02
28	484	1,458 *	1,942	17,113	25.97
29	444	1,338 *	1,782	18,895	28.67
30	452	851	1,303	20,198	30.65
31	417	1,526	1,943	22,141	33.60
Sep 1	658	1,943	2,601	24,742	37.55
2	450	1,531	1,981	26,723	40.55
3	463	1,558	2,021	28,744	43.62
4	343	1,816	2,159	30,903	46.90
5	359	1,791	2,150	33,053	50.16
6	370	1,892	2,262	35,315	53.59
7	243	1,659	1,902	37,217	56.48
8	282	1,701	1,983	39,200	59.49
9	276	1,374	1,650	40,850	61.99
10	266	1,525	1,791	42,641	64.71
11	424	1,497	1,921	44,562	67.63
12	275	1,209	1,484	46,046	69.88
13	254	1,242	1,496	47,542	72.15
14	353	1,164	1,517	49,059	74.45
15	231	929	1,160	50,219	76.21
16	299	993	1,292	51,511	78.17
17	423	802	1,225	52,736	80.03
18	431	978	1,409	54,145	82.17
19	466	823	1,289	55,434	84.13
20	514	1,176	1,690	57,124	86.69
21	644	1,121	1,765	58,889	89.37
22	457	1,150	1,607	60,496	91.81
23	488	625	1,113	61,609	93.50
24	582	698	1,280	62,889	95.44
25	685	980	1,665	64,554	97.97
26	449	891	1,340	65,894	100.00
Total	16,420	49,474	65,894		

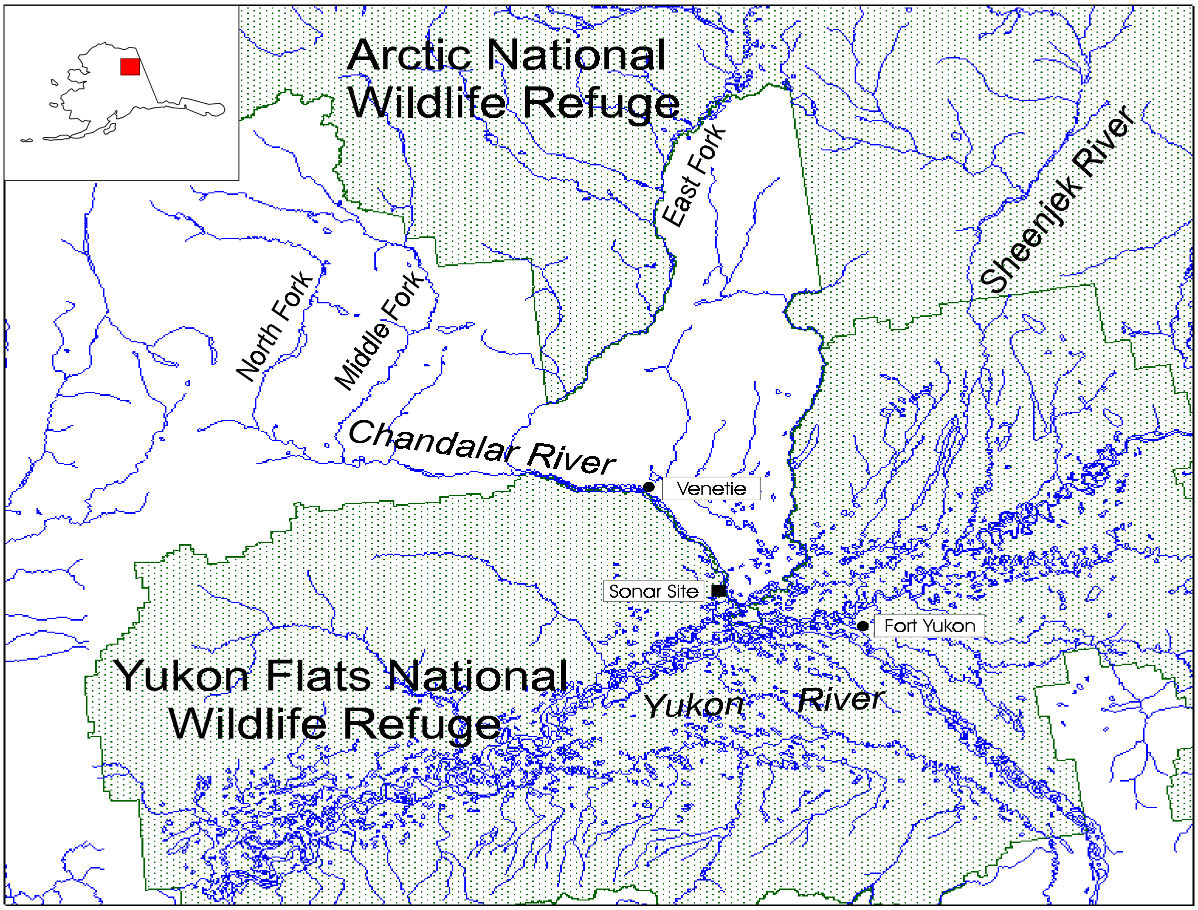

FIGURE 1.— Major tributaries of the Yukon River near the U.S. /Canada boarder.

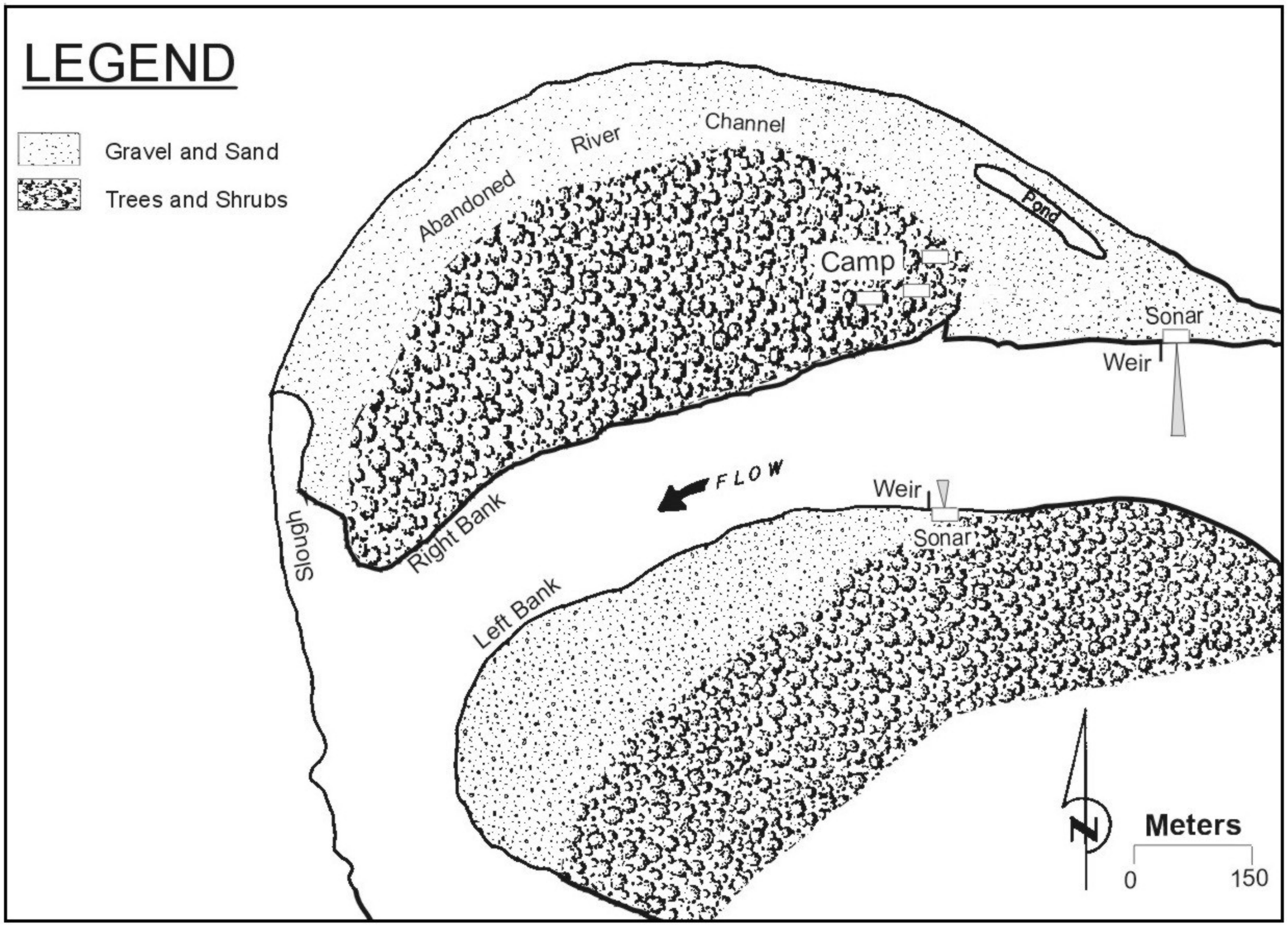

Figure 2.— Site map of the Chandalar River sonar facilities, 2000.

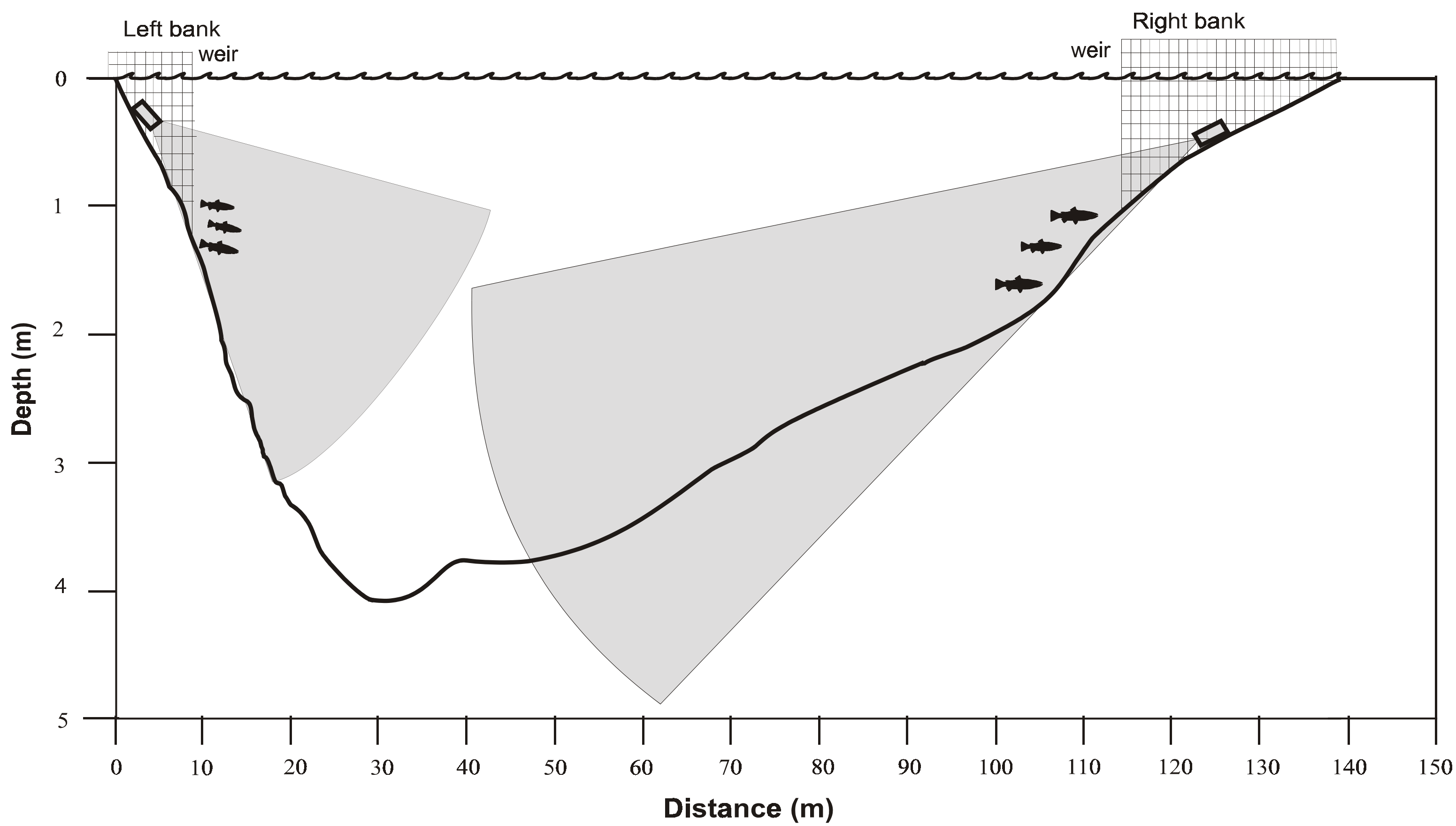

FIGURE 3.— River channel profile and estimated ensonified zones of the left and right banks, Chandalar River, 2000. Different axis scales are used to enhance readability.

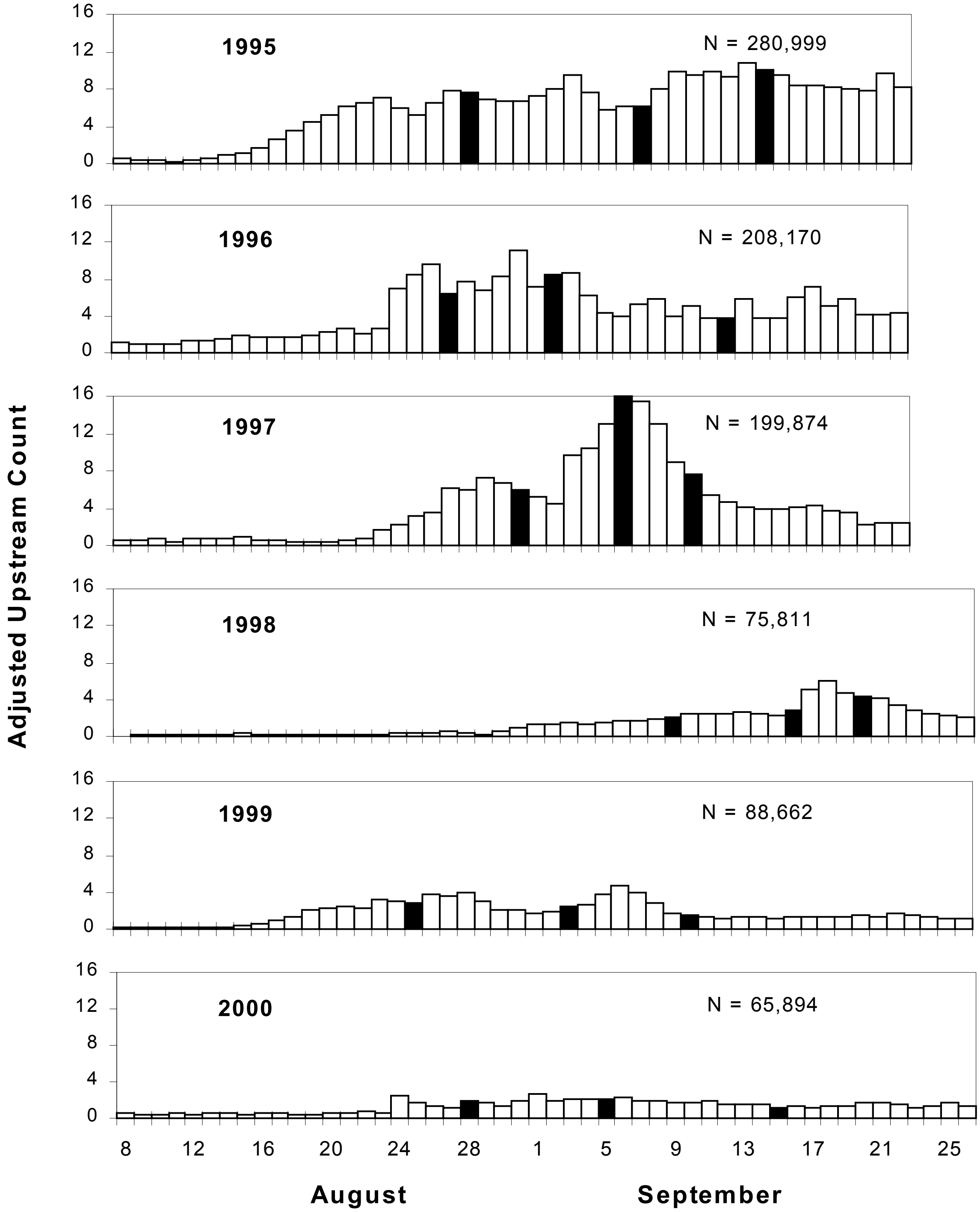

FIGURE 4.— Adjusted daily counts (thousands) of fall chum salmon, Chandalar River, 1995 -2000. Shaded bars represent quartiles of the total count.

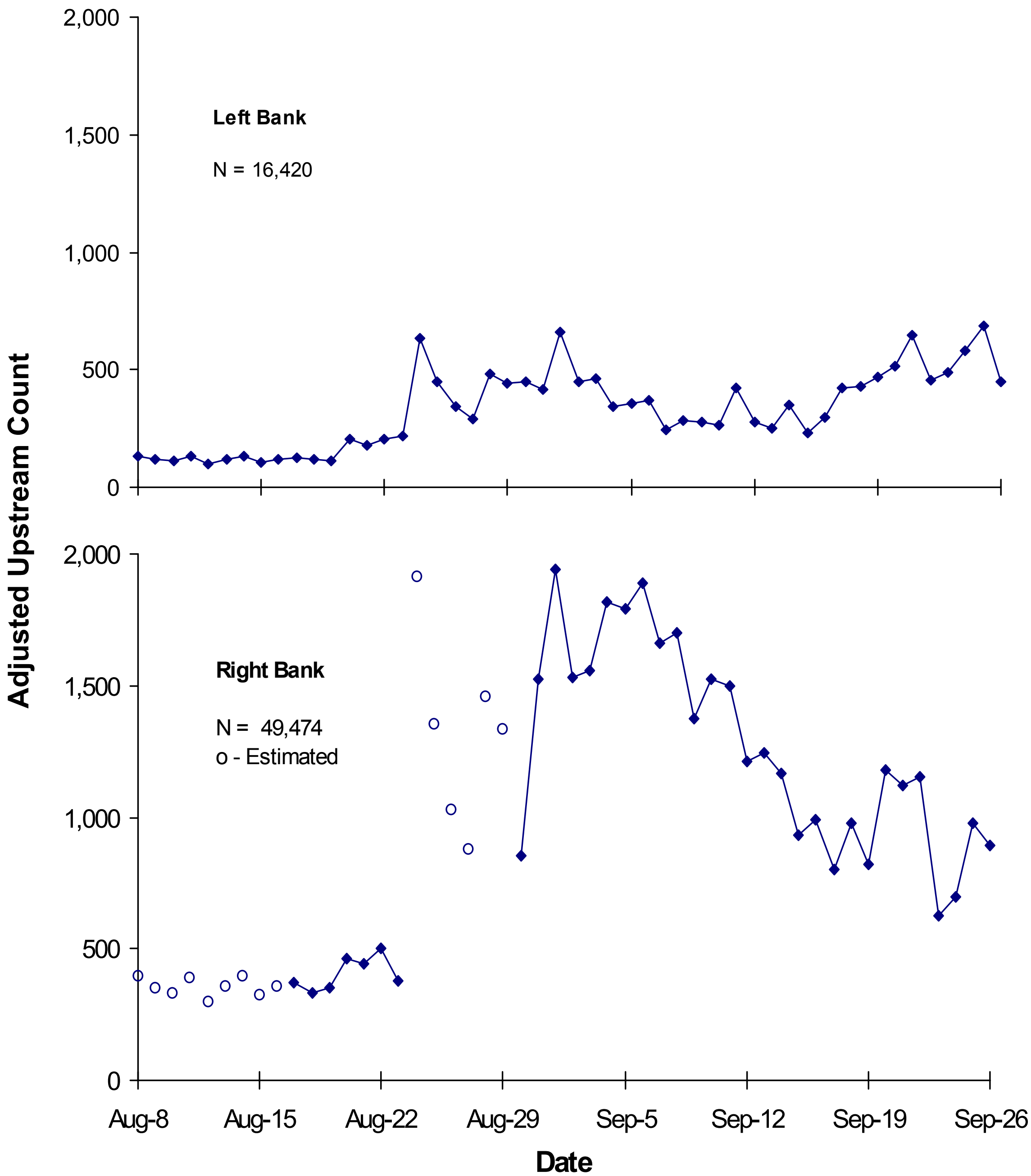

FIGURE 5.— Adjusted daily counts of fall chum salmon by bank, Chandalar River, 2000. Daily counts were estimated using ratio estimator method for 15 days on the right bank.

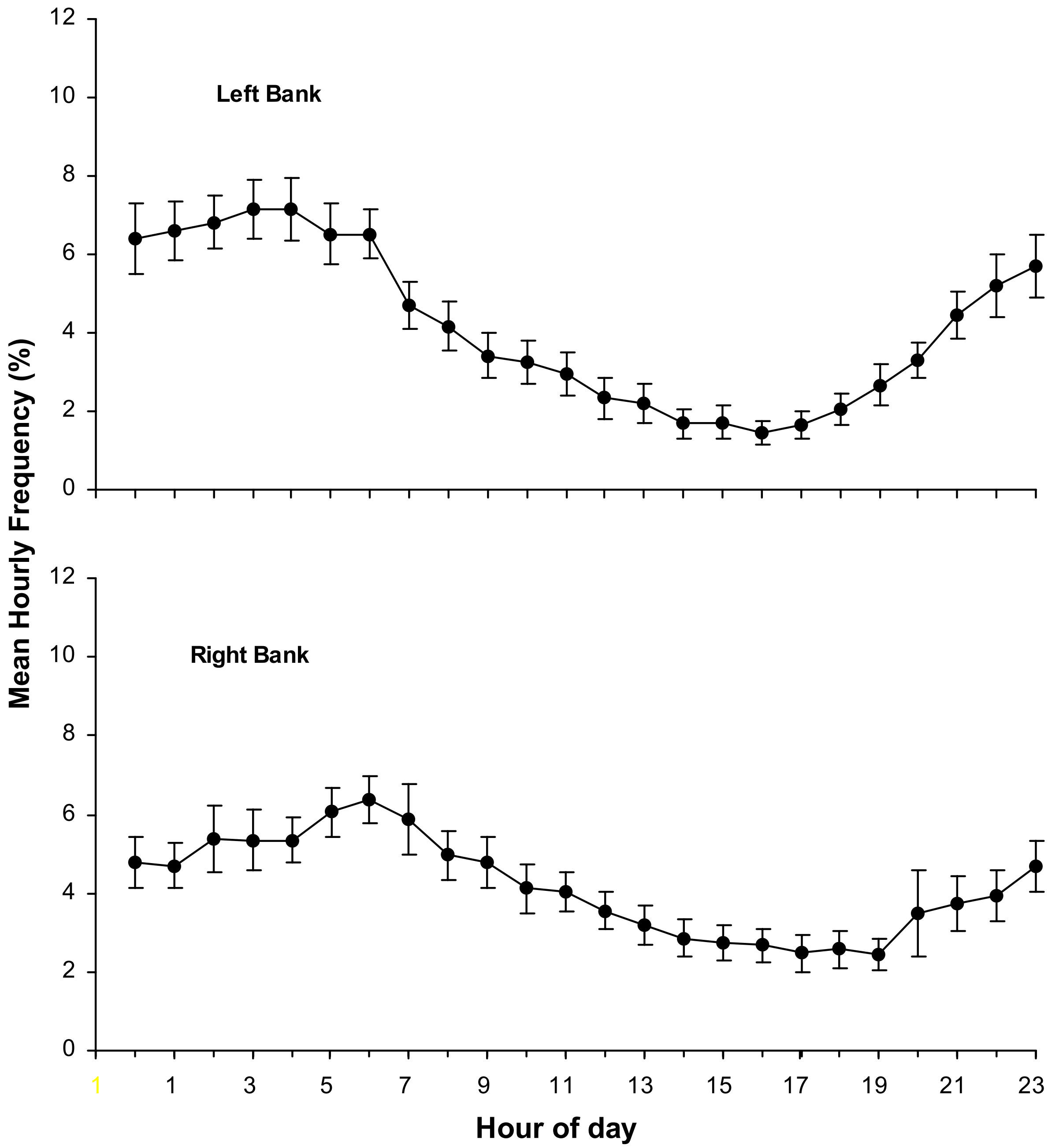

FIGURE 6.— Mean (±2 SE) hourly frequency of upstream fish, Chandalar River, 2000. Data from 45 days of continuous 24 hour data on the left bank and 27 days on the right bank.

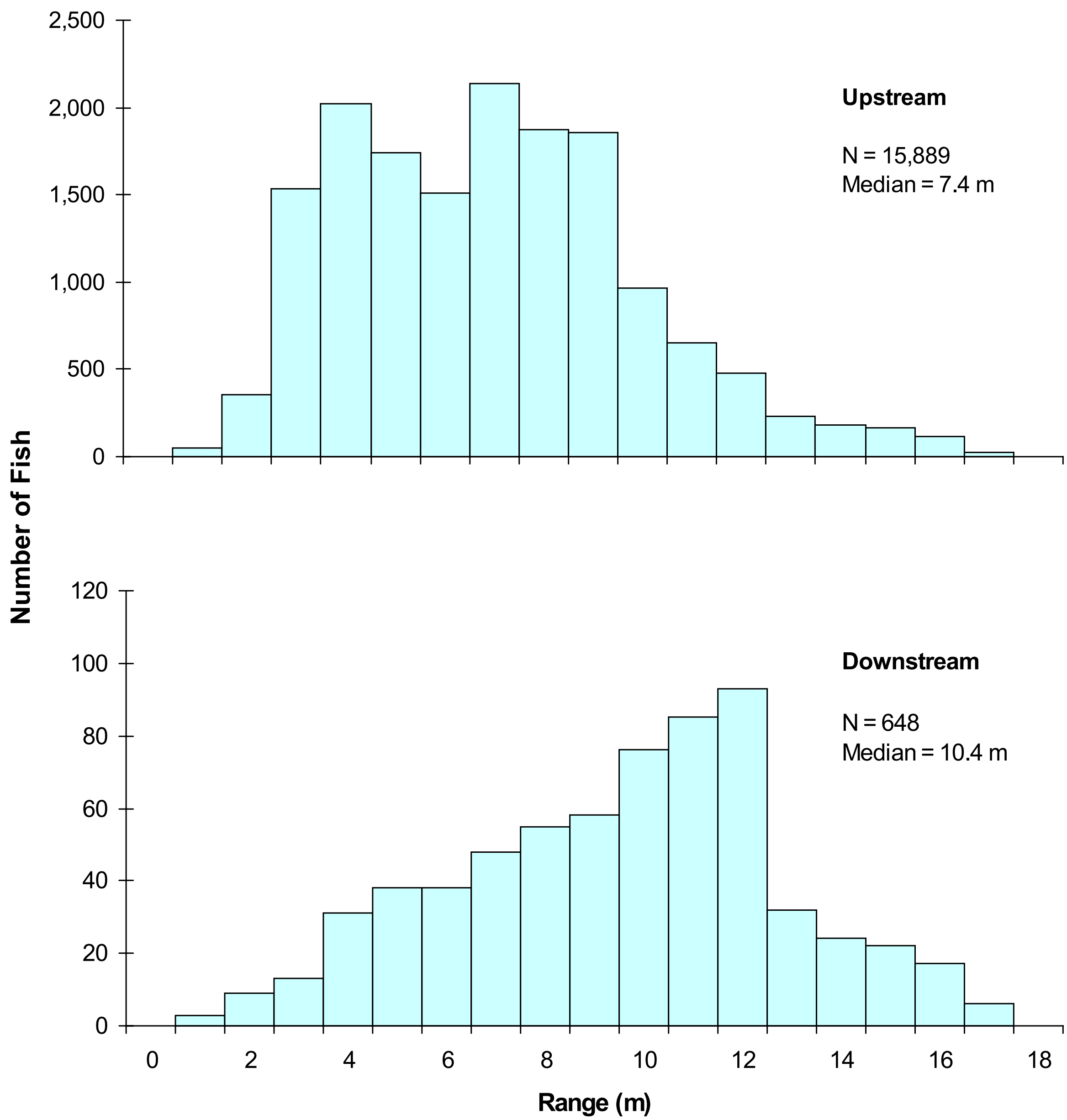

FIGURE 7.— Range (horizontal distance from transducer) distribution of upstream and downstream fish, left bank Chandalar River, August 8 to September 26, 2000.

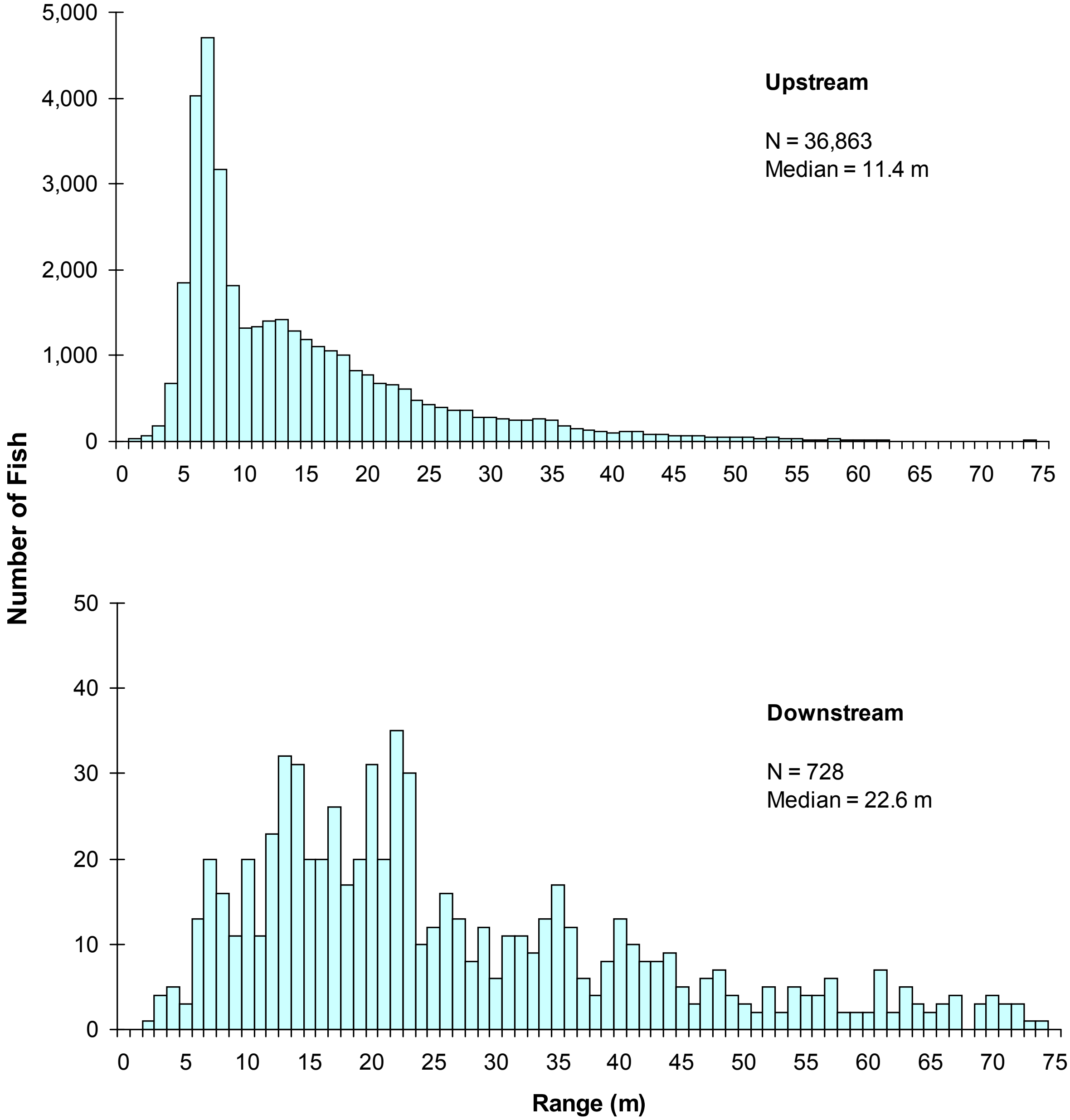

FIGURE 8.— Range (horizontal distance from transducer) distribution of upstream and downstream fish, right bank, Chandalar River, August 8 to September 26, 2000.

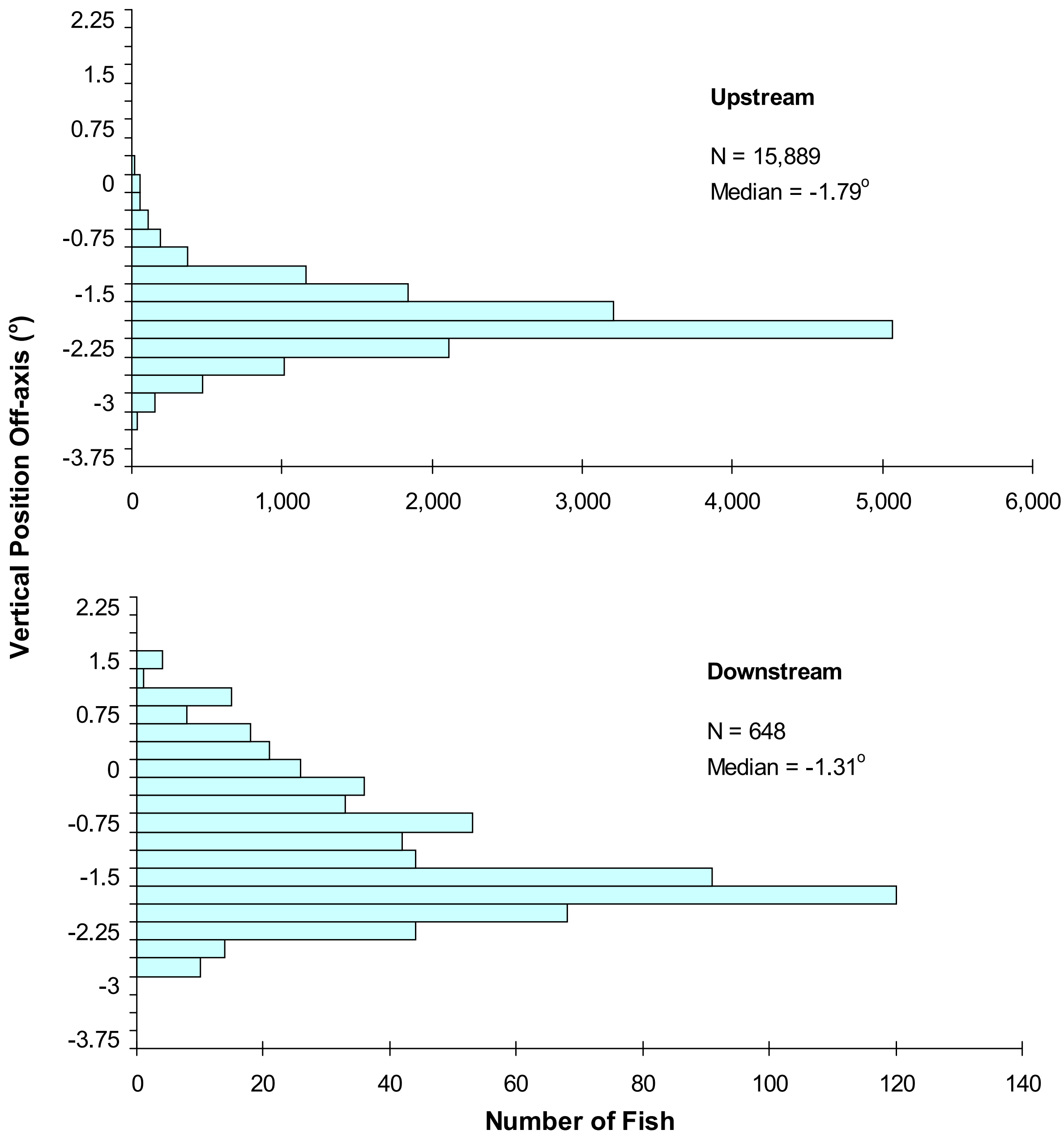

FIGURE 9.— Vertical distribution of upstream and downstream fish, left bank, Chandalar River, August 8 to September 26, 2000.

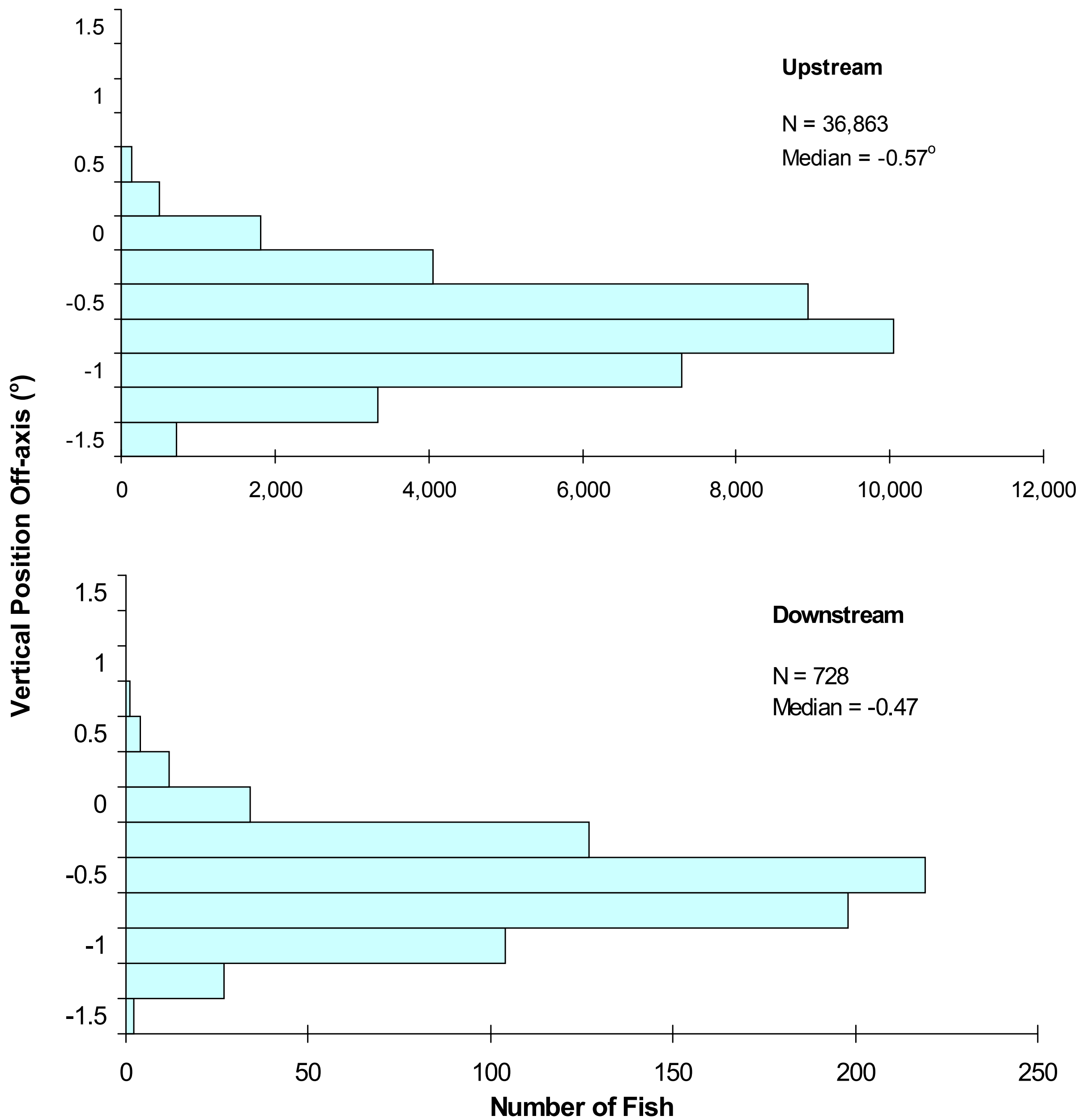

FIGURE 10.— Vertical distribution of upstream and downstream fish, right bank, Chandalar River, August 8 to September 26, 2000.

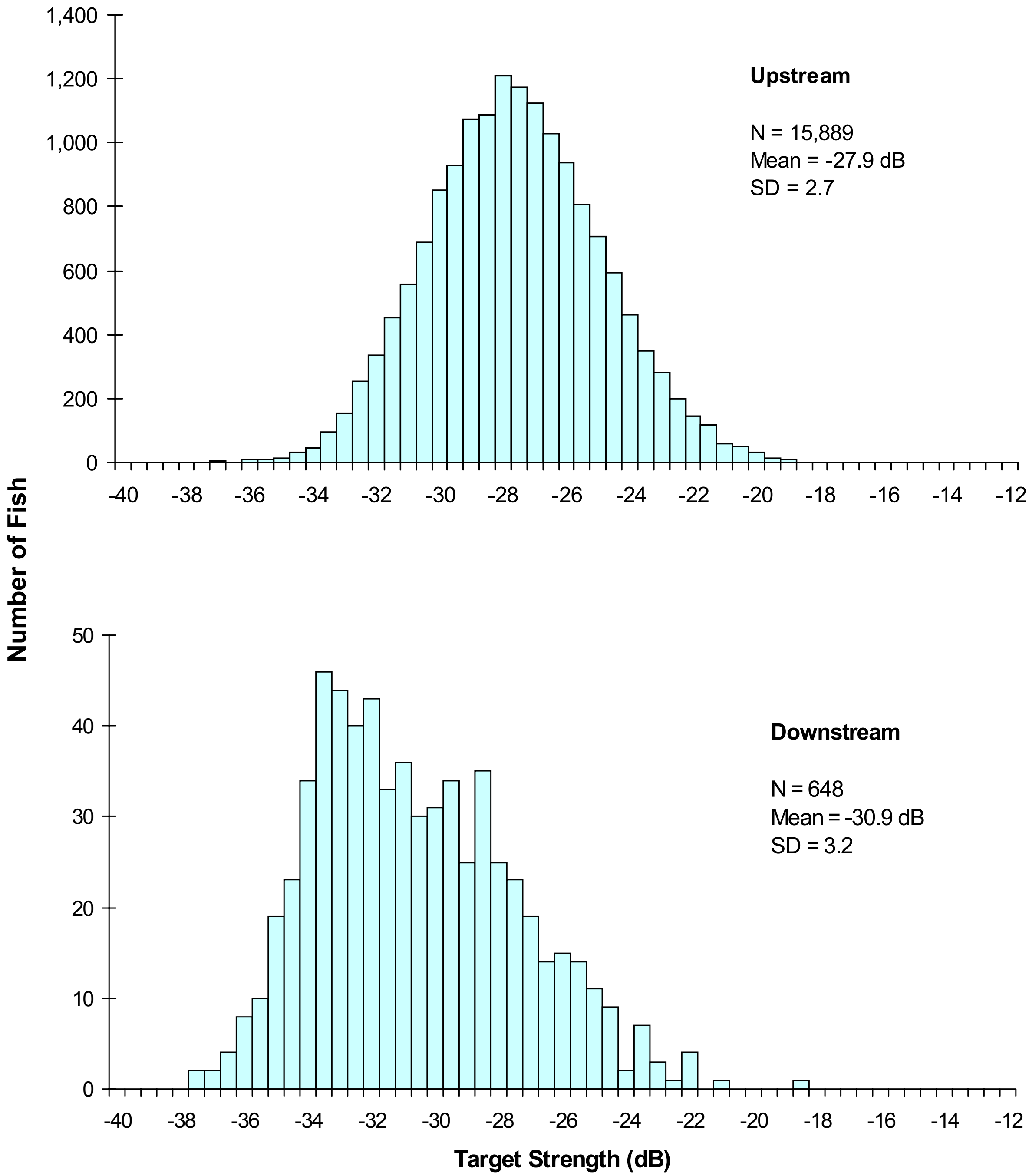

FIGURE 11.— Target strength distribution of upstream and downstream fish, left bank, Chandalar River, August 8 to September 26, 2000.

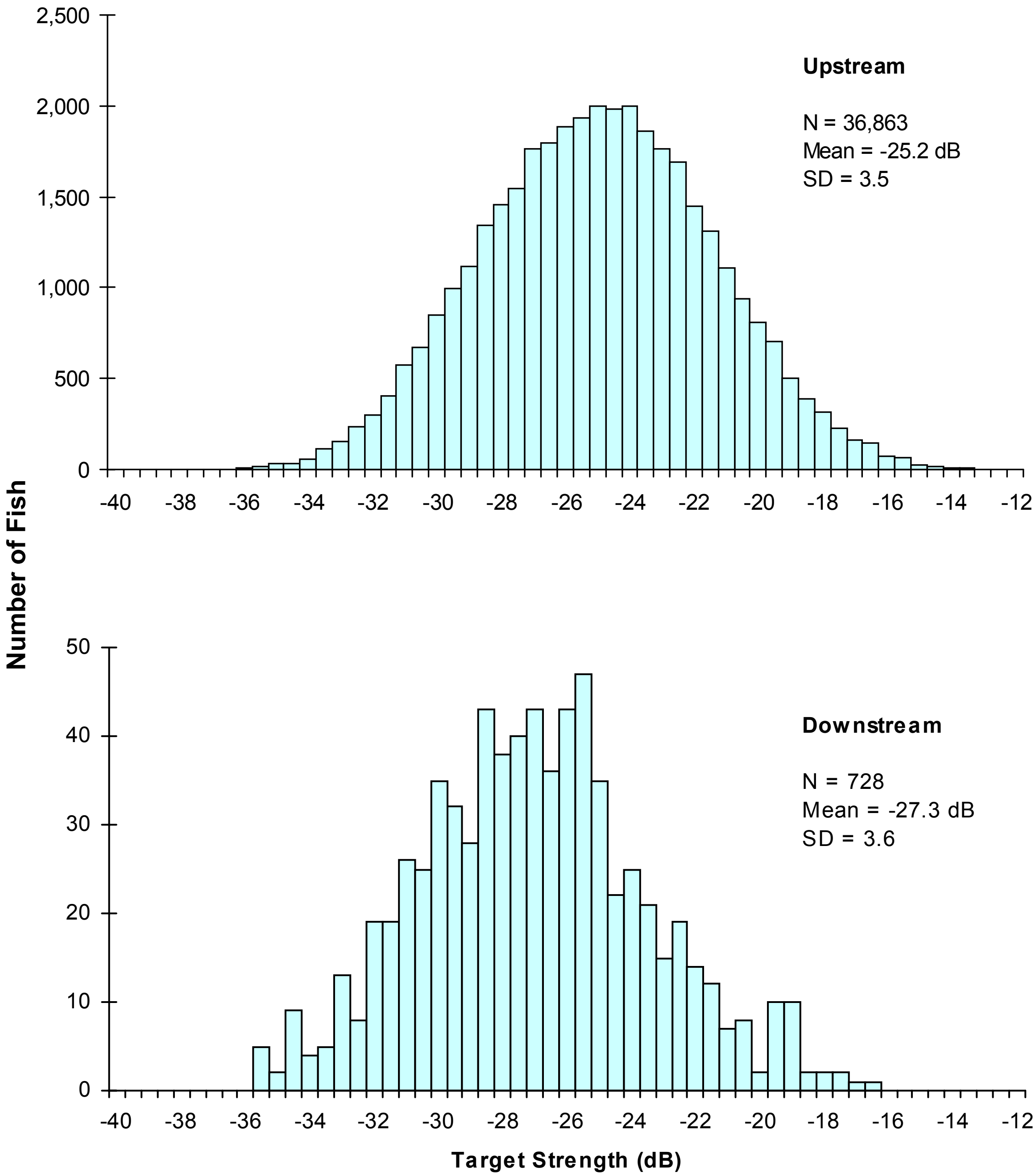

FIGURE 12.— Target strength distribution of upstream and downstream fish, right bank, Chandalar River, August 8 to September 26, 2000.

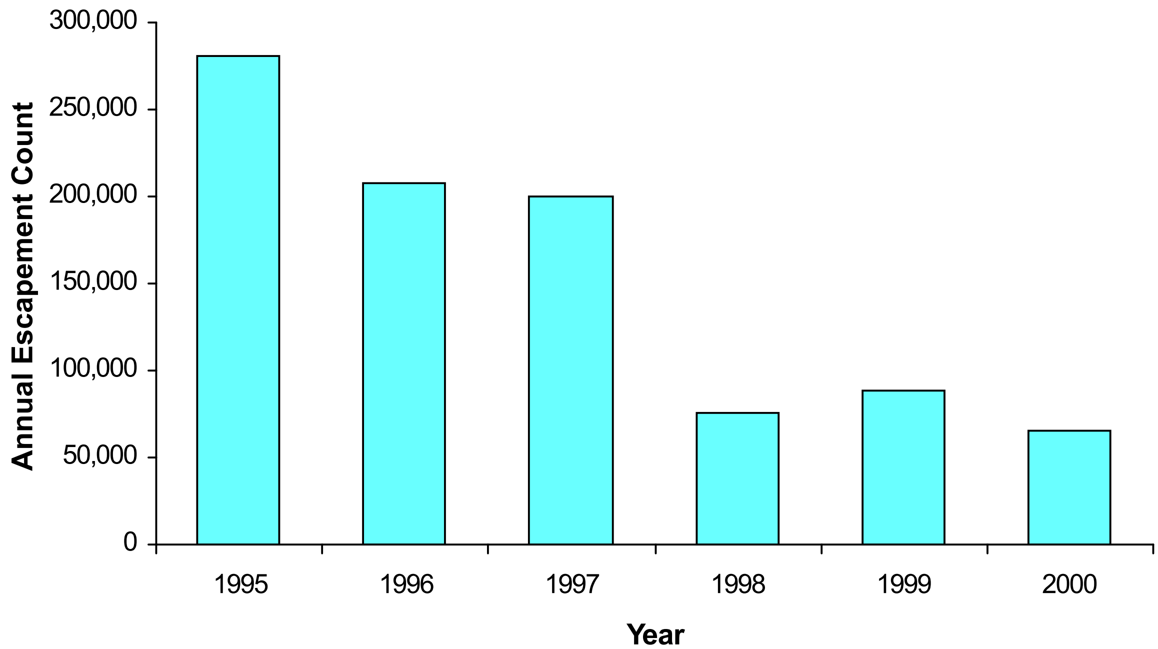

FIGURE 13.— Annual sonar escapement estimates of fall chum salmon in the Chandalar River, 1995-2000.

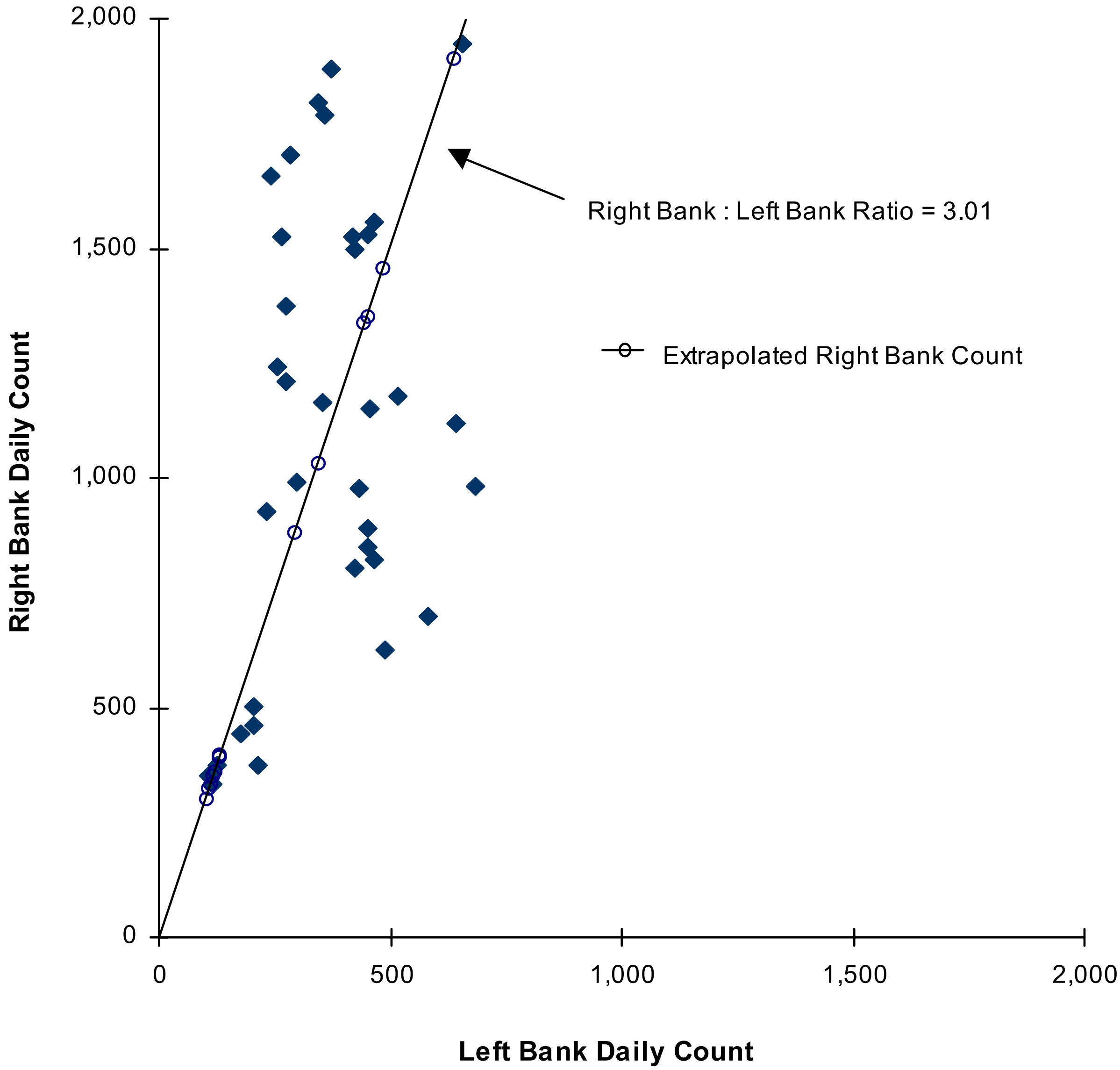

FIGURE 14.— Relationship of right bank to left bank adjusted daily counts of fall chum salmon, Chandalar River, August 8 to September 26, 2000. Missing right bank counts were extrapolated from left bank counts using the ratio estimator method (Cochran 1977).

APPENDIX 1.— Daily adjusted fall chum salmon count, Chandalar River, 1995. Asterisks represent daily estimate by linear interpolation due to high water.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	302	215	517	517	0.18
9	215	126	341	858	0.31
10	181	142	323	1,181	0.42
11	116	146	262	1,443	0.51
12	206	150	356	1,799	0.64
13	250	378	628	2,427	0.86
14	226	662	928	3,355	1.19
15	511	698	1,209	4,564	1.62
16	1,249	494	1,743	6,307	2.24
17	1,756*	877*	2,633	8,940	3.18
18	2,264*	1,259*	3,523	12,463	4.44
19	2,771*	1,642*	4,413	16,876	6.01
20	3,278	2,024*	5,302	22,178	7.89
21	3,678	2,407*	6,085	28,263	10.06
22	3,660	2,789*	6,449	34,712	12.35
23	3,960	3,172	7,132	41,844	14.89
24	3,138	2,858	5,996	47,840	17.03
25	1,680	3,485	5,165	53,005	18.86
26	2,216	4,253	6,469	59,474	21.17
27	2,997	4,753	7,750	67,224	23.92
28	3,028	4,544	7,572	74,796	26.62
29	2,652	4,182	6,834	81,630	29.05
30	2,686	3,991	6,677	88,307	31.43
31	2,504	4,233	6,737	95,044	33.82
Sep 1	2,662	4,571	7,233	102,277	36.40
2	2,643	5,339	7,982	110,259	39.24
3	3,426	6,074	9,500	119,759	42.62
4	3,518	4,054	7,572	127,331	45.31
5	2,457	3,380	5,837	133,168	47.39
6	2,317	3,769	6,086	139,254	49.56
7	2,145	3,987	6,132	145,386	51.74
8	2,625	5,465	8,090	153,476	54.62
9	3,571	6,276	9,847	163,323	58.12
10	2,734	6,688	9,422	172,745	61.48
11	3,620	6,250	9,870	182,615	64.99
12	3,890	5,373	9,263	191,878	68.28
13	4,377	6,331	10,708	202,586	72.09
14	4,397	5,698	10,095	212,681	75.69
15	4,567	4,960	9,527	222,208	79.08
16	3,675	4,649	8,324	230,532	82.04
17	3,626	4,813	8,439	238,971	85.04
18	3,290	4,984	8,274	247,245	87.99
19	3,059	5,027	8,086	255,331	90.87
20	2,693	5,143	7,836	263,167	93.65
21	3,080	6,525	9,605	272,772	97.07
22	2,138	6,089	8,227	280,999	100.00
Total	116,074	164,925	280,999		

APPENDIX 2.— Daily adjusted fall chum salmon count, Chandalar River, 1996.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	451	721	1,172	1,172	0.56
9	391	537	928	2,100	1.01
10	317	544	861	2,961	1.42
11	254	602	856	3,817	1.83
12	439	830	1,269	5,086	2.44
13	483	844	1,327	6,413	3.08
14	466	1,134	1,600	8,013	3.85
15	807	1,069	1,876	9,889	4.75
16	909	852	1,761	11,650	5.60
17	783	889	1,672	13,322	6.40
18	701	1,040	1,741	15,063	7.24
19	723	1,128	1,851	16,914	8.13
20	887	1,410	2,297	19,211	9.23
21	1,174	1,555	2,729	21,940	10.54
22	725	1,263	1,988	23,928	11.49
23	1,143	1,453	2,596	26,524	12.74
24	2,060	4,833	6,893	33,417	16.05
25	3,997	4,543	8,540	41,957	20.16
26	4,630	5,036	9,666	51,623	24.80
27	2,983	3,405	6,388	58,011	27.87
28	2,853	4,870	7,723	65,734	31.58
29	2,625	4,217	6,842	72,576	34.86
30	2,772	5,440	8,212	80,788	38.81
31	3,858	7,288	11,146	91,934	44.16
Sep 1	2,053	5,176	7,229	99,163	47.64
2	2,664	5,726	8,390	107,553	51.67
3	2,775	5,933	8,708	116,261	55.85
4	1,741	4,395	6,136	122,397	58.80
5	1,153	3,155	4,308	126,705	60.87
6	1,313	2,678	3,991	130,696	62.78
7	1,955	3,399	5,354	136,050	65.36
8	1,927	3,868	5,795	141,845	68.14
9	1,621	2,238	3,859	145,704	69.99
10	1,623	3,464	5,087	150,791	72.44
11	1,769	2,056	3,825	154,616	74.27
12	1,539	2,189	3,728	158,344	76.06
13	2,553	3,211	5,764	164,108	78.83
14	1,759	1,913	3,672	167,780	80.60
15	1,515	2,224	3,739	171,519	82.39
16	1,958	4,146	6,104	177,623	85.33
17	2,022	5,041	7,063	184,686	88.72
18	1,464	3,625	5,089	189,775	91.16
19	1,361	4,458	5,819	195,594	93.96
20	1,318	2,868	4,186	199,780	95.97
21	1,441	2,645	4,086	203,866	97.93
22	1,675	2,629	4,304	208,170	100.00
Total	75,630	132,540	208,170		

APPENDIX 3.— Daily adjusted fall chum salmon count, Chandalar River, 1997. Asterisks represent daily estimate by ratio estimator method due to high water.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	222	397	619	619	0.31
9	157	365	522	1,141	0.57
10	214	468	682	1,823	0.91
11	153	282	435	2,258	1.13
12	244	508	752	3,010	1.51
13	218	511	729	3,739	1.87
14	281	442	723	4,462	2.23
15	264	574	838	5,300	2.65
16	224	395	619	5,919	2.96
17	227	412	639	6,558	3.28
18	141	282	423	6,981	3.49
19	116	272	388	7,369	3.69
20	149	216	365	7,734	3.87
21	187	353	540	8,274	4.14
22	313	480	793	9,067	4.54
23	500	1,117	1,617	10,684	5.35
24	552	1,711	2,263	12,947	6.48
25	630	2,495	3,125	16,072	8.04
26	1,175	2,283	3,458	19,530	9.77
27	1,588	4,515	6,103	25,633	12.82
28	2,489	3,453	5,942	31,575	15.80
29	2,364	4,853 *	7,217	38,792	19.41
30	2,182	4,479 *	6,661	45,453	22.74
31	1,972	4,048 *	6,020	51,473	25.75
Sep 1	1,857	3,266	5,123	56,596	28.32
2	2,347	2,162	4,509	61,105	30.57
3	3,184	6,536 *	9,720	70,825	35.43
4	3,429	7,039 *	10,468	81,293	40.67
5	4,281	8,788 *	13,069	94,362	47.21
6	5,225	10,726 *	15,951	110,313	55.19
7	5,051	10,369 *	15,420	125,733	62.91
8	4,243	8,710 *	12,953	138,686	69.39
9	2,906	5,966 *	8,872	147,558	73.83
10	2,490	5,112 *	7,602	155,160	77.63
11	2,044	3,414	5,458	160,618	80.36
12	1,281	3,379	4,660	165,278	82.69
13	1,182	2,927	4,109	169,387	84.75
14	926	3,030	3,956	173,343	86.73
15	849	3,051	3,900	177,243	88.68
16	1,269	2,855	4,124	181,367	90.74
17	1,293	2,971	4,264	185,631	92.87
18	1,100	2,556	3,656	189,287	94.70
19	1,219	2,294	3,513	192,800	96.46
20	834	1,486	2,320	195,120	97.62
21	943	1,485	2,428	197,548	98.84
22	956	1,370	2,326	199,874	100.00
Total	65,471	134,403	199,874		

APPENDIX 4.— Daily adjusted fall chum salmon count, Chandalar River, 1998. Asterisks denote daily estimate by ratio estimator method* and linear interpolation**.

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	56	34	90	90	0.12
9	105	47	152	242	0.32
10	90	125 *	215	457	0.60
11	79 **	110 **	189	646	0.85
12	68 **	94 **	162	808	1.07
13	57	79 *	136	944	1.25
14	113	157 *	270	1,214	1.60
15	165	230 *	395	1,609	2.12
16	98	137 *	235	1,844	2.43
17	67	93 *	160	2,004	2.64
18	66	92 *	158	2,162	2.85
19	63	88 *	151	2,313	3.05
20	58	81 *	139	2,452	3.23
21	59	82 *	141	2,593	3.42
22	70	98 *	168	2,761	3.64
23	114	159 *	273	3,034	4.00
24	133	185 *	318	3,352	4.42
25	167	233 *	400	3,752	4.95
26	176	245 *	421	4,173	5.50
27	203	283 *	486	4,659	6.15
28	138	192 *	330	4,989	6.58
29	114	159 *	273	5,262	6.94
30	272	379 *	651	5,913	7.80
31	383	534 *	917	6,830	9.01
Sep 1	514	716 *	1,230	8,060	10.63
2	552	769 *	1,321	9,381	12.37
3	608	847 *	1,455	10,836	14.29
4	576	803 *	1,379	12,215	16.11
5	629	876 *	1,505	13,720	18.10
6	681	949 *	1,630	15,350	20.25
7	700	975 *	1,675	17,025	22.46
8	762	1,062 *	1,824	18,849	24.86
9	889	1,239 *	2,128	20,977	27.67
10	1,015	1,414 *	2,429	23,406	30.87
11	1,046	1,457 *	2,503	25,909	34.18
12	1,282	1,230	2,512	28,421	37.49
13	1,203	1,520	2,723	31,144	41.08
14	1,145	1,379	2,524	33,668	44.41
15	1,066	1,207	2,273	35,941	47.41
16	1,091	1,656	2,747	38,688	51.03
17	1,848	3,151	4,999	43,687	57.63
18	2,173	3,762	5,935	49,622	65.45
19	2,004	2,727	4,731	54,353	71.70
20	1,744	2,657	4,401	58,754	77.50
21	1,661	2,392	4,053	62,807	82.85
22	1,492	1,837	3,329	66,136	87.24
23	1,282	1,456	2,738	68,874	90.85
24	993	1,505	2,498	71,372	94.14
25	962	1,374	2,336	73,708	97.23
26	844	1,259	2,103	75,811	100.00
Total	31,676	44,135	75,811		

APPENDIX 5.— Daily adjusted fall chum salmon count, Chandalar River, 1999. Asterisks denote daily count estimated by ratio estimator method (*) or linear interpolation (**).

Date	Left bank	Right bank	Combined	Cumulative	Cumulative (%)
Aug 8	55	94	149	149	0.17
9	89	39	128	277	0.31
10	76 **	47 **	123	400	0.45
11	63 **	56 **	119	519	0.59
12	49	65 *	114	633	0.71
13	87	116 *	203	836	0.94
14	92	122 *	214	1,050	1.18
15	158	210 *	368	1,418	1.60
16	241	320 *	561	1,979	2.23
17	443	589 *	1,032	3,011	3.40
18	529	703 *	1,232	4,243	4.79
19	852	1,133 *	1,985	6,228	7.02
20	974	1,295 *	2,269	8,497	9.58
21	1,018	1,354 *	2,372	10,869	12.26
22	956	1,271 *	2,227	13,096	14.77
23	1,402	1,864 *	3,266	16,362	18.45
24	1,310	1,742 *	3,052	19,414	21.90
25	1,225	1,629 *	2,854	22,268	25.12
26	1,579	2,100 *	3,679	25,947	29.27
27	1,560	2,075 *	3,635	29,582	33.36
28	1,686	2,242 *	3,928	33,510	37.80
29	1,271	1,690 *	2,961	36,471	41.13
30	868	1,154 *	2,022	38,493	43.42
31	873	1,161 *	2,034	40,527	45.71
Sep 1	876	878	1,754	42,281	47.69
2	932	1,042	1,974	44,255	49.91
3	940	1,504	2,444	46,699	52.67
4	1,175	1,396	2,571	49,270	55.57
5	1,595	2,121 *	3,716	52,986	59.76
6	2,046	2,721 *	4,767	57,753	65.14
7	1,702	2,263 *	3,965	61,718	69.61
8	1,191	1,584 *	2,775	64,493	72.74
9	748	995 *	1,743	66,236	74.71
10	608	809 *	1,417	67,653	76.30
11	568	659	1,227	68,880	77.69
12	503	692	1,195	70,075	79.04
13	583	655	1,238	71,313	80.43
14	567	796	1,363	72,676	81.97
15	474	659	1,133	73,809	83.25
16	531	826	1,357	75,166	84.78
17	590	750	1,340	76,506	86.29
18	536	816	1,352	77,858	87.81
19	455	877	1,332	79,190	89.32
20	486	1,024	1,510	80,700	91.02
21	470	854	1,324	82,024	92.51
22	607	1,021	1,628	83,652	94.35
23	663	827	1,490	85,142	96.03
24	672	690	1,362	86,504	97.57
25	495	617	1,112	87,616	98.82
26	622	424	1,046	88,662	100.00
Total	38,091	50,571	88,662		