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Enumeration of Chandalar River Fall Chum Salmon Using Split-beam Sonar, 1998

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ABSTRACT

A five-year, 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 provided since 1996. Operational methods and procedures for collecting continuous acoustic data have been finalized. This report presents the results for the 1998 season and describes the annual variability in run size and timing. Elliptical-beam transducers were installed on opposite river banks to optimize sonar beam coverage and aimed perpendicular to the river current. Both sonar units were operated from August 8 through September 26, except for a prolonged period of high water from mid-August to mid-September. The right bank sonar missed 34.0 days of sampling and the left bank missed 3 3 days during the high water period

A total of 1,452 hours of digital echo processor data were collected and manually tracked, resulting in 59,259 fish written to file. Upstream traveling fish accounted for 98% of the total tracked targets The median number of acquired echoes per upstream fish was 21 on the left bank and 18 on the right bank. Downstream fish had medians of 14 echoes per fish on the left bank and 15 echoes per fish on the right bank.

The estimated 1998 fall chum salmon escapement count from August 8 through September 26 was 75,811 fish ± 5,938 (95% confidence interval). The right bank accounted for 58% of the total estimated 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 fish passage rate was only 90 upstream fish on the first day of counting (0 1% of the total estimated count) and 2,103 fish on the final day (2.8% of the total) The 1998 count was only 33% of the 1995-1997 average of 229,681 fish. The Chandalar River had the highest escapement of all monitored populations of fall chum salmon in the Yukon River drainage in 1998.

Precision of the 1998 estimate varied between banks. On the left bank, the precision of the estimate was considered high because 91% of the season was acoustically sampled and 96% of the left bank's adjusted count was actually tracked The right bank monitored only 30% of the season and tracked fish represented 62% of the right bank's total adjusted count The largest potential source of error was in estimating daily right bank counts for 33 missing 24-h periods during high water.

Daily passage rates indicated a uni-modal run, with the peak daily count of 5,935 fish on September 18 The median passage date was on September 16, 11 days later than the 1995-1997 average The run arrived later than previous years by approximately 11 days, with the first 25% not passing until September 9. Unlike earlier years, hourly passage rates of upstream fish did not show any strong diel patterns Previously, the left bank exhibited a strong diel trend, with highest passage rates occurring 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

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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, monitoring long-term population trends, and influencing U.S./Canada salmon treaty negotiations for allocating trans-boundary chinook *Oncorhynchus tshawytscha* and chum salmon *O. keta* stocks 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. 1997)

The Yukon River drainage, encompassing 854,700 km^2, is among the largest producers of wild chinook and chum salmon 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 on refuge lands are conserved in their natural diversity, international treaty obligations are met, and subsistence opportunities are maintained An important component of this mandate is providing accurate spawning escapement estimates for the major salmon stocks in the drainage

In limited use in Alaska since the early 1960's (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 the second largest population of fall chum salmon in the U.S. portion of the Yukon River drainage Annual sonar counts 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 due to the recent declining trend of some Yukon River salmon stocks

(Bergstrom et al. 1995), a five-year 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). In 1995, daily and seasonal estimates of spawning escapement were calculated in the 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 since sonar enumeration began in 1986 (Appendix 1) In 1996, the project became fully operational (Osborne and Daum 1997) Daily run 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). This report presents the escapement information from the 1998 season and describes annual variability in run size and timing

STUDY AREA

The Chandalar River is a fifth order tributary of the Yukon River, draining from the southern slopes of the Brooks Range. It consists of three major branches. East, Middle, and North Forks (Figure 1). Principal water sources include rainfall, snowmelt, and to a lesser extent, 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 majority 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 (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 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 faster water velocity than the right bank River bottom slopes were approximately 7.2° on the left bank and 3.4° on the right bank The consistent linear appearance of the bottom on the right bank (1994-1997) had changed in 1998. The bottom was bumpy and uneven past 57 m offshore, probably caused by sediment deposited from severe bank erosion during a flood event in early summer. River substrate consisted of small rounded cobble/gravel on the left bank and sand/silt on the right bank During the 1998 season, river width at the site averaged 146 m (ranging from 138 to 176 m) and maximum depth averaged 4 9 m (ranging from 4.1 to 6 3 m) Water levels were higher than all previous years, except 1994 when the site flooded (Figure 4) Water temperature decreased from 15 to 5°C as the season progressed and conductivity remained fairly constant, varying from 230 to 320 μS/cm (Figure 5) Specific methodology for constructing cross-sectional river profiles and measuring daily water elevation, temperature, and conductivity can be found in Osborne and Daum (1997). Due to high water throughout the 1998 season, buoys were not used as reference points during river profiling. This resulted in bottom slopes and distance measurements from thalweg to shore being approximated.

METHODS

Data Collection

Fixed-location, split-beam hydroacoustics was used to monitor the upstream migration of adult fall chum salmon in the Chandalar River in 1998 Systems were installed on opposite river banks to optimize sonar beam coverage of the river cross-sectional area Both sonar units were operated continuously from August 8 through September 26, except for a prolonged period of high water from mid-August to mid-September. The right bank sonar missed 34 0 days of sampling and the left bank system missed 3 3 days during the high water event. Counting was extended four days beyond the previous years' termination date of September 22 due to the late arrival of the 1998 run.

Equipment description

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 having network capabilities (Figure 6) 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 1998) 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 between 0.1 and 2.6 dB of factory calibrated values (Table 1). When the standard target was positioned near the bottom edge of the beam, *in situ* target strength values and variability (SD) increased

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 2). 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 to -34 dB on-axis for data collected at far ranges For the season, average peak amplitude noise levels varied from -56 to -42 dB for the left bank and -52 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, primarily due to transducer re-deployment as water levels varied. Left bank acquisition range changed from 14 to 21 m, the final 10 m distance to the thalweg was not ensonified due to an inflection in the river bottom. Right bank beam coverage ranged from 32 to 42 m, with approximately 55 m left unensonified due to reverberation from the irregular bottom. In previous years, beam coverage was nearly complete on the right bank All 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 back-up 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 Target strength threshold settings were kept constant for the season at -40 dB. 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 1998 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 0 by 10.1°on the right bank The transducers had low side-lobes which allowed the beam to be aimed close to the river bottom (−16 4 dB for the left bank and −23 3 dB for the right bank, measured on a one-way beam pattern plot)

The transducers and remote-controlled rotators were mounted on aluminum T-bar frames and secured in place with sandbags at a depth of 0.6-1.5 m (Figure 7). 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. A small rise in vertical aim could allow fish to pass undetected under the beam 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. 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) Non-fish echoes from boat motors, acoustic noise, and rocks were excluded from the database Echoes from boat motors and acoustic noise were visually identified by the random nature of individual echoes displayed on software-produced echograms Rock targets exhibited a stationary bottom position in the beam with no movement in the upstream or downstream direction. Suspected fish targets, represented by a contiguous series of 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. All upstream swimming fish were assumed to be chum salmon; based on five previous seasons of gill net catches consisting of over 99% chum salmon (Daum and Osborne 1996) 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

Escapement estimate and run timing

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

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

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, i.e., 44 days on the left bank and 14 days on the right 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 (*see Results, Figure 14*). 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 event, 31 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). The 95% confident interval for the missing-days estimate was reported For two days, when both banks were inoperable, the daily counts were estimated by linear interpolation between the daily count before and after the event 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

Spatial distribution of tracked fish

Fish position data provide 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

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

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

Target strength distribution of tracked fish

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).

Fish orientation in the beam and noise-induced bias affect the precision of target strength estimates Precision of target strength estimates were measured using within-fish target strength variability (SD) for upstream and downstream fish Standard deviations for each fish were plotted and mean values were calculated Mean within-fish target strength variability between upstream and downstream fish by bank were compared using a two-sample *t* test for means with unequal variances.

RESULTS

Acoustic Data Verification and Fish Tracking

For the season, over 1,450 hours of acoustic data were collected and 59,259 fish were manually tracked. Daily summary information for all tracked echo processor files is presented in Tables 3 and 4 Upstream traveling fish accounted for 98% of the total tracked fish On the left bank, 91% of the season was monitored, with 3 3 days missed during high water Right bank sample time was considerably less than the left bank due to down time from the high water event Approximately 30% of the season was sampled, with 34 0 days missed during high water Generally, upstream fish had more echoes/fish than downstream fish (Figures 8 and 9). The median number of acquired echoes per upstream fish was 21 on the left bank (range of 4-360) and 18 on the right bank (range of 4-418) Downstream fish had medians of 14 echoes per fish on the left bank (range of 4-188) and 15 echoes per fish on the right bank (range of 4-254)

Acoustic Data Analyses

Escapement estimate and run timing

The adjusted 1998 fall chum salmon escapement count for the Chandalar River was 75,811 upstream fish ± 5,938 (95% confidence interval, Table 5). The right bank accounted for 58% 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 only 90 upstream fish on the first day of sonar operation (0.1% of the total estimated count), while 2,103 fish passed on the final day of counting (2.8% of the total). Daily counts were more than 2,000 fish/d for 18 of the 50 counting days The 1998 count was only 33% of the 1995-1997 average of 229,681 fish (Figure 10).

Of the final adjusted upstream count of 75,811 fall chum salmon, 76% were actually tracked (57,871 fish) Missing days made up the largest block of estimated counts The right bank missed 33 24-h sampling periods during the high water event beginning August 10 and the left bank missed two complete days. This represented 66% of the entire 50 day sampling period on the right bank and 4% of the left bank total. Counts were also estimated for 78 missing hours for the season, 43 h on the left bank and 35 h on the right bank Count adjustments for partial hours made up only 11% of all hourly counts (counts ≥ 0.25 h), with the majority of incomplete hours having sample times ≥ 0 75 h.

Daily passage rates indicated a uni-modal run with the peak count of 5,935 fish on September 18 (Figure 10). The median passage date occurred on September 16, 11 days later than the 1995-1997 average. The run also arrived later than previous years by approximately 11 days, with the first quartile not passing until September 9. Run timing was similar between banks during the later part of the run (Figure 11) The beginning of the run could not be compared because of missing right bank counts.

Hourly passage rates of upstream fish on the left bank did not exhibit a strong diel pattern through the season as in previous years (Figure 12). The pattern of high passage rates during late night/early morning hours and low numbers during the day was only apparent for a few days in September. As in previous seasons, right bank fish did not show any trend in diel distribution through the season (Figure 13) The mean hourly passage rates for left and right bank fish did not show any diel tendency among upstream fish (Figure 14)

Spatial distribution of tracked fish

Upstream migrating chum salmon were shore-oriented and most fish were well within the range of acoustic detection for both banks (Figures 15 and 16) Over 91% of upstream fish were within 10 m of the left bank transducer and 23 m of the right bank transducer Downstream fish were more distributed across the full detection range For the season, median range values for upstream fish were 6 m closer to shore than downstream fish on the left bank and 5 m closer to shore on the right bank.

Vertical fish position data showed that upstream swimming chum salmon on both banks were bottom-oriented (Figures 17 and 18). Over 99% of upstream fish on each bank passed below the acoustic axis Downstream fish were more widely distributed throughout the ensonified zone. For the season, the median vertical position of upstream fish was lower in the water column than downstream fish. These trends in spatial position of tracked fish were similar to results from the previous four years.

Target strength distribution of tracked fish

For the season, the average target strength of upstream swimming fall chum salmon was -29.7 dB on the left bank and -28.0 dB on the right bank (Figures 19 and 20). Downstream fish had significantly smaller target strengths than upstream fish (P values < 0 001), averaging -30.7 dB on the left bank and -29.4 dB on the right bank Mean target strengths from both upstream and downstream fish on the right bank were larger than fish on the left bank (P values < 0.001). Trends in target strength between upstream and downstream fish and between fish from opposite banks were similar to 1994-1997 results. Within-fish target strength variability (SD) averaged 3 5 dB for upstream fish on the left bank and 4 1 dB for fish on the right bank (Figures 21 and 22) Mean within-fish target strength variability was slightly greater for downstream fish than upstream fish on the left bank (difference of 0 1 dB, P < 0 05). On the right bank, mean within-fish target strength variability was greatest for upstream fish (difference of 0 2 dB, P < 0.001).

DISCUSSION

In 1998, the Chandalar River had the lowest escapement of fall chum salmon since split-beam sonar enumeration began in 1995 (Figure 23) Escapements to other major spawning grounds in the upper Yukon River drainage dropped substantially from the 1994-1997 levels (Bergstrom et al., in press). In three of the last four years, the Chandalar River has had the highest escapement in the entire Yukon River drainage. The 1998 Chandalar River estimate was approximately 45% of the combined total for all upper Yukon River enumeration projects, i.e., Chandalar, Sheenjek, Fishing Branch, and Canadian mainstem Yukon rivers. The Sheenjek River, located 116 km upstream from the Chandalar River, had similar run characteristics to the Chandalar River Both runs experienced peak counts between September 16 and September 22, with the median passage date on the Sheenjek River (September 18) occurring two days after the Chandalar River's median date of September 16 (L. Barton, Alaska Department of Fish and Game, personal communication) Median passage dates between the two rivers have been within 2 days of each other since 1995.

The precision of the 1998 Chandalar River escapement estimate varied between banks. On the left bank, the precision of the estimate was considered high Acoustic data were collected for 91% of the season and few adjustments were made to the actual tracked fish count (96% of the left bank's final count was actually tracked) The right bank monitored only 30% of the season and tracked fish represented 62% of the right bank's total adjusted count The largest potential source of error was in estimating daily right bank counts for the 33 missing 24-h periods due to high water Fortunately, the majority of estimated right bank counts were for days when passage rates were assumed low. 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 24) The left and right bank daily counts were highly correlated for the 17 non-missing days ($r = 0.95$, $P < 0.001$). In addition, the 95% confidence interval around the missing-days estimate was within 7.8% of the total seasonal count. However, the ratio, calculated from mostly high passage days, was used to estimate right bank counts during low passage. This may have introduced bias to the estimate

Fish position data suggested that most upstream fish passing the sonar site were within the ensonified zone during the 1998 season As in the previous four 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 However, the acquisition range of the right bank was more limited than previous years because of the irregular bottom in 1998 For the majority of the season, the acquisition range was 32 m, compared to normal annual ranges of between 65 and 80 m. On average, only 2.7% of past years' right bank counts were from fish beyond 31 m offshore (ranging from 4 8% in 1996 to 1.1% in 1995). Examination of chart recordings past 32 m provided additional evidence that few fish passed beyond the acquisition range 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)

High variability in target strength within and among fish could result in undercounting fish or cause elevated target strength calculations due to voltage threshold bias (MacLennan and Simmonds 1992). *In-situ* calibration data from 1995-1998 showed higher target strength variability for the standard target when it was positioned near the bottom of the beam compared to an on-axis position. Because Chandalar River chum salmon are bottom orientated, high variability in target strength would be expected Results from the 1995 *in-situ* target strength experiment on free-swimming fish confirmed the high variability found in target strength values, both within and among fish (Daum and Osborne 1996) For most of the 1998 season, the voltage threshold was set substantially lower (10 dB) than predicted target strength values for fish of chum salmon length (Love 1977) to insure that acoustic data were not biased; threshold set at -40 dB During high noise events, the voltage threshold was increased to -34 dB at far ranges (beyond approximately 15 m on the left bank and 25 m on the right bank). This may have caused biased target strength values and undercounting of fish past these ranges. However, most upstream fish had target strengths substantially above the elevated threshold setting (Figures 19 and 20) and few fish occurred at far ranges (Figures 15 and 16). Daily comparisons of chart counts to the electronic data set revealed that few fish were missed at the higher voltage threshold setting In addition, fish traces at far ranges were closely scrutinized while visually tracking upstream targets 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.

The year-specific and overall project objectives of the five-year study have been completed. Annual escapement estimates of Chandalar River fall chum salmon have been made since 1995 and daily in-season counts provided since 1996. Operational methods and procedures for collecting continuous split-beam acoustic data on the Chandalar River have become finalized. Data verification and manual fish tracking continue to be labor intensive due to large numbers of salmon and software limitations Considerable time would be saved if an automatic tracking system was developed that provided accurate counts of upstream traveling fish on the Chandalar River. Until that time, manual tracking of fish targets will be necessary to ensure data integrity and count accuracy

Annual sonar enumeration of fall chum salmon in the Chandalar River should continue into the future, based on the Chandalar River's significant contribution to the total run of Yukon River fall chum salmon (Bergstrom et al , in press) and the importance of the stock to subsistence users throughout the drainage. During upcoming seasons, daily in-season counts and post-season escapement estimates will be provided Future sampling schedules will attempt 24-h continuous acoustic monitoring However, sub-sampling may become necessary if in-season manual fish tracking falls behind schedule due to high fish passage rates.

The acoustical characteristics of the Chandalar River sonar site create a favorable setting for conducting many riverine acoustic experiments beyond the specific scope of enumerating upstream swimming salmon. Many acoustical problems relating to noise interference, automatic fish tracking, and testing of theoretical sonar models can be addressed using data from the Chandalar River. The sonar site's attributes include. a mono-specific fish run, good transducer deployment sites; low background noise levels compared to most riverine sonar projects; minimal interference from boat traffic and debris; and fish densities conducive to single target tracking. However, high water events, such as those experienced in 1998 could disrupt some investigations. For the 1999 season, target strength measurements from free-swimming chum salmon will be collected This information will be used by the University of Alaska, Electrical Engineering Department, to test an acoustical model being developed for the Alaska Science Foundation and the Alaska Department of Fish and Game. Also, Dr Peter Dahl of the Applied Physics Lab, University of Washington, has requested background reverberation data from different noise sources in the Chandalar River.

ACKNOWLEDGMENTS

Special appreciation is extended to the people that participated in the fifth year of this project and who are largely responsible for its success; C Gewin and L. Hanson for field assistance, and S. Johnston for technical assistance. We appreciate the assistance from R Carroll for providing transportation to the site. Success of this project was also dependant on the support from J. Gordon and M. Millard for assistance in computer programming and data analysis, S. Klosiewski for statistical advice, R Simmons for editorial and project review; J. Millard and J. Melegari for editorial review

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Table 1. Target strength measurements of a 38 1 mm tungsten carbide sphere, Chandalar River, 1998.

Type of calibration	Date	Mean target strength (dB)	SD	N	Target range (m)	Position of target
		Left bank				
Factory	Jun 16	-38.93	0 69	1,951	5.9	On-axis
In situ	Aug 5	-39.83	1 21	2,012	5.0	On-axis
In situ	Aug 5	-34.79	2 32	302	5 0	Bottom of beam
In situ	Sep 2	-38.65	0 73	1,790	6.1	On-axis
In situ	Sep 2	-34 07	2.69	1,162	6.1	Bottom of beam
In situ	Sep 22	-37.69	0 98	2,705	6.5	On-axis
In situ	Sep 22	-33.43	1 62	2,809	6.5	Bottom of beam
		Right bank				
Factory	Jun 17	-37 84	0.41	2,679	5.9	On-axis
In situ	Aug 7	-37.91	0 59	1,936	6 2	On-axis
In situ	Aug 7	-36.97	2 88	233	6 2	Bottom of beam
In situ	Sep 24	-35 29	0 62	1,803	6.6	On-axis
In situ	Sep 24	-34 90	3 00	918	6.6	Bottom of beam

Table 2. Echo acceptance criteria used for digital echo processing, Chandalar River, 1998 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 57 to 2 38	-5.41 to 5.41	-40[a]	14 to 21
Right	0 10 to 0 38	-1 49 to 1 49	-5.04 to 5.04	-40[a]	32 to 42

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

Table 3. Hydroacoustic data collected from the left bank, Chandalar River, 1998. Asterisks represent days when sampling was discontinued due to high water.

Date	Sample time (h)	Upstream count	Downstream count	Total count
Aug 8	23 63	55	8	63
9	23 44	102	15	117
10	7 5	31	2	33
11*	0	-	-	-
12*	0	-	-	-
13	10 26	25	1	26
14	23 22	112	1	113
15	23 48	162	3	165
16	23 18	93	3	96
17	23 80	66	0	66
18	22 36	61	3	64
19	23 62	62	3	65
20	23 76	58	7	65
21	23 79	59	5	64
22	23 80	69	4	73
23	23 79	113	5	118
24	23 75	132	2	134
25	23 80	165	1	166
26	23 80	174	3	177
27	22 79	194	6	200
28	22 71	132	5	137
29	23 68	112	15	127
30	23 74	269	7	276
31	23 39	375	5	380
Sep 1	23 33	501	18	519
2	22 99	531	6	537
3	23 70	599	8	607
4	23 68	568	2	570
5	23 79	624	6	630
6	23 39	668	5	673
7	23 79	694	6	700
8	23 75	756	13	769
9	23 21	873	6	879
10	23 80	1,008	10	1,018
11	23 77	1,038	18	1,056
12	23 79	1,274	25	1,299
13	23 49	1,184	34	1,218
14	23 74	1,134	34	1,168
15	23 80	1,056	46	1,102
16	23 81	1,082	43	1,125
17	23 80	1,834	22	1,856
18	23 26	2,115	19	2,134
19	23 79	1,987	13	2,000
20	23 78	1,728	27	1,755
21	23 81	1,647	28	1,675
22	23 30	1,454	42	1,496
23	23 66	1,263	29	1,292
24	23 81	983	11	994
25	23 76	952	15	967
26	10 52	393	11	404
Total	1,088.61	30,567	601	31,168

Table 4. Hydroacoustic data collected from the right bank, Chandalar River, 1998. Asterisks represent days when sampling was discontinued due to high water.

Date	Sample time (h)	Upstream count	Downstream count	Total count
Aug 8	23 48	33	4	37
9	13 40	29	4	33
10*	0	-	-	-
11*	0	-	-	-
12*	0	-	-	-
13*	0	-	-	-
14*	0	-	-	-
15*	0	-	-	-
16*	0	-	-	-
17*	0	-	-	-
18*	0	-	-	-
19*	0	-	-	-
20*	0	-	-	-
21*	0	-	-	-
22*	0	-	-	-
23*	0	-	-	-
24*	0	-	-	-
25*	0	-	-	-
26*	0	-	-	-
27*	0	-	-	-
28*	0	-	-	-
29*	0	-	-	-
30*	0	-	-	-
31*	0	-	-	-
Sep 1*	0	-	-	-
2*	0	-	-	-
3*	0	-	-	-
4*	0	-	-	-
5*	0	-	-	-
6*	0	-	-	-
7*	0	-	-	-
8*	0	-	-	-
9*	0	-	-	-
10*	0	-	-	-
11*	0	-	-	-
12	11.14	492	15	507
13	23 75	1,503	55	1,558
14	23 62	1,359	71	1,430
15	23 74	1,194	59	1,253
16	22 70	1,608	37	1,645
17	23 67	3,102	33	3,135
18	23 72	3,724	21	3,745
19	23 80	2,708	51	2,759
20	23 77	2,636	70	2,706
21	23 77	2,369	122	2,491
22	22 25	1,707	129	1,836
23	23 70	1,439	36	1,475
24	23 02	1,436	27	1,463
25	23 63	1,353	41	1,394
26	10 63	612	12	624
Total	363.79	27,304	787	28,091

Table 5. Daily adjusted fall chum salmon count, Chandalar River, 1998. Asterisks denote daily count estimated by ratio estimator method (*) or 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		

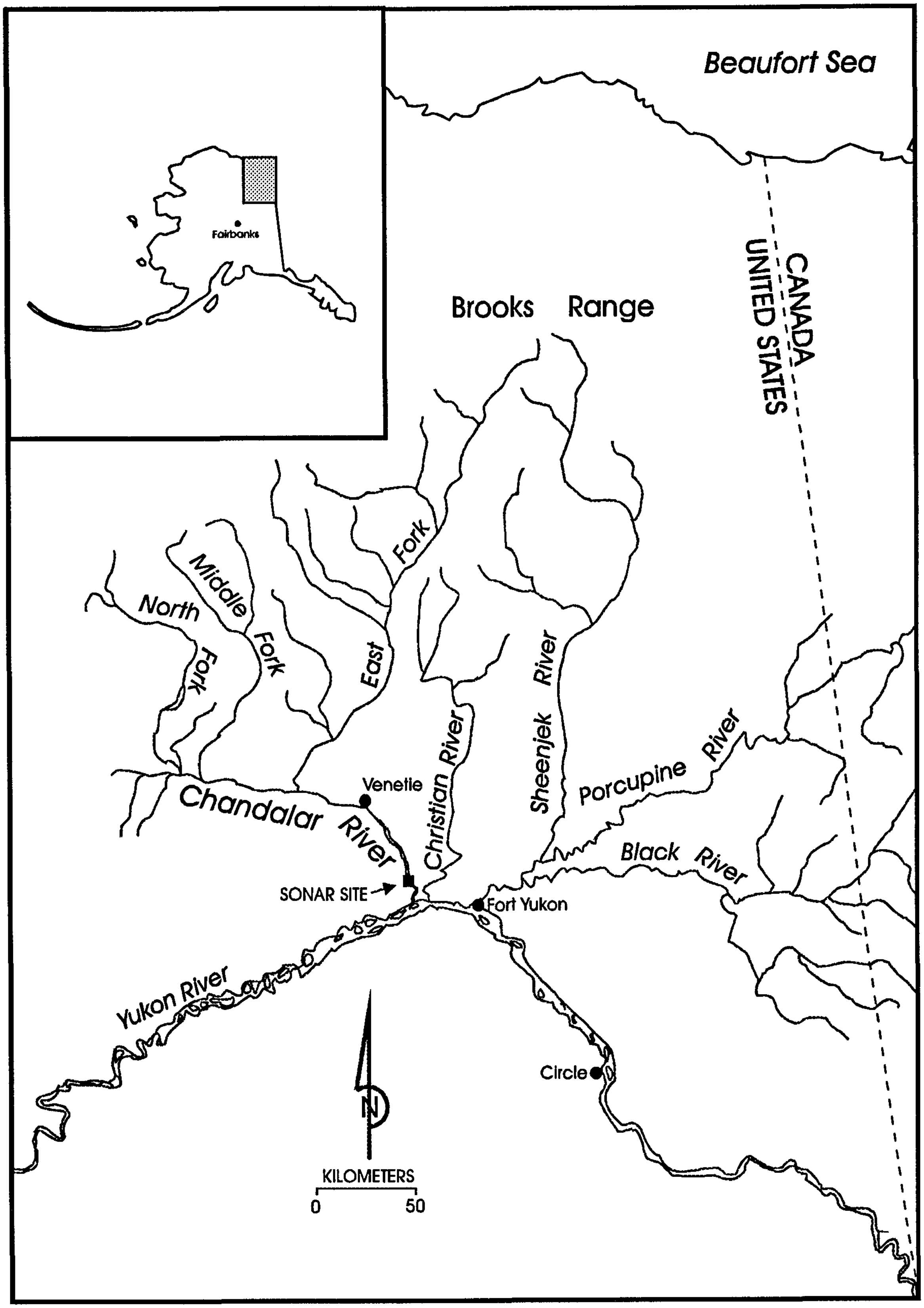

Figure 1. Major tributaries of the Yukon River near the U.S./Canada border.

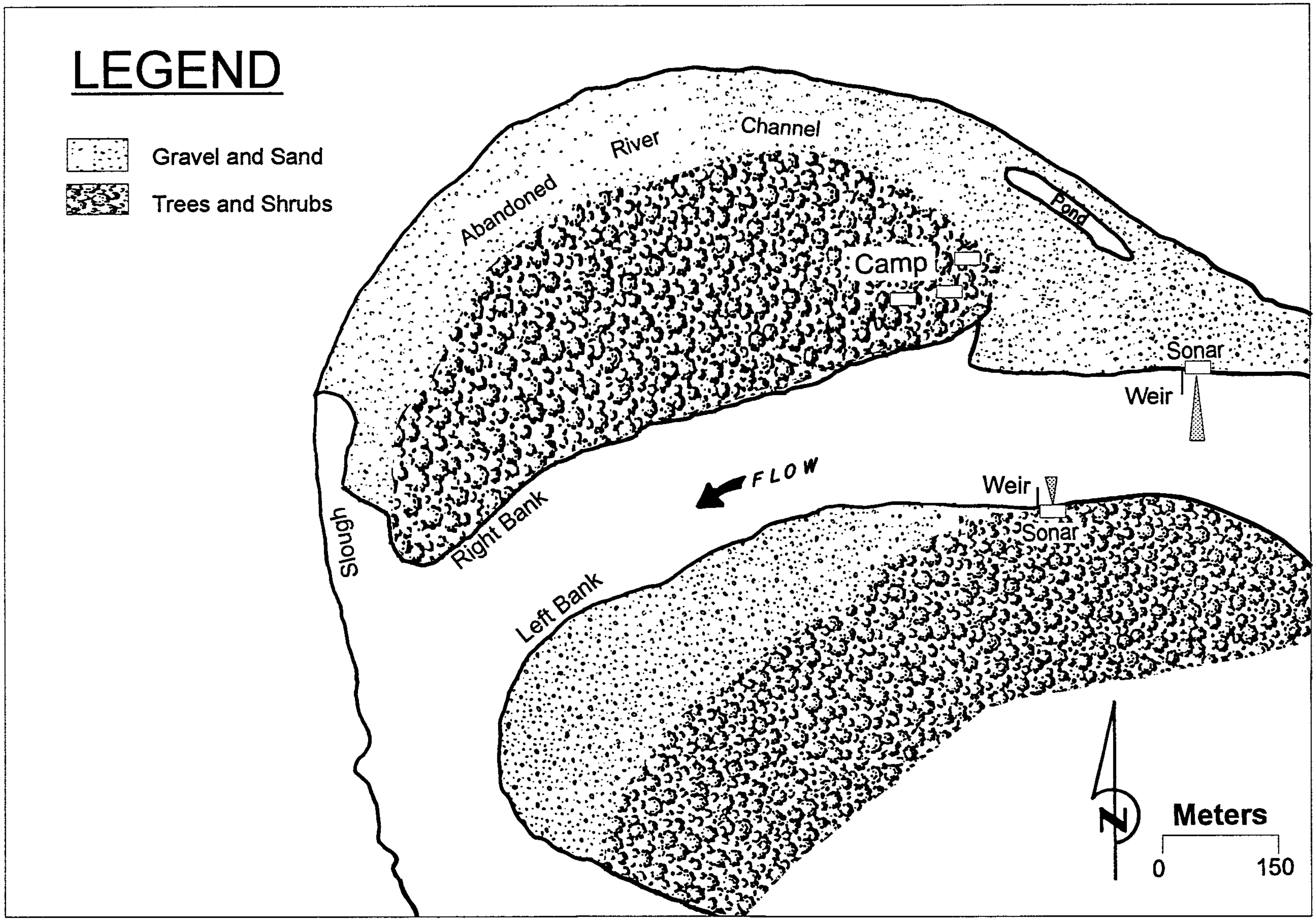

Figure 2. Site map of the Chandalar River sonar facilities, 1998.

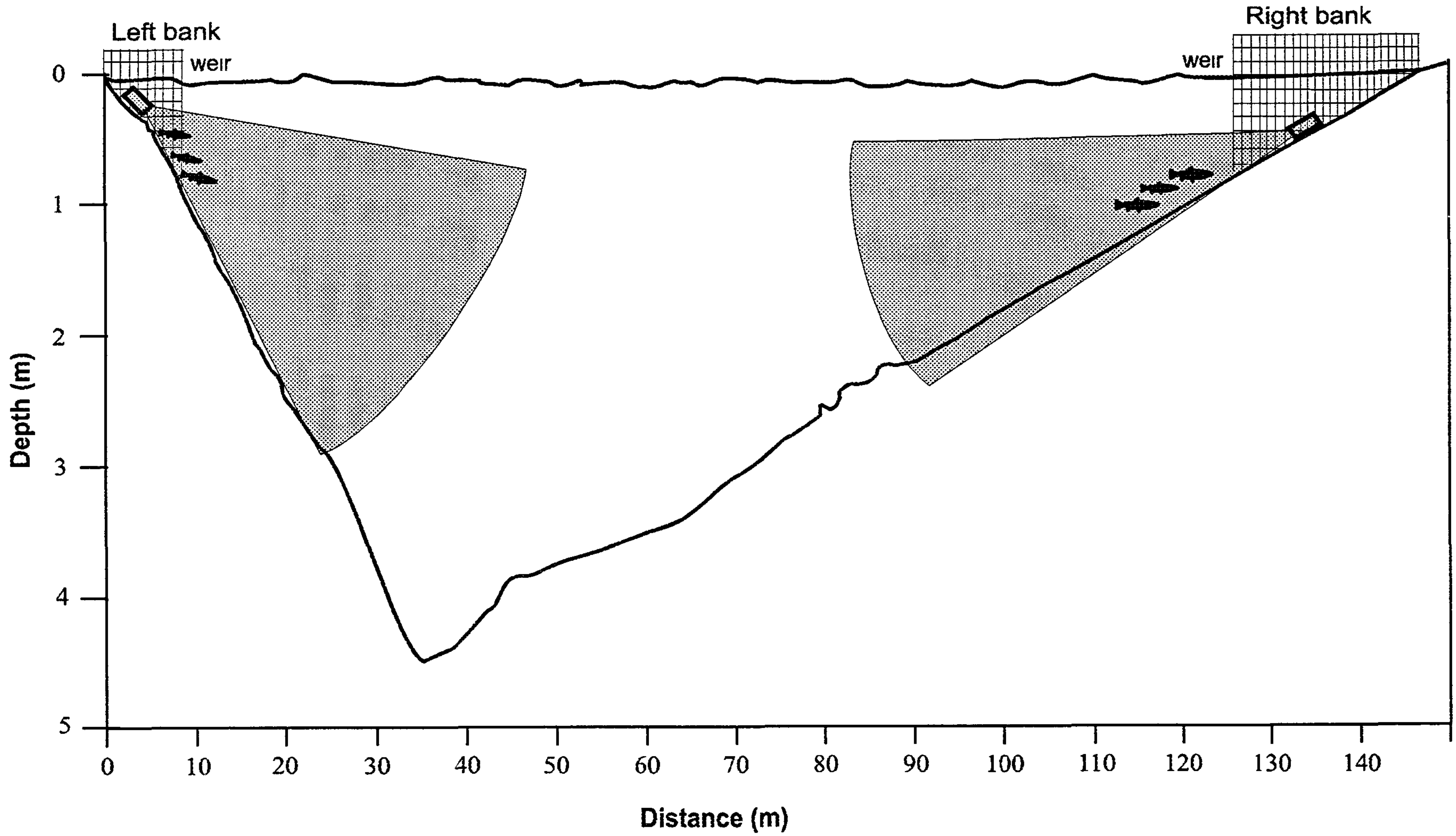

Figure 3. River channel profile and estimated ensonified zones of the left and right banks, Chandalar River, 1998. Different axis scales were used to enhance visibility.

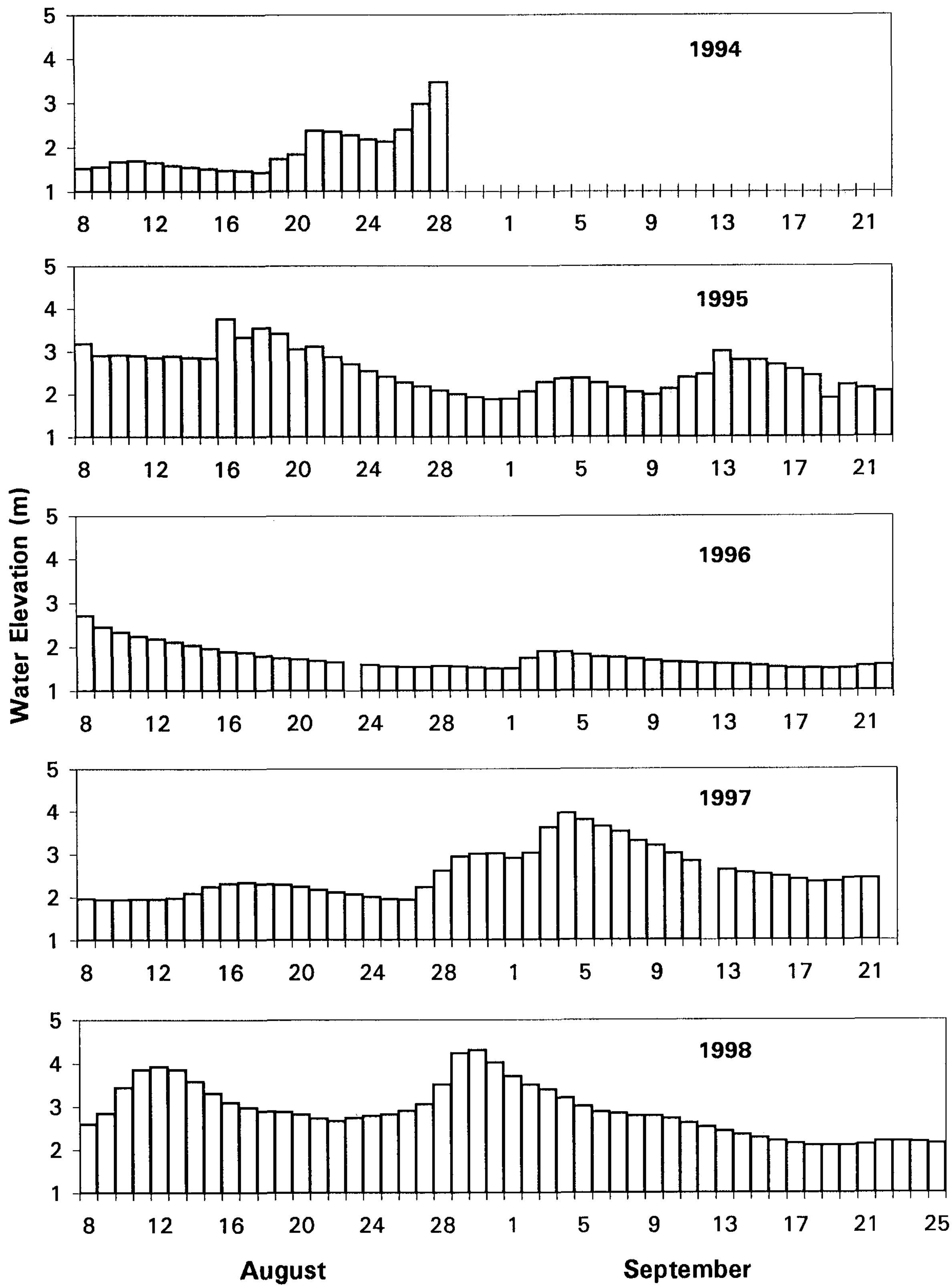

Figure 4. Daily water elevation during sonar operation, Chandalar River, 1994-1998

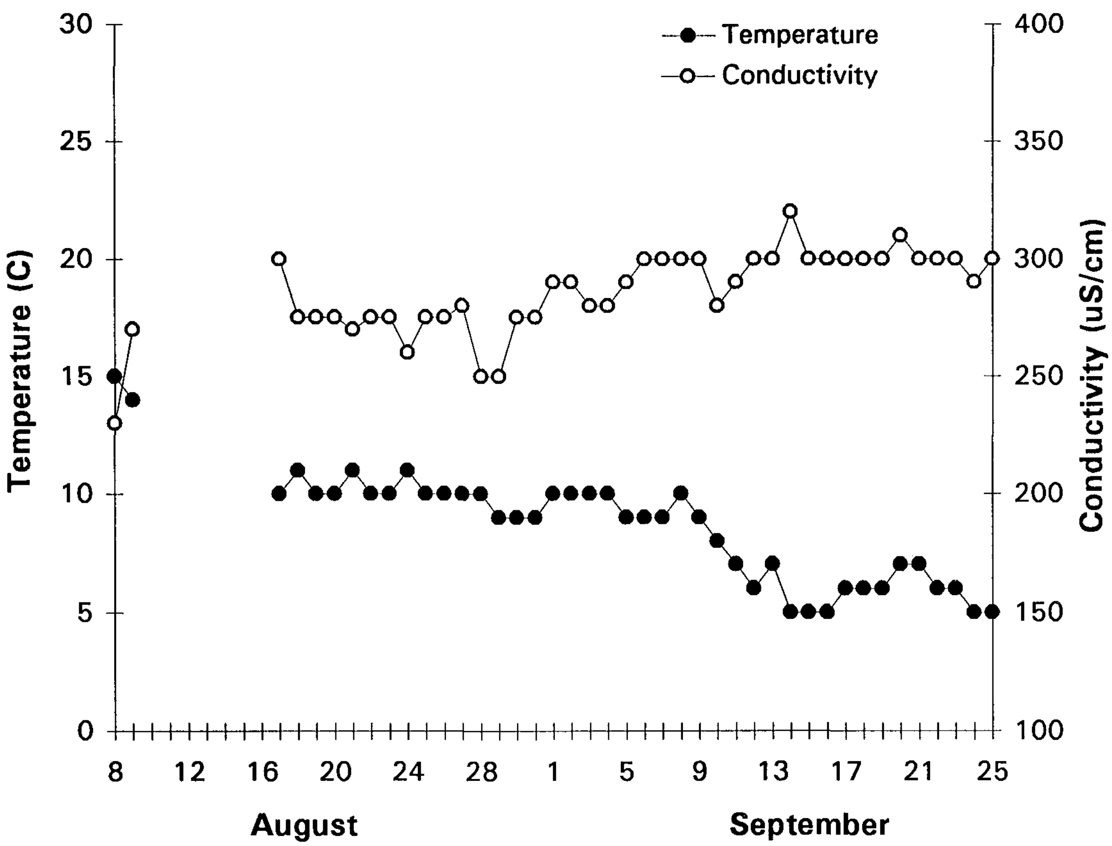

Figure 5. Daily water temperature and conductivity measurements, Chandalar River, August 8-September 25, 1998

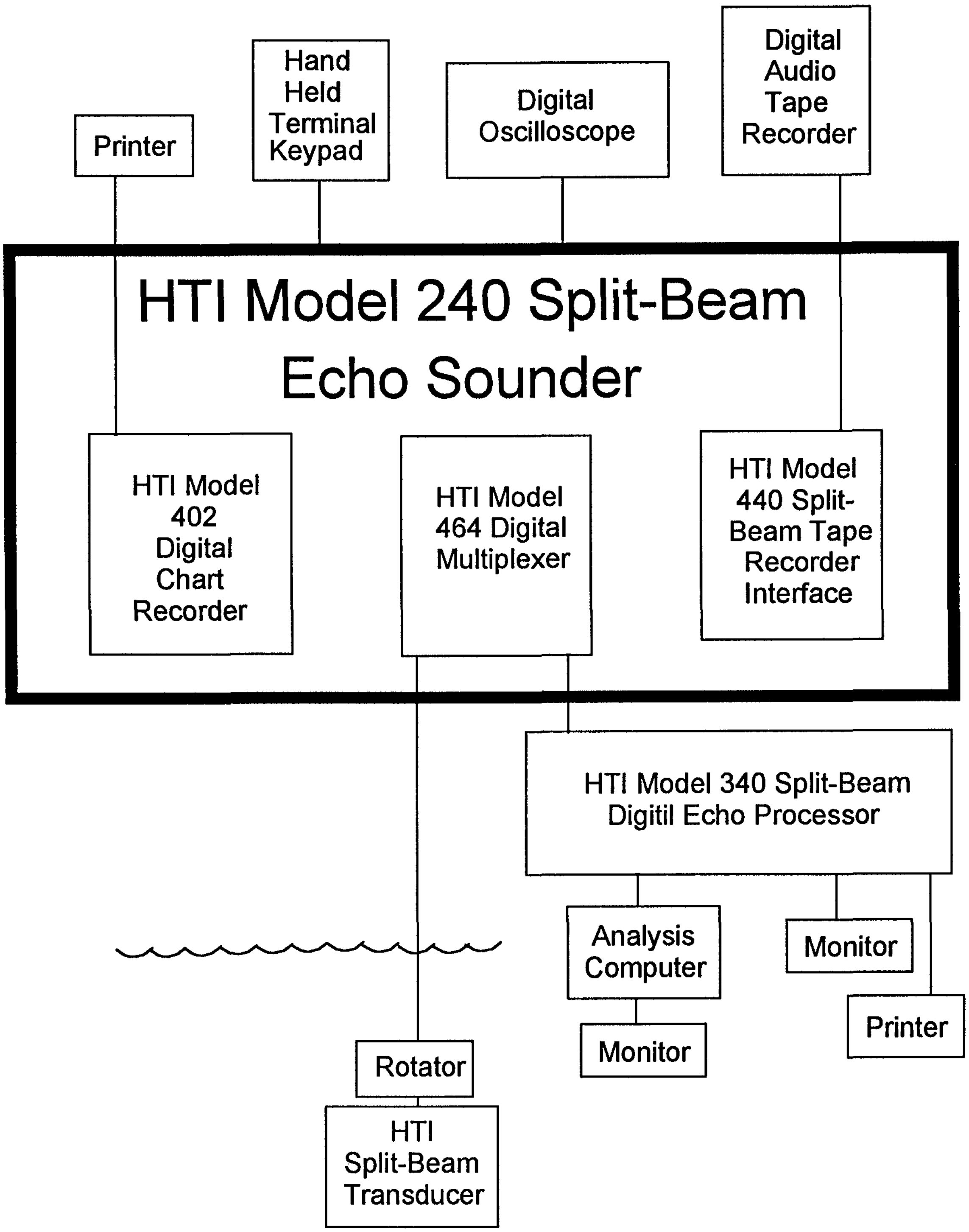

Figure 6. Split-beam hydroacoustic system, Chandalar River, 1998.

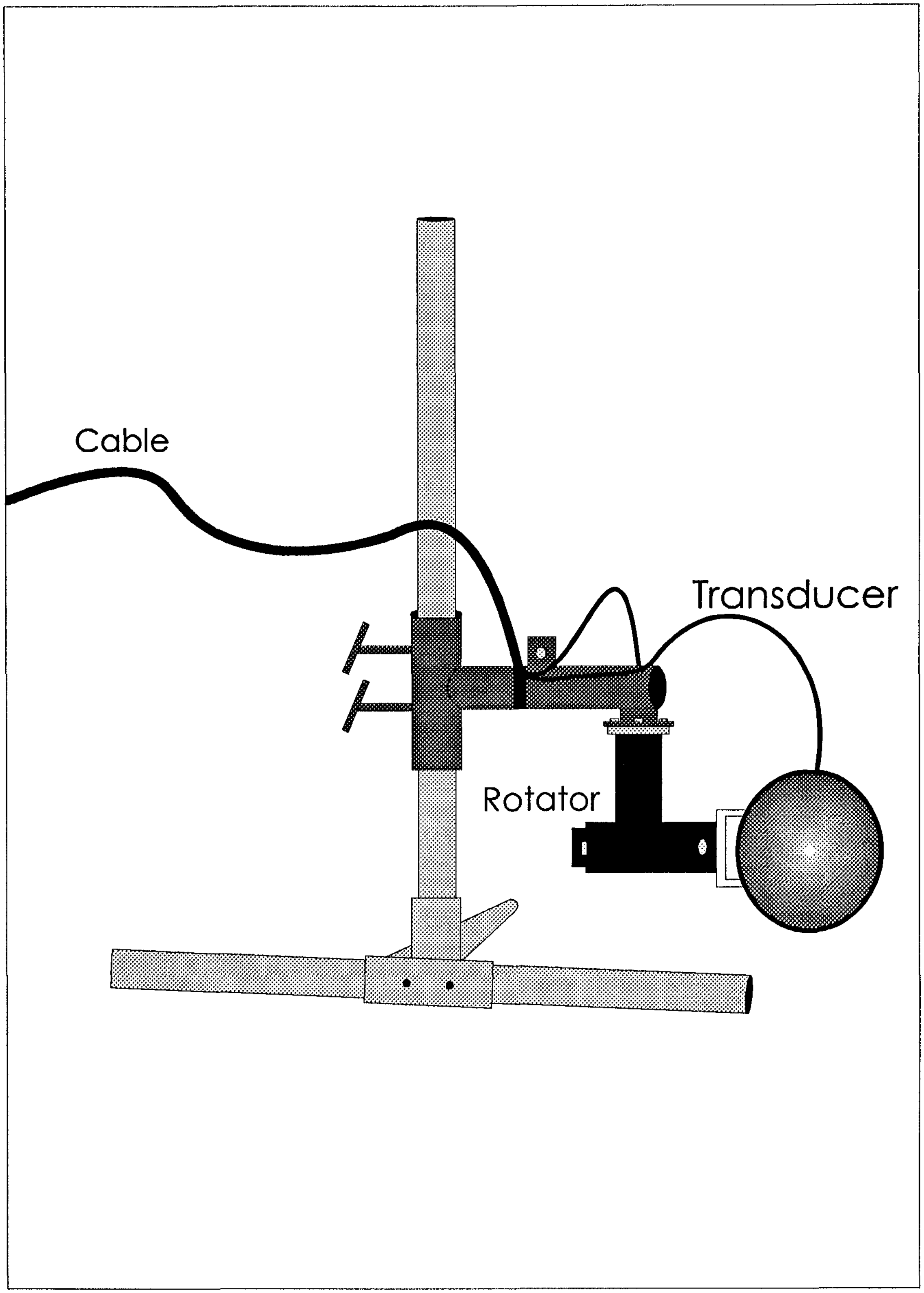

Figure 7. Split-beam transducer, remote rotator, and pod assembly, Chandalar River, 1998.

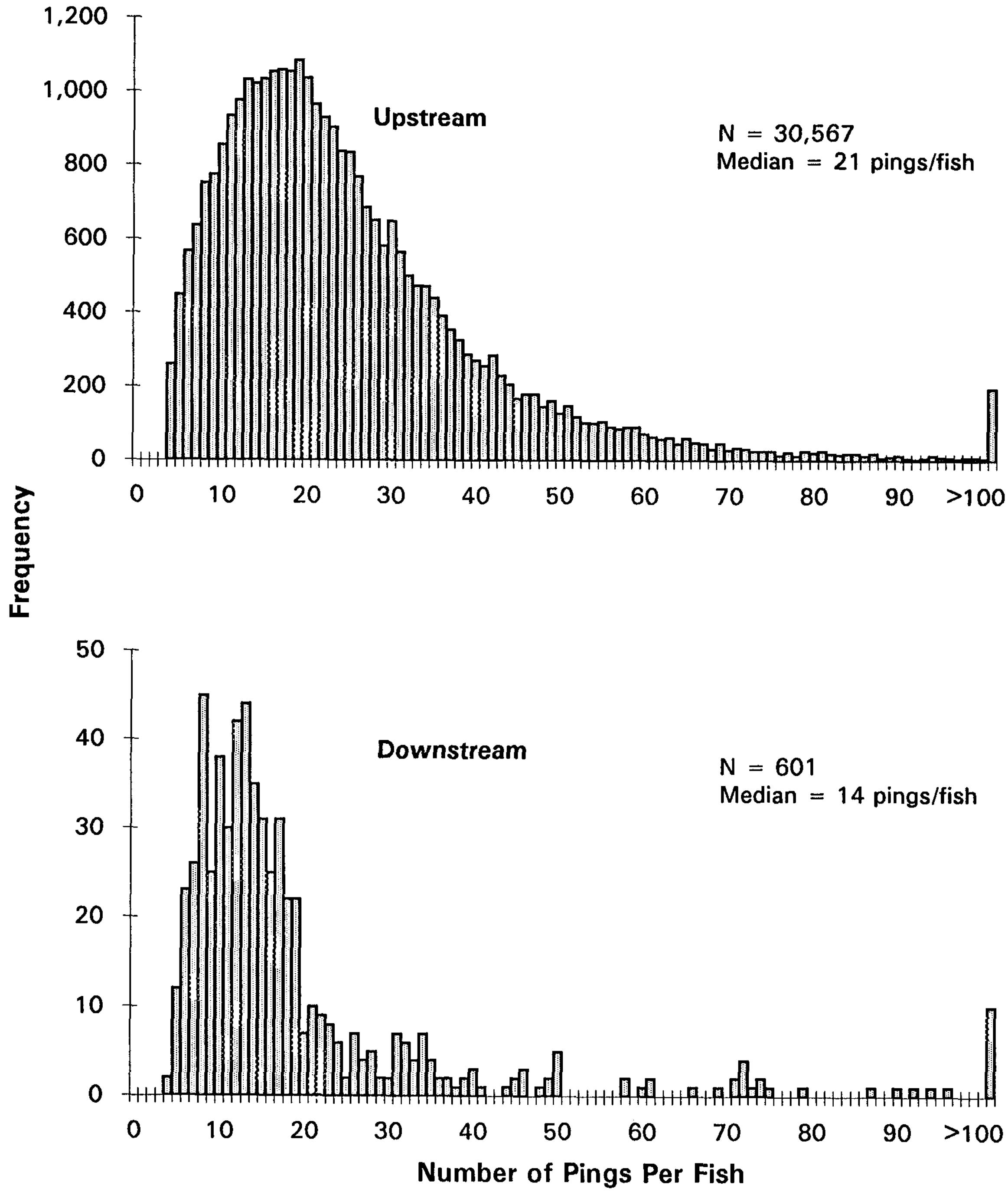

Figure 8 Number of acquired echoes per tracked fish, left bank, Chandalar River, August 8-September 26, 1998

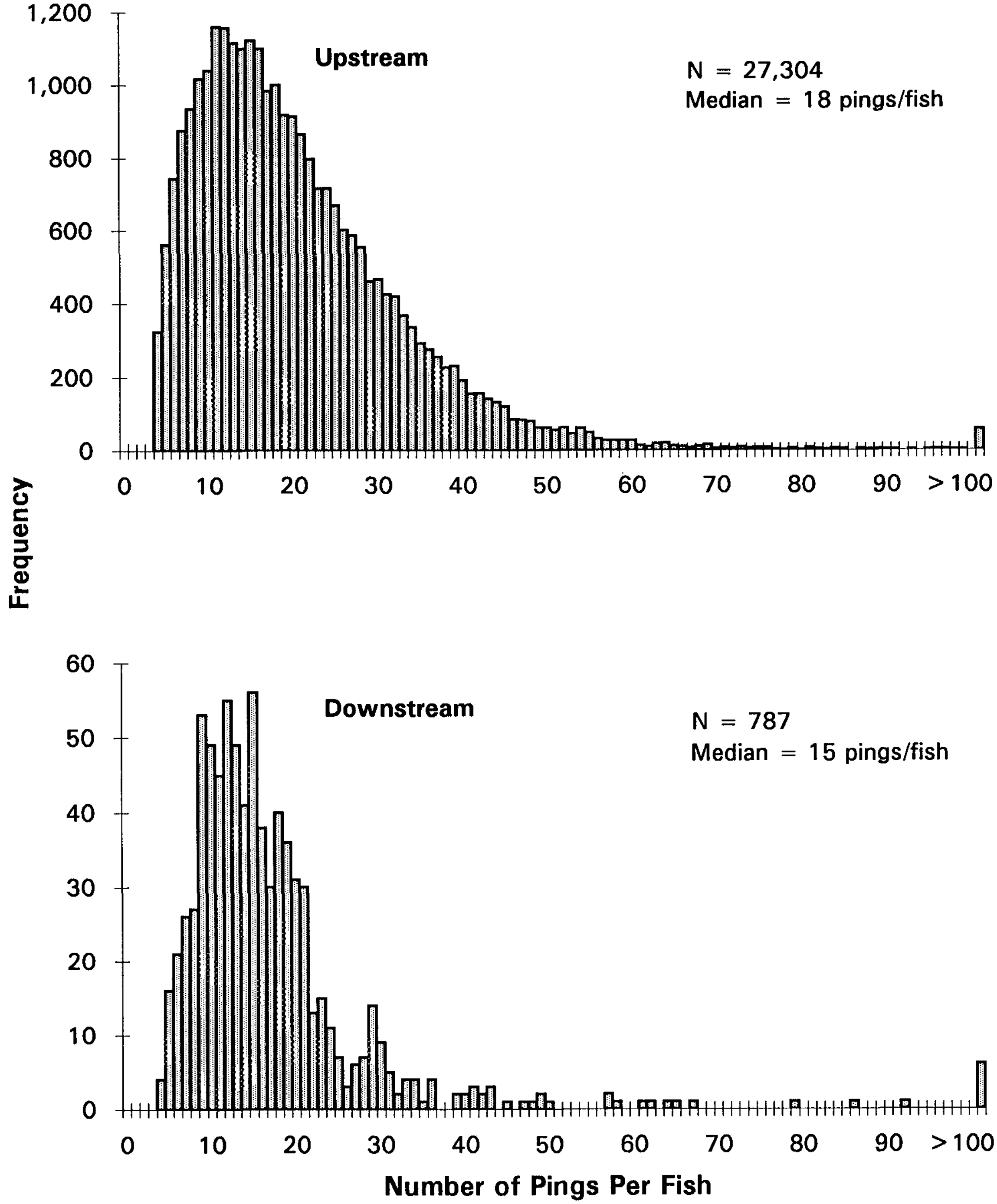

Figure 9. Number of acquired echoes per tracked fish, right bank, Chandalar River, August 8-September 26, 1998

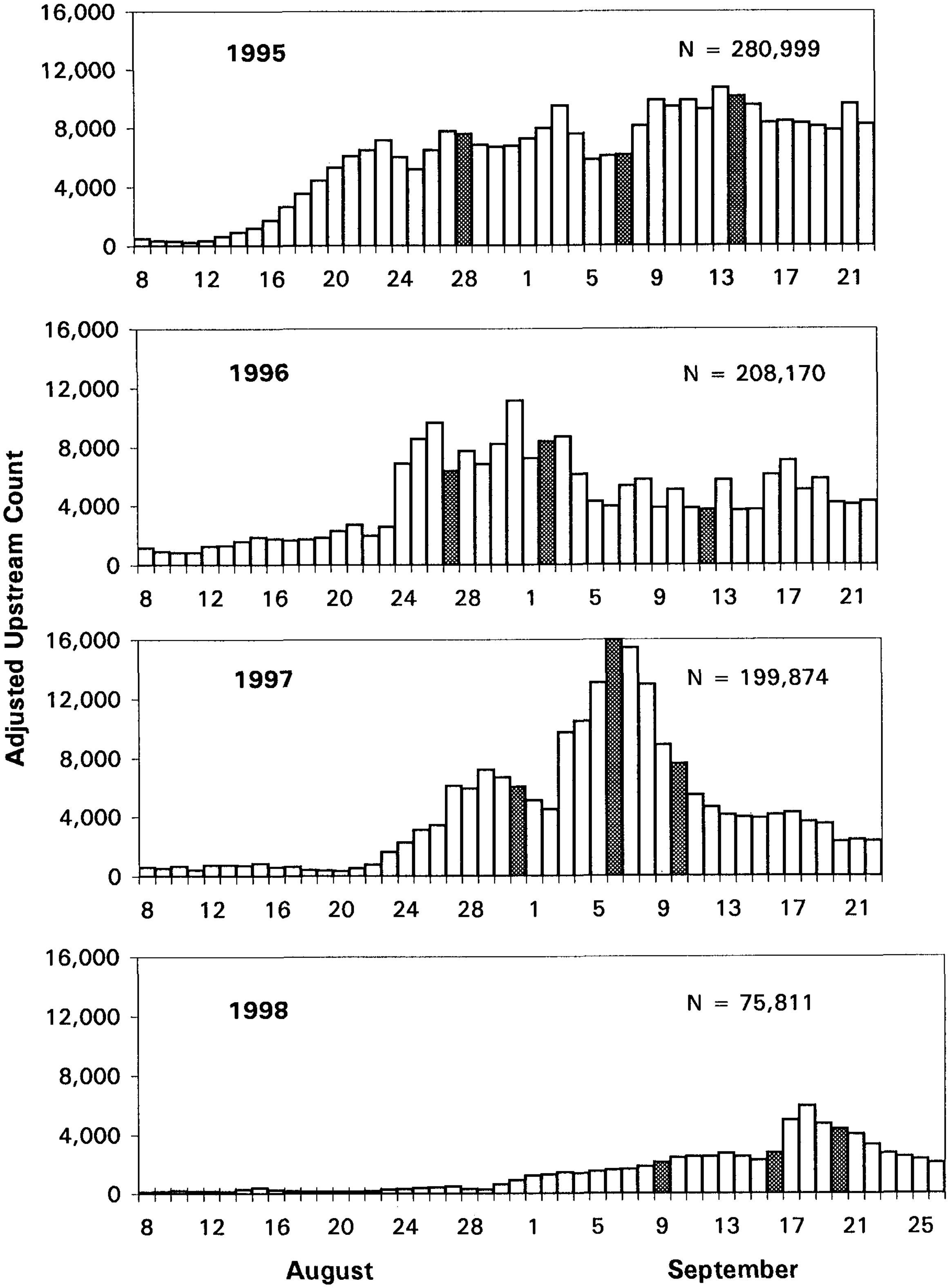

Figure 10. Adjusted daily counts of fall chum salmon, Chandalar River, 1995-1998 Shaded bars represent quartiles of the total count.

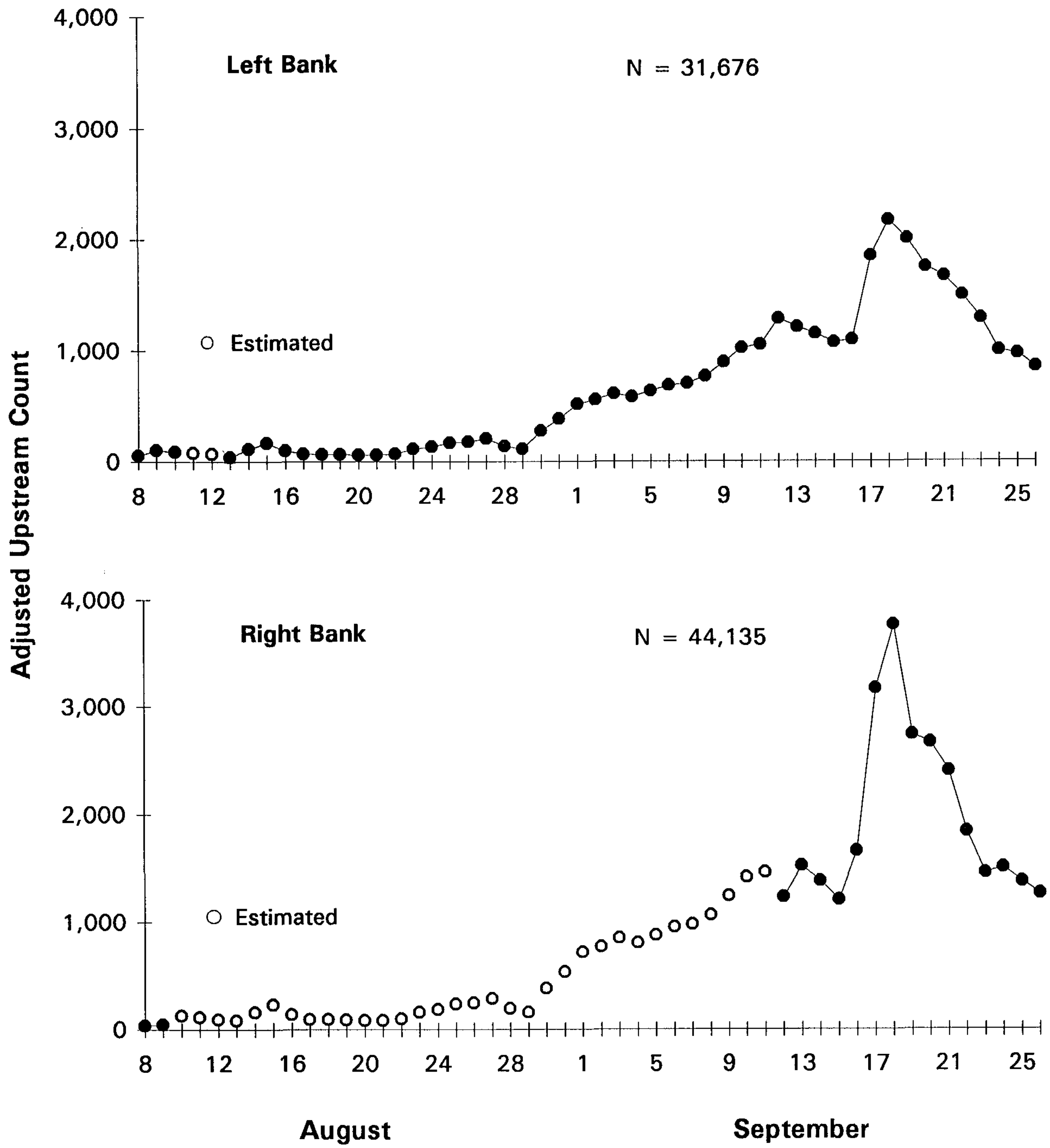

Figure 11. Adjusted daily counts of fall chum salmon by bank, Chandalar River, August 8-September 26, 1998. Daily counts were estimated for 33 days on the right bank and two days on the left bank due to high water.

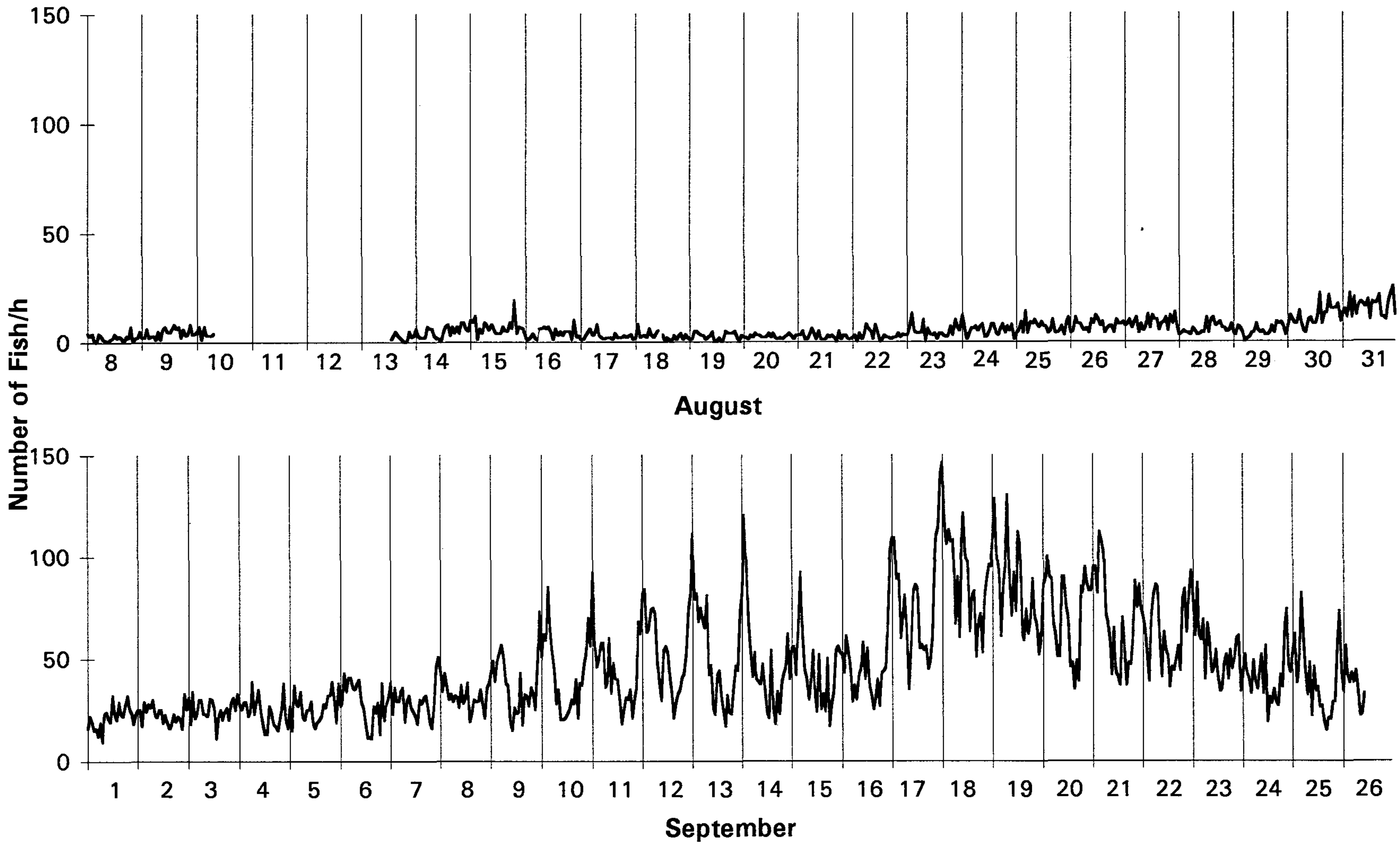

Figure 12. Diel distribution of upstream fish, left bank, Chandalar River, August 8-September 26, 1998.

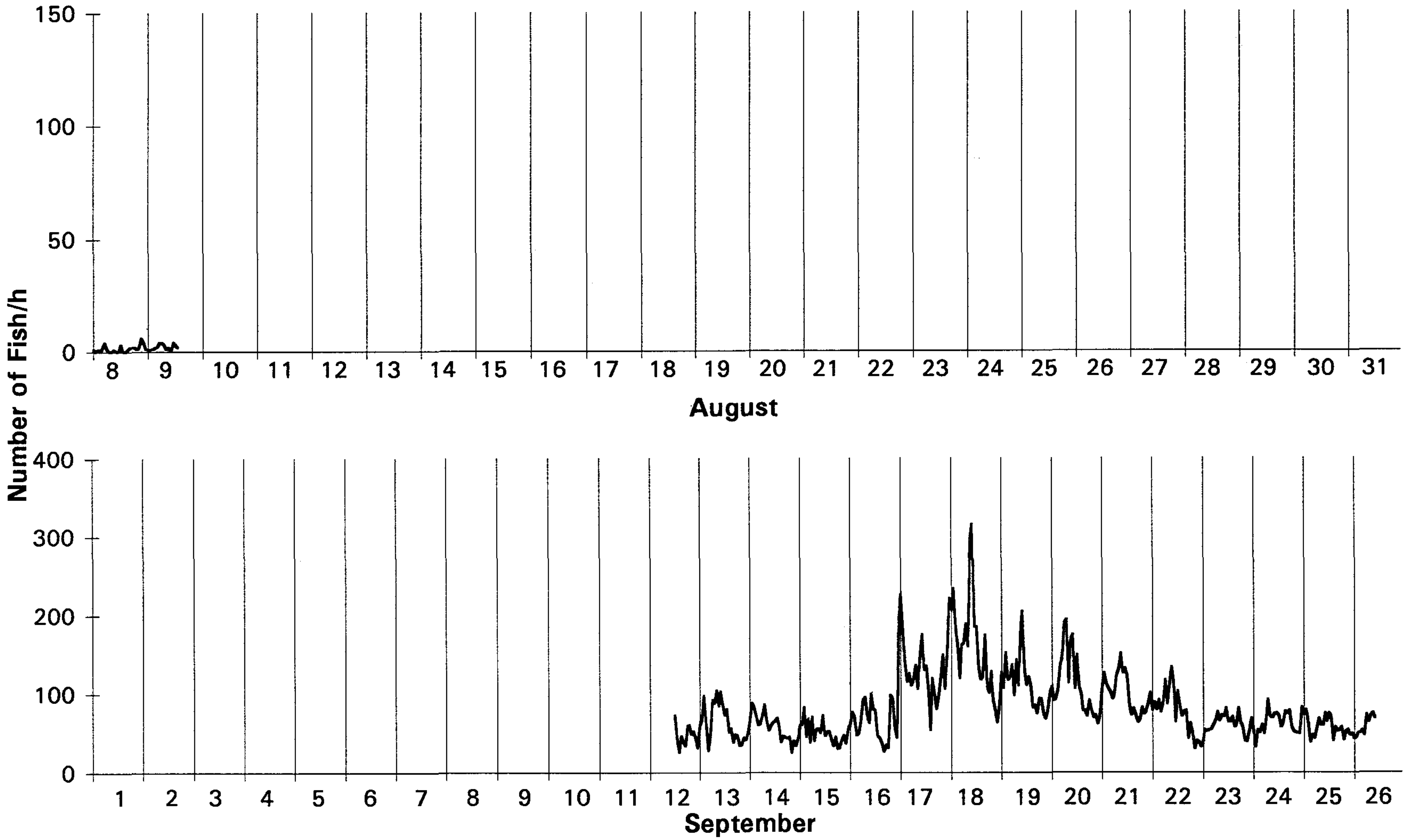

Figure 13. Diel distribution of upstream fish, right bank, Chandalar River, August 8-September 26, 1998.

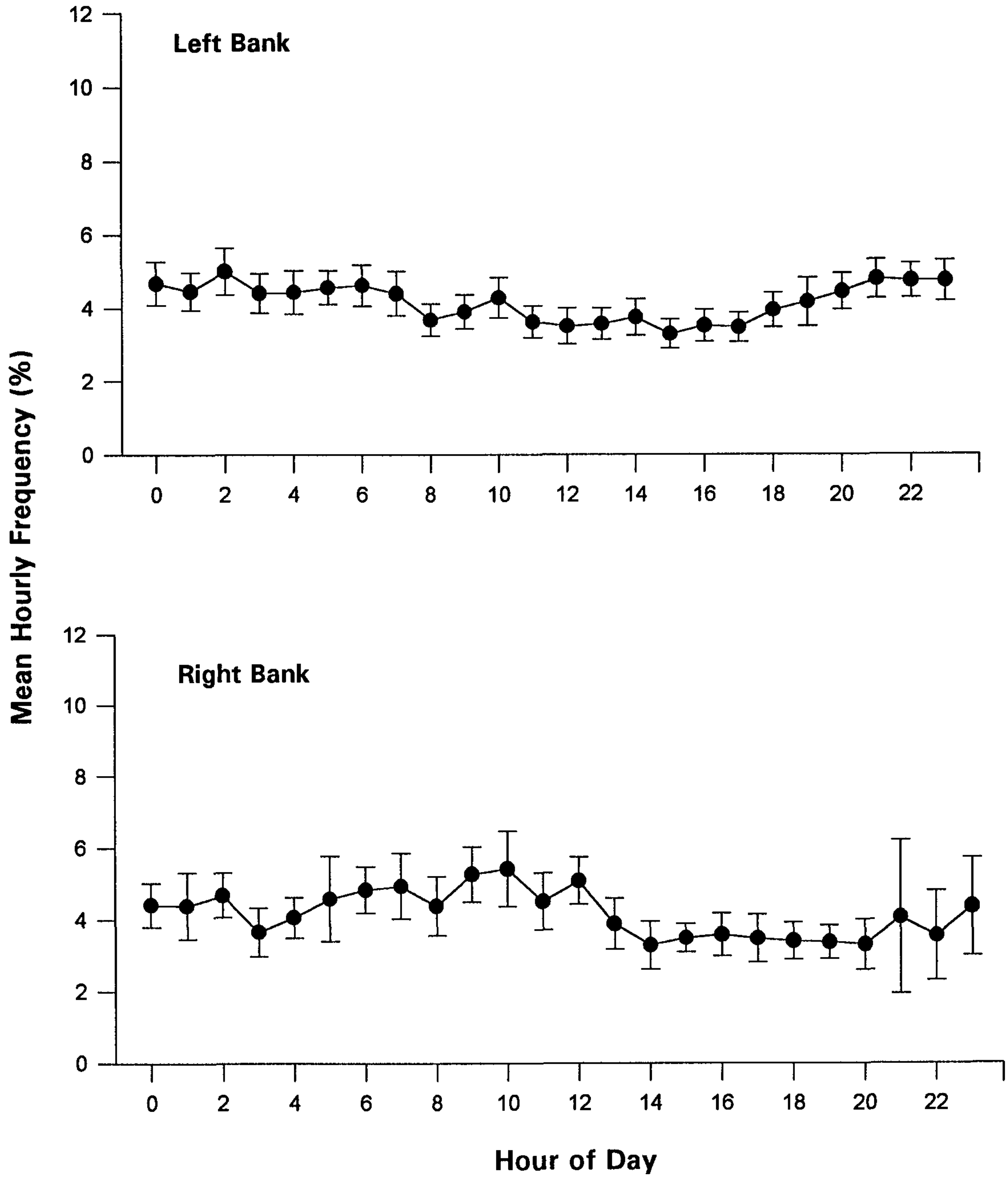

Figure 14 Mean (± 2 SE) hourly frequency of upstream fish, Chandalar River, 1998 Data from 44 days of continuous 24 h data on the left bank and 14 days on the right bank

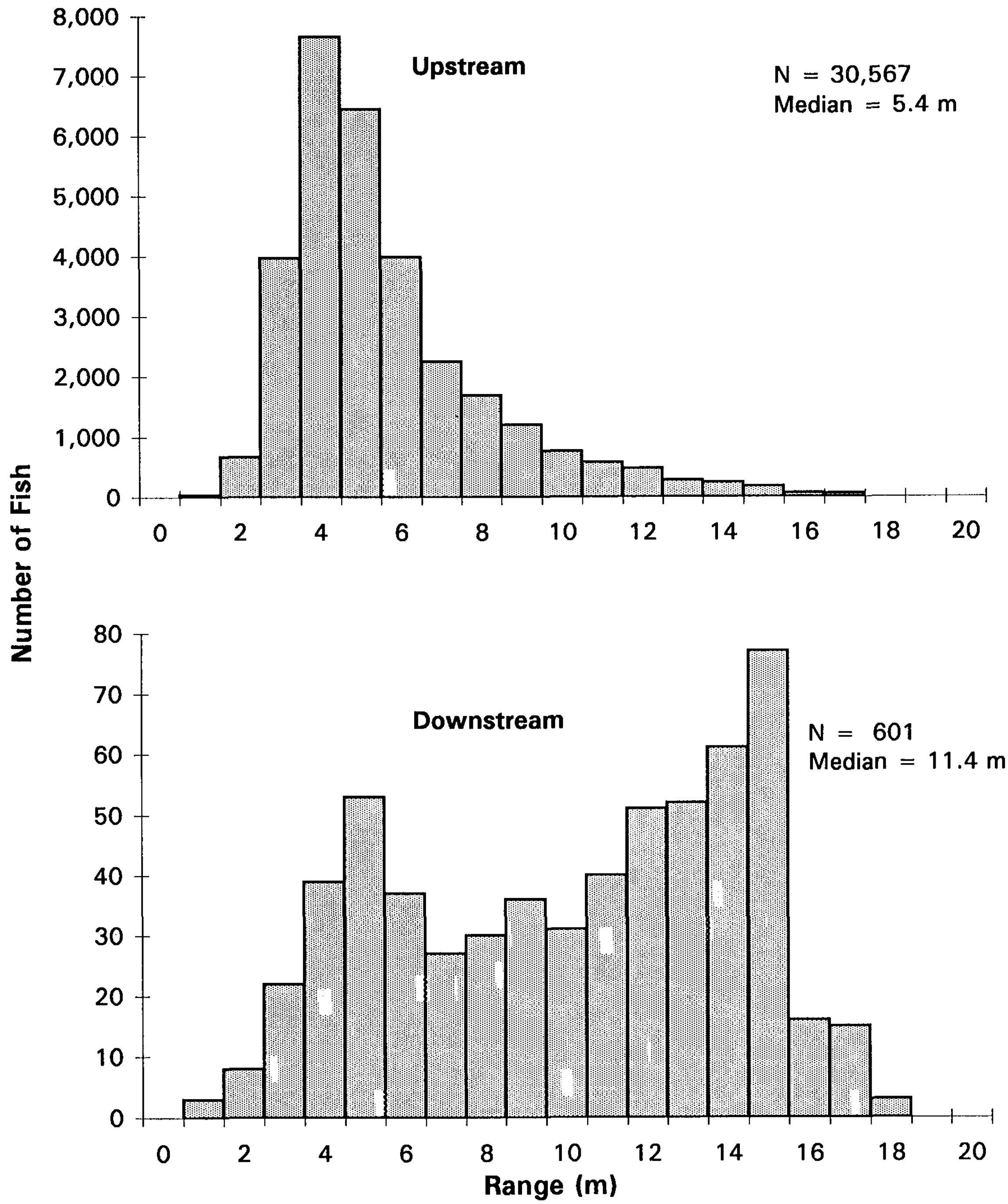

Figure 15. Range (horizontal distance from transducer) distribution of upstream and downstream fish, left bank, Chandalar River, August 8-September 26, 1998.

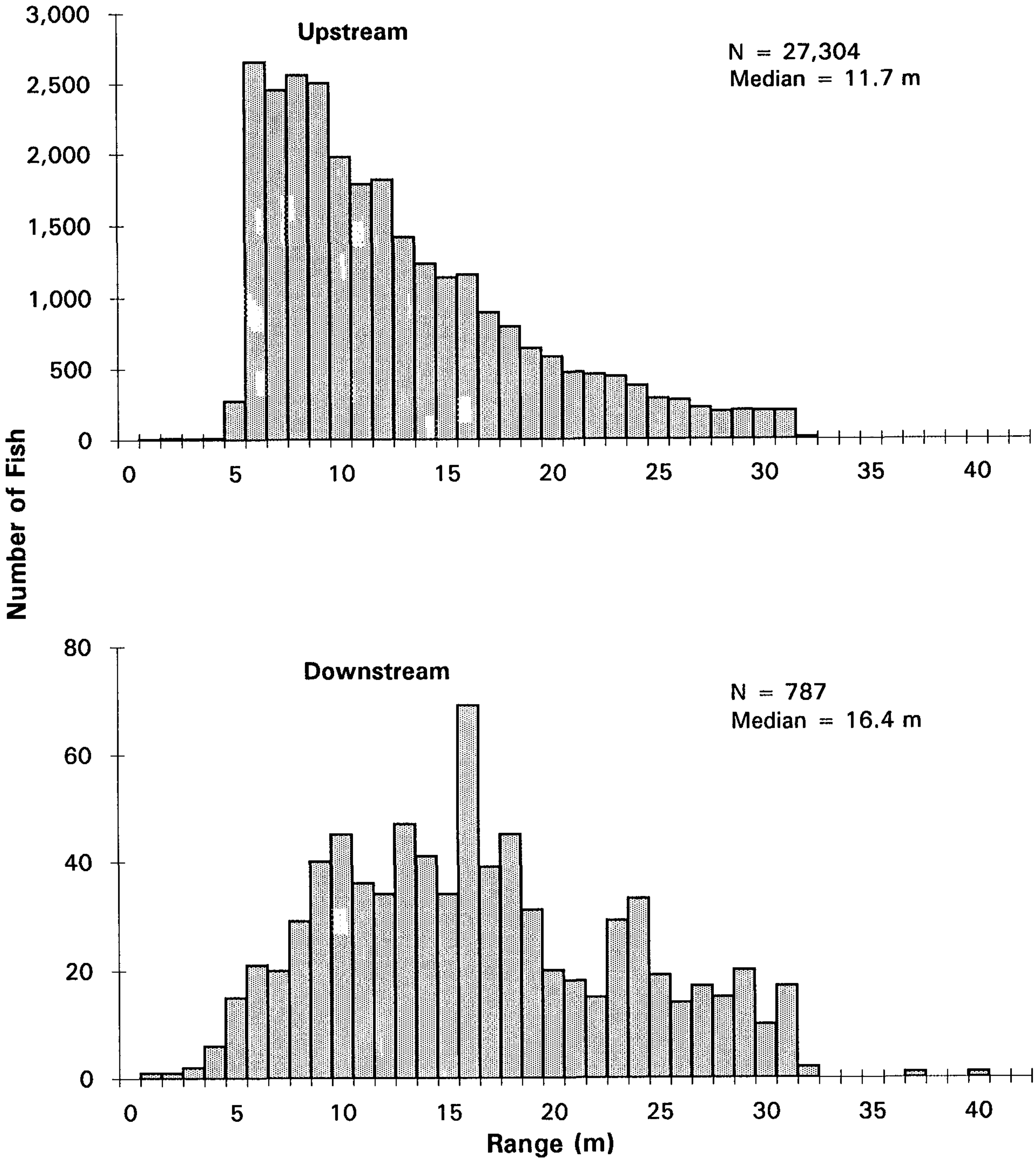

Figure 16 Range (horizontal distance from transducer) distribution of upstream and downstream fish, right bank, Chandalar River, August 8-September 26, 1998

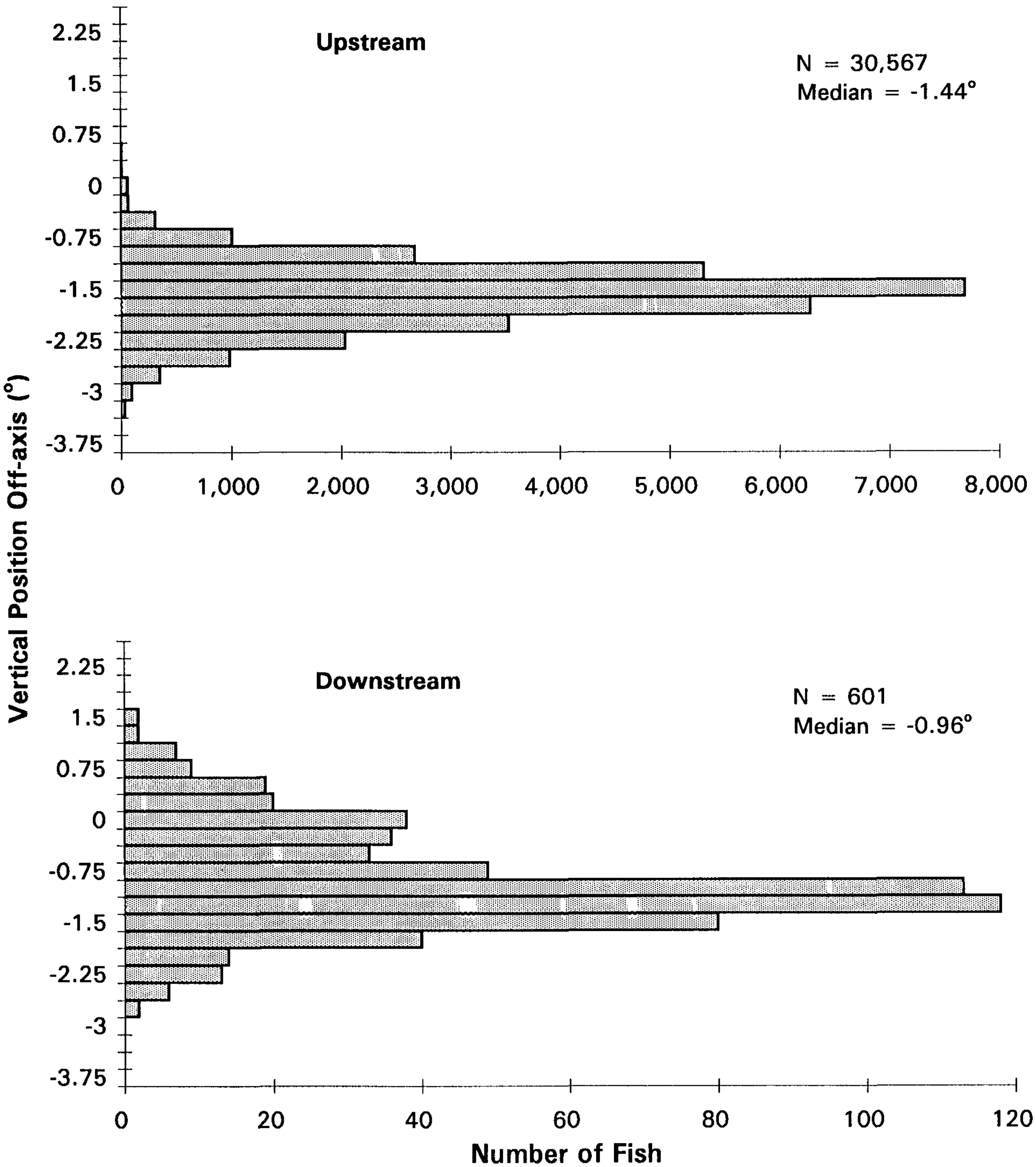

Figure 17 Vertical distribution of upstream and downstream fish, left bank, Chandalar River, August 8-September 26, 1998.

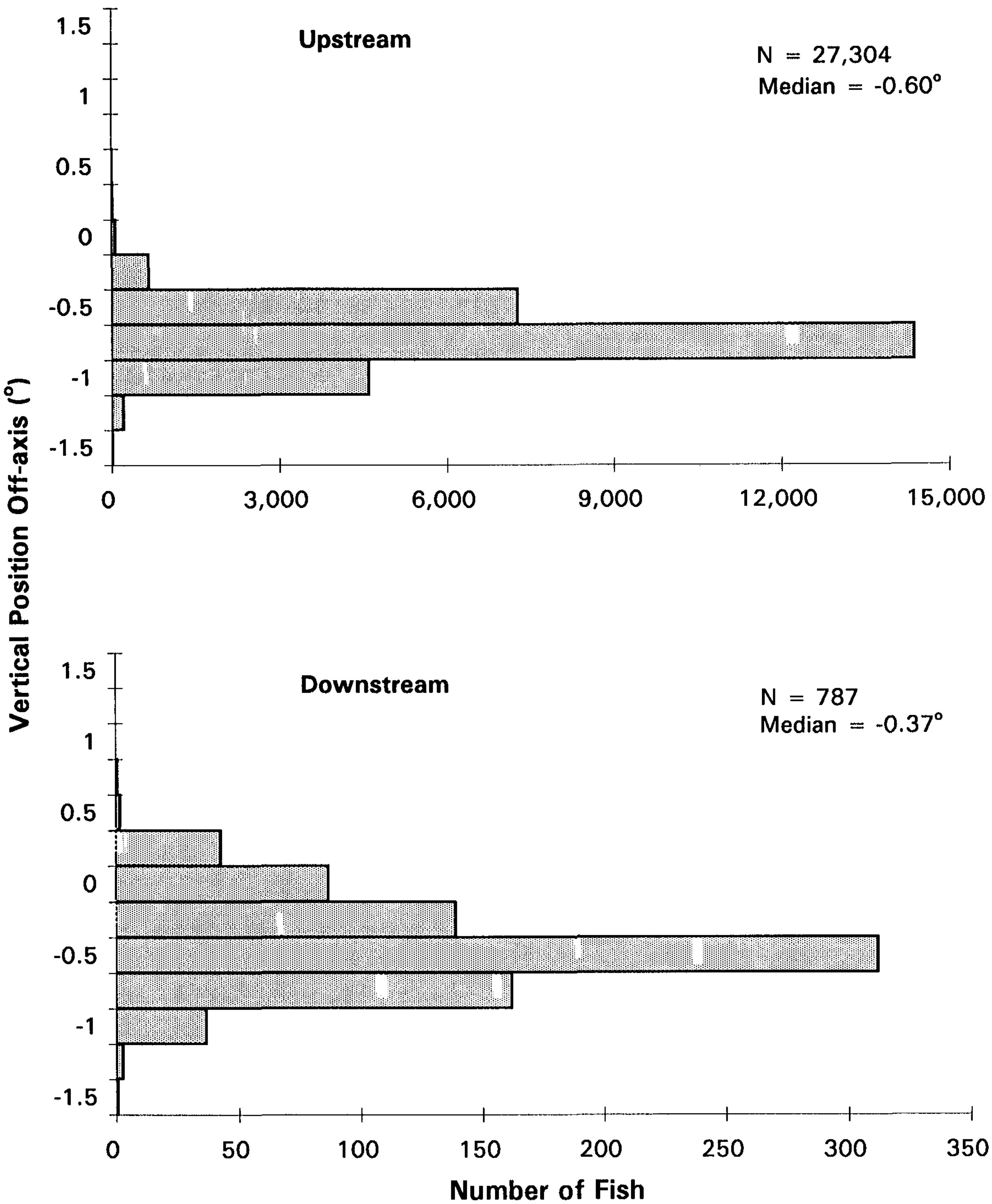

Figure 18 Vertical distribution of upstream and downstream fish, right bank, Chandalar River, August 8-September 26, 1998

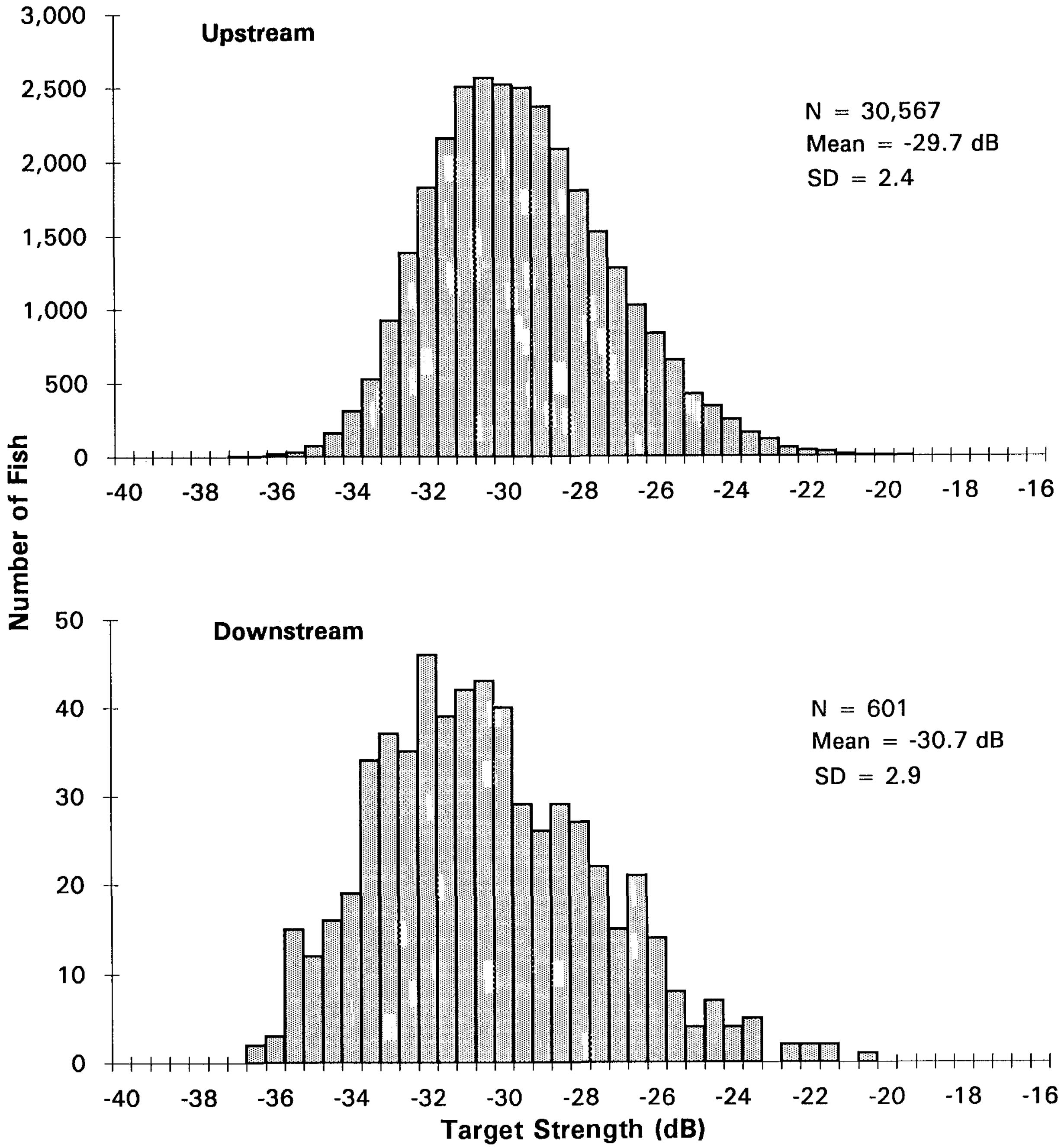

Figure 19. Target strength distribution of upstream and downstream fish, left bank, Chandalar River, August 8-September 26, 1998

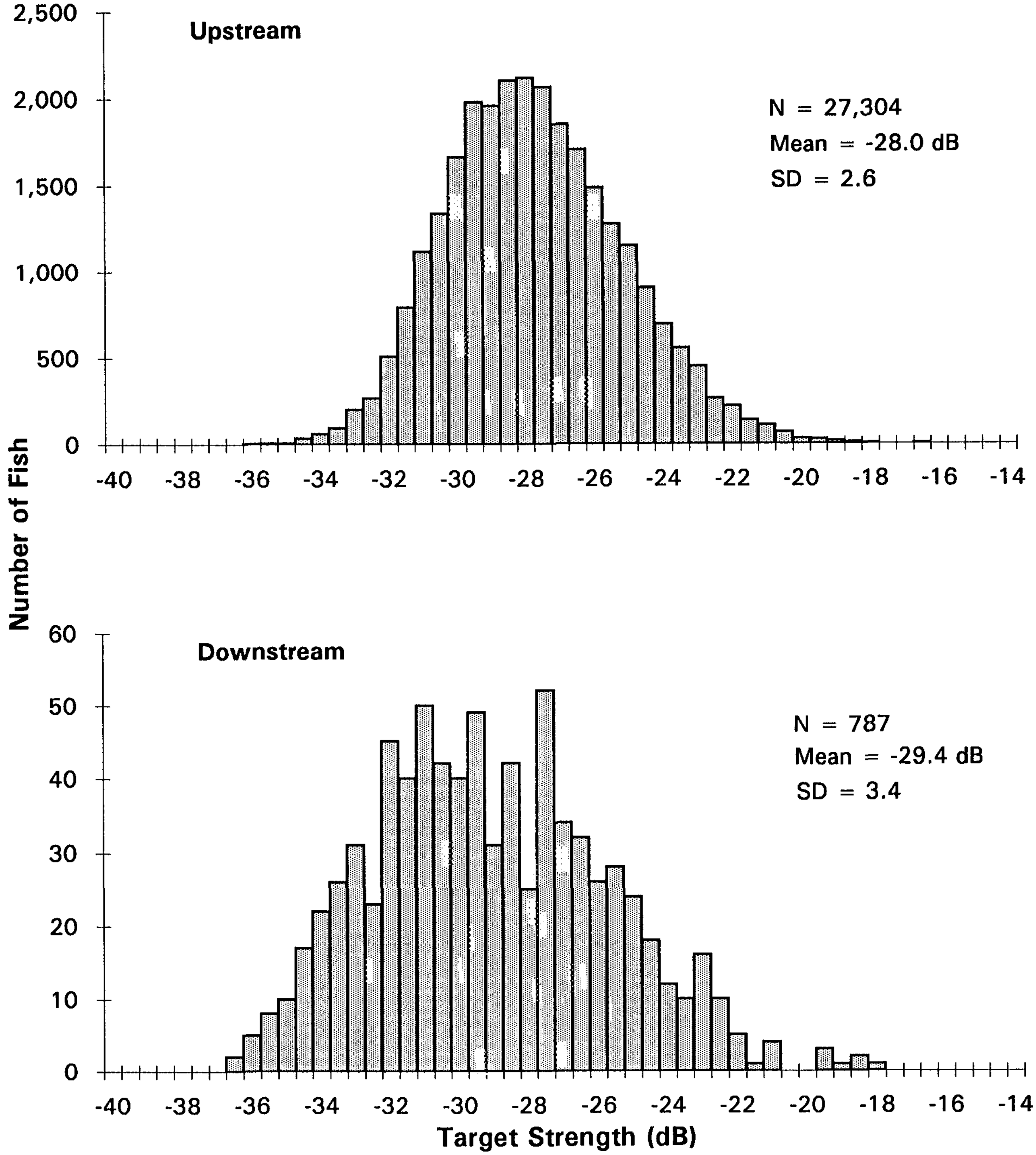

Figure 20 Target strength distribution of upstream and downstream fish, right bank, Chandalar River, August 8-September 26, 1998

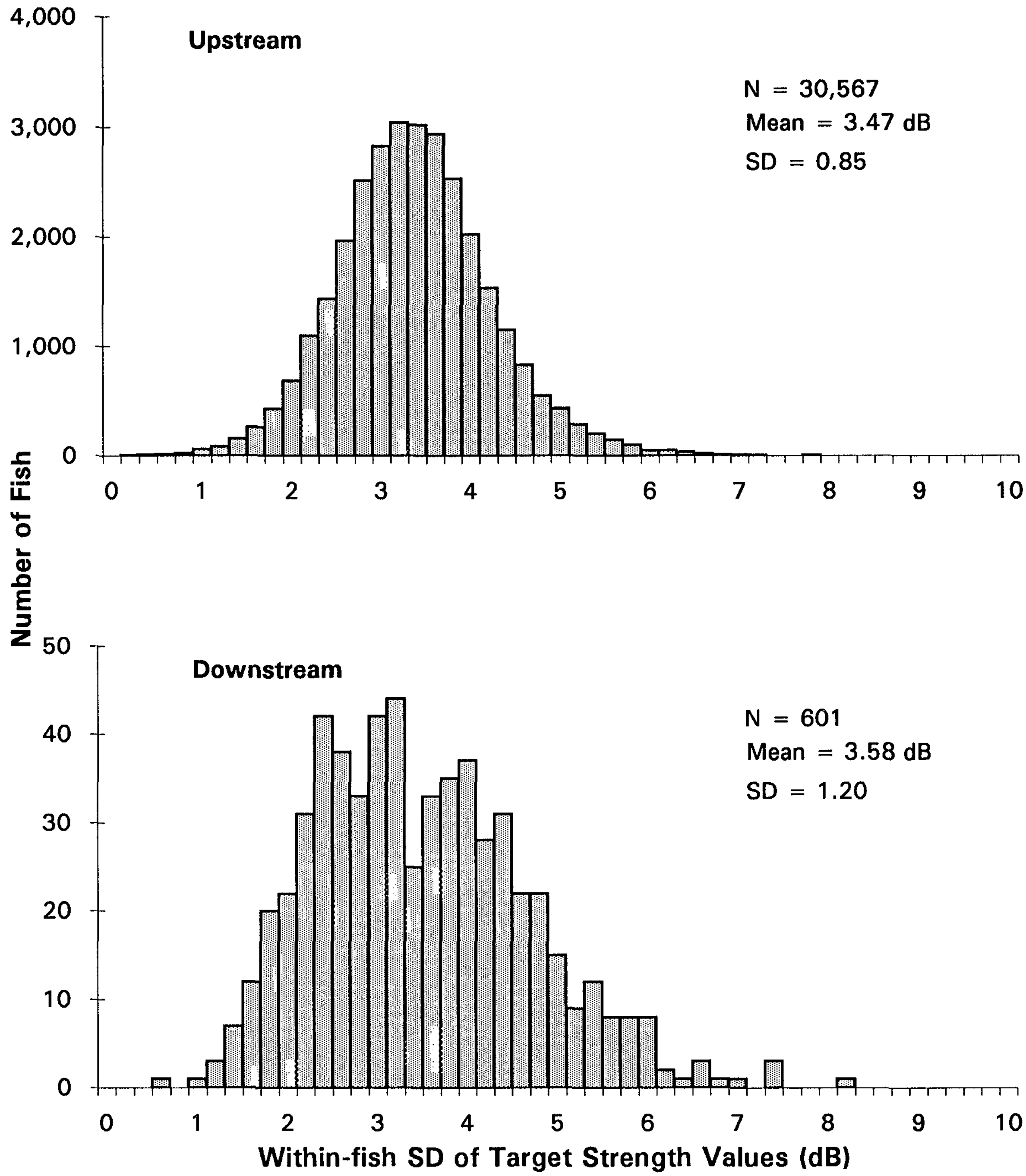

Figure 21. Within-fish target strength variability (SD) of upstream and downstream fish, left bank, Chandalar River, August 8-September 26, 1998

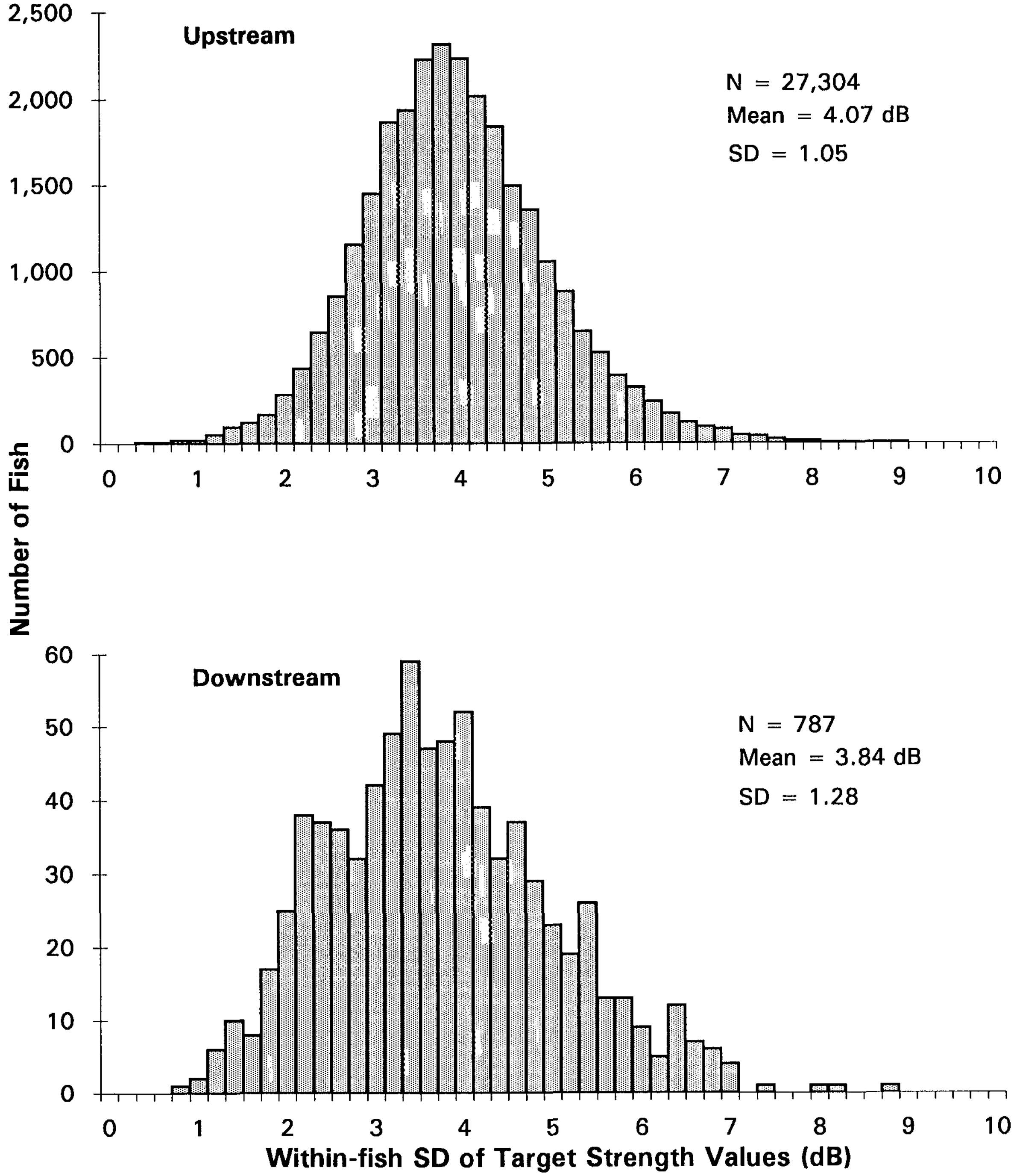

Figure 22 Within-fish target strength variability (SD) of upstream and downstream fish, right bank, Chandalar River, August 8-September 26, 1998

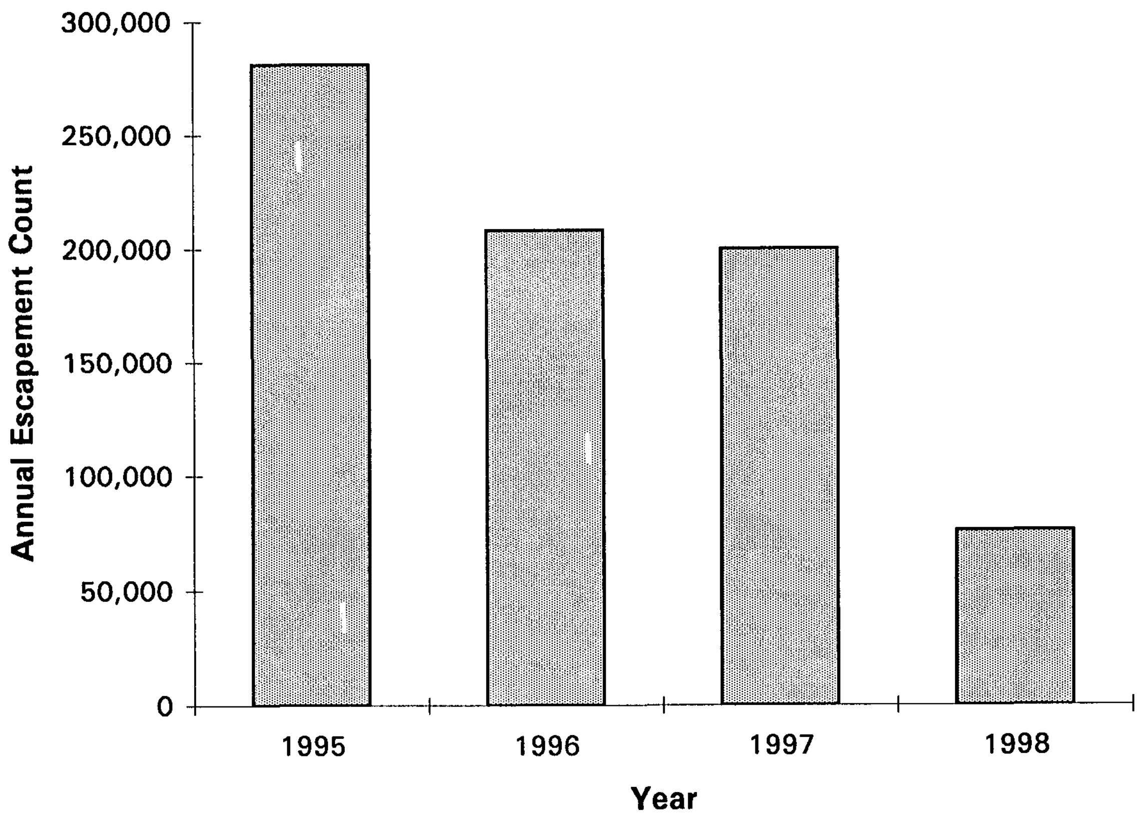

Figure 23. Annual sonar escapement counts of fall chum salmon, Chandalar River, 1995-1998.

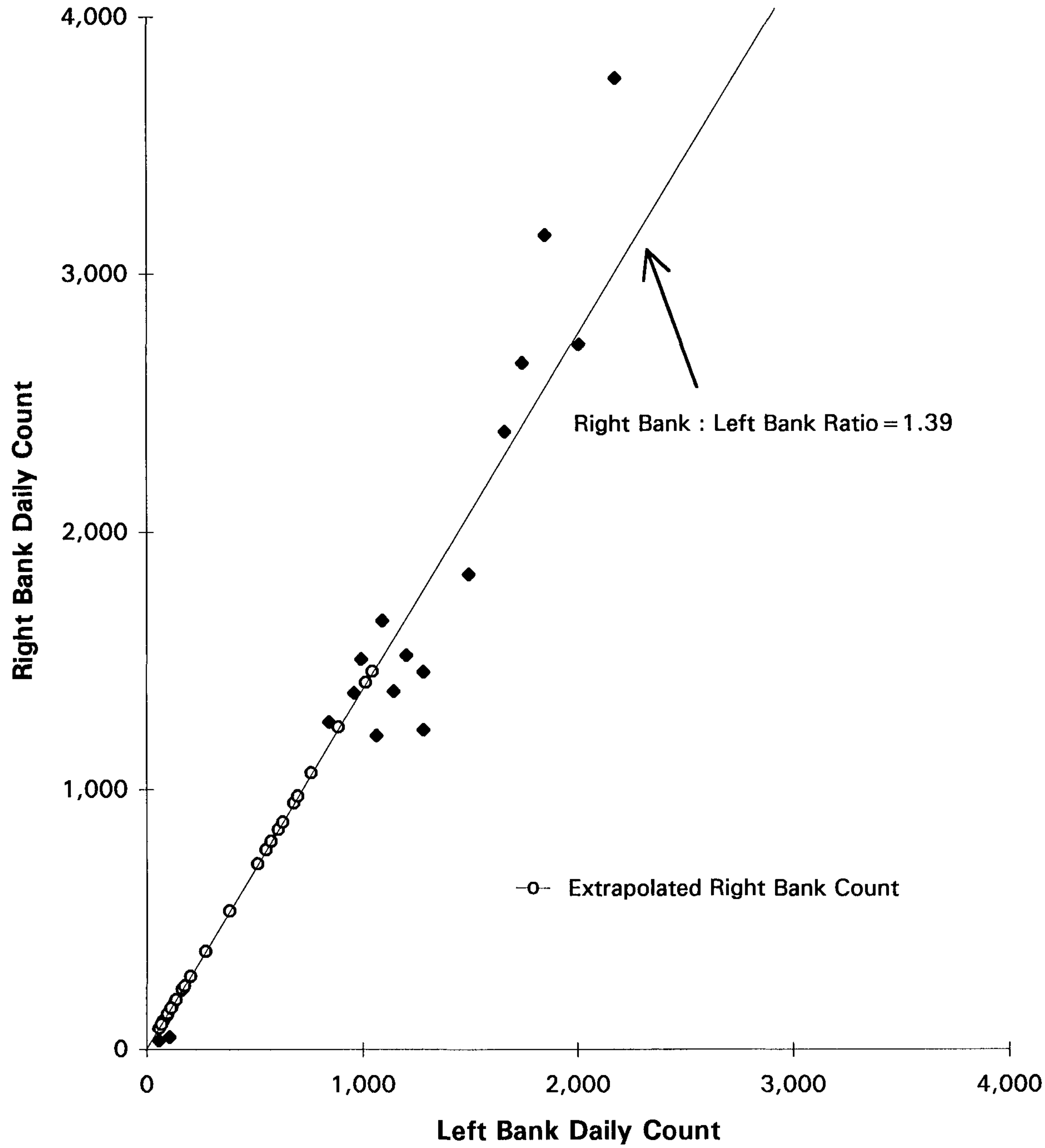

Figure 24. Relationship of right bank to left bank adjusted daily counts of fall chum salmon, Chandalar River, August 8-September 26, 1998 Missing right bank counts were extrapolated from left bank counts using the ratio estimator method (Cochran 1977).

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		