TECHNICAL FISHERY REPORT 93-01

Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 25526
Juneau, Alaska 99802-5526

March 1993

An Estimate of Juvenile Fish Densities in Skilak and Kenai Lakes, Alaska, Through the Use of Dual-Beam Hydroacoustic Techniques in 1991

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Technical Fishery Report No. 93-01

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ACKNOWLEDGMENTS

The authors would like to thank Randall Davis, Dave Westerman, Dennis Beliveau, and Jennifer Brannen for assisting during the field operations. Special thanks goes to Sandi Seagren for helping prepare the report. Finally, recognition is due to Joe Sullivan, Steve Fried, and Ken Florey for supporting the project through budget and scheduling decisions.

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ABSTRACT

The number and distribution of sockeye salmon *Onchorhynchus nerka* rearing in two glacial lakes of the Kenai River drainage were estimated from hydroacoustic surveys. Using dual-beam acoustic techniques, we collected *in situ* target strength information for scaling of the echo integrator. The average target strength of fish measured with a 420 kHz sounder was -52.86 dB in Skilak Lake and -54.55 dB in Kenai Lake. A decrease in target strength with depth was observed. In contrast, data collected with a 120 kHz sounder indicated no decrease in target strength with depth. Approximately 7.5 million sockeye salmon juveniles were estimated to reside in the lakes. The majority of fish were located in Skilak Lake. Trawl samples indicated that 95% of the sockeye salmon were age-0. The size of both age classes were small; the mean length of age-0 sockeye salmon in Skilak Lake were 51.4 mm, and mean weight was 1.5 g. Age-1 fish in Skilak Lake had a mean length of 73.8 mm and mean weight of 4.7 g.

KEY WORDS: hydroacoustic survey, sockeye salmon, target strength, glacial lake, Alaska, *Onchorhynchus nerka*

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) began investigations in 1972 to assess juvenile sockeye salmon *Onchorhynchus nerka* populations rearing in the major lakes of the Kenai River drainage (Figures 1, 2; Davis et al. 1973). As part of these investigations, juvenile sockeye salmon were collected from Skilak and Kenai Lakes using tow nets to estimate relative abundance, age structure, and growth (Davis et al. 1974; Namtvedt and Friese 1976). However, the inefficiency of tow netting restricted the usefulness of these data for abundance estimates (Waltemyer 1981). Therefore, in 1986 ADF&G began developing new methods to enumerate fry using hydroacoustic equipment (Tarbox and King 1988a, 1988b).

Since 1986 annual fall hydroacoustic surveys have been conducted in Kenai and Skilak Lakes to develop a time series of juvenile sockeye salmon population estimates. Program objectives for the 1991 field investigation were to (1) estimate the number and spatial distribution of sockeye salmon juveniles in Kenai and Skilak Lakes, (2) determine the target strength distribution in both lakes using dual-beam hydroacoustic techniques, (3) document the relative condition of juvenile sockeye salmon using length and weight measurements, and (4) estimate the age composition of sockeye salmon in Kenai and Skilak Lakes.

In addition, the 1991 studies are part of an ongoing project, Natural Resource Damage Assessment (NRDA) study 27, to assess the impacts on freshwater production of relatively large adult sockeye escapements into the Kenai River drainage. Starting in 1987 and continuing through 1989, the Kenai River system received spawning escapements in excess of 1.0 million fish. The escapement goal range is 400,000-700,000 fish. These large escapements were the result of ADF&G management decisions associated with the Glacier Bay oil spill in 1987 and the Exxon Valdez oil spill in 1989. In 1988 adult sockeye returns to systems other than the Kenai River reduced fishing opportunities on Kenai River stocks in the mixed stock fishery.

METHODS

Hydroacoustic surveys of Skilak and Kenai Lakes were conducted between late September and early October 1991 to assess the number of rearing sockeye salmon that had survived the summer. Because previous investigations of glacial lake systems on the Kenai Peninsula have shown that most sockeye salmon juveniles occur near the surface during daylight hours (Tarbox and King 1988a; Thorne 1981), surveys were conducted at night to maximize the available targets.

We used a stratified random sampling design for 1991 surveys to distribute sampling effort and provide an acceptable means of calculating sampling error. We divided each lake into sub-basins and established survey transects randomly distributed within each of these basins. In 1991 the number of transects was designed to reduce the relative error to 0.25 for Skilak Lake and 0.3 for Kenai Lake. Our sample size was based on the average coefficient of variation observed from 1986 to 1989. Because of the configuration of Skilak Lake, a total of 13 transects perpendicular to shore were surveyed within three sub-basins (Figure 3). In Kenai Lake a total of 27 transects were surveyed within five sub-basins

(Figure 4). The Kenai Lake survey was conducted on 5 and 6 October and the Skilak Lake survey on 27 and 28 September.

The equipment used for data acquisition consisted of a Biosonics Inc. Model 105[1] echo sounder with dual-beam receivers, a 420 kHz 6°/15° dual-beam transducer mounted in a V-fin for towing, a Model 171 tape recorder interface, a Sony model SL-HF400 video cassette recorder and PCM-501F1 digital audio processor, a chart recorder, and an oscilloscope. The selected pulse width was 0.4 ms and the pulse repetition rate was 5 pulses/s. Additional acoustic parameters used during data collection and processing are presented in Appendix A.1. Biosonics, Inc. calibrated the system prior to and following the surveys. The entire system was powered by 12-V batteries and carried in a 7.2-m vessel powered by an outboard motor. Vessel speed along each transect was estimated at 2.7 m/s. The transducer remained approximately 1 m below the water surface during surveys. Equipment procedures are outlined in King and Tarbox (1988).

Dual-beam data recorded on video cassette tape were processed through a Biosonics, Inc. Model 281 Echo Signal Processor[1] (ESP). A returning pulse was accepted as a valid target if the amplitude was below the bottom threshold of 9999 mV and above the counting threshold of 200 mV. Single targets were separated from multiple targets if the pulse width was within 20% of the transmitted pulse width at -6 dB and -18 dB. The maximum half-angle selected for data processing was 4°. Data were stratified for analysis in 5-m increments starting 2 m below the transducer, or 3 m below the water surface. Data were accepted for processing to a maximum depth of 97 m below the transducer in both lakes because visual examination of oscilloscope traces and chart recordings indicated that few fish were present below this depth.

Data generated by the dual-beam processor were transferred to microcomputer data files for analysis using the Biosonics, Inc. software "Target Strength Post Processing Program ESPTS." Computations of mean target strength and backscattering cross section were made from individual echoes, and a hard copy of the results was printed for each 5-m depth interval.

Estimates of fish density were made for each transect by echo integration using a Biosonics, Inc. ESP Model 221[1] echo integrator. Correction from the 40 log(R) setting used during data collection to the 20 log(R) used for data processing was accomplished by adjusting the B constant value for each depth stratum (Appendix A.1). The time-varied-gain (TVG) crossover for the system was 11.72 m.

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[1] Use of a company name does not constitute endorsement by ADF&G.

The echo integrator compiled data in 1-min sequences along each transect and sent outputs to computer files for further reduction and analysis using the Biosonics, Inc. software "Echo Integration Post Processing Program ESPCRNCH." Raw integrator outputs were edited to remove data that resulted from false bottom echoes. Where this occurred, fish densities were usually estimated using the average densities of adjacent sequences at the same depth. Overall fish density was obtained by calculating the average edited integrator output value across the transect for each depth strata. These averages were multiplied by the integrator scaling factor derived from the mean backscattering cross-section value obtained from the ESPTS program. Mean backscattering cross section values were calculated for each depth strata using data from those transects where false bottom did not occur or did not influence the target strength data.

The total number of fish (N_{ij}) for area stratum i based on transect j was estimated across depth stratum k and consisted of the number of fish estimated by hydroacoustic gear in the midwater section (M_{ij}) plus an estimate of fish unavailable to the hydroacoustic gear because of their location near the surface (S_{ij}) or bottom (B_{ij}), or

$$N_{ij} = S_{ij} + M_{ij} + B_{ij} .$$

The midwater component was estimated as

$$M_{ij} = \sum_{k=1}^{K} a_i w_{ijk} m_{ijk} ,$$

where a_i represented the surface area (m^2) of area stratum, i was estimated using a planimeter and USGS maps of Skilak and Kenai Lakes, and w_{ijk} was the average depth (≤5m) of depth stratum k measured along transect j in area i. This depth would be less than the maximum 5 m if the bottom was detected within depth stratum k anytime along the transect. The mean fish density in area i depth k across transect j was m_{ijk} in number per m^3.

The estimated number of fish near the surface (0-3 m) in area i was

$$S_{ij} = a_{is} m_{ij1} ,$$

where a_{is} was the estimated volume (m^3) of the surface area stratum, or 0-3 m, and m_{ij1} was the mean fish density for the first ensonified depth strata (2-7 m below transducer) of transect j.

The estimated number of fish near the bottom was

$$B_{ij} = \sum_{k=1}^{K} b_{ijk} m_{ijk} ,$$

where b_{ijk} was the estimated volume (m^3) in area i of depth k which could not be ensonified due to the proximity of the bottom along transect j, and m_{ijk} was the estimated fish density (number per m^3) along transect j in area i depth k which was ensonified. In cases where all of depth strata k was along the bottom, the mean density m_{ijk-1} from the next shallower depth strata (k-1) was used.

The abundance in area i (N_i) became the mean across total abundance estimated by each transect j, or

$$N_i = J^{-1} \sum_{j=1}^{J} N_{ij} ,$$

and its variance was estimated as

$$V(N_i) = \sum_{j=1}^{J} (N_{ij} - N_i)^2 (J-1)^{-1} J^{-1} .$$

Total abundance for each lake became the sum of its area estimates. Its variance became the sum of the area variances.

In an effort to quantify species composition of measured fish targets, a midwater trawl sampling program was conducted in Skilak Lake during daylight hours on 25 and 27 September. A similar program was conducted in Kenai Lake between 17 and 19 September. A total of 215 min were spent towing in Skilak Lake and 770 min in Kenai Lake. The trawl mouth opening was 6.1 m by 3.1 m, and trawl length was 14.9 m. Mesh size decreased from 7.62 cm at the mouth to 0.32 cm at the cod end. The gear was towed between two boats at approximately 2 m/s, and the majority of the tows were near the surface. The sampling program was designed to collect a minimum of 300 fish from each sub-basin of each lake. All captured fish were enumerated, identified, and preserved in 10% formalin. In the laboratory juvenile sockeye salmon were measured to the nearest mm (fork length), weighed to the nearest 0.1 g, and aged from scale samples using criteria outlined by Mosher (1969). Differences in age and species composition between areas were tested with chi-square analysis.

In addition to the survey conducted with the 420 KHz sounder, a second survey of Area 1 in Skilak lake was conducted on 10 October. The objective of this survey was to gather dual-beam target strength data at depth to assess if biological factors were influencing the 420 kHz target strength results. The equipment for this survey consisted of a Biosonics Inc. 120 kHz echo sounder with dual-beam receivers, a 120 kHz 10°/25° dual-beam transducer mounted in a v-fin for towing, and the same recording equipment

as the earlier survey. The selected pulse width was 0.4 ms, the pulse repetition rate was 3 pulses/s, and the bandwidth was 5 kHz. Additional acoustic parameters used during data collection and processing are presented in Appendix A.1. Biosonics, Inc. calibrated the system immediately following the survey. Scattering or attenuation of the 120 kHz system was assumed to be less because of the lower frequency.

For comparative purposes, data collected with the 420 kHz sounder were reprocessed with a threshold of -58.55 dB; these data were not used in the generation of the abundance estimates of juvenile sockeye salmon. This threshold was selected because of the noise level and sounder parameters associated with the 120 kHz system.

RESULTS

A total of 6,074 echoes in Kenai Lake and 42,363 in Skilak Lake were used to estimate target strength distributions. Mean target strength for Kenai Lake was -54.55 dB (Appendix A.2). As in past years, calculated mean target strengths decreased with depth. Near-surface measurements were -51.78 dB in contrast to -56.78 dB at a depth of 47 m. In Skilak Lake the mean target strength was -52.86 dB; mean target strength decreased from a near-surface value of -50.81 dB to -54.51 dB at 47 m. At depths greater than 47 m, target strengths were within 1 dB of the mean (Appendix A.3).

Estimates of fish abundance in surface (Appendix A.4) and bottom strata (Appendices A.5, A.6) that were not sampled by the hydroacoustic gear contributed a maximum of 41% to an individual transect estimate (Kenai Lake, Area 1, transect 2). Overall, the Kenai Lake surface estimates contributed 11% and bottom estimates 4% of the total. In Skilak Lake, surface estimates contributed 8% and bottom estimates 7% of the total.

The total estimated number of fish in both lakes was 7,517,200 (Table 1). Approximately 11%, or 804,740 fish, were found in Kenai Lake and the remaining 6,712,500 fish in Skilak Lake. Approximately 47.5% of the fish in Skilak Lake were located in Area 1, which composed 27.1% of the lake volume (Table 2). Within Kenai Lake 26.3% of the fish were located in Area 1, which composed 5.6% of the lake volume.

The depth distribution of fish between transects and areas was variable in Kenai Lake (Figures 5-10). The maximum density of fish observed in Kenai Lake was 0.0067 fish/m^3 between 17 and 22 m along transect 1 of Area 1 (Figure 5). The maximum density of fish observed varied from the 2-7 m strata to the 22-27 m strata along the remaining transects. Ten transects had maximum densities at the 17-22 m strata and nine at 2-7 m; in Area 5 maximum densities were at the surface in all six transects.

Depth distribution of fish in Skilak Lake was more consistent than Kenai Lake (Figures 11-13). The maximum fish density observed in Skilak Lake was 0.0068 fish/m^3 between 12-17 m along transect 2 of Area 1 (Figure 11). Maximum densities of fish were recorded in the 12-17 m depth range for 5 of the 13 transects. Five transects had maximum densities deeper and three shallower in the water column.

A total of 1,292 fish were captured during tow netting operations in Skilak Lake and 1,766 in Kenai Lake. Sockeye salmon were the predominant species in catches from both lakes, representing 100.0% of the total catch for Skilak Lake. Within Kenai Lake catches from each sub-basin were used to apportion estimated targets to sockeye salmon (Table 3).

Age-1 sockeye salmon made up 2.8% and age-0 composed 97.2% of the Kenai Lake juvenile sockeye estimate (N = 1,404; Table 3). Within Skilak Lake a difference in age composition among areas was observed (chi-square = 18.7, P = .05, df = 2); the age structure of Area 3 was significantly different than that of Areas 1 and 2 combined. Age-0 sockeye salmon composed 96.1% of the estimate for Areas 1 and 2 (N = 613), and 88.3% in Area 3 (N = 305; Table 3).

Length frequencies for each age class were well defined and quite distinct in both Skilak Lake and Kenai Lake (Figure 14). In general, the size of both age classes was relatively small. The mean length of age-0 sockeye salmon in Skilak Lake was 51.4 mm, and the mean weight was 1.5 g. Age-1 fish in Skilak Lake had a mean length of 73.8 mm and weight of 4.7 g. Both age groups of Kenai Lake sockeye salmon were larger (N.S.C.) in size than those collected in Skilak Lake (Table 4).

After adjusting the total number of targets using species and age composition data from trawl samples, the number of juvenile sockeye salmon in both lakes was estimated at 7,514,300. Of this total, 7,127,800 were age-0 sockeye salmon produced by the 1990 spawning population, and 386,500 were age-1 sockeye salmon produced by the 1989 spawning population (Table 3).

A total of 10,403 echoes were used in the analysis of the 120 kHz target strength data. The mean target strength was -47.41 dB. No decrease in target strength with depth was observed to 42 m. In contrast, the 420 kHz results indicated decreasing target strength with depth from -48.09 dB at 2-7 m to -52.10 dB at 37-42 m (Figure 15).

DISCUSSION

The 1991 target strength measurements in Skilak Lake were the highest recorded to date. The pattern of decreasing target strength with depth using the 420 kHz system was consistent with past years (Figure 16). Examination of sub-basin target strength trends (Figure 17) indicated a similar pattern for all areas of the lake. Higher mean target strengths recorded for deeper strata were possibly a result of small sample size and the occasional occurrence of large, non-juvenile sockeye targets at those depths. The 120 kHz data suggested that the phenomena creating the decreasing target strength with depth pattern is not biological, but may be due to equipment anomalies or to the physical and chemical properties of the lakes. The sounder and processing equipment were checked by the manufacturer prior to and after surveys. Standard target measurements were also made to field calibrate the sounder and processing equipment. No readily apparent equipment anomalies were identified. Therefore, we deduced that the physical and chemical properties causes this phenomena. Further specific investigations of these results are, however, necessary before final conclusions can be drawn.

The 1991 juvenile sockeye salmon estimates are the lowest recorded to date (Figure 18). Using historical data from the Kenai and Kasilof Rivers, the number of smolt projected to migrate from the Kenai River

in 1992 is 4 to 5 million fish. However, the 1990 juvenile and 1991 smolt estimates were divergent (Figure 18). Fall fry estimates were 25,387,000 fish (Tarbox and King 1992); the smolt outmigration was approximately 3 million (King et al. 1991). Overwinter survival was estimated at approximately 12%; however, juveniles in Russian and Hidden Lakes are not included in the fall estimate, so the overwinter survival of fish in Kenai and Skilak Lakes may have been considerably less.

The distribution of juvenile sockeye salmon within the Kenai River was similar to previous years (Figure 19). Approximately 11% of the total estimate was measured in Kenai Lake. The historical average contribution of Kenai Lake is 14%, ranging from approximately 11% to 17%. This consistent contribution of Kenai Lake fish to the total fry estimate occurred despite fry estimates ranging from 7 million fish to over 37 million fish, a five-fold difference.

The length (Figure 20) and weight (Figure 21) of age-0 sockeye salmon in both lakes continues to increase from the low values measured during the 1988 rearing year. Although average length has increased only slightly, the weight of age-0 fish has increased by almost 50%, possibly because there are fewer fry in the system.

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Table 1. Estimated number of fish present in Skilak and Kenai Lakes, Alaska in the fall of 1991.

Lake	Area	Transect	Estimated Number of Fish				Area Mean	Variance
			Surface	Midwater	Bottom	Total		
Skilak	1	1	5.6348E+05	2.6586E+06	5.7134E+05	3.7934E+06		
		2	1.8292E+05	3.8161E+06	4.2694E+05	4.4260E+06		
		3	1.3658E+05	2.3388E+06	1.9287E+05	2.6683E+06	3.1860E+06	1.0561E+11
		4	1.3477E+05	2.3972E+06	1.8793E+05	2.7199E+06		
		5	1.0753E+05	2.8345E+06	2.6143E+05	3.2035E+06		
		6	2.3391E+05	1.8477E+06	2.2330E+05	2.3049E+06		
	2	1	1.5880E+05	1.6292E+06	3.6336E+04	1.8243E+06		
		2	5.2368E+04	1.6178E+06	6.3496E+04	1.7337E+06	2.2259E+06	2.0043E+11
		3	7.9902E+04	2.8556E+06	1.8431E+05	3.1198E+06		
	3	1	1.4499E+05	1.0047E+06	5.3629E+04	1.2033E+06		
		2	3.0618E+05	9.2487E+05	2.6760E+04	1.2578E+06	1.3006E+06	9.1363E+09
		3	7.4588E+04	1.0356E+06	5.0039E+04	1.1602E+06		
		4	9.4770E+04	1.3711E+06	1.1508E+05	1.5810E+06		
	TOTAL						6.7125E+06	3.1518E+11
Kenai	1	1	2.3322E+04	3.3540E+05	1.1310E+05	4.7182E+05		
		2	6.2463E+04	2.4616E+05	1.1171E+05	4.2033E+05		
		3	7.5849E+03	8.3087E+04	1.7305E+04	1.0798E+05	2.1150E+05	3.8055E+09
		4	3.0826E+02	1.4931E+05	2.4929E+04	1.7455E+05		
		5	2.5638E+03	8.9756E+04	1.2723E+04	1.0504E+05		
		6	4.0530E+02	7.9987E+04	6.7297E+03	8.7122E+04		
		7	1.0468E+03	1.0075E+05	1.1882E+04	1.1368E+05		
	2	1	1.8894E+04	1.2115E+05	0.0000E+00	1.4004E+05		
		2	1.2563E+03	1.0114E+05	0.0000E+00	1.0240E+05		
		3	0.0000E+00	2.9288E+05	0.0000E+00	2.9288E+05	1.8784E+05	1.7844E+09
		4	3.9625E+03	2.1207E+05	0.0000E+00	2.1603E+05		
	3	1	4.8853E+02	9.0348E+04	0.0000E+00	9.0837E+04		
		2	1.4371E+04	1.8962E+05	0.0000E+00	2.0399E+05		
		3	6.1469E+02	9.3831E+04	0.0000E+00	9.4446E+04	1.1508E+05	5.6615E+08
		4	2.2599E+03	1.1758E+05	0.0000E+00	1.1984E+05		
		5	4.8758E+03	6.1399E+04	0.0000E+00	6.6275E+04		
	4	1	2.1301E+04	5.5386E+04	0.0000E+00	7.6687E+04		
		2	4.8111E+04	1.6188E+05	0.0000E+00	2.0999E+05		
		3	4.5352E+04	1.9026E+05	0.0000E+00	2.3561E+05	1.7966E+05	1.1715E+09
		4	1.4140E+03	1.2089E+05	0.0000E+00	1.2230E+05		
		5	2.6776E+04	2.2695E+05	0.0000E+00	2.5373E+05		
	5	1	6.9187E+04	1.6578E+05	0.0000E+00	2.3497E+05		
		2	1.1313E+04	5.8945E+04	0.0000E+00	7.0258E+04	1.1066E+05	7.1593E+08
		3	2.0559E+04	5.0662E+04	0.0000E+00	7.1221E+04		
		4	2.2664E+04	4.8912E+04	0.0000E+00	7.1576E+04		
		5	2.0477E+04	6.2033E+04	0.0000E+00	8.2510E+04		
		6	3.1390E+04	1.0201E+05	0.0000E+00	1.3340E+05		
	TOTAL						8.0474E+05	8.0435E+09
	TOTAL FOR BOTH LAKES						7.5172E+06	3.2323E+11

Table 2. Areas and volumes used for fish density estimates in Kenai and Skilak Lakes, Alaska 1991.

	Skilak Lake		
Area	Surface Area ($m^3 \times 10^6$)	Volume ($m^3 \times 10^6$)	Density of Fish (%)
1	43.03 (43.5%)	1689.8 (27.1%)	47.5
2	33.46 (33.8%)	2798.0 (44.8%)	33.2
3	22.50 (22.7%)	1755.0 (28.1%)	19.3
Total	98.99 (100.0%)	6242.8 (100.0%)	100.0

	Kenai Lake		
Area	Surface Area ($m^3 \times 10^6$)	Volume ($m^3 \times 10^6$)	Density of Fish (%)
1	7.72 (13.9%)	198.0 (5.6%)	26.3
2	11.91 (21.5%)	683.5 (19.2%)	23.3
3	10.54 (19.0%)	835.2 (23.5%)	14.3
4	14.37 (25.9%)	1169.4 (32.8%)	22.3
5	10.93 (19.7%)	673.8 (18.9%)	13.8
Total	55.47 (100.0%)	3559.9 (100.0%)	100.0

Table 3. Estimated contribution of age-0 and age-1 sockeye salmon to the total fish population in Kenai and Skilak Lakes, Alaska, in the fall of 1991.

Location	Total Fish	Estimated Sockeye Salmon	Percent Age-0	Total Age-0	Percent Age-1	Total Age-1
Skilak Lake						
Areas 1 & 2	5,411,900	5,411,900	96.1	5,200,836	3.9	211,064
Area 3	1,300,600	1,300,600	88.3	1,148,430	11.7	152,170
Total	6,712,500	6,712,500		6,349,266		363,234
Kenai Lake						
Area 1	211,500	211,500	97.1	205,367	2.9	6,133
Area 2	187,840	187,272	97.1	181,841	2.9	5,431
Area 3	115,080	115,080	97.1	111,743	2.9	3,337
Area 4	179,660	178,079	97.1	172,915	2.9	5,164
Area 5	110,660	109,896	97.1	106,709	2.9	3,187
Total	804,740	801,827		778,575		23,252
Total[1]	7,517,200	7,514,300		7,127,800		386,500

[1] Rounded to nearest 100 fish.

Table 4. Age, length, and weight of sockeye salmon collected in Skilak and Kenai Lake, Alaska, in the fall of 1991.

		Age-0				Age-1			
Location	Date	Mean[1] Length (mm)	Standard Deviation (mm)	Mean Weight (g)	Standard Deviation (g)	Mean[1] Length (mm)	Standard Deviation (mm)	Mean Weight (g)	Standard Deviation (g)
Skilak Lake									
	9/25-27/91	51.4 (n=863)	4.9	1.5 (n=286)	0.5	73.8 (n=55)	3.8	4.7 (n=14)	0.5
Kenai Lake									
	9/17-19/91	53.5 (n=1364)	6.5	2.0 (n=500)	0.6	75.9 (n=40)	4.8	5.5 (n=15)	1.0

[1] Fork length.

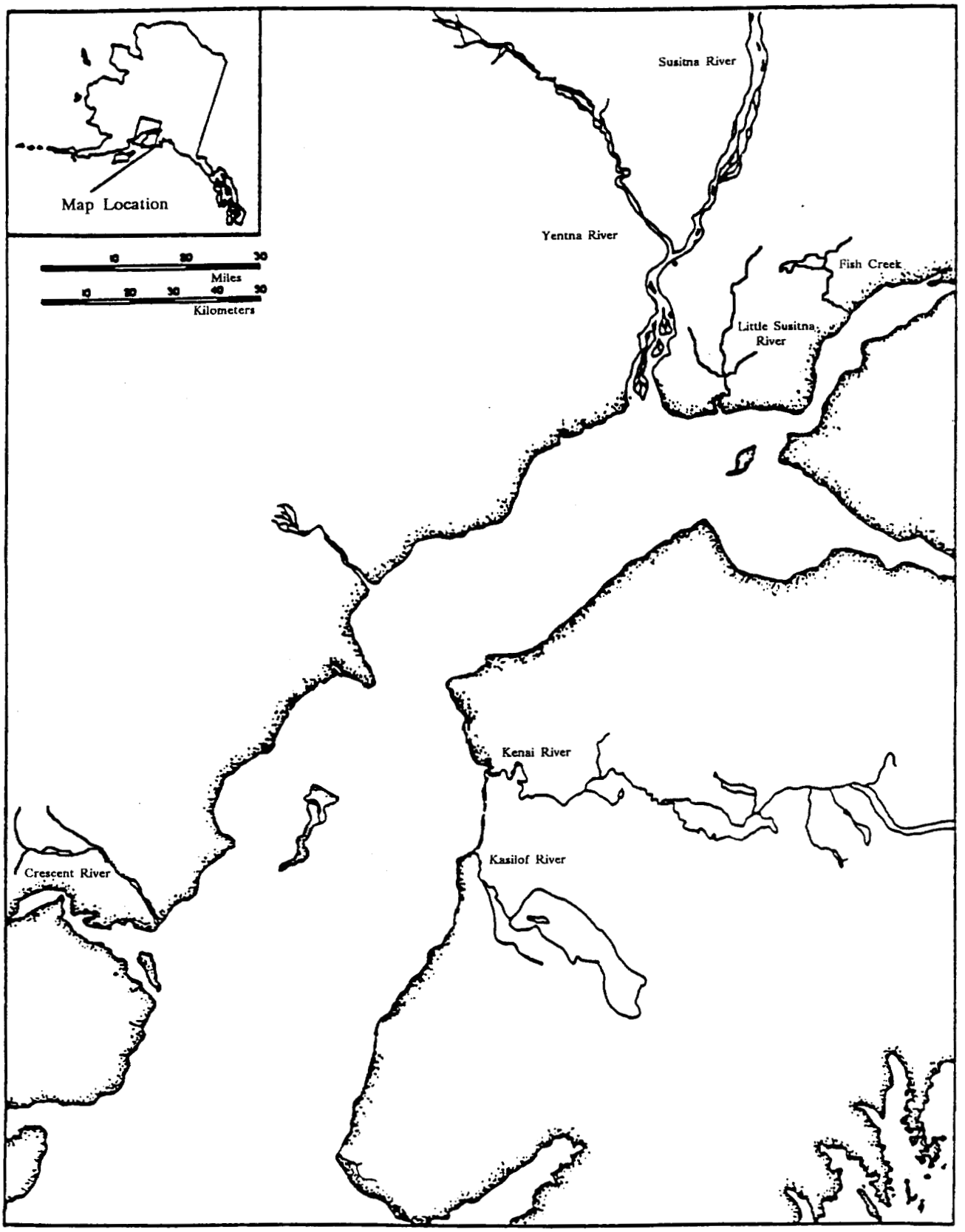

Figure 1. The Upper Cook Inlet area showing the locations of the Northern and Central Districts and the major sockeye salmon spawning drainages.

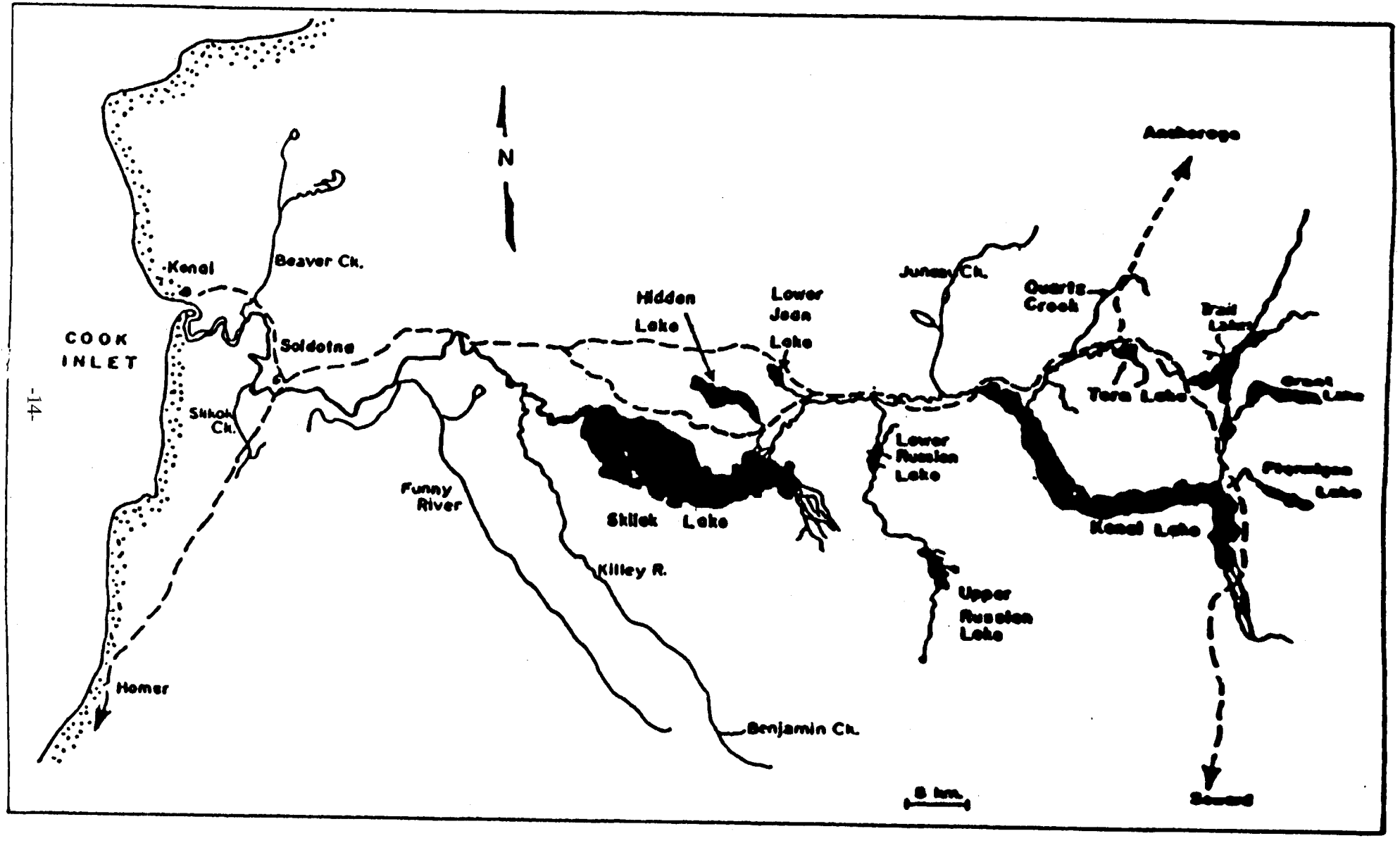

Figure 2. The location of the major lake systems, which are utilized by rearing sockeye salmon, of the Kenai River, Alaska, drainage.

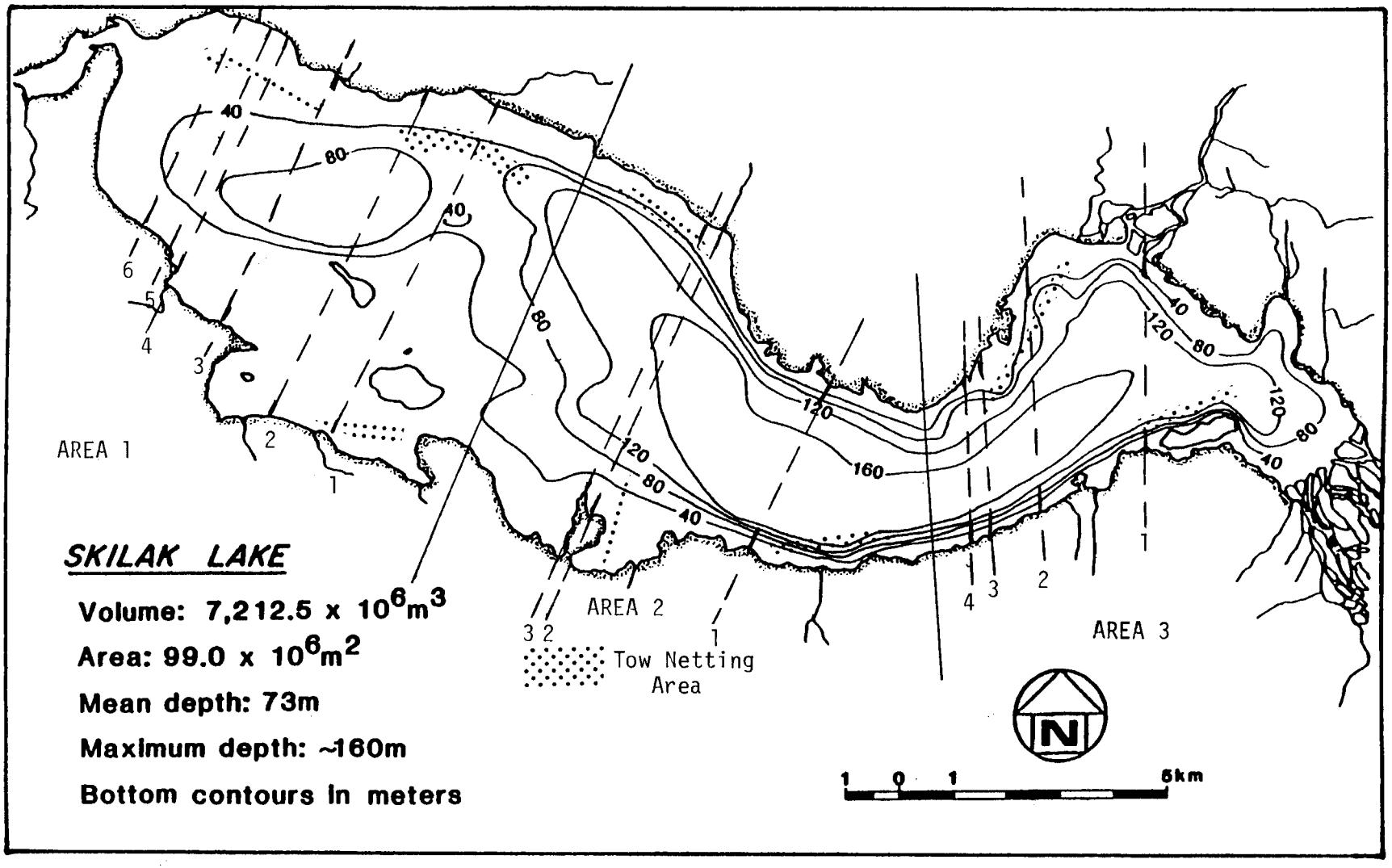

Figure 3. Skilak Lake, Alaska, area designations, hydroacoustic transect locations, and tow netting stations, 1991.

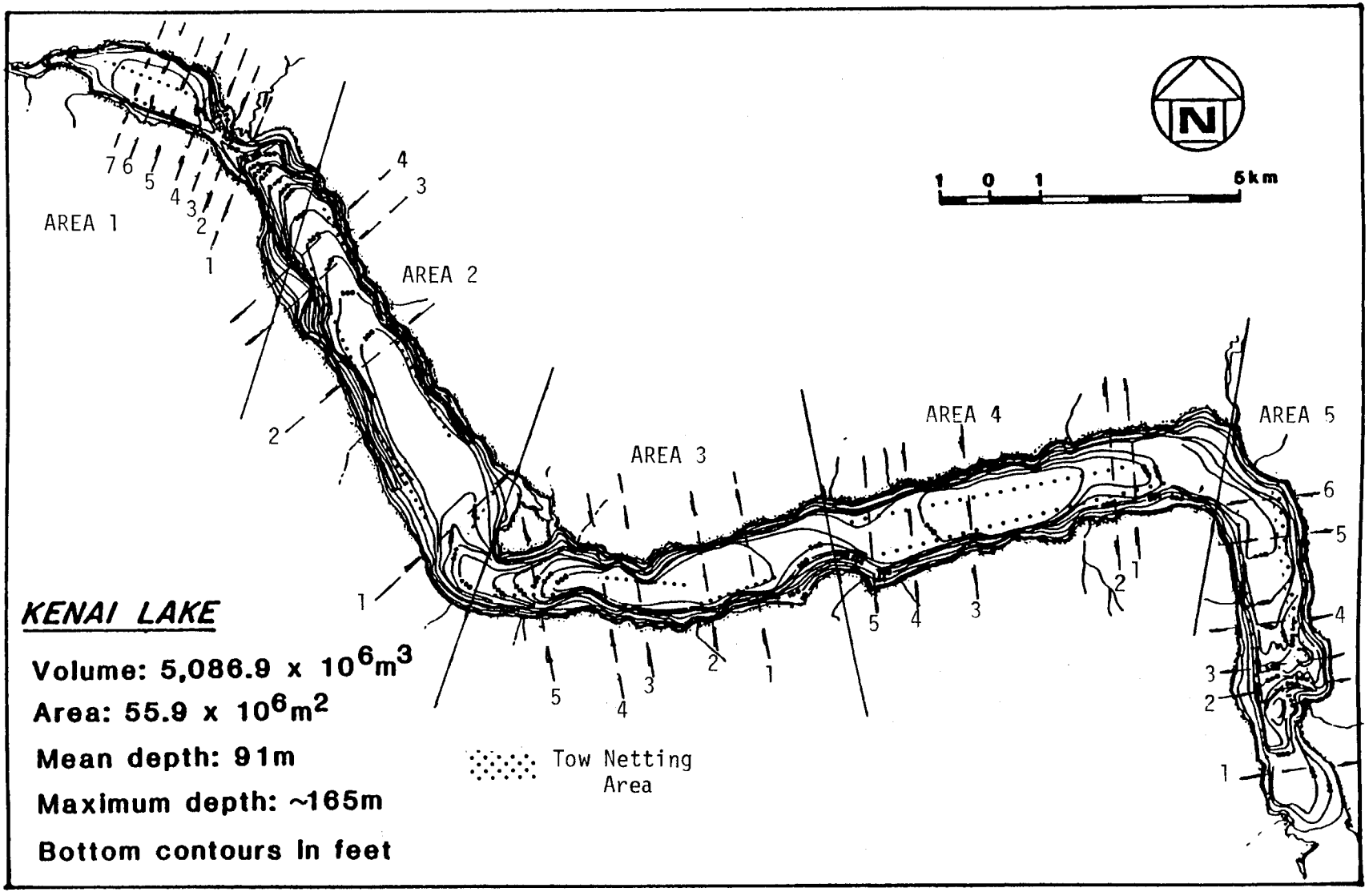

Figure 4. Kenai Lake, Alaska, area designations, hydroacoustic transect locations, and tow netting stations, 1991.

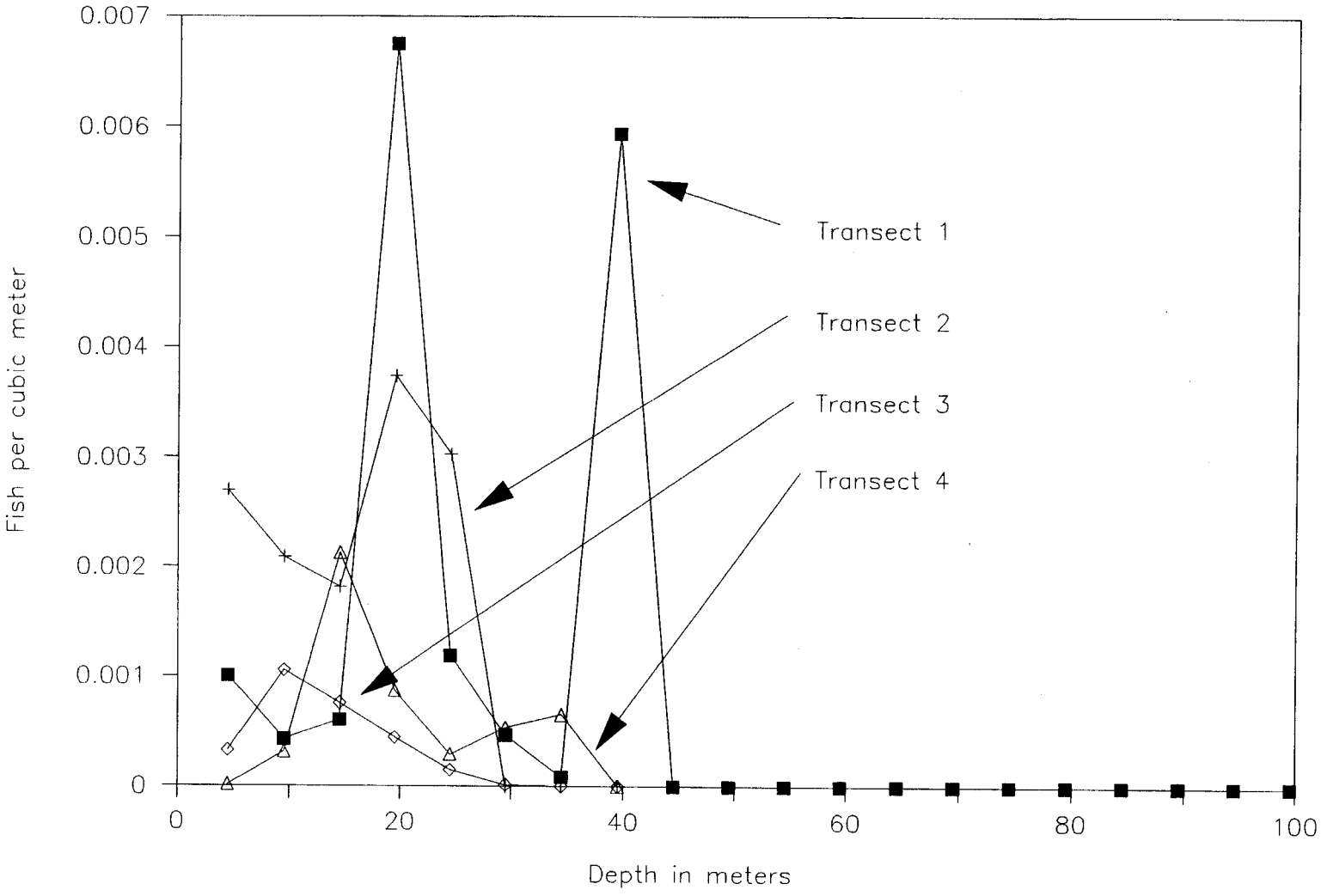

Figure 5. Fish density measured by depth in Area 1, Kenai Lake, Alaska. 1991. (transects 1 – 4).

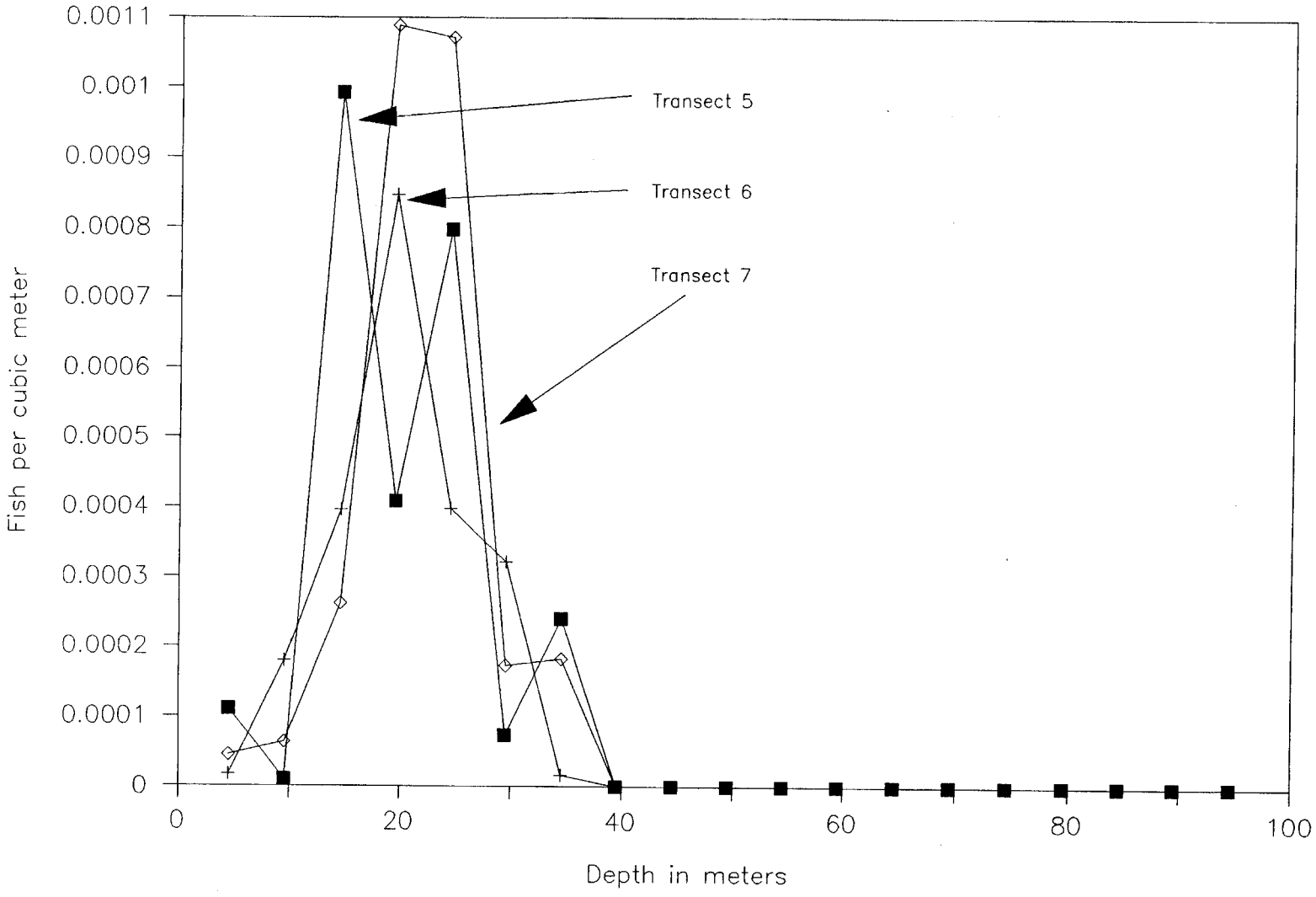

Figure 6. Fish density measured by depth Area 1, Kenai Lake, Alaska, 1991. (transects 5 – 7).

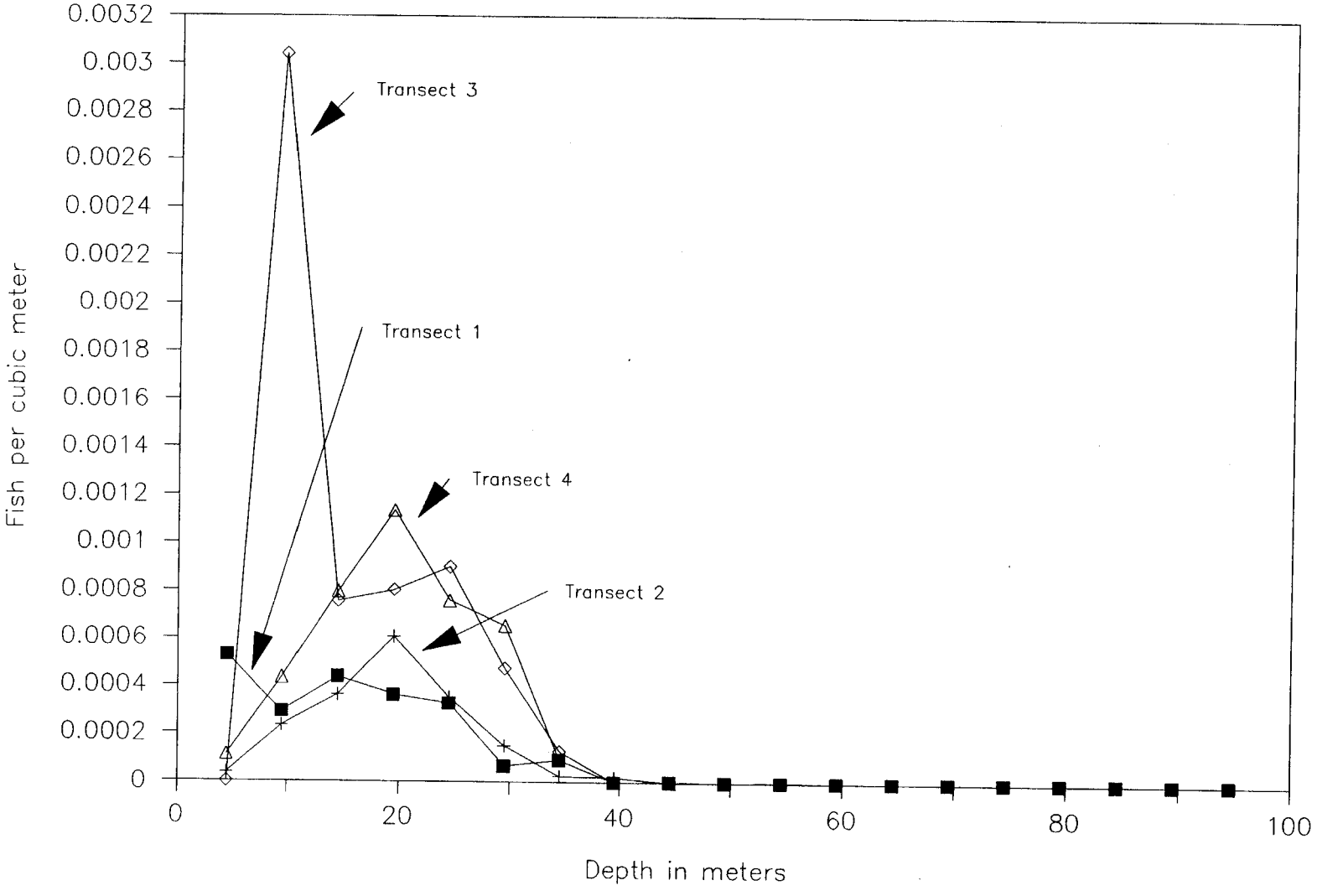

Figure 7. Fish density measured by depth in Area 2, Kenai Lake, Alaska. 1991.

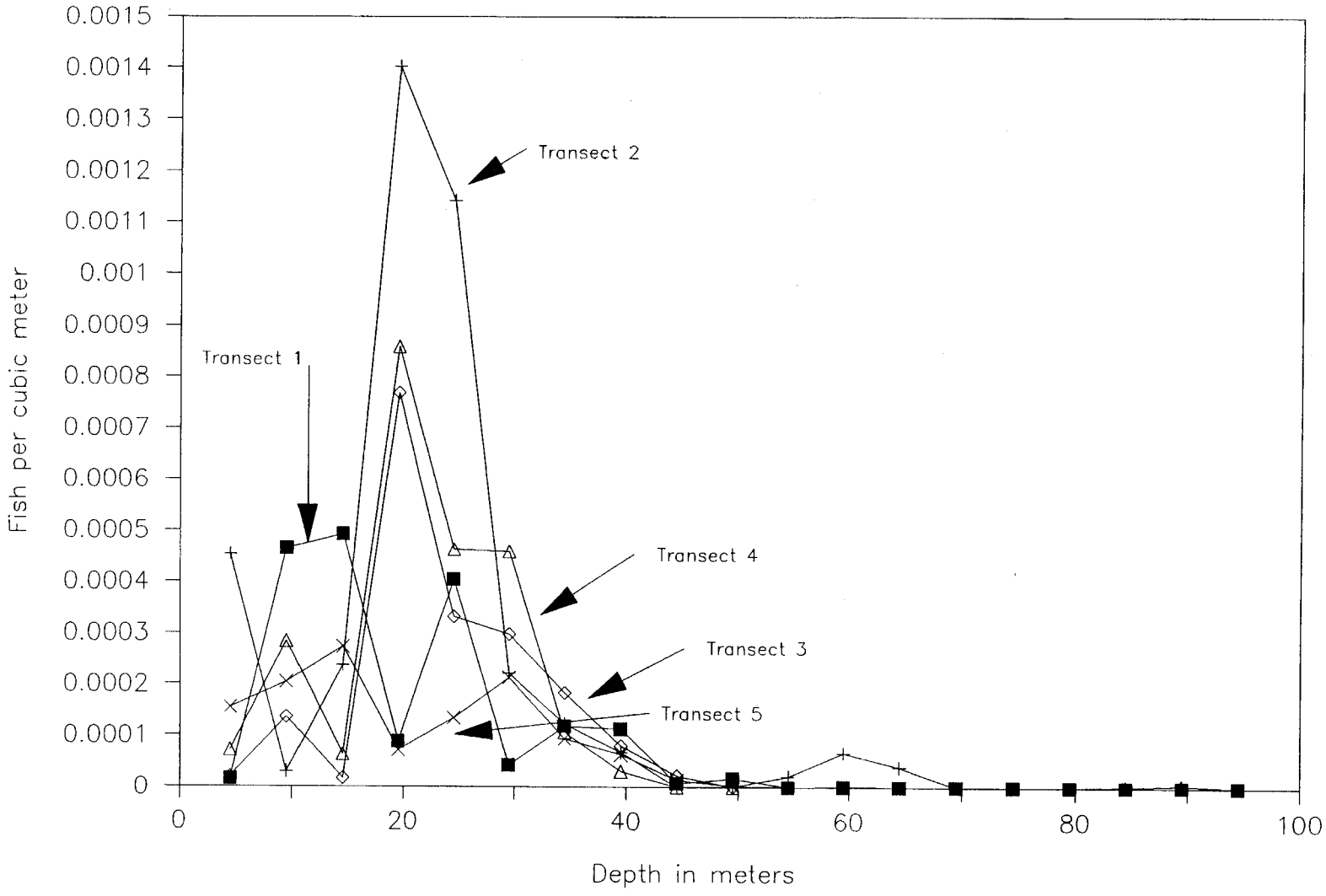

Figure 8. Fish density measured by depth in Area 3, Kenai Lake, Alaska. 1991.

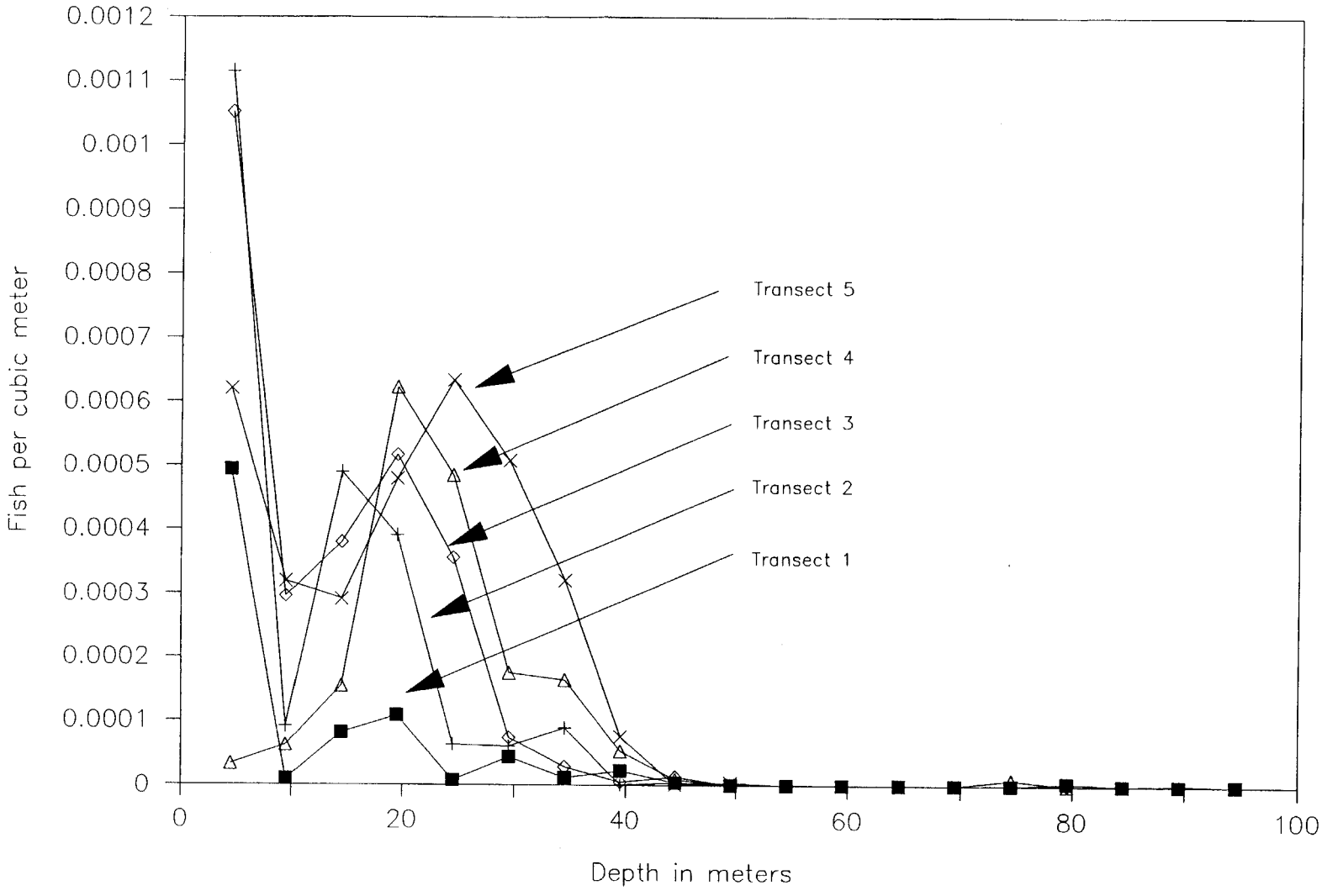

Figure 9. Fish density measured by depth in Area 4, Kenai Lake, Alaska. 1991.

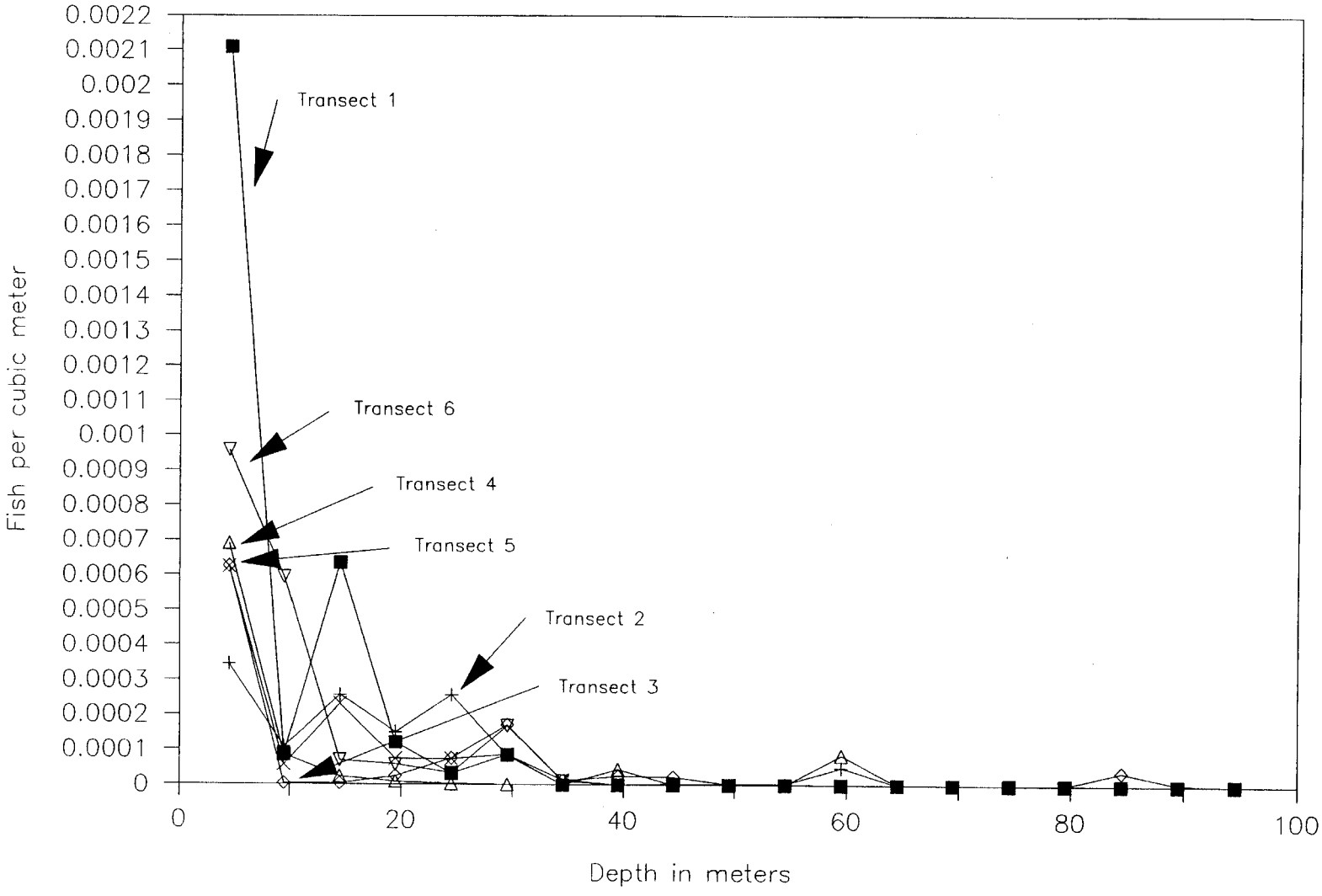

Figure 10. Fish density measured by depth in Area 5, Kenai Lake, Alaska. 1991.

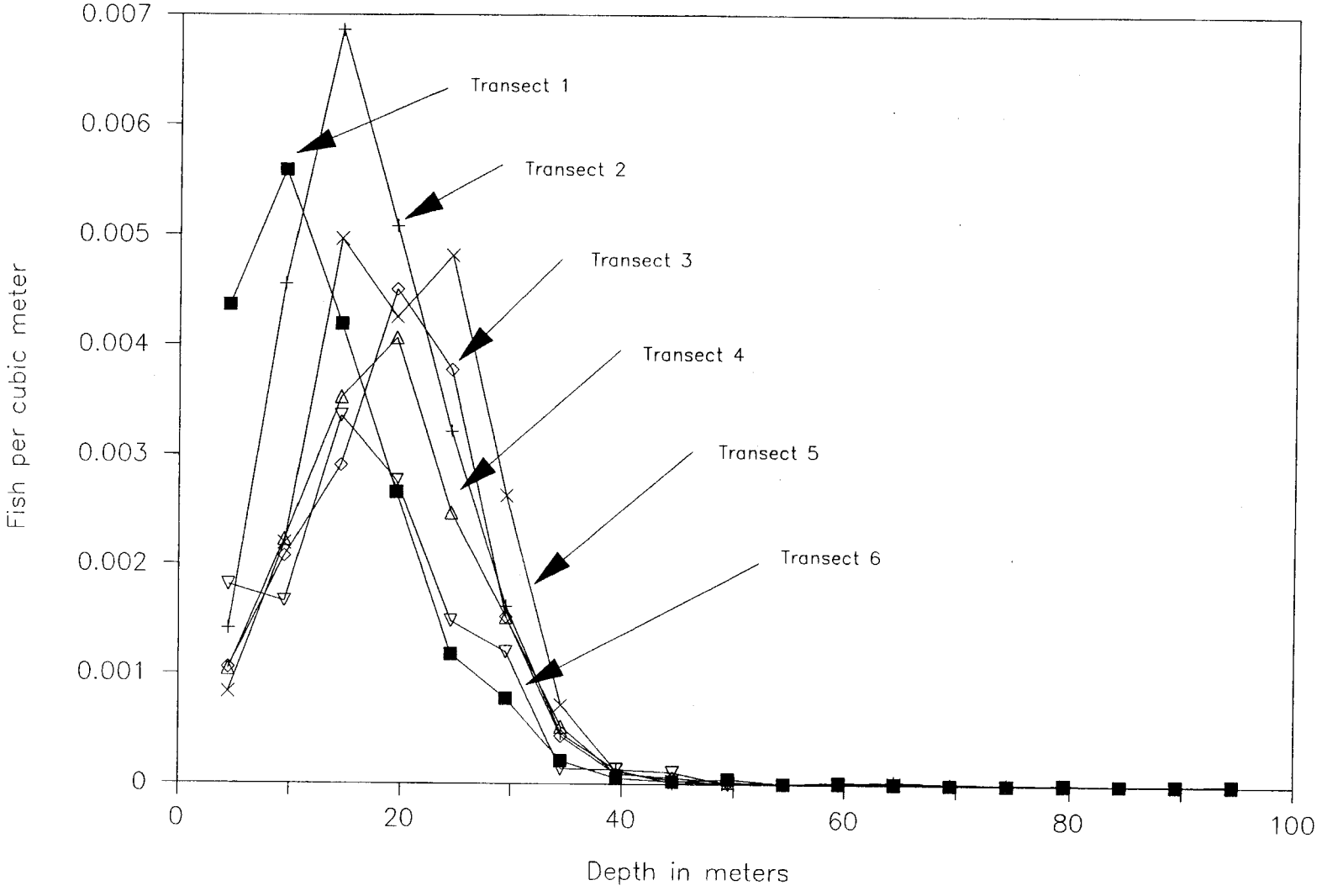

Figure 11. Fish density measured by depth in Area 1, Skilak Lake, Alaska. 1991.

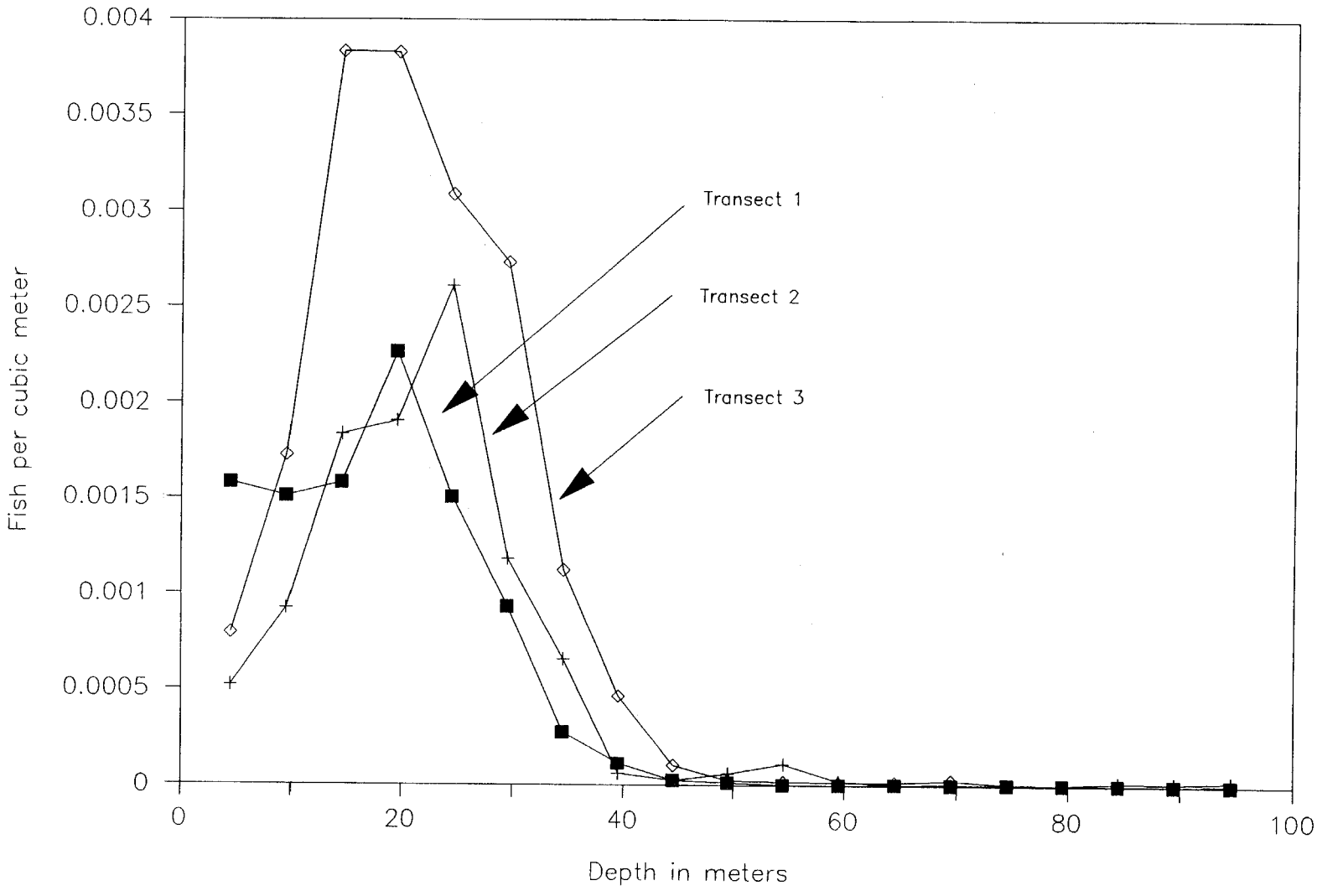

Figure 12. Fish density measured by depth in Area 2, Skilak Lake, Alaska. 1991

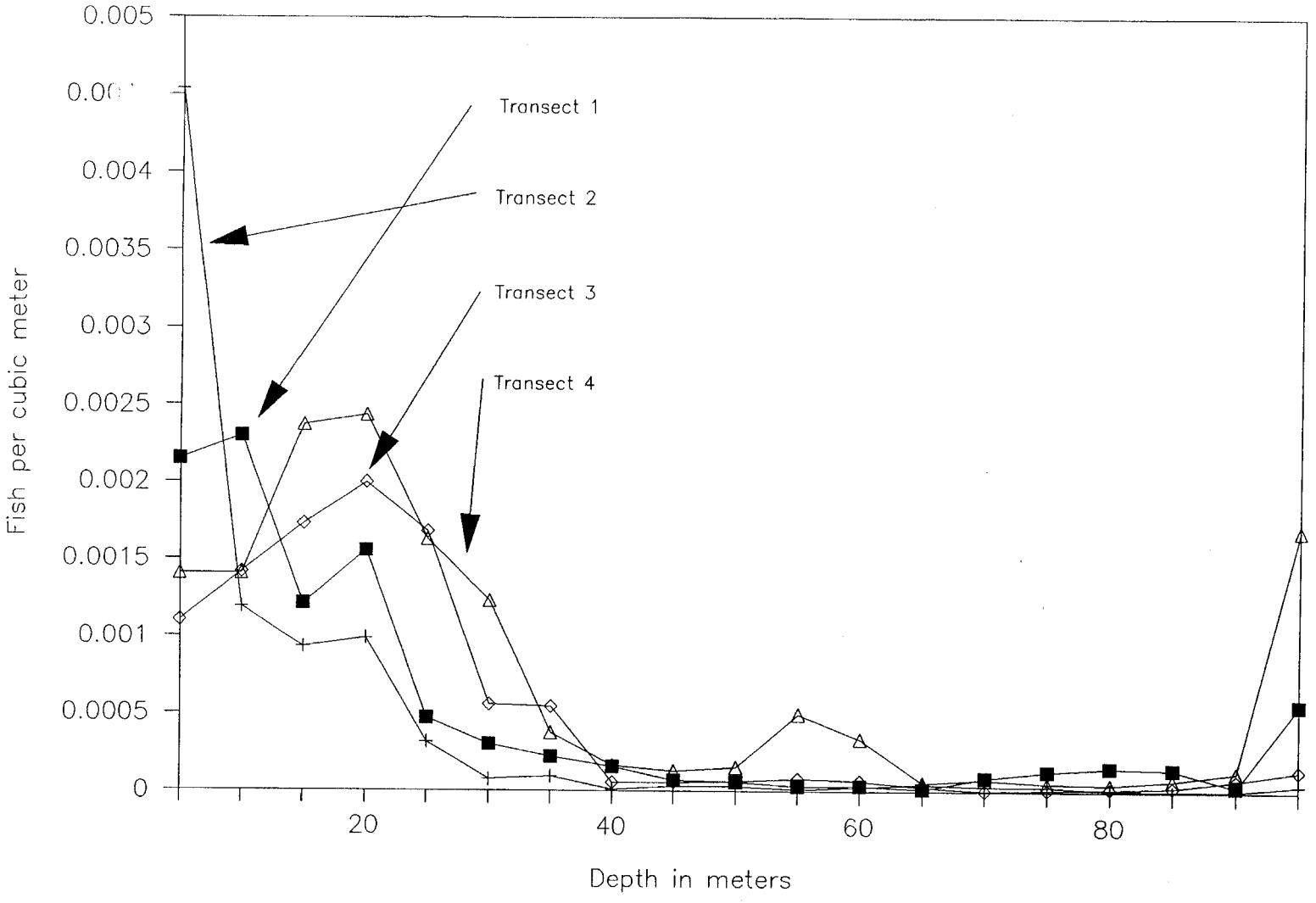

Figure 13. Fish density measured by depth in Area 3, Skilak Lake, Alaska. 1991

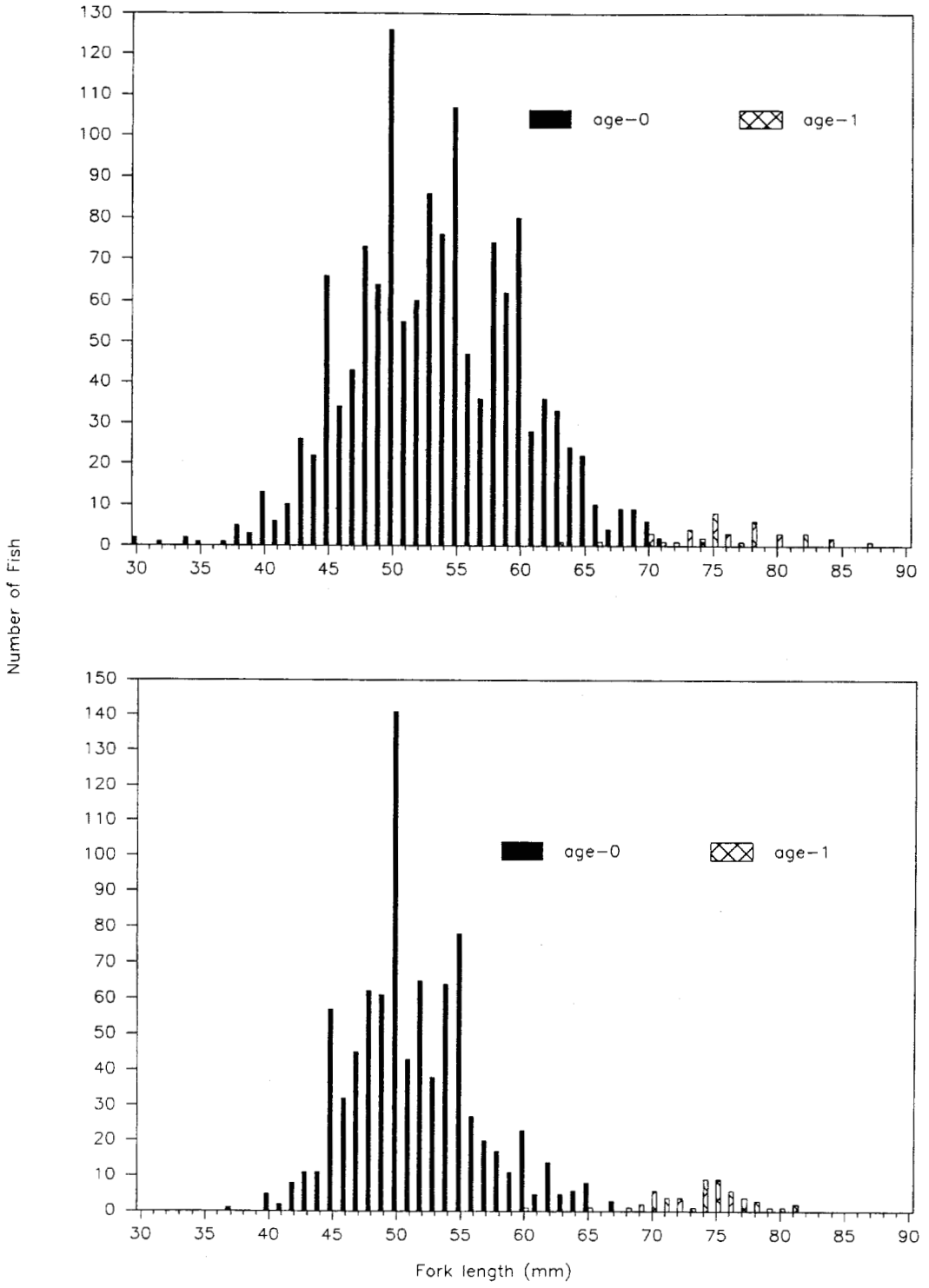

Figure 14. Length frequency distribution of sockeye salmon collected in Kenai (upper) and Skilak (lower) Lakes, Alaska. 1991.

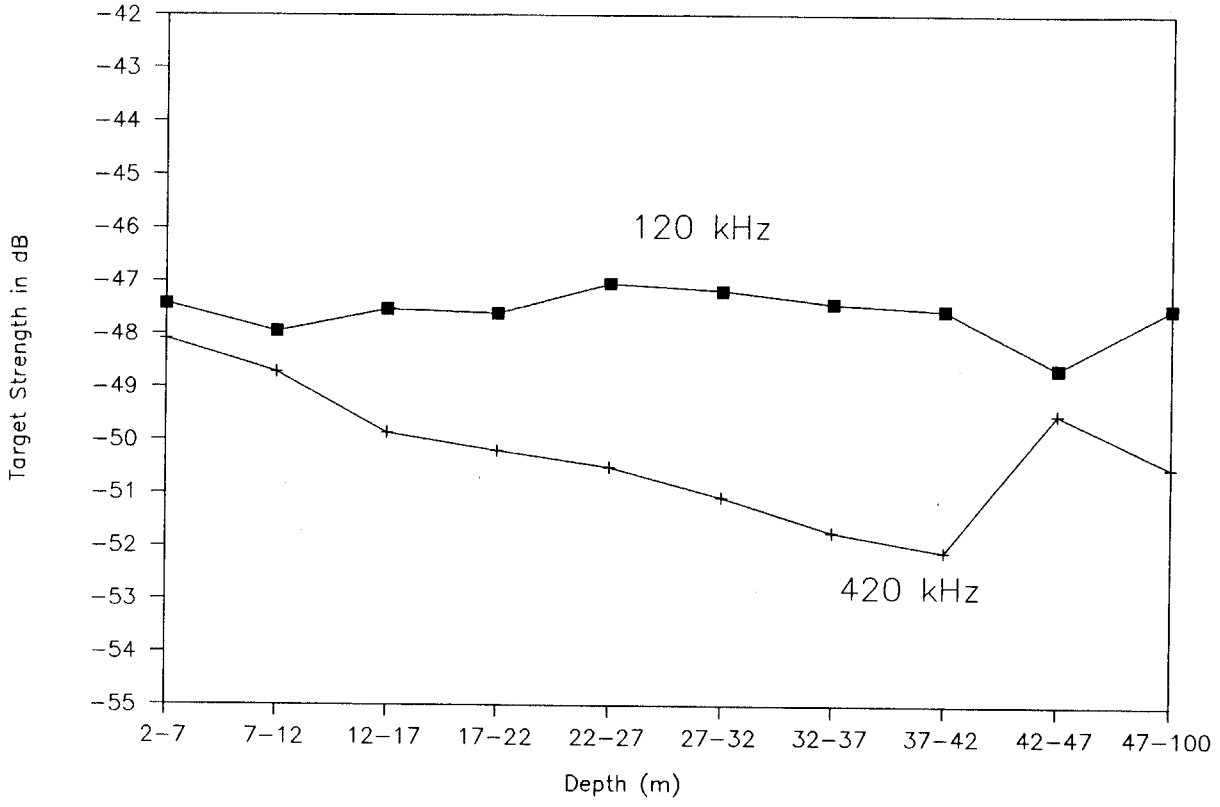

Figure 15. Fish target strength measured in Skilak Lake, Alaska by dual-beam hydroacoustic techniques, October, 1991.

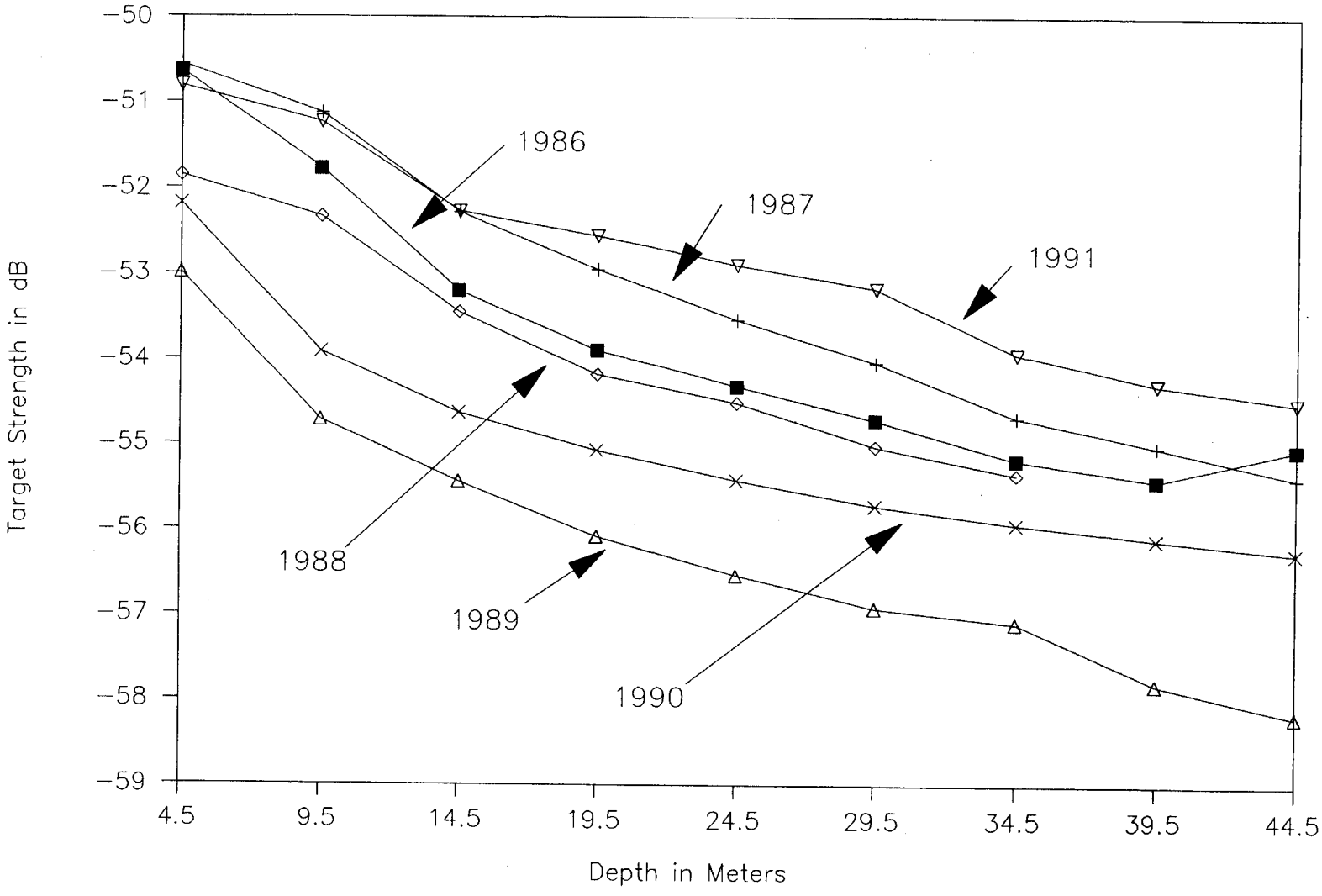

Figure 16. Fish target strengths measured in Skilak Lake, Alaska.

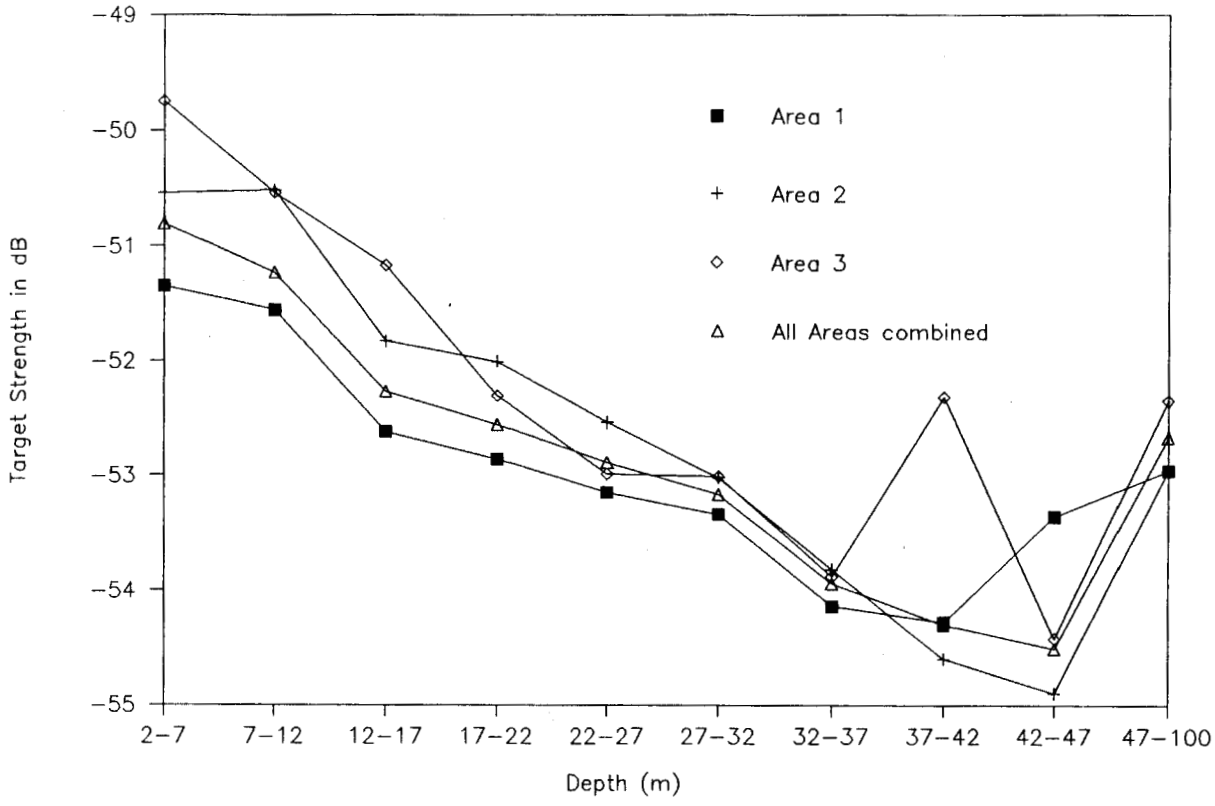

Figure 17. Fish target strength measured in Skilak Lake, Alaska by dual-beam hydroacoustic techniques (420 kHz) in 1991.

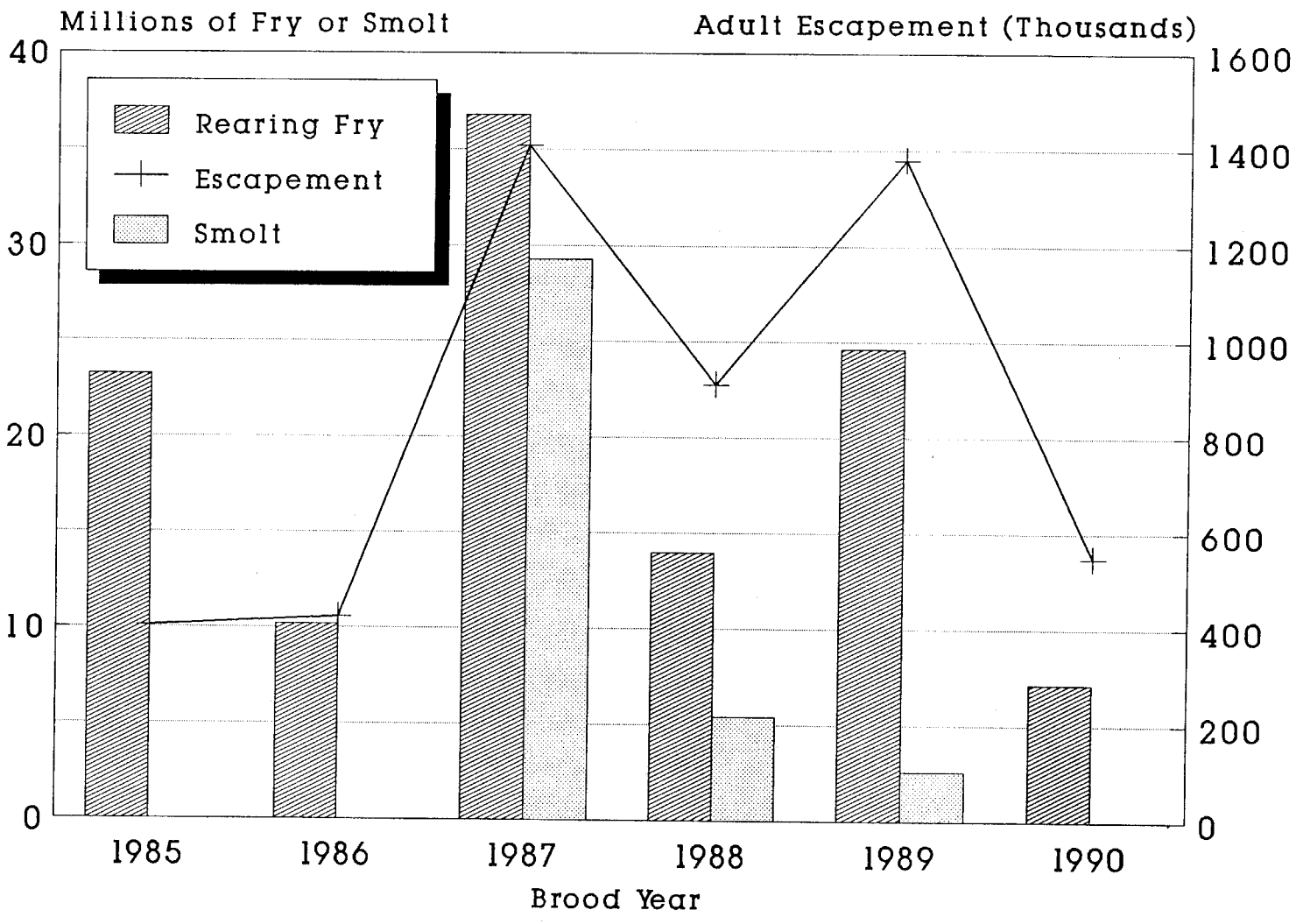

Figure 18. Estimated number of age-0 sockeye salmon rearing in Kenai and Skilak Lakes, Alaska, by brood year.

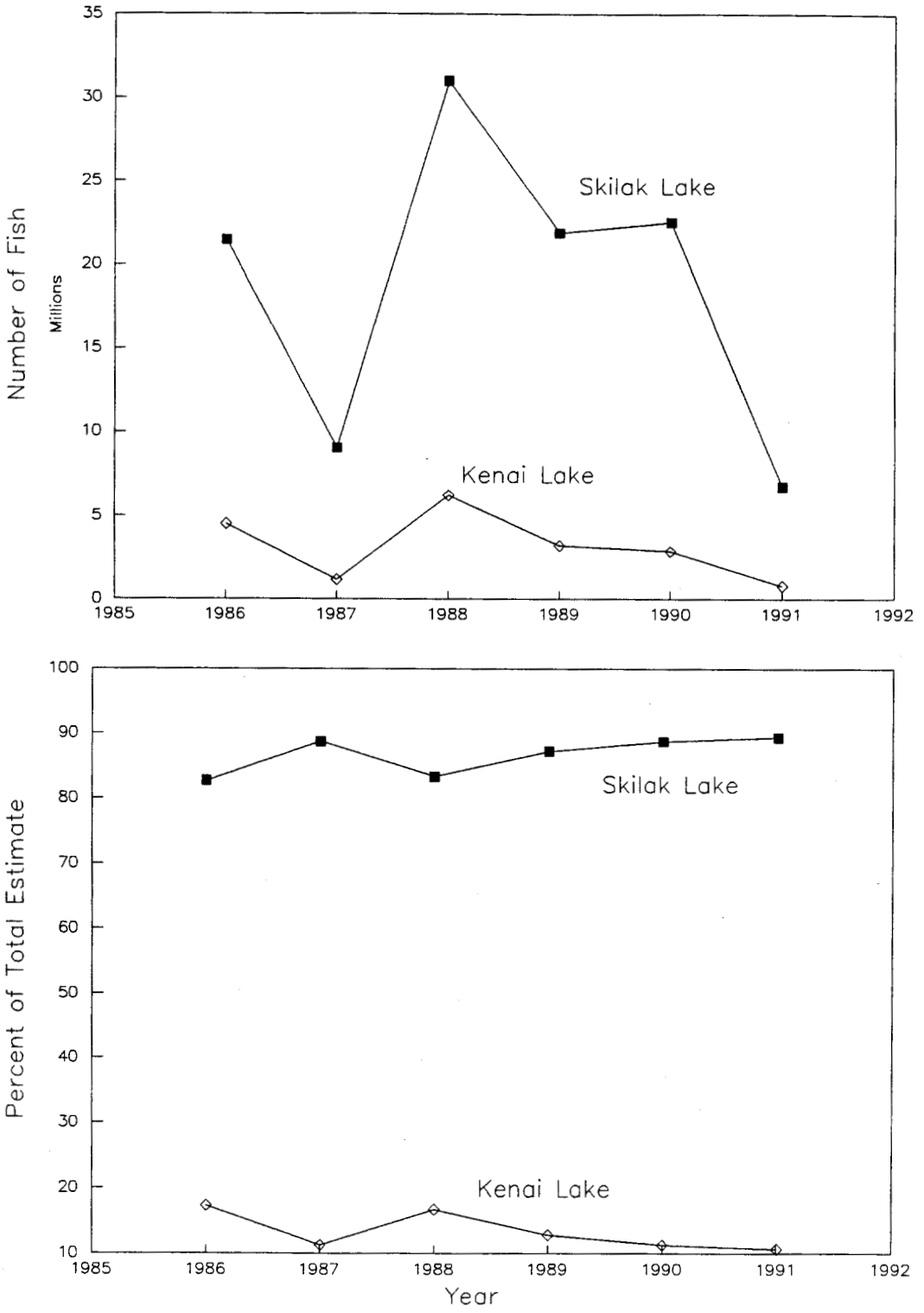

Figure 19. Relative distribution of juvenile sockeye salmon in the Kenai River system, Alaska. 1986 – 1991.

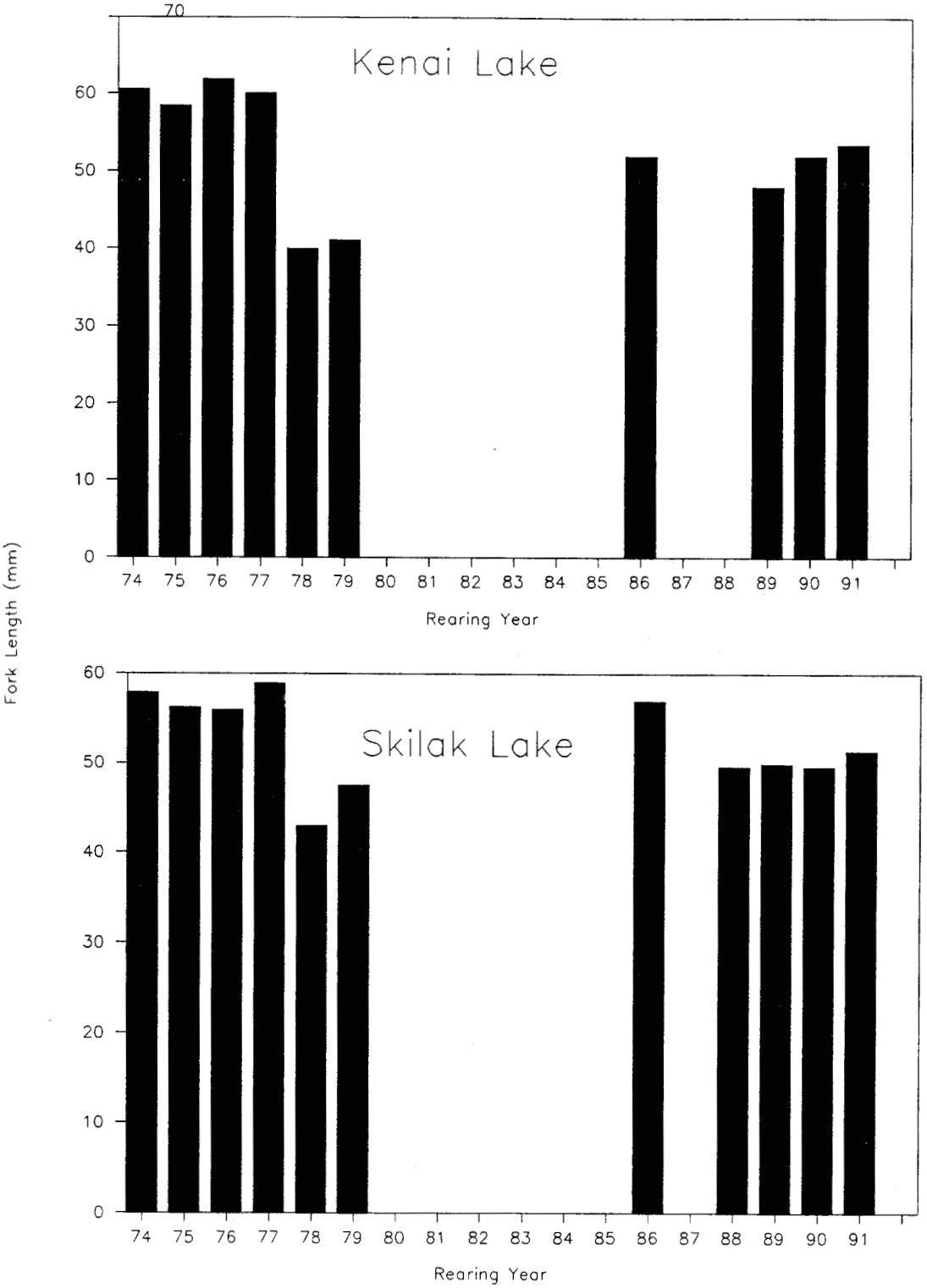

Figure 20. Length of age–0 sockeye salmon collected in Kenai (upper) and Skilak (lower) Lakes, Alaska (sample period usually September/October).

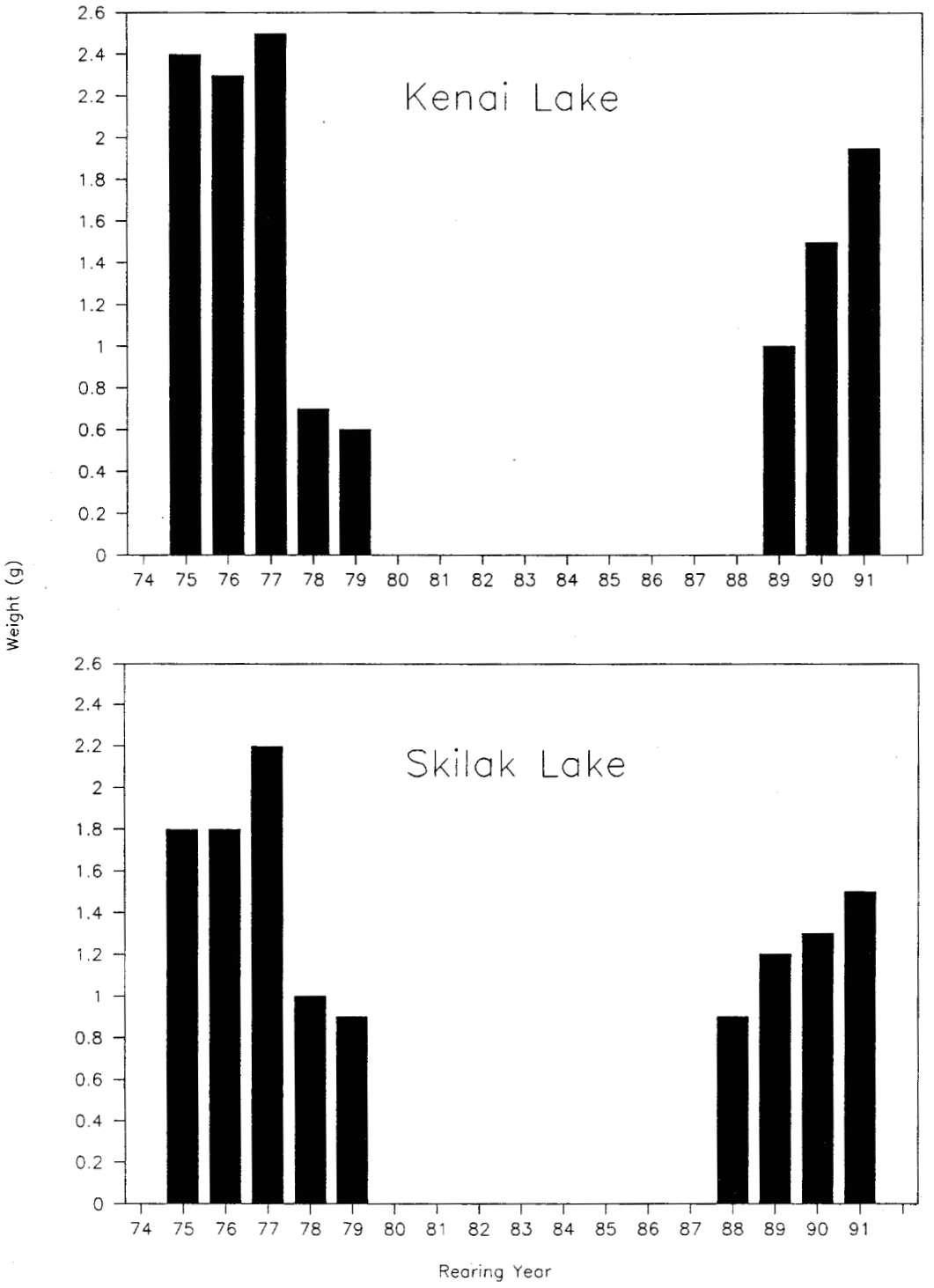

Figure 21. Weight of age–0 sockeye salmon collected in Kenai (upper) and Skilak (lower) Lakes, Alaska (sample period usually September/October).

APPENDIX

Appendix A.1. Calibration and processing parameters used in collection and analysis of Kenai and Skilak Lakes, Alaska, 1991 hydroacoustic data.

Sounder 420 kHz	Receiving sensitivity (dB/uP@1m)	Channel 1	40 log R =	-165.44 dB
			20 log R =	-144.06 dB
		Channel 2	40 log R =	-166.61 dB
			20 log R =	-144.72 dB
	Source level (dB/uP@1m)			217.67dB
	TVG Crossover			11.72 m
	Receiver gain			0 dB
Transducer	Beam width	Narrow		6 degree
		Wide		15 degree
	Wide beam dropoff	"A" coefficient		1.174 dB
		"B" coefficient		0.622 dB
	Beam pattern factor	Average squared value	Narrow	.001052
Dual-beam processor	Correction multiplier	Narrow beam		1.000
		Wide beam		1.263
	Threshold	Narrow beam		200 mV
		Wide beam		200 mV
		Bottom		9999 mV
	Maximum half angle			4^{o}
	Pulse width criteria	-18 dB	Maximum	.9478 mS
		-6 dB	Minimum	.2668 mS
		-6 dB	Maximum	.5336 mS
	Bottom window			2.0 meters
	Start depth			2.0 meters
		Depth		
Echo integrator	B constant value	2.0 - 7.0 m		6.7878
		7.0 - 12.0 m		1.5230
		12.0 - 17.0 m		0.6538
		17.0 - 22.0 m		0.3615
		22.0 - 27.0 m		0.2290
		27.0 - 32.0 m		0.1579
		32.0 - 37.0 m		0.1155
		37.0 - 42.0 m		0.0881
		42.0 - 47.0 m		0.0694
		47.0 - 52.0 m		0.0561
		52.0 - 57.0 m		0.0463
		57.0 - 62.0 m		0.0388
		62.0 - 67.0 m		0.0330
		67.0 - 72.0 m		0.0285
		72.0 - 77.0 m		0.0248
		77.0 - 82.0 m		0.0217
		82.0 - 87.0 m		0.0193
		87.0 - 92.0 m		0.0172
		92.0 - 97.0 m		0.0154

continued

Appendix A.1. (p 2 of 2)

Sounder 120 kHz	Receiving sensitivity (dB/uP@1m)	Channel 1	40 log R =	-174.94 dB
			20 log R =	-145.53 dB
		Channel 2	40 log R =	-176.96 dB
			20 log R =	-147.74 dB
	Source level (dB/uP@1m)			221.52dB
	TVG Crossover			29.56 m
	Receiver gain			0 dB
Transducer	Beam width	Narrow		10 degree
		Wide		25 degree
	Wide beam dropoff	"A" coefficient		1.234 dB
		"B" coefficient		0.787 dB
	Beam pattern factor	Average squared value	Narrow	.001725
Dual-beam processor	Correction multiplier	Narrow beam		1.000
		Wide beam		1.261
	Threshold	Narrow beam		200 mV
		Wide beam		200 mV
		Bottom		10000 mV
	Maximum half angle			4^{o}
	Pulse width criteria	-18 dB	Maximum	.96 mS
		-6 dB	Minimum	.28 mS
		-6 dB	Maximum	.52 mS
	Bottom window			2.0 meters
	Start depth			2.0 meters

Appendix A.2. Average backscattering cross section (sigma) and target strength data by depth strata for all transects combined, Kenai Lake, Alaska, 1991.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target[a] Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	90	.1563E-04	.2368E-04	-51.78	6.29
7.0 - 12.0	280	.1767E-04	.8189E-04	-52.08	5.42
12.0 - 17.0	723	.1116E-04	.3741E-04	-53.08	5.28
17.0 - 22.0	1276	.6004E-05	.6399E-05	-54.23	4.52
22.0 - 27.0	1477	.5128E-05	.6175E-05	-54.87	4.34
27.0 - 32.0	1147	.4340E-05	.3390E-05	-55.18	4.03
32.0 - 37.0	690	.4090E-05	.3356E-05	-55.45	3.99
37.0 - 42.0	235	.3574E-05	.2670E-05	-55.66	3.39
42.0 - 47.0	82	.4087E-05	.1321E-04	-56.78	3.95
47.0 -102.0	74	.3279E-04	.2360E-03	-56.32	6.09
Total	6074	.6759E-05	.3459E-04	-54.55	4.59

[a] Target strength determined from dual-beam data collected *in situ*.

Appendix A.3. Average backscattering cross section (sigma) and target strength data by depth strata for all transects combined, Skilak Lake, Alaska, 1991.

Depth Stratum (m)	Number of Targets	Sigma Mean	Sigma Standard Deviation	Target* Strength Mean (dB)	Target Strength Standard Deviation (dB)
2.0 - 7.0	499	1.740E-05	4.189E-05	-50.81	5.44
7.0 - 12.0	2130	1.343E-05	1.679E-05	-51.23	5.16
12.0 - 17.0	5234	1.062E-05	2.102E-05	-52.27	5.02
17.0 - 22.0	8296	9.118E-06	8.659E-06	-52.56	4.82
22.0 - 27.0	9450	8.324E-06	9.121E-06	-52.89	4.70
27.0 - 32.0	7785	7.486E-06	1.688E-05	-53.17	4.38
32.0 - 37.0	4280	6.258E-06	8.289E-06	-53.94	4.30
37.0 - 42.0	1552	6.809E-06	2.600E-05	-54.30	4.28
42.0 - 47.0	614	6.589E-06	9.236E-06	-54.51	4.75
47.0 -102.0	2523	8.738E-06	9.235E-06	-52.67	4.56
Total	42363	8.708E-06	1.472E-05	-52.86	4.73

* Target strength determined from dual-beam data collected *in situ*.

Appendix A.4. Estimated number of fish not available to hydroacoustic equipment because of surface orientation in Skilak and Kenai Lakes, Alaska during the fall of 1991.

Lake	Area	Transect	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
Skilak	1	1	4.3650E-03	1.2909E+08	5.6348E+05
		2	1.4170E-03	1.2909E+08	1.8292E+05
		3	1.0580E-03	1.2909E+08	1.3658E+05
		4	1.0440E-03	1.2909E+08	1.3477E+05
		5	8.3300E-04	1.2909E+08	1.0753E+05
		6	1.8120E-03	1.2909E+08	2.3391E+05
	2	1	1.5820E-03	1.0038E+08	1.5880E+05
		2	5.2170E-04	1.0038E+08	5.2368E+04
		3	7.9600E-04	1.0038E+08	7.9902E+04
	3	1	2.1480E-03	6.7500E+07	1.4499E+05
		2	4.5360E-03	6.7500E+07	3.0618E+05
		3	1.1050E-03	6.7500E+07	7.4588E+04
		4	1.4040E-03	6.7500E+07	9.4770E+04
Kenai	1	1	1.0070E-03	2.3160E+07	2.3322E+04
		2	2.6970E-03	2.3160E+07	6.2463E+04
		3	3.2750E-04	2.3160E+07	7.5849E+03
		4	1.3310E-05	2.3160E+07	3.0826E+02
		5	1.1070E-04	2.3160E+07	2.5638E+03
		6	1.7500E-05	2.3160E+07	4.0530E+02
		7	4.5200E-05	2.3160E+07	1.0468E+03
	2	1	5.2880E-04	3.5730E+07	1.8894E+04
		2	3.5160E-05	3.5730E+07	1.2563E+03
		3	0.0000E+00	3.5730E+07	0.0000E+00
		4	1.1090E-04	3.5730E+07	3.9625E+03
	3	1	1.5450E-05	3.1620E+07	4.8853E+02
		2	4.5450E-04	3.1620E+07	1.4371E+04
		3	1.9440E-05	3.1620E+07	6.1469E+02
		4	7.1470E-05	3.1620E+07	2.2599E+03
		5	1.5420E-04	3.1620E+07	4.8758E+03

- Continued -

Appendix A.4. (p. 2 of 2)

Lake	Area	Transect	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
	4	1	4.9410E-04	4.3110E+07	2.1301E+04
		2	1.1160E-03	4.3110E+07	4.8111E+04
		3	1.0520E-03	4.3110E+07	4.5352E+04
		4	3.2800E-05	4.3110E+07	1.4140E+03
		5	6.2110E-04	4.3110E+07	2.6776E+04
	5	1	2.1100E-03	3.2790E+07	6.9187E+04
		2	3.4500E-04	3.2790E+07	1.1313E+04
		3	6.2700E-04	3.2790E+07	2.0559E+04
		4	6.9120E-04	3.2790E+07	2.2664E+04
		5	6.2450E-04	3.2790E+07	2.0477E+04
		6	9.5730E-04	3.2790E+07	3.1390E+04

Appendix A.5. Estimated number of fish not available to hydroacoustic equipment because of bottom orientation in Skilak Lake, Alaska during the fall of 1991.

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	1	2-7	4.37E-03	3.7968E+07	1.6573E+05
		7-12	5.59E-03	3.2905E+07	1.8407E+05
		12-17	4.19E-03	4.5561E+07	1.9099E+05
		17-22	2.66E-03	5.0624E+06	1.3466E+04
		22-27	1.18E-03	7.5935E+06	8.9604E+03
		27-32	7.77E-04	7.5935E+06	5.8971E+03
		32-37	2.12E-04	5.0624E+06	1.0707E+03
		37-42	5.48E-05	5.0624E+06	2.7716E+02
		42-47	2.22E-05	1.2656E+07	2.8083E+02
		47-52	4.85E-05	5.0624E+06	2.4552E+02
		52-57	2.89E-06	7.5935E+06	2.1953E+01
		57-62	2.01E-05	5.0624E+06	1.0150E+02
		62-67	1.21E-05	5.0624E+06	6.1204E+01
		67-72	1.67E-07	5.0624E+06	8.4440E-01
		72-77	1.11E-06	1.0125E+07	1.1228E+01
		77-82	7.27E-06	5.0624E+06	3.6813E+01
		82-87	0.00E+00	1.0125E+07	0.0000E+00
		87-92	2.45E-06	1.0125E+07	2.4836E+01
		92-97	5.99E-06	1.5187E+07	9.1031E+01
		TOTAL			5.7134E+05
1	2	2-7	1.42E-03	1.7212E+07	2.4389E+04
		7-12	4.56E-03	2.0081E+07	9.1488E+04
		12-17	6.86E-03	2.5818E+07	1.7714E+05
		17-22	5.08E-03	2.0081E+07	1.0199E+05
		22-27	3.21E-03	5.7373E+06	1.8428E+04
		27-32	1.62E-03	5.7373E+06	9.2658E+03
		32-37	4.62E-04	5.7373E+06	2.6489E+03
		37-42	1.28E-04	5.7373E+06	7.3208E+02
		42-47	8.27E-06	1.1475E+07	9.4930E+01
		47-52	1.84E-05	5.7373E+06	1.0574E+02
		52-57	7.96E-06	8.6060E+06	6.8521E+01
		57-62	1.11E-05	5.7373E+06	6.3512E+01
		62-67	2.72E-05	5.7373E+06	1.5588E+02
		67-72	1.22E-05	1.1475E+07	1.4011E+02
		72-77	8.94E-06	1.1475E+07	1.0257E+02
		77-82	3.44E-06	1.4343E+07	4.9341E+01
		82-87	5.22E-06	1.4343E+07	7.4872E+01
		87-92	7.11E-08	2.0081E+07	1.4281E+00
		92-97	0.00E+00	0.0000E+00	0.0000E+00
		TOTAL			4.2694E+05

- Continued -

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	3	2-7	1.06E-03	2.0773E+07	2.1978E+04
		7-12	2.07E-03	2.0773E+07	4.3063E+04
		12-17	2.91E-03	1.7806E+07	5.1761E+04
		17-22	4.51E-03	8.9028E+06	4.0116E+04
		22-27	3.77E-03	5.9352E+06	2.2399E+04
		27-32	1.53E-03	5.9352E+06	9.0571E+03
		32-37	4.37E-04	5.9352E+06	2.5907E+03
		37-42	9.25E-05	5.9352E+06	5.4900E+02
		42-47	5.98E-05	1.1870E+07	7.1008E+02
		47-52	2.00E-05	8.9028E+06	1.7814E+02
		52-57	2.20E-06	8.9028E+06	1.9604E+01
		57-62	2.54E-05	5.9352E+06	1.5046E+02
		62-67	6.18E-06	8.9028E+06	5.5046E+01
		67-72	1.32E-05	8.9028E+06	1.1707E+02
		72-77	4.18E-06	1.1870E+07	4.9654E+01
		77-82	3.33E-07	2.3741E+07	7.9151E+00
		82-87	4.75E-06	1.4838E+07	7.0540E+01
		87-92	0.00E+00	0.0000E+00	0.0000E+00
		92-97	0.00E+00	0.0000E+00	0.0000E+00
		TOTAL			1.9287E+05
1	4	2-7	1.04E-03	1.9860E+07	2.0734E+04
		7-12	2.23E-03	1.6550E+07	3.6857E+04
		12-17	3.52E-03	6.6200E+06	2.3316E+04
		17-22	4.07E-03	1.3240E+07	5.3860E+04
		22-27	2.47E-03	1.3240E+07	3.2676E+04
		27-32	1.52E-03	9.9300E+06	1.5084E+04
		32-37	5.25E-04	6.6200E+06	3.4735E+03
		37-42	9.12E-05	6.6200E+06	6.0341E+02
		42-47	5.93E-05	9.9300E+06	5.8855E+02
		47-52	2.06E-05	1.3240E+07	2.7327E+02
		52-57	3.42E-06	9.9300E+06	3.3921E+01
		57-62	7.30E-06	9.9300E+06	7.2459E+01
		62-67	5.63E-06	1.3240E+07	7.4581E+01
		67-72	1.44E-05	1.9860E+07	2.8678E+02
		72-77	0.00E+00	1.6550E+07	0.0000E+00
		77-82	0.00E+00	1.9860E+07	0.0000E+00
		82-87	0.00E+00	0.0000E+00	0.0000E+00
		87-92	0.00E+00	0.0000E+00	0.0000E+00
		92-97	0.00E+00	0.0000E+00	0.0000E+00
		TOTAL			1.8793E+05

- Continued -

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	5	2-7	8.33E-04	2.1515E+07	1.7922E+04
		7-12	2.20E-03	1.7929E+07	3.9355E+04
		12-17	4.97E-03	1.4343E+07	7.1229E+04
		17-22	4.26E-03	1.0758E+07	4.5773E+04
		22-27	4.81E-03	1.0758E+07	5.1776E+04
		27-32	2.63E-03	1.0758E+07	2.8238E+04
		32-37	7.15E-04	7.1717E+06	5.1242E+03
		37-42	1.18E-04	1.0758E+07	1.2640E+03
		42-47	3.36E-05	7.1717E+06	2.4061E+02
		47-52	4.28E-06	1.4343E+07	6.1346E+01
		52-57	9.52E-06	1.0758E+07	1.0237E+02
		57-62	4.07E-06	1.0758E+07	4.3751E+01
		62-67	2.01E-05	1.4343E+07	2.8859E+02
		67-72	6.34E-07	1.4343E+07	9.0965E+00
		72-77	0.00E+00	7.1717E+06	0.0000E+00
		77-82	0.00E+00	0.0000E+00	0.0000E+00
		82-87	0.00E+00	0.0000E+00	0.0000E+00
		87-92	0.00E+00	0.0000E+00	0.0000E+00
		92-97	0.00E+00	0.0000E+00	0.0000E+00
		TOTAL			2.6143E+05
1	6	2-7	1.81E-03	1.9124E+07	3.4653E+04
		7-12	1.66E-03	1.4343E+07	2.3853E+04
		12-17	3.36E-03	2.3906E+07	8.0299E+04
		17-22	2.76E-03	1.4343E+07	3.9616E+04
		22-27	1.49E-03	1.4343E+07	2.1300E+04
		27-32	1.20E-03	1.4343E+07	1.7183E+04
		32-37	1.36E-04	1.4343E+07	1.9536E+03
		37-42	1.34E-04	1.4343E+07	1.9277E+03
		42-47	1.05E-04	2.3906E+07	2.5125E+03
		47-52	0.00E+00	0.0000E+00	0.0000E+00
		52-57	0.00E+00	0.0000E+00	0.0000E+00
		57-62	0.00E+00	0.0000E+00	0.0000E+00
		62-67	0.00E+00	0.0000E+00	0.0000E+00
		67-72	0.00E+00	0.0000E+00	0.0000E+00
		72-77	0.00E+00	0.0000E+00	0.0000E+00
		77-82	0.00E+00	0.0000E+00	0.0000E+00
		82-87	0.00E+00	0.0000E+00	0.0000E+00
		87-92	0.00E+00	0.0000E+00	0.0000E+00
		92-97	0.00E+00	0.0000E+00	0.0000E+00
		TOTAL			2.2330E+05

- Continued -

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
2	1	2-7	1.58E-03	3.5221E+06	5.5720E+03
		7-12	1.51E-03	3.5221E+06	5.3254E+03
		12-17	1.58E-03	3.5221E+06	5.5684E+03
		17-22	2.27E-03	3.5221E+06	7.9776E+03
		22-27	1.51E-03	3.5221E+06	5.3008E+03
		27-32	9.33E-04	3.5221E+06	3.2851E+03
		32-37	2.76E-04	7.0442E+06	1.9428E+03
		37-42	1.15E-04	7.0442E+06	8.0868E+02
		42-47	2.51E-05	7.0442E+06	1.7646E+02
		47-52	1.36E-05	1.0566E+07	1.4317E+02
		52-57	2.15E-06	7.0442E+06	1.5124E+01
		57-62	4.13E-06	7.0442E+06	2.9114E+01
		62-67	6.21E-06	7.0442E+06	4.3738E+01
		67-72	3.64E-06	7.0442E+06	2.5620E+01
		72-77	7.64E-06	7.0442E+06	5.3818E+01
		77-82	4.33E-06	7.0442E+06	3.0530E+01
		82-87	3.92E-06	7.0442E+06	2.7592E+01
		87-92	8.86E-07	1.0566E+07	9.3575E+00
		92-97	7.20E-08	7.0442E+06	5.0711E-01
		TOTAL			3.6336E+04
2	2	2-7	5.22E-04	2.0279E+06	1.0579E+03
		7-12	9.26E-04	4.0558E+06	3.7556E+03
		12-17	1.84E-03	4.0558E+06	7.4504E+03
		17-22	1.91E-03	4.0558E+06	7.7262E+03
		22-27	2.61E-03	8.1115E+06	2.1187E+04
		27-32	1.19E-03	8.1115E+06	9.6121E+03
		32-37	6.59E-04	1.2167E+07	8.0134E+03
		37-42	6.36E-05	1.4195E+07	9.0324E+02
		42-47	2.59E-05	1.6223E+07	4.2066E+02
		47-52	6.38E-05	1.4195E+07	9.0622E+02
		52-57	1.12E-04	1.6223E+07	1.8105E+03
		57-62	2.26E-05	1.0139E+07	2.2925E+02
		62-67	6.61E-06	1.0139E+07	6.6971E+01
		67-72	8.49E-06	1.0139E+07	8.6033E+01
		72-77	5.25E-06	8.1115E+06	4.2618E+01
		77-82	7.11E-06	6.0836E+06	4.3255E+01
		82-87	1.82E-05	6.0836E+06	1.1066E+02
		87-92	1.28E-05	2.0279E+06	2.6018E+01
		92-97	2.32E-05	2.0279E+06	4.7128E+01
		TOTAL			6.3496E+04

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Appendix A.5. (p. 5 of 7)

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
2	3	2-7	7.96E-04	2.3076E+06	1.8368E+03
		7-12	1.73E-03	9.2303E+06	1.5932E+04
		12-17	3.83E-03	9.2303E+06	3.5343E+04
		17-22	3.82E-03	1.1538E+07	4.4121E+04
		22-27	3.09E-03	1.3846E+07	4.2713E+04
		27-32	2.73E-03	1.1538E+07	3.1522E+04
		32-37	1.12E-03	6.9228E+06	7.7743E+03
		37-42	4.65E-04	6.9228E+06	3.2198E+03
		42-47	1.07E-04	6.9228E+06	7.3866E+02
		47-52	2.74E-05	9.2303E+06	2.5291E+02
		52-57	1.94E-05	9.2303E+06	1.7898E+02
		57-62	1.69E-05	6.9228E+06	1.1699E+02
		62-67	1.71E-05	6.9228E+06	1.1866E+02
		67-72	2.87E-05	6.9228E+06	1.9889E+02
		72-77	9.95E-06	6.9228E+06	6.8868E+01
		77-82	5.69E-06	6.9228E+06	3.9356E+01
		82-87	5.30E-06	6.9228E+06	3.6704E+01
		87-92	4.93E-06	9.2303E+06	4.5487E+01
		92-97	7.10E-06	6.9228E+06	4.9145E+01
		TOTAL			1.8431E+05
3	1	2-7	2.15E-03	3.6000E+06	7.7328E+03
		7-12	2.30E-03	3.6000E+06	8.2728E+03
		12-17	1.21E-03	3.6000E+06	4.3596E+03
		17-22	1.56E-03	3.6000E+06	5.6052E+03
		22-27	4.72E-04	3.6000E+06	1.6985E+03
		27-32	3.05E-04	3.6000E+06	1.0969E+03
		32-37	2.22E-04	5.4000E+06	1.2010E+03
		37-42	1.58E-04	7.2000E+06	1.1354E+03
		42-47	7.07E-05	9.0000E+06	6.3630E+02
		47-52	6.05E-05	9.0000E+06	5.4405E+02
		52-57	3.01E-05	1.2600E+07	3.7888E+02
		57-62	3.52E-05	1.2600E+07	4.4327E+02
		62-67	1.47E-05	1.0800E+07	1.5876E+02
		67-72	8.92E-05	9.0000E+06	8.0235E+02
		72-77	1.29E-04	9.0000E+06	1.1610E+03
		77-82	1.54E-04	7.2000E+06	1.1095E+03
		82-87	1.44E-04	7.2000E+06	1.0332E+03
		87-92	3.33E-05	5.4000E+06	1.8004E+02
		92-97	5.58E-04	2.8800E+07	1.6079E+04
		TOTAL			5.3629E+04

- Continued -

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
3	2	2-7	4.54E-03	1.5517E+06	7.0386E+03
		7-12	1.19E-03	1.5517E+06	1.8466E+03
		12-17	9.29E-04	4.6552E+06	4.3233E+03
		17-22	9.89E-04	7.7586E+06	7.6733E+03
		22-27	3.17E-04	7.7586E+06	2.4579E+03
		27-32	7.67E-05	6.2069E+06	4.7582E+02
		32-37	9.56E-05	3.1034E+06	2.9681E+02
		37-42	9.87E-06	3.1034E+06	3.0622E+01
		42-47	3.00E-05	4.6552E+06	1.3979E+02
		47-52	3.48E-05	6.2069E+06	2.1594E+02
		52-57	1.20E-05	6.2069E+06	7.4421E+01
		57-62	2.79E-05	4.6552E+06	1.2993E+02
		62-67	4.44E-05	6.2069E+06	2.7559E+02
		67-72	3.41E-05	7.7586E+06	2.6472E+02
		72-77	3.26E-05	9.3103E+06	3.0380E+02
		77-82	9.95E-06	1.0862E+07	1.0812E+02
		82-87	5.48E-06	7.7586E+06	4.2509E+01
		87-92	5.60E-06	6.2069E+06	3.4728E+01
		92-97	4.14E-05	2.4828E+07	1.0271E+03
		TOTAL			2.6760E+04
3	3	2-7	1.11E-03	0.0000E+00	0.0000E+00
		7-12	1.42E-03	0.0000E+00	0.0000E+00
		12-17	1.73E-03	5.6250E+06	9.7144E+03
		17-22	2.00E-03	8.4375E+06	1.6850E+04
		22-27	1.68E-03	5.6250E+06	9.4500E+03
		27-32	5.59E-04	5.6250E+06	3.1461E+03
		32-37	5.46E-04	5.6250E+06	3.0707E+03
		37-42	5.57E-05	5.6250E+06	3.1309E+02
		42-47	5.64E-05	5.6250E+06	3.1719E+02
		47-52	6.56E-05	5.6250E+06	3.6883E+02
		52-57	8.25E-05	5.6250E+06	4.6389E+02
		57-62	6.63E-05	5.6250E+06	3.7316E+02
		62-67	2.79E-05	5.6250E+06	1.5705E+02
		67-72	2.32E-06	8.4375E+06	1.9550E+01
		72-77	1.15E-05	8.4375E+06	9.6863E+01
		77-82	1.94E-05	5.6250E+06	1.0884E+02
		82-87	2.77E-05	5.6250E+06	1.5587E+02
		87-92	7.69E-05	5.6250E+06	4.3228E+02
		92-97	1.37E-04	3.6563E+07	5.0018E+03
		TOTAL			5.0039E+04

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Appendix A.5. (p. 7 of 7)

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
3	4	2-7	1.40E-03	0.0000E+00	0.0000E+00
		7-12	1.40E-03	0.0000E+00	0.0000E+00
		12-17	2.37E-03	2.8125E+06	6.6713E+03
		17-22	2.44E-03	5.6250E+06	1.3697E+04
		22-27	1.63E-03	8.4375E+06	1.3745E+04
		27-32	1.23E-03	5.6250E+06	6.9244E+03
		32-37	3.76E-04	5.6250E+06	2.1167E+03
		37-42	1.66E-04	5.6250E+06	9.3431E+02
		42-47	1.28E-04	5.6250E+06	7.2169E+02
		47-52	1.54E-04	8.4375E+06	1.3019E+03
		52-57	4.96E-04	8.4375E+06	4.1842E+03
		57-62	3.38E-04	8.4375E+06	2.8544E+03
		62-67	5.60E-05	8.4375E+06	4.7258E+02
		67-72	7.93E-05	1.1250E+07	8.9258E+02
		72-77	5.41E-05	1.1250E+07	6.0908E+02
		77-82	4.85E-05	5.6250E+06	2.7281E+02
		82-87	7.26E-05	8.4375E+06	6.1256E+02
		87-92	1.27E-04	1.6875E+07	2.1381E+03
		92-97	1.69E-03	3.3750E+07	5.6936E+04
		TOTAL			1.1508E+05

Appendix A.6. Estimated number of fish not available to hydroacoustic equipment because of bottom orientation in Kenai Lake, Alaska during the fall of 1990.

Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	1	2-7	1.0070E-03	5.1467E+06	5.1827E+03
		7-12	4.2900E-04	5.1467E+06	2.2079E+03
		12-17	6.0560E-04	1.0293E+07	6.2336E+03
		17-22	6.7510E-03	7.7200E+06	5.2118E+04
		22-27	1.1920E-03	1.0293E+07	1.2270E+04
		27-32	4.6940E-04	7.7200E+06	3.6238E+03
		32-37	8.6310E-05	1.0293E+07	8.8842E+02
		37-42	5.9400E-03	5.1467E+06	3.0571E+04
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			1.1310E+05
1	2	2-7	2.6970E-03	6.1760E+06	1.6657E+04
		7-12	2.0900E-03	9.2640E+06	1.9362E+04
		12-17	1.8130E-03	1.2352E+07	2.2394E+04
		17-22	3.7370E-03	9.2640E+06	3.4620E+04
		22-27	3.0240E-03	6.1760E+06	1.8676E+04
		27-32	0.0000E+00	0.0000E+00	0.0000E+00
		32-37	0.0000E+00	0.0000E+00	0.0000E+00
		37-42	0.0000E+00	0.0000E+00	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			1.1171E+05

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Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	3	2-7	3.2750E-04	7.7200E+06	2.5283E+03
		7-12	1.0530E-03	5.1467E+06	5.4194E+03
		12-17	7.5370E-04	7.7200E+06	5.8186E+03
		17-22	4.4440E-04	5.1467E+06	2.2872E+03
		22-27	1.4970E-04	7.7200E+06	1.1557E+03
		27-32	1.2390E-05	7.7200E+06	9.5651E+01
		32-37	0.0000E+00	0.0000E+00	0.0000E+00
		37-42	0.0000E+00	0.0000E+00	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			1.7305E+04
1	4	2-7	1.3310E-05	2.2057E+06	2.9358E+01
		7-12	3.1490E-04	2.2057E+06	6.9458E+02
		12-17	2.1260E-03	4.4114E+06	9.3787E+03
		17-22	8.7060E-04	4.4114E+06	3.8406E+03
		22-27	2.9280E-04	6.6171E+06	1.9375E+03
		27-32	5.3640E-04	8.8229E+06	4.7326E+03
		32-37	6.5220E-04	6.6171E+06	4.3157E+03
		37-42	0.0000E+00	0.0000E+00	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			2.4929E+04

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Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	5	2-7	1.1070E-04	1.9300E+06	2.1365E+02
		7-12	1.0670E-05	1.9300E+06	2.0593E+01
		12-17	9.9250E-04	3.8600E+06	3.8311E+03
		17-22	4.0920E-04	5.7900E+06	2.3693E+03
		22-27	7.9700E-04	3.8600E+06	3.0764E+03
		27-32	7.3370E-05	5.7900E+06	4.2481E+02
		32-37	2.4070E-04	1.1580E+07	2.7873E+03
		37-42	0.0000E+00	3.8600E+06	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			1.2723E+04
1	6	2-7	1.7500E-05	0.0000E+00	0.0000E+00
		7-12	1.7990E-04	0.0000E+00	0.0000E+00
		12-17	3.9600E-04	2.2057E+06	8.7346E+02
		17-22	8.4670E-04	2.2057E+06	1.8676E+03
		22-27	3.9810E-04	4.4114E+06	1.7562E+03
		27-32	3.2120E-04	6.6171E+06	2.1254E+03
		32-37	1.6170E-05	6.6171E+06	1.0700E+02
		37-42	0.0000E+00	1.1029E+07	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			6.7297E+03

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Area	Transect	Bottom Depth(m)	Estimated Fish Density (number/m^3)	Estimated Volume (m^3)	Estimated Number of Fish
1	7	2-7	4.5200E-05	0.0000E+00	0.0000E+00
		7-12	6.3910E-05	1.9300E+06	1.2335E+02
		12-17	2.6210E-04	3.8600E+06	1.0117E+03
		17-22	1.0890E-03	3.8600E+06	4.2035E+03
		22-27	1.0710E-03	3.8600E+06	4.1341E+03
		27-32	1.7310E-04	5.7900E+06	1.0022E+03
		32-37	1.8230E-04	7.7200E+06	1.4074E+03
		37-42	0.0000E+00	9.6500E+06	0.0000E+00
		42-47	0.0000E+00	0.0000E+00	0.0000E+00
		47-52	0.0000E+00	0.0000E+00	0.0000E+00
		52-57	0.0000E+00	0.0000E+00	0.0000E+00
		57-62	0.0000E+00	0.0000E+00	0.0000E+00
		62-67	0.0000E+00	0.0000E+00	0.0000E+00
		67-72	0.0000E+00	0.0000E+00	0.0000E+00
		72-77	0.0000E+00	0.0000E+00	0.0000E+00
		77-82	0.0000E+00	0.0000E+00	0.0000E+00
		82-87	0.0000E+00	0.0000E+00	0.0000E+00
		87-92	0.0000E+00	0.0000E+00	0.0000E+00
		92-97	0.0000E+00	0.0000E+00	0.0000E+00
		TOTAL			1.1882E+04