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HYDROACOUSTIC SURVEY OF FISH IN LAKES  
KOOTENAY, OKANAGAN AND SKAHA

by

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Final Report

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# HYDROACOUSTIC SURVEY OF FISH IN LAKES KOOTENAY, OKANAGAN AND SKAHA

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## INTRODUCTION

Sound has an exceptional capability to penetrate water and to detect the presence of fish. Consequently, hydroacoustic techniques are being increasingly used for study of fish distribution, abundance and behavior in lakes (Thorne and Thomas 1984; Thorne 1984). We used these techniques for assessment of kokanee populations in Lakes Kootenay, Okanagan and Skaha, British Columbia, during September 1985. This report describes the result of the survey.

## MATERIALS AND METHODS

### Data Acquisition Equipment

The principles underlying hydroacoustic techniques for fish detection and enumeration are detailed in several papers and books including Thorne (1984), Johannesson and Mitson (1983), and Clay and Medwin (1977). Basically, a pulse of sound is transmitted into the water and echoes from fish are received and analyzed. Although the principles are similar to those underlying depth sounders and commercial fish finders, the equipment and techniques applied for scientific purposes are more specialized and quantitative. The equipment used for the Kootenay lakes was a calibrated dual-beam echo sounding system, consisting of a BioSonics model 101 dual channel 420 kHz transceiver, 6 and 15° dual-beam transducer, Ross 250C chart recorder, BioSonics 171 recording interface, digital signal processor (Sony PCM), and Beta-format video

cassette recorder. A portable dual trace oscilloscope was used to monitor system performance. All components except for the chart recorder operate from 110 volt AC current and were powered using a 500 volt-amp static inverter which was driven from two 12-volt batteries wired in parallel. The chart recorder was connected directly to a 12-volt battery. The transducer was mounted in a V-fin towing vehicle and, using a davit, suspended alongside the boat at a depth of 0.5-1 m.

The selection of system settings was based on the smallest expected fish size, i.e., an age 0 sockeye salmon, for which this system have been extensively used (Thorne and Thomas 1984). The transmit level was -6 decibels (dB) and the receiver gains were +12 dB for both narrow and wide beam channels. A time-varied-gain (TVG) of 40 log range was used to obtain similar echo levels from individual fish independent of depth. Other parameters included pulse width of 0.5 msec, pulse rate of four transmissions per second, and a bandwidth of 5 kHz. Record levels for both narrow and wide channels on the digital signal processor were set so that a 5 volt-peak signal just reached the recording saturation level. Calibration tones were recorded at the beginning and end of each tape so that playback gains could be adjusted to proper levels for post survey processing.

#### Survey Design

The lakes were surveyed during 5 consecutive nights in September. Lake Kootenay was surveyed during the nights of September 9 and 10. Nine orthogonal transects were run over the lake, each replicated once. Lake Skaha was surveyed the night of September 11 by four replicated

transects and Lake Okanagan was surveyed the nights of September 12 and 13 by ten replicated transects. In all cases, replicates were run immediately and in the opposite direction of the first. Boat speed was about 3 m/sec and was maintained by running the boat motor at a constant rpm. Transects were located and course maintained by the ship's compass and radar in conjunction with maps and prominent landmarks onshore.

#### Data Processing

Target densities in all lakes were sufficiently low for employment of echo counting techniques (Thorne 1984). The hydroacoustic data were played back by the same recording instruments described above and were analyzed with a dual-channel storage oscilloscope. The water column was divided into four contiguous depth intervals based on the depth intervals used by British Columbia Fish and Wildlife to capture fish. For Lake Kootenay, the depth intervals were: 10-20, 20-30, 30-40, and 40-60 m. Each transect replicate was further divided into three equal time portions to investigate horizontal distribution. For Okanagan Lake, the depth intervals were: 5-16, 16-25, 25-35, and 35-55 m. These transect replicates were also divided into three sections. For Skaha Lake the four depth intervals were: 5-15, 15-25, 25-35, and 35-54 m. All targets which exceeded the minimum threshold were counted for each transect, replicate, section and depth interval. The counting threshold was set at  $0.24v$ , a level about 30 dB below peak echo voltage observed on the narrow beam channel, and slightly below the highest voltages observed from mysid scattering layers. For all three lakes, the effective sampling characteristics of the transducer beam were measured

by the duration-in-beam technique (Thorne 1984). Total lake estimates were determined by extrapolating the measured fish densities over the appropriate area represented by each transect. Total estimates were allocated to species/cohort groups from independent trawl catch data provided by British Columbia Fish and Wildlife.

#### Target Strength Analysis

In addition to the echo counting, target strength analysis was performed on the data with a BioSonics dual-beam target strength processing system (Ehrenberg 1974). Data from all transects on Kootenay Lake, Okanagan Lake, and from transect one of Skaha Lake were processed on the dual beam system. The dual-beam data were written to an MS-DOS diskette. The same target threshold of .24 volts-peak was used. The minimum pulse length for single target criteria was .350 msec at -6 dB and the maximum was .700 msec. Post processing of the target strength data included two types. The normal TS measurement program calculates the TS frequency and mean values on a per-echo basis. A second program, called TRACK (McClain 1985) tracks individual fish as they pass through the transducer beam and calculates values on a per-fish basis. This program was applied to the data with several different beam angle thresholds and minimum track numbers.

### RESULTS

#### Kootenay Lake Population Estimates

Significant differences were observed in the effective sampling beam of the transducer between transects 1-4 and the remainder of the lake, probably as a result of backscattering by mysid concentrations.

The duration in beam measurement of the effective sampling cone was  $7.8^\circ$  for transects 1-4 and  $9.1^\circ$  for transects 5-9 (720 echo duration measurements). The results of echo counts and density calculations by depth and transect, as well as variance calculations and echo duration measurements, are given in Appendix 1. The data are summarized by transect section in Table 1. The total estimated fish population in the lake was  $9,323,900 \pm 913,300$  fish. The breakdown by cohort according to the trawl data was: age 0 =  $5,455,400 \pm 534,400$ ; age 1 =  $1,421,900 \pm 139,300$ ; age 2 =  $2,149,200 \pm 210,500$  and age 3 =  $297,400 \pm 29,100$ . The confidence intervals for the various cohorts only incorporates variability from the acoustic data. The trawl cohort proportions were assumed constant and without error because the trawl data base was insufficient for a more rigorous treatment. Furthermore, some of the nearshore near-bottom fish targets in Kootenay and Okanagan lakes were suspected to be non-kokanee species. Therefore, the total population estimate likely over estimated the kokanee population.

#### Lake Okanagan Population Estimates

Six-hundred sixty-four echo duration measurements were made along transects in Lake Okanagan. The mean estimated sampling beam was  $9.2^\circ$  with no significant difference among transects. The resulting echo count and density measurements by depth and transect, as well as variance calculations and echo duration measurements are given in Appendix 2. Estimates by transect section are summarized in Table 2. The total lake estimate was  $9,630,900 \pm 366,700$  fish. Population breakdown by cohort from trawl data was: age 0 =  $4,373,700 \pm 166,500$ ; age 1 =  $1,502,400 \pm 57,200$ ; age 2 =  $1,236,600 \pm 47,000$ ; age 3 =  $2,385,600 \pm$

Table 1. Density and population estimates from Kootenay Lake.

Transect	Section	Mean density (#/1000 sq. m)	Population
1	West	20.42	1,241,600
	Middle	10.52	
	East	18.09	
2	West	9.34	928,800
	Middle	22.91	
	East	13.50	
3	West	11.41	1,000,600
	Middle	21.41	
	East	24.05	
4	West	13.04	953,300
	Middle	18.31	
	East	33.85	
5	West	23.11	1,035,300
	Middle	40.58	
	East	34.64	
6	West	37.85	661,400
	Middle	15.68	
	East	59.50	
7	West	24.87	861,800
	Middle	11.47	
	East	32.81	
8	West	38.51	1,595,700
	Middle	44.39	
	East	35.65	
9	West	24.11	1,045,400
	Middle	26.66	
	East	32.72	
TOTAL			9,323,900

Table 2. Density and population estimates from Okanagan Lake.

Transect	Section	Mean density (#/1000 sq. m)	Population
1	West	24.40	1,419,800
	Middle	37.95	
	East	27.31	
2	West	33.41	1,130,600
	Middle	45.72	
	East	21.50	
3	West	20.94	674,400
	Middle	31.62	
	East	16.56	
4	West	32.05	1,726,800
	Middle	58.26	
	East	34.66	
5	West	11.59	780,300
	Middle	36.98	
	East	27.72	
6	West	9.72	360,600
	Middle	19.71	
	East	12.47	
7	West	31.40	1,259,400
	Middle	40.06	
	East	30.60	
8	West	22.42	949,000
	Middle	29.39	
	East	27.87	
9	West	8.63	818,100
	Middle	27.49	
	East	15.29	
10	West	31.41	511,900
	Middle	35.37	
	East	23.56	
TOTAL			9,630,900

90,800, and age 4 =  $132,900 \pm 5,100$ . Again, the trawl cohort portions were treated as constants in the variance calculation.

#### Skaha Lake Population Estimates

The duration in beam measurement of the transducer sampling angle along transect 1 of Skaha Lake was  $8.06^\circ$ . Echo counts and corresponding densities are given in Table 3. As a result of a failure in the recording system, data from transects 2-4 were not recorded on tape, but were printed on the echogram. Consequently, estimates for these transects were obtained from analysis of the chart records. First, comparisons were made between oscilloscope counts and echogram counts for ten transect replicates on Lake Okanagan. The resulting linear regression had an  $r$  value of 0.974 (Appendix 3). This regression was then applied to the echograms from Skaha Lake to obtain fish density estimates. The resulting corrected echo counts and corresponding densities are given in Table 4. The total lake estimate was 489,600 fish. The estimate is partitioned by cohort and source (wild or hatchery) in Table 5. Confidence intervals were not calculated for Skaha because we lost the direct acoustic data.

#### Target Strength Measurements

The results of standard, dual-beam, single echo target strength measurements by depth are given in Appendix 4 and Figures 1A, B, C, D and 2A, B, C, D for Kootenay and Okanagan, respectively. Mean target strengths by depth are listed in Table 6. No partition by cohort is apparent in the data. Further analysis was conducted with the TRACK program and several different beam angle and track number combinations

Table 3. Population estimate and fish densities in various depth and sections of transect 1, Skaha Lake.

Transect	Depth (m)	Targets	Fish (#/1000 cu. m)	Density (#/1000 sq. m)
1-1	5-15	3	0.91	9.12
	15-25	7	1.16	11.56
	25-35	0	0.00	0.00
1-2	5-15	6	1.83	18.25
	15-25	7	1.16	11.56
	25-35	7	0.71	7.10
1-3	5-15	1	0.30	3.04
	15-25	3	0.50	4.96
	25-35	0	0.00	0.00
1R-3	5-15	1	0.27	2.73
	15-25	5	0.74	7.43
	25-35	5	0.46	4.56
1R-2	5-15	9	2.46	24.60
	15-25	6	0.89	8.91
	25-35	2	0.18	1.82
1R-1	5-15	4	1.09	10.93
	15-25	2	0.30	2.97
	25-35	2	0.18	1.82
Total Population, Transect 1 = 67,100				

Table 4. Densities and population estimates in various depths, transect areas 2-4, Skaha Lake.

Transect	Depth (m)	Targets		Density (#/1000 cu. m)	Population
		Chart	Corrected		
2	5-15	9	14.7	0.55	151,000
	15-25	43	61.7	1.25	
	25-35	46	65.8	0.82	
	35-54	7	11.9	0.05	
2R	5-15	16	24.3	0.88	
	15-25	66	93.4	1.84	
	25-35	42	60.3	0.73	
	35-54	4	7.8	0.03	
3	5-15	3	6.4	0.21	144,900
	15-25	39	56.1	1.02	
	25-35	71	100.4	1.11	
	35-54	23	34.0	0.13	
3R	5-15	9	14.7	0.45	
	15-25	52	74.1	1.24	
	25-35	64	90.7	0.93	
	35-54	22	32.6	0.12	
4	5-15	3	6.4	0.18	126,600
	15-25	35	50.6	0.80	
	25-35	71	100.4	0.97	
	35-54	6	10.5	0.04	
4R	5-15	3	6.4	0.18	
	15-25	49	70.0	1.10	
	25-35	56	100.6	0.77	
	35-54	5	9.1	0.03	

Total population, transects 2-4 = 422,500

Total lake population = 489,600

Table 5. Partition of Skaha Lake estimates into various components.

Age	Cohort wild	Proportion hatchery	Cohort wild	Population hatchery
0	0.189	0.493	92,530	241,370
1	0.026	0.073	12,730	35,740
2	0.060	0.099	29,380	48,470
3	0.040	0.013	19,580	6,360
4	0.007	0.00	3,430	0

Kootenay Lake 1985

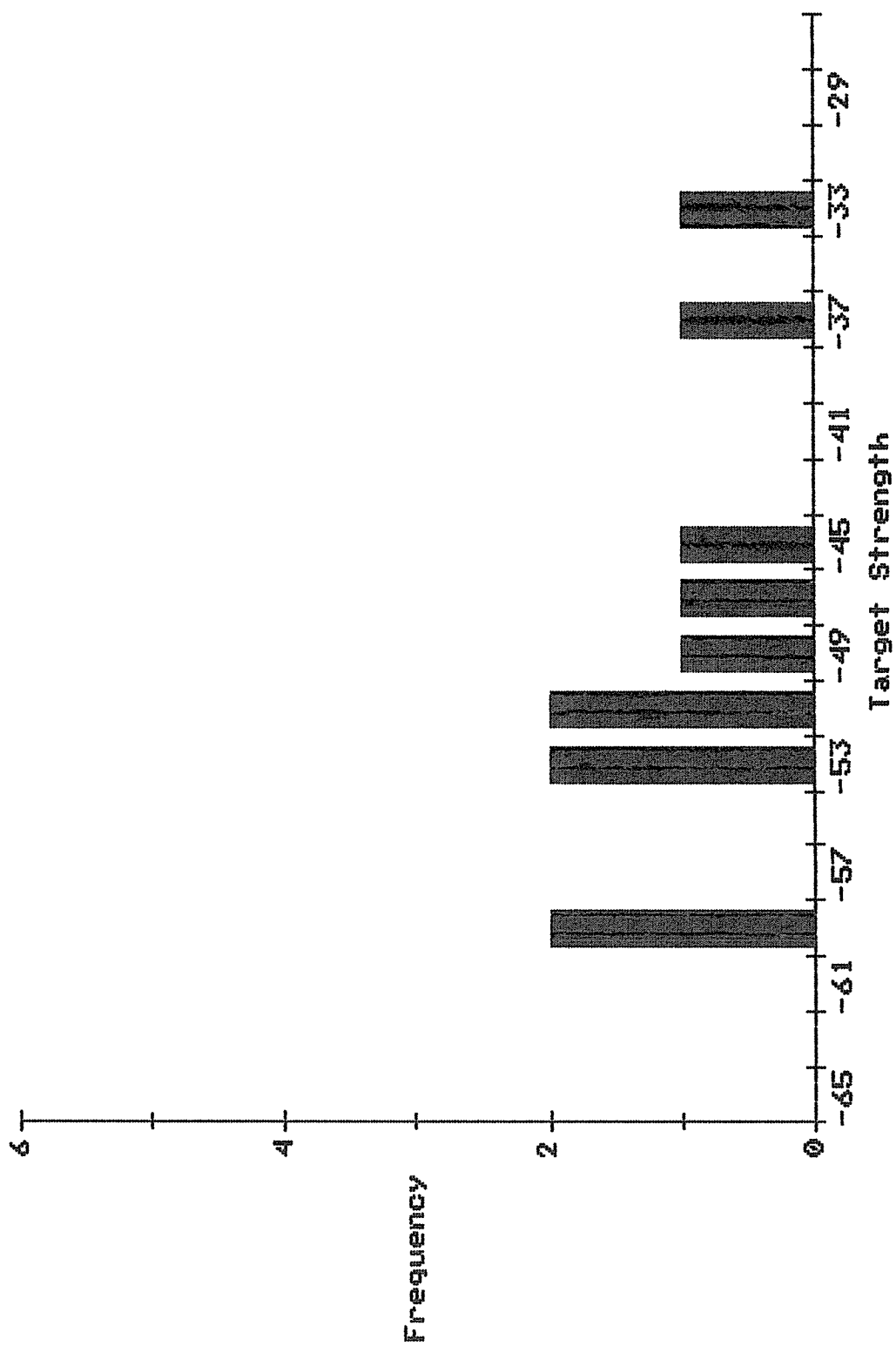


Figure 1A: Kootenay lake target strength histogram for depth interval 10-20 meters.

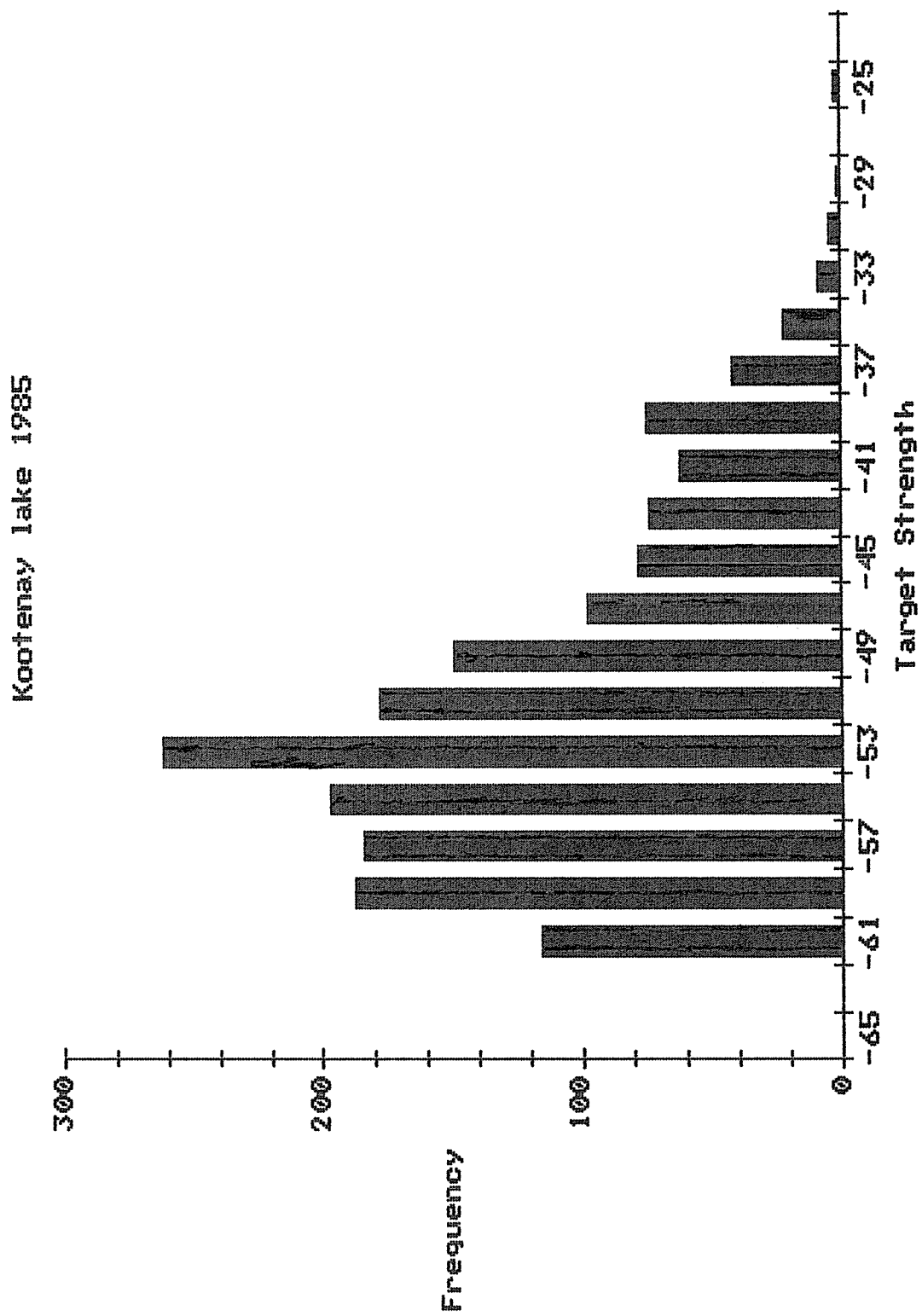


Figure 1B: Kootenay lake target strength histogram for depth interval 20-30 meters.

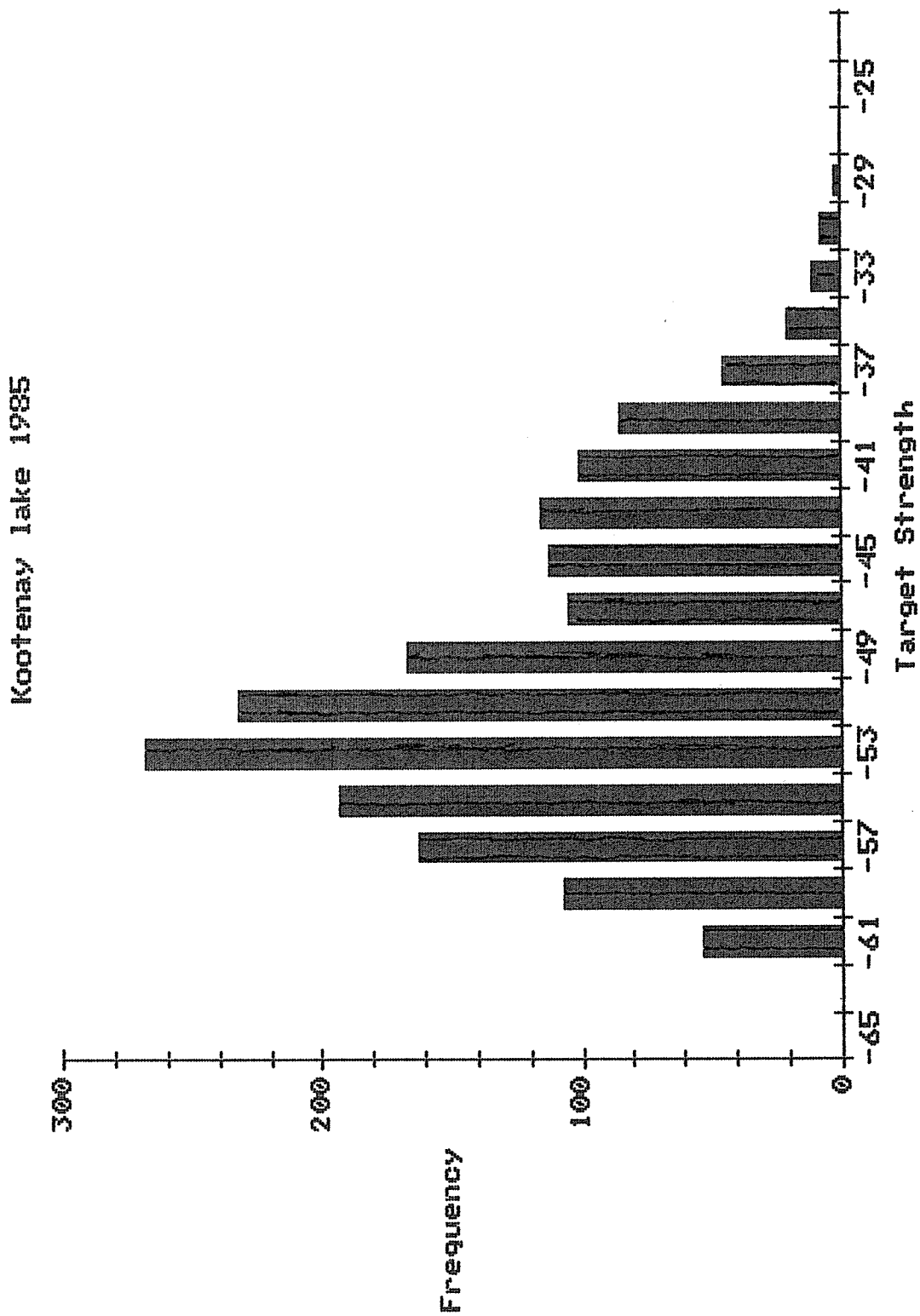


Figure 1C: Kootenay lake target strength histogram for depth interval 30-40 meters.

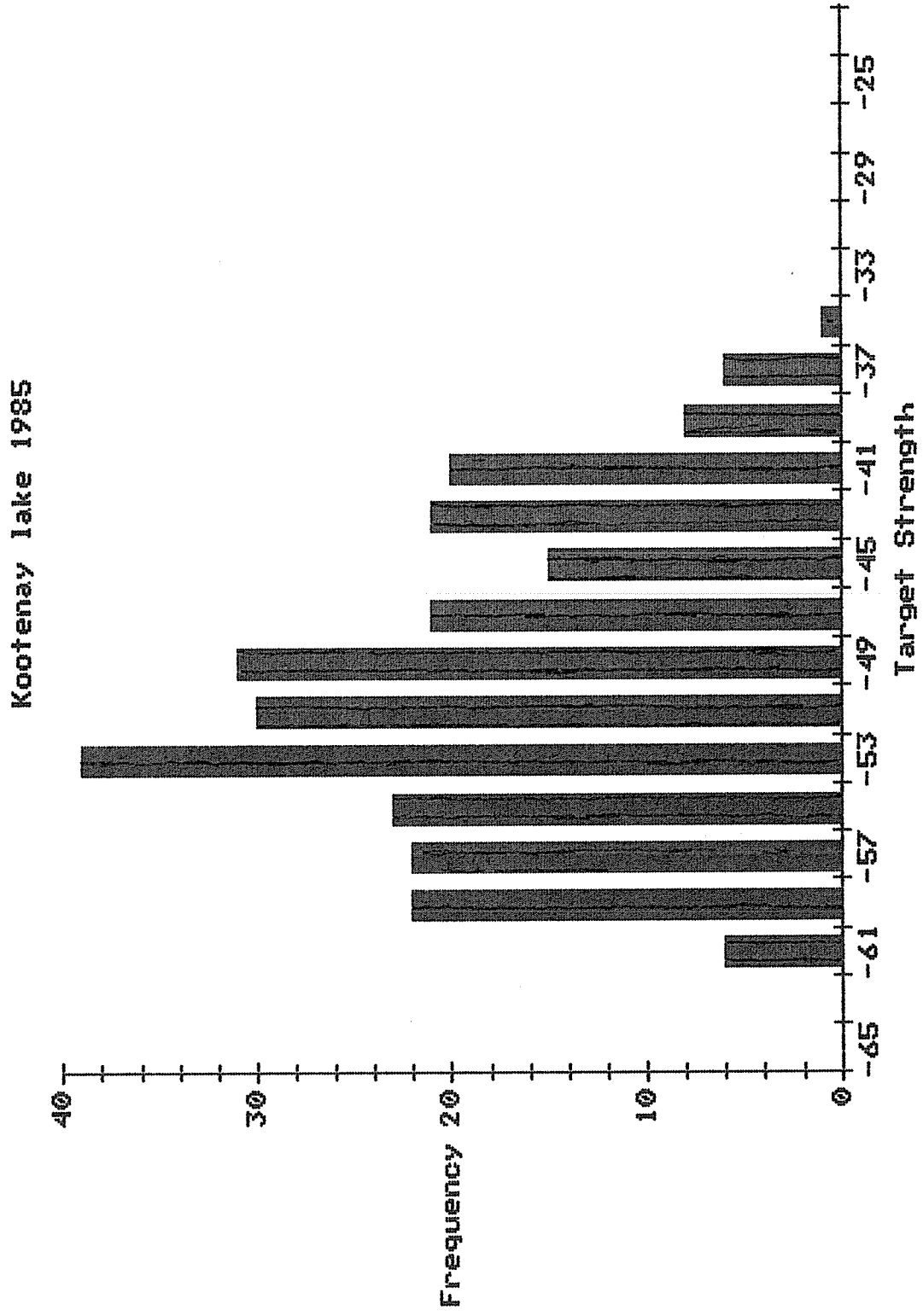


Figure 1D: Kootenay lake target strength histogram for depth interval 40-60 meters.

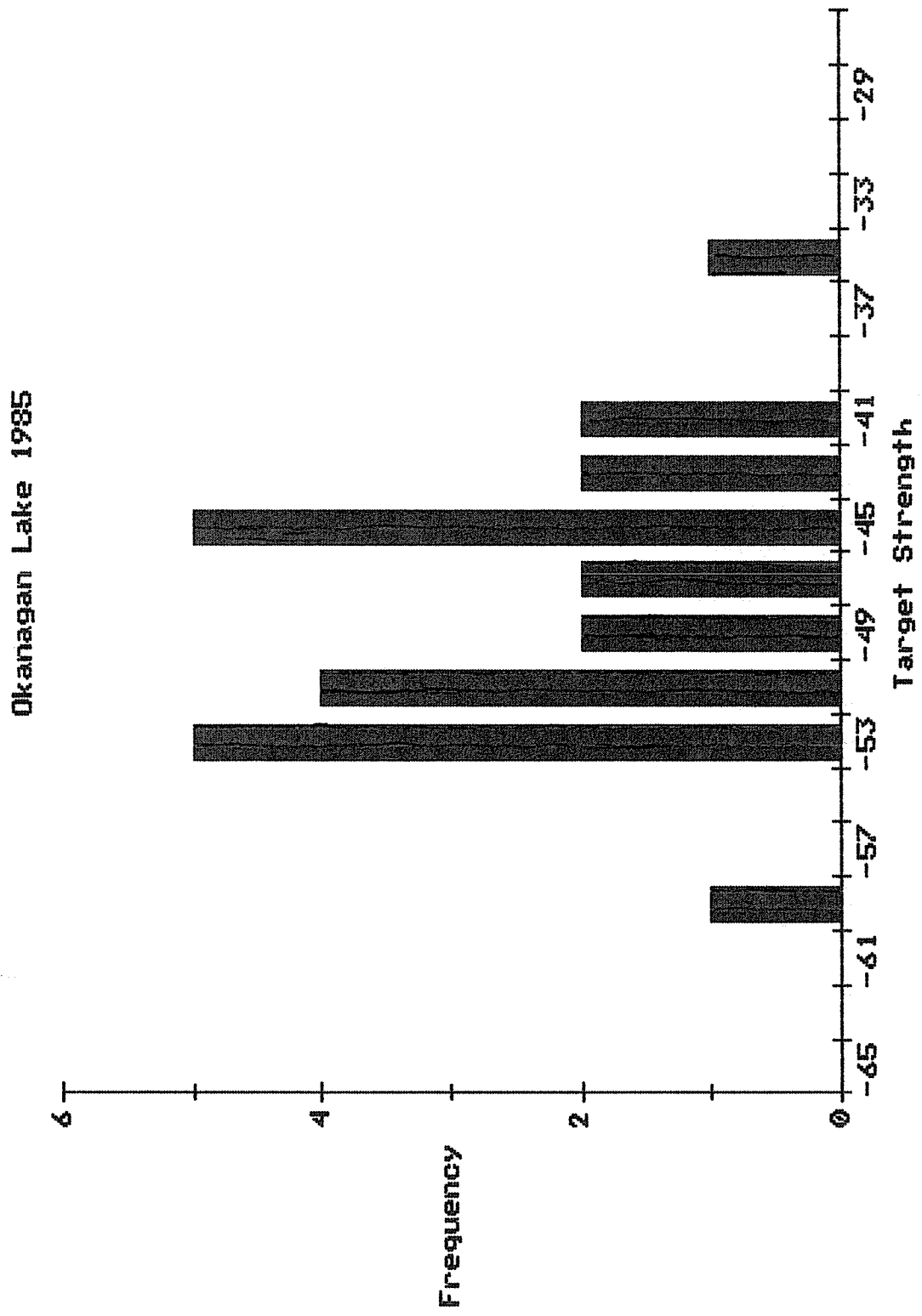


Figure 2A: Okanagan lake target strength histogram for depth interval 5-16 meters.

Okanagan Lake 1985

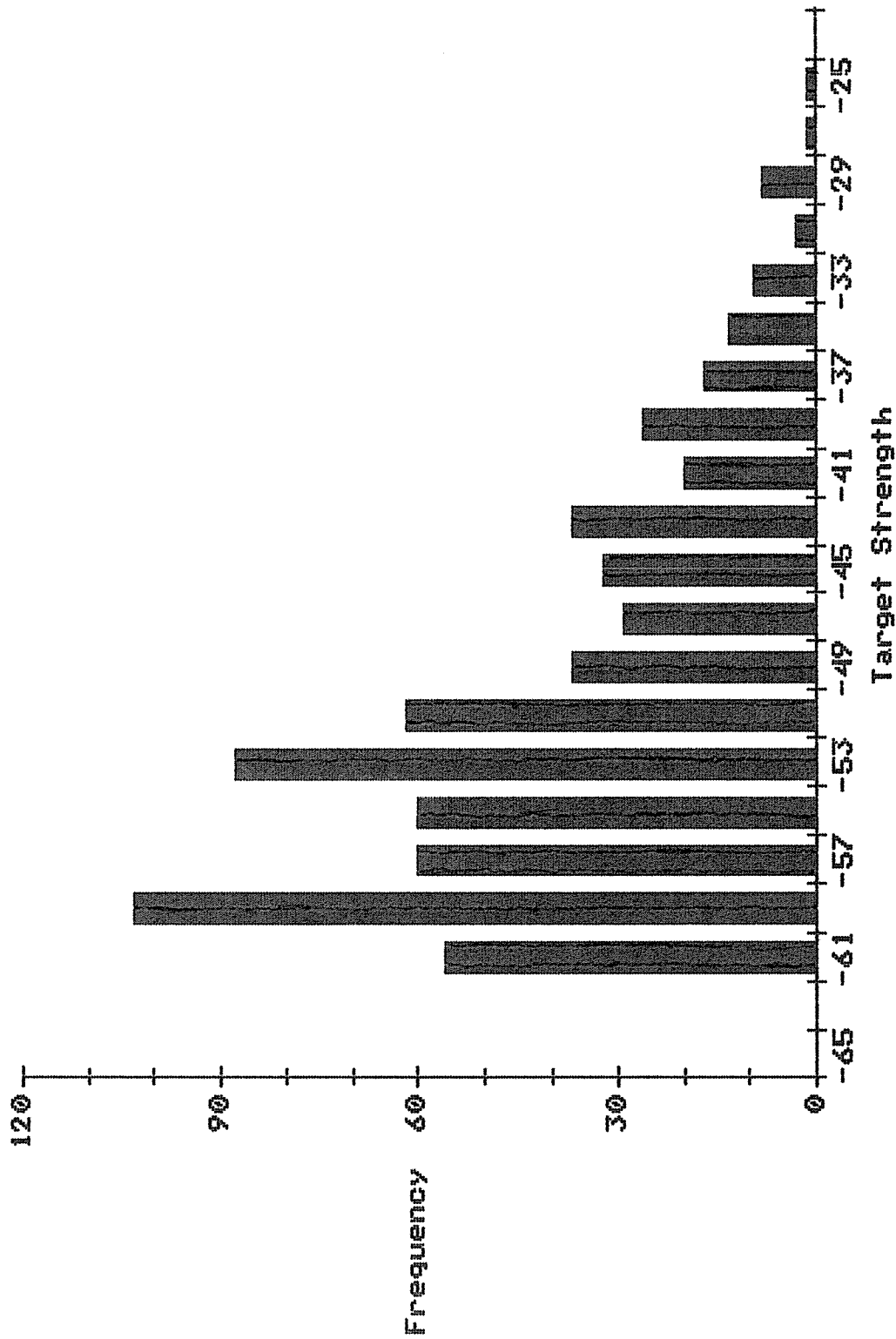


Figure 2B: Okanagan lake target strength histogram for depth interval 16-25 meters.

Okanagan Lake 1985

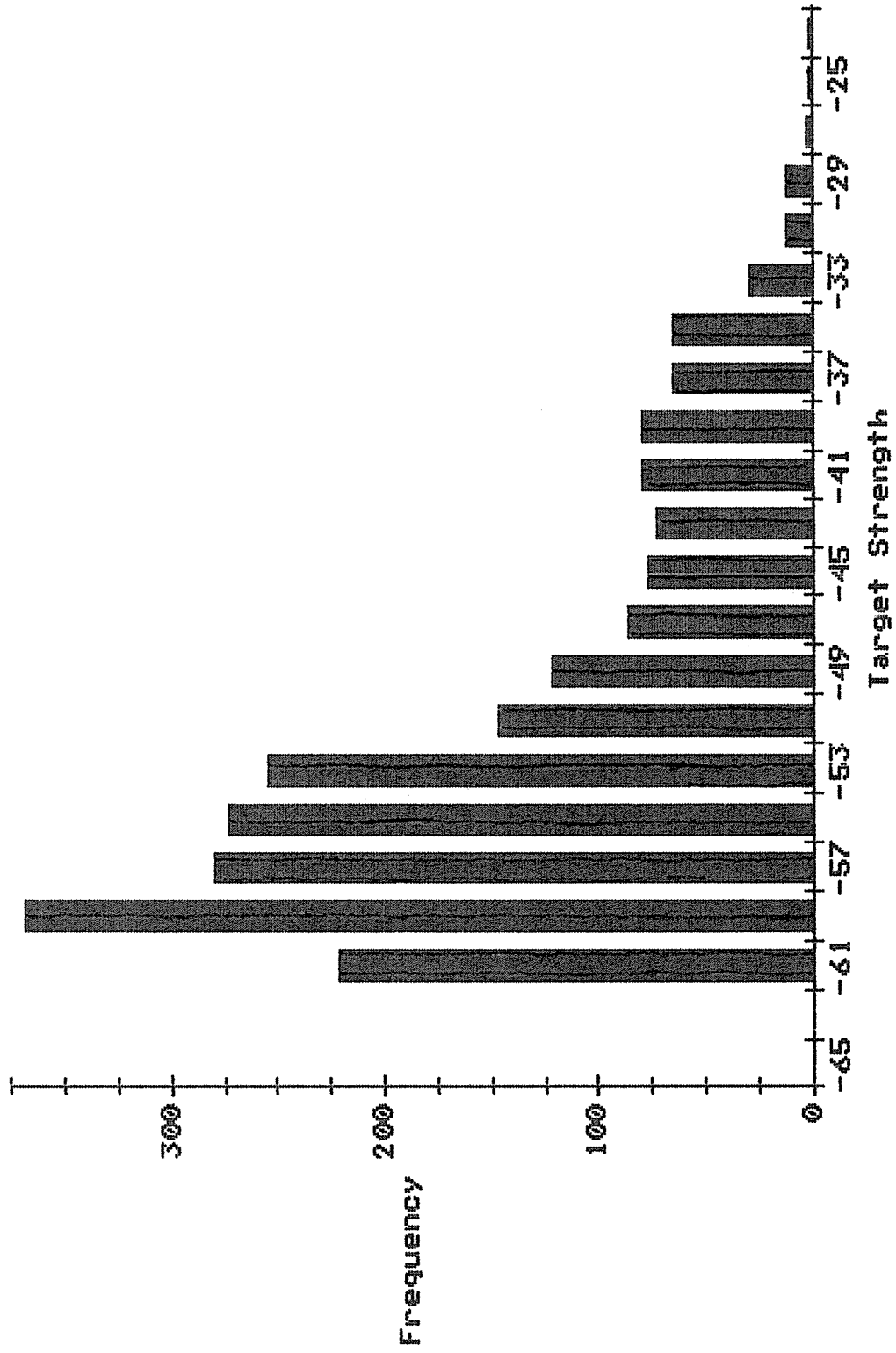


Figure 2C: Okanagan lake target strength histogram for depth interval 25-35 meters.

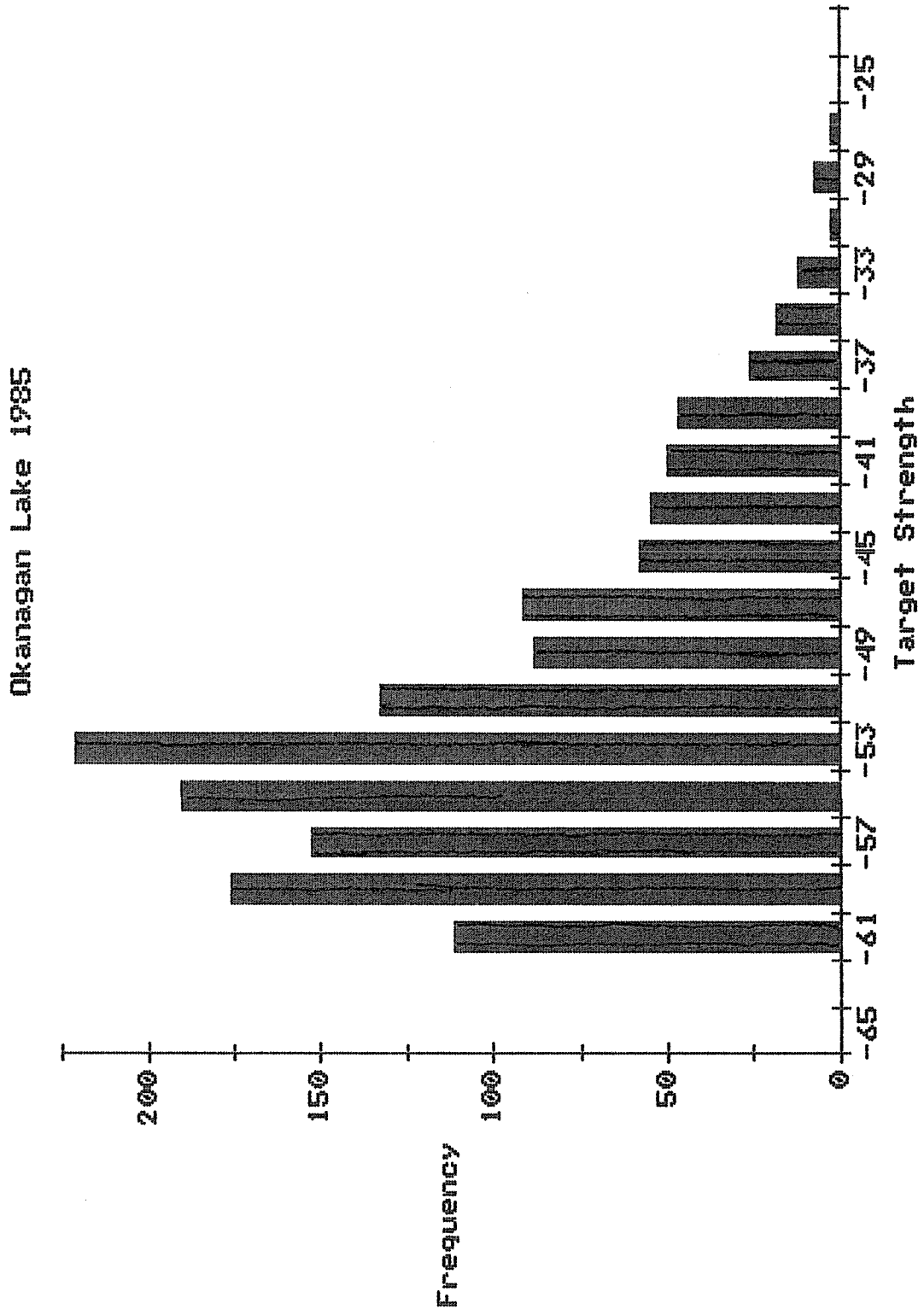


Figure 2D: Okanagan lake target strength histogram for depth interval 35-55 meters.

Table 6. Distribution of mean target strengths in various depths and lakes.

Depth interval	Kootenay		Okanagan		Skaha	
	TS	#	TS	#	TS	#
1	-48.9	11	-48.0	24	-50.8	9
2	-51.3	1726	-51.1	662	-51.9	10
3	-49.9	1778	-51.9	2245	-50.9	8
4	-50.0	265	-51.8	1440	--	0

were applied. Examples are illustrated in Appendix 5. Some separation into two groups appeared to occur with relatively narrow beam acceptance criteria (less than  $4.3^\circ$ ), and greater than 3 echoes per fish. However, even though the basic data set consisted of several thousand fish, these restrictive parameters reduced sample sizes to relatively small numbers, so the separation was not conclusive. The basic problem was that the relatively high transect speed, about 3 m/sec, restricted echo durations within  $4^\circ$  of the acoustic axis to less than 5 per target. This small number does not appear to converge on a mean target strength sufficiently for adequate separation of the cohorts. Central limit considerations would imply that echo duration numbers should be in the vicinity of 30 per fish before convergence on a mean is achieved. If this is the case, separation of cohorts by acoustic target strength may be possible only with large track numbers and near axis measurements. This circumstance would require separate data collection since this combination does not occur with the high boat speed used during normal surveys.

#### RECOMMENDATIONS AND CONCLUSIONS

The distribution of fish in the three lakes was very suitable for hydroacoustic estimation techniques. Fish were distributed in midwater away from surface or bottom boundaries which could confound detection, and densities were sufficiently low for application of echo counting, which is the most efficient data processing technique. Distributions were also sufficiently dispersed that estimates could be obtained with narrow confidence intervals. Reduction in transect effort may even be possible in future surveys, depending upon the desired precision. The

only difficulty, excepting the unfortunate loss of part of the Skaha Lake data, was in the cohort separation. The trawl data were limited and subject to bias from selective capture. Clear separation of the acoustic data was not obtained even with the advanced track routines. However, the data were clearly limited for this purpose because transect speed was relatively high. Acoustic partition of cohorts may be possible, but would require a separate mode of data collection, preferably a drifting or stationary deployment where large track numbers, 20-30 per fish, could be obtained. Such extra data collection could be achieved with a similar level of effort by slightly reducing the number of transects on Kootenay and Okanagan. This reduction is feasible considering the relatively narrow confidence intervals on the overall population estimates. An alternate approach would be to determine the degree of selectivity of the trawl by direct acoustic measurement of trawl efficiency. The trawl data suggest that virtual separation of the 0 age cohort from older fish occurs spatially during certain times of the year. Acoustic determination of fish density synoptic with the trawling operation allows direct measurement of the trawl efficiency. If the 0 age cohort is spatially separated, such measurements would also determine the trawl selectivity for the age 0 and older groups. In addition, target strength measurements under circumstances where age 0 fish are spatially separated would allow evaluation of the basic variance in the target strength measurement, and the track size necessary to separate the age 0 cohort acoustically. Since trawl operations are conducted at a relatively low speed (1.0-1.5 m/sec)

this mode of data collection might also provide adequate track sizes for the cohort partition.

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## APPENDICES

Appendix 1A. Kootenay Lake echoes and densities by depth and transect.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
1-W	10-20	4	10	0.07	22.94
	20-30	147	629	1.48	
	30-40	52	311	0.37	
	40-60	106	645	0.19	
M	10-20	0	0	0.00	15.06
	20-30	115	492	1.16	
	30-40	48	288	0.34	
	40-60	2	12	0.00	
E	10-20	3	8	0.05	26.15
	20-30	189	809	1.90	
	30-40	62	371	0.44	
	40-60	62	376	0.11	
1R-E	10-20	1	3	0.02	14.69
	20-30	80	342	0.97	
	30-40	29	174	0.25	
	40-60	53	322	0.11	
M	10-20	1	3	0.02	5.98
	20-30	27	116	0.33	
	30-40	28	168	0.24	
	40-60	2	12	0.00	
W	10-20	2	5	0.04	13.24
	20-30	72	308	0.87	
	30-40	36	216	0.31	
	40-60	23	140	0.05	
2-W	10-20	3	8	0.07	11.47
	20-30	38	163	0.52	
	30-40	50	300	0.49	
	40-60	14	85	0.03	
M	10-20	1	3	0.02	22.91
	20-30	104	445	1.43	
	30-40	82	491	0.80	
	40-60	8	49	0.02	
E	10-20	2	5	0.05	14.56
	20-30	54	231	0.74	
	30-40	61	365	0.60	
	40-60	15	91	0.04	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/1000 cu. m	Fish/1000 sq. m (10-60 m)
2R-E	10-20	0	0	0.00	12.43
	20-30	46	197	0.74	
	30-40	38	228	0.44	
	40-60	9	55	0.03	
M	Data lost - Tape break				
W	10-20	0	0	0.00	7.20
	20-30	14	60	0.35	
	30-40	17	102	0.31	
	40-60	7	43	0.03	
3-W	10-20	0	0	0.00	10.99
	20-30	37	158	0.60	
	30-40	41	246	0.47	
	40-60	5	30	0.01	
M	10-20	0	0	0.00	21.01
	20-30	78	334	1.26	
	30-40	70	419	0.81	
	40-60	6	36	0.02	
E	10-20	0	0	0.00	26.12
	20-30	85	364	1.37	
	30-40	97	581	1.12	
	40-60	21	127	0.06	
3R-E	10-20	1	3	0.03	21.97
	20-30	63	270	0.98	
	30-40	97	581	1.07	
	40-60	22	133	0.06	
M	10-20	0	0	0.00	21.81
	20-30	76	325	1.18	
	30-40	87	521	0.96	
	40-60	7	43	0.02	
W	10-20	0	0	0.00	11.83
	20-30	37	158	0.57	
	30-40	51	306	0.56	
	40-60	8	49	0.02	
4-W	10-20	0	0	0.00	13.50
	20-30	34	146	0.64	
	30-40	53	448	0.72	
	40-60	1	6	0.00	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
M	10-20	1	3	0.03	19.00
	20-30	27	116	0.51	
	30-40	98	587	1.31	
	40-60	8	49	0.03	
E	10-20	0	0	0.00	33.14
	20-30	45	193	0.84	
	30-40	177	1060	2.37	
	40-60	16	97	0.05	
4R-E	10-20	0	0	0.00	34.56
	20-30	48	205	0.93	
	30-40	168	1006	2.32	
	40-60	30	182	0.10	
M	10-20	1	3	0.03	17.62
	20-30	29	124	0.56	
	30-40	86	515	1.15	
	40-60	3	18	0.01	
W	10-20	0	0	0.00	12.58
	20-30	27	116	0.52	
	30-40	54	324	0.72	
	40-60	2	12	0.01	
5-W	10-20	12	25	0.67	24.32
	20-30	39	135	1.31	
	30-40	17	83	0.41	
	40-60	4	20	0.02	
M	10-20	6	13	0.34	38.13
	20-30	62	215	2.08	
	30-40	56	272	1.34	
	40-60	5	25	0.03	
E	10-20	6	13	0.34	29.30
	20-30	56	194	1.88	
	30-40	30	146	0.72	
	40-60	0	0	0.00	
5R-E	10-20	7	15	0.37	39.99
	20-30	88	305	2.79	
	30-40	35	170	0.79	
	40-60	4	20	0.02	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
M	10-20	7	15	0.37	43.04
	20-30	83	288	2.63	
	30-40	56	272	1.27	
	40-60	3	15	0.02	
W	10-20	3	6	0.16	21.91
	20-30	52	181	1.65	
	30-40	15	73	0.34	
	40-60	4	20	0.02	
6-W	10-20	1	2	0.10	31.35
	20-30	18	63	1.11	
	30-40	42	204	1.85	
	40-60	3	15	0.03	
M	10-20	0	0	0.00	13.68
	20-30	15	52	0.93	
	30-40	9	44	0.40	
	40-60	2	10	0.02	
E	10-20	2	4	0.21	54.71
	20-30	77	267	4.76	
	30-40	9	44	0.40	
	40-60	2	25	0.05	
6R-E	10-20	2	4	0.19	64.30
	20-30	97	337	5.42	
	30-40	17	83	0.68	
	40-60	7	35	0.07	
M	10-20	1	2	0.09	17.67
	20-30	21	73	1.17	
	30-40	12	58	0.48	
	40-60	1	5	0.01	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
W	10-20	0	0	0.00	44.35
	20-30	19	66	1.06	
	30-40	51	248	2.04	
	40-60	17	84	0.17	
7 W	10-20	0	0	0.00	23.55
	20-30	30	104	0.81	
	30-40	74	360	1.43	
	40-60	12	59	0.06	
M	10-20	0	0	0.00	11.88
	20-30	25	87	0.68	
	30-40	25	122	0.48	
	40-60	3	15	0.01	
E	10-20	0	0	0.00	32.99
	20-30	61	212	1.65	
	30-40	81	394	1.56	
	40-60	9	44	0.04	
7R-E	10-20	1	2	0.05	32.63
	20-30	68	236	1.91	
	30-40	62	301	1.24	
	40-60	6	30	0.03	
M	10-20	1	2	0.05	11.07
	20-30	12	42	0.34	
	30-40	34	165	0.68	
	40-60	4	20	0.02	
W	10-20	0	0	0.00	26.19
	20-30	30	104	0.84	
	30-40	82	398	1.65	
	40-60	13	64	0.06	
8-W	10-20	1	2	0.04	40.59
	20-30	84	292	2.16	
	30-40	101	491	1.85	
	40-60	1	5	0.01	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
M	10-20	0	0	0.00	40.88
	20-30	54	187	1.39	
	30-40	146	709	2.68	
	40-60	3	15	0.01	
E	10-20	1	2	0.04	27.07
	20-30	42	146	1.08	
	30-40	84	408	1.54	
	40-60	5	25	0.02	
8R-E	10-20	0	0	0.00	44.23
	20-30	47	163	2.87	
	30-40	81	394	1.47	
	40-60	9	44	0.04	
M	10-20	0	0	0.00	47.89
	20-30	75	260	1.90	
	30-40	155	753	2.81	
	40-60	9	44	0.04	
W	10-20	0	0	0.00	36.43
	20-30	83	288	2.10	
	30-40	79	384	1.43	
	40-60	12	59	0.05	
9-W	10-20	0	0	0.00	27.70
	20-30	50	174	1.37	
	30-40	70	340	1.37	
	40-60	4	20	0.02	
M	10-20	0	0	0.00	27.22
	20-30	44	153	1.20	
	30-40	76	369	1.48	
	40-60	4	20	0.02	
E	10-20	3	6	0.14	32.08
	20-30	69	240	1.88	
	30-40	58	282	1.13	
	40-60	6	30	0.03	
9R-E	10-20	0	0	0.00	33.36
	20-30	58	201	1.60	
	30-40	86	418	1.69	
	40-60	5	25	0.02	

## Appendix 1A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
M	10-20	0	0	0.00	26.10
	20-30	42	146	1.16	
	30-40	69	335	1.30	
	40-60	10	49	0.05	
W	10-20	3	6	0.14	20.52
	20-30	20	69	0.55	
	30-40	65	316	1.28	
	40-60	9	44	0.04	

Appendix 1B. Kootenay mean densities and variances by transect.

Transect	Area (1000 sq. m)	Density (#/ 1000 sq. m)	Mean	Variance	Population (1000 fish)	Variance
1 1R	75,992	21.38 11.33	16.35	25.3512	1,241.6	1.464E11
2 2R	60,910	16.31 9.82	13.06	10.5560	928.8	3.916E10
3 3R	52,779	19.37 18.54	18.95	0.1764	1,000.6	4.914E8
4 4R	43,872	21.88 21.59	21.73	0.0225	953.3	4.331E7
5 5R	31,586	30.58 34.98	32.78	4.8400	1,035.3	4.829E9
6 6R	17,555	33.25 41.98	37.62	19.0969	661.4	5.885E9
7 7R	37,390	22.81 23.30	23.05	0.0576	861.8	8.053E7
8 8R	40,380	36.16 42.85	39.51	11.2225	1,595.7	1.830E10
9 9R	37,567	29.00 26.66	27.83	1.3689	1,045.4	1.932E9
Total	398,000				9,323.9	2.171E11
95% C.I. = 913,286						

## Appendix 1C. Duration in beam measurements, Kootenay Lake.

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Transects 1-4; depth interval 27-33 m												
Duration: (echoes)	1	2	3	4	5	6	7	8	9	10	11	12
Sum observed:	13	40	57	92	135	132	119	136	45	80	55	24
Mean duration = 5.214	# observations = 240											
Transects 5-8; depth interval 27-33 m												
Duration:	1	2	3	4	5	6	7	8	9	10	11	12
Sum observed:	57	148	249	316	280	288	266	168	126	90	11	0
Mean duration = 4.165	# observations = 480											

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Appendix 2A. Okanagan Lake echoes and densities by depth and transect.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
1-W	5-16	12	19	.96	27.19
	16-25	24	76	1.20	
	25-35	17	78	.52	
	35-55	4	19	.03	
M	5-16	16	26	1.28	36.49
	16-25	30	94	1.50	
	25-35	26	120	.80	
	35-55	6	28	.04	
E	5-16	10	16	.80	25.33
	16-25	14	44	.70	
	25-35	20	92	.62	
	35-55	29	135	.20	
1R-E	5-16	14	23	1.10	29.28
	16-25	17	54	.84	
	25-35	24	111	.73	
	35-55	17	79	.12	
M	5-16	19	31	1.50	39.42
	16-25	22	69	1.09	
	25-35	34	157	1.03	
	35-55	21	98	.14	
W	5-16	5	8	.39	21.61
	16-25	28	88	1.38	
	25-35	11	51	.33	
	35-55	11	51	.08	
2W	5-16	1	2	13.85	42.13
	16-25	23	72	22.14	
	25-35	102	470	35.96	
	35-55	29	135	159.85	
M	5-16	1	2	.07	49.39
	16-25	42	132	1.90	
	25-35	99	456	2.75	
	35-55	32	149	.20	
E	5-16	0	0	0.00	22.85
	16-25	39	123	1.76	
	25-35	22	101	.61	
	35-55	7	33	.04	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
2R-E	5-16	0	0	0.00	20.16
	16-25	32	101	1.37	
	25-35	25	115	.66	
	35-55	10	47	.06	
M	5-16	0	0	0.00	42.04
	16-25	33	104	1.42	
	25-35	97	447	2.56	
	35-55	31	145	.18	
W	5-16	1	2	.07	24.69
	16-25	18	57	.77	
	25-35	54	249	1.43	
	35-55	23	107	.14	
3W	5-16	0	0	0.00	23.31
	16-25	17	54	.58	
	25-35	71	327	1.50	
	35-55	32	149	.15	
M	5-16	0	0	0.00	30.41
	16-25	32	101	1.10	
	25-35	83	382	1.76	
	35-55	31	145	.15	
E	5-16	1	2	.05	12.85
	16-25	8	25	.28	
	25-35	39	180	.82	
	35-55	16	75	.08	
3R-E	5-16	1	2	.05	20.26
	16-25	23	72	.78	
	25-35	50	230	1.04	
	35-55	25	117	.12	
M	5-16	0	0	0.00	32.83
	16-25	36	113	1.21	
	25-35	90	414	1.87	
	35-55	35	163	.16	
W	5-16	4	6	.22	18.58
	16-25	11	35	.37	
	25-35	54	249	1.12	
	35-55	18	84	.08	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
4W	5-16	1	2	.05	32.54
	16-25	36	113	1.11	
	25-35	99	456	1.88	
	35-55	38	177	.16	
M	5-16	1	2	.05	58.59
	16-25	39	123	1.20	
	25-35	196	902	3.72	
	35-55	118	550	.50	
E	5-16	0	0	0.00	34.76
	16-25	16	50	.49	
	25-35	110	506	2.09	
	35-55	111	517	.47	
4R-E	5-16	1	2	.05	34.55
	16-25	16	50	.51	
	25-35	108	497	2.12	
	35-55	93	434	.41	
M	5-16	0	0	0.00	57.93
	16-25	28	88	.89	
	25-35	189	870	3.71	
	35-55	145	676	.64	
W	5-16	1	2	.05	31.55
	16-25	33	104	1.05	
	25-35	89	410	1.75	
	35-55	46	214	.20	
5-W	5-16	0	0	0.00	8.10
	16-25	6	19	.24	
	25-35	19	88	.48	
	35-55	10	47	.06	
M	5-16	0	0	0.00	37.38
	16-25	17	54	.69	
	25-35	88	405	2.21	
	35-55	80	373	.45	
E	5-16	2	3	.13	27.62
	16-25	18	57	.73	
	25-35	60	276	1.51	
	35-55	40	186	.23	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
5R-E	5-16	2	3	.17	27.80
	16-25	11	35	.58	
	25-35	54	249	1.76	
	35-55	38	177	.15	
M	5-16	0	0	0.00	36.59
	16-25	16	50	.85	
	25-35	76	350	2.48	
	35-55	51	238	.21	
W	5-16	0	0	0.00	15.08
	16-25	7	27	.37	
	25-35	33	152	1.08	
	35-55	12	56	.05	
6-W	5-16	1	2	.09	8.59
	16-25	2	6	.11	
	25-35	12	55	.41	
	35-55	18	84	.12	
M	5-16	0	0	0.00	20.69
	16-25	1	3	.06	
	25-35	34	157	1.17	
	35-55	62	289	.42	
E	5-16	0	0	0.00	13.39
	16-25	0	0	0.00	
	25-35	27	124	.93	
	35-55	30	140	.21	
6R-E	5-16	0	0	0.00	11.55
	16-25	2	6	.11	
	25-35	14	65	.49	
	35-55	36	168	.28	
M	5-16	0	0	0.00	18.73
	16-25	0	0	0.00	
	25-35	33	152	1.15	
	35-55	46	214	.36	
W	5-16	1	2	.09	10.84
	16-25	0	0	0.00	
	25-35	21	97	.73	
	35-55	16	75	.13	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
7W	5-16	1	2	.05	30.46
	16-25	23	72	.74	
	25-35	61	280	1.21	
	35-55	124	578	.55	
M	5-16	1	2	.05	41.76
	16-25	31	98	1.00	
	25-35	90	414	1.79	
	35-55	160	746	.72	
E	5-16	1	2	.05	26.75
	16-25	26	82	.84	
	25-35	60	276	1.19	
	35-55	75	350	.34	
7R-E	5-16	1	2	.05	34.45
	16-25	37	116	1.21	
	25-35	67	308	1.35	
	35-55	104	484	.47	
M	5-16	0	0	0.00	38.36
	16-25	27	85	.89	
	25-35	94	433	1.90	
	35-55	126	587	.57	
W	5-16	0	0	0.00	32.33
	16-25	21	66	.69	
	25-35	72	332	1.45	
	35-55	128	597	.58	
8E	5-16	0	0	0.00	27.60
	16-25	34	107	1.37	
	25-35	51	235	1.26	
	35-55	24	112	.13	
M	5-16	0	0	0.00	29.61
	16-25	20	63	.80	
	25-35	76	350	1.88	
	35-55	32	149	.18	
W	5-16	0	0	0.00	22.36
	16-25	14	44	.56	
	25-35	64	295	1.58	
	35-55	13	61	.07	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
8R-W	5-16	0	0	0.00	22.47
	16-25	14	44	.55	
	25-35	62	285	1.49	
	35-55	25	117	.13	
M	5-16	1	2	.06	29.17
	16-25	19	60	.74	
	25-35	82	378	1.97	
	35-55	20	93	.11	
E	5-16	0	0	0.00	28.15
	16-25	29	91	1.13	
	25-35	66	304	1.58	
	35-55	20	93	.11	
9-W	5-16	1	2	.06	9.81
	16-25	14	44	.53	
	25-35	15	69	.35	
	35-55	8	37	.04	
M	5-16	0	0	0.00	29.87
	16-25	19	60	.72	
	25-35	73	336	1.71	
	35-55	60	280	.32	
E	5-16	1	2	.06	17.19
	16-25	16	50	.61	
	25-35	41	189	.96	
	35-55	14	65	.07	
9R-E	5-16	0	0	0.00	13.39
	16-25	10	32	.39	
	25-35	32	147	.76	
	35-55	21	98	.11	
M	5-16	0	0	0.00	25.10
	16-25	11	35	.43	
	25-35	58	267	1.39	
	35-55	69	322	.87	
W	5-16	1	2	.06	7.45
	16-25	12	38	.47	
	25-35	9	41	.21	
	35-55	4	19	.02	

## Appendix 2A - cont'd.

Transect	Depth (m)	Targets	Echoes	Fish/ 1000 cu. m	Fish/1000 sq. m (10-60 m)
10-W	5-16	5	8	.93	32.60
	16-25	20	63	2.33	
	25-35	2	9	.14	
	35-55	-	-	-	
M	5-16	5	8	.93	37.23
	16-25	21	66	2.45	
	25-35	7	32	.50	
	35-55	-	-	-	
E	5-16	3	10	.56	18.47
	16-25	7	22	.82	
	25-35	7	32	.50	
	35-55	-	-	-	
10R-E	5-16	4	6	.68	28.65
	16-25	20	63	2.13	
	25-35	3	14	.20	
	35-55	-	-	-	
M	5-16	5	8	.85	33.50
	16-25	19	60	2.03	
	25-35	9	41	.59	
	35-55	-	-	-	
W	5-16	4	6	.68	30.22
	16-25	23	72	2.45	
	25-35	1	5	.07	
	35-55	-	-	-	

Appendix 2B. Okanagan mean densities and variances by transect.

Transect	Area		Population			
	(1000 cu. m)	Density	Mean	Variance	(1000 fish)	Variance
1 1	47,500	29.67 30.10	29.89	.0484	1419.8	1.0920E8
2 2	33,710	38.12 28.96	33.54	20.9764	1130.6	2.3837E10
3 3	29,270	22.19 23.89	23.04	.7225	674.4	6.1899E8
4 4	41,450	41.96 41.34	41.66	.0900	1726.8	1.5463E8
5 5	30,650	24.37 26.50	25.46	1.0900	780.3	1.0240E9
6 6	25,810	14.22 13.71	13.97	.0676	360.6	4.5032E7
7 7	37,020	32.99 35.05	34.02	1.0609	1259.4	1.4539E9
8 8	35,730	26.52 26.60	26.56	.0016	940.0	2.0426E6
9 9	47,730	18.96 15.31	17.14	3.3489	818.7	7.6293E9
10 10	17,000	29.43 30.79	30.11	.4624	511.9	1.3363E8
Total	345,870				9630.9	3.50076E10

95% C.I. = 366722

## Appendix 2C. Duration in beam measurements, Okanagan Lake.

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Transects 1-5; depth interval 27-33 m													
Duration: (echoes)	1	2	3	4	5	6	7	8	9	10	11	12	13
Sum observed:	42	106	165	196	295	306	252	256	135	70	33	12	13
Mean duration =	4.656		# observations = 404										
Transects 7-8; depth interval 27-33 m													
Duration:	1	2	3	4	5	6	7	8	9	10	11	12	13
Sum observed:	33	64	117	132	165	180	203	112	81	30	22	24	13
Mean duration =	4.523		# observations = 260										

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## Appendix 3. Okanagan Lake 1985 echogram count analysis.

Transect	Time	Depth interval	Echogram count	Oscilloscope count	Mean oscilloscope count D <sub>v</sub> (1000 cu. m)
2	14:23	5-16	1	2	.05
		16-25	88	104	1.57
		25-35	140	223	2.07
		35-55	58	68	.14
2R	15:09	5-16	1	1	.02
		16-26	69	83	1.19
		25-35	152	176	1.55
		35-55	61	64	.13
4	21:06	5-16	2	2	.03
		16-26	74	91	.93
		25-35	247	405	2.56
		35-55	179	267	.38
4R	20:23	5-16	2	2	.03
		16-26	54	77	.82
		25-35	227	386	2.53
		35-55	221	284	.42
6	11:38	5-16	2	2	.03
		16-26	5	41	.06
		25-35	89	167	.84
		35-55	98	130	.25
6R	11:28	5-16	2	2	.03
		16-26	2	34	.04
		25-35	64	163	.79
		35-55	80	101	.26
7	20:08	5-16	1	3	.05
		16-25	70	80	.86
		25-35	175	211	1.40
		35-55	283	359	.54
7R	19:50	5-16	0	1	.02
		16-26	76	85	.93
		25-35	153	233	1.57
		35-55	283	358	.54

## Appendix 3. Okanagan Lake 1985 echogram count analysis - cont'd.

Transect	Time	Depth interval	Echogram count	Oscilloscope count	Mean oscilloscope count D <sub>v</sub> (1000 cu. m)
8	16:10	5-16	2	0	0.00
		16-26	43	68	.91
		25-35	129	191	1.57
		35-55	64	69	.13
8R	16:41	5-16	1	1	.02
		16-26	52	62	.81
		25-35	158	210	1.68
		35-55	52	65	.12

Scope = 2.2239 + 1.3821 Chart

$$r^2 = .9488$$

#### APPENDIX 4

Appendix 4 gives the mean target strength, by echo, and frequency histogram for each depth interval for Kootenay and Okanagan lakes.

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SUMMARY OF DATA FROM DEPTH 10.0 TO 20.0 Kootenay Lake 1985

## DEPTH INTERVALS

	FROM	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	
TS	TO	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	SUM
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		0	0	0	0	0	0	0	0	0	0	0
-59		0	0	0	0	0	0	0	1	1	0	2
-57		0	0	0	0	0	0	0	0	0	0	0
-55		0	0	0	0	0	0	0	0	0	0	0
-53		0	0	0	0	0	0	0	0	0	2	2
-51		0	0	0	0	1	0	0	0	0	1	2
-49		0	0	0	0	0	0	0	0	1	0	1
-47		0	0	0	0	0	0	0	0	1	0	1
-45		0	0	0	0	0	0	0	0	1	0	1
-43		0	0	0	0	0	0	0	0	0	0	0
-41		0	0	0	0	0	0	0	0	0	0	0
-39		0	0	0	0	0	0	0	0	0	0	0
-37		0	0	0	0	0	0	0	1	0	0	1
-35		0	0	0	0	0	0	0	0	0	0	0
-33		1	0	0	0	0	0	0	0	0	0	1
-31		0	0	0	0	0	0	0	0	0	0	0
-29		0	0	0	0	0	0	0	0	0	0	0
-27		0	0	0	0	0	0	0	0	0	0	0
-25		0	0	0	0	0	0	0	0	0	0	0
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 28880  
NUMBER OF TARGETS USED FOR STATISTICS = 11  
AVERAGE BACKSCATTERING CROSS SECTION = .6597E-04 IN dB = -41.81  
BACKSCATTERING CROSS SECTION STD DEV = .1392E-03  
AVERAGE TARGET STRENGTH IN dB = -48.94  
TARGET STRENGTH STD DEV IN dB = 7.97  
# TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 1  
NUMBER OF FISH USED = 28880  
ESTIMATED VOLUME IN CUBIC METERS = .226E+07  
DENSITY IN FISH PER CUBIC METER = .128E-01

---

 SUMMARY OF DATA FROM DEPTH 20.0 TO 30.0 Kootenay Lake 1985

## DEPTH INTERVALS

	FROM	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	
	TO	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	SUM
TS												
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		0	1	8	2	11	16	28	15	15	19	115
-59		1	4	3	8	17	32	38	32	32	21	188
-57		1	2	3	15	17	19	37	34	32	25	185
-55		5	0	3	11	13	32	24	42	33	34	197
-53		3	4	3	16	29	38	45	40	38	46	262
-51		2	3	5	7	14	21	26	30	31	39	178
-49		5	2	2	6	16	21	17	25	26	29	149
-47		0	0	1	6	8	14	14	18	24	12	97
-45		1	2	4	1	5	13	14	16	8	14	78
-43		1	0	0	6	2	12	9	17	13	14	74
-41		0	0	1	1	3	5	8	12	15	17	62
-39		1	3	1	2	3	11	10	10	12	22	75
-37		2	0	2	1	6	2	4	11	9	5	42
-35		0	0	0	0	4	1	3	6	6	2	22
-33		0	1	0	0	1	0	3	0	2	1	8
-31		0	0	0	1	0	0	1	2	0	0	4
-29		0	0	0	0	0	0	1	0	0	0	1
-27		0	0	0	0	0	0	0	0	0	0	0
-25		0	0	0	0	0	0	2	0	0	0	2
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 28880  
 NUMBER OF TARGETS USED FOR STATISTICS = 1739  
 AVERAGE BACKSCATTERING CROSS SECTION = .3368E-04 IN dB = -44.73  
 BACKSCATTERING CROSS SECTION STD DEV = .1331E-03  
 AVERAGE TARGET STRENGTH IN dB = -51.33  
 TARGET STRENGTH STD DEV IN dB = 6.78  
 # TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 193  
 NUMBER OF FISH USED = 28880  
 ESTIMATED VOLUME IN CUBIC METERS = .539E+07  
 DENSITY IN FISH PER CUBIC METER = .536E-02

---

 SUMMARY OF DATA FROM DEPTH 30.0 TO 40.0 Kootenay Lake 1985

## DEPTH INTERVALS

	FROM	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	
	TO	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	40.00	
TS												SUM
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		16	5	5	8	6	2	3	2	5	1	53
-59		28	15	16	18	8	5	7	3	3	4	107
-57		36	29	21	17	19	15	13	7	5	0	162
-55		43	32	31	23	16	13	18	10	4	3	193
-53		44	48	39	29	32	22	21	12	12	9	268
-51		36	31	35	35	31	15	17	15	9	8	232
-49		33	20	29	23	14	14	13	8	8	4	166
-47		14	17	13	16	14	7	6	7	5	6	105
-45		14	16	14	15	20	9	7	4	8	5	112
-43		16	20	15	16	15	10	6	7	5	5	115
-41		19	17	10	16	8	7	13	5	3	3	101
-39		12	14	19	14	7	6	4	1	4	4	85
-37		15	10	3	5	4	2	2	0	1	2	44
-35		5	1	4	5	1	1	2	0	0	1	20
-33		2	1	2	1	0	3	0	1	0	0	10
-31		2	0	1	0	1	1	1	0	1	0	7
-29		1	0	0	1	0	0	0	0	0	0	2
-27		0	0	0	0	0	0	0	0	0	0	0
-25		0	0	0	0	0	0	0	0	0	0	0
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 28880  
 NUMBER OF TARGETS USED FOR STATISTICS = 1782  
 AVERAGE BACKSCATTERING CROSS SECTION = .3585E-04 IN dB = -44.46  
 BACKSCATTERING CROSS SECTION STD DEV = .8814E-04  
 AVERAGE TARGET STRENGTH IN dB = -49.91  
 TARGET STRENGTH STD DEV IN dB = 6.53  
 # TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 99  
 NUMBER OF FISH USED = 28880  
 ESTIMATED VOLUME IN CUBIC METERS = .106E+08  
 DENSITY IN FISH PER CUBIC METER = .272E-02

## SUMMARY OF DATA FROM DEPTH 40.0 TO 60.0 Kootenay Lake 1985

## DEPTH INTERVALS

	FROM	40.00	42.00	44.00	46.00	48.00	50.00	52.00	54.00	56.00	58.00	
TS	TO	42.00	44.00	46.00	48.00	50.00	52.00	54.00	56.00	58.00	60.00	SUM
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		0	0	0	0	0	0	1	1	2	2	6
-59		5	1	0	1	1	0	3	5	5	1	22
-57		5	3	0	0	1	3	5	0	4	1	22
-55		2	4	2	2	2	2	1	2	5	1	23
-53		7	7	5	2	2	2	1	6	5	2	39
-51		6	4	0	3	2	3	3	5	1	3	30
-49		7	3	1	3	5	4	2	0	2	4	31
-47		1	0	1	5	3	4	3	1	1	2	21
-45		0	0	2	4	1	3	2	1	0	2	15
-43		2	7	2	3	3	0	0	2	1	1	21
-41		5	3	1	3	1	3	1	1	0	2	20
-39		3	1	0	1	1	1	0	1	0	0	8
-37		1	0	1	1	0	2	0	0	0	1	6
-35		1	0	0	0	0	0	0	0	0	0	1
-33		0	0	0	0	0	0	0	0	0	0	0
-31		0	0	0	0	0	0	0	0	0	0	0
-29		0	0	0	0	0	0	0	0	0	0	0
-27		0	0	0	0	0	0	0	0	0	0	0
-25		0	0	0	0	0	0	0	0	0	0	0
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 28880

NUMBER OF TARGETS USED FOR STATISTICS = 265

AVERAGE BACKSCATTERING CROSS SECTION = .2654E-04 IN dB = -45.76

BACKSCATTERING CROSS SECTION STD DEV = .4396E-04

AVERAGE TARGET STRENGTH IN dB = -49.97

TARGET STRENGTH STD DEV IN dB = 6.11

# TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 30

NUMBER OF FISH USED = 28880

ESTIMATED VOLUME IN CUBIC METERS = .409E+08

DENSITY IN FISH PER CUBIC METER = .705E-03

---

SUMMARY OF DATA FROM DEPTH 5.0 TO 16.0 Okanagan Lake 1985

## DEPTH INTERVALS

	FROM	5.00	6.10	7.20	8.30	9.40	10.50	11.60	12.70	13.80	14.90	
	TO	6.10	7.20	8.30	9.40	10.50	11.60	12.70	13.80	14.90	16.00	
TS												SUM
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		0	0	0	0	0	0	0	0	0	0	0
-59		0	0	0	0	0	0	0	0	0	1	1
-57		0	0	0	0	0	0	0	0	0	0	0
-55		0	0	0	0	0	0	0	0	0	0	0
-53		0	0	0	0	0	0	0	2	1	2	5
-51		0	0	0	0	0	0	0	1	2	1	4
-49		0	0	0	0	0	0	1	0	0	1	2
-47		0	0	1	0	0	0	0	0	0	1	2
-45		0	0	0	0	0	0	0	4	1	0	5
-43		0	0	0	0	0	0	0	1	0	1	2
-41		0	0	0	0	0	0	0	0	0	2	2
-39		0	0	0	0	0	0	0	0	0	0	0
-37		0	0	0	0	0	0	0	0	0	0	0
-35		0	0	0	0	0	0	1	0	0	0	1
-33		0	0	0	0	0	0	0	0	0	0	0
-31		0	0	0	0	0	0	0	0	0	0	0
-29		0	0	0	0	0	0	0	0	0	0	0
-27		0	0	0	0	0	0	0	0	0	0	0
-25		0	0	0	0	0	0	0	0	0	0	0
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 32189  
NUMBER OF TARGETS USED FOR STATISTICS = 24  
AVERAGE BACKSCATTERING CROSS SECTION = .3771E-04 IN dB = -44.24  
BACKSCATTERING CROSS SECTION STD DEV = .7459E-04  
AVERAGE TARGET STRENGTH IN dB = -48.00  
TARGET STRENGTH STD DEV IN dB = 5.49  
# TARGETS WITH BEAM PATTERN FACTORS > 0 dB= 1  
NUMBER OF FISH USED = 32189  
ESTIMATED VOLUME IN CUBIC METERS = .115E+07  
DENSITY IN FISH PER CUBIC METER = .279E-01

---

 SUMMARY OF DATA FROM DEPTH 16.0 TO 25.0 Okanagan Lake 1985

## DEPTH INTERVALS

TS	FROM	16.00	16.90	17.80	18.70	19.60	20.50	21.40	22.30	23.20	24.10	SUM
	TO	16.90	17.80	18.70	19.60	20.50	21.40	22.30	23.20	24.10	25.00	
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		0	0	1	4	3	10	9	4	6	19	56
-59		1	0	2	7	21	22	7	10	14	19	103
-57		1	0	1	9	7	11	2	7	8	14	60
-55		0	0	2	6	12	10	6	5	8	11	60
-53		0	0	1	11	9	17	10	10	11	19	88
-51		1	0	1	5	15	9	10	7	9	5	62
-49		1	1	1	1	5	5	6	3	7	7	37
-47		1	1	1	6	4	5	3	2	2	4	29
-45		2	1	3	4	6	7	2	2	4	1	32
-43		2	1	2	3	7	5	2	2	7	6	37
-41		1	0	2	1	0	2	5	2	2	5	20
-39		0	0	0	2	1	4	4	7	3	5	26
-37		1	0	1	0	0	2	3	2	5	3	17
-35		0	0	1	0	0	3	1	2	4	2	13
-33		0	0	1	0	0	0	1	3	3	1	9
-31		1	0	0	0	0	1	0	0	1	0	3
-29		1	0	0	0	1	0	2	3	0	1	8
-27		0	0	0	0	0	0	0	1	0	0	1
-25		0	0	0	0	0	1	0	0	0	0	1
-23		0	0	0	0	0	0	0	0	0	0	0
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 32189  
 NUMBER OF TARGETS USED FOR STATISTICS = 662  
 AVERAGE BACKSCATTERING CROSS SECTION = .6196E-04 IN dB = -42.08  
 BACKSCATTERING CROSS SECTION STD DEV = .2326E-03  
 AVERAGE TARGET STRENGTH IN dB = -51.12  
 TARGET STRENGTH STD DEV IN dB = 7.91  
 # TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 96  
 NUMBER OF FISH USED = 32189  
 ESTIMATED VOLUME IN CUBIC METERS = .368E+07  
 DENSITY IN FISH PER CUBIC METER = .876E-02

## SUMMARY OF DATA FROM DEPTH 25.0 TO 35.0 Okanagan Lake 1985

## DEPTH INTERVALS

	FROM	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	
	TO	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00	
TS												SUM
-75		0	0	0	0	0	0	0	0	0	0	0
-73		0	0	0	0	0	0	0	0	0	0	0
-71		0	0	0	0	0	0	0	0	0	0	0
-69		0	0	0	0	0	0	0	0	0	0	0
-67		0	0	0	0	0	0	0	0	0	0	0
-65		0	0	0	0	0	0	0	0	0	0	0
-63		0	0	0	0	0	0	0	0	0	0	0
-61		9	22	18	22	24	29	27	23	26	21	221
-59		26	32	45	48	32	59	31	35	41	20	369
-57		15	33	38	26	31	29	25	35	34	14	280
-55		13	28	22	42	24	32	33	24	31	24	273
-53		15	17	29	23	29	30	32	34	22	24	255
-51		8	17	11	16	18	19	11	20	14	13	147
-49		17	8	9	11	18	6	19	13	12	9	122
-47		10	6	3	10	5	14	7	13	11	7	86
-45		6	1	4	9	5	11	6	17	10	7	76
-43		6	5	4	5	7	10	7	9	12	8	73
-41		2	6	8	14	6	13	4	9	13	4	79
-39		9	4	7	7	8	8	13	10	6	7	79
-37		2	8	7	8	3	4	7	8	8	9	64
-35		7	4	5	10	8	7	10	4	5	5	65
-33		3	2	6	2	4	1	5	3	2	1	29
-31		2	1	1	0	3	3	0	2	0	0	12
-29		2	3	0	1	0	1	2	2	0	0	11
-27		0	0	0	0	1	0	0	0	0	1	2
-25		0	0	0	0	0	0	0	0	0	1	1
-23		0	1	0	0	0	0	0	0	0	0	1
-21		0	0	0	0	0	0	0	0	0	0	0
-19		0	0	0	0	0	0	0	0	0	0	0
-17		0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 32189

NUMBER OF TARGETS USED FOR STATISTICS = 2245

AVERAGE BACKSCATTERING CROSS SECTION = .4995E-04 IN dB = -43.01

BACKSCATTERING CROSS SECTION STD DEV = .1809E-03

AVERAGE TARGET STRENGTH IN dB = -51.89

TARGET STRENGTH STD DEV IN dB = 7.84

# TARGETS WITH BEAM PATTERN FACTORS > 0 dB= 366

NUMBER OF FISH USED = 32189

ESTIMATED VOLUME IN CUBIC METERS = .835E+07

DENSITY IN FISH PER CUBIC METER = .385E-02

## SUMMARY OF DATA FROM DEPTH 35.0 TO 55.0 Okanagan Lake 1985

## DEPTH INTERVALS

		FROM	35.00	37.00	39.00	41.00	43.00	45.00	47.00	49.00	51.00	53.00	
		TO	37.00	39.00	41.00	43.00	45.00	47.00	49.00	51.00	53.00	55.00	SUM
TS													
-75			0	0	0	0	0	0	0	0	0	0	0
-73			0	0	0	0	0	0	0	0	0	0	0
-71			0	0	0	0	0	0	0	0	0	0	0
-69			0	0	0	0	0	0	0	0	0	0	0
-67			0	0	0	0	0	0	0	0	0	0	0
-65			0	0	0	0	0	0	0	0	0	0	0
-63			0	0	0	0	0	0	0	0	0	0	0
-61			25	29	17	9	6	9	10	3	2	1	111
-59			39	57	28	16	11	8	8	5	2	2	176
-57			30	46	25	19	11	9	6	2	4	1	153
-55			45	43	40	14	16	12	7	4	7	2	190
-53			41	55	37	18	19	16	8	14	8	5	221
-51			35	23	24	8	10	9	3	8	6	7	133
-49			17	11	14	10	11	10	6	3	3	3	88
-47			26	19	9	9	10	6	1	4	6	1	91
-45			12	11	10	6	5	2	5	3	3	1	58
-43			9	9	12	8	5	6	1	1	2	2	55
-41			9	17	6	1	3	5	3	2	3	1	50
-39			10	9	11	5	6	3	1	0	2	0	47
-37			11	5	1	3	2	3	0	0	1	0	26
-35			4	7	1	2	3	0	0	1	0	0	18
-33			3	2	1	1	3	1	0	1	0	0	12
-31			0	2	0	0	0	0	0	0	0	0	2
-29			1	1	0	5	0	0	0	0	0	0	7
-27			1	0	0	1	0	0	0	0	0	0	2
-25			0	0	0	0	0	0	0	0	0	0	0
-23			0	0	0	0	0	0	0	0	0	0	0
-21			0	0	0	0	0	0	0	0	0	0	0
-19			0	0	0	0	0	0	0	0	0	0	0
-17			0	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER OF RECORDED TARGETS = 32189

NUMBER OF TARGETS USED FOR STATISTICS = 1440

AVERAGE BACKSCATTERING CROSS SECTION = .3631E-04 IN dB = -44.40

BACKSCATTERING CROSS SECTION STD DEV = .1408E-03

AVERAGE TARGET STRENGTH IN dB = -51.80

TARGET STRENGTH STD DEV IN dB = 6.89

# TARGETS WITH BEAM PATTERN FACTORS > 0 dB = 166

NUMBER OF FISH USED = 32189

ESTIMATED VOLUME IN CUBIC METERS = .356E+08

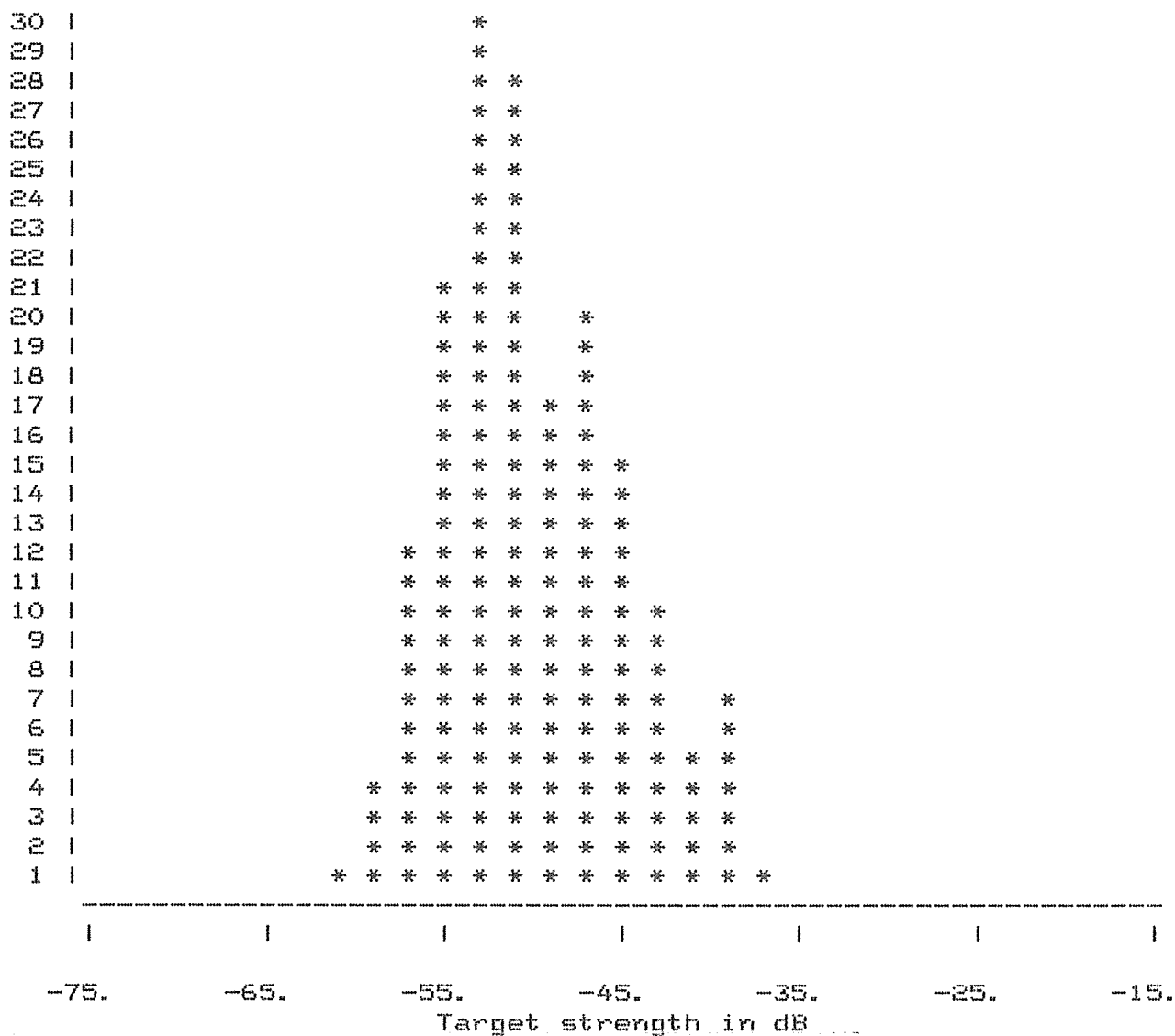
DENSITY IN FISH PER CUBIC METER = .905E-03

## APPENDIX 5

Appendix 5 gives examples of target strength analysis for Kootenay Lake using the BioSonics TRACK program and the effects of changing maximum beam angle and minimum echoes per fish. As maximum half angle increases more targets are accepted, yet the ability of the program to identify the target strength distribution by cohorts is offset by increased variation. Increasing the minimum number of pings in order to qualify a fish increases resolution, yet greatly reduces sample size.



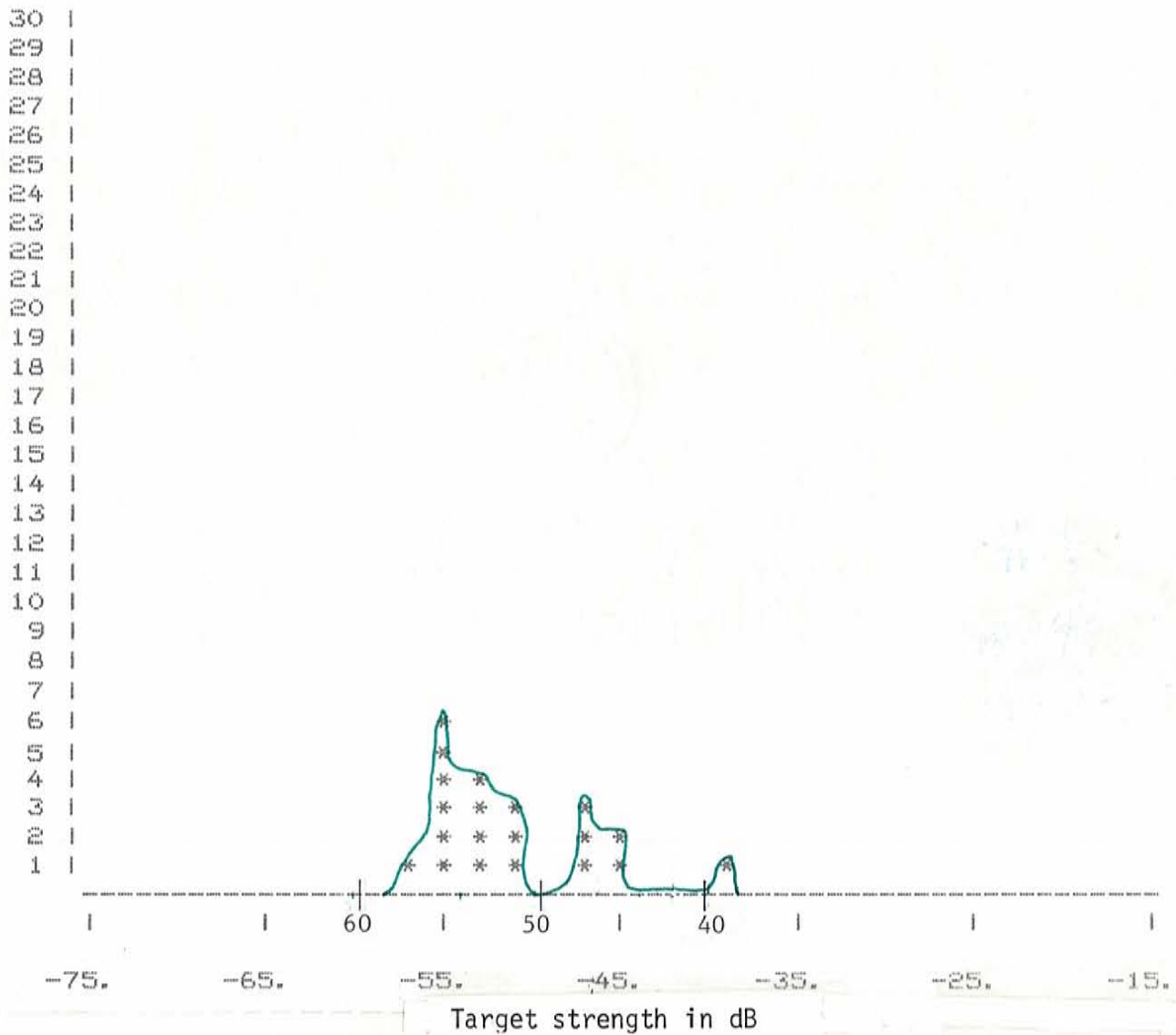
## Frequency Histogram of Target Strengths



TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	380
TOTAL NUMBER OF FISH TRACKED	=	175
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.2827E-04
IN dB	=	-45.4867
BACKSCATTERING CROSS SECTION STD DEV	=	.4918E-04
AVERAGE OF ALL FISH TARGET STRENGTHS	=	
IN dB	=	-50.1074
TARGET STRENGTH STD DEV IN dB	=	4.9911
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	30



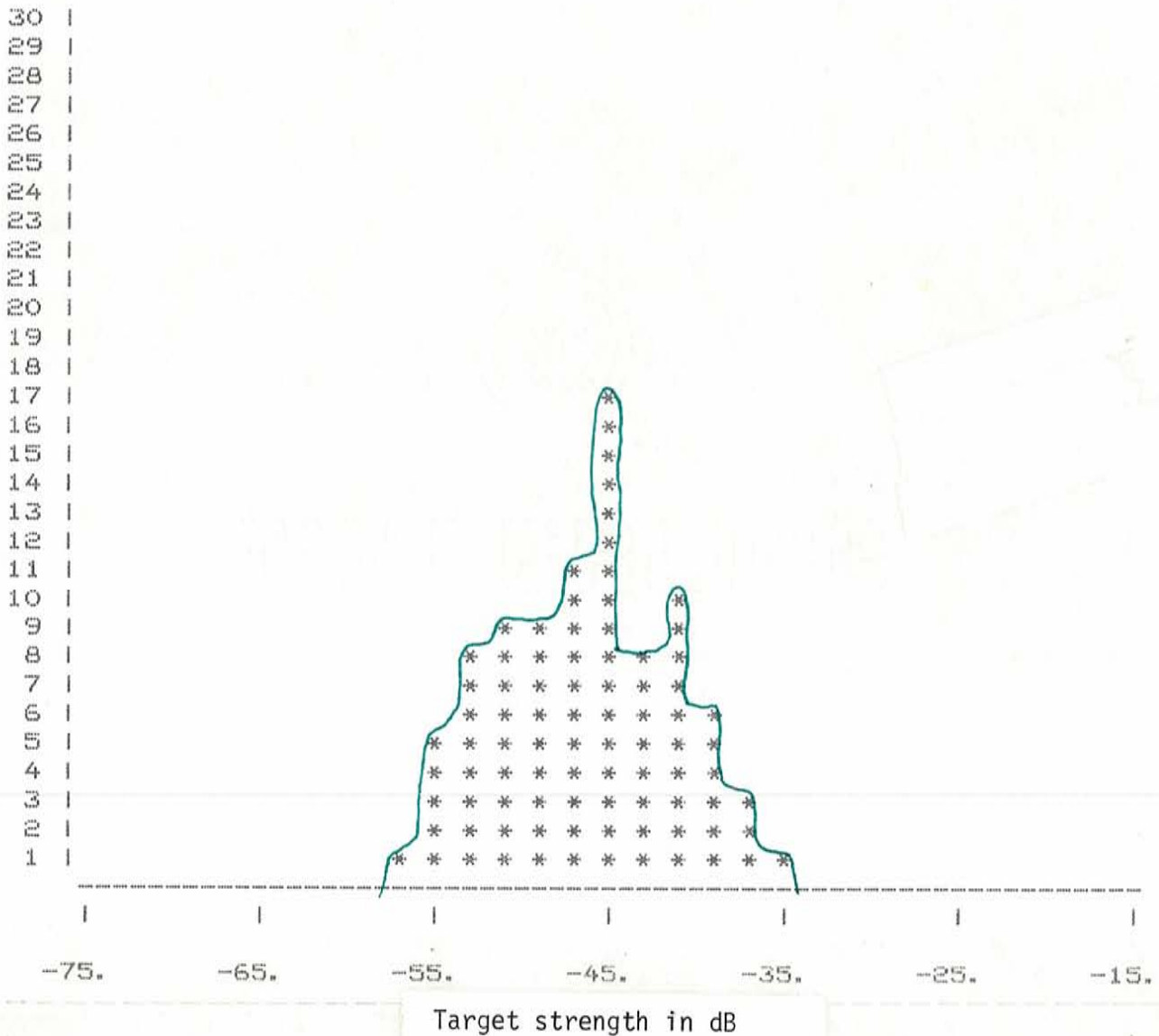
Frequency Histogram of Target Strengths



TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	70
TOTAL NUMBER OF FISH TRACKED	=	20
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.4053E-04
IN dB	=	-43.9227
BACKSCATTERING CROSS SECTION STD DEV	=	.9297E-04
AVERAGE OF ALL FISH TARGET STRENGTHS	=	
IN dB	=	-51.1558
TARGET STRENGTH STD DEV IN dB	=	4.6125
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	9



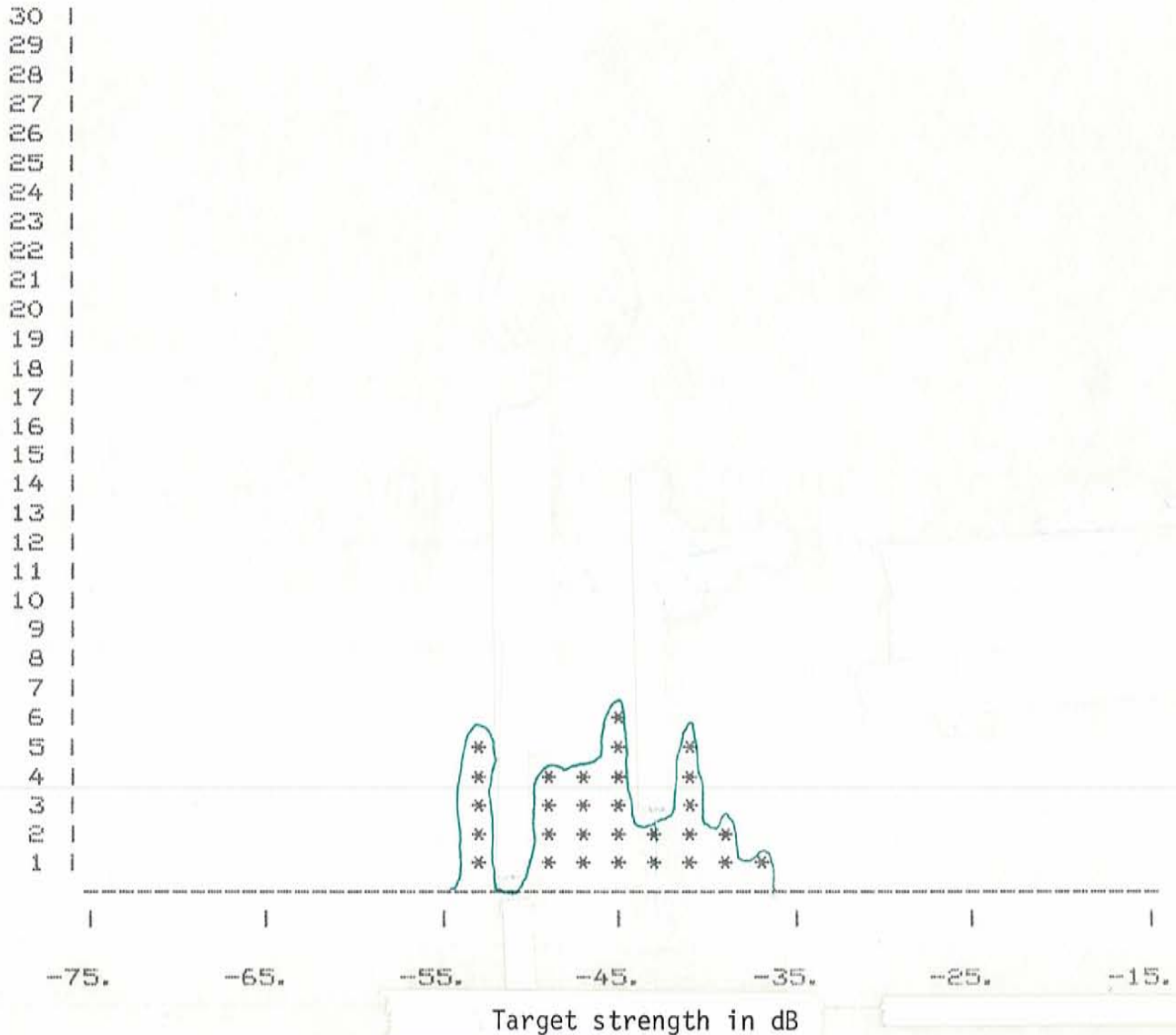
## Frequency Histogram of Target Strengths



TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	305
TOTAL NUMBER OF FISH TRACKED	=	88
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.7573E-04
IN dB	=	-41.2073
BACKSCATTERING CROSS SECTION STD DEV	=	.8282E-04
AVERAGE OF ALL FISH TARGET STRENGTHS	=	
IN dB	=	-46.2578
TARGET STRENGTH STD DEV IN dB	=	5.0755
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	15



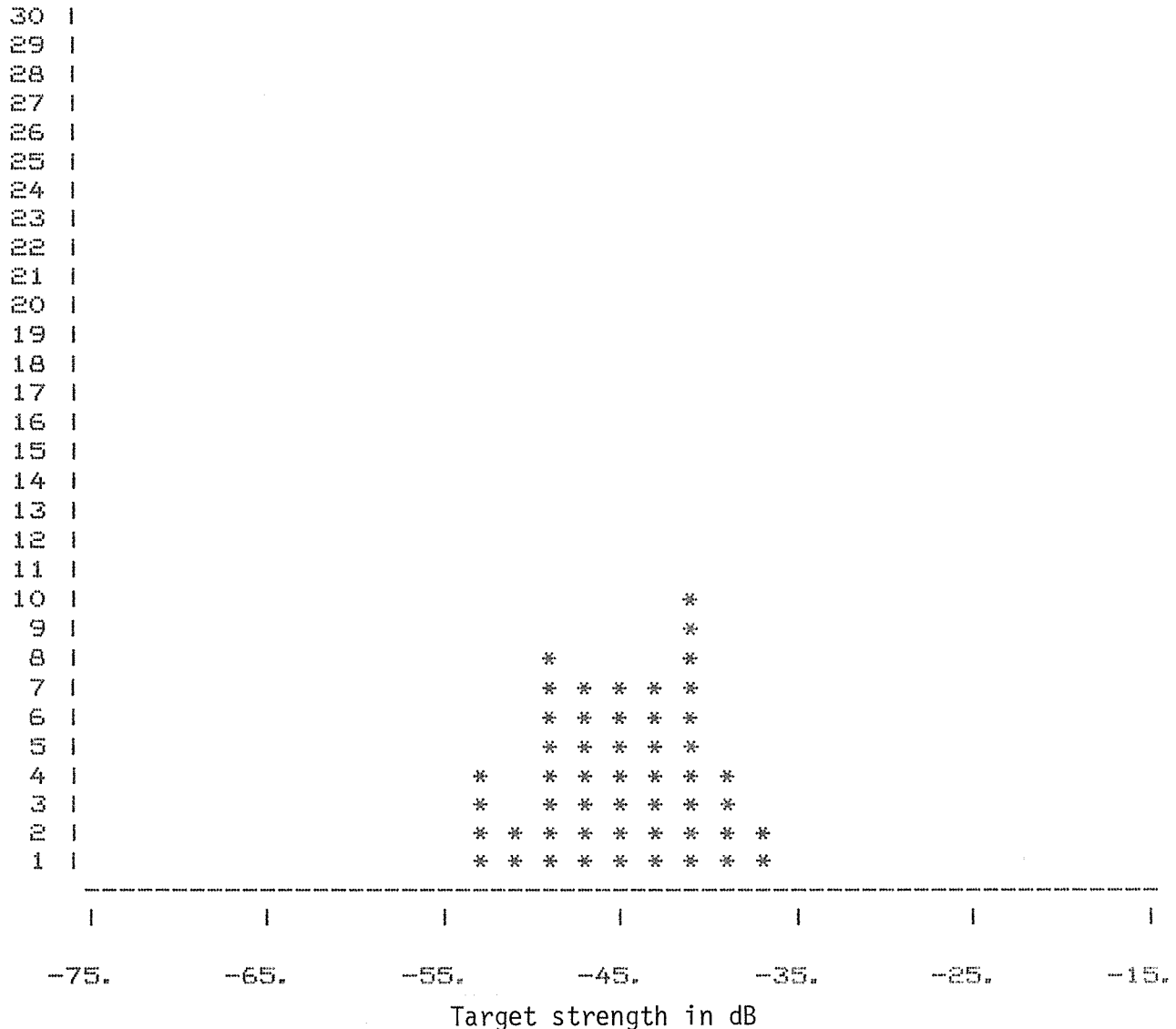
## Frequency Histogram of Target Strengths



TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	128
TOTAL NUMBER OF FISH TRACKED	=	29
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.7290E-04
	IN dB =	-41.3730
BACKSCATTERING CROSS SECTION STD DEV	=	.7213E-04
AVERAGE OF ALL FISH TARGET STRENGTHS		
	IN dB =	-45.8228
TARGET STRENGTH STD DEV IN dB	=	4.7101
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	4



## Frequency Histogram of Target Strengths

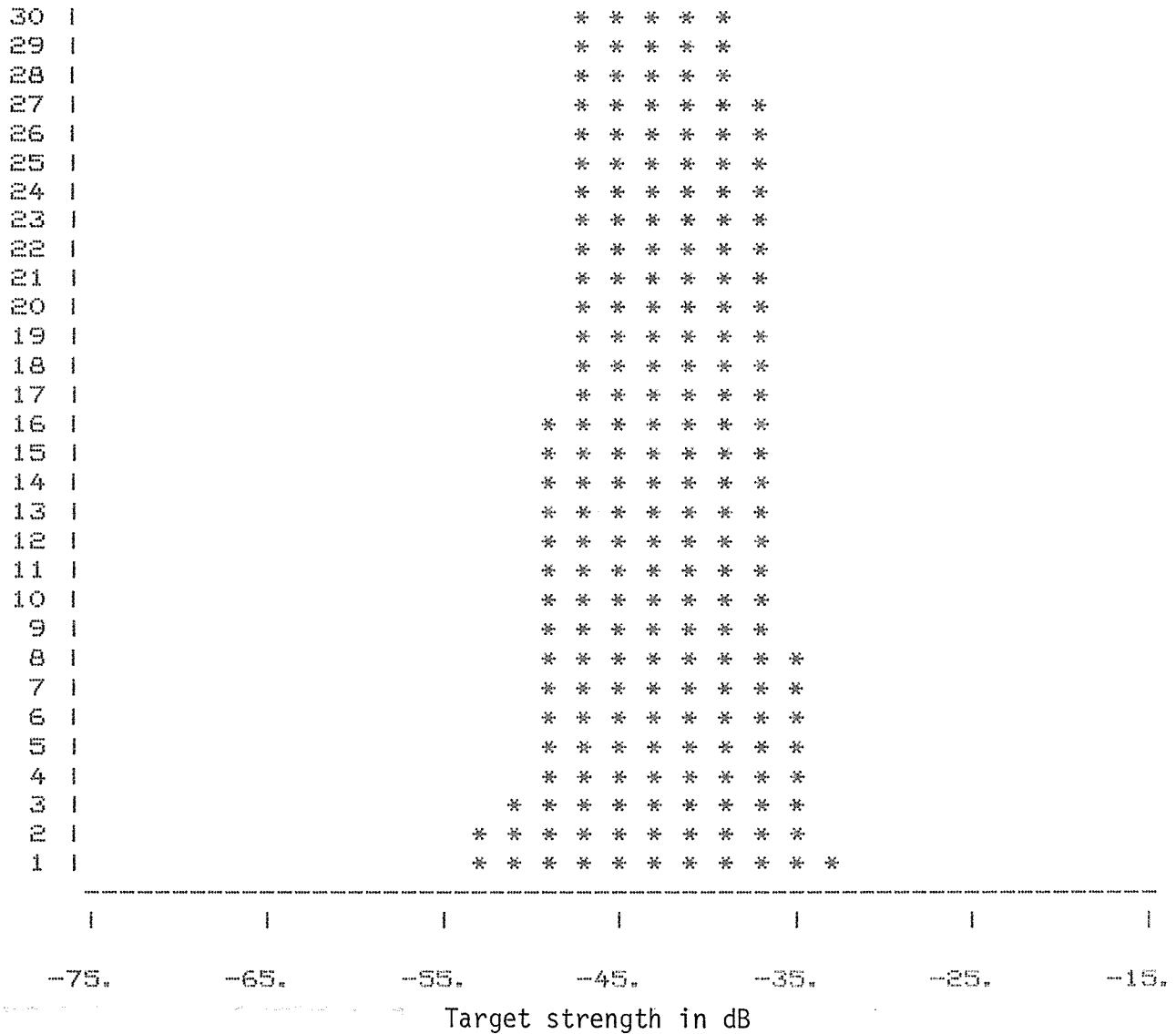



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TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	242
TOTAL NUMBER OF FISH TRACKED	=	51
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.8005E-04
IN dB	=	-40.9667
BACKSCATTERING CROSS SECTION STD DEV	=	.6797E-04
AVERAGE OF ALL FISH TARGET STRENGTHS	=	
IN dB	=	-45.0020
TARGET STRENGTH STD DEV IN dB	=	4.3860
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	9



Frequency Histogram of Target Strengths




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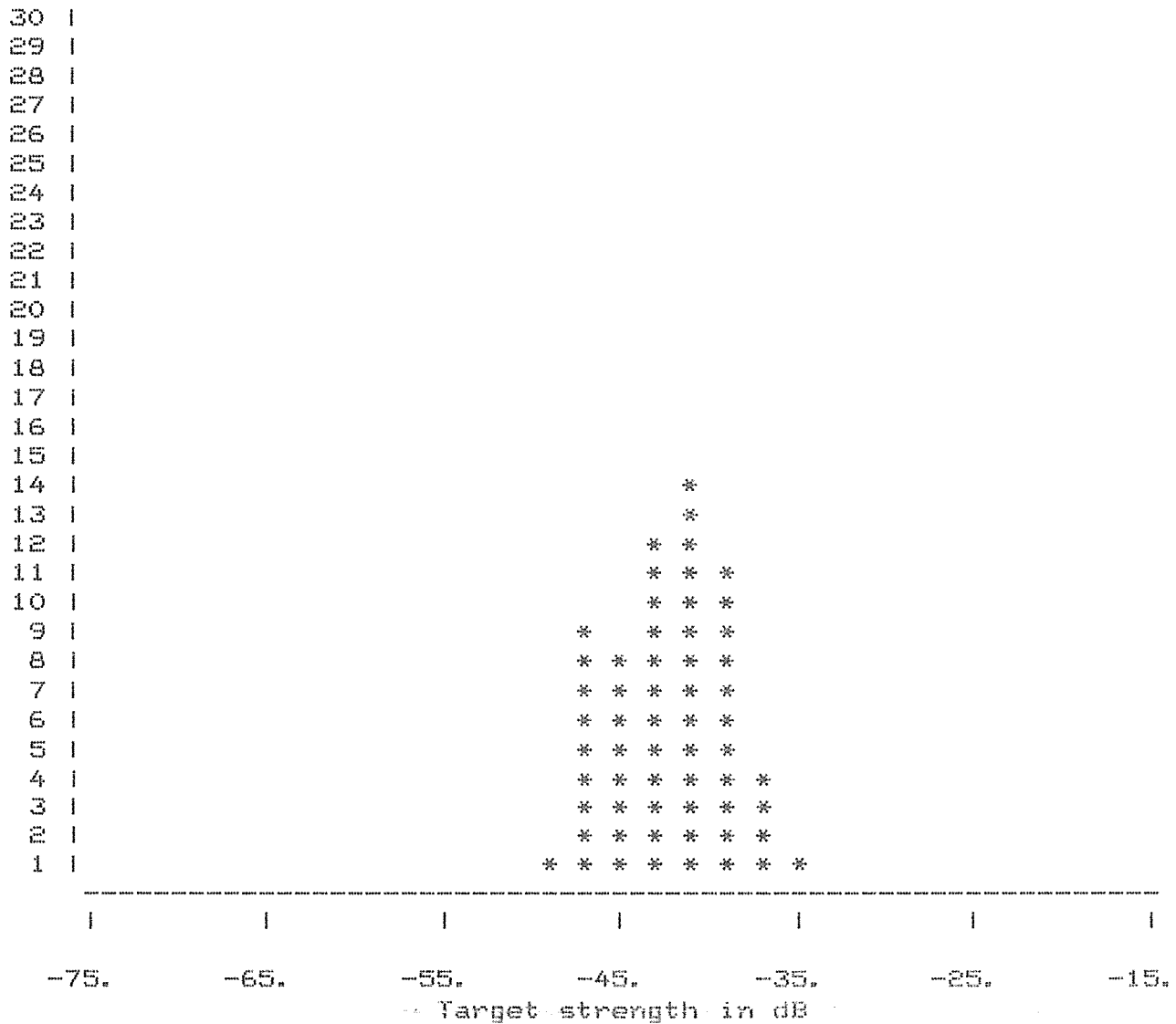
TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	1397
TOTAL NUMBER OF FISH TRACKED	=	279
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.1309E-03
	IN dB =	-38.8298
BACKSCATTERING CROSS SECTION STD DEV	=	.1137E-03
AVERAGE OF ALL FISH TARGET STRENGTHS	=	
	IN dB =	-42.3722
TARGET STRENGTH STD DEV IN dB	=	3.7934
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	21







Frequency Histogram of Target Strengths




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TOTAL NUMBER OF RECORDED ECHOES	=	14443
TOTAL ECHOES IN ALL FISH COMBINED	=	459
TOTAL NUMBER OF FISH TRACKED	=	60
AVERAGE OF ALL BACKSCATTERING CROSS SECTIONS FROM EACH FISH	=	.1303E-03
	IN dB =	-38.8502
BACKSCATTERING CROSS SECTION STD DEV	=	.1097E-03
AVERAGE OF ALL FISH TARGET STRENGTHS		
	IN dB =	-42.3293
TARGET STRENGTH STD DEV IN dB	=	3.1967
NUMBER OF ECHOES WITH BEAM PATTERN FACTORS > 0 dB	=	9



