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HYDROACOUSTIC SURVEYS OF FISH ABUNDANCE AND DISTRIBUTION IN TWIN LAKES, COLORADO

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16. ABSTRACT

Hydroacoustic surveys were conducted on Twin Lakes, Colorado, during September 1980 in order to measure the size and distribution of the resident fish population. Two distinct size groups of fish were observed: large fish below the thermocline (about 12 m) and small fish in the epilimnion. Net samples indicated that the large fish were predominately lake trout. Their estimated population size was 14,600, with 95% confidence limits of 4,100 to 25,000. The relatively large confidence intervals were the result of the relatively low fish density and its contagious distribution. The small fish were not identified, but may have been juvenile lake trout. Population estimates of this group were not made because of extreme patchiness and undersampling by the survey procedures, which focused on the larger fish.

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HYDROACOUSTIC SURVEYS OF FISH ABUNDANCE AND DISTRIBUTION IN TWIN LAKES, COLORADO

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ WATER AND POWER RESOURCES SERVICE

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On November 6, 1979, the Bureau of Reclamation was renamed the Water and Power Resources Service in the U.S. Department of the Interior. The new name more closely identifies the agency with its principal functions — supplying water and power.

FOREWORD

Twin Lakes are a pair of montane drainage lakes of glacial origin located on Lake Creek at the eastern foot of the Sawatch Range in the Upper Arkansas River Valley of central Colorado. The lakes are 2802 m above mean sea elevation at 39°05′ N. latitude and 106°20′ W. longitude. Maximum surface areas are about 263.4 ha for the upper lake and 736.5 ha for the lower, with corresponding depths of about 28 m and 27 m, respectively. The lower lake is connected to the upper lake by a narrow passage. The fishery of Twin Lakes was first described by Jordan (1889) [1][1] and Jordan and Evermann (1889) [2], and more recently by Nolting (1968) [3] and Finnell (1980) [4]. Presently, Twin Lakes has a substantial self-reproducing lake trout fishery and a put-and-take rainbow trout fishery. Limnological features of Twin Lakes are described by Juday (1906) [15] and (1907) [16], and more recently by Sartoris et al. (1977) [7] and LaBounty et al. (1980) [8]. Twin Lakes are dimictic, chemically soft water lakes, with maximum surface temperatures reaching 18°C during late July to mid-August. Phytoplankton flora consists mainly of diatoms and yellow-brown species, while zooplankton fauna consists of a mysis shrimp-copepod-rotifer association. Both lake trout and mysis shrimp were introduced to Twin Lakes.

The northwest corner of the lower lake is the site of the Mt. Elbert Pumped-Storage Powerplant, which is scheduled to begin operation during 1981. The powerplant houses two 100 MW pump-generators. Water will be pumped from the lower lake up into a newly constructed forebay reservoir. A scheduled increase in the water surface elevation will inundate the isthmus between the two lakes, creating one larger reservoir.

This report is one of a series that presents the results of investigations on the limnology and fishery of Twin Lakes, Colorado. The purpose of these studies is to document the ecological effects of operating the Mt. Elbert Pumped-Storage Powerplant. Data presented in this report will be used along with those collected from other preoperational studies at Twin Lakes to form a pool of information for comparison with data collected following commencement of powerplant operation. The information acquired at Twin Lakes, along with that from other similar studies in the Western United States, will be used to improve the planning process so that the environmental impacts of future pumped-storage facilities can be accurately evaluated and certain environmental features protected and enhanced.

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[1] Numbers in brackets refer to items in the bibliography.

CONTENTS

	Page
Foreword	iii
Introduction	1
Application	1
Methods and materials	1
Data acquisition equipment and procedures	1
Data analysis procedures	3
Results	4
Size and vertical distribution of targets	4
Horizontal distribution	5
Temporal variability	5
Population estimates	5
Discussion	12
Conclusions and recommendations	13
Bibliography	14

TABLES

Table		
1	Distribution of echo strength categories by depth and area	5
2	Densities of fish in various area and depth strata in Twin Lakes	11
3	Population estimates of fish in deep and intermediate strata in Twin Lakes	12

FIGURES

Figure		
1	Hydroacoustic system deployment for Twin Lakes study	2
2	Transect locations on Twin Lakes	3
3	Relative frequency of detection for echo strength categories 1, 3, and 5, in lower lake at night	6
4	Relative frequency of detection for echo strength categories 1 and 3+ in upper lake at night	7
5	Relative frequency of detection for large targets day versus night in lower lake	8
6	Echograms from night runs in areas 3 (lower) and 4 (upper)	9
7	Echogram from daytime run in lower lake, showing near-shore distribution	10
8	Echogram from night run in upper lake, showing near-shore distribution	10

INTRODUCTION

Twin Lakes, Colorado is the site of the Mt. Elbert Pumped-Storage Powerplant, which is currently in the final construction phase and nearing operational status. Concern exists over the effects of the powerplant on the ecology of the lakes, and especially on the lake trout. Previous data on the lake trout have been obtained primarily from experimental gill net studies, sport fishing catches, and limited mark-recapture studies (Finnell, 1980 [4]). The limited sampling power, unknown efficiency, and selectivity of gill nets have limited the usefulness of these results, and, in particular, cannot provide adequate estimates of population size. The sport fishing catch data are similarly limited in this regard. The mark-recapture studies also have not successfully provided population estimates because of limited numbers of tags, small number of recaptures, and unknown mortalities.

Hydroacoustic techniques have been successfully applied in several lakes (Thorne, 1976 [9]). These techniques have the advantages of very high sampling power and capability for population estimation, but are limited in species discrimination and resolution near-surface and near-bottom. Twin Lakes appeared to be well-suited to hydroacoustic techniques since the species composition is relatively simple and, in particular, the lake trout appear to be distributionally isolated from other species and accessible to hydroacoustic detection. Consequently, the authors were contracted by the Water and Power Resources Service, E & R (Engineering and Research) Center, and conducted hydroacoustic surveys of Twin Lakes during September 1980. This report presents the results of these surveys.

APPLICATION

The data in this report represent a significant part of the information that exists on the fishery of Twin Lakes. It provides the most accurate estimate of the Twin Lakes lake trout population to date. It also presents data on size and vertical distribution of fish in Twin Lakes. These data are necessary to accurately quantify the effects of powerplant operation on fish population.

Information in this report will also be of interest to fishery biologists who are considering new methods of measuring the distribution and density of fish populations in lakes and reservoirs. Therefore, the results of this study will be useful not only to fisheries managers responsible for the Twin Lakes fishery, but to other reservoirs like it.

METHODS AND MATERIALS

Data Acquisition Equipment and Procedures

The hydroacoustic system was deployed in a conventional down-looking mode from a transecting vessel (fig. 1). The echo sounder was an EK-120 Simrad Scientific Sounder used in conjunction with a 120 kHz transducer having a beam angle of about 10 degrees full angle at 6 dB down from the acoustic axis. Pulse length of the echosounder was 0.6 ms. A modified Ross 500 SL chart recorder both triggered the sounder at six soundings per second and provided a 0-100 ft scale echogram. The hydroacoustic data from the echosounder were recorded on analog magnetic tape with a TEAC 3440 recorder. Gain settings were adjusted in the field to optimize signal levels for the dynamic range of the tape recorder. For this reason a 20 log R range correction (TVG) was used for most of the survey rather than 40 log R. This setting allowed recording of small near-surface targets as well as the larger deep targets.

The system was deployed from a 16-ft Boston Whaler. The transducer was mounted in a 2-ft Braincon V-fin and towed alongside the boat, about 2 m below the surface. Boat speed was maintained about 2 m/s using a hand-held, flow-tube speedometer.

Transecting was conducted between September 15 and 18, 1980. The survey strategy was to divide the lakes into seven approximately equal parts, five in the lower lake and two in the upper, and to randomly select an orthogonal (north-south) transect location in each of these areas. The location of the transects is shown on figure 2. Both day and night transects were run. Ends of the transects were marked by flashing lights to aid navigation at night.

After initial set-up and testing, a series of 10 transects was run the night of September 16, consisting of replicated transects in each of the five areas of the lower lake (N 1 data). A similar series of four transects was run the next night in the two areas of the upper lake (N 2 data). During

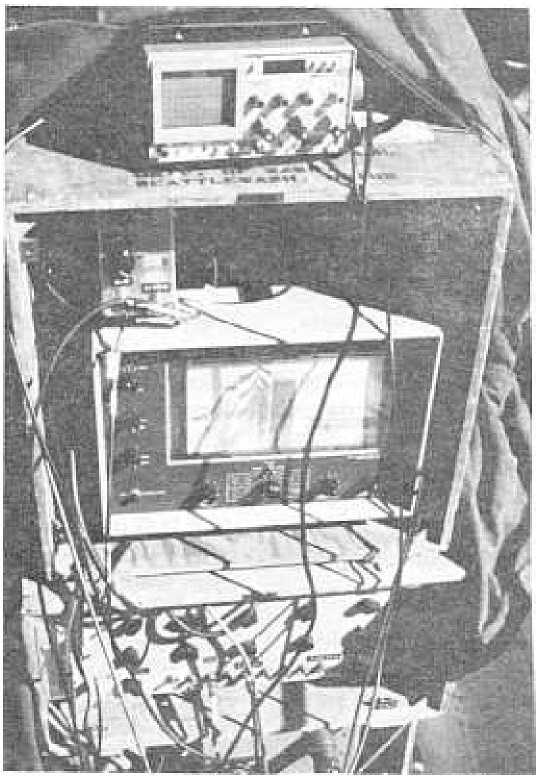

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Figure 1.—Hydroacoustic system deployment for Twin Lakes study.

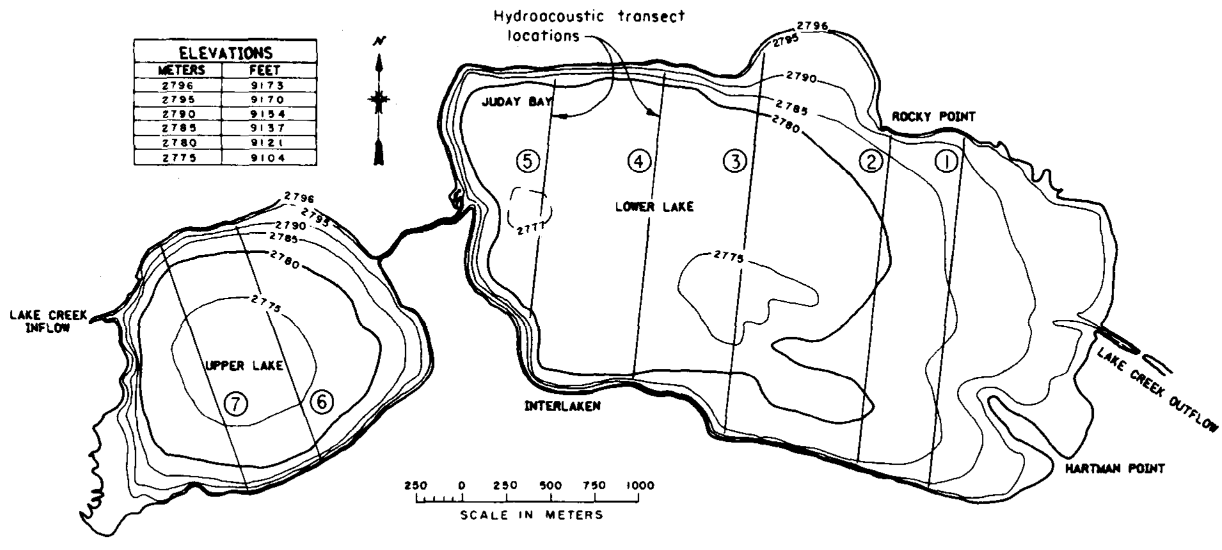

Figure 2.—Transect locations on Twin Lakes.

the day, September 17, a single transect was run in each of the seven areas (D 1 data), plus an extra west-to-east run down the center of both lakes. The seven-transect series was repeated that night, plus an additional replicate in each of the two highest density areas (N 3 data). Four runs were made the final day, September 18: a transect in each of the two high-density areas; and two experimental runs, one by the powerplant and one for target strength data.

Data Analysis Procedures

Fish densities were sufficiently low for echo-counting techniques. The analog magnetic tapes were analyzed using a Tectronics Model 7313 storage oscilloscope. Targets were stratified into three depth zones (3-7.5, 7.5-16, and 16-25 m) to facilitate range corrections, since most of the data were collected with a 20 log R TVG. This stratification also provided a convenient separation of shallow (above-thermocline), intermediate (transitional), and deep (below-thermocline) categories. In each of these categories, an amplitude threshold was established which corresponded to an acoustic target strength of about −60 dB at the midpoint of the depth interval.

The following information was obtained from each target: depth, time along transect, maximum amplitude, and number of echoes (above the threshold). The maximum amplitude data were converted to echo strength and categorized in −6 dB intervals. The mean number of echoes per target was calculated for each of the three depth categories and used in conjunction with the boat speed and sounding rate in order to determine the area sampled (m²) by the hydroacoustic beam (Saville, 1978 [10]). The formulation is:

$$r = \frac{2}{\pi} \cdot \frac{\bar{n}\,s}{p}$$

where r = the radius of the sampling cross-sectional area of the beam at the mean target depth, m,

$\bar{n}$ = mean number of echoes per fish target,

s = boat speed, m/s,

and p = sounding rate, the number of sound transmissions per second.

The actual boat speed for each transect was determined from the length and duration of the run. Density of fish in the lake area was determined from each transect and each of the three depth intervals:

$$D = \frac{e}{a}$$

where e = number of echoes from fish along the transect and

a = area sampled during the transect, m².

Weighted mean densities were then computed for each depth strata and lake area and various combinations:

$$\overline{D}_{ij} = \frac{\sum_{i=1}^{R} \left(A_{ijk} \, D_{ijk} \right)}{\sum_{i=1}^{R} \left(A_{ijk} \right)}$$

where A_{ijk} = area (m^2) of sample in lake i, depth strata j, and area strata k,

and

D_{ijk} = density (fish per square meter) of sample in lake i, depth strata j, and area strata k.

The following relationship from Seber (1973) [11] was used to estimate the variance of D:

$$\mathrm{Var}\ \overline{D}_{ij} = \frac{\sum_{i=1}^{R} \left(A_{ij} \, (D_{ij} - \overline{D}_i)^2 \right)}{A_{ij} \ (1 - R)}$$

The number of fish and variance for the upper and lower lakes by depth and area strata were computed by the following extrapolation formulae:

$$N_{ij} = A_T \, D_{ij}$$

$$\mathrm{Var}\ N_{ij} = (A_T^2) \ \mathrm{Var}\ \overline{D}_{ij}$$

The area sampled (A_{ijk}) was determined by multiplying the number of soundings by the cross-sectional area of the beam as derived above. The area represented by the transects was determined from the physical characteristics of the lake obtained from Sartoris, LaBounty, and Newkirk (1977) [7], and assuming a lake water surface elevation of 2800 m. The boundaries of the survey were the 3 m depth contour. Total lake area (A_T) over 3 m depth was determined to be 589 ha for the lower lake and 196 ha for the upper. These totals were allocated to the various transects in proportion to the length of the transects. The range among the seven transect areas was from 90 ha for area 5 (transects 9 and 10) to 135 ha for area 3 (transects 5 and 6).

In addition to the population estimates, various trends in both the numerical and size data were examined. Nonparametric hypothesis testing techniques were used in order to avoid making assumptions about the underlying distribution of the data (Siegel, 1956 [12]).

RESULTS

Size and Vertical Distribution of Targets

There was a clear distributional separation of two size categories. Small targets were associated with the shallow water (table 1). Most of the echoes from this depth category were in the smallest detectable echo strength category (−61 to −55dB) for the gain settings used at Twin Lakes. The mean echo strength from the shallow depth category was −58.4dB. Taking into account the directivity pattern of the transducer, this echo strength corresponds to an acoustic target strength of −51.4 dB. This value usually corresponds to a fish size of 90 to 100 mm, but would be an overestimate of mean size in this case since smaller targets were below the detection threshold.

The intermediate depth zone had fewer targets and a greater echo strength spread, with a mean echo strength of −50.8 dB. This mean echo strength, correcting for the beam pattern effect, corresponded to a target strength of −43.8dB and a fish size around 150 to 200 mm. The fish in deep water were considerably larger, with a mean echo strength of −44.5 dB corresponding to a −37.5 dB target strength, about a 400 mm fish. The largest targets were about −28 dB. As a mean, this value would correspond to about a 1000 mm fish, but the variability in individual target strengths precludes precise size estimation from single observations.

The interaction between size and vertical distribution is apparent from figure 3, where the relative frequencies of detection are shown for three size categories, 1 (−61 to −55dB), 3 (−49 to −43dB) and 5 (−37 to −31dB) in the lower lake at night. The number of small targets is maximum at about 5 m depth, whereas the two larger categories are most frequently detected at around 21 m. A similar situation was observed in the upper lake (fig. 4), although the number of large targets is small.

Changes in vertical distribution of fish between day and night are common to limnetic fishes. Figure 5 shows the day and night vertical distributions for larger targets (over −49dB) in the lower

Table 1.—*Distribution of echo targets by depth and area*

Area	Shallow (3-7.5 m)					Intermediate (7.5-16 m)					Deep (16-25 m)				
	Echo Strength Categories*														
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	15	2	0	0	0	1	2	3	0	0	0	0	1	1	1
3	6	0	0	0	0	2	5	2	1	0	3	31	36	22	19
4	2	1	0	0	0	3	3	2	2	0	0	33	53	38	16
5	3	0	0	0	0	0	2	2	0	0	1	13	8	4	1
6	8	1	0	0	0	3	1	1	0	0	0	3	1	0	1
7	64	0	0	0	0	1	0	1	0	0	0	1	5	3	0
Total	100	4	0	0	0	10	13	11	3	0	4	81	104	68	38

*Category 1 is smallest target, category 5 is largest.

lake. The vertical distribution was broader at night, but still remains primarily in the deeper water. Very few small targets were observed during the day, so no comparisons could be made.

Because of the strikingly smaller target strength of the fish above the thermocline, this depth strata was treated separately from the deeper two in subsequent analyses. The fact that most of the shallow targets were in the lowest echo strength category indicates that the fish residing at this depth were undersampled. In addition, the extreme temporal and spatial variability in observations from this strata makes analysis of trends very difficult. In contrast, the deep and intermediate strata were pooled because of the similarity of the acoustic targets.

Horizontal Distribution

There were major differences in the density of fish in the deeper strata among transects. Highest densities were observed in areas 3, 4, and 5. These were significantly greater than the next most dense areas, 6 and 7. In fact, there was no overlap in density observations between these two groups. Similarly, areas 6 and 7 had significantly greater densities than areas 1 and 2 (Mann Whitney U, $\alpha = 0.05$).

There were also definite trends in the north-south distribution. These trends were not analyzed statistically, but can be seen from the echograms. Figure 6 illustrates the distribution at night in areas 3 and 4. Fish were more frequently detected in the southern half. In area 3 this distribution appeared to be associated with a ridge along the bottom about 500 m off the south shoreline which created a vertical dropoff of about 5 m. Daytime distribution was similar with one exception. On several occasions, large fish targets were observed near bottom, close to shore (fig. 7).

The shallow depth targets were characterized by extreme patchiness. Nevertheless, they appeared to be distributed primarily near shore, as illustrated by figure 8.

Temporal Variability

The daily variability in fish density measurement on the lower lake was large between the first and third night surveys (table 2). However, this trend was not significantly different (Wilcoxson match ranked pairs, $\alpha = 0.05$).

The diel variability in fish density measurements was low relative to most of the lakes that we have measured in the past. Although the fish density measurement during the day tended to be in the lower range of measurements in that area, this trend was not significant (Wilcoxson, $\alpha = 0.05$).

Population Estimates

Three population estimates were made during the survey by combining the intermediate and deep strata data collected on the upper and lower lake

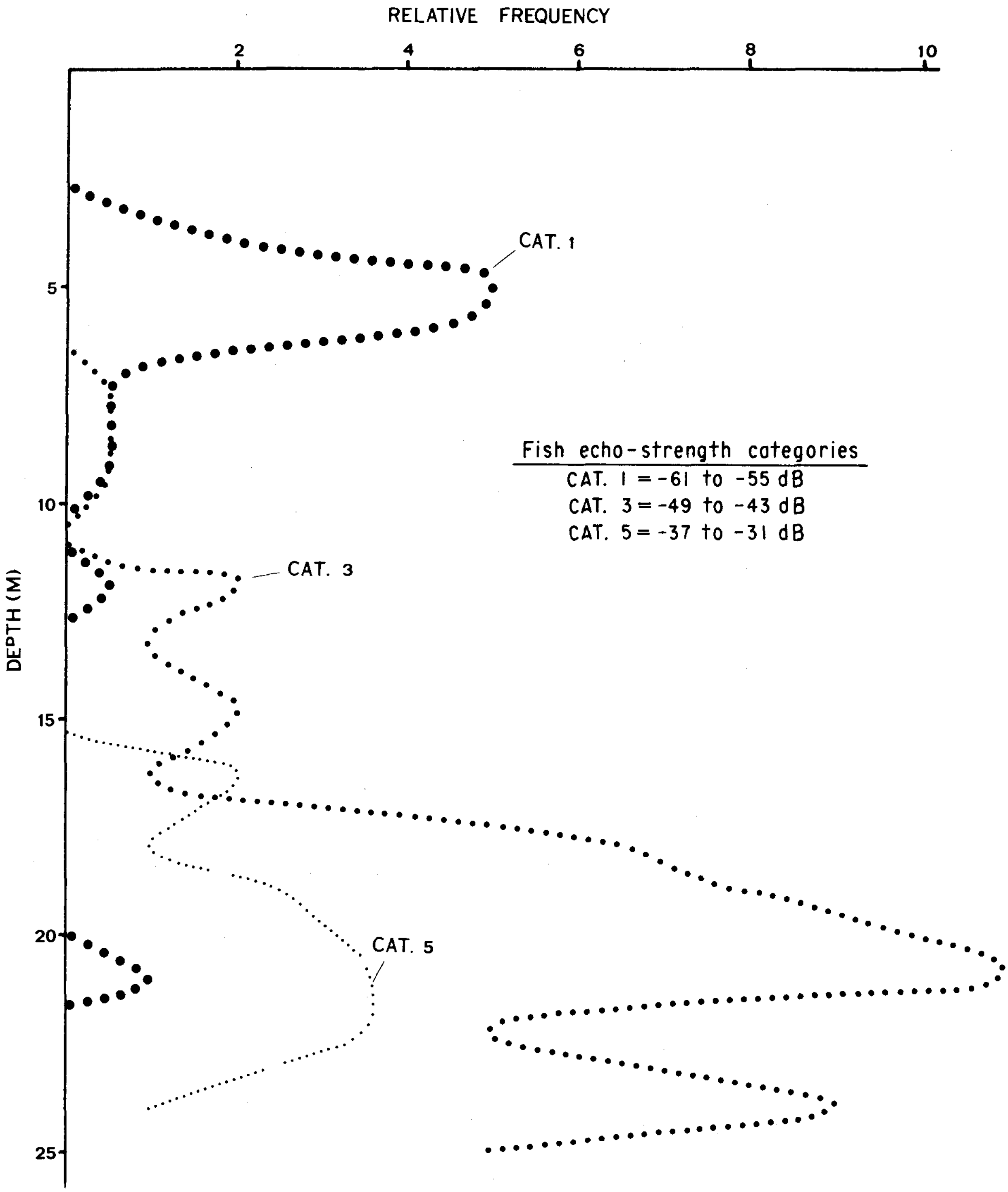

Figure 3.—Relative frequency of detection for echo strength categories 1, 3, and 5, in lower lake at night.

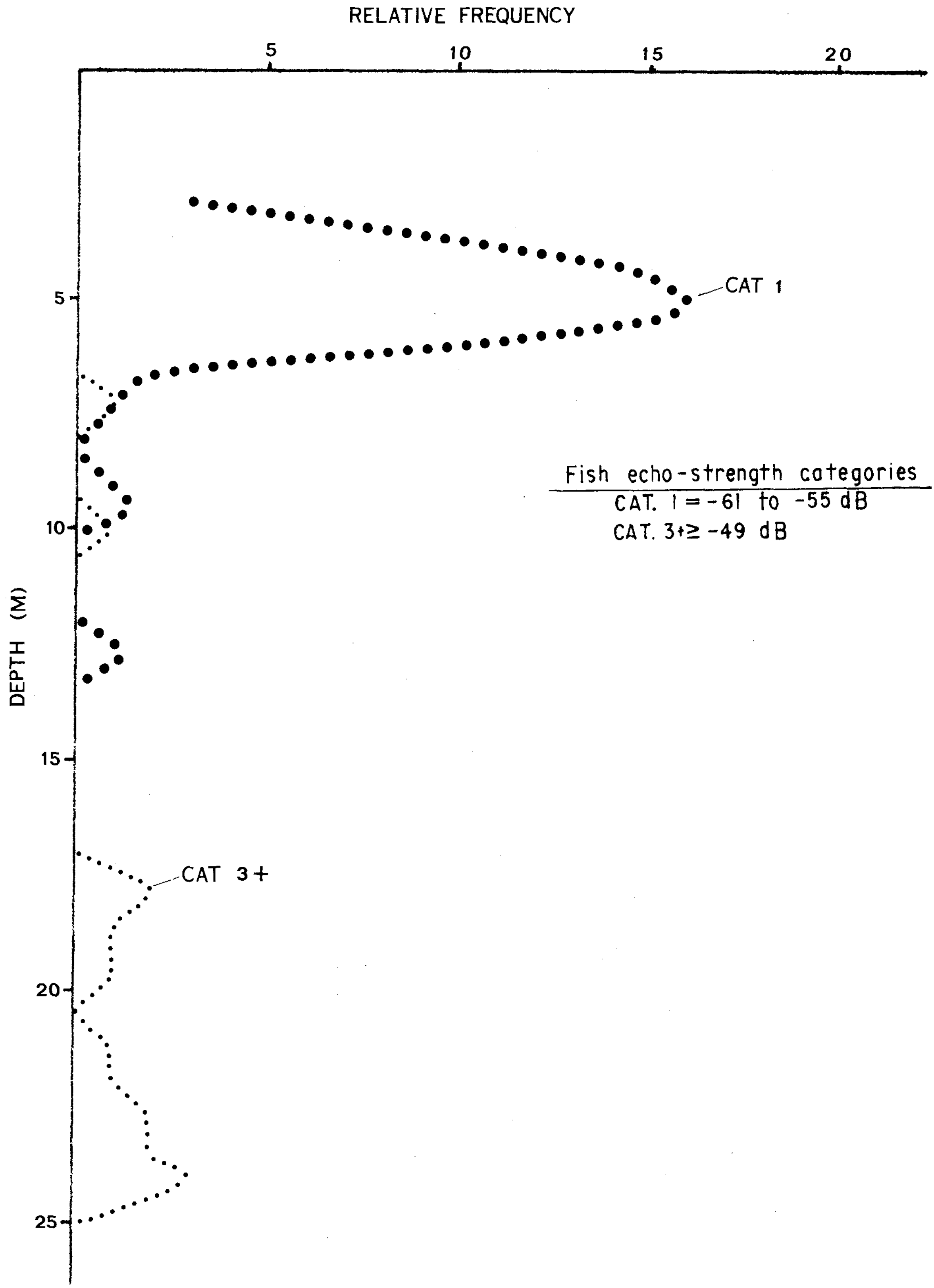

Figure 4.—Relative frequency of detection for echo strength categories 1 and 3+ in upper lake at night.

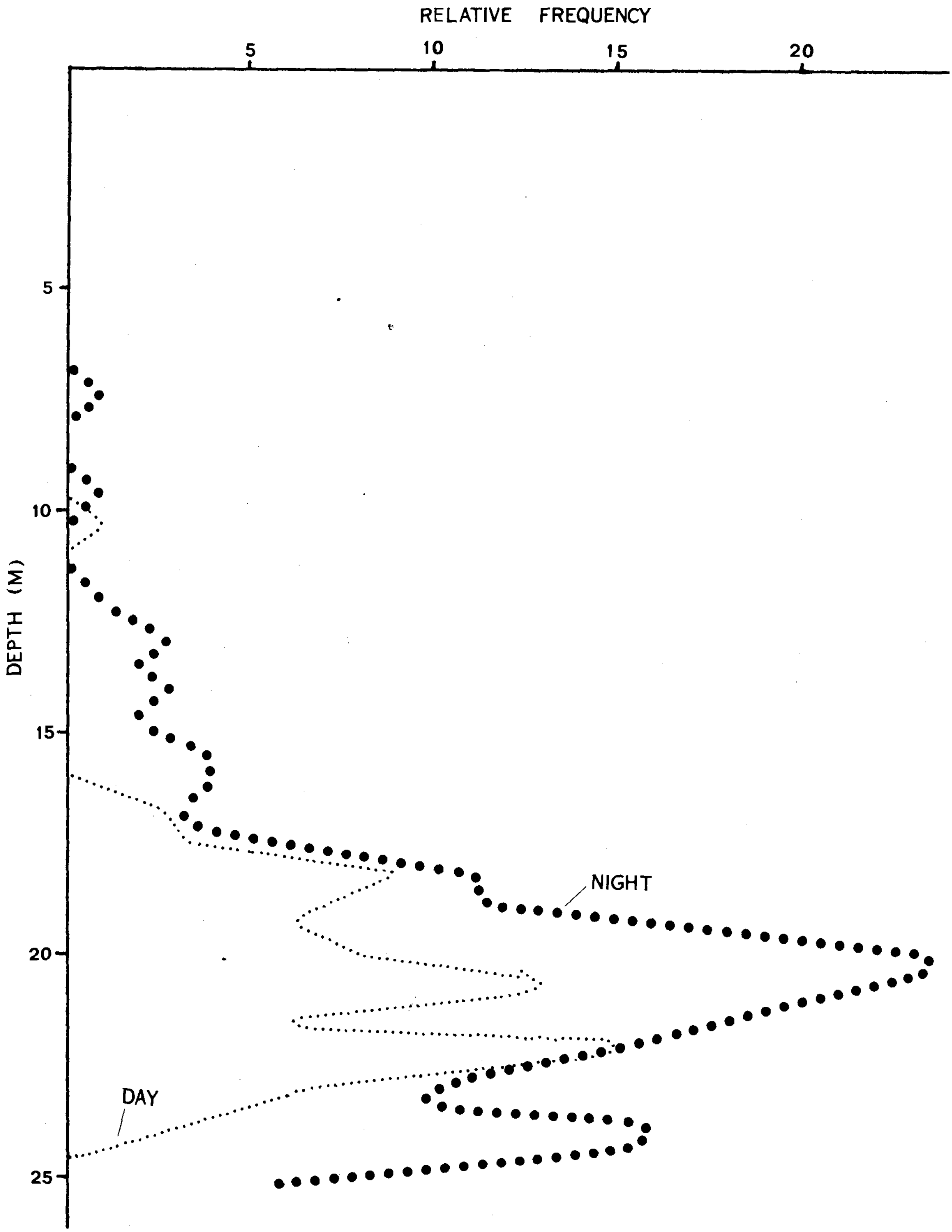

Figure 5.—Relative frequency of detection for large targets (over −49dB echo strength) day versus night in lower lake.

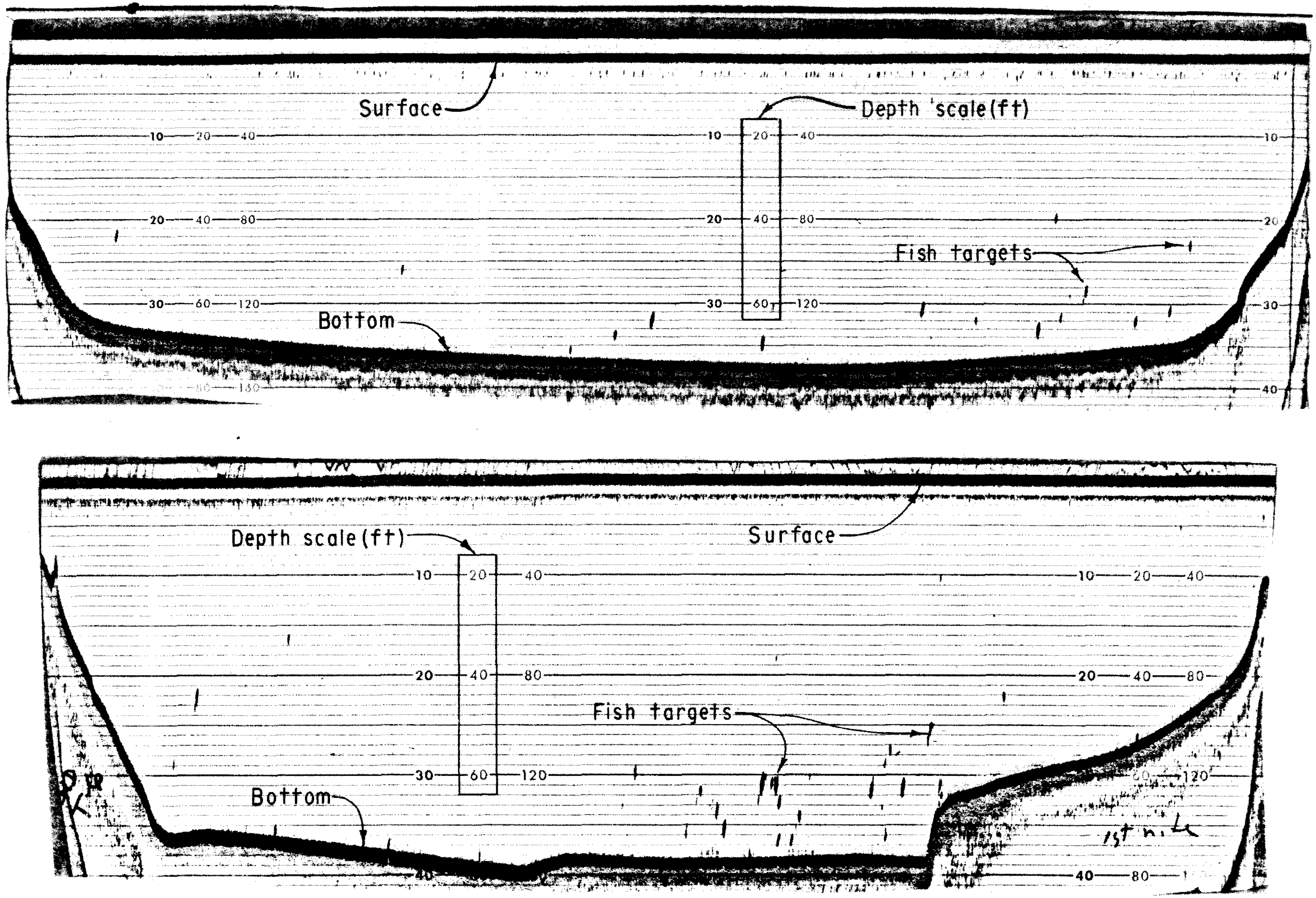

Figure 6.—Echograms from night runs in areas 3 (lower) and 4 (upper).

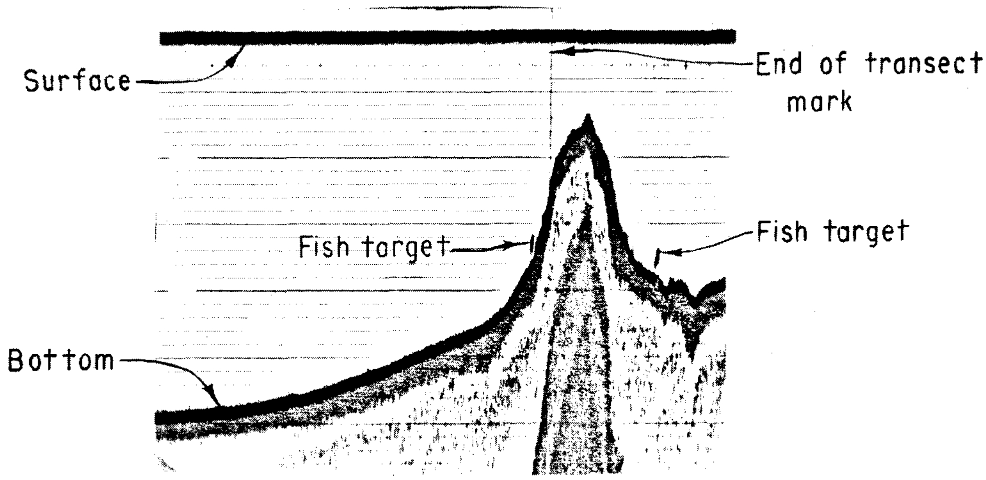

Figure 7.—Echogram from daytime run in lower lake showing near-shore distribution.

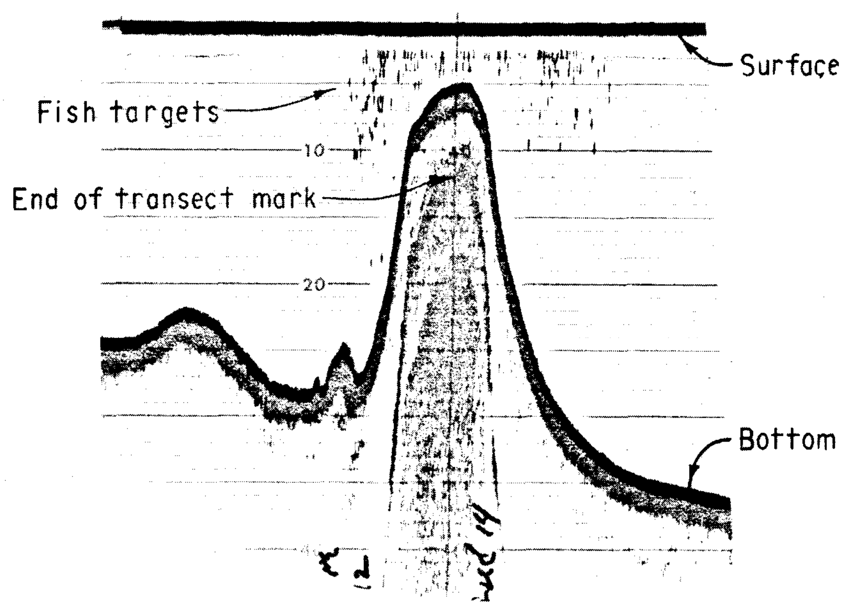

Figure 8.—Echogram from night run in upper lake showing near-shore distribution.

on nights 1 and 2, night 3, and day 1. The results were 17,389 ± 13,130, 10,206 ± 7,249 and 8,143 ± 8,081; respectively (table 3). The relative sampling error was highest at 45 percent for the daytime survey, indicating a more contagious distribution of fish during daylight. The relative sampling error for nights 1 and 2 estimate was higher than night 3 (34% versus 32%) despite complete replication with less than 5 percent deviation about the mean. This indicated the fish were more contagiously distributed on nights 1 and 2 than on night 3. The contagious distribution of the fish is believed the primary source of error in these estimates as indicated by the lower relative sampling error during the night, which also corresponded to a more uniform vertical distribution at night. Despite an approximate twofold difference in the population estimate between nights 1 and 2 and night 3 (night estimates being chosen the best on basis of lower error), the

Table 2.—*Densities of fish in various area and depth strata in Twin Lakes*

Area	Survey	Area sampled (10^3m^2)			Density (fish/10^3m^2)		
		Deep	Interm.	Shallow	Deep	Interm.	Shallow
1	N-1	77.3	10.1	2.8	0	0	0
(124 ha)	N-1	72.7	18.0	2.6	0	0	0
	N-3	81.0	20.0	2.9	0	0	0
	D-1	70.4	17.3	2.5	0	0	0.8
2	N-1	76.8	19.0	2.8	0.10	0.32	6.8
(128 ha)	N-1	80.5	21.8	2.9	0	1.06	4.6
	N-3	65.8	16.3	2.4	0.32	0	0
	D-1	85.6	21.2	3.1	0	0.57	0
3	N-1	88.3	21.8	3.2	3.14	1.10	0
(135 ha)	N-1	85.6	21.2	3.1	2.98	1.08	0.6
	N-3	88.3	21.8	3.2	1.94	9.14	1.8
	N-3	70.2	17.4	2.5	2.48	0.63	1.5
	D-1	77.3	19.1	2.8	2.29	0	0
	D-2	74.5	18.4	2.7	0.98	0	0
4	N-1	70.7	17.5	2.5	5.67	0.69	0.8
(113 ha)	N-1	73.6	18.2	2.6	5.53	.27	0.7
	N-3	60.7	15.0	2.2	2.26	.73	0
	N-3	63.4	15.7	2.3	3.21	.83	0.8
	D-1	63.4	15.7	2.3	2.87	.19	0
	D-2	60.3	14.9	2.2	1.36	0	0
5	N-1	58.3	14.4	2.1	1.48	1.04	0.9
(90 ha)	N-1	46.9	11.6	1.7	1.15	0	1.1
	N-3	49.7	12.4	1.8	1.40	0.29	1.1
	D-1	46.5	11.5	1.7	0.62	.43	0
6	N-2	57.3	14.2	2.1	.12	.42	3.6
(98 ha)	N-2	56.1	13.9	2.0	.20	.29	3.8
	N-3	47.4	11.7	1.7	.44	.60	1.1
	D-1	50.6	12.5	1.8	.16	0	0
7	N-2	50.1	12.4	1.8	.60	0	48.6
(98 ha)	N-2	54.0	13.4	1.9	.35	0	26.0
	N-3	44.6	11.0	1.6	.20	0.27	0
	D-1	48.6	12.1	1.8	.60	.41	2.1
SPECIALS	up W to E	60.7	15.0	2.2	.79	0	0
	low W to E	121.9	30.1	4.4	1.10	0	0
	40 log R	90.2	22.3	3.2	3.13	0	0

Table 3.—*Population estimates of fish in deep and intermediate strata in Twin Lakes*

Survey	Lake	N_T	Var (N_T)	Sampling error	Relative sampling error	95% confidence interval Upper	Lower
Night 2	Upper	961	2.30 E + 05				
Night 1	Lower	16,428	3.42 E + 07				
—	Total	17,389	3.43 E + 07	5,860	34%	34,778	5,259
Night 3	Upper	1,490	1.54 E + 05				
	Lower	8,716	1.07 E + 07				
—	Total	10,206	1.09 E + 07	3,295	32%	17,455	2,957
Day 1	Upper	1,137	3.46 E + 05				
	Lower	7,006	1.31 E + 07				
—	Total	8,143	1.35 E + 07	3,673	45%	16,286	62
Night pooled	Total	14,578	2.54 E + 07	5,040	35%	25,010	4,145

two nighttime estimates were within each others' 95-percent confidence limits. The pooled night surveys produced an estimate of 14,578 ± 10,432.

The data from the shallow depth stratum were not suited for population estimation because of the high variability, under-sampling, and uncertain composition. Nevertheless, for the sake of comparison, the total pooled runs would produce an estimate of 26,800, of which 85 percent result from the N 2 runs in area 7.

DISCUSSION

In many respects, Twin Lakes was ideally suited to application of hydroacoustic techniques. Fish densities were sufficiently low for echo counting techniques. Target sizes were generally large so that signal-to-noise characteristics were very good. Consequently, these results should provide valuable preoperational information on the fish populations in Twin Lakes. In addition, the results and experience will be of value to fisheries biologists faced with similar assessment problems. Both these positive aspects of the results and possible areas for improvement can best be appreciated by evaluating the sources of potential uncertainty in hydroacoustic estimates and their probable magnitude in the Twin Lakes study.

Uncertainty in hydroacoustic estimates comes from random and systematic sources. The amount of uncertainty due to random variability is quantified by the confidence intervals. The 95-percent confidence intervals on the hydroacoustic estimate for the deeper strata at Twin Lakes were about ± 72 percent of the mean. The major reason for these relatively wide confidence intervals was the low fish density. Hydroacoustic techniques are characterized by high sampling power, and during the 3-day effort about 5-percent of the volume of the lakes below the thermocline (about 12 m) was sampled. Normally, this level would produce high confidence. For example, similar surveys in Ozette Lake, Washington, produced 95-percent confidence intervals of ± 7 percent of the mean. However, the combined low density and contagious distribution at Twin Lakes resulted in much wider confidence intervals than are usually obtained with this level of sampling.

Sources of potential systematic error in the estimate can be categorized into three types: (1) those associated with the techniques for estimating the abundance of hydroacoustically detectable fish targets, (2) error associated with assumptions concerning species composition, and (3) error due to undetectable fish targets. Studies of the sources and magnitudes of error in echo counting techniques have been conducted by Nunnallee (1980) [13]. Using his model, the maximum bias in the technique under the conditions at Twin Lakes would be less than 5 percent for the deeper depth strata. The bias in the shallow depth strata is potentially large, because of the unknown portion of the population with target strengths below the minimum detectable with the gain settings used at Twin Lakes.

The major objective of the study was to investigate the abundance and distribution of lake trout. While the total error in the estimate of the fish population in the deeper strata of Twin Lakes is insignificant, as stated above, error can be associated with the interpretation of the estimate with respect to the lake trout population. This potential error is associated with uncertainties in the species composition and the proportion of hydroacoustically undetectable fish.

Simultaneous gill net sampling was conducted by the Colorado Cooperative Fishery Research Unit. Their results indicated that the species composition below the thermocline was almost exclusively lake trout. Ninety-five percent of the fish from the net samples in this stratum, including 100 percent in the midwater sets, were lake trout (Tom Nesler, personal communication). The intermediate depth stratum in the hydroacoustic estimate extended to 7.5 m, thus it included a few targets from above the thermocline (see figs. 4 and 5), where net samples indicated presence of rainbow and brown trout and suckers as well as lake trout. However, these gill net sets were on bottom, and the other species, especially the suckers, might not have been sufficiently off-bottom for detection with the hydroacoustic system. Thus it seems reasonable to conclude that the population estimate from the combined deep and intermediate strata is predominately lake trout.

An occasional lake trout was caught near shore in the shallow depth strata and along the bottom in the intermediate depth strata. Those in the shallow zone would be excluded from the estimate even if detected, and those in the intermediate stratum would not have been detected if within 1/4 m of the bottom. However, the species composition and distributional information indicate that both the contribution of other than lake trout to the hydroacoustic estimate and the number of lake trout not included are probably minor, as well as opposite in direction of error, so that the hydroacoustic estimate of abundance from the two deeper strata is a reasonable estimate of the lake trout population.

The only previous population estimate of lake trout in Twin Lakes was obtained from a mark-recapture study. This population estimate of 73,556 with 95-percent confidence limits of 33,690 to 200,608 was based on only 6 recaptures and some uncertain mortality assumptions (Griest, 1977 [14]). The hydroacoustic estimate of 14,578 $\pm$ 10,432 indicates either that the mark-recapture estimate was in error, or that considerable reduction in population occurred between the two estimates.

The hydroacoustic data indicated considerable abundance of small fish in shallow, near-shore water. Possible species are rainbow trout, suckers, and juvenile lake trout. Rainbow trout are known to be present in this stratum, and previous hydroacoustic studies on rainbow have indicated considerable patchiness (Thorne, 1976 [9]). However, their abundance should be relatively low in September, and their acoustic size should be larger than those observed in the surveys. Suckers are undoubtedly abundant in this area, but should be near-bottom and hydroacoustically undetectable. The observations might be accounted for by juvenile lake trout. The literature suggests that young-of-the-year lake trout prefer the water temperatures below the thermocline, but there was no indication of an abundance of small targets in the deeper strata. Possibly the juveniles move into the shallow water at night, and are on bottom during the day. This would account for both the observations and the extreme variability.

CONCLUSIONS AND RECOMMENDATIONS

The hydroacoustic techniques provided considerable information on the abundance and distribution of fish in Twin Lakes. Some improvements in the procedures are possible. The low density and contagious distribution resulted in wider than expected confidence intervals. If these trends hold, future surveys should obtain larger sample sizes and in particular allocate more effort in the limited higher density areas. Minor improvements in the population estimate and considerably greater precision in fish size information could be obtained with a dual-beam system (Thorne, 1976 [9]). The low densities in Twin Lakes are ideal for the dual-beam, but provide too small a sample for good size discrimination with a single beam.

The hydroacoustic and gill net samples were very complementary. The hydroacoustic data provided distributional and abundance information, while the gill nets provided species composition, biological samples, and data from near-shore and near-bottom. Continued use of these techniques in complement is recommended in order to maximize the value of the gill net effort. The present level of mortalities from gill net sampling probably does not adversely affect the population; however, the population size is sufficiently small that research techniques involving removals must be viewed cautiously. Greater information on the efficiency and selectivity of gill nets could be obtained by simultaneous use with stationary acoustic systems, especially dual-beam systems. This is an area which is, unfortunately, neglected in fisheries research. It is theoretically possible to precisely evaluate gill net performance as a function of fish density, size, and swimming speed with a stationary dual-beam system. Stationary systems can also provide data on fish abundance and distribution during ice cover (Thorne, 1980 [15]).

The objectives of this study were focused on the larger lake trout, and the hydroacoustic system used in the survey at Twin Lakes was not well suited for estimation of fish abundance in the shallow and near-shore depth zones. In addition to the inappropriate gain settings for these smaller targets, the sample size is very small. The proportion of the shallow depth strata sampled during the entire survey was less than 1 percent. The shallow and near-shore strata can readily be surveyed with hydroacoustic techniques, but require a system and survey designed specifically for that purpose.

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