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ACOUSTIC SURVEY II OF SHUSWAP LAKE, BRITISH COLUMBIA, CANADA

by

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Robert L Burgner
Director

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INTRODUCTION

A second acoustic survey of the Shuswap Lake fish population was made by members of the Fisheries Research Institute at the University of Washington at the request of the International North Pacific Salmon Fisheries Commission. The field work was completed during the nights between October 12 and 15, 1972. These dates are comparable to the period of the 1971 survey when the field work was done during the nights between October 6 and 9. The primary objective of the survey, as in 1971, was to acquire permanent records that will be of help in future analysis of fish abundances, distributions and target strength measurements. The acoustic survey techniques and methods of analysis of the 1972 survey were similar to those used for the 1971 survey with several improvements that will be discussed later. There is still a continuing need for improvement and simplification of the technique however.

METHODS AND MATERIALS

Field Observations

The survey was conducted from a 16-ft covered I-O powered boat provided by the Commission. The data collection system used for the 1972 survey was the same as that described previously with the addition of a calibration circuit whereby the echo sounder gain can be standardized easily at any time in the field or during data analysis. A procedure similar to that established for the 1971 survey was applied to the 1972 survey except that Little Shuswap Lake was included. The records obtained for each transect included; 1) a log stating transect time and duration, a measure of system gain, direction heading and any necessary comments, 2) an echogram, except for transects 28 through 39 which were lost due to equipment failure and 3) recordings of received signals on magnetic tape. The location of each transect is shown in Fig. 1 and a summary of pertinent data in Table 1.

ANALYSIS

Analysis of the data recorded on magnetic tape during the acoustic survey of Little Shuswap and Shuswap Lakes was done to attain three major parameters: (1) estimation of absolute fish density; (2) description of the spatial distribution of fish targets; and (3) estimation of fish size through target strength analysis.

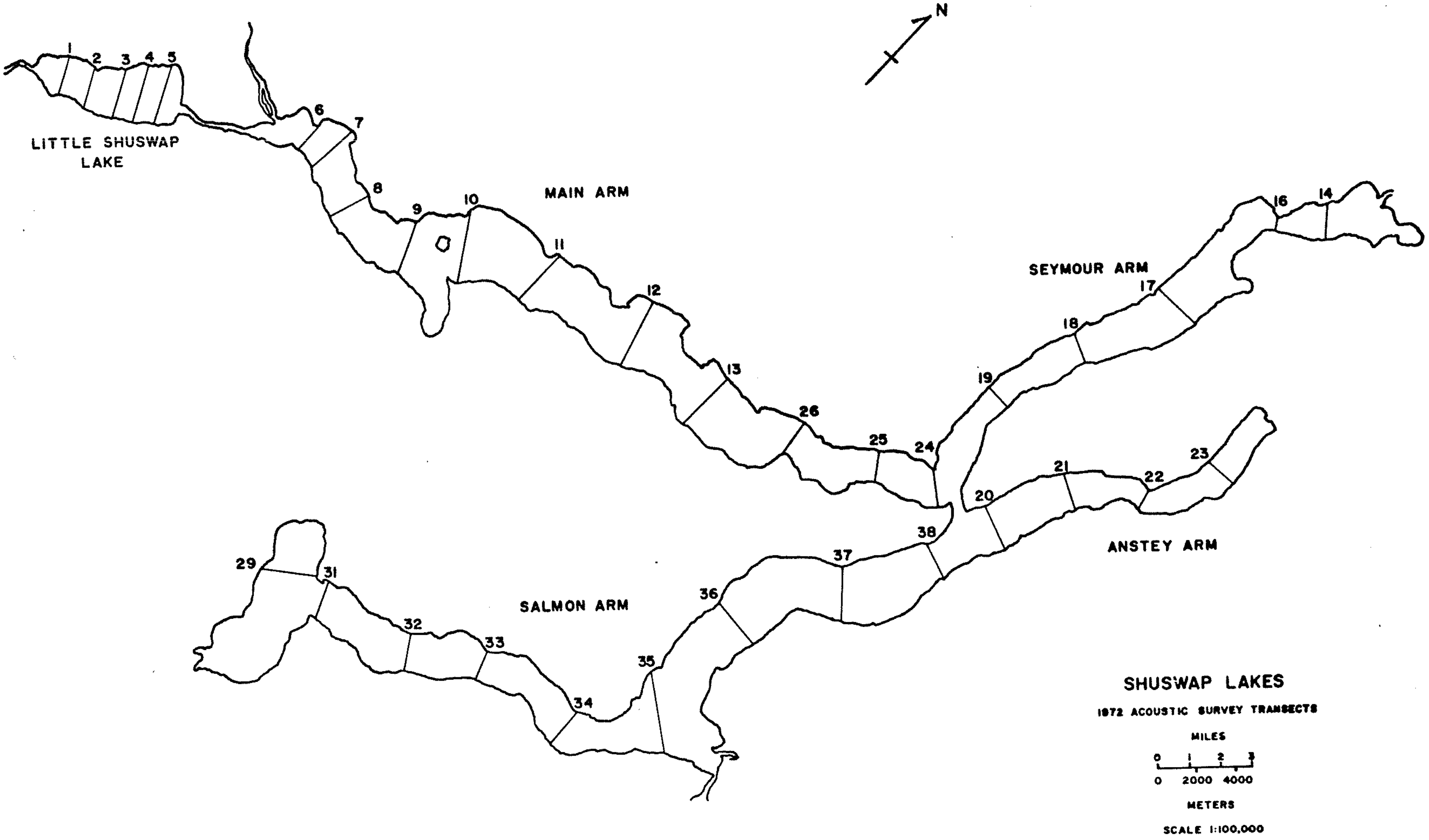

Fig. 1. Location of transects used for the 1972 acoustic survey of Little Shuswap and Shuswap Lake.

Table 1. Summary of echograms and magnetic tape recordings from Shuswap Lake, British Columbia, October 12-15, 1972

Date	Location	Transect no. 1972	Time		Duration (min)	Corresponding transect no. 1971
			Start	Stop		
Oct 12-13	Little Shuswap	1	2121	2144	23	
12-13		2	2153	2210	17	
12-13	"	3	2219	2240	21	
12-13	"	4	2248	2310	22	
12-13	"	5	2320	2340	20	
12-13	Main Arm	6	0024	0035	11	2
12-13	"	7	0055	0110	15	
12-13	"	8	0140	1158	18	3
12-13	"	9	0210	0232	22	4
12-13	"	10	0245	0313	28	5
12-13	"	11	0445	0508	23	6
12-13	"	12	0538	0607	29	7
12-13	"	13	0624	0645	21	8
13-14	Seymour Arm	15	2045	2100	15	14
13-14	"	16	2109	2119	10	15
13-14	"	17	2205	2220	15	16
13-14	"	18	2240	2253	13	17
13-14	"	19	2345	2355	10	18
13-14	Ansty Arm	20	0018	0035	17	20
13-14	"	21	0047	0100	13	21
13-14	"	22	0115	0120	5	22
13-14	"	23	0128	0150	22	23
13-14	Main Arm	24	0235	2047	12	11
13-14	"	25	0300	0311	11	10
13-14	"	26	0327	0336	9	9
13-14	Salmon Arm	29	1909	1937	28	24
13-14	"	31	2015	2027	12	25
13-14	"	32	0845	0859	14	26
13-14	"	33	2127	2140	13	27
14-15	"	34	2152	2210	18	28
14-15	"	35	2214	2240	26	29
14-15	"	36	2257	2320	23	30
14-15	"	37	2345	0005	20	
14-15	"	38	0020	0030	10	19

Acoustic Sample Volume

Fish densities derived by hydroacoustic techniques most easily are expressed as the number of fish targets per unit volume. To convert the number of fish detected per pulse of the echo sounder to a density expression it was necessary to determine the effective sample volume per pulse. The method utilized has been described thoroughly by Nunnallee and Mathisen (1972). The results of the effective sample volume estimation are given in Tables 2 and 3.

Target Counts

Fish target counts were made by observing specific depth intervals on an oscilloscope while tape recordings representative of Little Shuswap Lake, and the Main Arm, Seymour-Anstey Arms, and Salmon Arm of Shuswap Lake were played back. Cursory analysis of the tape recordings and of the echograms indicated nearly all of the fish detected were distributed above 44 m depth. For purposes of analysis the interval from 3.7 to 32.8 m was divided into six strata. The initial interval extended from 3.7 to 7.3 m, followed by 7.3 m intervals starting at 7.3 m and stopping at 43.9 m. System noise and transect pulse length eliminated counts shallower than 3.7 m.

The propagation of sound through fresh water requires 1.37 ms/sonar m; the time required for the echo of a pulse of sound to return to its place of origin after its reflection from a target at a distance of 1 m. Depth was interpolated from the oscilloscope display by conversion of the delay (ms) after the transmitted pulse when a target was detected. Successive echo traces were displayed on the oscilloscope at the rate of two/sec. All data were recorded at a tape speed of 9.5 cm/sec. Each division on the cathode ray tube screen was made to represent a 7.3 m interval by setting the sweep function of the oscilloscope at 10 ms/div. A 10x expanded sweep function of the oscilloscope allowed observation of each 7.3 m (10 ms) depth interval across the full width of the screen, thus eliminating fish echoes detected above or below the depth interval of interest.

Target counts for all depth intervals along each transect were made in 2 min segments. One minute segments were counted in Little Shuswap because of the relatively short transects and shallow water. All counting commenced and ended at the 4 m depth contour in Little Shuswap and the 18 m depth contour in Shuswap Lake in an attempt to eliminate counting resident nonsalmonid fish along the shoreline. Counts were made of all target detections observed in each of the time-depth cells of transects selected as representatives of the four survey sections of Little Shuswap and Shuswap Lake. Absolute fish densities were then calculated by use of the effective sample volume estimates described previously.

Table 2. Frequency of observation of detections per fish and the mean number of detections per fish at the midpoints of specified depth intervals

Detections per fish	Frequency of observation at midpoint of depth interval (m)					
	5.5	11.0	18.3	25.6	32.9	40.2
1	21	37	12	1	6	1
2	1	31	22	10	5	1
3		25	30	13	7	5
4		7	25	16	7	5
5		0	25	11	6	11
6		1	14	9	6	3
7			2	15	11	2
8			1	12	11	5
9				4	11	10
10				0	9	14
11				1	4	6
12					1	5
13					2	3
14						1
15						0
16						1
Total number detections (d_i)	23	208	477	481	567	590
Total number observations (0_i)	22	101	131	92	86	73
Mean number detections per fish ($d_i/0_i$)	1.05	2.06	3.64	5.23	6.59	8.08

Table 3. Effective beam dimensions and pulse volumes for the indicated depth intervals.

Depth interval (m)	Radius of cone at midstratum depth (m)	Effective pulse sample volume (m^3)
3.7 - 7.3	0.39	1.76
7.3 - 14.6	0.77	13.70
14.6 - 21.9	1.36	42.76
21.9 - 29.3	1.98	89.65
29.3 - 36.6	2.46	138.74
36.6 - 43.9	3.03	210.71

Counting errors were directly proportional to the concentration of fish observed. To reduce this error when high fish densities were encountered, the two/sec display rate of echo traces on the oscilloscope screen was halved by reducing the tape speed from 9.5 to 4.8 cm/sec. The oscilloscope sweep speed was also halved to compensate for the slower tape speed.

Integration Procedure

Target counting from the oscilloscope is both tedious and time consuming. It is also limited to relatively low density situations. Therefore, the overall enumeration of fish densities for the four survey areas of Lake Shuswap was accomplished through echo integration by a small computer.

The integration of data recorded on magnetic tape was accomplished by the use of the Digital Data Acquisition and Processing System (DDAPS) computer (Moose et al, 1971). The system integrates voltages from fish targets within a maximum of 9 preselected depth intervals simultaneously and calculates fish abundances using input calibration and target strength data (Moose, Green, Ehrenberg, 1971). The abundance information is automatically printed out on a line printer for each predetermined depth interval. The determination of average target strengths of the fish within an acoustic survey area is difficult to determine and is usually complex due to their depth or areal distributions. Therefore, when the tape recordings of the survey were analyzed by use of the DDAPS computer, dummy parameters were used. This resulted in DDAPS density outputs that were relative than absolute. A means of converting relative to absolute densities was achieved by integrating the same recordings of transects that were analyzed by target counting on the oscilloscope. The depth and time intervals established previously were used to define the cells within which the integration of target data were completed. Care was taken to insure that the time intervals integrated along a specific transect corresponded precisely with those established for target counting of the same transect. The DDAPS density output for each depth and time interval was compared to the absolute density values calculated from target counts by a linear regression. Conversion of relative to absolute densities was made by applying the intercept and slope coefficients to the DDAPS relative density outputs. Regressions of target counts per/1,000^3 on DDAPS relative density outputs (Table 4) were estimated for a considerable number of depth-time cells within each of the four statistical areas of the lakes. In order to reduce variance due to possible integration of the bottom echo in shallower water, the first and last time segments of each transect were eliminated as variables from the regression equations. Two regressions were computed for Salmon Arm of Shuswap Lake when it was discovered that the fish were not uniform in size and were segregated by depth. The two regressions shown in Table 4 indicate a significantly different slope for the two depth strata, with the larger fish being the deepest. Further confirmation of this observation was that the range of target strengths in the shallower strata were single moded while those in the deeper strata were double moded and larger than the first. The effect was not apparent in the other survey areas.

Table 4. Results of linear regressions of oscilloscope density estimates on DDAPS relative density outputs for the indicated depth limits

Survey section	Depth limits (m)	Regression equations	C.L. slope coefficient (95%)
Little Shuswap Lake	3.7 to 58.5	$Y = 5.521 + 60.007 (X)$	42.6 to 77.4
Main Arm, Shuswap	3.7 to 58.5	$Y = 0.708 + 24.381 (X)$	22.13 to 26.64
Seymour - Ansty Arms	3.7 to 58.5	$Y = 1.100 + 22.974 (X)$	19.70 to 26.25
Salmon Arm	3.7 to 21.9	$Y = 2.736 + 71.169 (X)$	62.32 to 80.02
	21.9 to 58.5	$Y = 0.110 + 28.016 (X)$	24.67 to 31.36

Estimation of Fish Population

After determining the parameters necessary to convert DDAPS relative densities to absolute values for each of the four survey areas, the remaining transects in each area were integrated. Integration commenced and ended at the 18 m depth contour in all areas except Little Shuswap, where the 4 m depth contour was utilized. The preselected depth and time interval parameters used by the DDAPS computer remained unchanged through the analysis of the entire study.

The conversion of the DDAPS relative densities to absolute density estimates was done by a computer program written specifically for this purpose (Roger, 1972). The program calculated the absolute density of fish/1,000 m^3 for each time interval and depth stratum. It also estimated the number of fish/100 m^2 surface area for each depth stratum and for the surface area of the lake.

An estimation of the fish population in Little Shuswap Lake and in the Main Arm, Seymour-Anstey Arms, and Salmon Arm of Shuswap Lake was made by obtaining an average value of fish density/unit surface area of the lake in each area and by expanding these values to the total surface area of each of the four sections respectively. The total surface areas of Little Shuswap Lake and Shuswap Lake were known. However, the total surveyed surface area was somewhat less since it included only that area encompassed by the 18 m depth contour in Shuswap Lake and the 4 m contour in Little Shuswap Lake. A planimeter was used to calculate the actual surveyed surface areas of the three sections of Shuswap Lake and of Little Shuswap Lake. A list of the transects included in the four statistical areas was given previously in Table 1 and their location shown in Fig. 1.

Target Strength Measurement

Techniques for the estimation of target strength were applied to the recordings made in each section of the Shuswap Lake hydroacoustic survey in order to determine the size distributions of the fish. Tow net hauls were also made in these same areas and a comparision of estimated to observed fish size will be presented.

Target strength is defined as the ratio, expressed in decibels, of reflected to incident sound intensities and is therefore proportional to the size of a target. By convention, a 100% reflecting sphere with a diameter of 2 m has been accepted as having a 0 dB target strength. All hydroacoustic target strength measurements are referenced to this standard.

When hydroacoustic techniques are used in the measurement of target strengths, all of the parameters that influence the apparent target intensities must be known and their effects be accounted for. These parameters include the reduction of intensity per unit area of a transmitted pulse of sound with depth due to spreading (square law effect), the efficiency of the transducer as it converts electrical power to acoustical pressure and then pressure back to electrical power when an echo is received, and the gain of the receiver.

The mathematical equation used for determining target strength is:

$$TS = Vrms - SL - VR + 40\log R - \text{System Gain}$$

where TS = target strength in dB

$Vrms$ = target voltage at calibrated output, dB//1 volt

SL = source level, dBμ/v//1 μBar at 1 yd

VR = receiving voltage response, dBv/μBar//1v

r = distance to target in yd

The source level and receiving voltage response for the transducer were determined by usual calibration procedures at the Applied Physics Lab., University of Washington. For convenience, the decibel level of the transmitted voltage pulse applied to the transducer (ref to 1 volt) and the correction coefficient for the conversion of voltage to acoustic pressure were summed and used as the source level. The source level of the transmitter and the receiving voltage response of the transducer remained constant throughout the survey. The 40 logR term corrects for sound transmission loss due to spreading and consequently its value is depth dependent. A built-in calibrator was used to put a known voltage (100 microvolts rms) into the receiver. By recording the output on magnetic tape it was possible to calculate the gain of the system (echo sounder receiver, interface amplifier and tape player) at any depth (time) after the transmitted pulse. Because of a 20 logR time varied gain control circuit built into the receiver by the manufacturer to correct for one way spreading loss, the calibration tone output increases with time after the transmitter pulse. Therefore, the system gain is also depth (time) dependent and was measured at the depth corresponding to the center of each depth stratum analyzed.

Target strength measurements were made in each of the three survey areas of Shuswap Lake and Little Shuswap Lake. Specific transects were selected relative to their proximity to tow net hauls. Tape recordings of each transect were displayed on an oscilloscope and the fish echoes were observed at depth intervals previously established for target counts. Only the largest target amplitude from each series of successive insonifications of individual fish were measured. The largest amplitudes occurred when each fish was insonified nearest the axis of the sounder cone and was assumed to most nearly represent actual fish size. Target amplitudes were recorded only from a 2.9 m (4 ms) depth interval in the center of each 5.5 m depth stratum so that the mean depth for each interval contained negligible error due to spreading loss. All depth intervals in a transect were analyzed and combined because the target strength equation references all targets to a depth of 1 yd.

The calculation of raw target strength distribution curves were made by classifying measured target strengths into decibel categories. The initial step in the procedure involved calculating the target strength of the smallest echo pulse observed in the shallowest depth interval of a transect and then by chosing a convenient decibel level slightly smaller as a reference point. Using this as a starting point, a series of categories, increasing in 5 dB steps was established to cover the range of observed target strengths. The voltages associated with each 5 dB point on this span of target strengths was then calculated and the observed target voltages from fish echoes were placed into their repsective categories.

This classification of measured fish target amplitudes was carried out for all analyzed depth intervals of a transect. Because the same reference point (1 yd) was used to establish the 5 dB categorization for all depths, it was possible to sum the raw target amplitude distributions in all corresponding dB categories for all depth intervals. This resulted in an overall target amplitude distribution for each entire transect.

The amplitude of a fish echo is dependent upon its aspect and location within the sounder cone when it is detected. Therefore, a target amplitude distribution is not equivalent to a target strength distribution and is not a true representation of an actual fish size distribution because it cannot be assumed that each target is passed directly through the axis of the sounder cone.

A method whereby the size of fish can be estimated by use of target strength measurement has been suggested previously (Craig and Forbes, 1969). This method was applied to the Lake Shuswap survey data. The mean target strengths of each of the various target strength distributions from the survey sections of the lake, which were also representative of mean fish lengths, were calculated by use of the following equation.

$$\overline{TS} = \frac{\sum_{j=1}^{K} n_i \, dB_i \, Z}{N}$$

where n_i = number of observations in category i

dB_i = mean TS (dB) of category i

K = number of TS categories

$N = \sum_{j=1}^{K} n_i$ = total number of observations in all categories.

The distributions of target strength observations for Little Shuswap Lake and for each of the sections of Shuswap Lake and the mean target strength and estimated fish lengths represented by each mode of these distributions are summarized in the RESULTS section.

Analysis of Variance of Replicate Transects

One transect in each of the previously described survey sections in Shuswap Lake was duplicated in order to calculate variances associated with fish density estimates due to effects of survey section, transect and depth respectively. The duplicate sets were chosen randomly at the time of the survey. The second transect of each designated pair was recorded immediately upon completion of the first by returning over the exact course of the previous transect.

A double nested analysis of variance design was used to analyze the data. The survey sections within Shuswap Lake were treated as fixed effects with three levels corresponding to the three survey areas. Pairs of transects within survey sections and depths within transects were considered as random effects with two levels for transects and six for depth. By considering the transects within each pair as replicates, it was possible to define replicate observations within each depth interval of a transect as the absolute density values from corresponding two minute time intervals. Because the length of transects varied among sets, only density values from the last four time intervals of the first transect and the first four time intervals of the second transect in each set were used as replicate observations.

The data were analyzed by the BMD-08V computer program which performs an analysis of variance for any hierarchical design with equal cell sizes. Replicate observations were assumed to be independent and uncorrelated. The model used was:

$$Y_{ijkr} = \theta_i + \alpha_{j(i)} + \beta_{k(ij)} + e_{ijkr}$$

where:

θ_i = survey sections with i = 1, 2, 3

α_j = transects with j = 1, 2

β_k = depths with k = 1, .., 6

e = error term

r = replicate observations.

The results of the analysis of variance are shown in Table 5.

A second and third analysis of variance associated with observed fish densities was designed to make a rough test of the effectiveness of the sampling scheme used in the Shuswap survey. This was done first by assuming that alternate transects could be classified into two series that could be treated as replicate surveys of the lake. Second, three replicates were generated by a similar method. The purpose of these tests was to see to what extent the sampling effort could have been reduced without significant deterioration of accuracy. The transects associated with each series and test are shown in Table 6.

Table 5. Analysis of variance to determine the validity of replicate transects in Shuswap Lake

Source	df	ss	ms	F ratio
Total	168	621.56		
CFM	1	309.83		
Arms	2	41.13	20.56	70.89
Transects within arms	3	0.88	0.29	0.04
Depths within transects	36	237.54	6.57	25.66
Residual	126	32.28	0.26	

H_o: No fish density differences among depths within replicate transects
$F_{.05}(36,126) = 1.61$; $25.66 > 1.61$, $\therefore$ reject H_o.

H_o: No difference among replicate transects within arms.
$F_{.05}(3,36) = 3.46$; $0.04 < 3.46$, $\therefore$ accept H_o.

H_o: No fish density difference within arms.
$F_{.05}(2,3) = 16.04$; $70.89 > 16.04$, $\therefore$ reject H_o.

Table 6. Listing of the transects associated with each series and test of the analysis of variance used to test the effectiveness of the Shuswap Lake survey

Test	Series	Transect number											
1	A	7	9	11	13	25	19	29	32	34	36	38	21
	B	8	10	12	26	24	18	31	33	35	37	20	22
2	A	7	10	13	24	29	33	36	20				
	B	8	11	26	19	31	34	37	21				
	C	9	12	25	18	32	35	38	22				

The model used in the analysis is as follows:

$$Y_{ijkr} = \theta_i + \alpha_{j(i)} + \beta_{k(ij)} + e_{ijkr}$$

where:

θ_i = series with i = 1, 2 or i = 1, 2, 3.

α_j = transects within series with j = 1, ..., 12 or j = 1, ..., 8.

β_k = depths within transects with k = 1, ..., 6. (for both tests)

e = error term

r = replicate observations with r = 1, ..., 4. (4 two min time intervals were taken from the center of each transect).

The results of the two ANOVA tests are shown in Tables 7 and 8.

It can be seen from Table 7 that although there are significant fish density differences among depths and transects, there is no significant difference between the two series. Table 8 does indicate significant differences among the three series used as replicates. This implies that perhaps the sampling effort on Shuswap Lake could be halved without significant deterioration of the accuracy of fish density and subsequent population estimates. However, the sources of error associated with estimation of fish density by the acoustic techniques described previously have been ignored in this test and the amount of effort expended during the 1972 survey of the lake could probably not be reduced much without significant loss of accuracy. The above tests do imply that the present sampling scheme is probably adequate, however.

RESULTS

The mean density of fish/100 m^2 surface area of Little Shuswap Lake and Shuswap Lake ranged from 4 to 26 in 1972. A list of the fish densities observed for each transect in the 1972 acoustic survey and the corresponding densities observed in 1971 are given in Table 9. They are also shown graphically on a map of the area in Fig. 2.

Population estimates of the fish in each of the statistical areas was made by expansion of the mean fish density/m^2 over the area of each section. The results of the expansion are shown in Table 10.

Target strength analysis was applied to the data collected during the survey of Little Shuswap and Shuswap Lake to estimate the size of the fish. The mean target strength of the various modes, the estimated fish lengths and the mean lengths from tow net hauls are shown in Table 11. The frequency of occurrence in the various target strength categories are shown

Table 7. ANOVA results of test to determine if significant fish density estimate differences would result if sampling effort was reduced to one-half

Source	df	ss	ms	F ratio
Total	576			
CFM	1	2991.5	2991.5	
Series	1	2.1	2.1	1.06
Transects within series	22	1246.8	56.7	29.06
Depths within transects	120	4961.0	41.3	21.20
Residual	432	842.4	2.0	

H_o: No difference in density among depths within transects.

$F_{.05}(120,432) = 1.17$; $21.2 > 1.17$, $\therefore$ reject H_o.

H_o: No difference in density among transects within series.

$F_{.05}(22,432) = 1.55$; $29.06 > 1.55$, $\therefore$ reject H_o.

H_o: No mean density difference between series.

$F_{.05}(1,432) = 3.84$; $1.06 < 3.84$, $\therefore$ accept H_o.

Table 8. ANOVA results of test to determine if significant density estimate differences would result if sampling effort was reduced to one-third

Source	df	ss	ms	F ratio
Total	576			
CFM	1	2991.5	2991.5	
Series	2	21.3	10.63	5.45
Transects within series	21	1227.7	58.46	29.90
Depths within transects	120	4960.0	41.34	21.20
Residual	432	842.4	1.95	

H_o: No difference among depths within transects.

$F_{.05}(120,432) = 1.17$; $21.2 > 1.17$, $\therefore$ reject H_o.

H_o: No difference among transects within series.

$F_{.05}(21,432) = 1.56$; $29.9 > 1.56$, $\therefore$ reject H_o.

H_o: No difference among series.

$F_{.05}(2,432) = 3.00$; $5.45 > 3.00$, $\therefore$ reject H_o.

Table 9. Transect numbers and fish densities observed during the 1971 and 1972 Shuswap Lake acoustic surveys

Transect number			Densities/are	
1971	1972	Area	1971	1972
	1	Little Shuswap		3.80
	2	" "		21.50
	3	" "		19.30
	4	" "		18.97
	5	" "		4.54
2	6	Main Arm	70.60	5.35
	7	" "		8.84
3	8	" "	75.00	17.25
4	9	" "	26.70	5.19
5	10	" "	56.30	4.35
6	11	" "	25.60	5.68
7	12	" "	27.80	8.44
8	13	" "	8.80	5.94
14	15	Seymour Arm	12.40	8.07
15	16	" "	25.20	6.88
16	17	" "	24.50	12.69
17	18	" "	12.40	13.12
18	19	" "	17.60	10.19
20	20	Ansty Arm	10.60	11.34
21	21	" "	7.70	8.92
22	22	" "	6.60	7.87
23	23	" "	6.60	10.13
11	24	Main Arm	14.60	6.65
10	25	" "	19.40	6.58
9	26	" "	9.10	7.72
24	29	Salmon Arm	26.00	26.10
25	31	" "	37.30	16.82
26	32	" "	21.60	22.80
27	33	" "	24.90	23.88
28	34	" "	16.80	28.89
29	35	" "	15.00	25.73
30	36	" "	24.90	18.80
	37	" "		19.29
19	38	" "	12.40	14.26

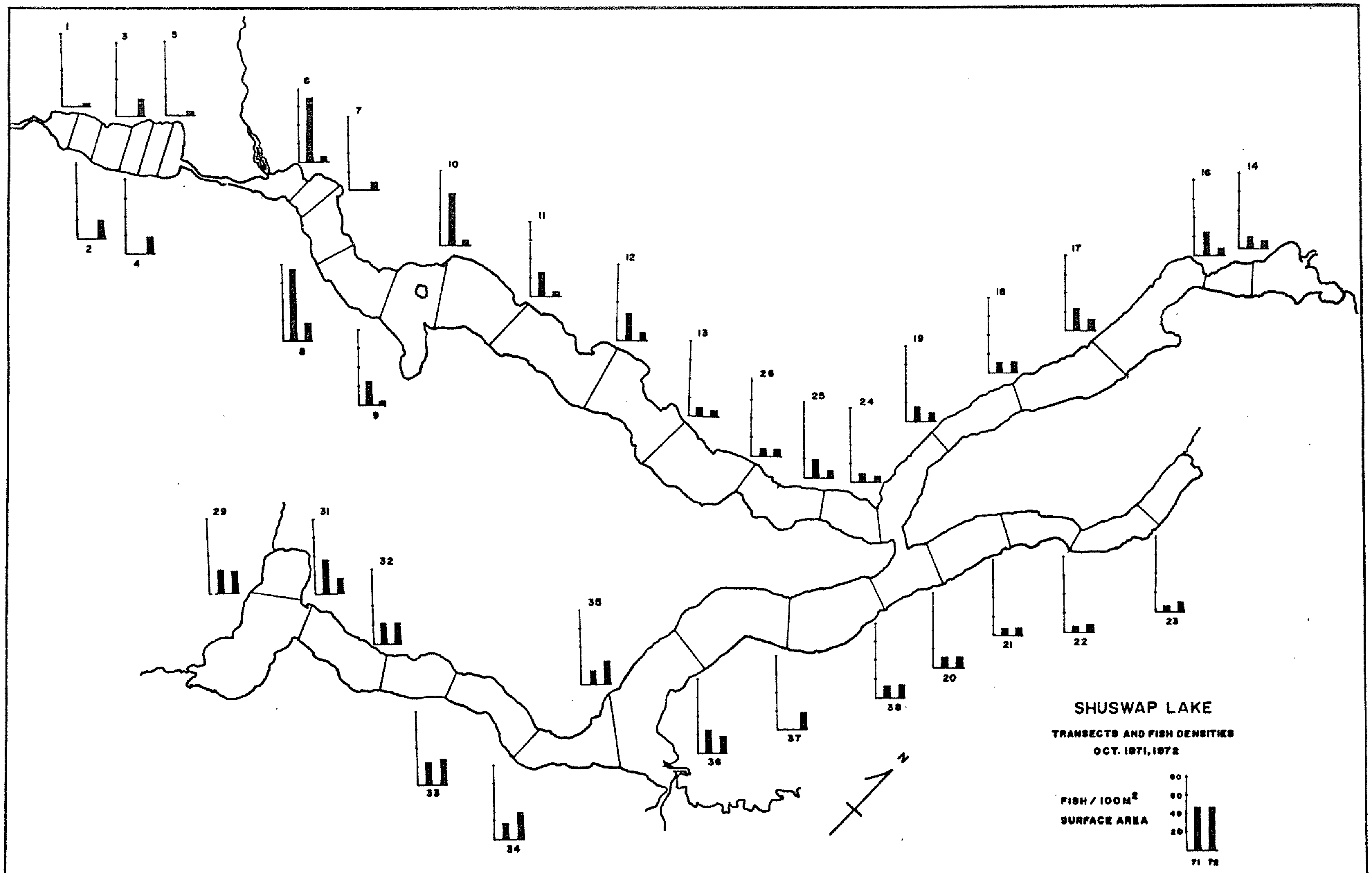

Fig. 2. The location and density of fish/are observed during the 1971 and 1972 acoustic surveys of Little Shuswap and Shuswap lake.

Table 10. The surface area, mean fish density/are and a population estimate for each of the 4 statistical areas of the 1972 acoustic survey of Little Shuswap and Shuswap Lake.

Area	Mean density/are	Surface area ($x10^6 m^2$)	Population ($x10^6$)
Little Shuswap	13.06	16	2.09
Shuswap Lake:			
Main Arm	7.38	96	7.08
Seymour - Ansty Arm	10.31	74	7.63
Salmon Arm	21.56	98	21.13
Estimate of total fish population, 1972			37.93
Estimate of total fish population, 1971			73.0

Table 11. Means of target strength distributions indicated and corresponding length calculations

Figure	Range of mode (dB)	Target strength (dB)	Estimated length (mm)	Observed length (mm) (townet)
3-A (Little Shuswap)	-75 to -40	-56.7	a. 42.4 b. 44.3	73.0
3-B (Seymour-Ansty Arms)	-70 to -40	-54.3	a. 51.0 b. 54.4	59.2
3-C (Main Arm)	-70 to -40	-55.3	a. 47.2 b. 49.9	64.6
3-E (Salmon Arm)	-70 to -40	-57.4	a. 40.2 b. 41.8	
3-F (Salmon Arm)	-70 to -55	-65.5	a. 21.6 b. 21.0	58.1
	-60 to -40	-48.1	a. 82.1 b. 92.1	

a. Calculated after Urick, 1967.

b. Calculated after Johannesson and Losse, 1971.

for each area in Fig. 3. There is not good correlation between estimated fish lengths and those observed in tow net samples. Probably several sources of error are responsible for the discrepancy. Large variability in the techniques due to imprecise determination of system gain and personal bias in the measurement of target amplitudes contributes considerably to the problem. Very large variability in the amplitudes of received echo pulses due to aspect and position of fish in the acoustic beam are other important sources of error. Also, the equations used to convert target strength to fish length were derived for larger, nonsalmonid fishes, and may not be applicable to juvenile salmon. Further study of the relationship of target strength and fish size may show that length is not as good a parameter as the weight of a fish. Further study and development of the technique is necessary before meaningful results can be achieved consistently.

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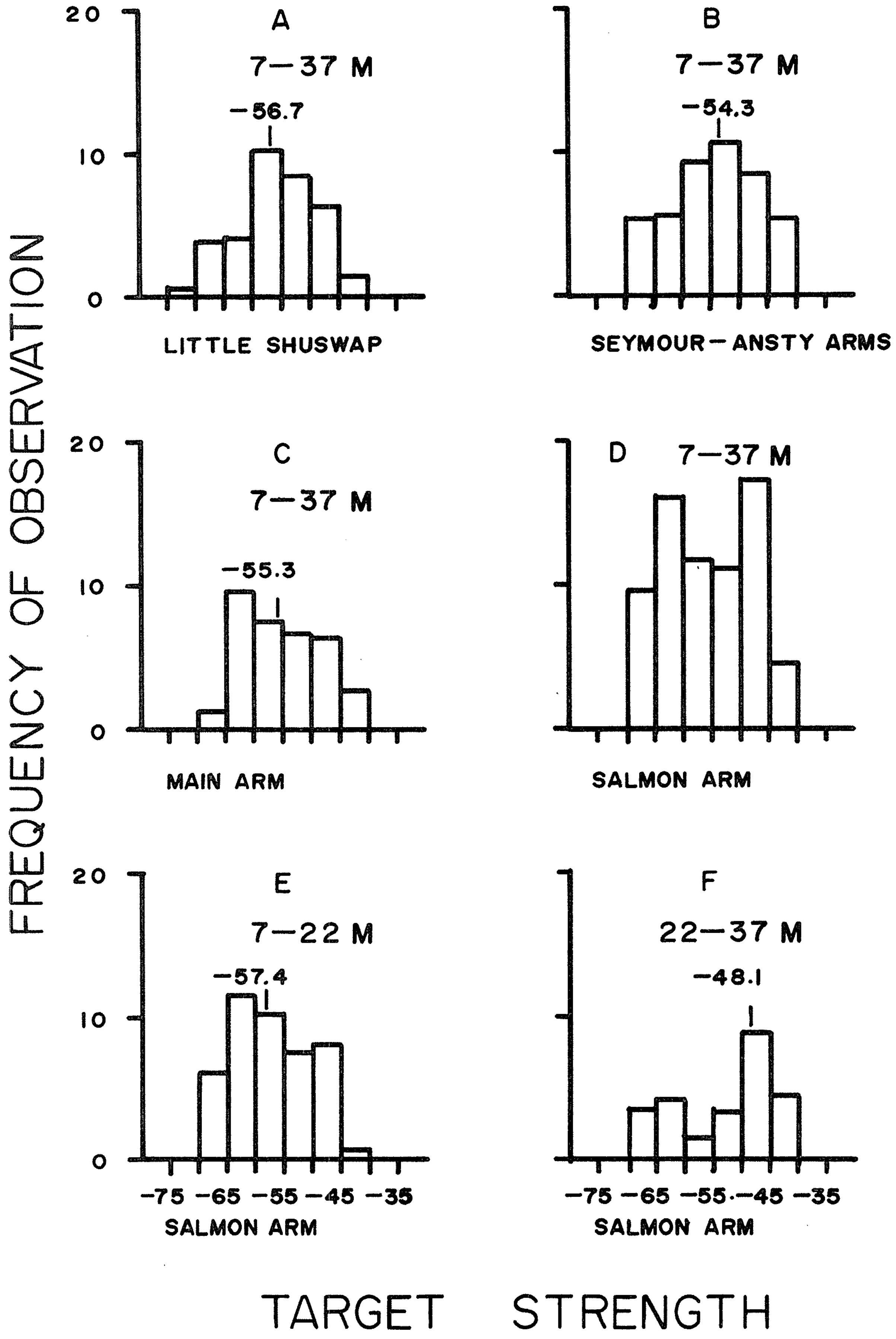
Fig. 3. Observed target strength distributions for each of the survey areas of Little Shuswap and Shuswap Lake for the period October 12 to 15, 1972.


FREQUENCY OF OBSERVATION
A
7—37 M
—56.7
20
10
0
LITTLE SHUSWAP
B
7—37 M
—54.3
SEYMOUR—ANSTY ARMS
C
7—37 M
—55.3
20
10
0
MAIN ARM
D
7—37 M
SALMON ARM
E
7—22 M
—57.4
20
10
0
—75 —65 —55 —45 —35
SALMON ARM
F
22—37 M
—48.1
—75 —65 —55 —45 —35
SALMON ARM
TARGET STRENGTH

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