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HYDROACOUSTIC SURVEY III OF SHUSWAP LAKE, BRITISH COLUMBIA, CANADA

by

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HYDROACOUSTIC SURVEY III OF SHUSWAP LAKE, BRITISH COLUMBIA, CANADA

INTRODUCTION

Reported herein is the third consecutive annual hydroacoustic survey of the fish population of Shuswap Lake by the Fisheries Research Institute, University of Washington, Seattle, under contract with the International Pacific Salmon Fisheries Commission. The field work was completed in two parts: (1) the upper half of the Main arm of Shuswap Lake and the Seymour, Anstey, and Salmon arms were surveyed on the nights of 5, 6, and 7 October 1973; (2) the lower half of the Main arm was surveyed on the night of 21 October 1973. The dates are comparable to those of the 1971 and 1972 surveys. The primary objective was to acquire permanent records of fish abundance, distributions, and target strength measurements. Since the juvenile sockeye salmon in the lake were the progeny of a very small escapement, an estimate, or an upper bound, of the population of resident fish was derived.

MATERIALS AND METHODS

Field Observations

The boat used in 1972 was made available again by the Salmon Commission. The data collection system and the sampling design were the same as in the two previous surveys. The locations of transects are shown in Fig. 1, and a summary of the field log is given in Table 1. The transects were numbered consecutively in the order in which they were run. The magnetic tape recordings from Little Shuswap Lake were lost, but the echograms indicated the occurrence of very low densities of fish, hence a resurvey was not considered worth the time and fuel necessary.

Analysis

Analysis was conducted as described previously in Nunnallee et al., 1973, including estimation of beam dimension, echo integration, and calculation of fish densities, population sizes, and target strengths. The analysis is of special interest when considered in conjunction with the analyses for the two previous surveys since the juvenile sockeye salmon in the lake during the three survey years were progeny of a peak spawning run, a moderate run, and a very low run, respectively.

From the number of spawners in each year and their average fecundity, the potential egg deposition was estimated. On the basis of this information, the survival from eggs to fry in the first part of October was computed. The population size in 1973, when the lowest density of salmon fry was observed, can serve as a baseline in future surveys. As in the two previous years, the densities of fish in all transects and the sizes of populations in all arms of Shuswap Lake were estimated. Target strength analysis was conducted, and the mean lengths of fish in the Main, Seymour, and Salmon arms were calculated.

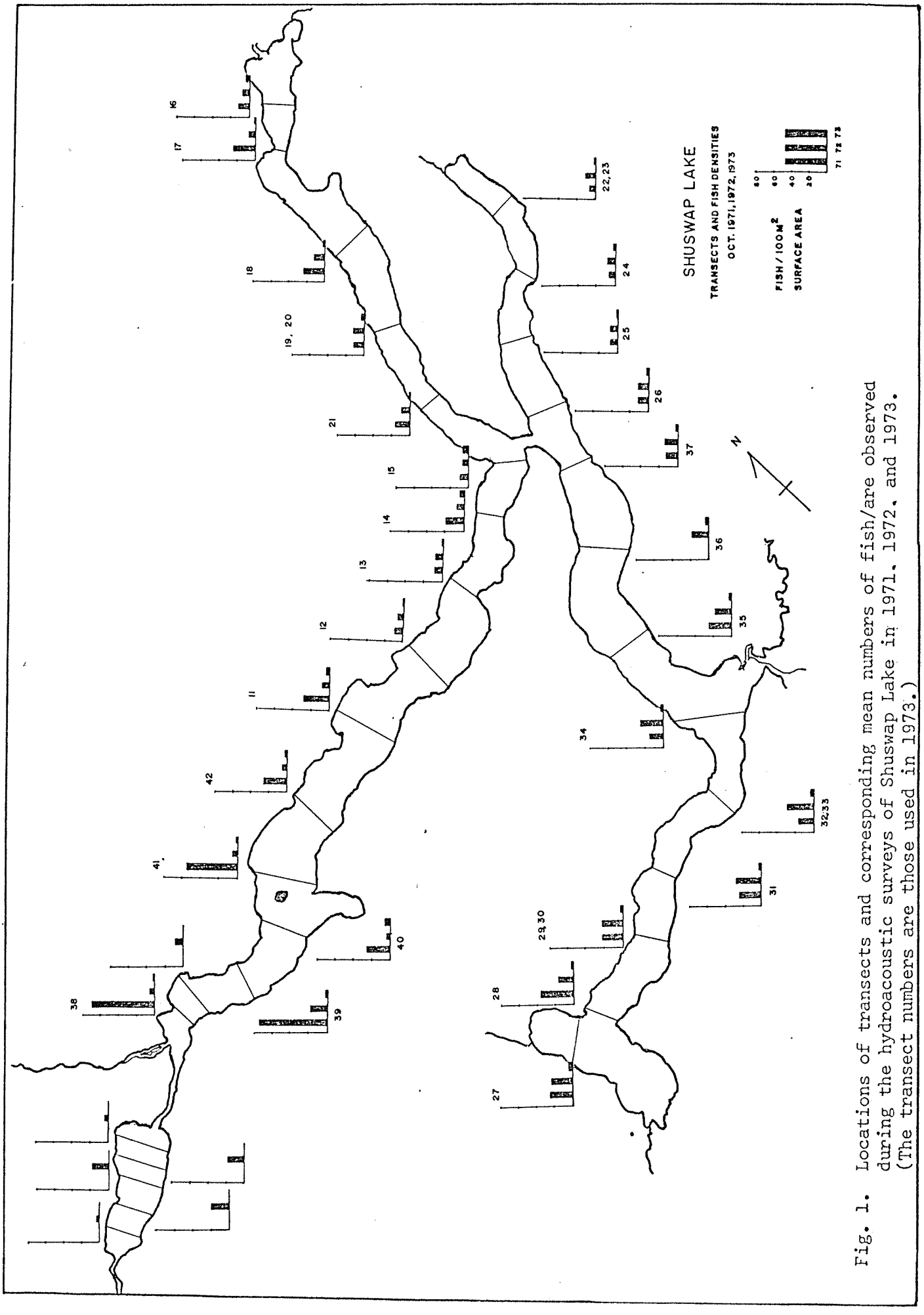

Fig. 1. Locations of transects and corresponding mean numbers of fish/are observed during the hydroacoustic surveys of Shuswap Lake in 1971, 1972, and 1973. (The transect numbers are those used in 1973.)

Table 1. Summary of the field log, hydroacoustic survey of Shuswap Lake, British Columbia, Canada, in 1973

Date	Location	Time		Corresponding transect numbers		
		Start	Duration (min)	1973	1972	1971
10/21-22	Main arm	2015	10.5	38	6	2
		2045	15.1	39	8	3
		2110	23.5	40	9	4
		2145	22.5	41	10	5
		2250	20.2	42	11	6
10/4-5	Main arm	0350	30.1	11	12	7
		0450	23.1	12	13	8
		0530	15.1	13	26	9
		0555	12.7	14	25	10
		0620	10.2	15	24	11
10/5-6	Seymour arm	2006	13.2	16	14	14
		2030	4.0	17	16	15
		2045	19.3	18	17	16
		2120	12.5	19	18	17
		2132[a]	11.2	20	--	--
		2155	13.2	21	19	18
	Anstey arm	2230	18.9	22	23	23
		2250[a]	19.3	23	--	--
		2325	13.3	24	22	22
		2345	8.5	25	21	21
		2405	12.6	26	20	20
10/6-7	Salmon arm	2000	16.7	27	29	24
		2030	12.9	28	31	25
		2055	16.6	29	32	26
		2113[a]	16.0	30	--	--
		2140	11.0	31	33	27
		2208	16.1	32	34	28
		2225[a]	16.0	33	--	--
		2300	21.0	34	35	29
		2350	24.6	35	36	30
		0040	19.0	36	37	--
		0120	13.7	37	38	19

[a]Replicate of previous transect.

RESULTS

In 1973 the densities of fish ranged from 1.03 to 5.84 fish/are (100 m^2); significantly greater densities occurred in the two previous years. In Appendix A the numbers of fish/are and fish/1000 m^3 of the water column are given for nine depth strata within each transect of the 1973 survey. The mean numbers of fish/are by transects are summarized in Fig. 1 for 1973 and are given with the corresponding values for 1971 and 1972 in Table 2.

Fish Population Estimates

For the 1972 and 1973 surveys the population of fish in each of the three statistical areas of Shuswap Lake--Main arm, Seymour-Anstey arm, and Salmon arm--was estimated by expansion of the mean number of fish/are over the surface area of each section bounded by the 18-m depth contour line. Only an occasional fish was observed, either by eye or by echo sounder, in shallower depths during any of the three surveys. The population in 1971 was estimated by expansion of the mean density of fish/are for the entire lake over the total surface area. This population estimate was revised in 1973 by calculation of the mean density of fish/are in each statistical area, rather than the lake as a whole, and by expansion of these values over the redefined surface areas. The lake surface area and, consequently, the 1971 population estimate was reduced by about 10 percent (Table 3).

Table 3. Estimated fish populations in Shuswap Lake, British Columbia, Canada, by statistical areas, during the 1971, 1972, and 1973 surveys

Area	Population estimate (X 10^6)		
	1971	1972	1973
Little Shuswap Lake	---[a]	2.09	---[b]
Main arm, Shuswap Lake	32.05	7.08	2.94
Seymour-Anstey arm, Shuswap Lake	9.73	7.63	1.73
Salmon arm, Shuswap Lake	21.92	21.13	2.86
TOTALS	63.70[c]	37.93	7.53

[a] No survey.
[b] Negligible number of fish seen on echograms.
[c] Revised population estimates.

Table 2. Mean numbers of fish/are observed in Shuswap Lake, British Columbia, during the 1971, 1972, and 1973 hydroacoustic surveys

Transect number	Area	Mean number of fish/are 1971	1972	1973
38	Main arm	70.60	5.35	1.03
39		75.00	17.25	1.80
40		26.70	5.19	6.21
41		56.30	4.35	2.03
42		25.60	5.68	1.93
11		27.80	8.44	3.61
12		8.80	5.94	1.34
13		9.10	7.72	1.66
14		19.40	6.58	5.22
15		14.60	6.65	5.84
16	Seymour arm	12.40	8.07	4.10
17		25.20	6.88	1.95
18		24.50	12.69	2.21
19		12.40	13.12	3.56
20[a]		--	--	3.67
21		17.60	10.19	1.23
22	Anstey arm	6.60	10.13	1.62
23[a]		--	--	2.23
24		6.60	7.87	2.48
25		7.70	8.92	1.26
26		10.60	11.34	2.28
27	Salmon arm	26.00	26.10	4.16
28		37.30	16.82	1.56
29		21.60	22.80	3.17
30[a]		--	--	3.18
31		24.90	23.88	3.38
32		16.80	28.89	3.26
33[a]		--	--	3.63
34		15.00	25.73	2.34
35		24.90	18.80	2.34
36		--	19.29	2.78
37		12.40	14.26	3.10

[a]Replicate of previous transect.

Sockeye Salmon Fry and Resident Fish Population Estimates

A point of particular interest in Table 3 is that an apparently stable population of fish was observed in Salmon arm in 1971 and 1972. The fish could not have been kokanee since the number of kokanee spawners necessary to produce the number of fry indicated (21 million) had not been observed in the area. Neither could they have been nonsalmonids, since no large number was indicated by the tow net catches. A reasonable explanation is that the fish were juvenile sockeye salmon emigrants from the major spawning areas adjacent to the Main arm of the lake.

If a 5-percent survival of the 1973 age group of juvenile sockeye salmon from egg to fry in early October is assumed, the population of sockeye salmon fry in the lake can be estimated directly. The resident fish population can then be estimated by subtraction of the juvenile salmon population from the total fish population. If one further assumes that this size had been relatively stable and subtracts the estimate from the total population estimates of the two previous years, one obtains estimates of the salmon populations in 1971 and 1972 (Table 4). The relationship of the number of female sockeye salmon in the escapement to the number of fry surviving to early October is shown in Fig. 2. The pronounced lower survival of the 1970 progeny of fry can be traced either to the higher population density or to unfavorable environmental factors or to a combination of both.

Table 4. The derivation of a sockeye salmon spawner-recruitment (fry) survival curve and of a resident pelagic fish population estimate for Shuswap Lake, British Columbia, Canada, 1971, 1972, and 1973

	Year of observation			
	1970	1971	1972	1973
Available female sockeye salmon[a]	849,818	167,887	3,583	
Potential egg depositions ($\times 10^6$)[b]	3,025.4	597.7	12.8	
Population estimate ($\times 10^6$)[c]		63.7	37.93	7.53
5-percent egg survival ($\times 10^6$)				0.64
Resident fish population estimate ($\times 10^6$)[d]		6.89	6.89	6.89
Sockeye fry population estimate ($\times 10^6$)		56.81	31.04	0.64
Eggs/fry		53.25	19.25	20.00
Percent survival[e]		1.9	5.2	5.0

[a] Female sockeye salmon escapement from Annual Report of Int. Pac. Salmon Fish. Comm., for the years 1970, 1971, and 1972.
[b] Average fecundity = 3,560 eggs (Op. cit.)
[c] Derived by hydroacoustic techniques.
[d] Assumed stable through 1971, 1972, and 1973.
[e] Survival of eggs to fry in early October of following year.

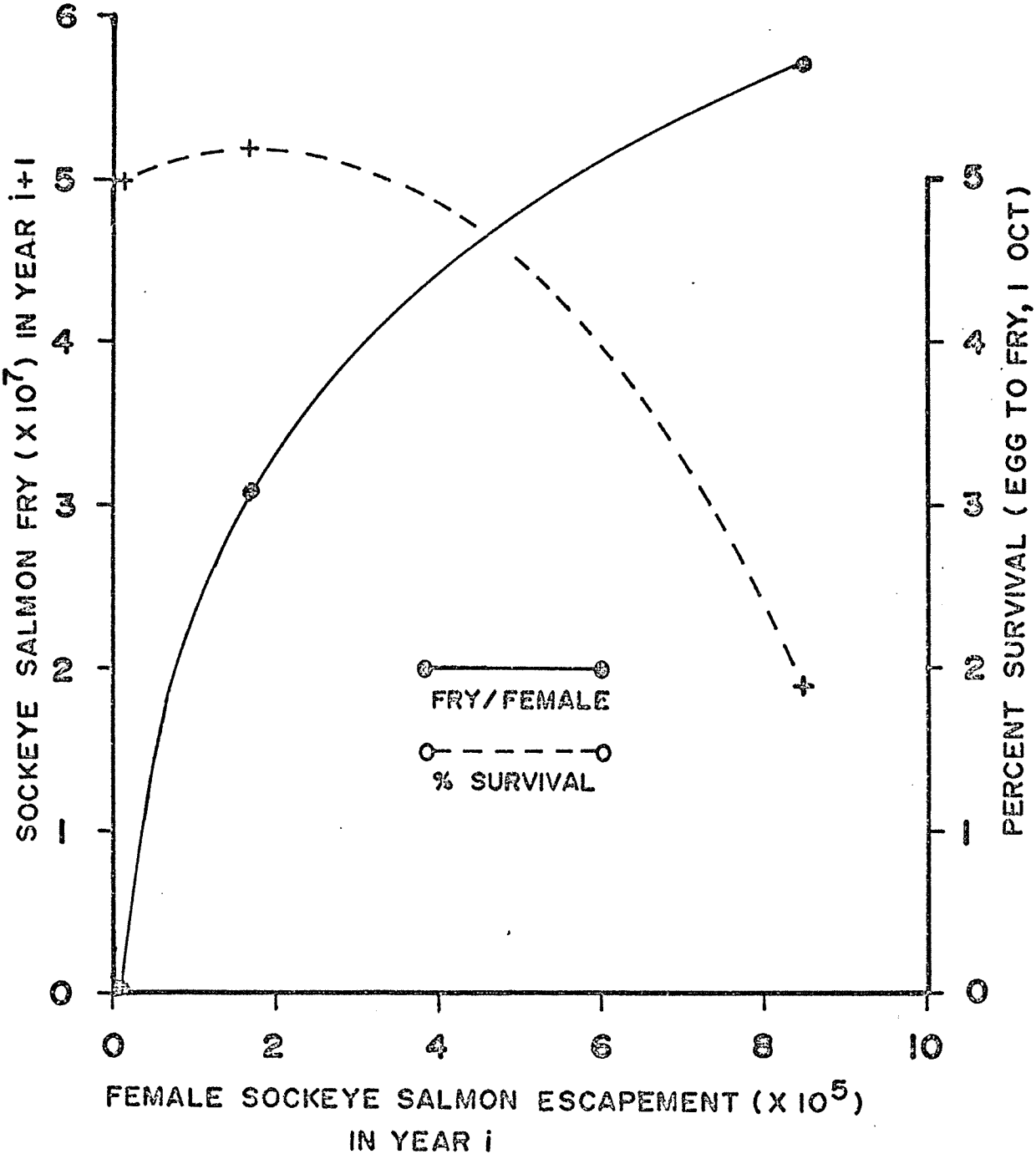

Fig. 2. The relationship of the number of spawning female sockeye salmon to the number of fry surviving in October the following year.

Depth, Target Strength, and Size Distributions of Fish

Three transects of the 1973 Shuswap Lake survey--number 40 in the Main arm, number 19 in Seymour arm, and number 32 in Salmon arm--were chosen for target strength analysis because of their proximity to areas townetted by members of the International Pacific Salmon Fisheries Commission (Fig. 1). Four depth strata, 18-26, 26-33, 33-40, and 40-48 m, were chosen for analysis, corresponding with the depths of the net hauls. The depth distributions of the fish in the three arms of the lake and the analyzed depth strata are shown in Fig. 3.

The technique of target stremgth analysis used has been described by Nunnallee et al., 1973. Target strength was converted to fish size through the following equation (McCartney and Stubbs, 1971):

$$TS = 24.5 \log_{10} L_{(m)} - 4.5 \log_{10} \lambda - 21.9,$$

where L = fish length expressed in meters,
λ = wave length, in meters.

The distributions of target strength measurements for the three analyzed transects and for all depths combined are shown in Fig. 4. Superimposed on the target strength distributions are the target strength frequency distributions calculated from the observed lengths of fish in the tow net catches. The resulting target strength distributions are wider than would be expected from the size distributions of fish in the net catches (Fig. 4). The difference is due to a large amount of variability associated with the townetting, such as net selectivity. Because of the variability, the mean target strength of the distribution is more meaningful than its spread. In one instance, transect 19, a double mode was observed in the distribution, and the mean of each was calculated. The mean target strengths of fish in the analyzed transects, the corresponding lengths of fish, and the mean lengths of fish from adjacent tow net hauls are given in Table 5 for transects 40, 19, and 32.

Table 5. Mean target strengths of fish, corresponding lengths of fish, and mean lengths of fish from adjacent tow net hauls for transects 40, 19, and 32

Transect	$\overline{TS}$ (dB)	Mean fish length (calculated)(mm)	Mean fish length (observed) (mm)	Number of fish in net catch
40	-47.5	36.5	66.0	30
19	-35.3	115.0	70.0	3
	-56.0	16.4		
32	-36.0	107.7	106.0	6

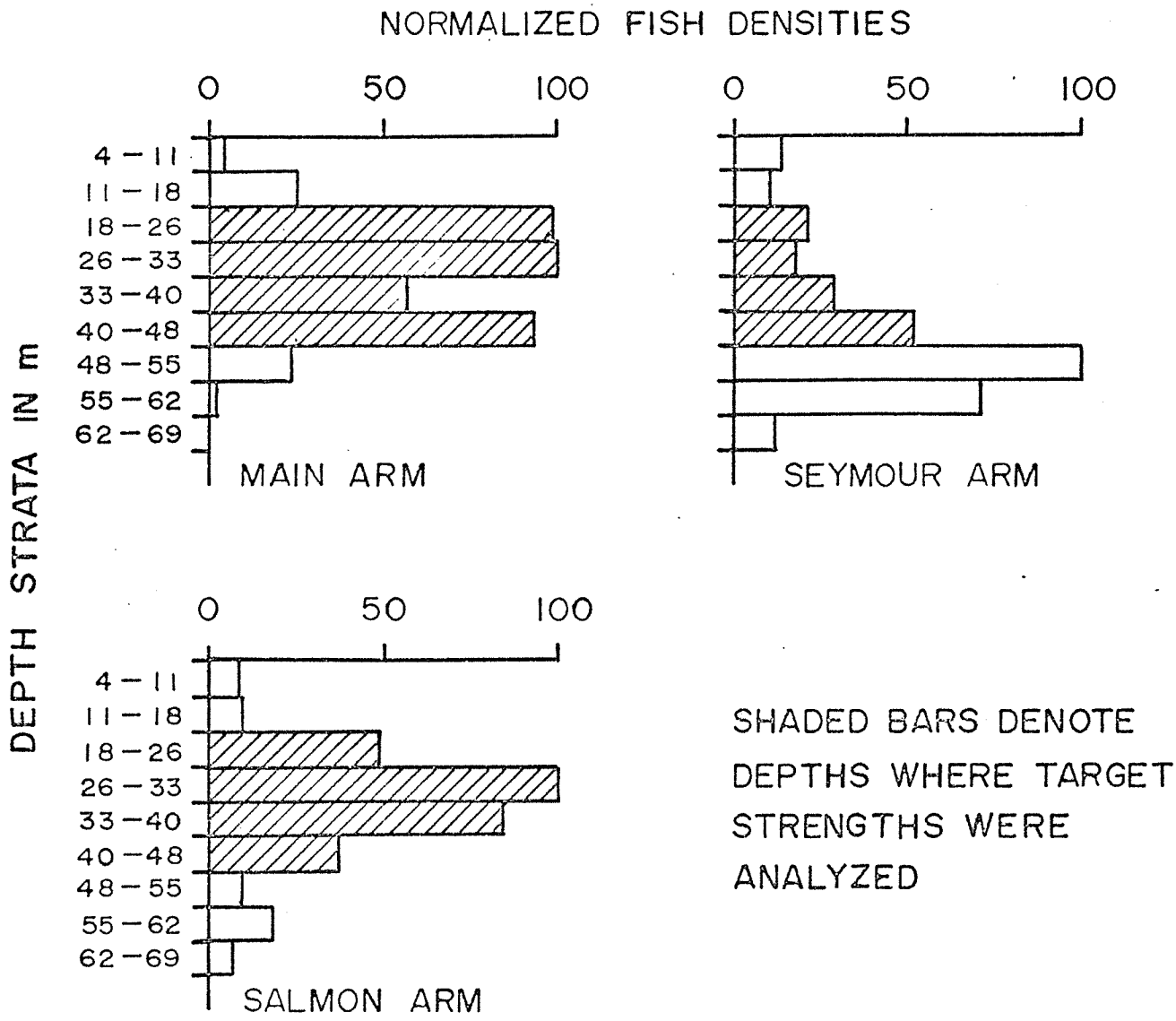

Fig. 3. The depth distributions of fish in the Main arm (transect 40), Seymour arm (transect 19) and Salmon arm (transect 32) of Shuswap Lake, British Columbia, Canada.

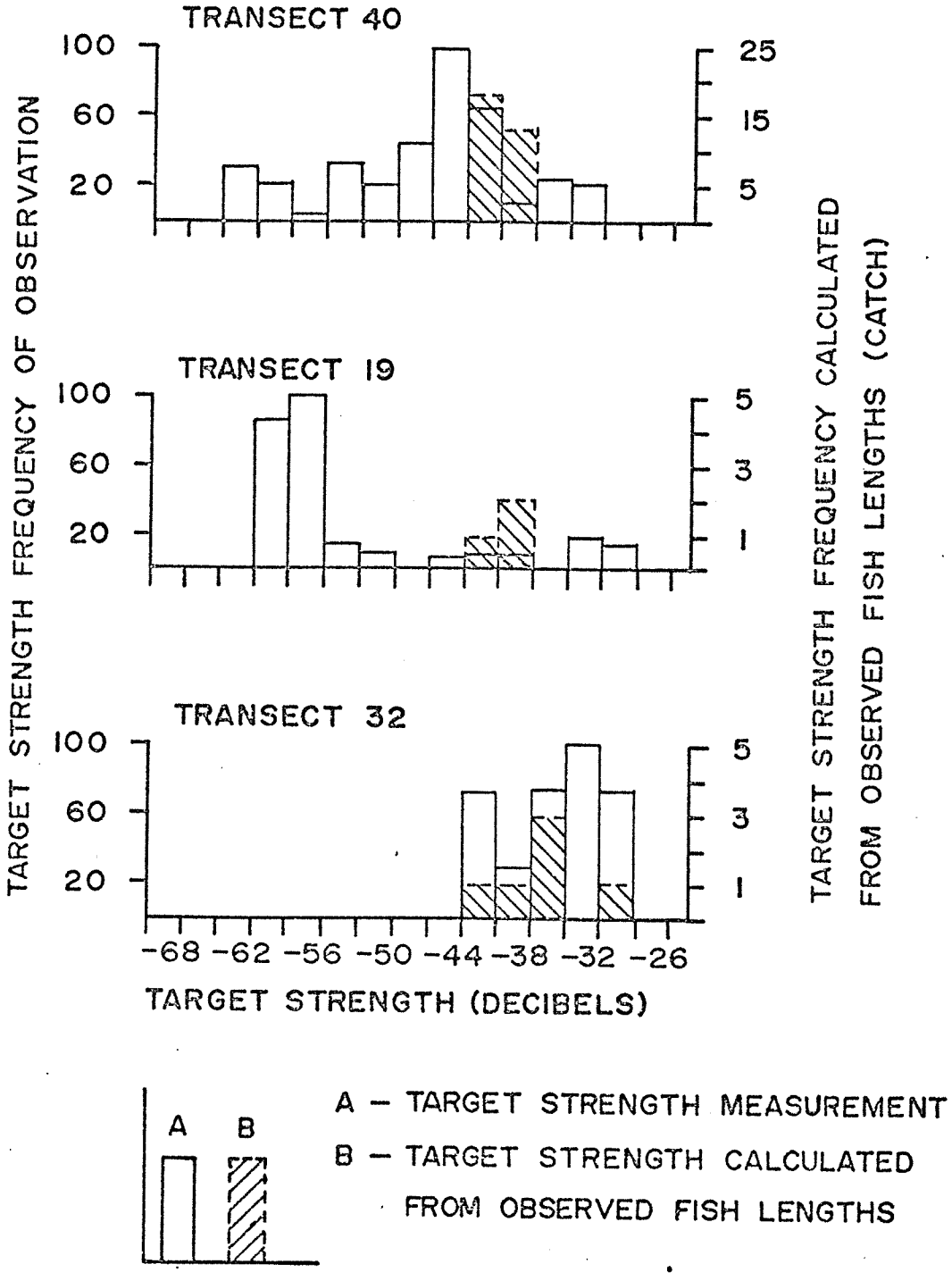

Fig. 4. The distributions of measured target strengths (plain bars) and target strengths calculated from sizes of of fish in net catches (hatched bars) in three arms of Shuswap Lake.

The low correlation between the fish sizes indicated by target strength analysis and the sizes observed in tow net hauls is due in part to the relatively small samples of fish that were caught, but in the main to the technique of target strength analysis that was used.

ACKNOWLEDGMENTS

Messrs. T. W. Gjernes, T. R. Eburn, and D. P. Barnes of the International Pacific Salmon Fisheries Commission rendered valuable assistance in all aspects of the field work involved in the acoustic survey of the fish population of Shuswap Lake.

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APPENDIX A

Numbers of fish/are and fish/1,000 m^3 of the water column within nine depth strata of each transect of Shuswap Lake, British Columbia, Canada, 1973 hydroacoustic survey

SHUSWAP LAKE SURVEY 73, TRANSECTS = 38 39 40 41 42 11 12 13 14

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METERS) INTERVAL:	38	39	40	41	42	11	12	13	14
4 - 11	.06215	.25573	.06439	.06364	.06304	.10608	.10137	.07847	.07684
11 - 18	.30958	.26316	.38628	.20393	.10639	.26148	.11179	.10301	.52150
18 - 26	.45261	.70304	1.52447	.43931	.55058	1.80040	.49674	.64640	1.10814
26 - 33	.09695	.34431	1.54694	.77693	.64186	1.02345	.40231	.46080	1.34550
33 - 40	.03265	.14305	.88589	.40444	.34552	.15286	.08847	.15107	1.32632
40 - 48	.04455	.00165	1.43228	.07262	.15341	.07279	.06270	.06195	.54866
48 - 55	.02271	0.00000	.35386	.05332	.06487	.13148	.07283	.05802	.14796
55 - 62	.00510	0.00000	.01502	.01244	0.00000	.06106	0.00000	.05634	.08462
62 - 69	0.00000	0.00000	0.00000	0.00000	0.00000	.00034	0.00000	.04059	.05684
TOTAL	1.02629	1.84093	6.20913	2.02664	1.92566	3.60993	1.33620	1.65664	5.21638

DENSITY PER 1000 CUBIC METERS:

DEPTH (METERS) INTERVAL:	38	39	40	41	42	11	12	13	14
4 - 11	.08614	.35049	.08849	.08810	.09130	.14617	.13964	.10913	.10544
11 - 18	.47335	.36791	.53731	.28561	.14762	.36653	.15760	.14730	.71692
18 - 26	1.18029	1.29221	2.15485	.68191	.78741	2.65804	.71832	.95140	1.53720
26 - 33	.32105	.99212	2.30861	1.13856	.95191	1.65693	.59889	.70495	1.88346
33 - 40	.12754	.79766	1.50760	.65212	.54792	.29671	.13673	.23984	1.88122
40 - 48	.21918	.23784	3.80266	.22946	.28718	.15132	.11184	.10229	.78751
48 - 55	.15630	0.00000	2.70464	.42916	.28112	.32419	.16987	.10104	.21740
55 - 62	.08614	0.00000	.38511	.67380	0.00000	.27799	0.00000	.11547	.12726
62 - 69	0.00000	0.00000	0.00000	0.00000	0.00000	.25929	0.00000	.11423	.08874

SHUSWAP LAKE SURVEY 73•TRANSECTS = 15 16 17 18 19 20 21 22 23

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METERS) INTERVAL:	15	16	17	18	19	20	21	22	23
4 - 11	.21278	.08229	.26798	.09506	.14884	.06313	.07275	.01334	.06273
11 - 18	1.47349	.17432	.37562	.09278	.11375	.08783	.08022	.13734	.07218
18 - 26	2.64425	.73809	.12052	.28243	.23084	.63450	.22390	.47898	.51699
26 - 33	1.08621	.84379	.34008	.31174	.19792	.15363	.15679	.58543	.82375
33 - 40	.13256	1.82638	.25090	.59682	.31802	.33749	.28755	.06321	.44041
40 - 48	.07632	.31424	.03836	.53429	.56431	.56814	.19543	.25087	.14593
48 - 55	.08062	.12336	.54254	.15713	1.09024	1.11317	.08801	.06060	.05672
55 - 62	.06344	.00110	.01319	.08444	.77400	.59815	.07426	.01413	.05987
62 - 69	.07193	0.00000	0.00000	.05891	.12494	.11015	.05584	.01194	.04881
TOTAL	5.84159	4.10358	1.94920	2.21359	3.56286	3.66619	1.23475	1.61585	2.22738

DENSITY PER 1000 CUBIC METERS:

DEPTH (METERS) INTERVAL:	15	16	17	18	19	20	21	22	23
4 - 11	.29242	.11527	.38127	.13056	.20519	.08688	.10017	.08992	.08632
11 - 18	2.04610	.25279	.56002	.12846	.15941	.12226	.11194	.95605	.10055
18 - 26	3.71821	1.11387	.19184	.39388	.33665	.90385	.32025	3.59823	.74134
26 - 33	1.54797	1.33621	.59254	.44014	.30273	.22453	.22859	4.71542	1.20945
33 - 40	.19240	3.05995	.48924	.85433	.50675	.51120	.42848	.55272	.66482
40 - 48	.11281	.59044	.08614	.77147	.93565	.88831	.29679	2.43729	.22808
48 - 55	.12280	.42654	1.53804	.23003	1.88733	1.80990	.13611	.68371	.09192
55 - 62	.09978	.10357	.08614	.12522	1.38514	.99738	.11682	.19279	.10058
62 - 69	.12503	0.00000	0.00000	.08876	.23267	.19023	.08961	.20404	.08671

SHUSWAP LAKE SURVEY 73, TRANSECTS = 24 25 26 27 28 29 30 31 32

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METERS) INTERVAL:	24	25	26	27	28	29	30	31	32
4 - 11	.07548	.12045	.09768	.11119	.11010	.15950	.11570	.11373	.08393
11 - 18	.19964	.17052	.11589	.39007	.39094	.13775	.18316	.32763	.09637
18 - 26	.40447	.18178	.55652	1.20391	.63189	.44551	.66849	.51163	.49247
26 - 33	1.01526	.21629	.83656	1.05108	.32493	.80287	.92997	1.45145	1.02266
33 - 40	.41524	.21099	.41047	.52452	.10498	.89092	.61943	.51644	.86017
40 - 48	.17358	.16533	.09611	.43893	0.00000	.47876	.35083	.27343	.36759
48 - 55	.06979	.12472	.05405	.26409	0.00000	.24796	.31386	.10810	.09078
55 - 62	.05336	.05058	.06603	.10254	0.00000	.00224	0.00000	.04803	.18598
62 - 69	.07351	.04284	.04429	.06910	0.00000	0.00000	0.00000	.02984	.05656
TOTAL	2.48034	1.24350	2.27759	4.15542	1.56285	3.16550	3.18144	3.38030	3.25650

DENSITY PER 1000 CUBIC METERS:

DEPTH (METERS) INTERVAL:	24	25	26	27	28	29	30	31	32
4 - 11	.10377	.16583	.13444	.15936	.15211	.22007	.15881	.15643	.11554
11 - 18	.27937	.23725	.16271	.63613	.78689	.19441	.25761	.45805	.13441
18 - 26	.59725	.14484	.80724	2.18493	2.17500	.66473	.99621	.74236	.69774
26 - 33	1.59252	.31613	1.28722	2.09618	2.25636	1.26629	1.48179	2.22901	1.49329
33 - 40	.68260	.33078	.69468	1.18215	.94876	1.50788	1.02918	.84082	1.30759
40 - 48	.30204	.24112	.17242	1.05833	0.00000	.99366	.62637	.47613	.58529
48 - 55	.13115	.30624	.10350	.68827	0.00000	.72491	.70525	.20299	.15348
55 - 62	.10839	.09185	.14030	.29063	0.00000	.17692	0.00000	.10343	.34071
62 - 69	.16804	.08861	.11612	.21015	0.00000	0.00000	0.00000	.08635	.11202

SHUSWAP LAKE SURVEY 73.TRANSECTS = 33 34 35 36 37

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METERS) INTERVAL:	33	34	35	36	37
4 - 11	.07096	.10159	.06843	.07516	.12806
11 - 18	.12851	.08678	.06925	.11446	.16576
18 - 26	.38509	.34505	.68695	1.24704	1.86079
26 - 33	1.33520	.75531	.86223	.80832	.61436
33 - 40	.96294	.52911	.34048	.25720	.11875
40 - 48	.27703	.26619	.10553	.10079	.05908
48 - 55	.25233	.11978	.05670	.06185	.06530
55 - 62	.14723	.07646	.09631	.06286	.04475
62 - 69	.06960	.06138	.05195	.05582	.04696
TOTAL	3.62889	2.34164	2.33783	2.78350	3.10382

DENSITY PER 1000 CUBIC METERS:

DEPTH (METERS) INTERVAL:	33	34	35	36	37
4 - 11	.09741	.13942	.09395	.10331	.17579
11 - 18	.17767	.11947	.09591	.15811	.22950
18 - 26	.54188	.48371	.98261	1.74008	2.69404
26 - 33	1.92618	1.15745	1.26112	1.14458	.92727
33 - 40	1.43805	.88099	.51078	.37329	.18980
40 - 48	.43133	.40882	.16162	.14997	.10255
48 - 55	.41925	.22958	.08885	.09447	.12226
55 - 62	.25984	.15094	.15692	.09847	.08955
62 - 69	.13685	.12913	.08897	.09072	.10077