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HYDROACOUSTIC SURVEY V OF SHUSWAP LAKE IN 1976, BRITISH COLUMBIA, CANADA

by

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Director

CONTENTS

HYDROACOUSTIC SURVEY OF SHUSWAP LAKE, BRITISH COLUMBIA, CANADA IN 1976

INTRODUCTION

This report discusses results of the fifth consecutive annual hydroacoustic survey of pelagic fish populations of Shuswap Lake, British Columbia, by the Fisheries Research Institute, University of Washington, Seattle, under contract to the International Pacific Salmon Fisheries Commission. In all years the primary objective has been to provide an estimate of the abundance and distribution of fish targets in the limnetic zone of Shuswap Lake. It has been assumed that the stocks of resident fishes remain stable both in numbers and distribution from year to year so that differences in total population estimates are due primarily to changes in abundance of juvenile sockeye salmon (*Oncorhynchus nerka*).

The acquisition of hydroacoustic data in the field was accomplished October 20-22, 1975, on dates which are comparable to those of the previous surveys, 1971-1974.

MATERIALS AND METHODS

Data Acquisition System and Technique

The survey was made with a Ross 200A echosounder, equipped with a narrow beam transducer, interface amplifier, and a Sony 560D tape deck. The system was powered by a 12VDC storage battery, with 110VAC generated by a Toredo Model 50-200 Atlas inverter. The Salmon Commission provided both a boat and operator for the survey.

The sample design remained the same as that used in earlier surveys in Shuswap Lake and was expanded to include four transects in Little Shuswap Lake and four additional transects in Mara Lake. The locations of the transects in Shuswap Lake are shown in Fig. 1, and a summary of years is given in Table 1. The system of numbering the transects is sequential during a survey and may change from year to year, but the transect locations remain invariant.

Analysis

Analysis of the data, stored on magnetic tape, includes estimation of effective sample volume, integration of intensities, and calculation of absolute fish densities, population sizes, and target strengths as discussed by Nunnallee, et al., 1973.

Fish densities were estimated for each transect and the population sizes computed for the individual arms of Shuswap Lake, Little Shuswap Lake, and Mara Lake. An average fish density was calculated for the lake

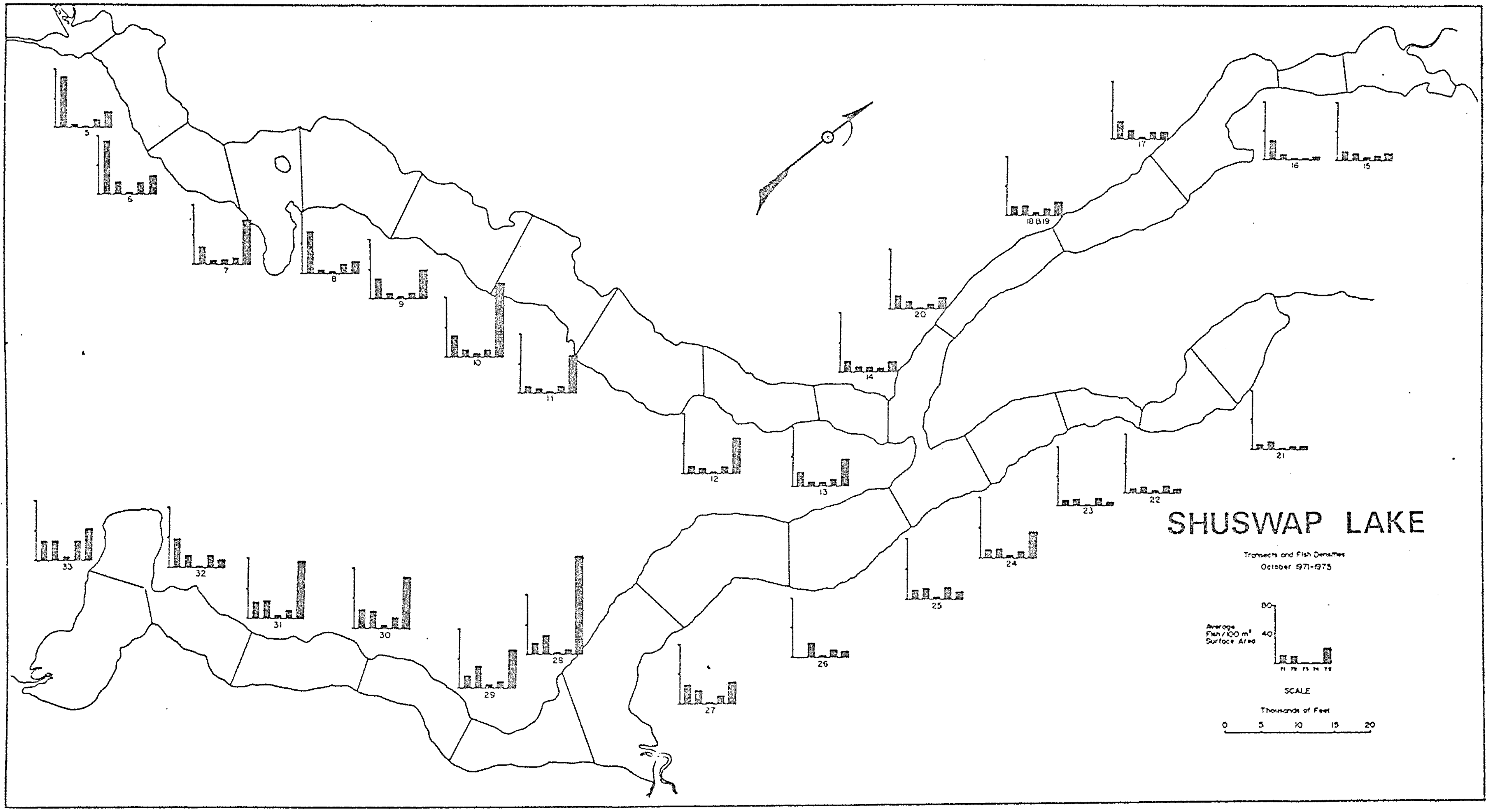

Fig. 1. Locations of transects and mean numbers of fish/are observed during the hydroacoustic surveys of Shuswap Lake in 1971, 1972, 1973, 1974, and 1975. (The transect numbers have been revised for 1975).

Table 1. Summary of the field log for the hydroacoustic survey of Shuswap Lake, British Columbia, Canada, in 1975

Date	Location	Time		Corresponding transect numbers				
		Start	Duration (min)	1975	1974	1973	1972	1971
10/20-21	Little Shuswap	2027	14	1				
		2048	16	2				
		2112	18	3				
		2140	18	4				
10/20-21	Main Arm	2221	17	5	1	38	6	2
		2249	14	6	2	39	8	3
		2311	24	7	3	40	9	4
		2345	30	8	4	41	10	5
		0027	21	9	5	42	11	6
		0103	31	10	6	11	12	7
		0147	27	11	7	12	13	8
		0232	16	12	8	13	26	9
		0258	14	13	9	14	25	10
		0323	9	14	10	15	24	11
		-	-	-	11	-	-	-
10/21-22	Seymour Arm	1856	14	15	17	16	14	14
		1918	3	16	16	17	16	15
		1941	19	17	15	18	17	16
		2012	13	18	14	-	-	-
		2026	10	19	13	19,20	18	17
		2049	8	20	12	21	19	18
10/21-22	Anstey Arm	2130	13	21	30	22,23	23	23
		2150	9	22	29	24	22	22
		2208	14	23	28	25	21	21
		2233	23	24	27	26	20	20
		2259	14	25	26	37	30	19
10/21-22	Salmon Arm	2330	20	26	18	27	29	24
		2356	25	27	19	28	31	25
		0035	25	28	20	29,30	32	26
		0112	20	29	21	31	33	27
		0141	15	30	22	32,33	34	28
		0211	11	31	23	34	35	29
		0232	15	32	24	35	36	30
		0300	12	33	25	36	37	-
10/21-22	Mara Lake	0436	9	35				
		0457	7	36				
		0516	12	37				
		0534	10	38				

with associated variance and confidence limits. The potential egg deposition was estimated in the same manner as in the previous two years and used to estimate survival from egg to the fry stage of sockeye salmon in October.

Variance Estimate

Variance of the population density was derived from the cluster "ratio estimator" method of mean density (Harvey, et al., 1975). This method utilizes the concept that each transect represents a cluster of readings, each cluster being randomly chosen from the water column. Randomness is assured despite the systematic layout of the transects because the fish are considered mobile relative to transect location. The primary source of low precision would then come from a small sample size or number of transects (Cochran, 1963). However, in this case, the number of transects or clusters can be said to be relatively high; therefore, the cluster ratio estimator ($\hat{R}$) is also an intuitively appealing estimator of mean density since:

$$\hat{R} \doteq \overline{Y}_R = \frac{\sum_{j=1}^{n} N_j}{\sum_{j=1}^{n} V_j}$$

where $\overline{Y}_R$ = mean density

N_j = the number of fish targets in the jth transect

V_j = the volume surveyed in the jth transect

And for the entire population:

$$E(N_j) = \hat{\beta} V_j$$

for a given β then the ratio estimator is unbiased (Cochran, 1963). An estimation of the variance of the cluster ratio estimator is given by:

$$\mathrm{Var}\,(\overline{Y}_R) \doteq \frac{1}{\left(\sum_{j=1}^{n} V_j\right)^2} \cdot \frac{n}{(n-1)} \cdot \sum_{j=1}^{n} (N_j - \hat{R}V_j)^2 \,.$$

In order to calculate the variance of the cluster ratio estimator it was necessary to first compute the sampled volume and the number of fish targets for each transect. A summary of the data is given in Table 2.

The sampled volume, V_j, for each transect was derived by computing the effective sample volume of the transducer and moving this cone over

Table 2. Summary of the data used in calculation of cluster ratio density estimate and associated variance

Location	Transect	Number of pings	Total sample volume (m^3)	Sample volume excluding bottom (m^3) (V_j)	Number of fish in V_j (N_j)
Little Shuswap	1	1630	413950	41268	217
	2	1808	459155	56182	412
	3	2165	549817	116993	97
	4	2225	565055	8281	52
Main Arm	5	1971	500550	322375	1446
	6	1715	435537	154903	1792
	7	2923	742318	521950	8074
	8	3612			1774
	9	2516			3195
	10	3527	895707	671857	10950
	11	3065	778379	592051	5035
	12	1580	401252	344301	2718
	13	1643	417252	389926	2156
	14	1552	394141	370444	1088
Seymour-Anstey Arms	15	1273	323287	181166	545
	16	498	126470	87101	79
	17	2252	571912	536932	914
	18	1334	338779	315869	976
	19	1297	329382	306555	974
	20	845	214594	207938	547
	21	1303	330906	280125	239
	22	945	239989	208521	192
	23	1535	389824	276651	378
	24	1711	434521	407798	2258
Salmon Arm	25	1404	356556	311381	555
	26	2361	599593	566362	893
	27	2879	731143	696724	3133
	28	2434	618132	595061	12715
	29	2366	600863	491364	4422
	30	1743	442647	379554	4468
	31	1218	309320	252143	3562
	32	1655	420299	264012	885
	33	1142	290019	69587	723
	34	1684	427664	292466	2578
Mara Lake	35	1108	281384	118679	1395
	36	805	204435	86487	2971
	37	1480	375857	115600	3301
	38	1458	370269	96891	1118
				$\Sigma V_j = 1.17 \times 10^7$	$\Sigma N_j = 88827$

Table 2. Summary of the data used in calculation of cluster ratio density estimate and associated variance - continued

$$\overline{Y}_R = \frac{\sum_{j=1}^{n} N_j}{\sum_{j=1}^{n} V_j} = \frac{88827 \text{ fish}}{1.17\text{x}10^{7} \text{ m}^3} = 7.59\text{x}10^{-3} \text{ fish/m}^3$$

$$\text{Var}\ (\overline{Y}_R) \doteq \left(\frac{1}{\sum_{j=1}^{n} V_j} \right)^2 \frac{n}{(n-1)} \sum_{j=1}^{n} (N_j - \hat{R}V_j)^2$$

$$\doteq \frac{1}{(1.17\text{x}10^{7}\text{m}^3)^2} \quad \frac{38}{(38-1)} \quad (1.98\text{x}1\ ^{8} \text{ fish})$$

$$\doteq 1.49\text{x}10^{-6} \text{ fish/m}^3$$

the length of the transect in question. The resulting volume for each transect was then corrected for bottom interference by determining the proportion of total possible vertical samples taken by the integrator.

The number of fish targets, N_j, in the jth transect were derived from the density estimates per unit volume given in the computer output of Appendix A and B. Assuming that the distribution of fish over a given transect is homogeneous, the resulting numbers of fish calculated for that transect would be very near the actual numbers present.

Population Estimates

Separate estimates were made of the fish populations in the Main Arm, the Seymour-Anstey Arms complex, and in the Salmon Arm, as well as in two small adjacent lakes, Little Shuswap Lake and Mara Lake. Two transects, 8 and 9, were analyzed by visual oscilloscope counts of targets above a threshold referenced to a noise level of 0.016 volt peak at 75 ms or an equivalent depth of 54.9 m. These counts were then used to develop functional regression equations between absolute counts and relative integrated values of the same transect. These equations were then used to convert relative densities obtained from the integrator into absolute densities for the remainder of the lake. The resulting estimates were then extrapolated over the surface area of each section of Shuswap Lake, Little Shuswap Lake, and Mara Lake bounded by the 18 m depth contour line. The results for the years 1971-1975 are tabulated in Table 3.

RESULTS

Fish Densities

Estimated fish densities ranged from 0.950 to 116.201 fish/are (100 m^2), a considerably wider range than has been observed in past years (Table 4). Appendix A contains the average number of fish/are and the average number of fish/1000 m^3 throughout the water column for the two shallowest depth strata extending from 4-11 m and from 11-18 m. The total number of fish/are for the two strata combined are likewise listed. Transects 8 and 9 were each divided into several segments for the purpose of analysis. Appendix B contains the same information for the remaining seven depth strata. Due to a TVG and integrator calibration coefficient anomaly which occurred during the integration phase of data analysis, it was necessary to perform a separate functional regression on the upper two strata independent of the remaining seven strata.

It was necessary to normalize the mean densities within each contiguous section of the lake due to variability in transect length. This procedure had not been employed in the 1971 survey, therefore, those standard means were converted to normalized means for comparative purposes. The equation for normalizing density follows:

Table 3. Estimated fish populations in Shuswap Lake, British Columbia, Canada, by statistical areas, in October of 1971, 1972, 1973, 1974, and 1975

Area	Population estimates (X 10^6)				
	1971	1972	1973	1974	1975
Little Shuswap Lake	– [1]	2.09	– [2]	– [1]	0.819
Main Arm, Shuswap Lake	21.98	7.08	2.94	3.69	18.629
Seymour-Anstey Arm, Shuswap Lake	5.80	7.63	1.73	1.97	5.855
Salmon Arm, Shuswap Lake	13.90	21.13	2.86	3.25	30.809
Mara Lake	– [1]	– [1]	– [1]	– [1]	6.186
TOTAL Shuswap Lake	41.70[3]	37.93	7.53	8.91	62.298

[1]No survey.

[2]Negligible number of fish seen on echograms.

[3]Revised population estimates.

Table 4. Mean numbers of fish/are observed in Shuswap Lake, British Columbia, in October of 1971, 1972, 1973, 1974, and 1975

Transect number	Area	Mean number of fish/are				
		1971	1972	1973	1974	1975
1	Main Arm	70.60	5.35	1.03	12.61	12.38
2		75.00	17.25	1.80	18.59	12.92
3		26.70	5.19	6.21	10.38	50.43
4		56.30	4.35	2.03	13.02	3.72
5		25.60	5.68	1.93	7.72	6.74
6		27.80	8.44	3.61	8.18	102.16
7		8.80	5.94	1.34	8.03	44.47
8		9.10	7.72	1.66	8.36	21.65
9		19.40	6.58	5.22	9.69	16.51
10		14.60	6.65	5.84	4.19	8.14
11[1]		-	-	-	5.14	-
12	Seymour Arm	17.60	10.19	1.23	6.45	5.64
13		12.40	13.12	3.56	7.11	1.00
14[1]		24.50	12.69	2.21	8.03	10.91
15[1]		-	-	-	7.89	11.49
16		25.20	6.88	1.95	3.72	11.35
17		12.40	8.07	4.10	6.18	6.36
18	Salmon Arm	26.00	26.10	4.16	25.48	5.19
19		37.30	16.82	1.56	15.69	8.14
20		21.60	22.80	3.17	11.01	28.60
21		24.90	23.88	3.38	14.21	116.20
22		16.80	28.89	3.26	7.97	43.59
23		15.00	25.73	2.34	7.13	42.62
24		24.90	18.80	2.34	11.36	33.38
25		-	19.29	2.78	10.55	4.05
26		12.40	14.26	3.10	5.14	23.45
27	Anstey Arm	10.60	11.34	2.28	8.35	2.85
28		7.70	8.92	1.26	8.21	2.31
29		6.60	7.87	2.48	7.35	4.44
30		6.60	10.13	1.62	11.35	26.23

[1]Replicate of previous transect.

$$\bar{\rho}_{Norm.} = \frac{1}{n} \sum_{j=1}^{n} \left(\frac{p_i \bar{\rho}_j}{p_{max.}} \right)$$

where:

$\bar{\rho}_{Norm.}$ = Normalized mean density

$\bar{\rho}_j$ = Standard mean density in the jth transect

p_j = Sonic transmissions in the jth transect

$p_{Max.}$ = Maximum numbers of sonic transmissions in the contiguous section

The resulting total population estimate for 1971 was reduced approximately 35 percent as a result of the normalizing procedure. This intuitively follows if one compares the results over the five year period 1971-1975 which are plotted in Fig. 1.

Variance and Confidence Limits

The mean density ($\bar{Y}_R$) calculated from the cluster ratio estimator method described in an earlier section was found to be 7.59×10^{-3} fish/m^3 with an associated variance of 1.49×10^{-6} fish/m^3 for Shuswap Lake, Mara Lake, and Little Shuswap Lake, combined (Table 2). The depth of interest used for this analysis was approximately 69 m. The volume considered accounts for approximately 42 percent of the total lake volume or 8.21×10^9 m^3 while approximately 0.14 percent of this volume was sampled during the survey or about 1.17×10^7 m^3.

Confidence limits were computed at the 95 percent level for the population mean density by the normal approximation using the following probability statement:

$$P\left(\bar{Y}_R - 1.96 \sqrt{Var\ (\bar{Y}_R)} \leq \frac{\sum_{j=1}^{n} T_j}{\sum_{j=1}^{n} V_j} \leq \bar{Y}_R + 1.96 \sqrt{Var\ (\bar{Y}_R)} \right) = .95$$

The resulting confidence limits on the mean fish density (fish/m^3) estimate were:

$$P' \{5.20 \times 10^{-3} \leq 7.59 \times 10^{-3} \leq 9.98 \times 10^{-3}\} = .95$$

These limits represent a spread of approximately ± 31 percent as might be expected by the variability in densities throughout the lake (Fig. 1).

Survival Estimates

An estimate of survival from egg to fry stage in October was computed as in the past years. Next a constant resident fish population estimate was subtracted from the total acoustic population estimate, which gives an estimate of the number of salmon fry present in the lake (Table 5).

It has been assumed that the resident fish population remains fairly constant from year to year. As a result of the very small salmon escapement in 1972, the acoustic population estimate the following year was considered close to that of the resident fish population. Assuming a 5 percent survival from egg to fry stage in October, next year under these low populations, this resulted in a resident fish population estimate of 6.89 million and a juvenile sockeye salmon population estimate of 0.64 million (Table 5). If such a resident fish population estimate is deducted from the acoustic estimates for all years surveyed, one can estimate the survival from egg to fry stage in October for those years, as was done in the above-mentioned table.

The extremely low survival in 1970-71 was at first thought to have been the result of unfavorable environmental conditions as was observed in Alaska and elsewhere. However, since we again observe a low survival this year of approximately 2.04 percent, an alternate explanation is that these two estimates reflect the limits of the carrying capacity of the nursery area.

The effect of parental stock density upon recruitment is seen to be density dependent and an appropriate recruitment curve is of the form:

$$R = aSe^{-bS}$$

where,

S = size of parental stock (spawners)
R = number of recruits (progeny)
a and b = parameters related to S

The parameters of the log transform of the original equation were estimated utilizing a preprogrammed routine, program No. FRD 312, for weighted linear regression (Dahlberg, 1968) with the female sockeye salmon escapement in the year i assumed to be the independent variable.

Table 5. 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, 1973, 1974, and 1975

	Year of observation					
	1970	1971	1972	1973	1974	1975
Number female sockeye salmon[1]	849,818	167,887	3,583	6,708	634,071	
Potential egg depositions (X 10^6)[2]	3,025.4	597.7	12.8	23.9	2,712.11	
Total lake population estimates (X 10^6)[3]		41.7	37.93	7.53	8.91	62.30
5% egg survival (X 10^6)				0.64	1.19	135.61
Total resident fish population estimates (X 10^6)[4]		6.89	6.89	6.89	6.89	6.89
Sockeye fry population estimates (X 10^6)		34.81	31.04	0.64	2.02	55.41
Eggs/fry		86.91	19.25	20.00	11.83	48.95
Percent survival of eggs to fry in October		1.2	5.2	5.0	8.5	2.04

[1]Female sockeye salmon escapements from Annual Report of Int. Pac. Salmon Fish. Comm., for the years 1970, 1971, 1972, 1973, and 1974.

[2]Average fecundity = 3,560 eggs (4274 eggs in 1975) (Op. cit.).

[3]Derived by hydroacoustic techniques.

[4]Assumed stable through 1971, 1972, 1973, 1974, and 1975.

A summary of the output may be found in Appendix C as well as a plot of the log transformed line from the equation:

$$\ln (R/S) = \ln a - bS$$

It should be noted that, despite a high level of correlation in the data (.9568), we are only considering three of the five points since the points for 1973 and 1974 are so near the origin. Therefore, although we have been able to get an unusually good fit utilizing a compound-exponential type model (Fig. 2), more variability is expected with inclusion of additional data.

Target Strength Analysis

Target voltage measurements as described by Nunnallee, et al., 1973 were made on 334 targets in a depth range of 30-40 ms (21.9-29.3 m) and on 238 targets in a depth range of 40-50 ms (29.3-36.6 m). The method of Craig and Forbes (1969) was used to convert the apparent target strength data to relative frequencies based on the directivity pattern of the transducer utilizing program No. FRT 340 (Traynor, 1973).

Appendix D contains the results of the target strength analysis. The relative frequencies show a bimodal distribution of target strengths which may indicate two distinct size classes of fish (Fig. 3). The -37 to -31 decibel range would seem to represent the majority of fish present in the water column, namely sockeye salmon.

ACKNOWLEDGMENTS

Thanks goes to T. W. Gjernes of the International Pacific Salmon Fisheries Commission for his assistance in making arrangements for the survey. Sincere appreciation goes to Peter Buck and Tom Eburne for their participation in conducting the survey of Shuswap Lake. Valuable assistance with analysis was rendered by E. P. Nunnallee and C. Lee of the Fisheries Research Institute, University of Washington.

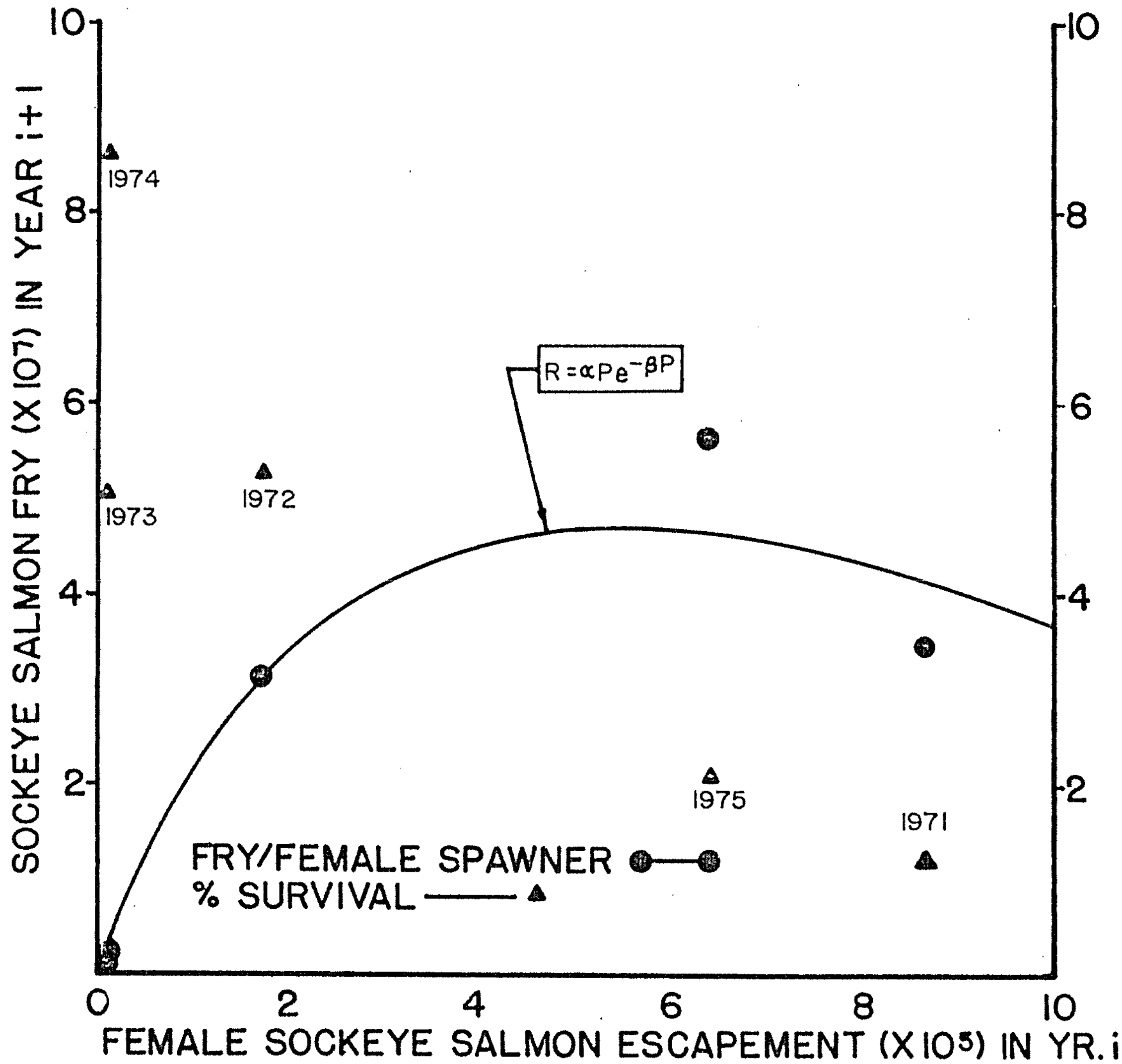

Fig. 2. The relationship of the number of spawning female sockeye salmon to the number of fry surviving in October the following year.

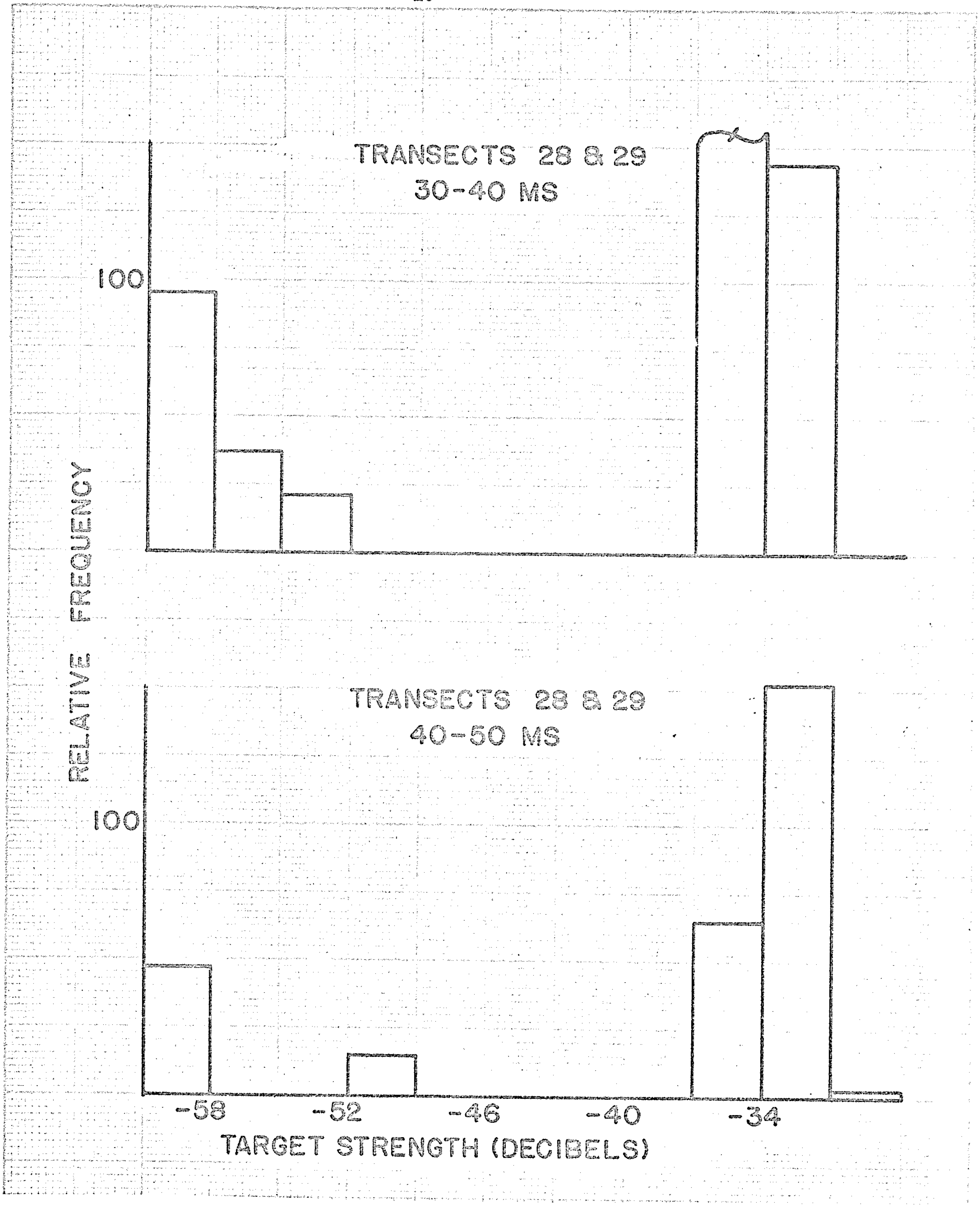

Fig. 3. The distribution of measured target strengths of transects 28 and 29 in Shuswap Lake.

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APPENDICES

APPENDIX A

Numbers of fish/are and fish/1000 m^3 of the water column within the top two depth strata of each transect of Shuswap Lake, British Columbia, Canada, 1975 hydroacoustic survey.

SHUSWAP LAKE SURVEY 75.TRANSECTS = 1 2 3 4 5 6 7 8A 8B

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE 'ETERS SURFACE AREA

DEPTH (METER) INTERVAL:	1	2	3	4	5	6	7	8A	8B
4 - 11	4.49625	9.77786	.61379	7.79158	1.31752	1.89954	7.69211	4.13144	3.54597
11 - 18	.13522	.08774	.19035	.31973	6.34799	9.99141	23.24451	5.27726	7.10748
TOTAL	4.63146	9.86560	.80414	8.11131	7.66551	11.89095	30.93662	9.40871	10.65345

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	1	2	3	4	5	6	7	8A	8B
4 - 11	7.26741	13.78424	.84487	11.37338	1.80951	2.61614	10.54332	5.65649	4.85750
11 - 18	3.26615	.87908	.52821	1.13641	9.00793	14.14921	31.93772	7.34142	9.73627

SHUSWAP LAKE SURVEY 75, TRANSECTS = 8C 8D 9A 9B 9C 9D 10 11 12

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	8C	8D	9A	9B	9C	9D	10	11	12
4 - 11	1.31194	.39655	13.60466	8.83131	7.78191	10.16369	9.10318	3.47518	.63942
11 - 18	3.87590	2.04216	4.79625	11.35761	12.67667	10.96436	20.93113	3.54372	2.72858
TOTAL	5.18785	2.43872	18.40290	20.18892	20.45858	21.12805	30.03430	7.01890	3.36799

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	8C	8D	9A	9B	9C	9D	10	11	12
4 - 11	1.79718	.54322	18.63926	12.09768	10.66015	13.95434	12.47798	4.76052	.87603
11 - 18	5.30946	2.79762	6.57706	15.55837	17.36531	16.06066	29.06152	4.90951	3.76273

SHUSWAP LAKE SURVEY 75, TRANSECTS = 13 14 15 16 17 18 19 20 21

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	13	14	15	16	17	18	19	20	21
4 - 11	1.53141	.92638	.57553	.35659	.46319	.43561	.48706	.42567	.42728
11 - 18	1.21980	.97566	3.67222	.79364	.82214	1.48854	1.18576	.78754	.89283
TOTAL	2.75121	1.90204	4.24775	1.15023	1.28533	1.92415	1.67282	1.21321	1.32011

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	13	14	15	16	17	18	19	20	21
4 - 11	2.09782	1.26902	.78840	.48848	.63451	.59672	.66747	.58365	.58477
11 - 18	1.67269	1.33971	5.04153	1.09020	1.12713	2.04492	1.63906	1.08947	1.22617

SHUSWAP LAKE SURVEY 75, TRANSECTS = 22 23 24 25 26 27 28 29 30

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	22	23	24	25	26	27	28	29	30
4 - 11	.52188	.37731	.84964	.44286	.53708	.68009	2.77972	2.51313	5.15282
11 - 18	1.19877	.79012	1.80904	1.30879	.85882	1.57139	2.44268	1.24726	1.31732
TOTAL	1.72065	1.16742	2.65868	1.75165	1.39591	2.25148	5.22240	3.76039	6.47014

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	22	23	24	25	26	27	28	29	30
4 - 11	.71490	.51702	1.16389	.60666	.73598	.93332	3.82473	3.44264	7.09938
11 - 18	1.64403	1.14449	2.48712	1.79904	1.18187	2.17361	3.37451	1.70990	1.85895

SHUSWAP LAKE SURVEY 75, TRANSECTS = 31 32 33 34 35 36 37 38

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER)	INTERVAL:	31	32	33	34	35	36	37	38
4 - 11		3.24783	1.81118	1.19704	.87073	.60986	1.43044	1.35407	1.03483
11 - 18		5.18180	1.04394	3.46900	3.41881	2.40197	3.63691	3.06888	3.11250
	TOTAL	8.42963	2.85511	4.66603	4.28954	3.01183	5.06735	4.42296	4.14733

DENSITY PER 1000 CUBIC METERS

DEPTH (METER)	INTERVAL:	31	32	33	34	35	36	37	38
4 - 11		4.45670	2.51148	1.80616	1.25587	.87213	1.99930	1.98277	1.42181
11 - 18		7.28472	1.49466	6.83688	5.64052	3.67743	5.32584	4.80518	4.75221

APPENDIX B

Numbers of fish/are and fish/1000 m^3 of the water column within the bottom seven depth strata of each transect of Shuswap Lake, British columbia, Canada, 1975 hydroacoustic survey.

SHUSWAP LAKE SURVEY 75, TRANSECTS = 1 2 3 4 5 6 7 8A 8B

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	1	2	3	4	5	6	7	8A	8B
18 - 26	.00000	.00000	.06617	.00000	4.93117	11.74288	16.73378	2.10364	7.12970
26 - 33	.00000	.00000	.07718	.00000	5.22939	2.93831	9.45630	1.64227	4.25660
33 - 40	.00000	.00000	.02853	.00000	3.24317	.00000	3.72230	.91203	1.63798
40 - 48	.00000	.00000	.00000	.00000	.73683	.00000	.00199	.44523	1.02278
48 - 55	.00000	.00000	.00000	.00000	.18720	.00000	.00000	.11192	.00197
55 - 62	.00000	.00000	.00000	.00000	.08470	.00000	.00000	.00000	.00000
62 - 69	.00000	.00000	.00000	.00000	.07657	.00000	.00000	.00000	.00000
TOTAL	.00000	.00000	.17188	.00000	14.48904	14.68119	29.91436	5.21510	14.05902

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	1	2	3	4	5	6	7	8A	8B
18 - 26	.00000	.00000	.34224	.00000	8.37643	17.51029	22.74071	2.95449	9.63472
26 - 33	.00000	.00000	.73145	.00000	10.77089	12.00858	13.85145	2.54641	5.84456
33 - 40	.00000	.00000	1.69515	.00000	7.42249	.00000	9.72386	1.81567	2.24361
40 - 48	.00000	.00000	.00000	.00000	1.85452	.00000	4.01619	1.34398	1.88346
48 - 55	.00000	.00000	.00000	.00000	.55007	.00000	.00000	2.69713	.54188
55 - 62	.00000	.00000	.00000	.00000	.28361	.00000	.00000	.00000	.00000
62 - 69	.00000	.00000	.00000	.00000	.29107	.00000	.00000	.00000	.00000

SHUSWAP LAKE SURVEY 75, TRANSECTS = 8C 8D 9A 9B 9C 9D 10 11 12

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	8C	8D	9A	9B	9C	9D	10	11	12
18 - 26	3.69684	1.82644	8.36591	8.77271	15.16296	5.17862	32.67140	15.58108	12.70833
26 - 33	1.74496	.44256	4.51211	3.37969	7.91430	2.49766	22.20928	14.26377	14.21818
33 - 40	.74948	.26006	.69232	1.91747	2.64893	1.43677	10.71313	7.43095	9.35814
40 - 48	.32010	.08807	.08166	1.07437	2.61445	.80325	5.27487	4.34585	5.44660
48 - 55	.00000	.00000	.00000	.77109	.85220	.27243	1.13157	2.28740	2.85245
55 - 62	.00000	.00000	.00000	.00000	.00268	.00000	.12175	.22601	.27421
62 - 69	.00000	.00000	.00000	.00000	.00000	.00000	.00583	.01736	.10635
TOTAL	6.51138	2.61713	13.65200	15.91533	29.19553	10.18874	72.12783	44.15242	44.96426

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	8C	8D	9A	9B	9C	9D	10	11	12
18 - 26	4.99573	2.55455	11.57361	11.85501	20.49049	7.98611	45.52969	21.72199	17.64707
26 - 33	2.39035	.69414	6.67534	4.62971	10.84151	4.15517	31.97958	20.77839	20.69203
33 - 40	1.02668	.50746	1.56643	2.62667	3.62867	2.53686	15.92443	11.35195	14.08325
40 - 48	.71504	.41935	1.60591	1.58322	3.58144	1.62041	8.63994	7.44134	8.49230
48 - 55	.00000	.00000	.00000	3.29442	1.29791	1.41080	2.37775	4.49326	4.67806
55 - 62	.00000	.00000	.00000	.00000	.37518	.00000	.40897	.61478	.53032
62 - 69	.00000	.00000	.00000	.00000	.00000	.00000	.23532	.43361	.29767

SHUSWAP LAKE SURVEY 75, TRANSECTS = 13 14 15 16 17 18 19 20 21

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER)	INTERVAL: 13	14	15	16	17	18	19	20	21
18 - 26	10.57387	4.47235	2.99473	2.40931	5.10435	5.50238	4.13618	5.76006	.89080
26 - 33	10.93934	5.60793	.77061	.31792	2.74662	9.08247	10.44891	6.24419	.30377
33 - 40	5.85402	3.27702	.91549	.15926	.53055	1.93359	2.57921	1.08425	.51277
40 - 48	3.52541	2.07422	.12865	.14496	.22829	.29147	.35796	.32316	1.06513
48 - 55	1.38412	.74240	.91092	.13016	.19745	.27046	.18814	.32822	.45832
55 - 62	.23611	.23508	.00000	.18305	.22646	.18806	.20382	1.19411	.21583
62 - 69	.16895	.19456	.00000	.00000	.58949	.20111	.17707	.80023	.15404
TOTAL	32.68181	16.60354	5.72040	3.35467	9.62322	17.46954	18.09129	15.73422	3.60166

DENSITY PER 1000 CUBIC METERS

DEPTH (METER)	INTERVAL: 13	14	15	16	17	18	19	20	21
18 - 26	14.41615	6.20980	4.31071	3.37319	6.95417	7.62138	5.77039	7.90548	1.25319
26 - 33	15.33675	8.02967	1.31370	.48317	3.86344	13.22893	15.28236	8.75129	.45384
33 - 40	8.35179	4.75062	1.90769	.23155	.76208	2.87277	3.82285	1.53166	.80110
40 - 48	5.13207	3.04480	.37080	.29071	.33584	.43965	.53844	.46028	1.74354
48 - 55	2.08132	1.11192	7.34168	.33113	.29674	.41308	.28672	.46925	.82273
55 - 62	.37368	.35535	.00000	.94108	.35594	.26826	.31143	1.69146	.42480
62 - 69	.29800	.31573	.00000	.00000	.97330	.316-5	.28132	1.18411	.36521

SHUSWAP LAKE SURVEY 75, TRANSECTS = 22 23 24 25 26 27 28 29 30

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	22	23	24	25	26	27	28	29	30
18 - 26	1.11460	.99696	5.22672	2.01776	1.75110	6.64126	24.43511	12.67943	11.45402
26 - 33	.65253	1.00949	7.09994	1.89184	2.87048	8.95216	53.52926	20.79810	26.33028
33 - 40	.39665	1.22416	5.79685	1.59398	1.89461	5.27287	35.44765	12.05432	18.14345
40 - 48	.77386	1.18193	7.79974	1.66807	1.08956	4.12847	16.46259	2.96957	6.12680
48 - 55	.53678	.60807	4.52825	1.20549	.46437	.88449	1.75254	.46499	1.34522
55 - 62	.16165	.21501	1.12724	.34697	.25845	.26110	.28439	.18773	.37244
62 - 69	.15408	.10589	.28304	.15671	.20251	.20320	.31223	.13126	.15582
TOTAL	3.79015	5.34151	31.86179	8.89082	8.53107	26.34355	132.22377	49.28540	63.92803

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	22	23	24	25	26	27	28	29	30
18 - 26	1.53330	1.57303	7.16267	2.78009	2.40217	9.14953	33.44839	17.25732	16.13214
26 - 33	.96226	1.77263	9.97931	2.71684	4.10917	12.67569	74.63302	30.06576	39.09365
33 - 40	.61838	2.29951	8.34690	2.39625	2.75411	7.55694	49.90498	21.06389	26.3-511
40 - 48	1.25995	2.50407	11.63613	2.66093	1.60081	5.97790	27.41578	5.82402	10.05000
48 - 55	.92[illegible]8	1.50497	6.87665	2.06168	.69165	1.30110	2.53084	.94900	2.33562
55 - 62	.29484	.58768	1.73327	.65768	.38916	.38642	.41389	.39084	.69626
62 - 69	.32365	.39084	.46277	.35459	.31809	.31167	.47625	.29146	.33049

SHUSWAP LAKE SURVEY 75, TRANSECTS = 31 32 33 34 35 36 37 38

TIME INTERVALS OF VARIABLE DURATION

DENSITY PER 100 SQUARE METERS SURFACE AREA

DEPTH (METER) INTERVAL:	31	32	33	34	35	36	37	38
18 - 26	7.51542	3.36737	3.99555	4.65181	4.33792	21.06055	17.45712	9.76721
26 - 33	17.02366	5.19229	1.55641	10.13825	11.28787	39.51391	12.96284	.00000
33 - 40	17.49317	2.43345	.00000	12.52621	6.56000	11.31297	.00000	.00000
40 - 48	19.05962	1.38703	.00000	5.39551	.98565	.00000	.00000	.00000
48 - 55	7.32177	.68030	.00000	1.92898	.00000	.00000	.00000	.00000
55 - 62	1.78992	.00304	.00000	.73435	.00000	.00000	.00000	.00000
62 - 69	.26631	.00000	.00000	.43214	.00000	.00000	.00000	.00000
TOTAL	70.46986	13.06348	5.55196	35.80723	23.17145	71.88743	30.41996	9.76721

DENSITY PER 1000 CUBIC METERS

DEPTH (METER) INTERVAL:	31	32	33	34	35	36	37	38
18 - 26	10.66246	5.06329	11.75729	8.03841	7.54427	31.94687	32.64383	28.44949
26 - 33	25.69834	8.54572	21.18717	19.34987	24.62391	73.10018	74.78889	.00000
33 - 40	28.11430	4.22345	.00000	25.37833	20.51400	59.38867	.00000	.00000
40 - 48	32.59618	2.60890	.00000	11.95825	13.30039	.00000	.00000	.00000
48 - 55	13.77009	2.09386	.00000	4.58363	.00000	.00000	.00000	.00000
55 - 62	3.82393	.28071	.00000	1.88679	.00000	.00000	.00000	.00000
62 - 69	.74705	.00000	.00000	1.23519	.00000	.00000	.00000	.00000

APPENDIX C

Results of a transformed weighted linear regression fit of the Ricker model curve.

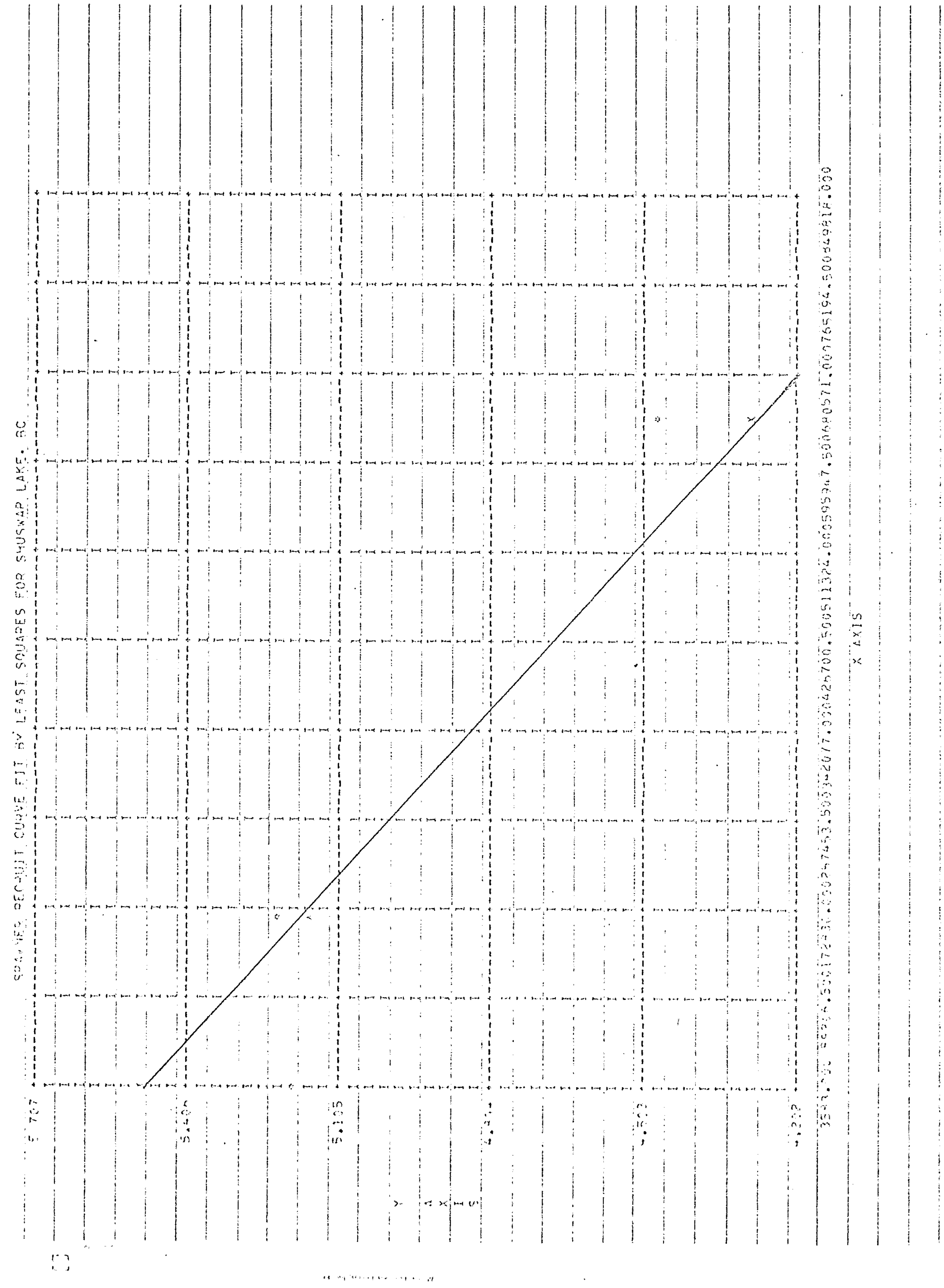
WEIGHTED LINEAR REGRESSION

SPAWNER RECRUIT CURVE FIT BY LEAST SQUARES FOR SHUSWAP LAKE, BC

SUM W = 5.00000000E+00		
SUM W*X = 1.66204710E+06		SUM W*Y = 2.42955406E+01
$\bar{X}$ = 3.32413420E+05		$\bar{Y}$ = 4.85910812E+00
RANGE OF X GOES FROM 3.58830000E+03 TO 8.49815000E+05		RANGE OF Y GOES FROM 3.71259598E+00 TO 5.70754207E+00
$(\text{SUM W*X})^2$ = 2.76244671E+12	(SUM W*X)*(SUM W*Y) = 4.03808163E+07	$(\text{SUM W*Y})^2$ = 5.90273293E+02
$\frac{(\text{SUM W*X})^2}{\text{SUM W}}$ = 5.52489342E+11	$\frac{(\text{SUM W*X})*(\text{SUM W*Y})}{\text{SUM W}}$ = 8.07616326E+06	$\frac{(\text{SUM W*Y})^2}{\text{SUM W}}$ = 1.18054659E+02
SUM W*X^2 = 1.15244055E+12	SUM W*X*Y = 6.92276476E+06	SUM W*Y^2 = 1.20476544E+02
$\text{SUM W*}(X-\bar{X})^2$ = 5.99947234E+11	$\text{SUM W*}(X-\bar{X}) * (Y-\bar{Y})$ =-1.15339850E+06	$\text{SUM W*}(Y-\bar{Y})^2$ = 2.42188514E+00
VARIANCE(X) = 1.49986801E+11	COVARIANCE(XY) =-2.88349625E+05	VARIANCE(Y) = 6.05471284E-01
ST. DEV.(X) = 3.87286208E+05	CORRELATION COEFFICIENT = 9.56823023E-01	ST. DEV.(Y) = 7.78120353E-01
ST. ERR.$(\bar{X})$ = 1.73203234E+05	R-SQUARED = 9.15510298E-01	ST. ERR.$(\bar{Y})$ = 3.47986001E-01

```
WEIGHTED LINEAR REGRESSION

SPAWNER RECRUIT CURVE FIT BY LEAST SQUARES FOR SHUSWAP LAKE, BC
******************************************************************************************
REGRESSION EQUATION

F(X) =  B0  +  B1*(X(I))               VARIANCE(B0)  = 2.62034017E-02      VARIANCE(B1) = 1.13682621E-13

     =  5.49313 - 1.92237181B3+06    *(X(I))   ST. DEV.(B0)  = 1.61874648E-01      ST. DEV.(B1) = 3.37168535E-07

                                                        COVARIANCE OF B0 WITH B1 =-3.77896265E-08

                                        95 PERCENT CONFIDENCE INTERVAL FOR--
                                  B0 EXTENDS                          B1 EXTENDS
                                    FROM  4.98304515E+00                 FROM -2.99524211E-06
                                      TO  6.01321541E+00                   TO -8.49501553E-07

                          VARIANCE ABOUT LINE  = 6.82091177E-02   ST. DEV. ABOUT LINE = 2.61166839E-01

   F(X) =  YBAR + B1*(X(I)-XBAR)

        =        4.85411 -     .00000 *(X(I) - 8413.40000)

   T-TEST OF HYPOTHESIS B1 =    .00000

                   T =   -5.70152  WITH    3 DEGREES OF FREEDOM

   T-TEST OF HYPOTHESIS B0 =    .00000

                   T =   33.93535  WITH    3 DEGREES OF FREEDOM
******************************************************************************************
                      ANALYSIS OF VARIANCE FOR WEIGHTED LINEAR REGRESSION
******************************************************************************************
      SOURCE OF VARIATION      DEGREES OF FREEDOM      SUM OF SQUARES      MEAN SQUARE       F-RATIO
******************************************************************************************
      DUE TO REGRESSION                1            2.21726078E+00     2.21726078E+00     32.50729

      DEVIATION ABOUT REG.             3            2.04624353E-01     6.82081177E-02
******************************************************************************************
      TOTAL                            4            2.42188514E+00
```

NUMBER OF OBSERVATION	INDEPENDENT VARIABLE (X)	DEPENDENT VARIABLE (Y)	PREDICTED VALUE VALUE	ST. DEV. OF PREDICTED	RESIDUAL (OBS - PRED) (INITIAL)	WEIGHTING FACTORS (NORMALIZED)	WEIGHTING	.95 CONF INTERVAL (PLUS - MINUS)
1	69812.0000	3.7126	3.8645	.3351	-.1519	1.0000	1.0000	.66503
2	87447.[illegible]	5.2194	5.1754	.2914	.0444	1.0000	1.0000	.41144
3	3543.[illegible]	5.1853	5.4912	.3068	-.3060	1.0000	1.0000	.51243
4	6709.30[illegible]	5.7075	5.4852	.3064	.2223	1.0000	1.0000	.51013
5	44071.[illegible]	4.4764	4.2792	.3036	.1912	1.0000	1.0000	.49281


SPAWNER RECRUIT CURVE FIT BY LEAST SQUARES FOR SHUSWAP LAKE, BC
5.707
5.406
5.105
Y AXIS
X AXIS

APPENDIX D

Results of target strength analysis
on fish targets detected between 30-
40 ms. and 40-50 ms. on transects
28 and 29 of Shuswap Lake, B.C., Canada.

TARGET STRENGTH ANALYSIS   SHUSWAP LAKE-1975   40-50 MS

SAMPLE   DB BOUNDARIES AND CALCULATED CRAIG AND FORBES RELATIVE FREQUENCIES

NO.	-28	-31	-34	-37	-40	-43	-46	-49	-52	-55	-58	-61	-64	-67	-70	-73	-76
1	4	153	64	-50	-7	-20	-21	15	-11	-22	22	-32	-40	-31	-25	-25	

TOTALS - SUM OF RELATIVE FREQUENCIES FOR ALL SAMPLES

4	153	64	0	0	0	0	15	0	0	22	0	0	0	0	0	

TOTALS - CRAIG FORBES RELATIVE FREQUENCIES CALCULATED FROM SUMS OF RAW DB FREQUENCIES FOR ALL SAMPLES

4	153	64	-50	-7	-20	-21	15	-11	-22	22	-32	-40	-31	-25	-25	

PROP. .017.591.248.000.000.000.000.059.000.000.085.000.000.000.000.000

SAMPLE   DB BOUNDARIES AND RAW FREQUENCIES UNCORRECTED BY CRAIG AND FORBES

NO.	-28	-31	-34	-37	-40	-43	-46	-49	-52	-55	-58	-61	-64	-67	-70	-73	-76
1	15	59	47	14	24	14	11	20	11	6	17	0	0	0	0	0	

TOTALS - SUM OF RAW FREQUENCIES

15	59	47	14	24	14	11	20	11	6	17	0	0	0	0	0	

TARGET STRENGTH ANALYSIS   SHUSWAP LAKE-1975   30-40 MS

SAMPLE NO. — DB BOUNDARIES AND CALCULATED CRAIG AND FORBES RELATIVE FREQUENCIES

SAMPLE NO.	-28	-31	-34	-37	-40	-43	-46	-49	-52	-55	-58	-61	-64	-67	-70	-73	-76
1		0	143	188	-36	-66	-42	-48	-47	22	39	95	-32	-84	-77	-56	-53

TOTALS - SUM OF RELATIVE FREQUENCIES FOR ALL SAMPLES

0	143	188	0	0	0	0	0	22	39	95	0	0	0	0	0

TOTALS - CRAIG FORBES RELATIVE FREQUENCIES CALCULATED FROM SUMS OF RAW DB FREQUENCIES FOR ALL SAMPLES

0	143	188	-36	-66	-42	-48	-47	22	39	95	-32	-84	-77	-56	-53

PROP. .001.292.386.000.000.000.000.000.045.081.196.000.000.000.000.000

SAMPLE NO. — DB BOUNDARIES AND RAW FREQUENCIES UNCORRECTED BY CRAIG AND FORBES

SAMPLE NO.	-28	-31	-34	-37	-40	-43	-46	-49	-52	-55	-58	-61	-64	-67	-70	-73	-76
1		1	50	84	29	15	15	8	5	24	33	54	16	0	0	0	0

TOTALS - SUM OF RAW FREQUENCIES

1	50	84	29	15	15	8	5	24	33	54	16	0	0	0	0