FRI-UW-7722
July 1977

LAKE WASHINGTON SOCKEYE SALMON STUDIES

1976-1977

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Richard E. Thorne and James J. Dawson

FINAL REPORT
Service Contract No. 737
Washington State Department of Fisheries
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Robert L. Burgner
Director

INTRODUCTION

Acoustic techniques for the assessment of sockeye salmon were developed under the University of Washington Sea Grant Program and have been applied to studies of juvenile sockeye salmon in Lake Washington since 1969, and to assessment of adult sockeye returning to Lake Washington since 1971. These population estimates provide valuable information for the management of the Lake Washington sockeye salmon run, and support for the studies has been provided by the Washington Department of Fisheries (WDF) since 1974. Results of the acoustic surveys during the past year are described in this contract report.

MATERIALS AND METHODS

Survey Equipment and Procedure

The acoustic data-acquisition system consisted of a Ross 200 A echo sounder with modifications for data collection on magnetic tape. The system is detailed in Thorne et al. (1972) and Nunnallee (1975).

Four acoustic surveys of the adult sockeye salmon were conducted in 1976. The first two surveys, on July 12 and 13, were conducted during the period of peak migration into Lake Washington. The final two surveys were completed on July 26 and 27 when virtually all adult sockeye salmon were in the lake. The transect pattern used was the same one used in previous years (Fig. 1). All surveys were run at night and at a vessel speed of 6-8 knots.

Only one series of acoustic surveys on the juvenile salmon was conducted during 1976, consisting of 16 diagonal transects. The southern half of the lake was surveyed on March 8 and the northern half on March 9. The associated midwater trawl sampling with a 3-m IKMT from the R.V. COMMANDO was also completed on these two nights. The trawl sampling stations and depths were unchanged from previous years (Fig. 2).

Data Analysis: Adult Salmon Surveys

Counts of large fish targets were made using four different thresholds which were equivalent to acoustic target strengths of -32, -35, -38, and -41 decibels (dB). Target strength measurements and comparisons among lock counts, tower counts, and acoustic counts from previous years have indicated that the -38 dB threshold provides a good estimate. However, in 1975, the -35 dB threshold provided a better agreement with the escapement estimated from tower counts, and target strength studies have indicated that the -38 dB threshold is more sensitive to error due to large resident fish.

The area sampled by the echo sounder is determined from measurements of the duration of targets within the acoustic beam. Larger acoustic thresholds have correspondingly smaller sampled areas. Measurements were made during 1976 at -35 dB, -38 dB, and -41 dB to check for consistency with measurements from previous years. Numbers of fish echoes counted above these thresholds were divided by the appropriate sampling area to determine the numbers of

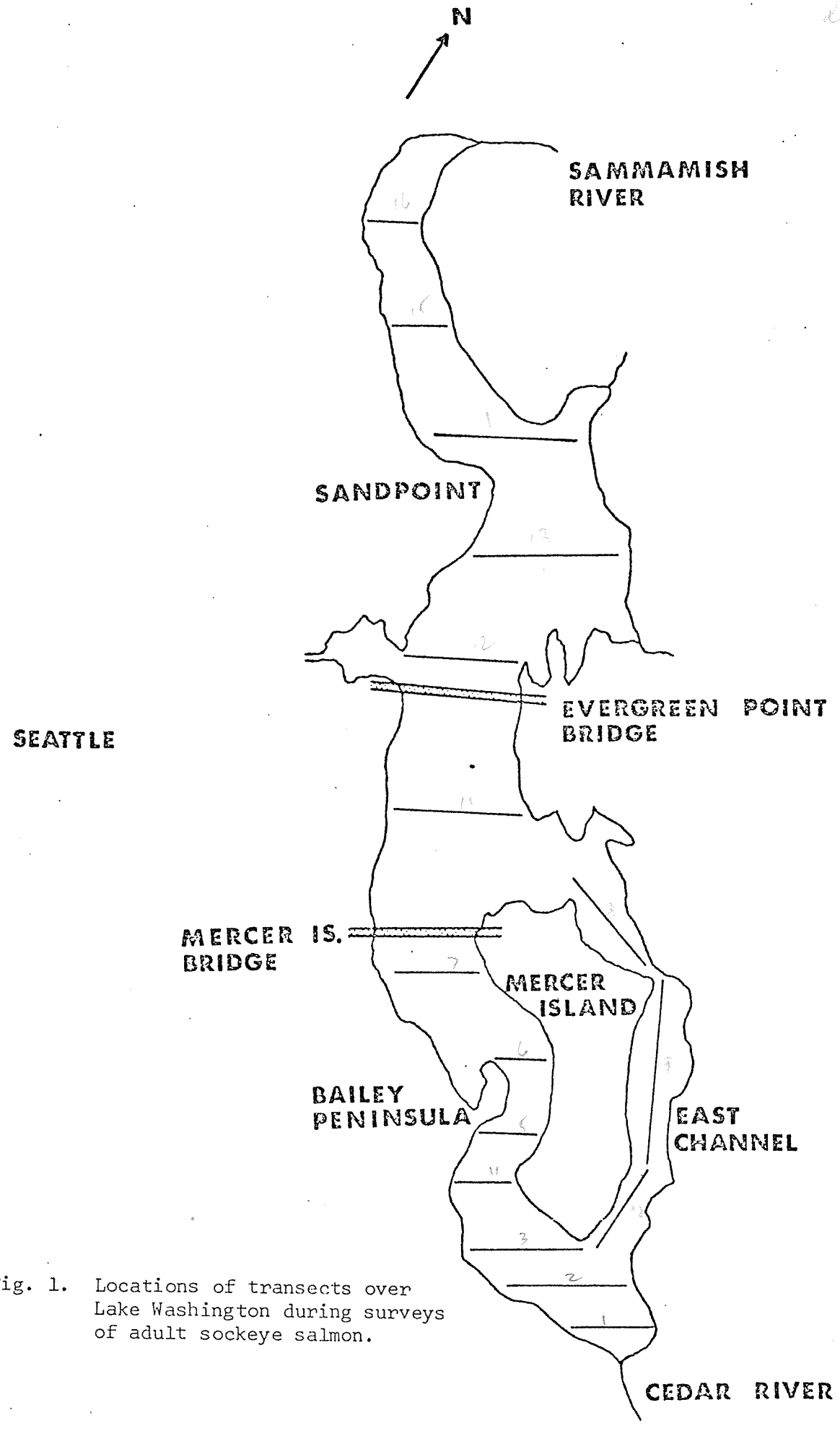

Fig. 1. Locations of transects over Lake Washington during surveys of adult sockeye salmon.

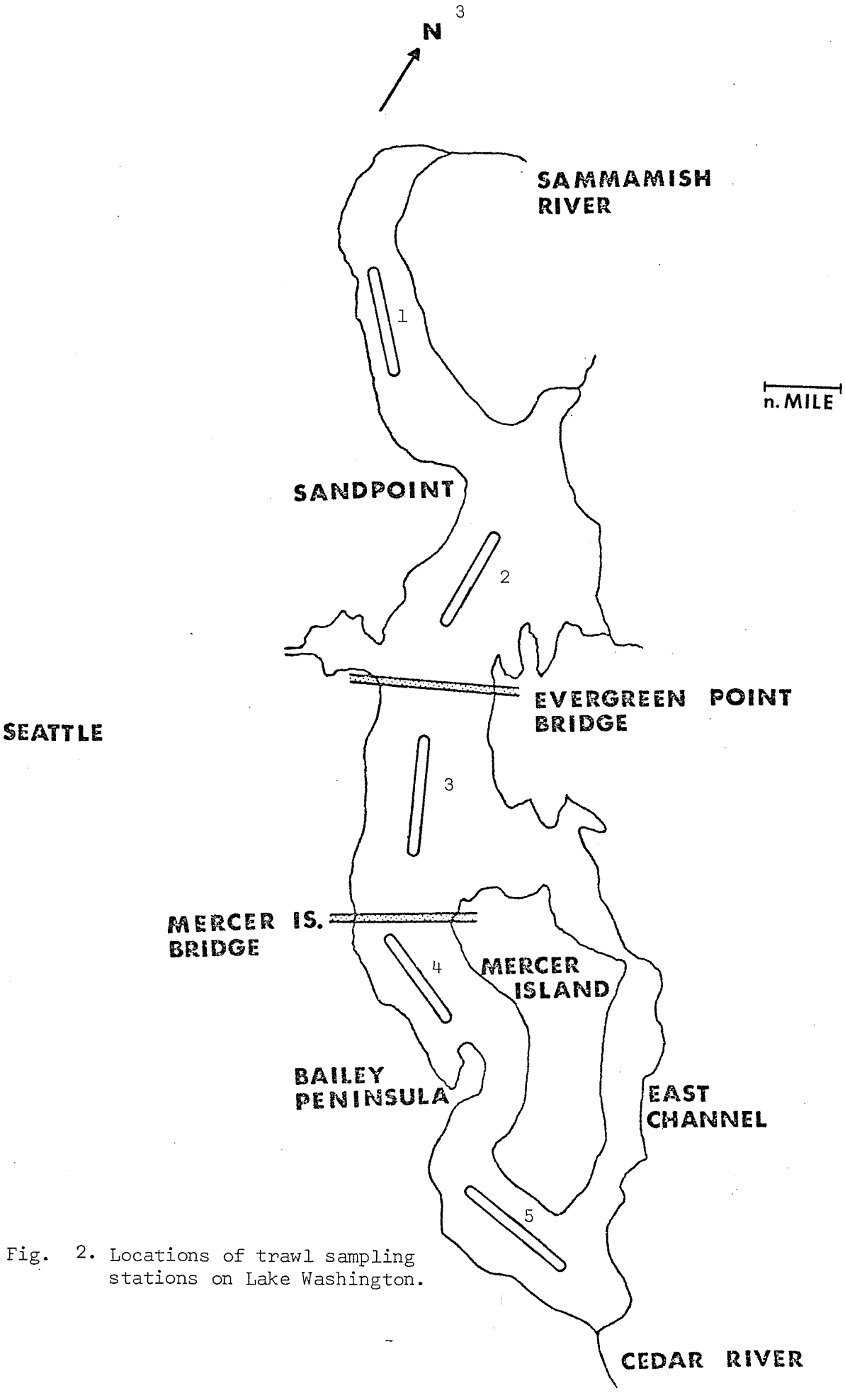

Fig. 2. Locations of trawl sampling stations on Lake Washington.

fish per unit surface area for each transect and total numbers in the transects were calculated by extrapolation over the surface areas represented by the transects. Counts at -32 dB were made only for an indication of the size of targets. Population estimates were not made at this threshold because of lack of historical measurements of the sampled area of the echo sounder for a -32 dB target.

Data Analysis: Juvenile Sockeye Salmon Survey

The acoustic data from the juvenile salmon surveys were again analyzed by digital echo integration techniques (Thorne et al. 1975). The integrator was calibrated by means of regression against fish densities derived from oscilloscope counting techniques. This procedure is essentially an indirect method of determining the mean acoustic target strength of the fish. This year it was necessary to derive two separate regression relationships--one for all depths above 25 m and one for depths below 25 m because of a pronounced size difference between fish above and below 25 m (Fig. 3).

The integration analysis resulted in estimates of total fish abundance in various depth and area strata. The species composition from the net tows corresponding to these strata was then used to allocate the abundance to the various species, and total abundance for each species in the lake was calculated by summing over the strata.

In addition to the acoustic estimates, the net tows were used to estimate density by assuming a swept volume of 1000 m^3 per min of tow, as in previous years. These densities were then extrapolated by the volume of the strata to derive estimates of total lake abundance. The net and acoustic estimates of total abundance are completely independent, but the species composition of the two estimates is obviously the same.

RESULTS AND DISCUSSION

Adult Salmon Surveys

Counts of fish targets for various thresholds, transects, and dates are given in Table 1. The resulting estimates of large fish abundance in Lake Washington for each of the four dates and for the -35, -38 and -41 dB thresholds are given in Table 2. Background populations were assumed based on the previous 3 years, and estimates of sockeye salmon escapement were derived by subtracting the background from the mean of the two surveys at the end of July.

The estimate based on the -38 dB threshold was 246,000. This threshold provided a good correspondence with lock counts and tower counts during 1972-1974, but was higher in 1975. The estimate based on -35 dB was 194,000. This threshold was first used in 1975 and provided the best correspondence.

The estimated Lake Washington basin escapement from tower counts and spawning ground surveys in 1976 was 159,000, which is considerably less than any of the acoustic estimates. The preliminary lock count was 213,000, which agrees well with the acoustic estimate based on -35 dB.

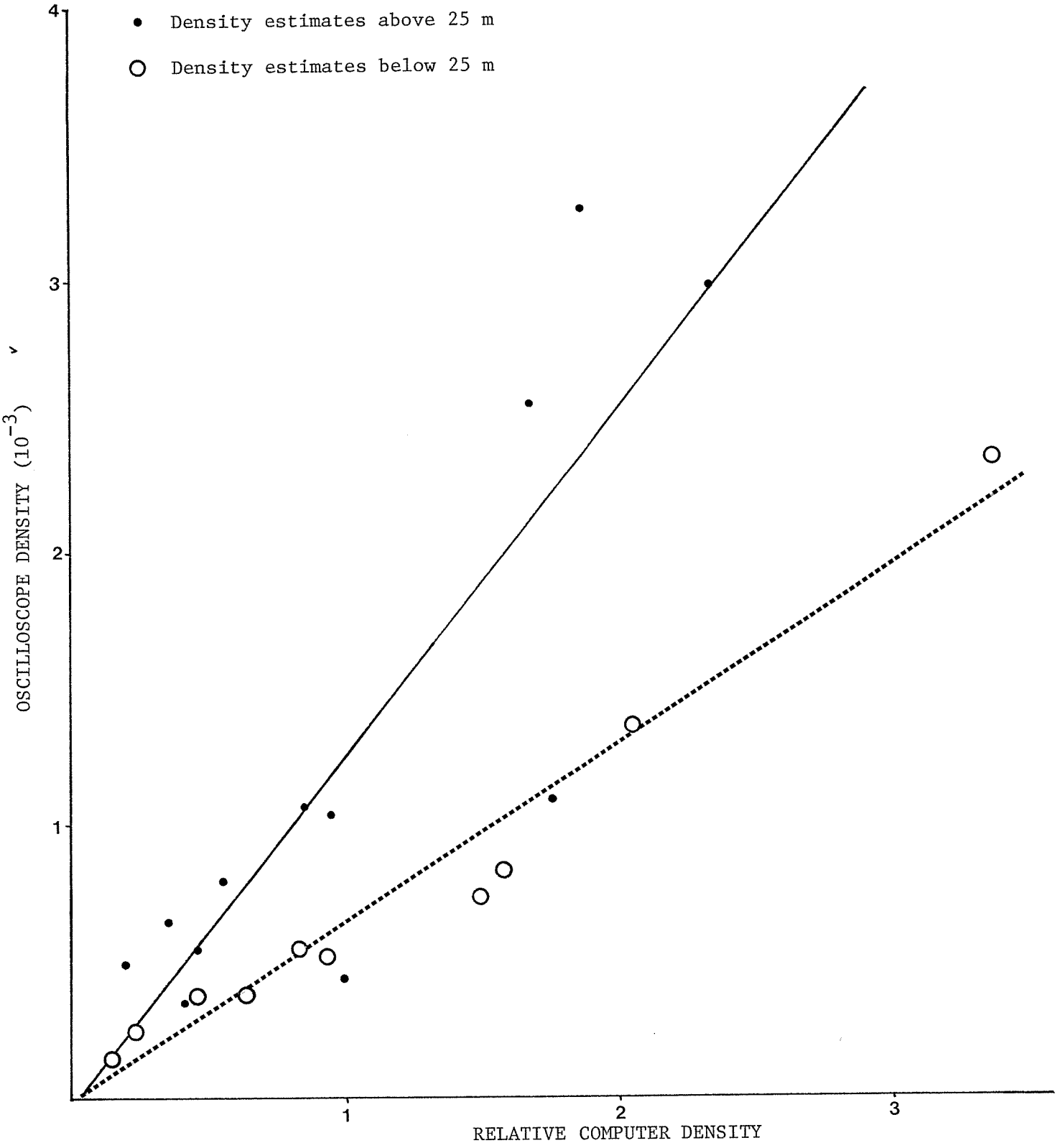

Fig. 3. Regression of relative densities of fish measured by the computer against density estimates from oscilloscope observations.

Table 1. Numbers of fish targets above various target strength thresholds observed along transects in Lake Washington, July 12, 13, 26 and 27

Date	Transect	Threshold level (decibels)			
		-32	-35	-38	-41
July 12	1	5	5	7	19
	2	15	17	20	24
	3	7	7	9	9
	4	10	10	17	17
	5	16	16	23	25
	6	12	12	17	17
	7	4	4	8	8
	8	8	9	13	14
	9	1	1	1	7
	10	3	3	5	5
	11	2	2	6	6
	12	1	1	1	1
	13	5	6	11	11
	14	0	0	3	3
	15	2	3	3	3
	16	0	0	0	0
	Total	91	95	144	169
July 13	1	10	10	10	10
	2	10	10	14	15
	3	7	10	10	11
	4	9	10	13	14
	5	17	17	26	26
	6	5	5	8	8
	7	1	1	1	1
	8	6	6	6	6
	9	0	1	1	1
	10	1	2	3	3
	11	3	3	4	4
	12	1	1	1	1
	13	3	3	3	4
	14	0	0	0	0
	15	2	2	3	3
	16	2	2	2	2
	Total	77	83	107	108

Table 1. Numbers of fish targets above various target strength thresholds observed along transects in Lake Washington, July 12, 13, 26 and 27 - Continued

Date	Transect	Threshold level (decibels)			
		-32	-35	-38	-41
July 26	1	27	27	35	35
	2	70	70	75	87
	3	32	32	42	42
	4	27	27	38	38
	5	14	14	18	24
	6	8	8	11	12
	7	7	7	10	11
	8	9	11	12	16
	9	2	2	4	4
	10	4	4	7	7
	11	3	3	7	9
	12	3	3	13	13
	13	5	5	10	10
	14	5	6	7	7
	15	2	2	3	4
	16	3	3	3	4
	Total	221	224	295	303
July 27	1	27	31	38	42
	2	54	54	61	70
	3	40	40	52	54
	3r	40	40	41	45
	4	28	30	40	40
	5	18	20	29	32
	6	6	6	8	8
	7	7	7	13	13
	8	5	5	6	6
	9	0	0	1	1
	10	1	1	2	2
	11	2	2	12	15
	12	2	2	5	6
	13	7	7	14	17
	14	2	2	4	4
	15	1	1	3	3
	16	4	4	4	4
	Total	204	212	286	309

Table 2. Estimates of adult sockeye salmon and large resident fish in Lake Washington from acoustic surveys, July 12, 13, 26, and 27, 1976

Date	Threshold level -35dB	-38dB	-41dB
July 12	106	142	148
13	90	97	96
26	214	271	279
27	204	261	274
Background (assumed)	15	20	35
Sockeye salmon estimate (mean of 26 and 27 minus background)	194	246	241

The lack of correspondence between the acoustic estimate based on the -38 dB threshold and the nonacoustic estimates of escapement may be the result of minor changes in the calibration data. The original target strength studies in 1972 indicated that -38 dB was the upper edge of the target strength distribution of many smaller resident fish in Lake Washington. Studies in 1975 indicated that substantial numbers of resident fish would be included in the counts with only a slight decrease in the threshold below -38 dB, whereas most targets which exceeded the -38 dB threshold also exceeded the -35 dB threshold. Thus, even a 1 dB uncertainty in the actual value of the threshold had a substantial effect at -38 dB, but virtually no effect at -35 dB. An uncertainty of as much as 2 dB is conceivable over the 5-year period. It is also noteworthy that the estimates from July 12 and 13 were in poor agreement with each other at -38 dB, but in good agreement at -35, and, furthermore, that the difference in the estimates arises primarily from targets counted in the north-central areas of Lake Washington where adult sockeye salmon have not been observed in any quantity during previous years. Thus, it appears that the -38 dB threshold may be more sensitive to inputs from smaller resident fish and may have resulted in overestimates of sockeye salmon escapement during the past 2 years due to either minor changes in calibration or changes in the resident fish population.

In contrast, the -35 dB threshold is sufficiently above the expected target strengths from resident fish so as to be insensitive to uncertainties in calibration. Further, most of the targets which exceeded the -35 dB threshold were also greater than -32, which would indicate that the -35 dB threshold is also insensitive to errors which would result from missing significant numbers of adult sockeye. The estimate based on -35 dB is still considerably greater than the estimated escapement derived from tower counts and spawning ground surveys. Partial explanations of the differences may be the presence of adult salmon of other species and higher percentage occurrence of beach spawners than for past years.

Juvenile Sockeye Salmon Surveys

The acoustic estimate of 1975 yearclass sockeye salmon for the total lake was 1.14 million fish. The population estimate based on midwater trawl data was 1.25 million fish. The majority of the fish was located south of the Evergreen Point Bridge, as in previous years (Appendix A).

The trend during previous years of fewer percent sockeye in the trawl catches was observed again during the March sampling. The 1974 yearclass of sockeye salmon comprised 18.3% of the limnetic fish population. The 1975 yearclass percentage dropped to 12.8%. Many of the trawl hauls were duplicated to determine species composition as precisely as possible. The species breakdown of the trawl catches is given in Table 3.

The presmolt sockeye salmon of the 1975 brood year are the progeny of a spawning run estimated at 120,000. Under favorable conditions, one would expect over 2 million smolts. The low population size of 1975 yearclass smolts is apparently due to poor river conditions during incubation and and emergence (Stober et al. 1976). There was no indication of distributional problems which might cause an underestimate as for the 1973 yearclass.

Table 3. Catches of various species and size classes during trawling series on Lake Washington, March 8 and 9, 1977

Area	Haul	Depth (m)	Sockeye		Smelt		Stickle-back	Other
			0	1	0	1		
1	20	15	0	0	50	2	18	0
	21	22	1	0	34	8	67	0
	22	28	0	1	30	8	15	0
2	23	15	1	1	47	4	20	1
	24	22	7	2	28	8	188	2
	25	28	4	6	16	2	112	0
	26	35	1	18	14	2	104	8
	27	50	1	8	11	0	13	0
	28	35	6	36	21	1	106	6
3	14	15	0	2	9	0	36	0
	15	22	0	1	2	0	2	1
	16	28	0	1	8	0	4	0
	17	35	1	3	7	1	21	2
	18	50	0	21	19	1	4	1
	19	50	0	34	28	4	5	0
4	8	15	0	4	11	1	1	1
	9	22	0	2	8	1	2	0
	10	28	0	5	5	3	2	0
	11	35	1	5	11	1	8	0
	12	28	1	7	7	1	2	0
	13	35	0	9	16	0	4	0
5	1	15	0	1	9	0	0	0
	2	22	2	5	12	1	0	0
	3	28	13	16	72	0	23	3
	4	15	haul aborted					
	5	15	0	7	5	0	0	1
	6	22	0	6	20	0	5	1
	7	28	8	8	23	1	8	2

Survival of the 1975 yearclass during their lake residence could not be examined, since only the single presmolt acoustic survey was conducted. However, fyke-net catches of fry taken from the Cedar River during movement into the lake were extrapolated to estimate a recruited population of 2.24×10^6 (Stober et al. 1976). Thus, lake survival from fry to presmolt is estimated at about 50%. This value is surprisingly high. However, data from acoustic series in previous years indicate that yearclasses of initially smaller magnitude have higher lake survival (Bryant 1976). An alternate possibility is that the apparent high survival could be due to an increased contribution of kokanee to the presmolt estimate. There are reports of increasing kokanee abundance (Grant Fiscus, WDF, personal communication). Significant populations of kokanee would cause overestimates of sockeye salmon lake survival and population size at outmigration.

ACKNOWLEDGMENTS

As in previous years, additional support for the Lake Washington studies was provided by the Washington Sea Grant Program. The net trawling series for the juvenile sockeye was again conducted in cooperation with the Western Coniferous Forest Biome project, part of the National Science Foundation's Ecosystem Analysis Program. The participation of Douglas Eggers and Bruce Doble of the Biome project is acknowledged with thanks.

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Appendix Table A. Densities of fish and numbers of sockeye in various strata of Lake Washington, March 8-9, 1977

Region	Transect	Depth interval	Volume in strata ($10^6 m^3$)	Density of fish (#/$10^3 m^3$)	% sockeye	# sockeye
1	1	4-11	34.88	3.68	0	0
		11-18	32.20	3.07	0	0
		18-25	26.85	3.29	0	0
		25-32	6.28	0.40	2	50
	2	4-11	16.80	3.42	0	0
		11-18	16.60	4.00	0	0
		18-25	16.06	4.02	0	0
		25-32	13.61	2.75	2	749
		32-39	0.72	0.49	2	7
	3	4-11	30.80	2.51	0	0
		11-18	30.77	6.42	0	0
		18-25	26.89	5.34	0	0
		25-32	23.96	3.82	2	1829
		32-39	11.98	2.04	2	489
2	4	4-11	37.10	5.79	1	2147
		11-18	37.10	11.96	1	4436
		18-25	37.10	9.03	1	3350
		25-32	37.10	7.04	4	10488
		32-39	37.10	1.64	16	9706
		39-46	8.46	0.51	20	862
	5	4-11	51.80	6.05	1	3133
		11-18	51.75	10.68	1	5529
		18-25	50.76	11.19	1	5682
		25-32	48.28	6.78	4	13087
		32-39	47.35	2.72	16	20586
		39-46	44.65	0.50	20	4466
		46-53	25.74	0.15	24	920
		53-60	0.21	0.04	24	2
	6	4-11	35.00	4.73	1	1656
		11-18	34.58	4.23	1	1462
		18-25	33.67	5.46	1	1827
		25-32	32.87	3.92	4	5146
		32-39	32.34	1.91	16	9907
		39-46	31.75	0.65	20	4115
		46-53	28.00	0.25	24	1705
3	7	4-11	16.02	1.77	4	601
		11-18	15.54	4.08	4	1828
		18-25	14.78	1.78	17	4474
		25-32	14.52	1.29	8	1494
		32-39	14.15	2.36	9	3009
		39-46	13.70	0.53	28	2032
		46-53	11.29	0.10	47	557
		53-60	1.00	0.35	47	165

Appendix Table A. Densities of fish and numbers of sockeye in various strata of Lake Washington, March 8-9, 1977 - Continued

Region	Transect	Depth interval	Volume in strata ($10^6 m^3$)	Density of fish ($\#/10^3 m^3$)	% sockeye	# sockeye
	8	4-11	37.10	1.24	4	1840
		11-18	37.10	3.42	4	5068
		18-25	36.77	2.93	17	18325
		25-32	36.06	1.40	8	4053
		32-39	32.76	3.08	9	9069
		39-46	30.94	0.75	28	6470
		46-53	22.48	0.31	47	3237
		53-60	0.96	0.01	47	4
	9	4-11	73.50	2.56	4	7535
		11-18	73.50	4.44	4	13051
		18-25	73.50	3.19	17	39814
		25-32	63.36	1.51	8	7671
		32-39	44.61	3.68	9	14796
		39-46	33.00	1.50	28	13832
		46-53	14.41	1.24	47	8398
		53-60	1.10	1.44	47	748
4	10	4-11	30.80	1.17	22	14997
		11-18	30.68	2.69	22	18156
		18-25	29.41	6.61	15	29183
		25-32	28.03	2.10	36	21146
		32-39	25.38	5.03	25	31938
		39-46	10.10	5.20	25	13129
		46-53	0.03	7.70	25	8
	11	4-11	17.47	1.90	22	7307
		11-18	16.91	3.59	22	13364
		18-25	15.40	3.30	15	7625
		25-32	14.02	7.24	36	36525
		32-39	11.90	8.46	25	25154
		39-46	1.77	0.57	25	253
	12	4-11	9.44	4.98	22	10339
		11-18	8.90	4.45	22	8715
		18-25	8.40	2.82	15	3557
		25-32	5.38	6.09	36	11789
		32-39	0.30	25.60	25	1944
5	13	4-11	9.58	6.19	32	18982
		11-18	6.22	0.54	32	1071
		18-25	4.90	2.84	22	3065
		25-32	3.72	8.88	14.5	4797
		32-39	0.20	0.16	14.5	5
	14	4-11	18.20	3.21	32	18668
		11-18	18.20	1.51	32	8816
		18-25	18.04	1.32	22	5249
		25-32	13.72	2.68	14.5	5329
		32-39	3.06	17.34	14.5	7687

Appendix Table A. Densities of fish and numbers of sockeye in various strata of Lake Washington, March 8-9, 1977 - Continued

Region	Transect	Depth interval	Density of strata ($10^6 10^3$)	Density of fish (#/$10^3 m^3$)	% sockeye	# sockeye
	15	4-11	20.30	5.39	32	35035
		11-18	20.24	11.07	32	71672
		18-25	19.85	14.88	22	65003
		25-32	17.80	11.12	14.5	28706
		32-39	1.81	11.32	14.5	2965
	16	4-11	24.50	5.97	32	46771
		11-18	20.12	13.80	32	107228
		18-25	18.62	27.22	22	134542
		25-32	8.16	24.64	14.5	35192
		32-39	0.53	18.00	14.5	1662