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LAKE WASHINGTON SOCKEYE SALMON STUDIES

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James J. Dawson and Richard E. Thorne

FINAL REPORT
Service Contract No. 897
Washington State Department of Fisheries
for the Period January 1, 1978-June 30, 1978

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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 in Lake Washington since 1969. In addition to providing valuable information for the management of the Lake Washington sockeye run, these population estimates add to a continually expanding data base which will clarify the effects of environment on spawning ground capacity, lake rearing capacity and survival, and potentially sustainable run size. Support for these population studies has been provided by the Washington State Department of Fisheries since 1974. Results of the acoustic surveys of the 1976 year class of sockeye salmon are described in this 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. Data were collected at 105 kHz through an 8° full angle transducer. The components of the system are detailed in Thorne et al. (1972) and Nunnallee (1975).

Two acoustic surveys were conducted on the 1976 year class of juvenile salmon: One on November 7-8 and the second on February 27-28, after the majority of the winter mortality had occurred. Both surveys followed the pattern of 16 diagonal transects used in previous years (Fig. 1). All surveys occurred at night for maximum dispersal of juvenile sockeye and at an estimated boat speed of approximately 8 knots.

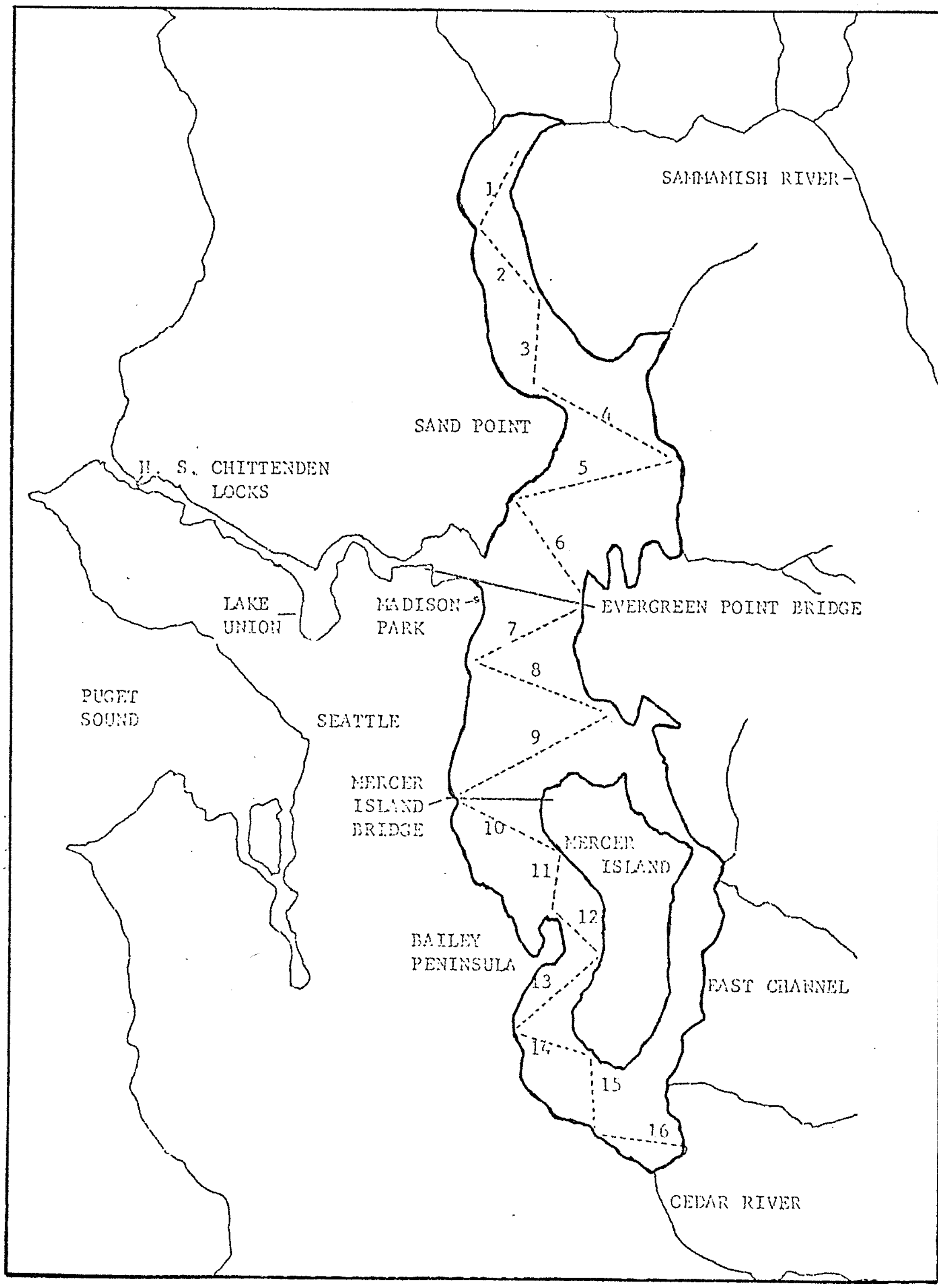

Fig. 1. Map of Lake Washington showing transect pattern.

In conjunction with these acoustic surveys, a 3-m IKMWT was used from the R.V. Commando to collect biological samples for determination of species composition. All trawls were completed at night at a speed of 5.2 knots. Trawl depths of 15, 22, 28, 35, and 50 m were sampled when feasible at each of 5 standard trawl stations (Fig. 2). The number of each species and year class was recorded in the field and samples were preserved in formalin or frozen for a WDF-sponsored electrophoresis study.

Data Analyses

The acoustic data from the juvenile salmon survey in November were analyzed by digital echo integration techniques (Thorne et al. 1975). The integration 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. To reduce the biases introduced by widely varying target strengths in Lake Washington, a separate regression of computer density on oscilloscope density was calculated for each trawl sampling depth and area. The integrator output for each transect and depth was then scaled by the appropriate regression constant and by the fraction of sockeye in the catch.

Because of the unusually uniform distribution of sockeye in February, it was not possible to obtain a good regression analysis. Consequently, the analysis of the February acoustic data consisted of applying oscilloscope counting techniques to selected transects. One transect representing each trawl area was counted, adjusted for fraction of sockeye in the catch, and extrapolated over the lake area represented by the trawl.

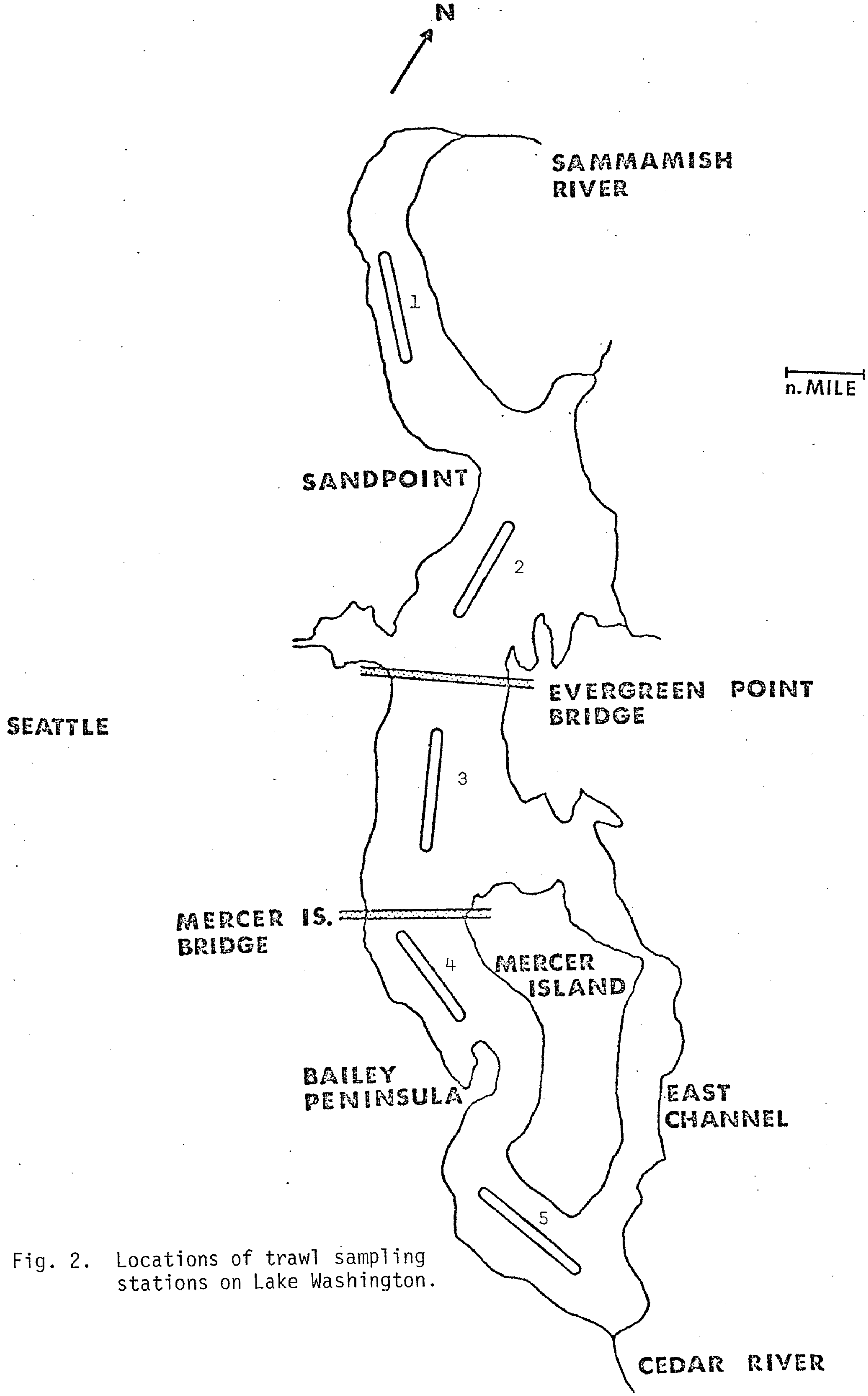

Fig. 2. Locations of trawl sampling stations on Lake Washington.

In addition to the acoustic estimates, the net tows were used to estimate density by assuming a swept volume of 1,000 m^3 per minute 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 independent except that the species composition of the two estimates are the same.

RESULTS AND DISCUSSION

The acoustic and pelagic trawl estimates of the 1976 year class sockeye salmon in each of the five sampling areas and the total lake are shown in Table 1. The acoustic estimate for the total lake in November was 5.8 million. The corresponding net estimate of 8.8 million was considerably higher. Each density estimate calculated by acoustic means should be more precise than those from net hauls. The acoustic technique used in November sampled a volume approximately 100 times that of the trawl. Each acoustic transect extended across the entire lake, while all the hauls in a given sampling area were made in a localized area measuring about 1 x 1/4 nautical miles. Due to increased aerial coverage and sample volumes the degree of extrapolation required by the acoustic technique was much less than that used to calculate population size from trawl hauls. In addition, the acoustic gear should sample all of the pelagic fish it passes over, requiring no assumption of catch efficiency. Sample volume of the acoustic system can be estimated more closely than the mouth opening and efficiency of the trawl. The acoustic gear sampled continuously from 2 meters below the surface to about 2 meters from the bottom, while the trawl sampled in depth slices about 3 meters thick at the previously mentioned sampling depths.

Table 1. 1976 year class population estimates and catch statistics.

Sample date	Sample area	Acoustic estimate	Net estimate	% Sockeye in catch	Av. # sockeye/haul	S.D. of av. catch	S.D. as % of mean
		10^6	10^6				
Nov. 77	1	1.04	0.95	48.9			
	2	1.94	3.77	76.7			
	3	1.97	3.64	77.7			
	4	0.55	0.30	25.0			
	5	0.26	0.19	21.4			
	Total	5.76	8.85	58.8	38.7	58.71	152
Feb. 78	1	0.80	0.43	37.1			
	2	0.70	1.54	35.9			
	3	1.67	2.06	59.5			
	4	0.36	0.38	39.2			
	5	0.43	0.34	18.9			
	Total	3.96	4.75	37.5	16.9	10.95	65

The acoustic estimate of sockeye for the total lake in February was 4.0 million fish. The population estimate based on midwater trawl data was 4.7 million fish. The acoustic techniques used in February had a sampling power about 20 times that of the trawl sampling. The closer agreement in February is due to the more uniform horizontal and vertical distribution.

Table 1 also gives the mean number of sockeye per haul, the associated standard deviation expressed as a percent of the mean catch and the percent sockeye in the catch for each sampling area. Similar statistics for the previous three year classes of sockeye salmon in Lake Washington are given in Table 2. The standard deviation of the number of sockeye per haul in February 1978 was 65% of the mean. This statistic was over 100% in previous years. Both this statistic and the number of sockeye estimated by acoustic techniques for each area of the lake show the unusual uniformity by area and depth of the sockeye distribution in February 1978. Also unlike the presmolt acoustic estimate of the 1973 year class, which was low due to distributional problems (unusually deep distribution) the February estimate of the 1976 year class appears unbiased by any distributional anomalies.

The presmolt estimate provides an indication of the size of the subsequent adult run. The smolts of the 1976 year class sockeye salmon will return to Lake Washington as adults during summer 1980. The accuracy of the forecast of the adult run from the presmolt estimates depends upon the consistency of the marine survival. Past estimates of marine survival of Lake Washington sockeye have indicated considerable variability but are undoubtedly affected by uncertainty in the enumeration techniques for

Table 2. 1973-1975 year class population estimates and catch statistics.

Year class	Sample date	Sample area	Acoustic estimate	Net estimate	% Sockeye in catch	Av. # sockeye/haul	S.D. of av. catch	S.D. as % of mean
			10^6	10^6				
1973	Mar 75	1	0.11	0.28	25.4			
		2	0.80	0.94	52.6			
		3	0.84	1.00	41.5			
		4	0.09	0.11	12.2			
		5	0.10	0.20	12.4			
		Total	1.94	2.53	33.0	10.69	10.9	102
1974	Feb 76	1	0.00	0.00	0.0			
		2	0.02	0.02	1.6			
		3	0.16	0.07	11.9			
		4	0.23	0.33	37.2			
		5	0.35	0.43	16.7			
		Total	0.76	0.85	18.3	4.16	5.73	138
1975	Mar 77	1	0.003	0.01	0.4			
		2	0.11	0.62	6.8			
		3	0.17	0.63	21.6			
		4	0.26	0.18	53.2			
		5	0.60	0.17	17.1			
		Total	1.14	1.61	10.4	7.74	9.51	123

catch and escapement as well as presmolts, and also may be affected by the proportion of kokanee in the presmolt estimate. The average of the marine survival estimates is about 8%, which would lead to a return of 320-380 thousand adults.

The presmolt estimates also provide information which can be used in conjunction with other data to evaluate various factors which affect the run production. Table 3 gives values for fry production and lake survival for 1968 to 1976 year classes. In 1975, 1.76 million fry (Stober et al. 1978) were produced by 120-165 thousand spawners resulting in an estimated production of 1.14 million sockeye smolts. In 1976, 22.8 million fry (Stober et al. 1978) were produced by 140-194 thousand spawners and approximately 4 million of these fish survived to become smolts. Lake survival is estimated for these two year classes by dividing the presmolt estimate by the initial estimate based on fry counts at the mouth of the Cedar River. The results suggest density-dependent survival. The percent survival in the lake for year classes 1968-1972 were also calculated by Bryant (1976). His initial estimates were made by assuming that the instantaneous mortality rate calculated between surveys on a given year class was constant for the entire period of lake residence. An estimate on July 1 for each year class was then back-calculated based on this mortality rate. Although the initial estimates calculated for the 1968-1972 year classes by this method are more questionable, the results support the hypothesis of a density-dependent relationship between apparent mortality rates and the population size at recruitment. The 1969 and 1976 year classes were of similar magnitude initially and at

Table 3. Population estimates during lake residence.

Year class	Initial estimate	Final estimate[1]	% Survival
	10^6	10^6	
1976	22.80 **	3.96	17
1975	1.76 **	1.14	65
1974	Not available	0.76	-
1973	Not available	3.20	-
1972	4.41 *	3.58	81
1971	3.11 *	1.70	55
1970	3.80 *	2.00	53
1969	29.30 *	3.80	13
1968	6.18	3.19	52

* From Bryant (1976).
** From Stober et al. (1978).
1 Fisheries Research Institute pre-smolt acoustic estimates.

outmigration, and both had a similar lake survival rate. The other year classes started initially at a much lower level and had much higher lake survival.

LITERATURE CITED

Bryant, M.D. 1976. Lake Washington sockeye salmon: biological production and a simulated harvest by three fisheries. Ph.D. Dissertation, Univ. Washington, Seattle. 159 pp.

Nunnallee, E.P. 1975. An operators' manual for the hydroacoustic data collection system. Washington Sea Grant Tech. Rep. 75-1. 28 pp.

Stober, Q.J., R.E. Narita, and A.H. Hamalainen. 1978. Instream flow and the reproductive efficiency of sockeye salmon. Univ. Washington, Fish. Res. Inst. Final Rep. FRI-UW-7808. 124 pp.

Thorne, R.E., E.P. Nunnallee, and J. Green. 1972. A portable hydroacoustic data acquisition system for fish stock assessment. Washington Sea Grant Pub. 72-4. 15 pp.

Thorne, R.E., J.J. Dawson, J.J. Traynor, and R.L. Burgner. 1975. Population studies of juvenile sockeye salmon in Lake Washington with the use of acoustic assessment techniques. Pages 328-345 *in* Robin L. Welcomme, ed. EIFAC Technical Paper No. 23, Suppl. 1, Symposium on the methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers.

Appendix Table A-1. Catches of fish from net tows in Lake Washington, November 7-9, 1977.

Haul	Area	Depth (m)	Duration (min)	Sockeye		Smelt		Stickleback	Cottids	Others
				1976 YC	1975 YC	1976 YC	1975 YC			
1	5	15	10	1	0	1	3	9	0	0
2		22	10	11	0	0	3	22	2	2
3		28	10	14	0	0	6	55	3	6
4		22	10	6	0	3	4	28	0	0
5		28	10	20	0	1	1	45	3	6
6	4	15	10	1	0	13	3	9	0	0
7		22	10	6	0	8	4	18	0	0
8		28	10	8	0	4	2	14	0	0
9		35	10	15	0	1	1	14	2	4
10		28	10	1	0	6	1	20	1	0
11		35	10	20	0	0	0	12	0	0
12		22	10	1	0	2	6	8	1	0
13	3	15	10	3	0	8	5	4	0	0
14		22	10	0	0	3	3	3	0	0
15		28	10	9	0	0	3	11	1	0
16		35	10	45	1	1	6	6	1	0
17		50	10	167	2	0	1	1	1	0
18		50	5	69	0	0	3	0	0	0
19	1	35	10	34	1	3	4	3	0	2
20		15	10	10	0	3	47	5	0	0
21		22	10	21	0	2	7	18	0	0
22		28	10	130	0	0	0	52	0	5
23		28	5	35	0	0	3	27	0	5
24		22	10	17	0	0	2	32	0	2
25	2	15	10	2	0	0	6	10	0	0
26		15	10	1	0	1	7	11	0	0
27		22	10	3	0	0	2	10	0	0
28		28	10	8	0	0	5	17	0	0
29		35	10	71	3	0	3	7	0	0
30		50	10	227	3	0	0	5	2	0
31		50	5	76	1	0	1	2	3	0
32		35	10	26	2	0	1	6	0	0
Total				1,058	13	60	143	484	20	32

Appendix Table A-2. Catches of fish from net tows in Lake Washington, February 27-28, 1978.

Haul	Area	Depth (m)	Duration (min)	Sockeye 1977 YC	Sockeye 1976 YC	Smelt 1976 YC	Smelt 1975 YC	Stickleback	Cottids	Others
1	5	15	10	0	8	1	0	8	20	11
2		22	10	3	6	3	0	31	4	8
3		28	5	0	11	3	2	25	3	32
4		15	10	1	7	12	11	7	2	1
5		22	10	1	18	5	7	24	0	5
6		28	10	2	25	6	15	31	11	33
7	4	15	10	0	14	4	7	7	0	0
8		22	10	1	11	3	5	7	0	0
9		28	10	0	11	2	0	13	0	0
10		35	10	0	12	0	0	8	0	14
11		15	10	0	9	2	5	3	0	0
12		22	10	0	6	3	2	10	0	0
13		28	10	0	9	0	2	9	1	0
14		35	10	0	13	0	0	16	0	8
15	3	15	10	1	14	9	18	7	0	0
16		22	10	0	16	8	6	2	0	0
17		28	10	0	11	4	3	9	0	1
18		35	10	0	38	1	3	6	1	5
19		50	10	0	44	2	2	2	0	1
20		15	10	0	7	6	15	0	0	0
21		28	10	0	21	4	3	9	1	5
22		50	10	0	46	2	1	0	0	2
23	1	15	10	0	27	12	5	19	0	12
24		22	10	0	19	3	8	21	2	2
25		28	10	0	19	6	2	18	0	3
26		35	10	0	22	2	1	5	0	12
27		15	10	0	8	10	5	5	0	0
28		25	10	0	7	6	4	13	5	1
29	2	15	10	0	8	3	28	25	1	0
30		22	10	0	18	1	5	75	3	0
31		28	10	0	18	4	2	21	1	1
32		35	10	1	30	2	1	7	1	4
33		50	10	0	35	1	2	6	0	0
34		10	10	0	6	10	1	80	0	0
Total				10	574	150	171	529	56	161

Appendix B. Population estimation procedure from net catches in Lake Washington.

The density of each year class and species is estimated from the net catches by assuming an effective sampling power of 1000 cu m/min of tow. Each tow depth and sampling area defines a stratum. As seen in the data form (Appendix Fig. B-1) there are 20 strata defined in Lake Washington from 5 sampling areas and 3-5 sampling depths. Each stratum represents a volume which is printed in the lower right corner of each stratum on the data form. The average density from the net tows in each stratum is entered in the appropriate square of the data form, and the population in that stratum is estimated by the product of the density and volume. Density values for unsampled strata are estimated by interpolation from surrounding strata.

Appendix Fig. B-1. Lake Washington limnetic fish population estimate.

Trip ____________ Date ______________

Gear __________ Speed __________ kts. Duration __________ min. VPUE __________ $m^3 x 10$

Species _______________ Year class ___________________

Limnetic Area

Depth Fished (m)	1	2	3	4	5
15	81.0*	200.7	218.5	91.0	120.9
22	48.6	122.2	135.5	55.1	72.3
28	80.9	97.8	109.4	43.2	69.2
35		146.9	158.7	146.0	
50		154.2	186.4		
Area Total					

Lake Total ______________________

*Volumes are $m^3 \times 10^6$