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College of Fisheries
University of Washington
Seattle, Washington 98195

MONITORING OF THE KVICHAK SPAWNING AND NURSERY AREAS, 1974

by

P. H. Poe, G. D. Cortner, N. A. Lemberg,
P. B. Roger, and O. A. Mathisen

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(Final Report for the Period June 1, 1974 through June 30, 1975)

INTRODUCTION

The Kvichak River system is the largest producer of sockeye salmon in Bristol Bay. Returns of sockeye salmon to the system are cyclic in nature and largely determine the annual magnitude of the total Bristol Bay run. Observations on sockeye salmon of the Kvichak system have been made over the last half century.

During the period 1920-1946 the Bureau of Commercial Fisheries conducted investigations which were primarily studies to determine the relative size and the distribution of the escapement on the spawning beds. The Naknek-Kvichak District catch was also sampled for age, size, and sex during this period.

Annual studies by the Fisheries Research Institute of the sockeye salmon run to the Kvichak River system began in 1947 upon the request of the Bristol Bay Salmon Industry. During the years 1947-1954 the Institute concentrated in collecting quantitative and qualitative data on the adult sockeye salmon returns. Both the yearly catch and escapement were sampled for age, size, and sex. The Bureau of Commercial Fisheries continued to conduct annual surveys of the spawning grounds to determine the relative size and distribution of the escapement on the spawning beds. The Institute also conducted limited spawning ground surveys during this period.

In 1955 the Institute expanded its systematic studies of the Kvichak system to include the enumeration of the Kvichak River escapement and a smolt indexing program to assess the relative abundance, age, and size of outgoing smolts from the system. Spawning ground surveys also became more extensive, and the Bureau of Commercial Fisheries continued its annual surveys of the Kvichak spawning grounds up through 1959.

In 1961, all the work of sampling both the outgoing smolts and returning adults was assumed by the Alaska Department of Fish and Game, and the Institute initiated studies directed toward determining the factors limiting freshwater production. Programs were initiated to study juvenile sockeye salmon in the system's nursery lakes and to determine the extent of available and utilized spawning areas.

Since 1961 the Institute has maintained a program of studies to monitor the ecological conditions and changes that have taken place in the spawning and nursery areas of the Kvichak system. These studies are presently supplementing those maintained by the Alaska Department of Fish and Game. The purpose of our research program is to adequately determine the factors causing the cyclic variability in freshwater production so that a more rational basis for the setting of catch and escapement goals can be developed which will ultimately help fish managers to more accurately determine and regulate for the optimum sustainable yield of the Kvichak sockeye salmon resource.

The 1974 field season marked the twentieth year of the life studies programs conducted by the Fisheries Research Institute in the Kvichak River system. Financial support was provided jointly by the Alaska Department of Fish and Game, the Bristol Bay canning industry through the Association of Pacific Fisheries, and the University of Washington. Studies were limited to monitoring programs for maintenance of year-to-year comparisons. Monitored were (1) abundance distribution, and growth of juvenile sockeye salmon and competitor species in Iliamna Lake and Lake Clark, (2) relative abundance and distribution of adult sockeye salmon on the spawning beds and age compositon of selected spawning groups, (3) primary and secondary production, (4) Iliamna Lake heat budget, (5) solar radiation, and (6) other climatic conditions during the summer field season. The following report is a summary of data collected during the 1974 field season with comparisons to data collections from prior years. A outline of the studies continued in 1974 and reported on in this report is shown in Fig. 1.

ADULT SALMON STUDIES

The 1974 inshore run of sockeye salmon to Bristol Bay numbered 11 million. Although the catch in the Naknek-Kvichak District was poor for the third consecutive year (Fig. 2), the escapement of 4.3 million to the Kvichak system provides encouragement for a more optimistic outlook toward the production of Bristol Bay sockeye salmon during the latter 1970's.

Remembering back, during the period 1969-1971, there was an attempt to manage the Kvichak salmon run so as to re-establish the historical five-year cyclic pattern; that pattern being a parity of escapement levels during two and/or three years out of a five year cycle. Escapements of 8.4, 13.9, and 2.4 million, respectively, reached the spawning beds during this period. Optimism was high that a return to a more balanced cyclic pattern would likely develop, and subsequently a more stable pattern of production and harvesting would result. Unfortunately two successive very cold winters and late springs very adversely affected the survival of the progeny of the 1969 and 1970 brood years. The production that has resulted thus far from these two brood years has been much lower than would have been expected had normal environmental conditions existed during that time.

The 1975 peak year run of sockeye salmon to the Kvichak system is forecasted to be somewhat larger than in 1974 (Krasnowski, 1975). If indeed the 1975 escapement is comparable in magnitude to the 1974 escapement, there may develop a dampened cyclic pattern of runs to the Kvichak system along with a shift from a five-year to a four-year cycle.

Spawning Ground Surveys

Observations on the spawning populations of sockeye salmon of the Kvichak River system have been made continuously since 1920, except during the years 1942 and 1943. Continuous records of the annual timing, distribution, and relative abundance indices of returns to the individual spawning units are needed to monitor the effects of the yearly fishing regulations in Bristol Bay and to further define factors limiting the production of sockeye salmon in the Kvichak system.

Distribution of Escapement and Indices of Abundance

Regulation of the 1974 Bristol Bay commercial fishery resulted in a very low rate of exploitation of Kvichak stocks. The annual timing, distribution, and relative indices of abundance of returns to the major spawning groups of the Kvichak system was determined by aerial and/or ground surveys conducted from late July to early September. Aerial surveys were conducted on 7/28, 8/03, 8/13, 8/14, 8/15, and 9/05. The principal pilots and their aircraft were Nels (Sonny) Hedlund in a Piper 150 on floats and a Cessna 180 on floats and Dave Wilder in a Beaver on floats. The principal observer for the Institute was Patrick Poe. Weather, light, and water conditions were generally very good during most of the surveys. Unfortunately, inclement weather during late September prevented the completion of the Lake Clark spawning ground survey. However, pre-peak indices of relative abundance for many of the major spawning areas of the Lake Clark system were procured

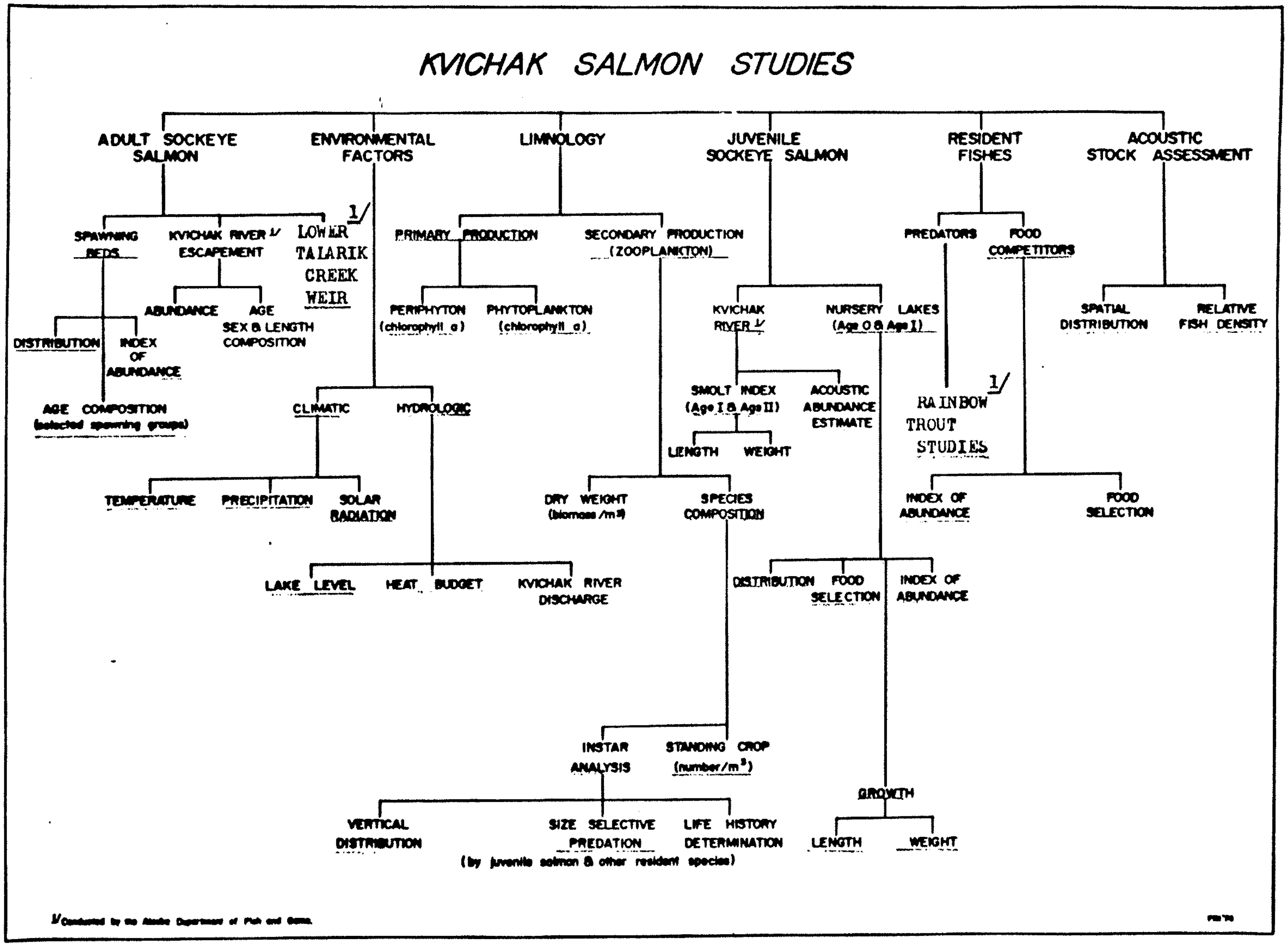

Fig. 1. Schematic outlining Kvichak Salmon Studies. Results from most of the studies continued in 1974 are contained in the following data report (those underlined in red). Studies underlined in green were conducted but were not analyzed at the time of this report. Studies underlined in blue conducted by the Alaska Department of Fish and Game in 1974. Data underlined in yellow collected by other agencies.

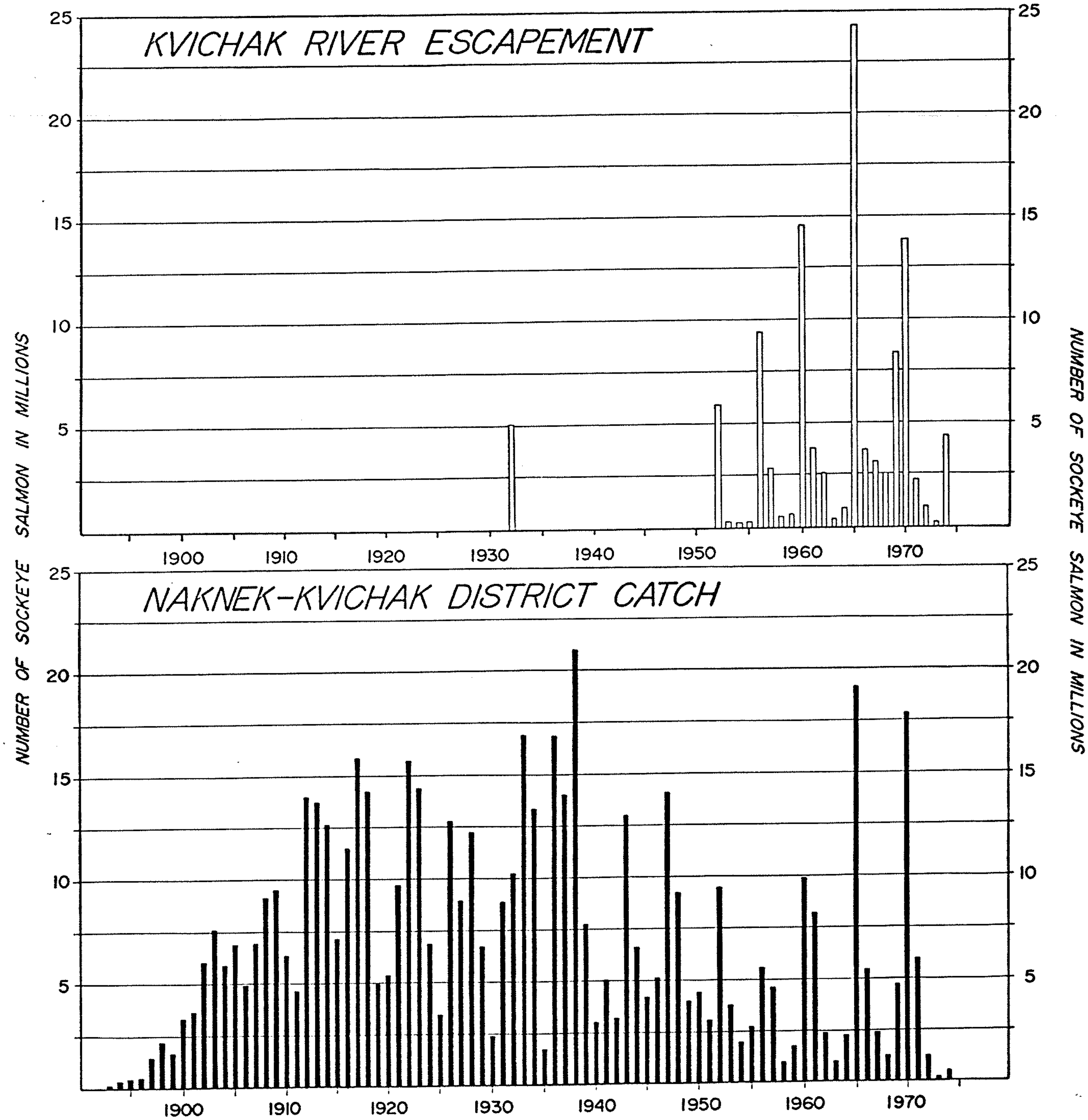

Fig. 2. Naknek-Kvichak district sockeye salmon catch, 1893-1974, and Kvichak River sockeye salmon escapement, 1932 and 1952-1974.

from surveys flown during late July and early August. All aerial survey data were recorded on a Panasonic cassette recorder and the tapes were transcribed to aerial survey summary forms at a later date. A total of 96 different spawning areas were surveyed. The distribution and relative abundance of spawners in 1974, and in peak and nonpeak cycle years on Kvichak spawning grounds, 1955-1973, is shown by Fig. 3. A comparison of 1974 indices of abundance of sockeye salmon to 16 geographic regions of the Kvichak system to the arithmetic mean percentage in other nonpeak cycle years from 1955-1973 is detailed in Table 1. All the currently summarized quantitative data on escapement, and the indices of relative abundance for the different spawning area types of the Kvichak system for the years 1920-1974 are summarized in Table 2.

The 1974 spawning ground surveys showed unusually high indices of spawners for a nonpeak cycle year in some of the early areas. The relatively high abundance of early spawners probably resulted from the absence of substancial commercial fishing and/or the exceptionally good timing and conditions during the early surveys in 1974, i.e., a greater proportion of early spawners were seen in 1974 as compared to past years. Regulation of the Bristol Bay commercial fishery in 1975 may also result in a low fishing mortality on stocks of sockeye salmon returning to the Kvichak system. Therefore, observations should be made to monitor any changes in distribution that may occur as a result of any lower rate of exploitation on Kvichak stocks.

Age Composition

Relative escapement-return relationships and trends in relative production by age group for different spawning area types and individual areas have been procured through the sampling of a selected few spawning groups for age composition. Escapement-return data for the Kvichak system as a whole and for two of the major spawning groups, namely the Copper River and Woody Island, are summarized in Tables 3-5. These data suggest that the mean return per spawner is greater for the Copper River stock than for the Woody Island stock and the Kvichak system as a whole. These apparent differences may be unfounded, since the data for the individual spawning groups is dependent on the consistency of the aerial survey abundance indices and the representiveness of the limited sampling for age composition, while the data for the Kvichak system as a whole is based on data from tower counts and from sampling for age composition through the course of the run.

In 1974 spawners from eight selected spawning groups were sampled for description of age and size. In addition, a sample of spawners bound for Lake Clark spawning areas was taken from the Nondalton resident fishery. A summary of the spawning ground sampling is given in Table 6. Otoliths were collected from 445 male and 477 female sockeye salmon spawners, respectively. Preliminary data from the sampling of the Kvichak escapement at Igiugig by personnel of the Alaska Department are summarized by Krasnowski (1974).[1/] The data on age composition are summarized in Tables 7 and 8. The sampling shows a predominance of five-year fish from the 1969 brood year in all areas sampled. The sampling also indicated that six-year fish were more abundant in the Copper River and Gibraltar Creek than in the other areas sampled (Table 8).

[1/] Paul Krasnowski, 1974, Preliminary 1974 Bristol Bay sockeye salmon catch and escapement data, summary. Alaska Dep. Fish Game. (Processed)

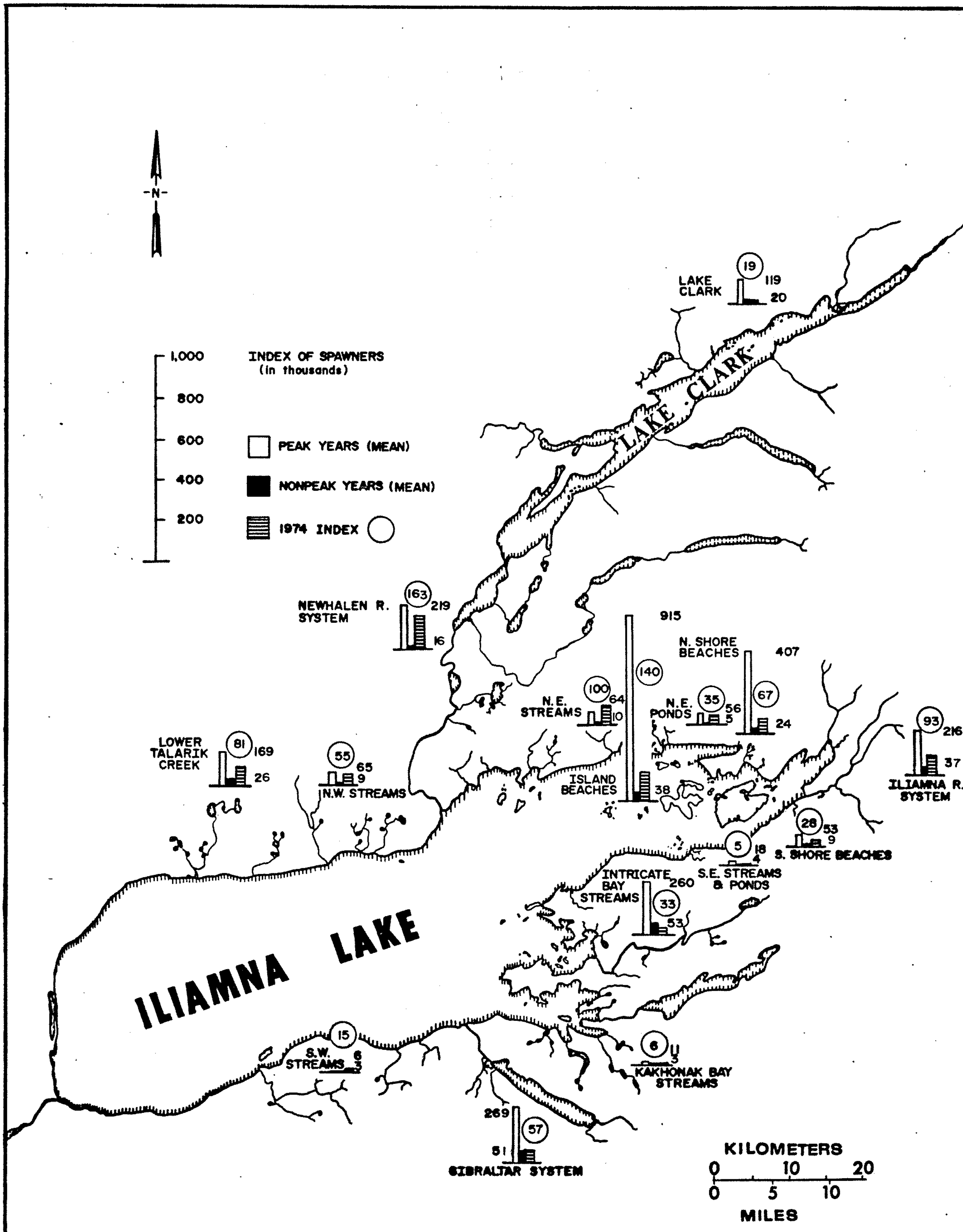

Fig. 3. Distribution and relative abundance of spawners in 1974, and in peak and nonpeak cycle years on Kvichak spawning grounds, 1955-1973.

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Table 1. Comparison of 1974 indices of abundance of sockeye salmon to 16 geographic regions of the Kvichak River system to mean percentage in other nonpeak cycle years from 1955-1973

Area	1974 Index of abundance	Percent of total accounted for on spawning grounds 1974	Mean percent other nonpeak years
Lower Talarik Creek	81,270	9.1	8.6
N.W. streams			
Middle Talarik Creek	11,225		
Upper Talarick Creek	32,125		
Pete Andrew Creek	8,655		
Car Creek	3,375		
Total	55,380	6.2	2.8
Newhalen River system			
Newhalen River	48,400		
Lovers Creek	0		
Little Bear Creek and Ponds	1,050		
Alexi Creek	185		
Alexi Lakes	6,165		
Steam Bath Creek	1,505		
Tazimina River	104,470		
Six Mile Lake beaches	No survey		
Pickerel Creek	312		
Pickerel Lakes	570		
Total	162,657	18.2	5.1
N.E. streams			
Roadhouse Creek	4,286		
N.W. Eagle Bay Creek	5,366		
N.E. Eagle Bay Creek and Ponds	29,225		
Young's Creek	3,925		
Chekok Creek and Ponds	4,305		
Tomkok Creek	25,625		
Canyon Creek	17,725		
Mink Creek	2,545		
Knutson Creek	625		
Russian Creek	5,575		
Pile River	601		
Lonesome Bay streams	450		
Total	100,253	11.2	3.4

Table 1. Comparison of 1974 indices of abundance of sockeye salmon to 16 geographic regions of the Kvichak River system to mean percentage in other nonpeak cycle years from 1955-1973 - continued

Area	1974 Index of abundance	Percent of total accounted for on spawning grounds 1974	Mean percent other nonpeak years
Island beaches (Iliamna Lake)			
Rabbit Island group	2,275		
Eagle Island group	1,585		
Triangle Island group	41,593		
Halfway Island and reefs	No survey		
Seal Rookery Island	1,295		
E-2 Island group	1,145		
Knutson Island group	6,120		
Hedlund Island group	2,655		
Woody Island	44,375		
Pedro Bay Island group	3,100		
Porcupine Island group	23,650		
Ross Island group	11,815		
Kakhonak Bay Island group	No survey		
Middle Islands	No survey		
Intricate Bay Island group	105		
Total	139,713	15.6	12.2
N. Shore beaches			
Eagle Bay	0		
Chekok	1,315		
Knutson Bay	58,515		
Pedro Peninsula	515		
Pedro Bay	970		
Lincoln Rock	150		
Lonesome Bay	4,515		
Dumbell Lakes	700		
Total	66,680	7.4	7.7
S. Shore beaches			
Pile Bay	0		
Finger	21,200		
Southeast	3,050		
S. Shore	No survey		
Tommy	3,680		
Intricate Bay	No survey		
Kakhonak Bay	125		
Total	28,055	3.1	3.0

Table 1. Comparison of 1974 indices of abundance of sockeye salmon to 16 geographic regions of the Kvichak River system to mean percentage in other nonpeak cycle years from 1955-1973 - continued

Area	1974 Index of abundance	Percent of total accounted for on spawning grounds 1974	Mean percent other nonpeak years
N.E. ponds			
Hundson's Creek and Ponds	1,025		
Prince Creek and Ponds	3,650		
Canyon Springs	550		
Wolf Creek Ponds	16,750		
Knutson Ponds	885		
Pedro Creek and Ponds	11,670		
Total	34,530	3.8	1.6
Iliamna River system			
Iliamna River	86,580		
Bear Creek and Ponds	695		
False Creek	0		
Old Williams Creek	0		
Chinkelyes Creek	5,410		
Total	92,685	10.4	11.9
S.E. streams			
Swamp Creek	1,165		
Jack Durand Creek	2,300		
Surprise Creek	0		
Squirrel Village Creek	425		
Tommy Creek	980		
Total	4,870	0.5	1.3
S.E. ponds			
Tommy Springs	30	0.0	0.1
Intricate Bay streams			
Copper River	32,595		
Pope Creek	10		
Nancy Creek	0		
Nick G. Creek	540		
Total	33,145	3.7	17.2

Table 1. Comparison of 1974 indices of abundance of sockeye salmon to 16 geographic regions of the Kvichak River system to mean percentage in other nonpeak cycle years from 1955-1973 - continued

Area	1974 Index of abundance	Percent of total accounted for on spawning grounds 1974	Mean percent other nonpeak years
Kakhonak Bay streams			
Kakhonak River	705		
Alec Flyum Creek	350		
Bear Creek	40		
Cabin Creek	125		
Granite Creek	575		
Lake Creek	1,230		
Nick N. Creek	2,515		
Total	5,540	0.6	1.1
Gibralter system			
Gibralter Creek (River)	20,835		
Little Gibralter Creek	8,850		
Leon Creek	No survey		
Dream Creek	10,195		
Southeast Creek	10,810		
Trout Creek	850		
Gibralter Ponds	950		
Gibralter Lake beaches	4,255		
Total	56,745	6.3	16.5
Lake Clark			
Priest Rock Creek and Ponds	No survey		
Kijik River	2,625		
Little Kijik River	1,775		
Kijik Lake tributaries	0		
Kijik Lake beaches	8,800		
Tlikakila River	No survey		
Chokotonk River	No survey		
Currant Creek	No survey		
Tanalian River	No survey		
22 Creek	No survey		
Sucker Bay Lake	1,115		
Lake Clark beaches	4,950		
Total	19,265	2.2	6.6
S.W. streams			
Camp Creek	1,285		
Dennis Creek	5,109		
Belinda Creek	8,705		
Total	15,099	1.7	0.9

Table 2. Peak indices of abundance of sockeye salmon and number of areas surveyed by type of spawning area and as percentages of total number of sockeye salmon observed on the spawning beds, total number of areas surveyed, total Kvichak River escapement, and percentage of the total escapement accounted for on the spawning grounds, Kvichak River system, 1920-1974. 4/

Year	STREAMS Escape. Index	No. Areas Surveyed	%	PONDS Escape. Index	No. Areas Surveyed	%	MAINLAND BEACHES Escape. Index	No. Areas Surveyed	%	ISLAND BEACHES Escape. Index	No. Areas Surveyed	%	TOTAL Escapement accounted for on spawning grounds	Number areas surveyed	Kvichak River escapement	Percentage of escapement accounted for on spawning grounds
1920	1,500	3			0			0			0		1,500	3		
1921	638,300	8			0			0			0		638,300	8		
1922	1,142,600	6			0			0			0		1,142,600	6		
1923	387,000	6			0			0			0		387,000	6		
1924	367,800	7			0			0		0	1		367,800	8		
1925	40,250	5			0			0		200	1		40,450	6		
1926	469,000	6		2,000	1		50,000	1		2,000	1		523,000	9		
1927	167,850	4			0			0		50	1		167,900	5		
1928	605,020	7		30,000	1		125,000	1			0		760,020	9		
1929	283,000	7			0			0			0		283,000	7		
1930	18,594	8		2,030	1			0			0		20,624	9		
1931	238,000	7		129,000	2		34,000	2			0		401,000	11		
1932		0			0			0			0			0	5,064,014 1/	
1933	50,000	1			0			0			0		50,000	1		
1934		0			0			0			0			0		
1935		0			0			0			0			0		
1936		0			0			0			0			0		
1937	115,000	3			0			0			0		115,000	3		
1938		0			0			0			0			0		
1939		0			0			0			0			0		
1940	500,000	1			0			0			0		500,000	1		
1941		0			0			0			0			0		
1942		0			0			0			0			0		
1943		0			0			0			0			0		
1944	13,450	10			0		2,550	3			0		16,000	13		
1945	55,150	15		450	1		3,350	3			0		58,950	19		
1946		0			0			0			0			0		
1947	24,098	8			0		6,000	2			0		30,098	10		
1948	202	2			0			0			0		202	2		
1949	12,014	9		150	1			0			0		12,164	10		
1950	77,900	10		300	1		12,700	3			0		90,900	14		
1951	194,810	9	84.84	500	1	.22	34,300	3	14.94		0		229,610	13	2/	
1952	464,600	10	99.02	600	1	.13	4,000	1	.85		0		469,200	12	5,970,000 2/	7.86
1953	114,483	14	84.99	1,125	3	.84	19,100	3	14.18		0		134,708	20	321,000 2/	41.97
1954	39,540	17	84.36	300	2	.64	7,030	3	15.00		0		46,870	22	241,000	19.45
1955	28,296	29	87.39	357	3	1.10	3,725	3	11.50		0		32,378	35	250,546	12.92
1956	1,006,050	25	75.56	17,000	4	1.28	265,030	6	19.90	43,400	1	3.26	1,331,480	36	9,443,318	14.10
1957	261,237	35	73.92	7,486	7	2.12	79,500	9	22.49	5,200	1	1.47	353,423	52	2,842,810	12.43
1958	66,972	27	67.95	1,000	6	1.01	26,820	9	27.21	3,770	1	3.83	98,562	43	534,785	18.43
1959	95,533	30	74.52	3,634	9	2.83	11,147	7	8.70	17,880	3/1	13.95	128,194	47	680,000	18.85
1960	1,333,382	29	46.85	28,950	7	1.02	488,500	8	16.99	1,000,000	1	35.14	2,845,832	45	14,630,000	19.45
1961	392,105	27	59.91	3,120	6	.48	152,350	7	23.28	106,850	4	16.33	654,425	44	3,705,849	17.66
1962	220,430	43	77.06	9,918	8	3.47	45,553	9	15.92	10,150	4	3.55	286,051	64	2,580,884	11.08
1963	36,069	41	69.70	2,598	11	5.02	8,016	9	15.49	5,069	3	9.79	51,752	64	338,760	15.28
1964	70,444	44	73.98	2,595	11	2.73	7,374	10	7.75	14,791	7	15.54	95,204	72	957,120	9.95
1965	1,251,896	43	34.04	80,650	10	2.19	387,174	11	10.53	1,957,500	14	53.23	3,677,220	78	24,325,926	15.12
1966	422,169	46	68.21	14,020	9	2.27	133,939	11	21.64	48,790	9	7.88	618,918	75	3,775,184	16.39
1967	358,810	45	67.09	6,873	8	1.29	150,490	10	28.14	18,645	10	3.49	534,818	73	3,216,208	16.63
1968	215,617	54	63.92	8,463	11	2.51	36,355	13	10.78	76,872	11	22.79	337,307	89	2,557,440	13.19
1969	406,282	56	59.71	27,936	11	4.11	114,345	18	16.81	131,850	11	19.38	680,413	96	8,394,204	8.11
1970	1,309,313	46	49.78	132,161	11	5.02	546,395	18	20.77	642,790	11	24.43	2,630,659	86	13,935,306	18.88
1971	315,193	35	72.18	8,615	7	1.97	51,390	13	11.77	61,460	10	14.08	436,658	65	2,387,392	18.29
1972	145,468	47	78.02	3,828	11	2.05	26,711	13	14.32	10,463	12	5.61	186,470	83	1,010,000	18.46
1973	57,553	55	76.89	834	11	1.11	9,803	14	13.10	6,662	13	8.90	74,852	93	226,554	33.04
1955-1973 Average			67.19			2.29			16.69			14.59				16.22
1974	587,309	54	65.56	48,305	11	5.39	120,590	18	13.46	139,713	13	15.59	895,917	96	4,433,480	20.21

1/ Escapement counted through electronic weir operating from June 28 through August 5, 1932.

2/ Escapement estimates derived from 1952-1954 FRI aerail surveys. Numbers not reliable but may be representative of relative escapement.

3/ The peak spawning times of island spawners were not known in 1960 and no direct aerial estimate was made at that time. An indirect estimate of island beach spawners for 1960 was made by comparing the abundance of spent fish in 1960 with that of 1965 and multiplying this ratio by the live peak index count in 1965.

4/ Survey data compiled for the years 1920-1954 is incomplete for many of the years. Although considerable observations were made on the spawning beds during these years ,much of the data available at the time of this compilation was qualitative rather than quantitative in nature and therefore not included. It is known that considerable amounts of quantitative data were also collected during this period and hopefully these data can be located and incorporated into the above summary table at some future date.

Table 3.

KVICHAK RIVER SYSTEM, 1952-1969

BROOD YEAR	ESCAPEMENT	RETURN 1.1	1.2	2.1	1.3	2.2	2.3	TOTAL RETURN	RETURN PER SPAWNER
1952	5970000.000	2255.000	9259739.860	.000	3906732.240	1848110.190	598958.080	15615795.370	2.616
1953	321000.000	.000	56544.210	.000	56472.240	335043.250	56304.000	504363.700	1.571
1954	241000.000	.000	74014.590	16364.880	27472.000	610504.000	.000	728355.470	3.022
1955	249544.000	.000	239292.000	13600.000	89243.000	533848.700	389296.200	1265279.900	5.070
1956	9443318.000	13600.000	22012005.400	.000	5111624.520	4832353.650	1132702.220	33102285.790	3.505
1957	2842810.000	.000	181327.590	.000	211856.720	3004118.340	218727.260	3616029.910	1.272
1958	534785.000	.000	68384.400	320.000	40576.540	116566.320	24301.480	250148.740	.468
1959	680000.000	.000	182494.070	954.720	108705.460	196845.400	7950.250	496949.900	.731
1960	14622685.000	.000	1252726.090	131211.600	423006.000	41421139.760	5620790.520	48848873.970	3.341
1961	3705849.000	372.000	295041.000	.000	165159.750	2042213.610	601965.610	3104751.970	.838
1962	2580564.000	.000	92991.870	1817.000	134350.560	4212334.280	343133.100	4784626.810	1.854
1963	337670.000	.000	43742.240	3215.000	42029.610	540349.290	223347.960	852684.100	2.525
1964	956867.000	7911.000	1888891.080	98185.500	246284.850	2146333.620	508967.550	4896573.600	5.117
1965	24323472.000	23575.760	9049374.620	484627.360	367218.640	29133252.540	1025185.760	40083234.680	1.648
1966	3767223.000	10931.000	440041.930	10600.000	894602.520	3921265.790	300700.000	5578141.240	1.481
1967	3214673.000	.000	303207.420	2061.840	224680.000	703120.000	70101.360	1303170.620	.405
1968	2549227.000	.000	170100.000	.000	26259.660	66142.440	119959.140	382461.240	.150
1969	8394204.000	.000	111012.300	10556.280	291318.300	4156259.100	.000	4569145.980	.544 1/

KVICHAK RIVER SYSTEM, 1952-1969 (YEAR OF LIFE RUN)

BROOD YEAR	ESCAPEMENT	RETURN (YEAR OF LIFE) 3RD	4TH	5TH	6TH	7TH	8TH	TOTAL RETURN	RETURN PER SPAWNER
1952	5970000.000	2255.000	9259739.860	5762944.320	601632.000	521.000	.000	15627092.180	2.618
1953	321000.000	.000	56544.210	392104.080	56304.000	.000	11678.000	516630.290	1.609
1954	241000.000	.000	90593.580	638112.000	.000	21507.000	.000	750212.580	3.113
1955	250546.000	.000	251600.000	622140.750	404175.060	.000	.000	1277915.810	5.101
1956	9443318.000	13600.000	22012005.400	9957097.440	1132702.220	105.000	.000	33115510.060	3.507
1957	2842810.000	7315.000	181327.590	3205722.870	220678.360	.000	.000	3615043.820	1.272
1958	534785.000	.000	68768.400	157387.440	24407.600	2454.000	.000	253017.440	.473
1959	680000.000	320.000	183907.430	305614.440	7950.250	.000	.000	497792.120	.732
1960	14630000.000	369.000	1385330.580	41905893.800	5638941.600	5581.000	.000	48936115.980	3.345
1961	3705849.000	1272.000	295041.000	2206075.040	608116.080	.000	.000	3110504.120	.839
1962	2580884.000	.000	94519.960	4343283.560	353235.090	2445.000	.000	4793483.610	1.657
1963	338760.000	.000	47343.930	581672.520	225604.000	6950.000	.000	861570.450	2.543
1964	957120.000	7911.000	1977988.160	2400159.060	516424.950	.000	.000	4902483.170	5.122
1965	24325926.000	23575.760	9532921.170	29587491.300	1029011.080	.000	.000	40172999.310	1.651
1966	3775184.000	13991.680	455727.910	4822484.480	296820.000	.000	.000	5589024.070	1.480
1967	3216208.000	.000	308746.350	926160.000	70101.360	.000	.000	1305007.710	.406
1968	2557440.000	.000	170100.000	92402.100	123302.550	.000	.000	385804.650	.151
1969	8394204.000	.000	122678.640	4447577.400	.000	.000	.000	4570256.040	.544 1/

1/ Based on returns only through five-year-old fish

Table 4.

COPPER RIVER SYSTEM, 1962-1969 (6 PREDOMINANT AGE GROUPS)

BROOD YEAR	ESCAPEMENT INDEX	RETURN 1.1	1.2	2.1	1.3	2.2	2.3	TOTAL RETURN INDEX	RETURN PER SPAWNER
1958	20000.000	.000	1351.200	.000	494.340	1589.640	2383.890	5819.070	.291
1959	35000.000	.000	1458.660	.000	2508.810	5239.560	12196.800	21403.830	.612
1960	139000.000	.000	15962.320	2714.400	.000	489911.040	156362.400	664950.160	4.784
1961	120000.000	.000	.000	.000	.000	12813.030	10085.900	22898.930	.191
1962	43300.000	.000	582.930	.000	4187.000	147732.200	47567.790	200069.920	4.621
1963	10500.000	.000	.000	530.000	476.000	25386.660	21534.480	47927.140	4.564
1964	16015.000	.000	19715.160	420.000	14182.630	39770.180	.000	74087.970	4.626
1965	288000.000	.000	23107.370	1043.840	.000	404861.240	71641.760	500654.210	1.738
1966	76200.000	.000	26082.020	1614.000	16549.600	100595.690	44483.450	189324.760	2.485
1967	106000.000	.000	2821.940	.000	4155.210	16616.480	13120.380	36714.010	.346
1968	80066.000	.000	.000	.000	2013.480	2013.480	5979.460	10006.420	.125
1969	62150.000	.000	511.560	.000	1316.700	26985.000	.000	28813.260	.464 1/

COPPER RIVER SYSTEM, 1962-1969 (YEAR OF LIFE RUN)

BROOD YEAR	ESCAPEMENT INDEX	RETURN (YEAR OF LIFE) 3RD	4TH	5TH	6TH	7TH	8TH	TOTAL RETURN INDEX	RETURN PER SPAWNER
1958	20000.000	.000	1351.200	2100.000	2394.300	.000	.000	5845.500	.292
1959	35000.000	.000	1458.660	7809.120	12196.800	.000	.000	21464.580	.613
1960	139000.000	.000	19394.040	492759.360	156362.400	1060.000	.000	669575.800	4.817
1961	120000.000	.000	.000	12885.420	10144.200	.000	.000	23029.620	.192
1962	43300.000	.000	575.310	151813.200	49537.020	311.000	.000	202236.530	4.671
1963	10500.000	.000	651.900	25854.660	21752.000	.000	.000	48258.560	4.596
1964	16015.000	.000	19994.220	53856.480	.000	.000	.000	73850.700	4.611
1965	288000.000	.000	24098.310	408592.680	71909.080	.000	.000	504600.070	1.752
1966	76200.000	.000	28894.480	118289.920	43909.470	.000	.000	191093.870	2.508
1967	106000.000	.000	2833.050	20741.360	13121.640	.000	.000	36696.050	.346
1968	80066.000	.000	.000	4025.700	5923.050	.000	.000	9948.750	.124
1969	62150.000	.000	511.560	28301.700	.000	.000	.000	28813.260	.464 1/

1/ Based on returns only through five-year-old fish

Table 5.

WOODY ISLAND, ILIAMNA LAKE, 1958-1969

BROOD YEAR	ESCAPEMENT INDEX	RETURN 1.1	RETURN 1.2	RETURN 2.1	RETURN 1.3	RETURN 2.2	RETURN 2.3	TOTAL RETURN INDEX	RETURN PER SPAWNER
1958	3770.000	.000	240.000	.000	346.680	1574.040	.000	2160.720	.573
1959	17880.000	.000	5223.090	.000	1865.340	671.160	.000	7759.590	.434
1960	305100.000	.000	16570.070	1994.720	.000	1044040.000	28427.040	1091031.830	3.576
1961	66850.000	.000	.000	.000	75.270	12117.420	9253.770	21446.460	.321
1962	8000.000	.000	148.410	.000	589.340	10345.720	221.400	11304.870	1.413
1963	4899.000	.000	.000	.000	.000	1051.830	.000	1051.830	.215
1964	11910.000	.000	37504.860	2075.850	.000	18170.000	.000	57750.710	4.849
1965	607000.000	.000	82525.300	1500.800	16817.720	408771.580	26668.680	536284.080	.883
1966	19450.000	.000	3748.060	.000	11778.000	53119.820	1102.050	69747.930	3.586
1967	12440.000	.000	2776.220	.000	901.460	447.440	66.780	4191.900	.337
1968	35955.000	.000	6153.840	.000	370.440	2440.620	696.420	9661.320	.269
1969	70550.000	.000	1059.660	.000	1726.200	44177.700	.000	46963.560	.666 1/

WOODY ISLAND 1958-1969(YEAR OF LIFE RUN)

BROOD YEAR	ESCAPEMENT INDEX	RETURN (YEAR OF LIFE) 3RD	4TH	5TH	6TH	7TH	8TH	TOTAL RETURN INDEX	RETURN PER SPAWNER
1958	3770.000	.000	240.000	1967.280	.000	.000	.000	2207.280	.585
1959	17880.000	.000	5223.090	2307.240	.000	.000	.000	7530.330	.421
1960	305100.000	.000	18755.460	1050110.000	28427.040	.000	.000	1097292.500	3.597
1961	66850.000	.000	.000	12255.300	9307.260	.000	.000	21562.560	.323
1962	8000.000	.000	146.470	10920.140	221.400	.000	.000	11288.010	1.411
1963	4899.000	.000	.000	1051.830	.000	.000	.000	1051.830	.215
1964	11910.000	.000	39409.880	18285.000	.000	.000	.000	57694.880	4.844
1965	607000.000	.000	83260.500	421045.020	26768.190	.000	.000	531073.710	.875
1966	19450.000	.000	3709.220	65039.360	1087.830	.000	.000	69836.410	3.591
1967	12440.000	.000	2787.150	1342.320	66.780	.000	.000	4196.250	.337
1968	35955.000	.000	6153.840	2811.060	689.850	.000	.000	9654.750	.269
1969	70550.000	.000	1059.660	45903.900	.000	.000	.000	46963.560	.666 1/

1/ Based on returns only through five-year-old fish

Table 6. **Summary of spawning ground sampling of selected groups, Kvichak system, 1974**

Locality	Date	Length measurements		Otolith samples		
		Male	Female	Male	Female	Sexes combined
ILIAMNA LAKE						
Lower Talarik Ck.	8/17	100	100	100	100	200
Woody Island	8/17	63	72	63	72	135
Triangle Island	8/19	61	82	61	82	143
Copper River	9/03	29	23	29	23	52
Gibraltar Creek	9/04	57	51	57	51	108
Pedro Ponds	9/15	22	20	22	20	42
Knutson Bay	9/15	53	53	53	53	106
Newhalen River	9/22	28	26	28	26	54
Subtotal:		413	427	413	427	840
LAKE CLARK						
Nondalton Fishery	8/02	32	50	32	50	82
GRAND TOTAL:		445	477	445	477	922

Table 7. Percentage age distribution of sockeye salmon and sample sizes by sex and locality, Kvichak District, 1974.

Area	1.2 size	1.2 %	2.1 size	2.1 %	1.3 size	1.3 %	2.2 size	2.2 %	1.4 size	1.4 %	2.3 size	2.3 %	Total
Streams													
Lower Talarik Creek 1/													
♂			(1)	1.0	(6)	6.0	(93)	93.0					100
♀					(7)	7.0	(93)	93.0					100
Combined			(1)	0.5	(13)	6.5	(186)	93.0					200
Copper River													
♂					(1)	3.4	(24)	82.8			(4)	13.8	29
♀					(1)	4.4	(17)	73.9			(5)	21.7	23
Combined					(2)	3.8	(41)	78.9			(9)	17.3	52
Gibraltar Creek													
♂	(1)	1.8			(6)	10.5	(46)	80.7			(4)	7.0	57
♀	(1)	2.0			(2)	3.9	(34)	66.7			(14)	27.4	51
Combined	(2)	1.8			(8)	7.4	(80)	74.1			(18)	16.7	108
Newhalen River													
♂					(1)	3.6	(27)	96.4					28
♀					(1)	3.8	(25)	96.2					26
Combined					(2)	3.7	(52)	96.3					54
Subtotal													
♂	(1)	0.5	(1)	0.5	(14)	6.5	(190)	88.8			(8)	3.7	214
♀	(1)	0.5			(11)	5.5	(169)	84.5			(19)	9.5	200
Combined	(2)	0.5	(1)	0.2	(25)	6.0	(359)	86.8			(27)	6.5	414
Beaches													
Woody Island													
♂					(1)	1.6	(61)	96.8			(1)	1.6	63
♀					(4)	5.6	(67)	93.0			(1)	1.4	72
Combined					(5)	3.7	(128)	94.8			(2)	1.5	135
Triangle Island													
♂					(1)	1.6	(60)	98.4					61
♀					(2)	2.4	(80)	87.6					82
Combined					(3)	2.1	(140)	97.9					143
Knutson Bay													
♂			(1)	1.9	(2)	3.8	(50)	94.3					53
♀							(52)	98.1			(1)	1.9	53
Combined			(1)	0.9	(2)	1.9	(102)	96.3			(1)	0.9	106
Subtotal													
♂			(1)	0.6	(4)	2.2	(171)	96.6			(1)	0.6	177
♀					(6)	2.9	(199)	96.1			(2)	1.0	207
Combined			(1)	0.3	(10)	2.6	(370)	96.3			(3)	0.8	384
Nondalton Fishery 2/													
♂	(2)	6.2			(1)	3.1	(28)	87.6			(1)	3.1	32
♀	(4)	8.0					(44)	88.0			(2)	4.0	50
Combined	(6)	7.3			(1)	1.2	(72)	87.8			(3)	3.7	82
SPAWNING BEDS GRAND TOTAL (all areas)													
♂	(3)	0.7	(2)	0.5	(19)	4.5	(389)	92.0			(10)	2.3	423
♀	(5)	1.1			(17)	3.7	(412)	90.2			(23)	5.0	457
Combined	(8)	0.9	(2)	0.2	(36)	4.1	(801)	91.0			(33)	3.8	880

Alaska Department of Fish & Game Sampling (Weighted apportioned Kvichak River escapement) 3/

Sexes		1.2	2.1	1.3	2.2	1.4	2.3	Total
Sexes	Number	41,011	39,250	277,446	3,958,342	4,262	113,169	4,433,480
Combined	Per cent	0.9	0.9	6.2	89.3	0.1	2.6	100.0

1/ Sample collected by the Alaska Dept. of Fish & Game, Division of Sport Fisheries.
2/ Sample collected by Mr. Larry Aumiller of the Alaska Dept. of Fish & Game, Division of Sport Fisheries.
3/ 1974 Preliminary Bristol Bay Sockeye Salmon Catch and Escapement Data Summary, by Paul Krasnowski,

Table 8. Comparison of percentage returns in 1974, by brood year, from sockeye salmon sampled on Kvichak spawning grounds and from the Kvichak River escapement

Location of sampling	1968 Brood Year (6-year-old fish) age classes		1969 Brood Year (5-year-old fish) age classes		1970 Brood Year (4-year-old fish) age classes		Sample size # aged
	2.3	1.4	2.2	1.3	2.1	1.2	
Streams - Iliamna Lake							
Lower Talarik Ck.	-	-	93.0	6.5	0.5	-	200
Total	-		99.5		0.5		
Copper River	17.3	-	78.9	3.8	-	-	52
Total	17.3		82.7		-		
Gibraltar Ck.	16.7	-	74.1	7.4	-	1.8	108
Total	16.7		81.5		1.8		
Newhalen River	-	-	96.3	3.7	-	-	54
Total	-		100.0		-		
Beaches - Iliamna Lake							
Woody Island	1.5	-	94.8	3.7	-	-	135
Total	1.5		98.5		-		
Triangle Island	-	-	97.9	2.1	-	-	143
Total	-		100.0		-		
Knutson Bay	0.9	-	96.3	1.9	0.9	-	106
Total	0.9		98.2		0.9		
Lake Clark							
Nondalton Fishery	3.7	-	87.8	1.2	-	7.3	82
Total	3.7		89.0		7.3		
Combined Spawning Ground Sampling	3.8	-	91.0	4.1	0.2	0.9	880
Total	3.8		95.1		1.1		
ADF&G Sampling 1/ Kvichak Escapement Igiugig (sexes comb.)	2.6	0.1	89.3	6.2	0.9	0.9	
Total	2.7		95.5		1.8		

1/ Data from 1974 Preliminary Bristol Bay Sockeye Salmon Catch and Escapement Data Summary (Krasnowski, 1974).

ENVIRONMENTAL FACTORS

Climatological Observations

Although the reasons for the differential production of sockeye salmon fry in the Kvichak system are very complex and not entirely understood, there is general agreement that these changes in freshwater production are linked to changes in environmental conditions and, hence, to changes in the food base. Favorable environmental conditions during the period between emergence of juvenile salmon from the gravel and movement into the littoral zones of the lakes and the subsequent commencement of feeding are critical to survival.

Records of incident solar radiation may well be an indicator of general environmental conditions during the critcal spring period when salmon fry emerge from the gravel and move into the littoral areas of the nursery lakes. Incident solar radiation certainly influences the timing of the breakup of lake ice and the subsequent spring bloom of phytoplankton.

Daily incident solar insolation values have been recorded from mid-June through early September at the Porcupine Island weather station for most years since 1961. The effect of each summer season's solar insolation on water temperature has been measured through the annual observations of Iliamna Lake thermodynamics. Annual variations in thermal conditions in the lake have been expressed in terms of changes in the amount of stored heat. Therefore, changes in incident solar insolation are indirectly related to changes in lake productivity and hence to the survival and growth of juvenile sockeye salmon.

The 1974 spring and summer weather was much drier, clearer, and warmer than normal. The effect of the 1974 temperature regime on the size of Age 0 sockeye salmon in Iliamna Lake is compared to observations from past years in Fig. 4. A summary of the solar insolation data collected at Porcupine Island during the period July 1 through September 10 for the years 1966-1974 is given in Table 9. In 1974 the total cumulative solar insolation during the period July 1 through September 10 was the highest recorded since observations began (Table 9). The daily solar insolation values at the Porcupine Island weather station for 1974 are summarized in Table 10a.

Since 1961 data on the (1) daily fluctuations in lake level, (2) daily precipitation, and (3) daily maximum and minimum air temperatures have also been collected at the Porcupine Island weather station during the summer field season. The 1974 data collected from July 2 through September 26 is summarized in Tables 10a and 10b. The exceptionally dry spring and summer of 1974 was responsible for creating the lowest lake levels observed since observations began in 1961 (Table 10a and Fig. 5).

Lake Thermodynamics

Iliamna Lake Heat Budget

The heat budget for Iliamna Lake is calculated each year from data on water temperature collected by vertical bathythermograph hauls. Since 1961 casts have usually been made at from 22 to 30 stations spatially distributed throughout Iliamna Lake. Bathythermograph casts have generally been made in late June to early July, mid-to late July, and mid-to late August.

During 1974 B.T. casts were made at (1) 22 stations in late July to mid-August, and (2) 22 stations in early to mid-September. The distribution

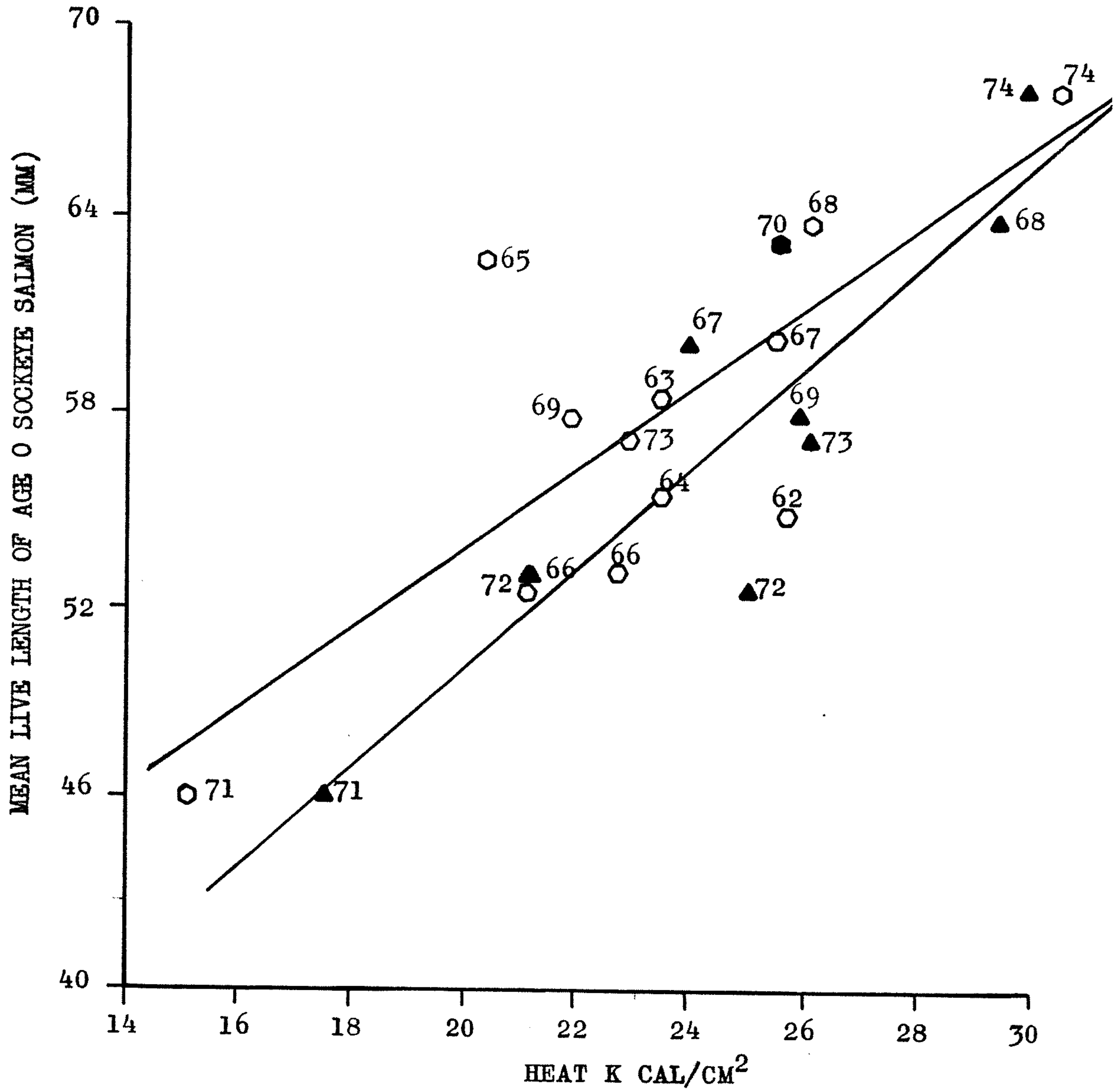

Fig. 4. Size of Age 0 sockeye salmon in Iliamna Lake adjusted to September 1 regressed on (1) the amount of stored heat in excess of 4°C in Iliamna Lake, 1962-1974 (○——○), and (2) the amount of total solar insolation during the period July 1 through September 10, 1966-1974 (▲——▲).

Table 9. Total solar radiation (cal/cm^2), mean radiation per day, and percentage of total summer radiation by month, July 1-September 10, Iliamna Lake, Alaska

	Period									
	July 1-31			August 1-31			September			
	Solar radiation			Solar radiation			Solar radiation			
Year	Total	Mean/day	Percent	Total	Mean/day	Percent	Total	Mean/day	Percent	Total
1966	11,585	374	54.8	7,366	238	34.8	2,195	220	10.4	21,146
1967	12,724	410	53.2	9,395	303	39.2	1,818	182	7.6	23,937
1968	14,559	470	49.2	11,776	380	39.8	3,266	327	11.0	29,601
1969	11,074	357	42.7	12,230	395	47.2	2,629	263	10.1	25,933
1970	12,722	410	49.7	9,523	307	37.2	3,333	333	13.0	25,578
1971	9,182	296	52.1	6,247	202	35.4	2,199	220	12.5	17,628
1972	13,693	442	54.5	9,213	297	36.6	2,233	223	8.9	25,139
1973	12,771	412	48.8	10,650	344	40.7	2,739	274	10.5	26,160
1974	14,922	497	49.9	11,785	380	39.4	3,217	322	10.8	29,924
1966-74 Mean	12,581	408	50.3	9,798	316	39.2	2,625	263	10.5	25,004

Table 10a. Daily precipitation, solar radiation, and lake level at Porcupine Island, July, 1974

Day Month	Day Year	Precipitation (inches)	Solar radiation (cal/cm²)	Lake level (mm below reference point) 1974	1961-73 mean 1/	Deviation from mean
2	184	.00		2537	2022	-515
3	185	.00	625	2522	2010	-512
4	186	.00	618	2519	2006	-513
5	187	.00	363	2509	1990	-481
6	188	T	417	2500	1977	-523
7	189	T	509	2487	1963	-524
8	190	.21	486	2452	1952	-500
9	191	.01	553	2432	1943	-489
10	198	.00	668	2437	1935	-502
11	193	.03	520	2447	1926	-521
12	194	T	646	2462	1903	-559
13	195	T	740	2452	1880	-572
14	146	.00	744	2427	1868	-559
15	197	.07	379	2427	1858	-579
16	198	T	319	2413	1846	-567
17	199	.00	495	2413	1841	-572
18	200	.00	608	2457	1821	-636
19	201	.16	321	2457	1805	-652
20	202	.41	327	2378	1808	-570
21	203	.04	413	2357	1794	-583
22	204	.01	336	2374	1789	-585
23	205	.02	478	2365	1765	-600
24	206	T	438	2352	1748	-604
25	207	.03	363	2338	1743	-595
26	208	.00	321	2335	1739	-596
27	209	.00	704	2320	1741	-579
28	210	.00	616	2307	1731	-576
29	211	.00	646	2342	1737	-615
30	212	.00	602	2306	1715	-591
31	213	.00	667	2335	1708	-627

1/ Calculated from years where either actual or estimated values are given.

Table 10a. Daily precipitation, solar radiation, and lake level, Porcupine Island, August, 1974 - Continued

Day Month	Day Year	Precipitation	Solar radiation	Lake level (mm below reference point) 1974	1963-1973 mean[2/]	Deviation from
1	214	.00	472	2312	1695	-617
2	215	.00	440	2315	1690	-625
3	216	T	579	2315	1681	-634
4	217	.00	516	2305	1678	-627
5	218	.00	475	2337	1661	-676
6	219	T	261	2337	1650	-687
7	220	.03	201	2287	1628	-659
8	221	*	428	(2286)[3/]	1625	-661
9	222	*	365	(2285)	1610	-675
10	223	*	415	(2283)	1596	-687
11	224	.31[1/]	566	2282	1581	-701
12	225	.00	478	2264	1574	-690
13	226	.00	453	2267	1560	-707
14	227	.00	484	2257	1559	-698
15	228	.00	509	2257	1559	-698
16	229	.00	340	2251	1545	-706
17	230	*	516	(2242)	1539	-703
18	231	T[1/]	484	2232	1517	-715
19	232	.00	472	2227	1509	-718
20	233	*	434	(2232)	1520	-712
21	234	.00	478	2237	1510	-727
22	235	.00	509	2232	1489	-743
23	236	.05	283	2237	1481	-756
24	237	.06	195	2272	1470	-802
25	238	*	321	(2272)	1461	-811
26	239	.28[1/]	239	2272	1456	-816
27	240	.42	201	2242	1463	-779
28	241	T	226	2282	1440	-842
29	242	.01	119	2252	1450	-802
30	243	T	163	2232	1438	-794
31	244	*	163	(2208)	1427	781

*No observation.
1/ Includes precipitation which may have occurred on the previous series of days with missing observations.
2/ Calculated from years where either actual or estimated values are given.
3/ Values in parentheses are linear estimates between days of observation.

Table 10a. Daily precipitation, solar radiation, and lake level, Porcupine Island, September, 1974 - Continued

Day Mo.	Day Year	Precipitation (inches)	Solar radiation (cal/cm²)	Lake level (mm below reference point) 1974	1972-73 mean[2/]	Deviation from mean
1	245	*	258	(2184)[3/]	1428	-756
2	246	.76[1/]	228	2160	1415	-745
3	247	*	340	(2163)	1414	-749
4	248	.01	377	2167	1413	-754
5	249	.00	358	2152	1407	-745
6	250	.00	462	2150	1415	-735
7	251	.00	258	2157	1415	-742
8	252	.00	245	2144	1429	-715
9	253	.00	402	2147	1432	-715
10	254	.15	289	2135	1427	-708
11	255	.62	170	2159	1376	-783
12	256	.35	236	2102	1369	-733
13	257	.02	302	2102	1365	-737
14	258	T	165	2097	1364	-733
15	259	.80	104	2122	1348	-774
16	260	.03	245	2099	1370	-729
17	261	*	189	(2092)	1350	-742
18	262	*	245	(2085)	1422	-663
19	263	*	176	(2078)	1428	-650
20	264	*	201	(2071)	1438	-633
21	265	*	239	(2064)	1294	-770
22	260	.35[1/]	182	2057	1309	-748
23	267	T	I67	2042	1334	-708
24	268	.22	136	2002	1265	-737
25	269	.32	192	2025	1109	-816
26	270	.27	220	1962	1109	-853

* No observation.

1/ Includes precipitation which may have occurred on the previous series of days with missing observations.

2/ Calculated from years where either actual or estimated values are given.

3/ Values in parentheses are linear estimates between days of observation.

Table 10b. Daily maximum and minimum air temperatures (°F)[1/], Procupine Island, July 2 through September 26, 1974

JULY				AUGUST				SEPTEMBER			
Day		Temp.		Day		Temp.		Day		Temp.	
Mo.	Yr.	Max.	Min.	Mo.	Yr.	Max.	Min.	Mo.	Yr.	Max.	Min.
1	183			1	214	71	48	1	245	(62)	(47)
2	184	72	44	2	215	74	46	2	246	62	51
3	185	76	44	3	216	77	46	3	247	(65)	(42)
4	186	74	50	4	217	74	48	4	248	72	44
5	187	69	48	5	218	72	52	5	249	66	45
6	188	67	52	6	219	58	53	6	250	65	42
7	189	71	47	7	220	58	52	7	251	61	49
8	190	62	52	8	221	(62)	(50)	8	252	62	48
9	191	64	48	9	222	(58)	(44)	9	253	68	38
10	192	69	48	10	223	(60)	(42)	10	254	56	52
11	193	68	50	11	224	74	42	11	255	54	51
12	194	60	52	12	725	73	45	12	256	58	50
13	195	64	52	13	226	77	48	13	257	58	46
14	196	70	48	14	227	72	50	14	258	55	42
15	197	60	50	15	228	72	52	15	259	56	46
16	198	66	50	16	229	65	50	16	260	57	46
17	199	66	50	17	230	(62)	(48)	17	261	-	(44)
18	200	73	42	18	231	70	45	18	262	(49)	(36)
19	201	58	50	19	232	80	48	19	263	(51)	(36)
20	202	58	49	20	233	(68)	(46)	20	264	(52)	(46)
21	203	60	48	21	234	76	44	21	265	(51)	(42)
22	204	58	46	22	235	70	43	22	266	60	41
23	205	72	44	23	236	56	44	23	267	52	49
24	206	66	41	24	237	56	44	24	268	54	48
25	207	66	52	25	238	(55)	(44)	25	269	52	40
26	208	65	53	26	239	62	47	26	270	50	40
27	209	70	48	27	240	61	47				
28	210	72	42	28	241	58	43				
29	211	60	54	29	242	59	52				
30	212	71	53	30	243	62	57				
31	213	66	44	31	244	(54)	(49)				

[1/] Temperatures in parentheses were estimated from recording thermograph charts.

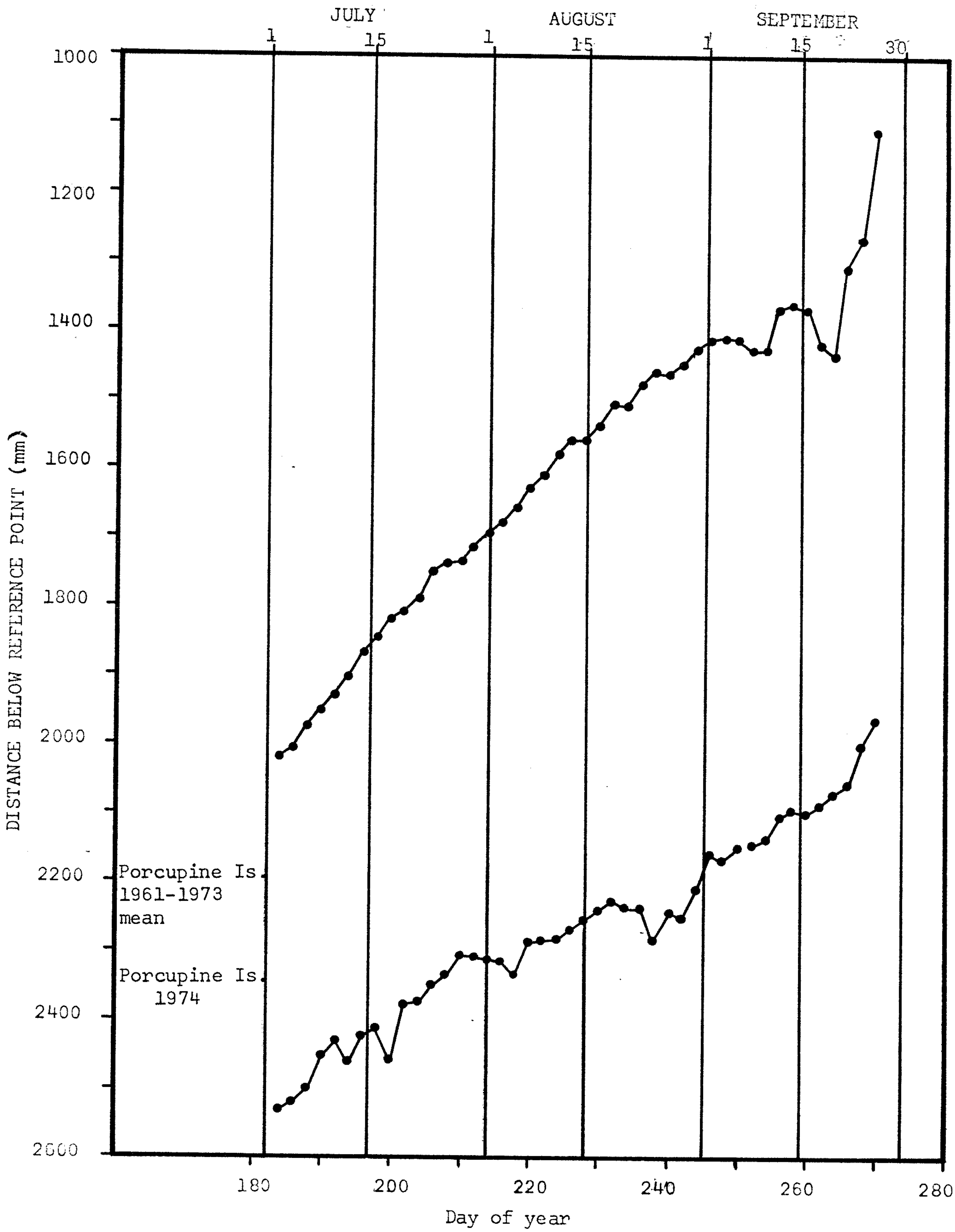

Fig. 5. Fluctuations in water level at Porcupine Island during the summer of 1974 compared with mean fluctuations at Porcupine Island, summers 1961-1973.

of the 1974 sampling effort is shown in Fig. 6 and a summary of the B.T. sampling is given in Table 11. The heat budget values from all the 1974 B.T. sampling are presented in Tables 12a and 12b, and are compared to the years 1961-1973 in Table 13. The annual budget for 1974 is the highest recorded since observations began.

PRIMARY PRODUCTION

Periphyton studies

It has been hypothesized that the magnitude of the peak cycle returns of sockeye salmon to the Kvichak River system is in part determined by the survival of the island beach spawning stocks. The progeny of island beach spawning stocks stay close to shore for 1-2 months after emergence from the gravel before moving into the pelagic areas. While in the littoral, it has also been hypothesized that juvenile sockeye salmon feed primarily on insect larvae, which depend on periphyton and detritus for their food. Because of the high concentration of fry in littoral areas during the spring months of some years, high food production is necessary for favorable early survival (Miller, 1970). In an effort to determine specific mechanisms which affect survival of the progeny of island beach spawners, in 1969 periphyton studies were initiated on selected island beach areas in the eastern portion of Iliamna Lake.

The periphyton on the island beaches during the summer consists of a green and brown algal slime on the rocks from the edge of the water to a depth of about 2 feet. During the late summer and early fall a dense mass of brown periphyton has also been observed in deeper water in certain island beach spawning areas(Roger, 1971). During the early summer of 1973 Poe and Carlson (personal observation) noted a dense mass of brown periphyton growing to a depth of 3 feet on a mainland beach where a landslide had occurred three years before. Miller (1970) found that diatoms comprise most of the periphyton, but filamentous algae become abundant during late summer.

Periphyton growth has been monitored at selected locations on certain island beaches since 1969. During the summer of 1974 periphyton growth on artificial substrate was monitored at five stations (Fig. 7). Trays of 50mm X 75mm glass slides were placed and kept approximately 12 inches under water and periodically slides were removed for determination of the content of chlorophyll _a_. The growth of periphyton at the five stations monitored in 1974, measured through determining the content of chlorophyll _a_ in the periphyton samples from slides, is summarized in Fig. 8 and Table 14. Abundance was highest and increased steadily at Station P3 during the sampling period, August 6 through September 15. Abundance was intermediate and increased rapidly after August 18 at Ststion W3. Abundance was low and increased slowly after August 18 at Station W3. Abundance was low and increased very slowly during the sampling period at Stations W2 and W1.

Presently it is felt that the differences observed within and between years at the different periphyton stations can be mostly explained through complex differences in the biotic and abiotic conditions existing at the different sampling sites.

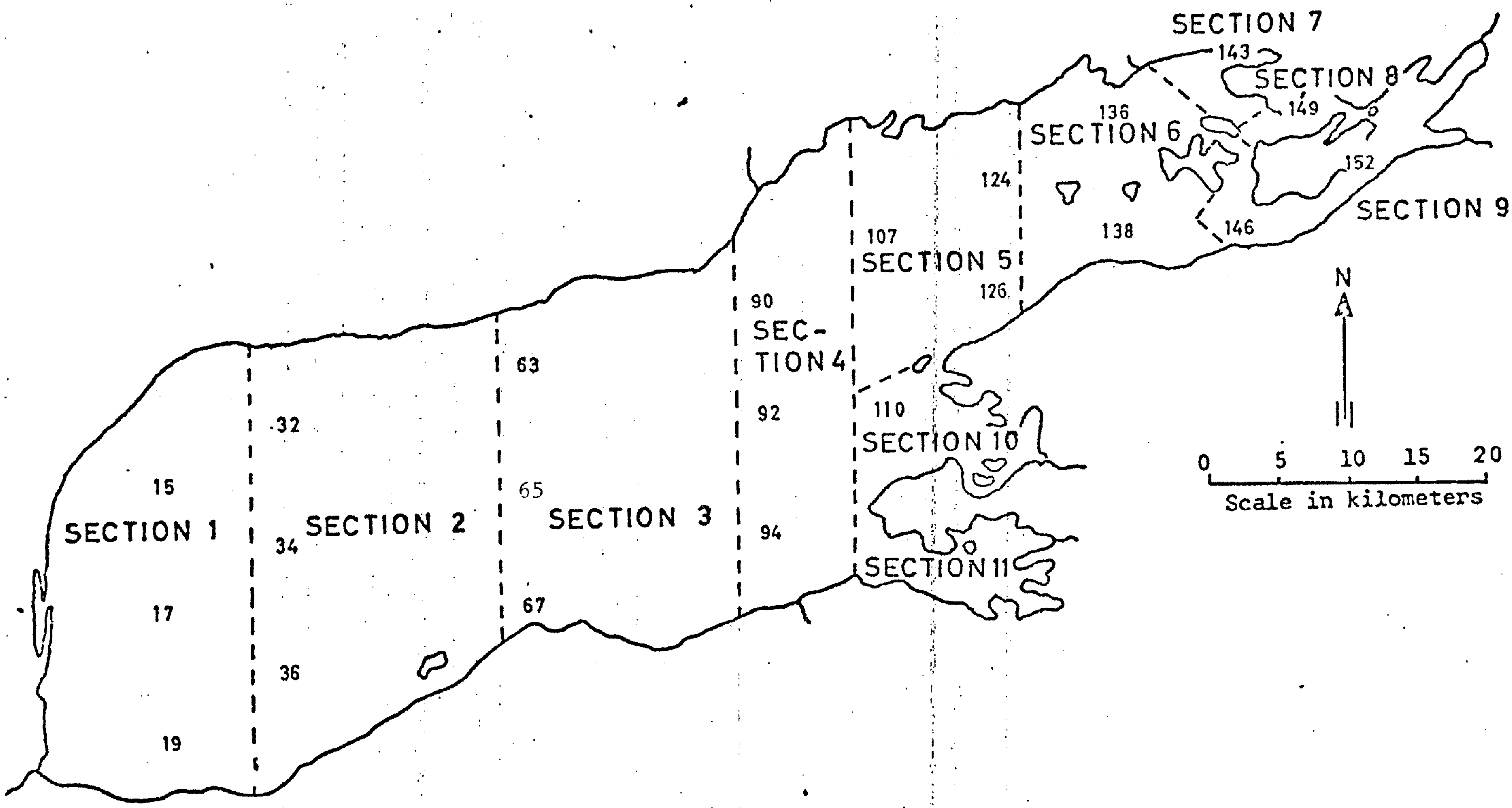

Fig. 6. Locations of the eleven sections of Iliamna Lake (towing division) and the bathythermograph sampling stations.

Table 11. Summary of bathythermograph[1/] sampling in Iliamna Lake and Lake Clark, 1974

Date	Cast #'s	Station(s)
Iliamna Lake		
7/27	1	149
7/30	2-4	124, 136, and 143
7/31	5	107
8/01	6-7	92, and 110
8/02	8-14	15, 32, 34, 63, 65, 67, and 94
8/03	15-17	17, 19, and 36
8/07	19-20	145, and 152
8/08	21-23	126, 138, and 149
8/09	24-25	90, and 107
8/18	26	149
8/31	27	149
9/02	28-29	17, and 19
9/03	30-34	32, 34, 65, 67, and 94
9/05	35-36	92, and 110
9/06	37	90
9/08	38-41	107, 124, 126, and 136
9/09	42-43	145, and 152
9/12	44-45	138, and 149
9/14	46	143
Lake Clark		
8/10	1-3	169, and 161

[1/] B.T. #6167 used for all casts less than 65 meters and B.T. #LL04452 used for all casts more than 65 meters in depth.

Table 12a. **Amounts of stored heat in excess of 4°C (cal/cm^2) in Iliamna Lake, 1974**

Lake Sections	July	August and September
1-4	24,168	26,427
5-6	29,703	36,582
7-9	29,117	37,789
10-11	17,254	21,245
Entire lake	26,165	30,669

Table 12b. **Amounts of stored heat in excess of 4°C (cal/cm^2) at station 149, eastern end of Iliamna Lake, 1974**

Sampling Date	Amount of stored heat, station 149
7/27	26,402
8/08	19,010
8/18	29,442
8/31	24,743
9/12	28,603

Table 13. Amounts of stored heat in excess of 4° C (cal/cm^2) in Iliamna Lake, 1961-1974. Annual heat budget is computed from values in August and September

Sections	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
							June							
1-4	*	*	*	4,765	4,527	5,109	7,623	7,687	6,009	10,640	-6,099	4,692	x	x
5-6	*	*	*	-1,251	4,496	-1,619	993	5,882	4,940	8,897	-9,438	1,196	x	x
7-9	*	*	*	-8,868	- 894	-1,291	6,508	2,466	7,729	4,021	-8,639	-4,690	6,349	x
10-11	*	*	*	9,481	6,150	7,535	5,470	8,573	5,393	8,597	-1,387	-3,348	x	x
Entire lake	*	*	** *	1,274	4,261	3,692	5,511	6,479	5.945	9,152	-6,285	851	*	x
							July							
1-4	*	*	*	11,233	11,116	13,377	17,434	18,346	14,947	x	x	x	18,215	24,168
5-6	*	*	*	8,974	13,111	13,660	23,602	18,434	17,474	x	x	x	18,045	29,703
7-9	*	*	*	2,549	8,058	12,908	18,727	12,966	23,823	x	x	x	19,414	29,117
10-11	*	*	*	10,713	9,221	13,217	20,980	14,204	14,204	x	x	x	11,996	17,254
Entire lake	*	*	*	9,331	11,203	13,389	19,207	17,663	16,895	x	x	x	18,129	26,165
							August and September							
1-4	24,883	21,805	22,335	21,474	19,895	20,912	24,211	24,909	19,387	23,433	12,546	21,386	20,379	26,427
5-6	35,775	30,031	28,798	29,560	22,670	24,772	29,115	28,837	27,636	29,879	16,237	14,087	25,986	36,582
7-9	41,390	35,220	19,780	27,751	23,760	28,448	26,193	27,618	22,087	27,800	23,290	21,263	29,229	37,789
10-11	18,459	17,013	17,988	18,053	17,273	13,637	19,267	18,534	18,250	13,942	15,038	21,786	15,119	21,245
Entire lake (Annual budget)	30,175	25,882	23,635	23,688	20,389	22,835	25,712	26,163	22,011	25,514	15,168	21,161	23,005	30,669

*Data insufficient for determination of values for comparative purposes

xData not taken.

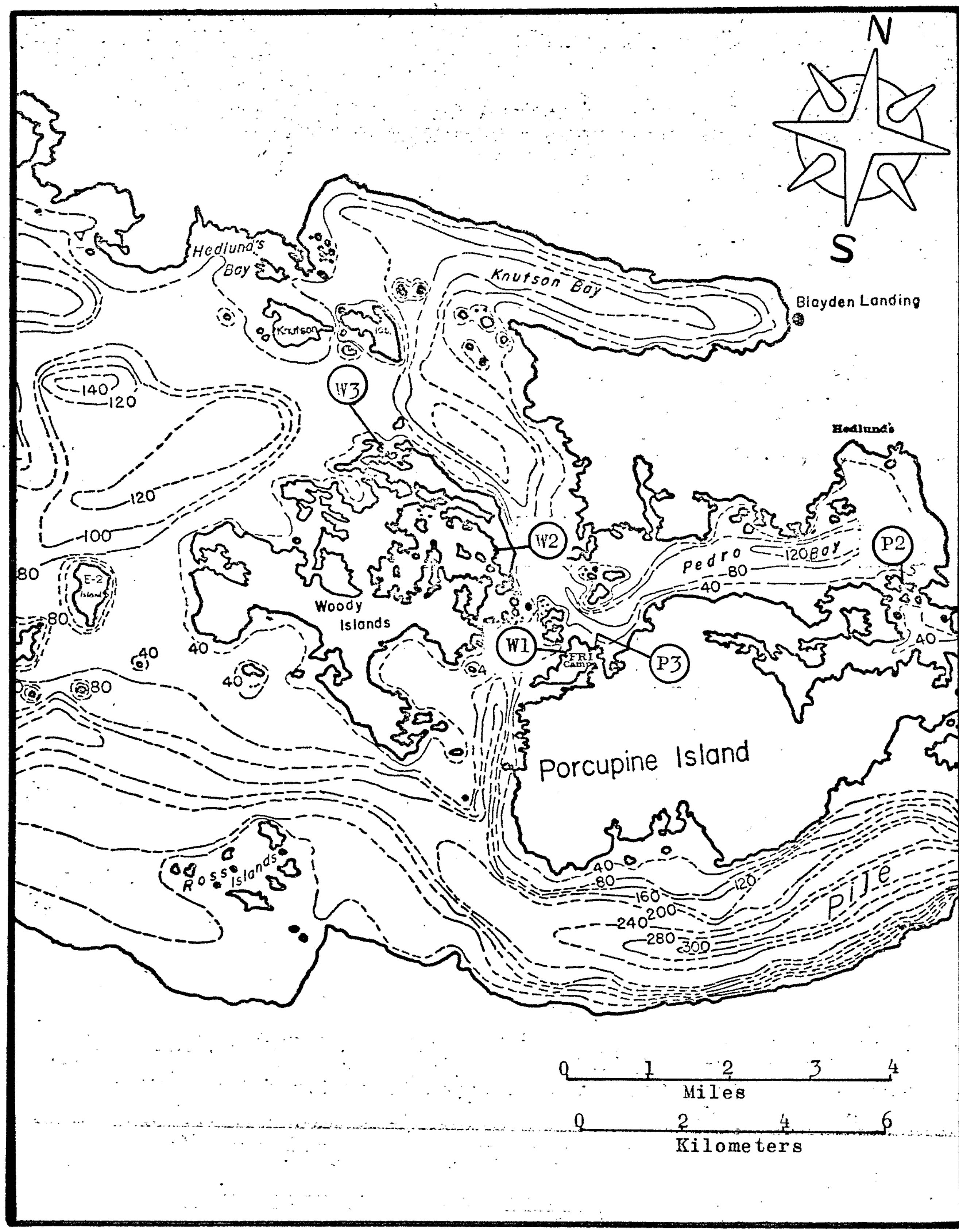

Fig. 7. Locations of the five periphyton stations sampled in 1974.

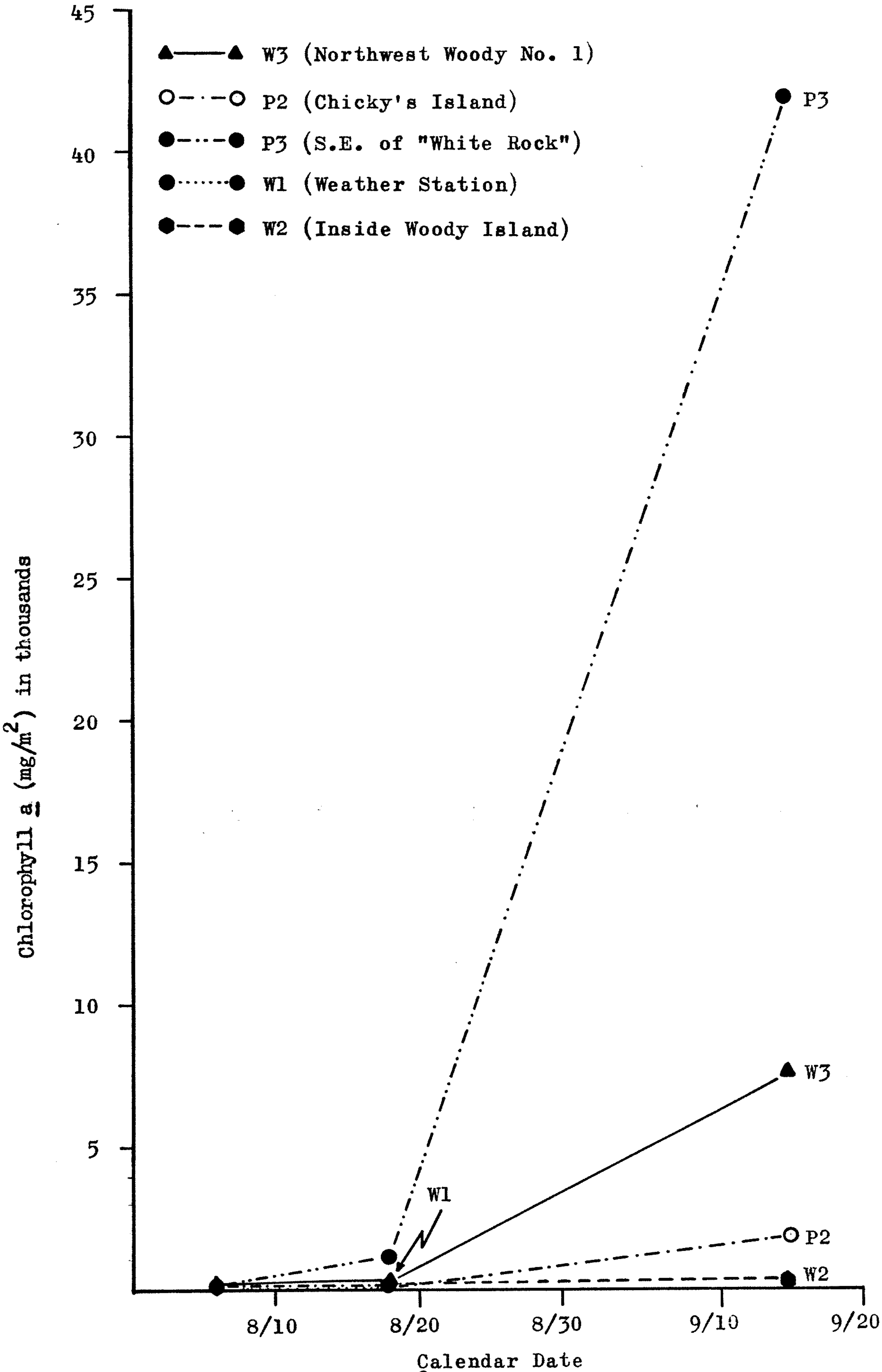

Fig. 8. Chlorophyll a (mg/m^2) in periphyton sampled from island beach areas of Iliamna Lake, 1974.

Table 14. Chlorophyll a in periphyton from sampling at five island beach stations in the eastern end of Iliamna Lake, 1974

Date	(1) Sample number	(2) 11.6(665-750)	(3) 1.31(645-750)	(4) .14(630-750)	(5) 2-3-4(5)	(6)[1/] Ml acetone / surface area of substrate
8/06	W1-1	0.4640	0.03144	0.00238	0.43018	159.7519
8/18	W1-2	0.8468	0.05240	0.00364	0.79075	293.6572
8/06	W2-1	0.4988	0.03275	0.00224	0.46381	172.2408
8/18	W2-2	0.6496	0.04601	0.00308	0.60591	225.0111
9/15	W2-3	0.4060	0.02751	0.00210	0.37639	279.5529
8/06	W3-1	0.5220	0.03406	0.00280	0.48514	180.1619
8/18	W3-2	1.0440	0.07336	0.00546	0.96518	358.4299
9/15	W3-3	5.5564	0.32881	0.02814	5.19945	7,723.4848
8/06	P2-1	0.1392	0.01310	0.00252	0.12358	45.8928
8/18	P2-2	0.6032	0.03930	0.00308	0.56082	208.2665
9/15	P2-3	2.8304	0.15065	0.01190	2.66785	1,981.4690
8/06	P3-1	0.7772	0.04978	0.00392	0.72350	268.6794
8/18	F3-2	3.3756	0.19781	0.01540	3,16239	1,174.3873
9/15	P3-3	3.7468	0.18733	0.02492	3.53455	42,002.9709

[1/] Slides used during 1974 were 3"x2", or 51x66 mm, allowing 1 cm to be placed in the slot on the slide tray. Two slides were processed per station on 8/06 and 8/18 while one slide was processed per station on 9/15.

Calculation of mg chlorophyll a/m^2.

Chlorophyll a = $11.6(D_{665} - D_{750}) - .14(D_{630} - D_{750}) - 1.31(D_{645} - D_{750})$

Chlorophyll a/m^2 (chlorophyll a) $\left(\frac{\text{Ml acetone extract}}{\text{surface area of substrate}}\right)$[2/]

[2/] For all samples taken on 8/06 and 8/18: $\frac{5 \text{ ml acetone}}{0.013464 m^2}$ (surface area of 2 slides)

For samples taken on 9/15 at all stations: $\frac{\text{Number ml acetone}}{0.006732\ m^2}$ (surface area of 1 slide)

Standing Crop of Phytoplankton

The food chain leading from inorganic nutrients to production of juvenile sockeye salmon is complicated by many factors. Studies at the primary trophic level are necessary to understand how cyclic changes in escapement level affect the food base and hence the survival rate and growth rate of juvenile sockeye salmon in the Kvichak system. One hypothesis has been that the biogenic elements released by decomposed adult carcasses enrich the productivity of the nursery lakes of the Kvichak system and thereby enhance the survival rate of juvenile sockeye salmon proportional to the size of the escapement.

Since 1961 the summer primary production of Iliamna Lake has been studied by estimation of the standing crop of phytoplankton by measuring the amount of chlorophyll a in the water at three stations, 19, 107, and 143 (Fig. 9). These stations were initially chosen to represent three distinct physical regions in Iliamna Lake (Table 15). Station 19, average depth 27m, represents section A, the lower end and shallow part of Iliamna Lake. Station 107 in section B, or mid-lake area, has a average depth of 110 m. Station 143 represents section C, the eastern end of Iliamna Lake.

Loh Lee Low (1972) determined that chlorophyll a concentrations in Iliamna Lake decreased from 1961 to 1963 and then generally increased through 1971. Likewise concentrations of chlorophyll a were found to decrease from the eastern end of the lake toward the western end (Low, 1972).

Low (1972) also found that the general increase in chlorophyll a concentration was also reflected in an increasing trend of phytoplankton abundance. Concentrations of phytoplankters were found to be highest at station 143 and approximately the same at stations 19 and 107, and the general trend in concentration of total numbers and volumes of phytoplankton was highest in June.

Low (1972) concluded that year-to-year differences in chlorophyll a concentrations can be detected by the technique presently used and further suggested that increased returns of adult sockeye salmon to the Kvichak system in recent years may be responsible for the observed increased level of primary productivity, as measured by chlorophyll a concentrations and phytoplankton abundance.

It has also been suggested by some investigators that the magnitude of variation involved in chlorophyll a determination in the early years of sampling may have been greater than during recent years due to the (1) vagaries of sampling conditions, (2) differences in technique between people conducting the sampling and making the readings, and (3) differences associated with the timing of the filtering of water samples and the storage of filters over prolonged periods.

Analyses of past primary production studies have not revealed any clear relationship between the abundance of sockeye salmon enumerated as returning adults or as juvenile salmon in the nursery lakes. The weighted mean yearly concentrations of chlorophyll a determined from the annual sampling of three stations in Iliamna Lake since 1961 have exhibited significant variation that has been attributed to seasonal differences in primary productivity. It can be hypothesized that much of this annual variation is caused by seasonal variation in phytoplankton abundance relative to the rather constant calendar dates of sampling.

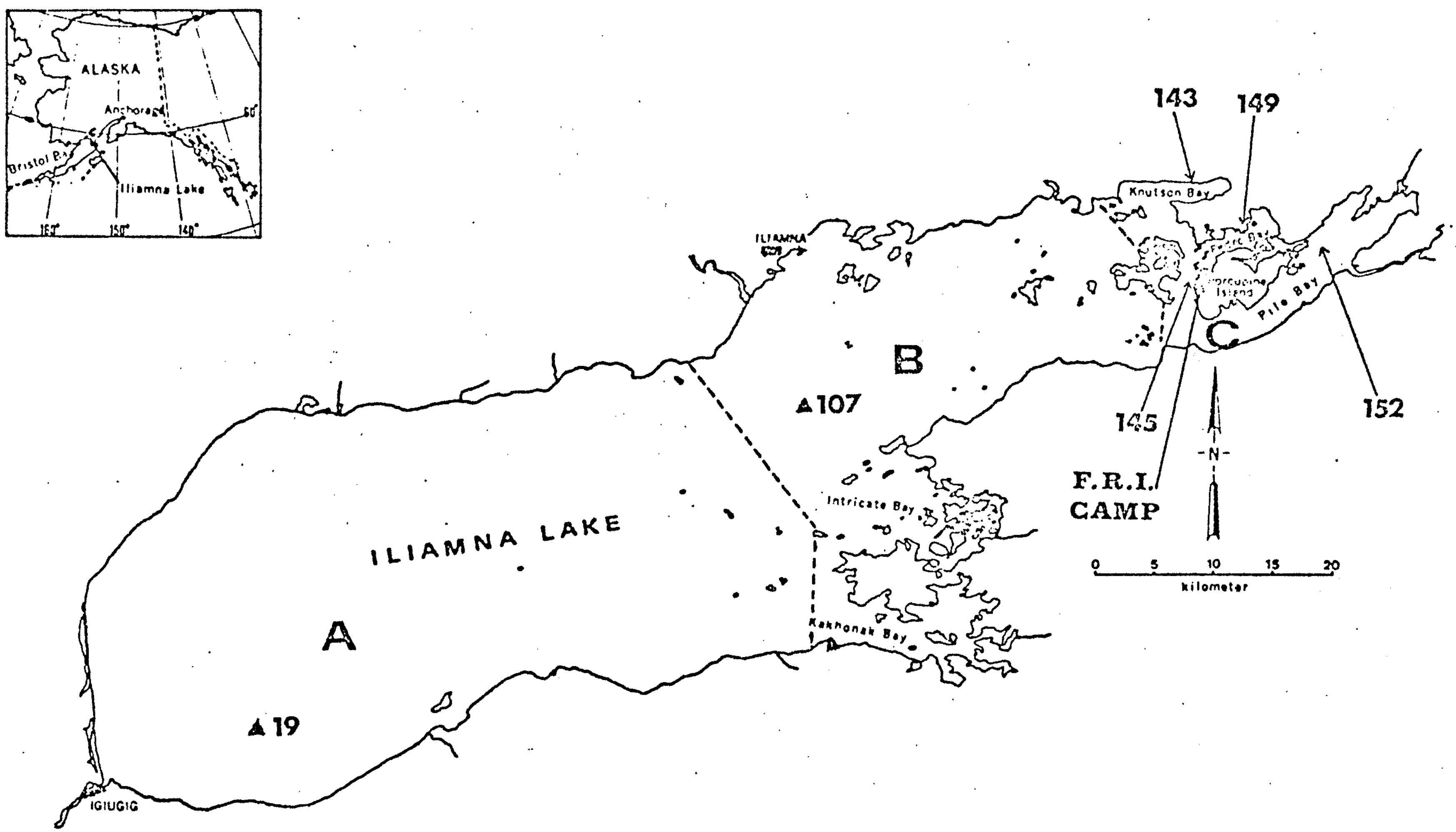

Fig. 9. Map of Iliamna Lake showing the divisions between the three major areas and the positions of stations for measurements of primary production.

Table 15. Physical measurements and characteristic features of three sampling areas in Iliamna Lake.

Measurement	Section A	Section B	Section C	Total
Area (km^2)	1,858.0	610.0	154.0	2,622.0
Per cent of total	70.9	23.2	5.9	100.0
Volume (km^3)	62.4	36.3	16.6	115.3
Per cent of total	54.1	31.5	14.4	100.0
Maximum depth (m)	40.0	240.0	393.0	
Mean depth (m)	33.6	39.5	107.6	44.0
Sampling station	19	107	143	
Potential spawning ground (km^3)				
Streams	0.66	0.57	1.51	2.74
Beaches			0.33	0.33
Total	0.66	0.57	1.84	3.07
Per cent of total	21.0	19.0	60.0	100.0

Source: Low (1972).

The concentrations of chlorophyll a from the seasonal sampling at stations 19, 107, and 143 for the years 1961-1974 are summarized in Table 16. Data on the relative timing and progression of the breakup of Iliamna Lake ice for the years 1961-1974 has just been recently assembled (Table 17). The mean concentrations of chlorophyll a at stations 19, 107, and 143 for the years 1961-1974 were plotted according to calendar date and also according to the number of days after the breakup of lake ice (Figs. 10-15). General trends in phytoplankton abundance at the three sampling stations are more apparent from the data plotted according to the number of days after the breakup of lake ice. The general trend at station 19 indicates phytoplankton abundance to be greatest shortly after the breakup of lake ice witha subsequent low level occurring approximately 75 days after ice breakup and a second bloom is indicated to occur approximately 90 days after ice breakup (Fig. 13). The early fall phytoplankton bloom at station 19 can probably be attributed to increased mixing of nutrients caused by the onset of the fall stormy weather. The general trend at station 107 is less evident with some indication of a peak in phytoplankton standing crop approximately 50 days after the breakup of lake ice and a general decrease throughout the remainder of the season (Fig. 14). The abiotic and biotic factors affecting the primary trophic level at station 107 are probably much more complex and variable than those acting at station 19. The general trend at station 143 indicates phytoplankton abundance to be the highest shortly after the breakup of lake ice with a general decrease throughout the remainder of the sampling season (Fig. 15).

The mean concentrations of chlorophyll a at stations 19, 107, and 143 for two successive 5-year cyclic periods, 1961-1965 and 1966-1970, and for the period 1971-1974 were plotted according to the number of days after the breakup of lake ice (Figs. 16-24). These data indicate a general trend of increasing primary production through 1971 with a marked decline occurring thereafter.

Monitoring the primary production by estimation of the standing crop of phytoplankton by measuring the amount of chlorophyll a in the water was continued at stations 19, 107, and 143 during the 1974 field season. The 1974 chlorophyll a concentrations by station and depth are summarized in Table 18 and the weighting factors used for the computations are summarized in Table 19a and 19b. The yearly mean concentrations of chlorophyll a for the years 1961-1974 are shown in Fig. 25. The 1974 yearly mean concentration is based on samples taken in early August and early September. The peak abundance of phytoplankton obviously occurred well before our sampling was conducted. Budget limitations the past two years have resulted in shortening the field season. Consequently, there has been no early primary production studies the past two field seasons. Therefore, the 1973 and 1974 yearly mean concentrations of chlorophyll a are not directly comparable to previous years.

Table 16. Concentrations of chlorophyll a (mg/m^3) in June, July, and August at stations 19, 107, and 143, weighted mean yearly concentrations,[1/] and standard error of the mean[2/], Iliamna Lake, 1961-1974

	Station 19				Station 107				Station 143				Weighted	Standard
Year	June	July	Aug.	Mean	June	July	Aug.	Mean	June	July	Aug.	Mean	mean yearly concentrations	error of the mean
1961	0.74*	0.49	0.65	(0.63)	0.80	0.65	0.77	(0.74)	0.65	0.71	0.66	(0.67)	0.67	0.06
Date		7/21	8/23		6/29	7/13	8/23		7/16	8/06	8/24			
1962	0.85	0.59	0.17	(0.54)	0.78	0.77	0.46	(0.67)	0.79	0.65	0.27	(0.57)	0.59	0.16
Date	6/06	7/18	8/15		6/05	7/14	9/09		6/03	7/17	8/18			
1963	0.54*	0.34*	0.27	(0.38)	0.74	0.62	0.24	(0.53)	0.59	0.54	0.49	(0.54)	0.45	0.11
Date			8/16		6/14	7/09	8/06		6/13	7/07	8/12			
1964	0.60	0.45	0.27	(0.44)	0.76	0.52	0.65	(0.64)	0.69	0.61	0.73	(0.68)	0.54	0.10
Date	7/01	7/23	8/14		6/25	7/18	8/11		6/23	7/11	8/07			
1965	0.74	0.48	0.65	(0.62)	0.87	0.37	0.69	(0.64)	0.59	0.68	0.64	(0.64)	0.63	0.10
Date	6/24	7/21	8/29		6/30	7/14	8/06		6/24	7/18	8/02			
1966	0.78	0.56	0.36	(0.57)	0.68	0.56	0.37	(0.54)	1.07	0.90	0.62	(0.86)	0.60	0.16
Date	6/28	7/17	8/14		6/26	7/15	8/11		6/25	7/13	8/10			
1967	0.63	0.33	0.50	(0.49)	0.45	0.61	0.44	(0.50)	0.84	0.61	0.69	(0.71)	0.52	0.10
Date	6/26	7/28	8/22		6/20	8/02	8/27		6/18	8/06	8/29			
1968	0.56	0.50	0.76	(0.61)	0.92	1.00	0.55	(0.82)	0.92	0.92	0.86	(0.91)	0.72	0.13
Date	6/22	7/21	8/20		6/24	7/24	8/23		6/20	7/25	8/26			
1969	1.07	0.62	0.38	(0.69)	1.06	0.93	0.85*	(0.95)	0.91	1.38	0.89	(1.06)	0.83	0.19
Date	6/23	7/22	8/22		6/28	7/29			7/01	8/01	8/30			
1970	0.95*	0.82	0.86	(0.88)	0.76	0.96	0.44	(0.72)	1.31	1.14	0.77	(1.07)	0.86	0.16
Date		7/17	8/16		6/23	7/18	8/24		6/24	7/19	8/22			
1971	1.16	1.20	1.01	(1.12)	0.87	1.39	1.05	(1.10)	1.53	1.42	1.33	(1.43)	1.16	0.14
Date	6/25	7/26	8/11		6/27	7/28	8/12		6/27	7/29	8/31			
1972	0.91	0.37	0.52	(0.60)	0.91	0.97	0.62	(0.83)	1.12	0.98	1.11	(1.07)	0.74	0.18
Date	7/09	8/03	9/08		7/02	8/02	8/28		7/07	8/01	9/05			
1973	**	0.90	0.42	(0.66)	**	1.09	0.52	(0.81)[3/]	**	1.38	0.86	(1.12)[3/]	0.77	0.29
Date		7/28	8/16			7/24	8/17	9/05 0.62		7/29	8/20	9/05 0.70		
1974	**	0.34	0.42	(0.38)	**	0.41	0.39	(0.40)	**	0.59	0.54	(0.56)	0.42	0.08
Date		8/03	9/02			7/31	9/08			8/07	9/14			

1/ Yearly mean at each station weighted by the volume of the section of the lake they represent.

2/ ± 2 standard errors.

* Missing observations estimated by randomized block method from Snedecor, 1969, p. 317 (Low, 1972).

**No sampling in June, 1973.

3/ Concentrations of chlorophyll a taken on 9/05/73 not used in calculation of station means.

Table 17. Estimated date[1/] of the breakup of lake ice in three sections[2/] of Iliamna Lake, 1961-1974

Year	Section A		Section B		Section C	
	Calendar date	Day of year	Calendar date	Day of year	Calendar date	Day of year
1961	5/26	147	5/16	137	5/12	133
1962	5/31	152	5/23	144	5/20	141
1963	6/01	153	5/16	137	5/06	127
1964	6/21	173	6/11	163	6/07	159
1965	5/22	143	5/15	136	5/08	129
1966	6/18	170	6/03	155	6/02	154
1967	5/21	142	5/19	140	5/14	135
1968	5/23	144	5/17	138	5/17	138
1969	5/31	152	5/24	145	5/18	139
1970	4/15	106	4/15	106	3/19	79
1971	6/17	169	6/16	168	6/06	158
1972	6/11	163	6/07	159	6/05	157
1973	6/05	157	5/20	141	5/15	136
1974	5/24	146	5/23	144	5/19	140

1/ Source of data: Personal logs of FRI biologists and correspondence and/or personal diaries of residents of the Iliamna area.

2/ Primary production division of Iliamna Lake.

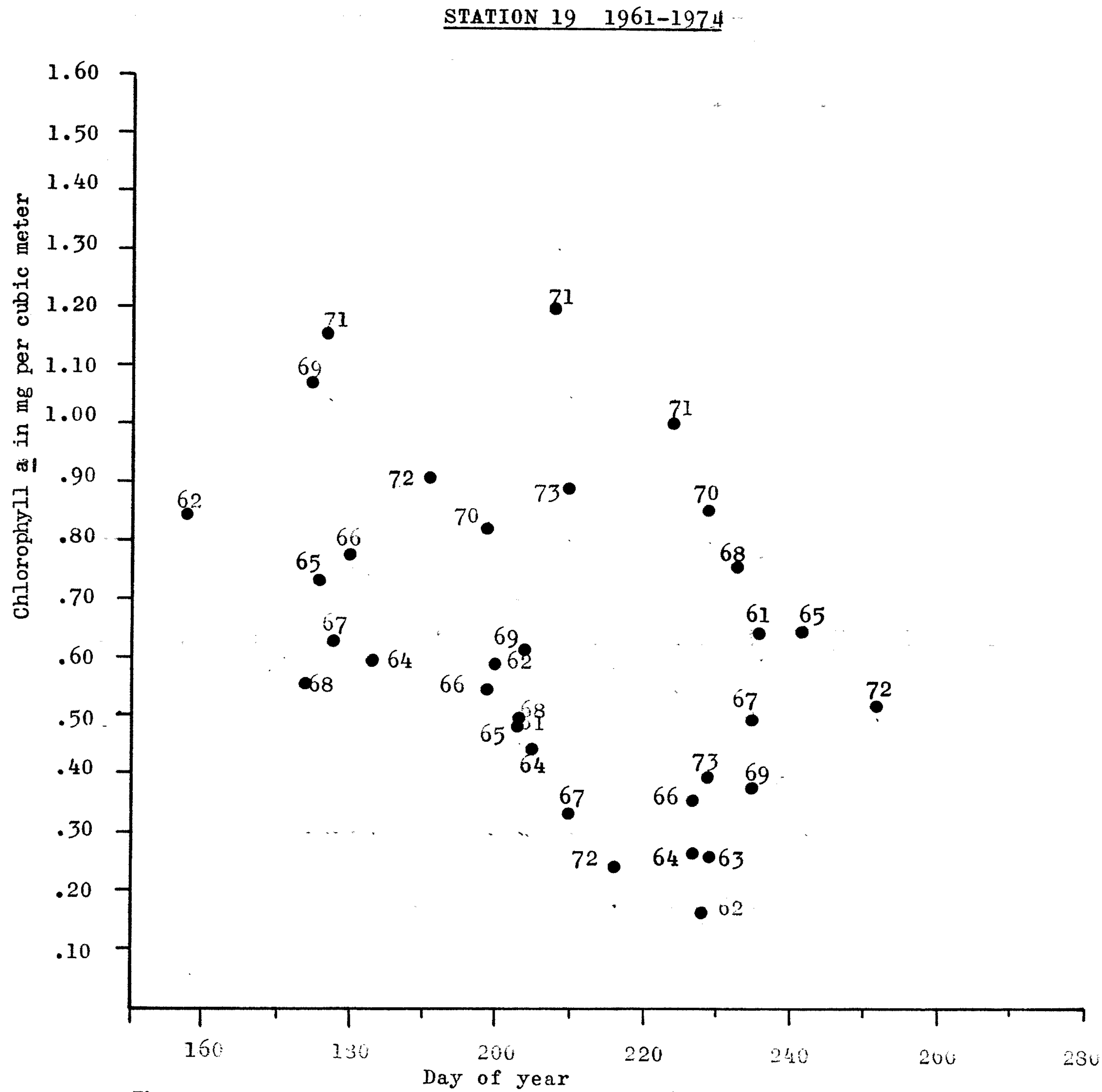

Fig. 10. The mean concentration of chlorophyll a (0-25m) at Station 19, Iliamna Lake, by day of year. Data for 1961-1974.

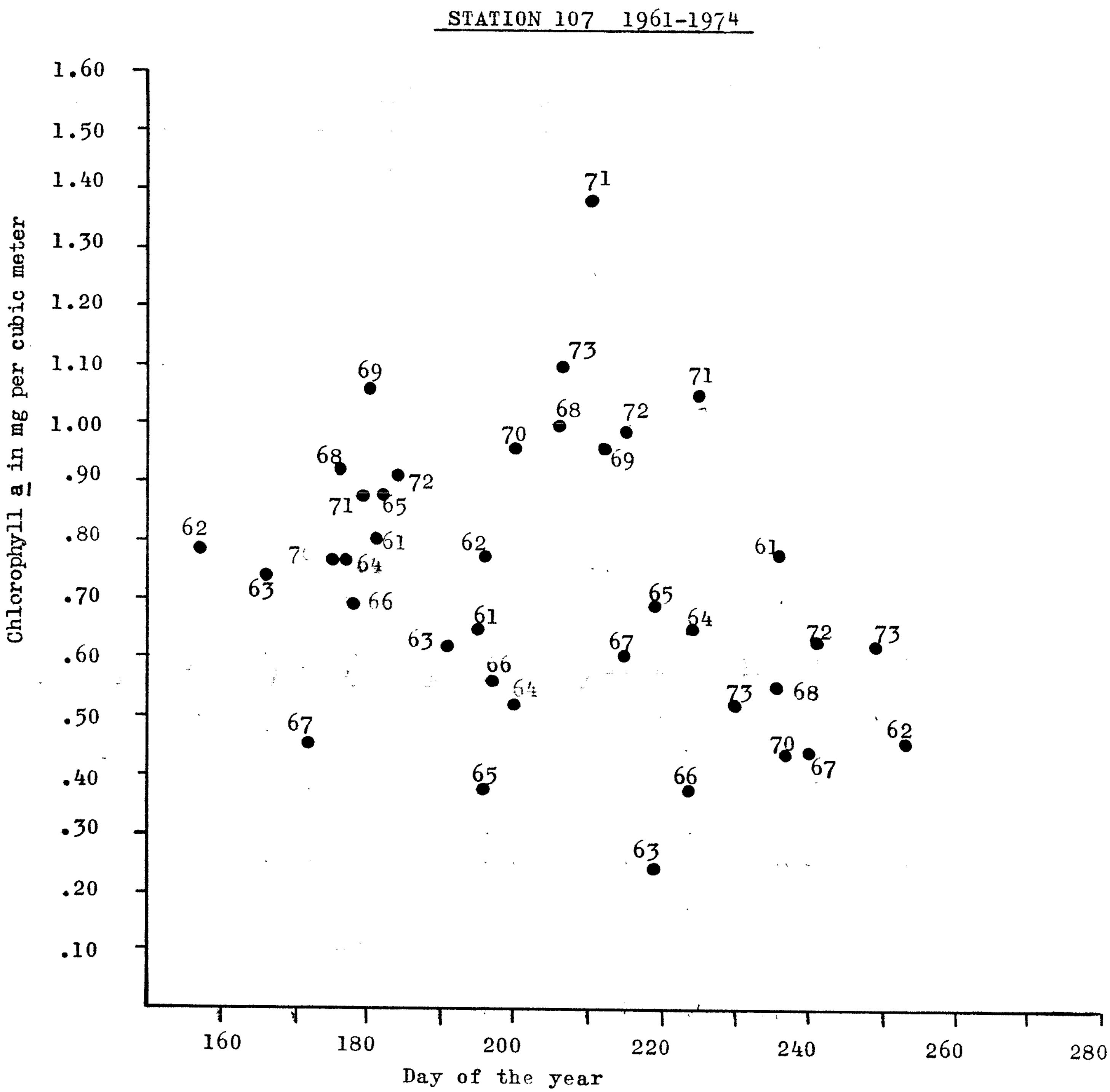

Fig. 11. The mean concentration of chlorophyll a (0-45m) at Station 107, Iliamna Lake, by day of year. Data for the years 1961-1974.

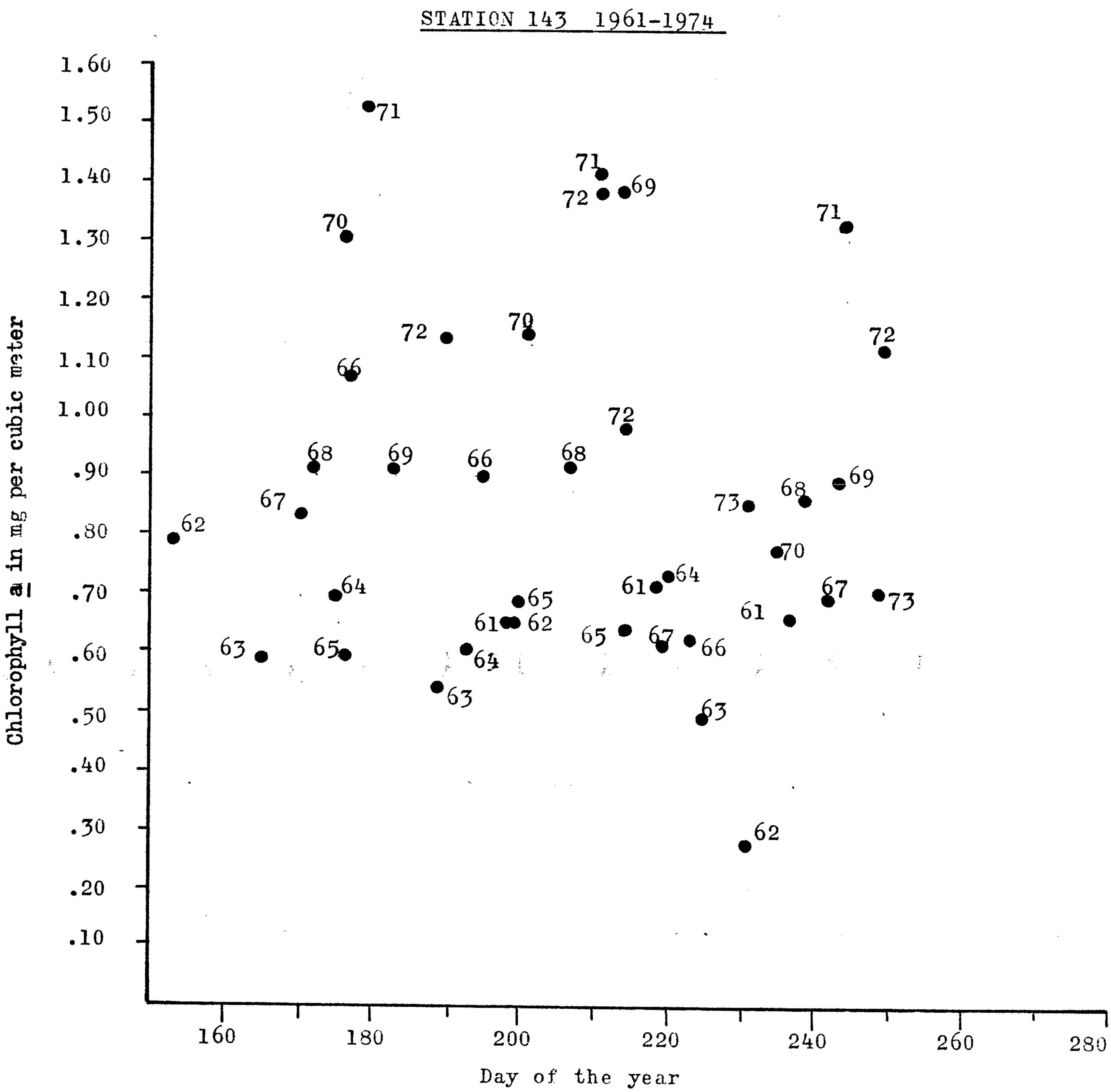

Fig. 12. The mean concentration of chlorophyll a (0-45m) at Station 143, Iliamna Lake, by day of year. Data for the years 1961-1974.

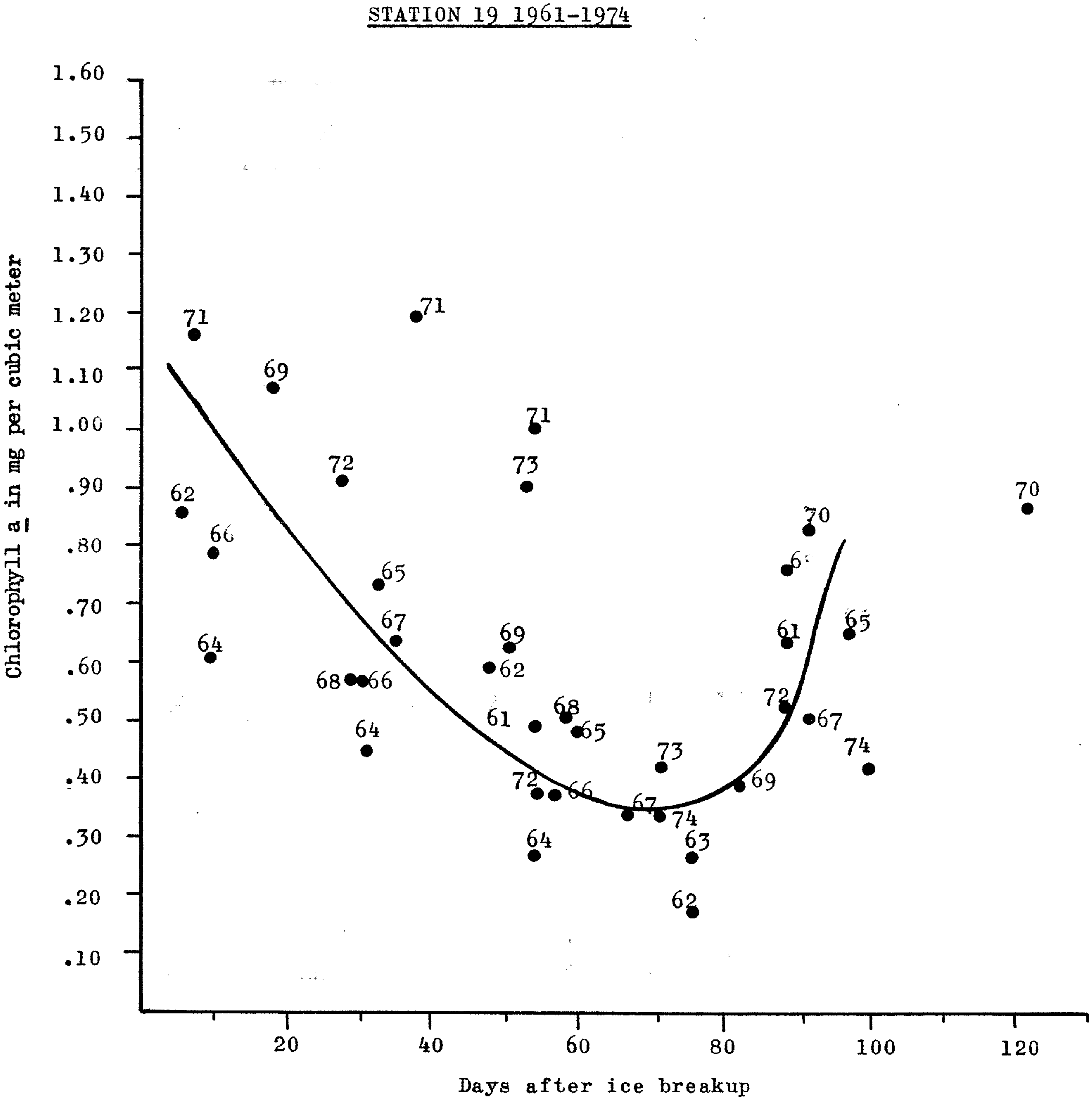

Fig. 13. The mean concentration of chlorophyll a (0-25m) at Station 19, Iliamna Lake, by days after the breakup of lake ice. Data from 1961-1974 (freehand curve).

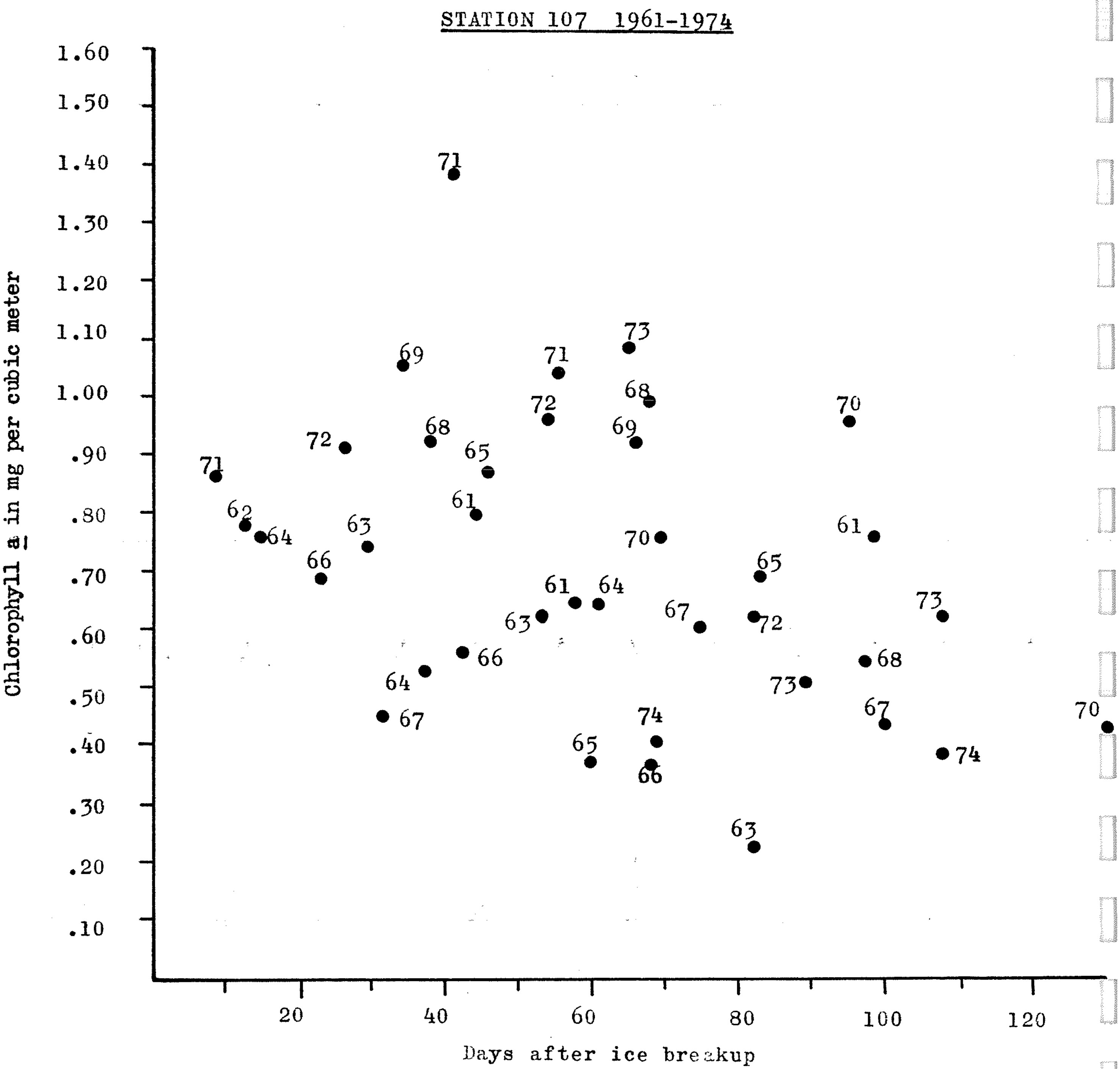

Fig. 14. The mean concentration of chlorophyll a (0-45m) at Station 107, Iliamna Lake, by days after the breakup of lake ice. Data for the years 1961-1974.

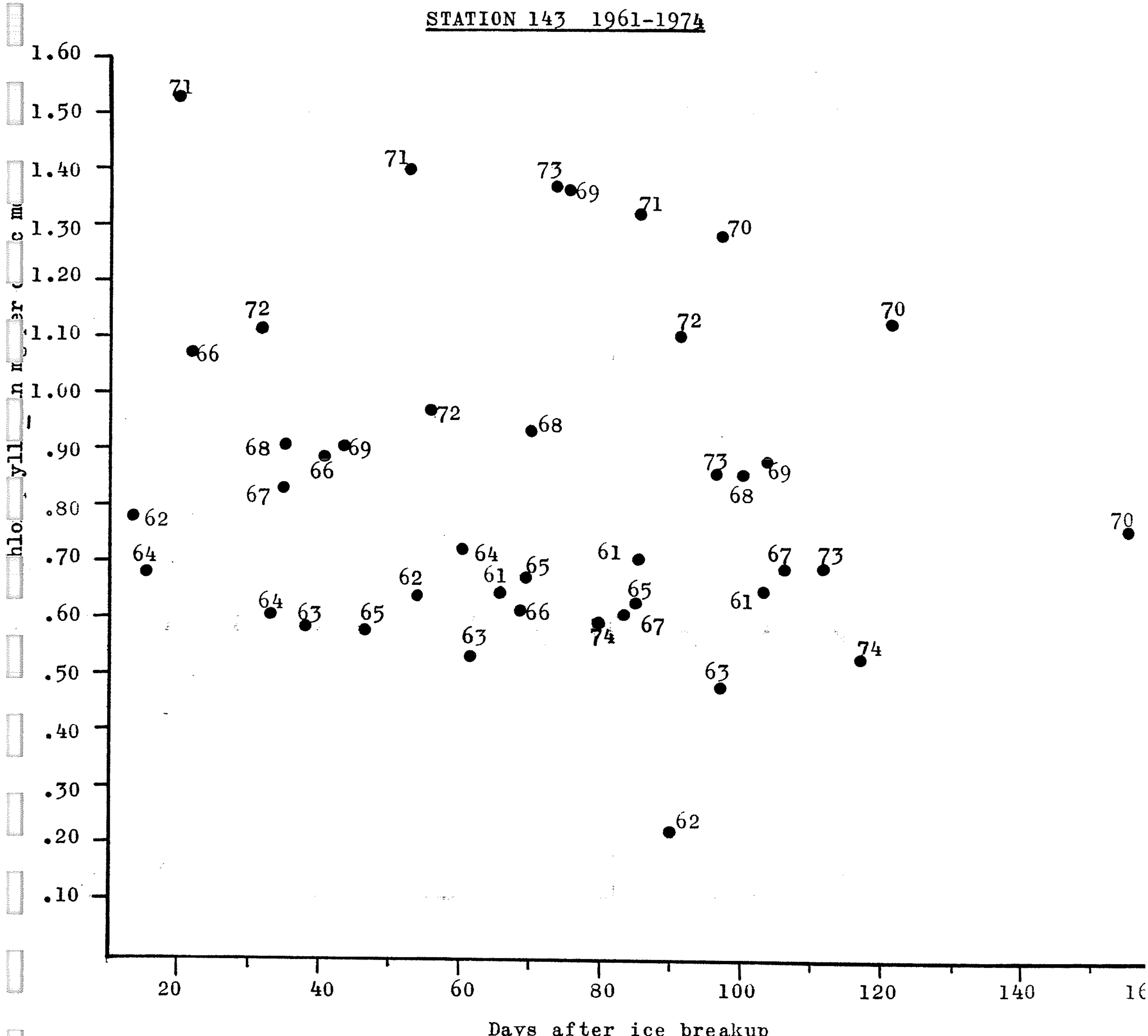

Fig. 15. The mean concentration of chlorophyll a (0-45m) at Station 143, Iliamna Lake, by days after the breakup of lake ice. Data for the years 1961-1974.

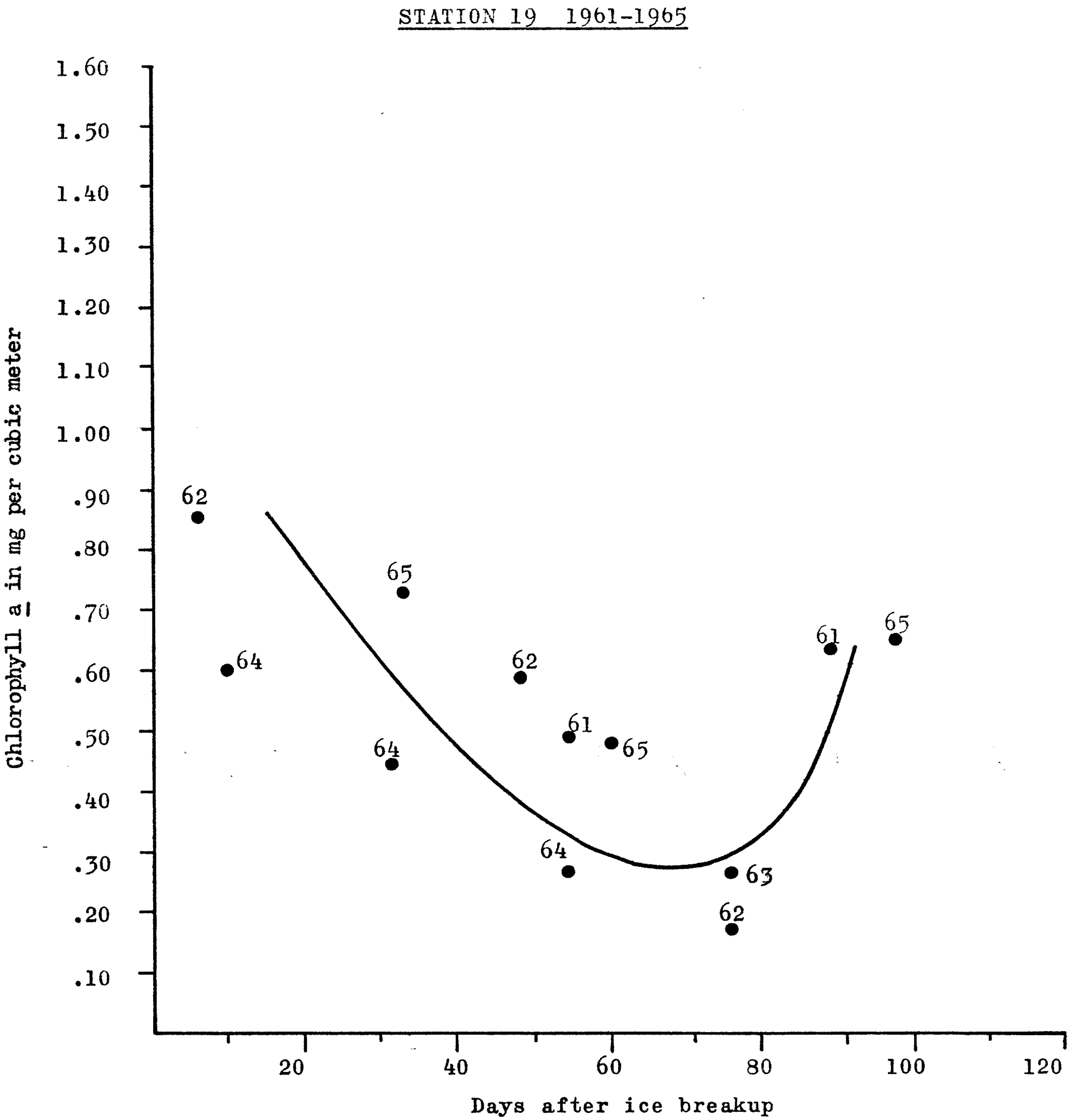

Fig. 16. The mean concentration of chlorophyll a (0-25m) at Station 19, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cyclic period 1961-1965 (freehand curve).

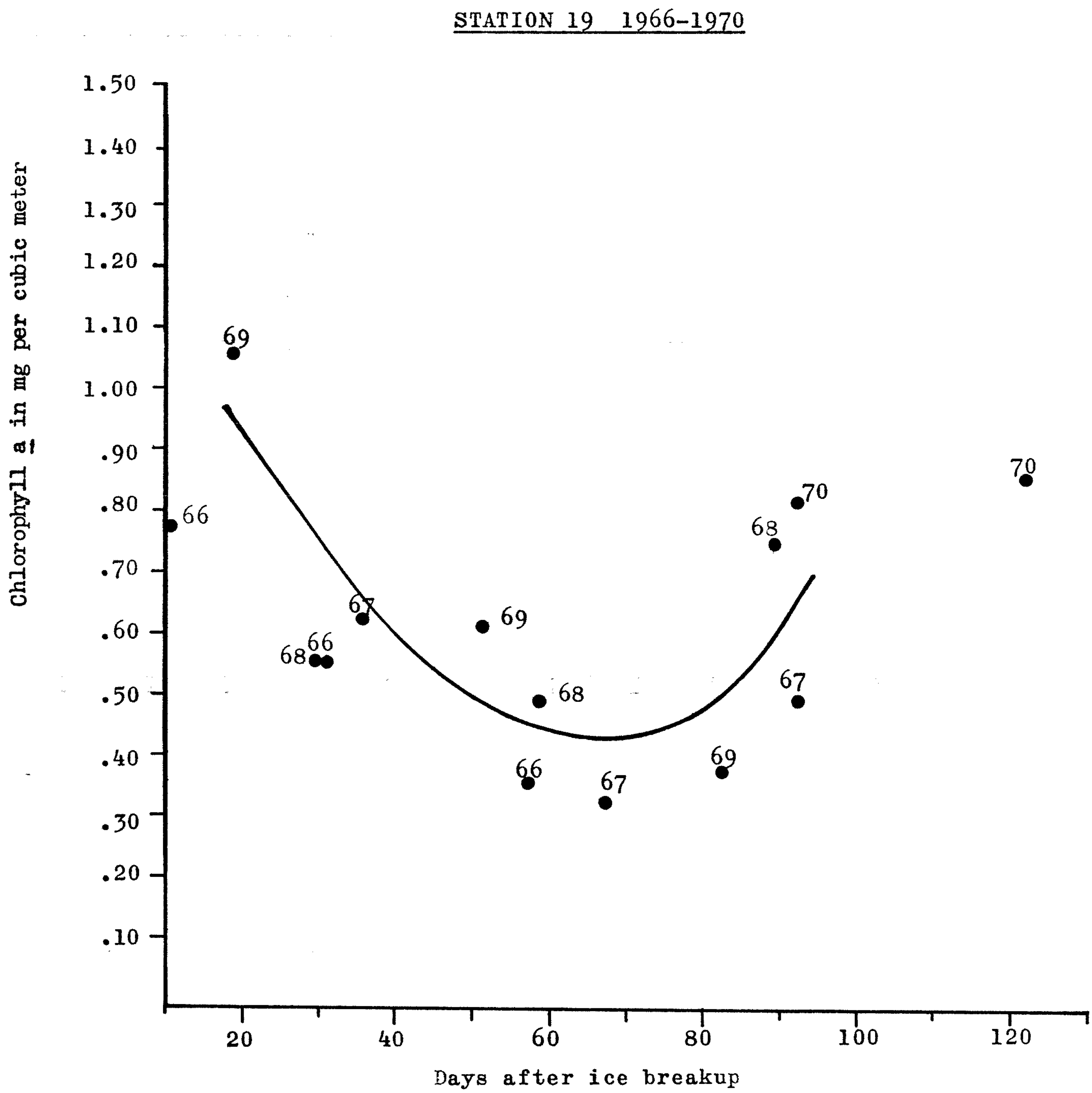

Fig. 17. The mean concentration of chlorophyll a (0-25m) at Station 19, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cycle 1966-1970 (freehand curve).

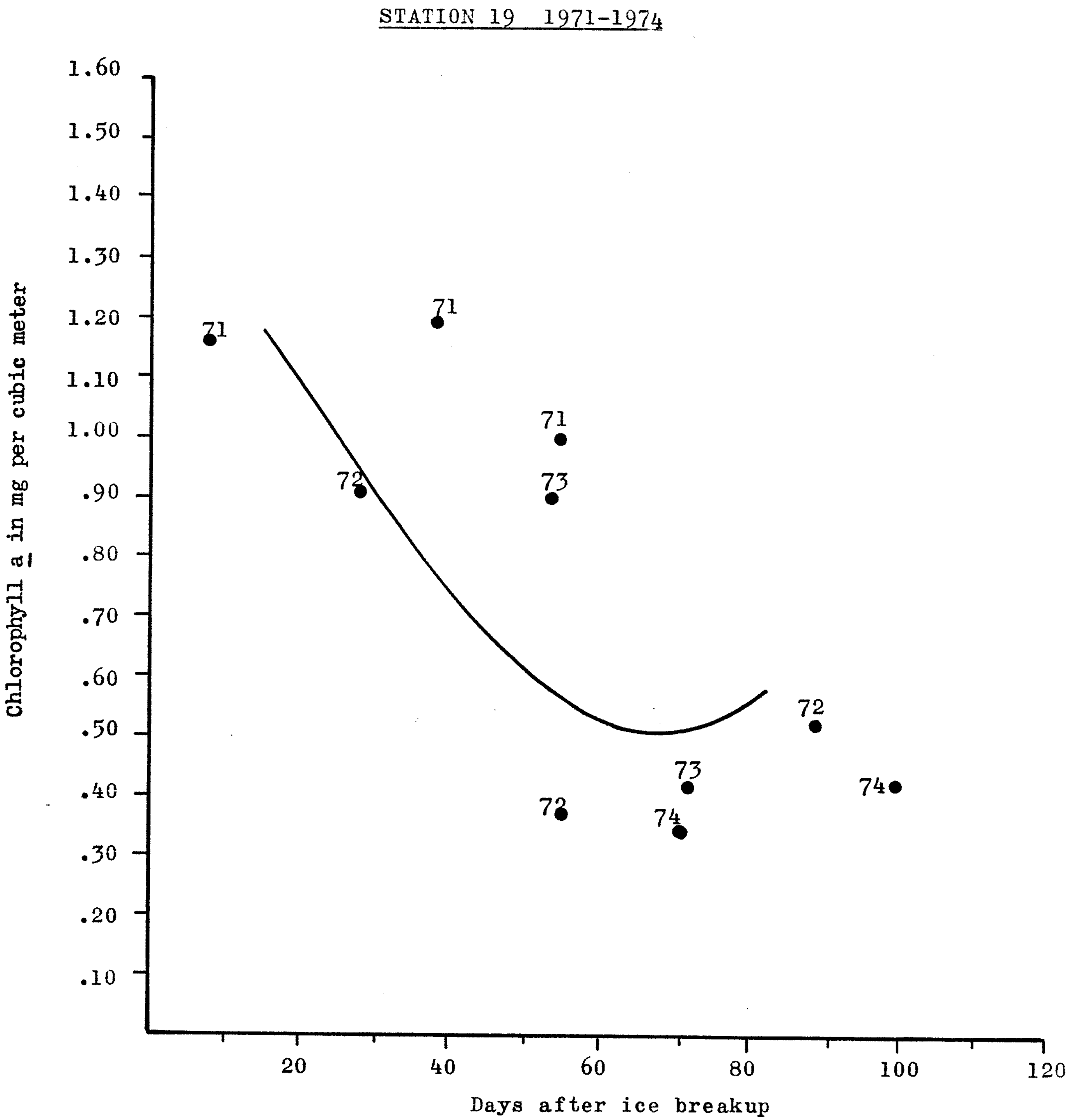

Fig. 18. The mean concentration of chlorophyll a (0-25m) at Station 19, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cycle 1971-1975, samples taken to date (freehand curve).

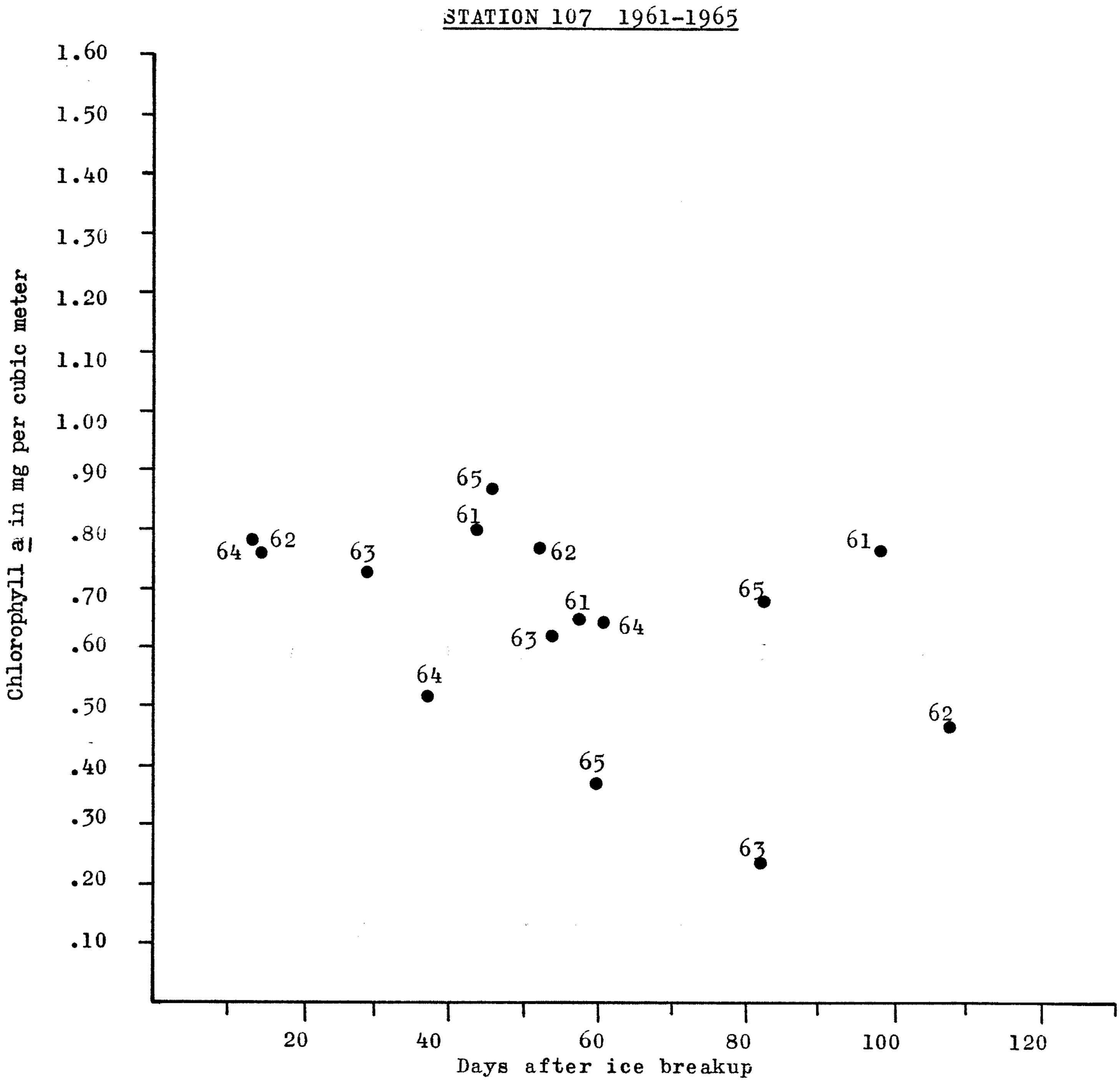

Fig. 19. The mean concentration of chlorophyll a (0-45m) at Station 107, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cycle period 1961-1965.

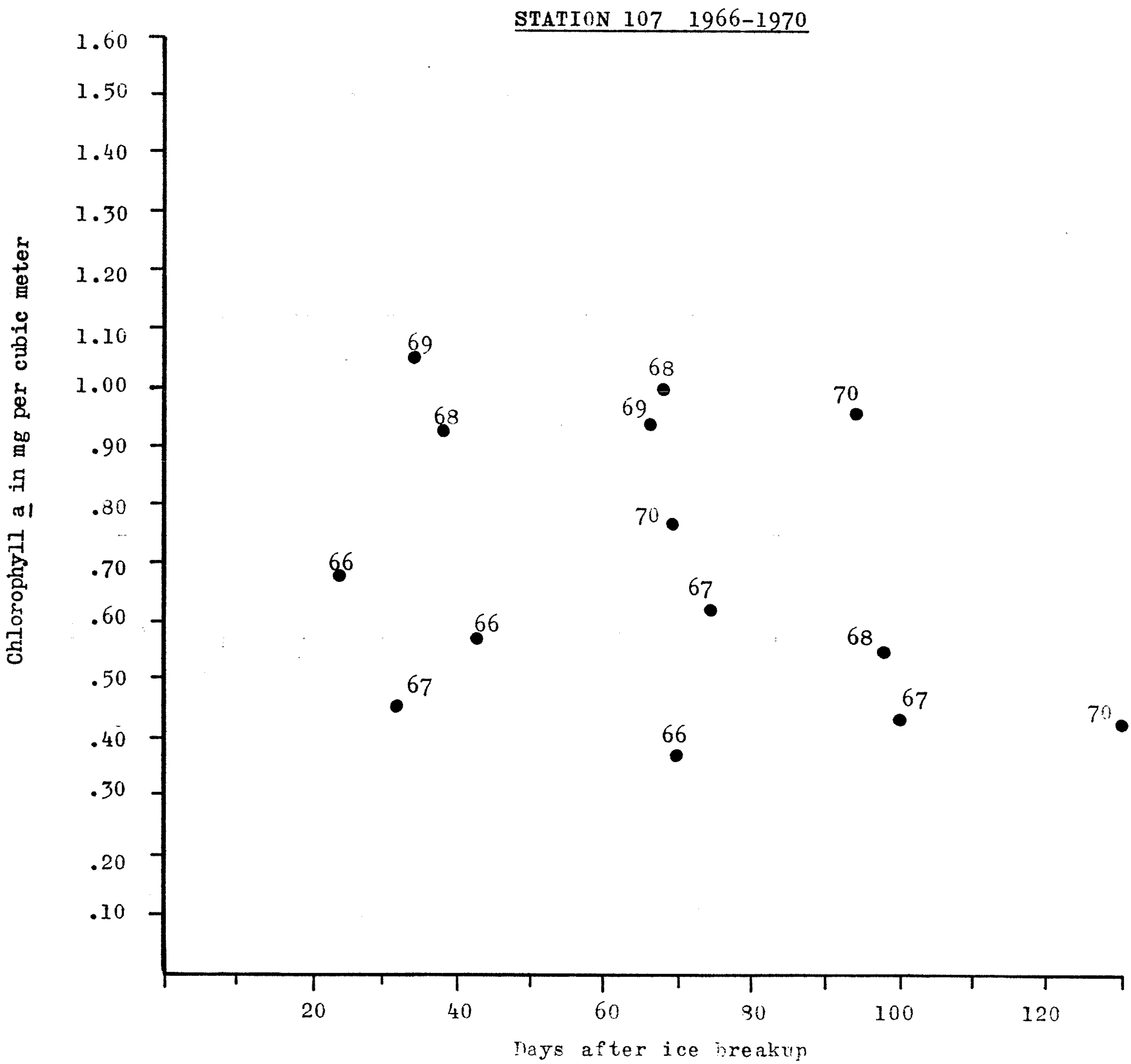

Fig. 20. The mean concentration of chlorophyll a (0-45m) at Station 107, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cycle 1966-1970.

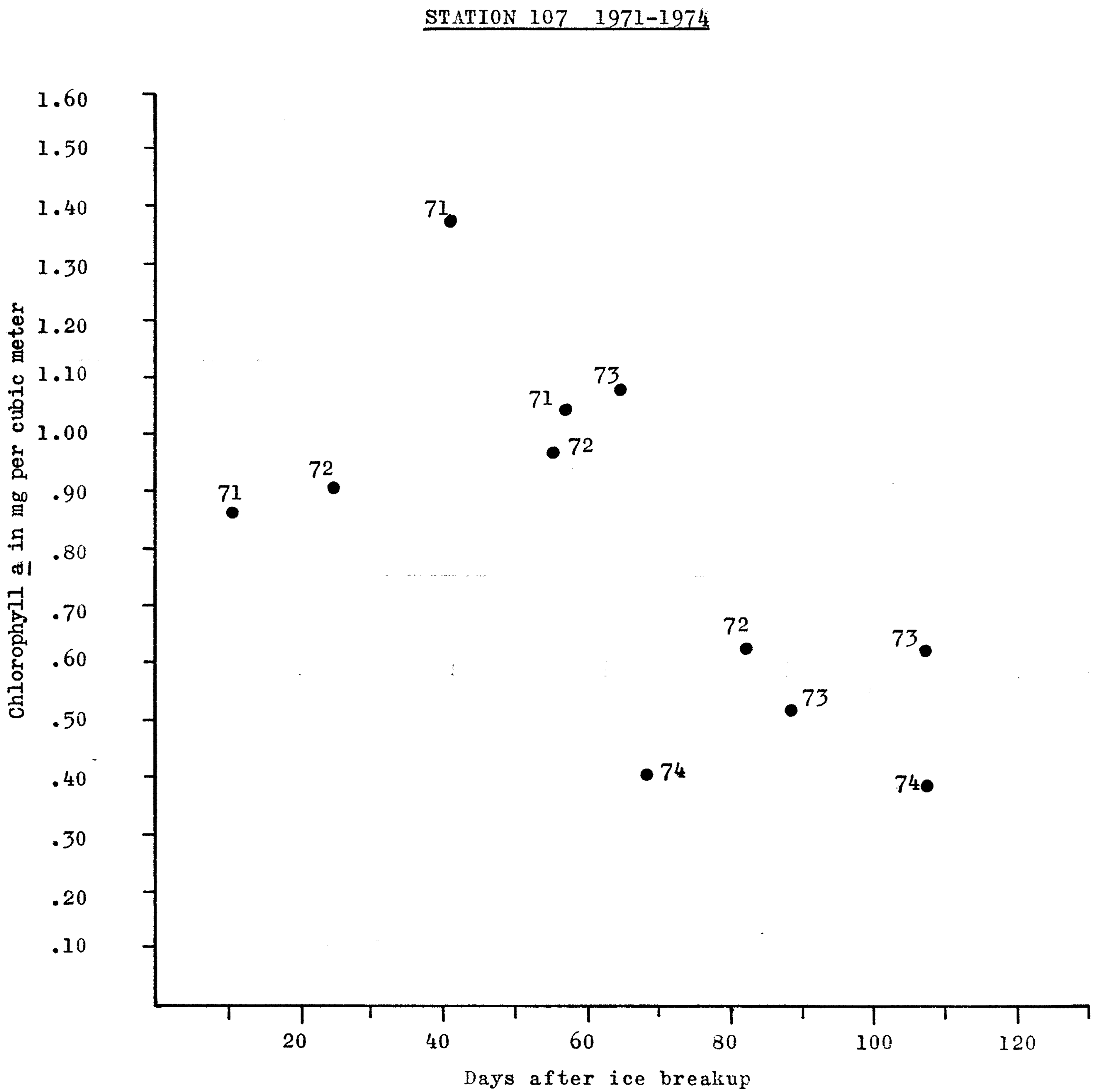

Fig. 21. The mean concentration of chlorophyll a (0-45m) at Station 107, Iliamna Lake, by days after the breakup of lake ice. Data for the years 1971-1974.

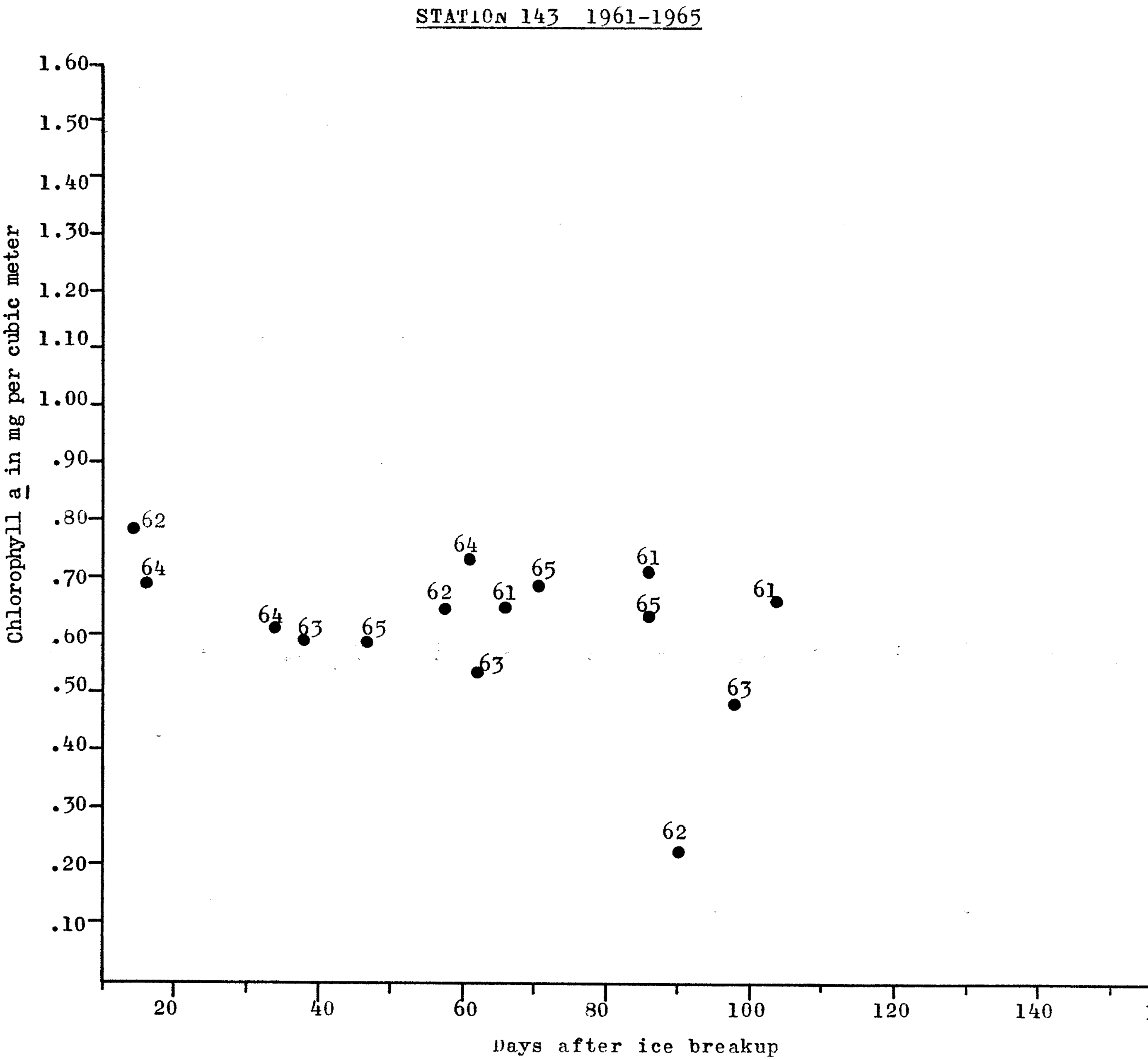

Fig. 22. The mean concentration of chlorophyll a (0-45m) at Station 143, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cyclic period 1961-1965 .

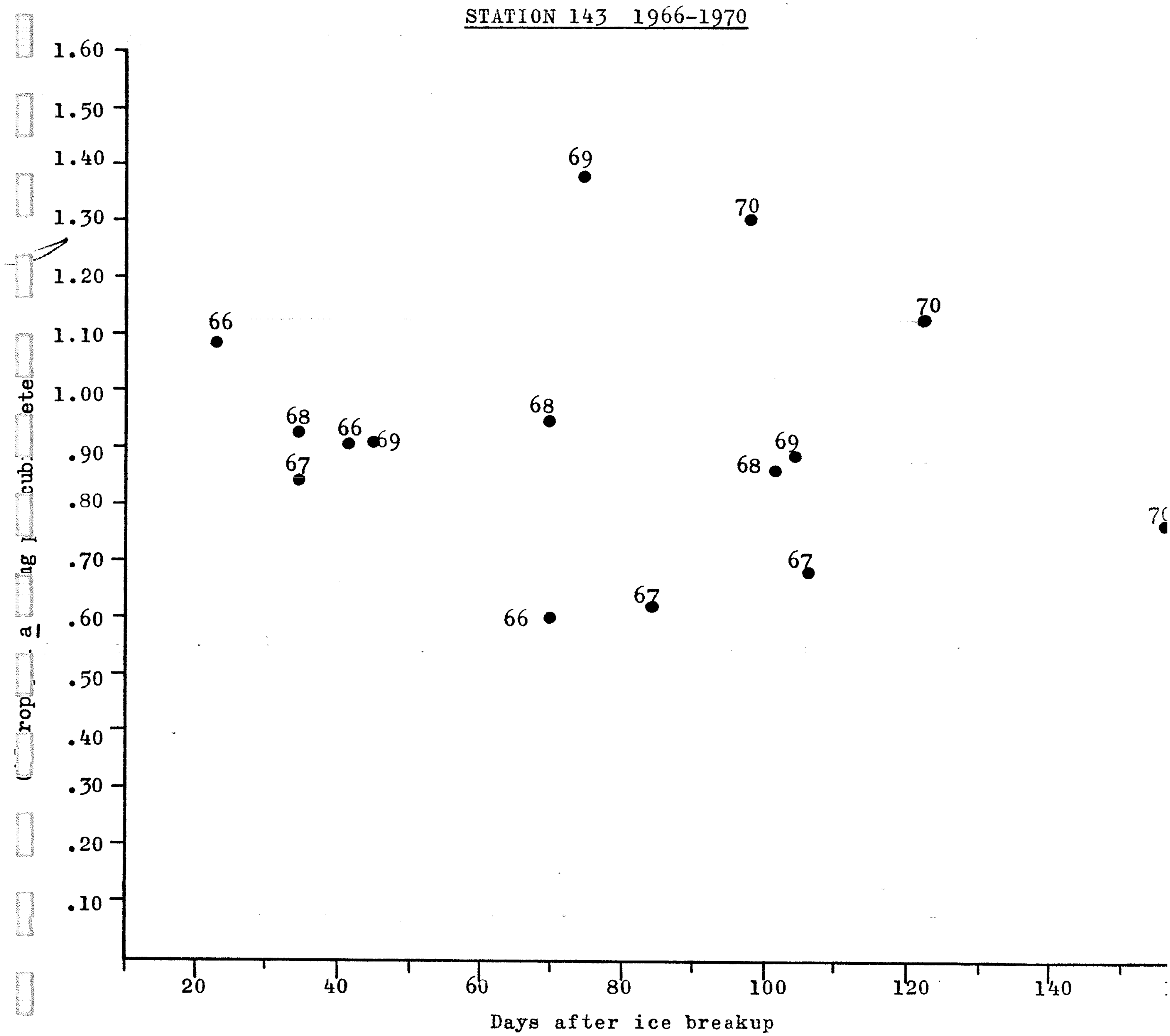

Fig. 23. The mean concentration of chlorophyll a (0-45m) at station 143, Iliamna Lake, by days after the breakup of lake ice. Data for the five-year cycle period 1966-1970.

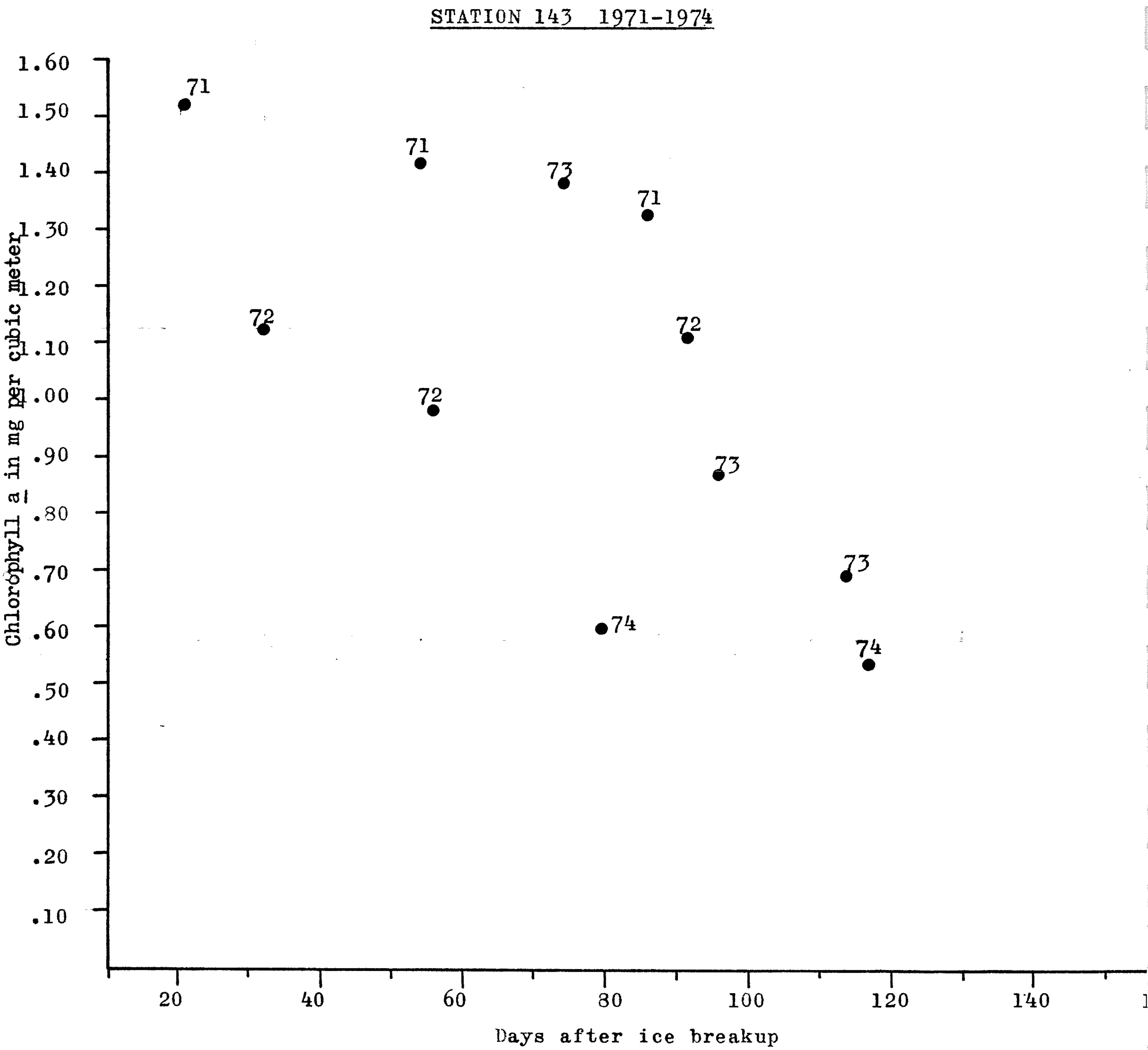

Fig. 24. The mean concentration of chlorophyll a (0-45m) at Station 143, Iliamna Lake, by days after the breakup of lake ice. Data for 1971-1974.

Table 18. Concentrations of chlorophyll a (mg/m^3)[1/] by depth and date of sampling at stations 19, 107, and 143, in Iliamna Lake, 1974

Depth (m)	Station 19		Station 107		Station 143	
	August 3	September 2	July 31	September 8	August 7	September 14
1	0.375	0.51	0.42	0.66	0.645	1.32
2	0.20	0.34	0.25	0.40	0.43	0.77
3	0.20	0.36	0.26	0.48	0.50	0.86
4	0.33	0.45	0.28	0.50	0.36	0.83
5	0.435	0.54	0.39	0.555	0.555	1.17
7	0.85	1.075	0.725	1.3	1.00	2.075
10	1.08	1.12	1.32	2.04	1.96	3.44
15	2.325	3.525	2.40	4.125	3.60	5.85
25	2.80	2.7	4.80	3.50	6.00	4.50
35	*	*	4.20	3.10	7.60	2.50
45	*	*	3.30	1.05	3.70	1.15
Weighted total	0.3438	0.4248	0.40767	0.39556	0.58556	0.54367

[1/] Values represent total chlorophyll a calculated by the method of Parsons and Strickland (1963). Source of data: output from computer program No. FRL 323B (Low, 1973).

[2/] Calculation of mean chlorophyll a concentration at a station:

$$\overline{\text{Chl}}\ a = \frac{(\text{Chl } ai \times Di)}{Di}$$

$\overline{\text{Chl}}\ a$ = mean concentration of Chl a (mg/m^3)

Chl ai = concentration of Chl a in the i^{th} depth stratum

Di = height of i^{th} depth (m) stratum

Di = depth (m) of deepest sample taken.

*Stations do not have these depths.

Weighting factors used for computations of mean chlorophyll a concentrations (mg/m^3) at stations 19, 107, and 143[1/]

Sample depth (i)	Chlorophyll a concentrations	
	Station 19	Stations 107 and 143
	Depth stratum (m)	Depth stratum (m)
1	1.5	1.5
2	1.0	1.0
3	1.0	1.0
4	1.0	1.0
5	1.5	1.5
7	2.5	2.5
10	4.0	4.0
15	7.5	7.5
25	5.0	10.0
35		10.0
45		5.0
Sum	25	45

[1/]Data from Low, 1972.

Weighting factors used for computation of weighted yearly mean concentration of chlorophyll a (mg/m^3), Iliamna Lake, Alaska[1/]

Lake section	Sampling station	Weighting factor	
		Volume (km^3)	% of total volume
A	19	62.4	54.1
B	107	36.3	31.5
C	143	16.6	14.4
	Total	115.3	100.0

[1/]Data from Low, 1972.

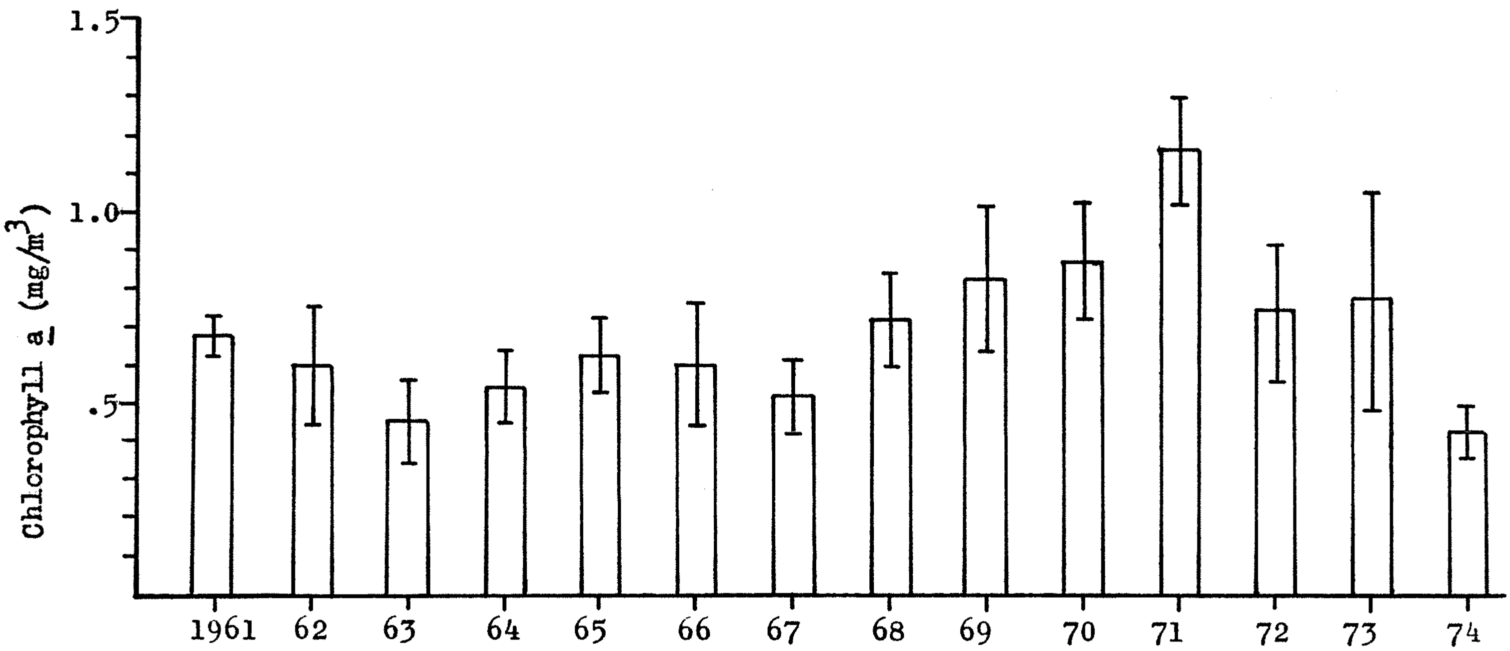

Fig. 25. Mean yearly concentrations of chlorophyll a ±2 standard errors of the mean from 1961 through 1974 for Iliamna Lake based on mean yearly concentrations at stations 19, 107, and 143 weighted by the volume they represent.

SECONDARY PRODUCTION

Secondary production studies in Iliamna Lake have sought to determine the point at which the lake's zooplankton production becomes a limiting factor in the production of juvenile sockeye salmon. Studies of the limnetic zooplankton community of Iliamna Lake were initiated in 1961. Since 1963 zooplankton samples have generally been taken at from 22-30 stations distributed throughout Iliamna Lake. Zooplankton sampling rounds have generally been made in June, July, and August, although sampling has also been conducted during September in some years. Vertical hauls have been systematically taken with a No. 6 mesh-nylon open-conical net having a ½ m diameter mouth opening and a mesh aperature of 223 microns fitted with a flowmeter. Annual and seasonal abundances of the standing crop of the different zooplankters have been determined from this sampling procedure. No strong correlation has yet been found between zooplankton standing crop in Iliamna Lake and the abundance or growth of juvenile sockeye salmon (Mathisen, 1969).

The distribution of the No. 6 net sampling effort during the 1974 field season is shown in Fig. 26. The results of the work are summarized in Table 20. The geometric means for the copepods and the cladocerans from each of the four lake sections, as well as the weighted average for the entire lake are presented. The mean from each section is weighted by the per cent of the total lake volume it represents (Table 21). The annual and seasonal changes in the abundance of total zooplankton, Cyclops scutifer, Bosmina coregoni, the calanoid copepods, Holopedium gibberum, and Daphnia longiremis for the years 1963-1974 are presented in Appendix A. Comparison of the 1974 data to values from past years shows (1) the highest abundance of total zooplankton ever recorded in August, (2) the highest abundance of Cyclops scutifer ever recorded in August, (3) the third highest abundance of Bosmina coregoni from August sampling, (4) the highest abundance of Daphnia longiremis ever recorded from sampling in August, (5) the highest abundance of of Holopedium gibberum ever recorded in August, and (6) the third highest abundance of Calanoid copepods from August sampling. Moreover, 1974's highest standing crop of zooplankton ever observed since studies began in 1961, coincided with the lowest relative abundance of juvenile sockeye salmon and threespine sticklebacks in the nursery lakes of the Kvichak system.

The seasonal abundance of zooplankton was examined at stations 19 and 149 for the years 1963-1974. These two stations were chosen to represent distinct physical regions in Iliamna Lake where the extreme differences in abiotic and biotic factors affecting the production of zooplankton would most likely be found. Station 19 has a mean depth of 27 m and station 149 has a mean depth of 144 m. Thermal conditions, current regimes, and fish-zooplankton communities are also considerably different between these two stations.

The abundances of Cyclops scutifer, Bosmina coregoni, and total herbivors were plotted in relation to the number of days after the breakup of lake ice for stations 19 and 149 (Figs. 27-32). Summary data from the No. 6 net sampling at stations 19 and 149 since 1963 are given in Tables 22 and 23. The abundance of Cyclops scutifer at stations 19 and 149 shows a trend of increasing during the early summer reaching a peak approximately 60 days after the estimated date of ice breakup. The abundance of herbivorous zooplankton at station 19 increases exponentially throughout the sampling period. At station 149, except for the year 1974, the abundance of herbivorous zooplankton doesn't begin to increase significantly until approximately 70 days after ice break-

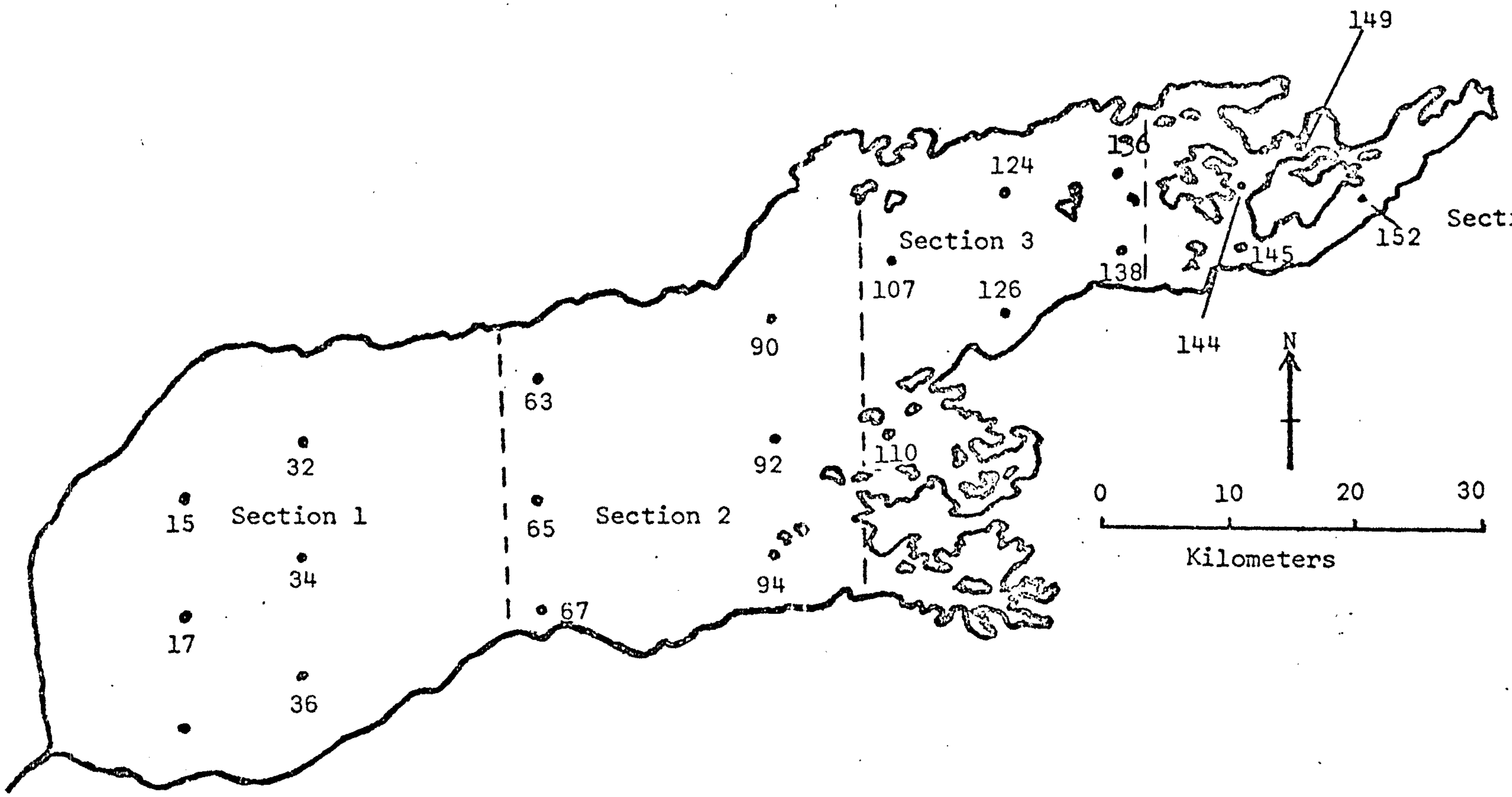

Fig. 26, Map of Iliamna Lake, showing the four limnological lake sections and the distribution of the 22 zooplankton stations sampled in 1974.

Table 20. Composition and distribution of the major species of zooplankton (geometric mean in number/m^3), Iliamna Lake, 1974

				Geometric Mean					
				Copepoda		Cladocera			
Lake section	Sample period	Number of stations sampled	Date of sampling	Calanoid	Cyclops	Bosmina	Daphnia	Holopedium	Total zoo-plankton
I	3	6	8/02,03	1,148	6,489	4,215	1,354	1,248	16,447
II	3	6	8/01,02,09	1,168	5,173	5,789	1,645	1,967	17,722
III	3	6	7/30,8/01,08,09	768	5,368	3,469	879	978	12,749
IV	3	4	7/30,8/07,08	677	5,740	1,896	936	410	10,741
Weighted[1/] geometric mean (August round)				968	5,710	4,044	1,219	1,223	14,808
Percent of weighted geometric mean total zooplankton				6.5	38.56	27.31	8.2	8.3	
I	4	4	9/02,03	1,016	3,380	4,135	1,172	128	11,703
II	4	6	9/03,05,06	952	2,679	3,403	1,181	41	9,496
III	4	6	9/05,08,13	803	3,034	3,263	548	32	9,145
IV	4	3	9/09,12	508	2,960	2,040	440	14	6,727
Weighted geometric mean (September round)				862	3,176	3,387	877	61	9,660
Percent of weighted geometric mean total zooplankton				8.9	32.88	35.06	9.1	.6	

1/ Section values weighted by the percentage of the total lake volume they represent.

Table 21. Volumes of water in the four sections of Iliamna Lake in cubic kilometers and as percentage of total lake volume

Section	Volume (km^3)[1]	Percentage of total volume of section
1	34.733	30.12
2	28.505	24.72
3	35.747	31.00
4	16.325	14.16
TOTAL	115.310	100.00

[1]Data from Anderson, 1969.

STATION 19 - CYCLOPS

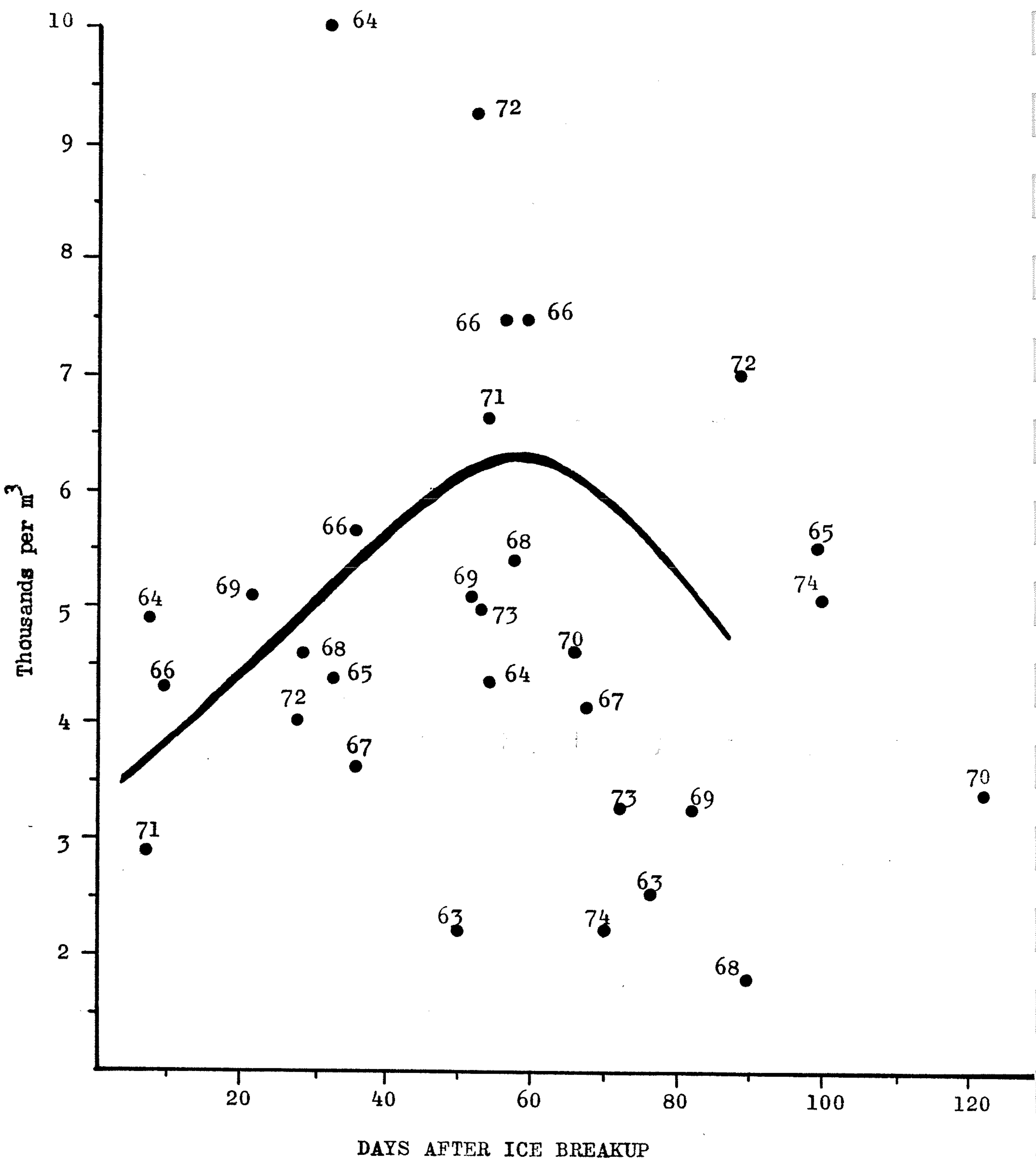

Fig. 27. Abundance of Cyclops scutifer Sars, Iliamna Lake , station 19, as a function of days after lake ice breakup, 1963-1974 (Freehand curve).

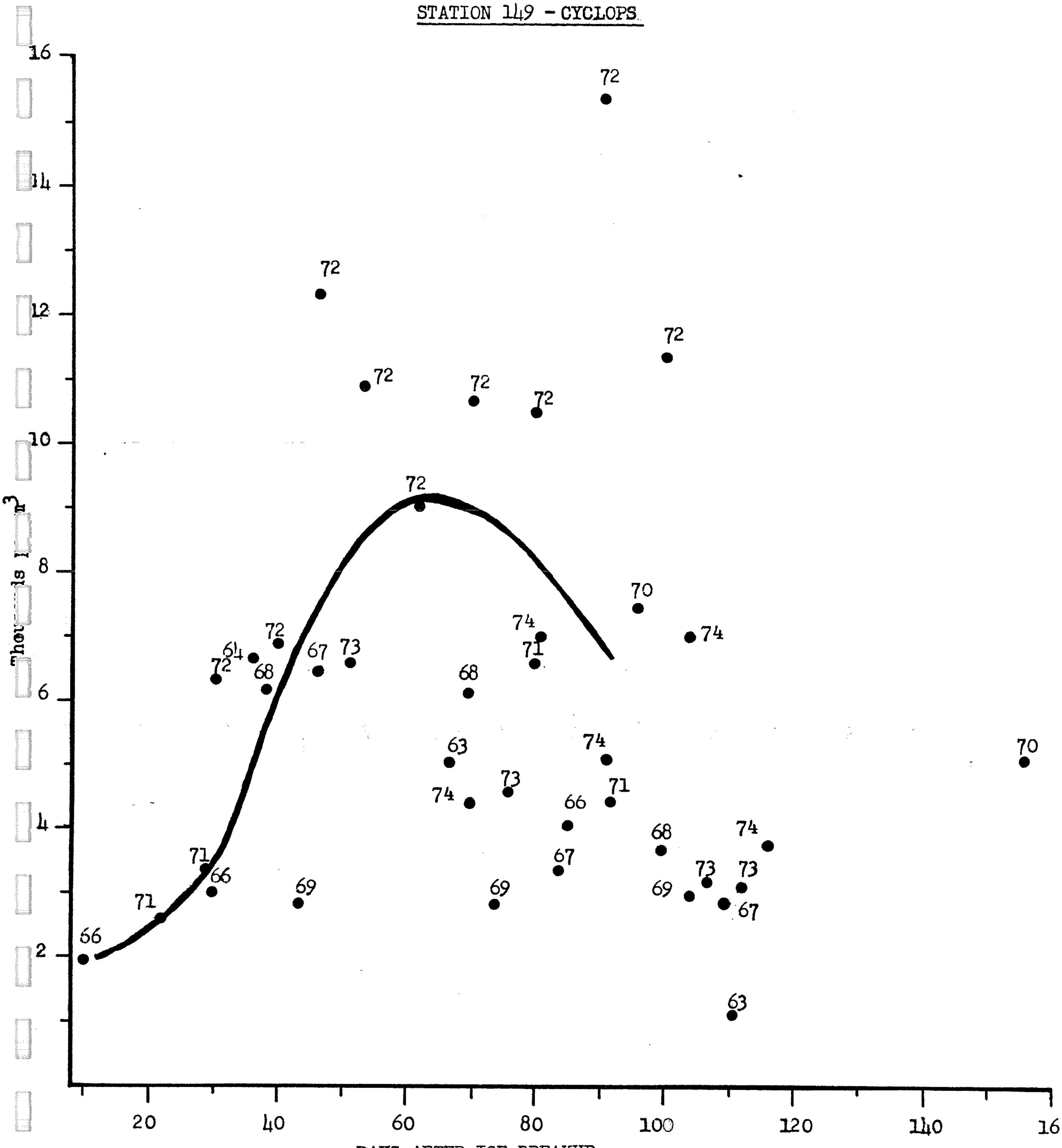

Fig. 28. Abundance of Cyclops scutifer Sars from No. 6 net sampling at station 149, Iliamna Lake, as a function of days after lake ice breakup, 1963-1974 (freehand curve).

STATION 19 - HERBIVORS

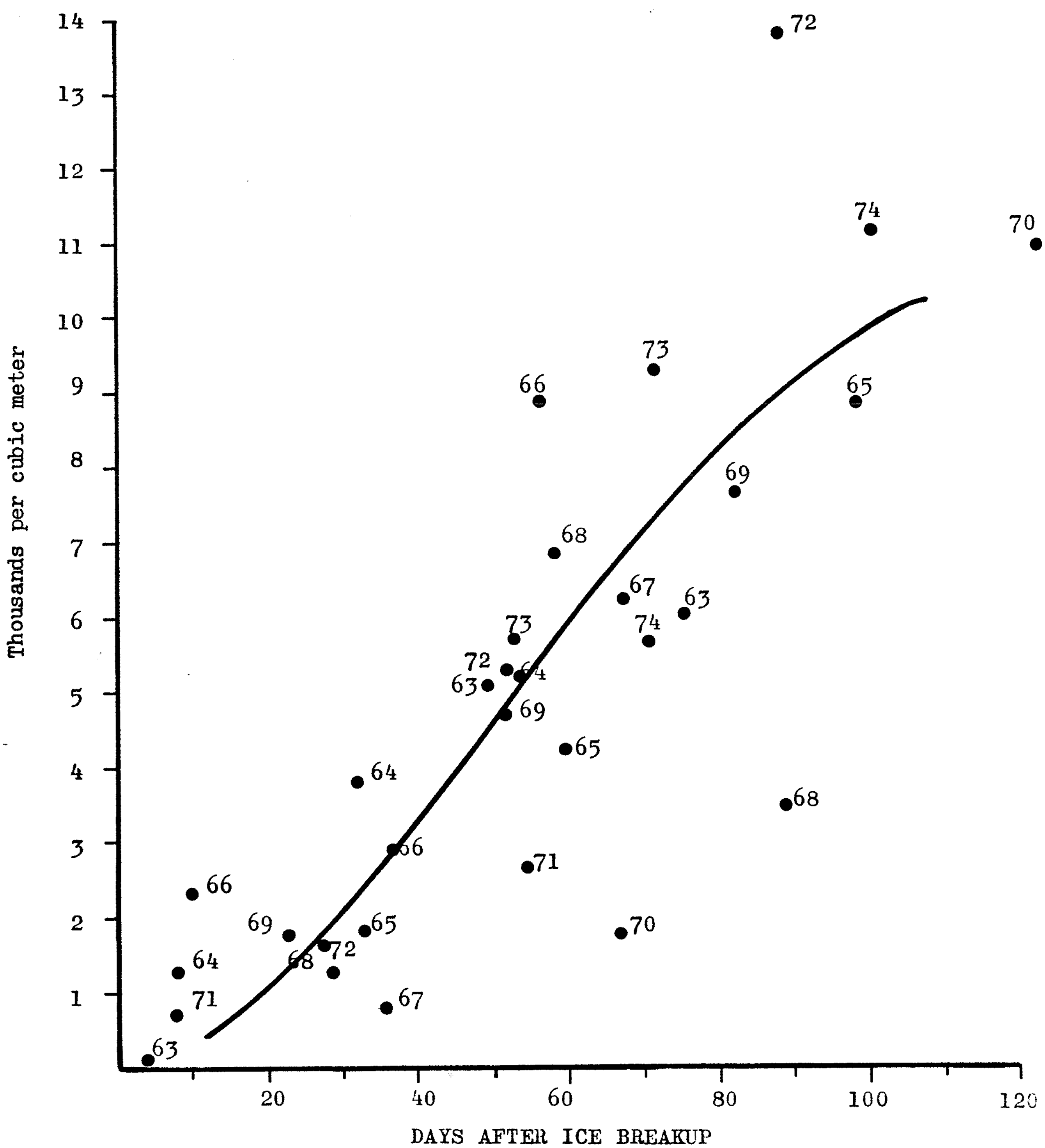

Fig. 29. Abundance of herbivorous zooplankton from No. 6 net sampling at station 19, Iliamna Lake, as a function of days after the breakup of lake ice, 1963-1974 (freehand curve).

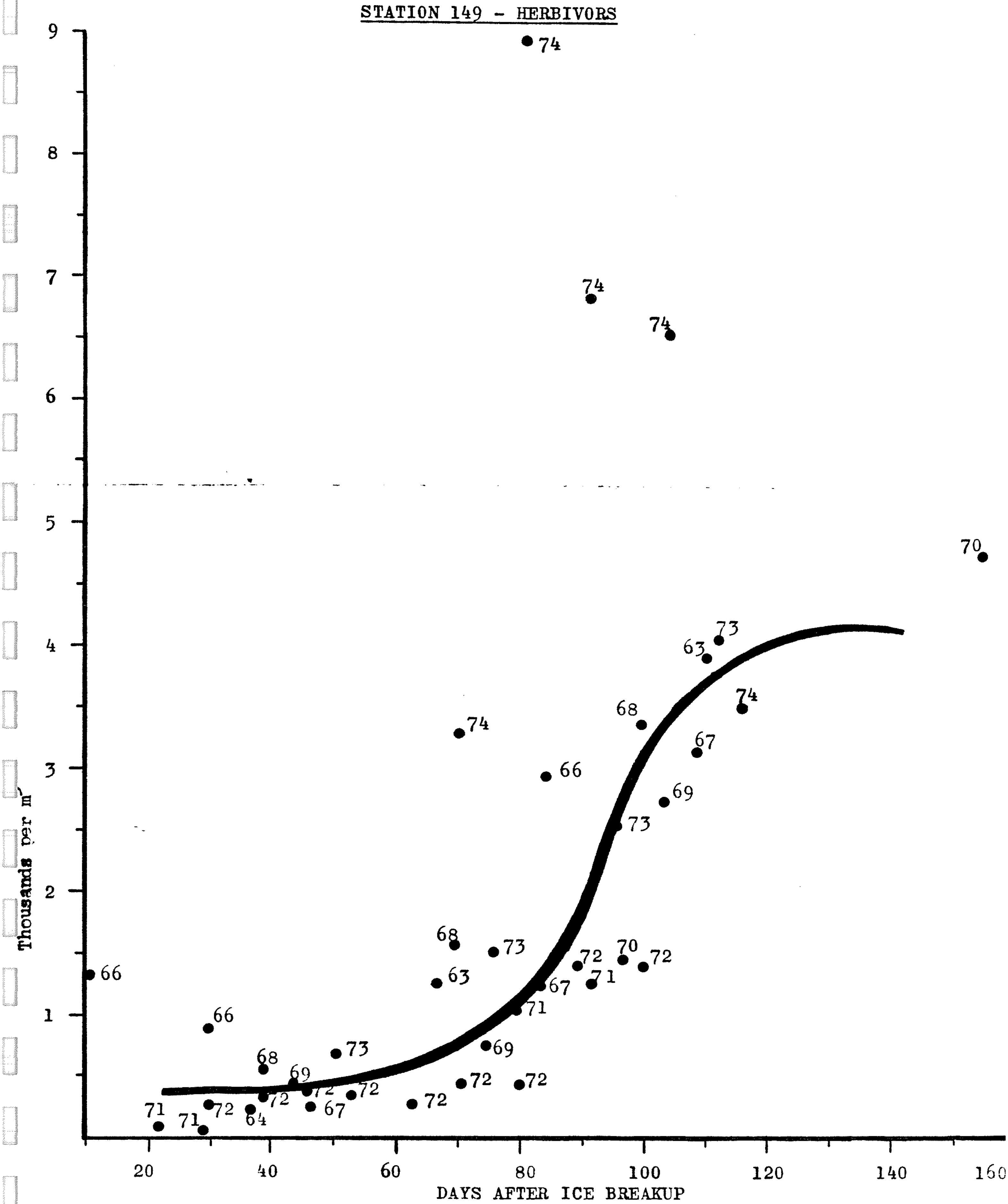

Fig. 30. Abundance of herbivorous zooplankton from No. 6 net sampling at station 149, Iliamna Lake, as a function of days after the breakup of lake ice, 1963-1974 (freehand curve).

STATION 19 - BOSMINA

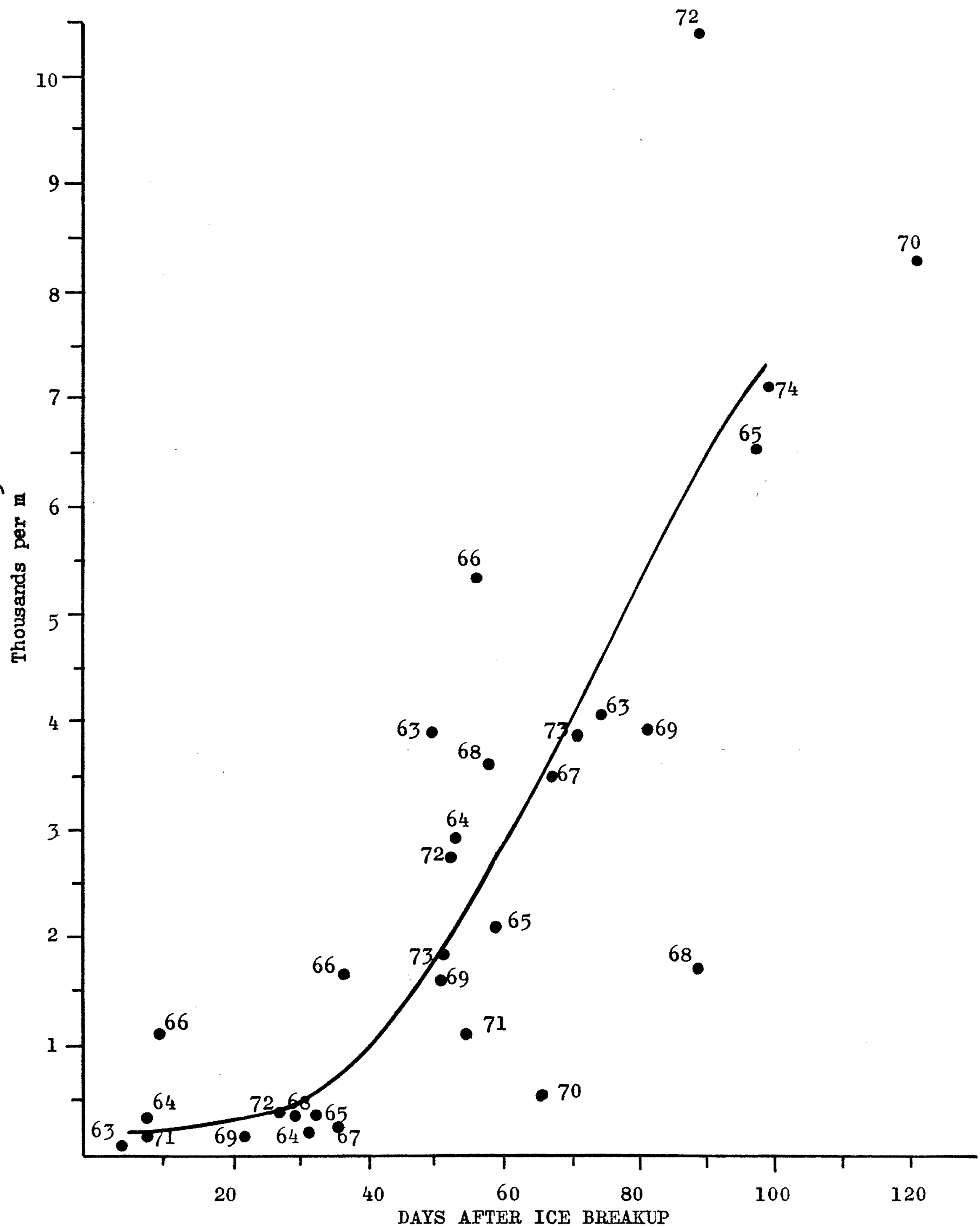

Fig. 31. Abundance of Bosmina coregoni Baird from No. 6 net sampling at station 19, Iliamna Lake, referenced to the number of days after the breakup of lake ice, 1963-1974 (freehand curve).

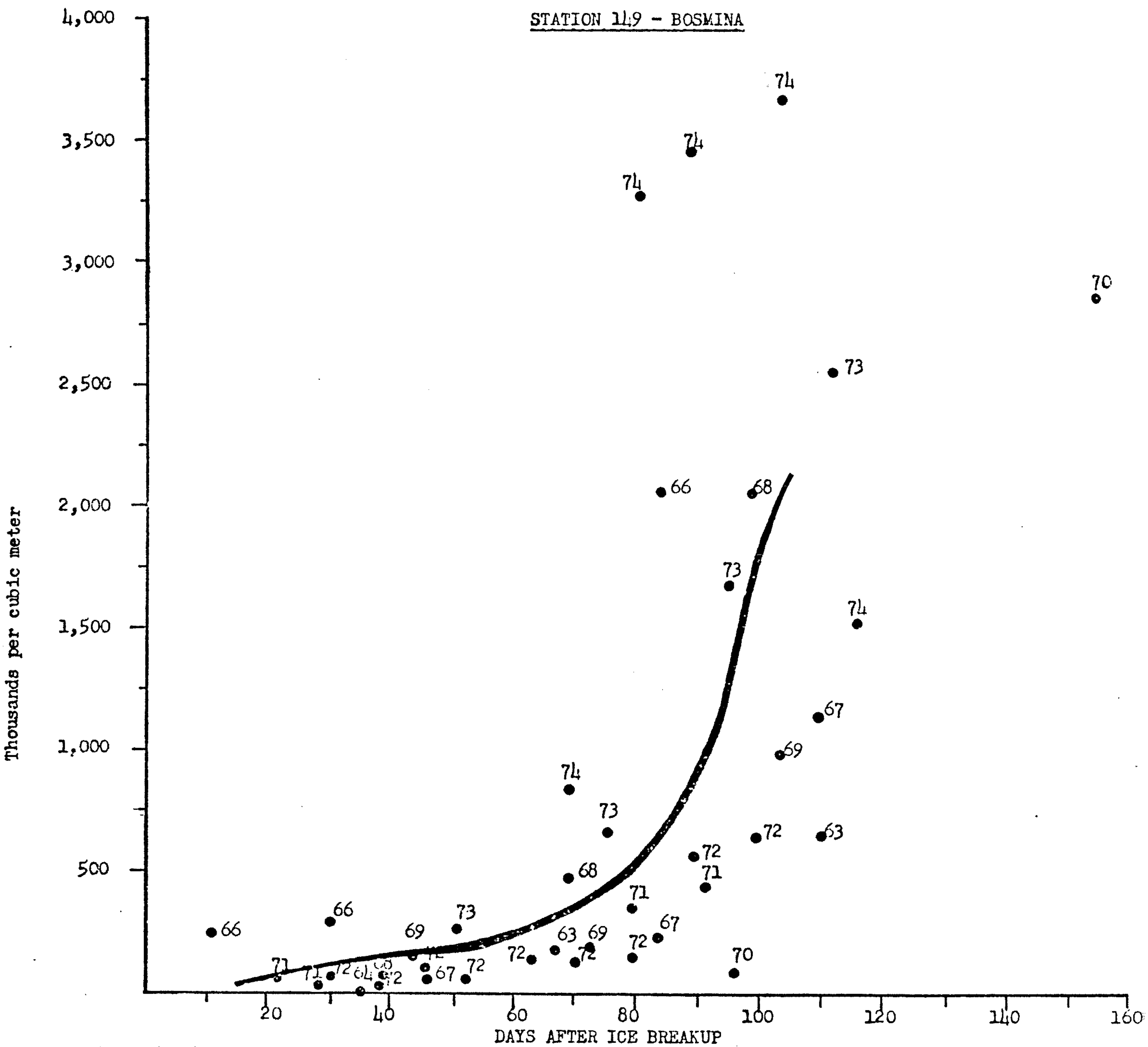

Fig. 32. Abundance of Bosmina coregoni Baird from No. 6 net sampling at station 149, Iliamna Lake, as a function of days after ice breakup, 1963-1974 (freehand curve).

Table 22. Abundance of *Cyclops scutifer* Sars, *Bosmina coregoni* Baird, total herbivors, and total zooplankton by sampling dates in relation to the breakup of lake ice, No. 6 net sampling, Station 19, Iliamna Lake, 1963-1974

Date of sampling			Cyclops scutifer	Bosmina coregoni	Total all herbivorous zooplankton	Total all zooplankton
Calendar	Day of year	Days from ice breakup				
			1963			
6/05	157	4	296	17	115	411
7/20	202	49	1,225	3,815	5,174	6,399
8/16	229	76	1,503	4,131	6,143	7,646
			1964			
6/29	181	8	3,964	288	1,334	5,298
7/23	205	32	10,398	225	3,828	14,226
8/14	227	54	3,354	2,946	5,255	8,609
			1965			
6/24	176	33	3,313	285	1,826	5,139
7/21	203	60	6,518	2,171	4,258	10,776
8/29	242	99	4,510	6,576	8,863	13,373
			1966			
6/28	180	10	3,335	1,167	2,368	5,703
7/25	207	37	4,801	1,688	2,951	7,752
8/14	227	57	6,527	5,345	8,939	15,466
			1967			
6/26	178	36	2,571	241	809	3,380
7/28	210	68	3,157	3,492	6,303	9,460
			1968			
6/21	173	29	3,648	294	1,351	4,999
7/21	203	60	4,467	3,628	6,876	11,343
8/20	233	91	739	1,679	3,553	4,292
			1969			
6/23	175	23	4,181	155	1,789	5,970
7/22	204	52	4,059	1,614	4,765	8,824
8/22	235	83	2,240	3,947	7,681	9,921
			1970			
6/21	173	67	3,632	516	1,778	5,410
8/16	229	123	2,305	8,244	10,995	13,300
			1971			
6/25	177	8	1,872	107	792	2,664
8/11	224	55	5,633	1,157	2,730	8,363
			1972			
7/09	191	28	2,939	319	1,656	4,595
8/03	216	53	8,283	2,726	5,269	13,552
9/08	252	89	5,983	10,377	13,779	19,762
			1973			
7/28	210	53	4,081	1,822	5,776	9,857
8/16	229	72	2,221	3,870	9,129	11,350
			1974			
8/03	216	70	2,236	2,579	5,706	7,942
9/02	246	100	4,944	7,044	11,259	16,204

Table 23. Abundance of Cyclops scutifer Sars, Bosmina coregoni Baird, total herbivors, and total zooplankton by sampling dates in relation to the breakup of lake ice, No. 6 net sampling, Station 149, Iliamna Lake, 1963-1974

Date of sampling			Cyclops scutifer	Bosmina coregoni	Total herbivorous zooplankton	Total zooplankton
Calendar	Day of year	Days from ice breakup				
			1963			
7/12	194	67	5,143	179	1,248	6,391
8/25	238	111	1,209	655	3,899	5,108
			1964			
7/14	196	37	6,761	0	232	6,993
			1966			
6/13	165	11	2,082	223	1,313	3,395
7/02	184	30	3,069	231	867	3,936
8/26	239	85	4,128	2,052	2,947	7,075
			1967			
6/30	182	47	6,493	48	253	6,746
8/06	219	84	3,548	203	1,234	4,782
8/31	244	109	2,902	1,234	3,225	6,127
			1968			
6/25	177	39	6,226	82	574	6,800
7/26	208	70	6,216	494	1,565	7,781
8/25	238	100	3,827	2,089	3,367	7,194
			1969			
7/01	183	44	2,863	65	424	3,287
8/01	214	75	2,879	194	767	3,646
8/30	243	104	3,078	997	2,745	5,823
			1970			
6/24	176	97	7,577	90	1,491	9,068
8/22	235	156	4,812	2,848	4,725	9,537
			1971			
6/23	180	22	2,730	50	96	2,826
7/05	187	29	3,550	26	56	3,606
8/25	238	80	6,755	344	1,031	7,786
9/06	250	92	4,512	422	1,276	5,783
			1972			
7/05	187	30	6,435	96	266	6,701
7/14	196	39	6,837	31	305	7,142
7/21	203	46	12,396	98	391	12,787
7/28	210	53	10,930	59	339	11,269
8/07	220	63	9,090	105	289	9,379
8/15	228	71	10,833	128	457	11,290
8/24	237	80	10,567	141	435	11,002
9/03	247	90	15,779	580	1,419	17,198
9/13	257	100	11,531	611	1,396	12,927
			1973			
7/05	187	51	6,643	254	680	7,323
7/30	212	76	4,717	663	1,513	6,230
8/19	232	96	2,979	1,672	2,501	5,480
9/05	249	113	2,959	2,555	4,169	7,128
			1974			
7/27	209	69	4,398	851	3,302	7,700
8/08	221	81	6,994	3,279	8,952	15,946
8/18	231	91	5,117	3,469	6,869	11,986
8/31	244	104	7,013	3,695	6,587	13,600
9/12	256	116	3,763	1,482	3,503	7,266

up and then increases exponentially until the end of the sampling period. The abundance of Bosmina coregoni at station 19 begins to increase about 40 days after ice breakup and continues to increase rapidly up through the end of the sampling period. At station 149, except for the year 1974, the abundance of Bosmina coregoni remains low until approximately 70 days after the breakup of lake ice and then slowly increases up through the end of the sampling period. The annual and seasonal abundances of the calanoid copepods and cladocerans are consistently much higher at station 19 than at station 149.

Additional information concerning the seasonal abundances of the different zooplankters at station 149 for the years when sampling was more extensive are compared to 1974 in Figs. 33-36.

The relationship between standing crop of zooplankton and changes in the relative biomass of the major planktivorous fish species in Pedro Bay during the period 1962-1974 is plotted in Fig. 37. Since no strong correlation is indicated, it can be suspected that the present methods of monitoring the food supply of juvenile sockeye salmon are not sensitive enough to representatively measure the effects that differing levels of fish predation have on the zooplankton community.

The species composition of the present Iliamna Lake zooplankton community has long ago stabilized itself following years of size specific predation by planktivorous fish species. Intraspecific selection of available zooplankton species and size selection intraspecies predation on species of the Iliamna Lake zooplankton community has only been partially documented from past studies (Hoag, 1968, Carlson, 1974, and Rogers, 1961). Carlson (1974) found that juvenile sockeye salmon selectively feed on the larger instars of Bosmina coregoni. Eggers (1975), through further analysis of data collected by Hoag (1968), found strong indications that sockeye salmon fry selectively feed on Bosmina coregoni, while sockeye salmon yearlings selectively feed on Cyclops scutifer.

The extent to which zooplankton species in Iliamna Lake are subjected to selective predation and the manner in which the age groups are temporally and spatially distributed is still largely unknown. Carlson (1974) concluded that further studies are needed to determine the exact nature of selective predation by juvenile sockeye salmon and sticklebacks in Iliamna Lake. Therefore, data on the availability and rates of production of zooplankton of the size sought by juvenile sockeye salmon is a must if accurate computations of the carrying capacity of the nursery lakes of the Kvichak system are to be determined.

Zooplankton samples are available from sampling conducted since 1961. A thorough instar analysis of these samples could provide valuable information on the changes in the available food supply sought by juvenile sockeye salmon in Iliamna Lake since 1961.

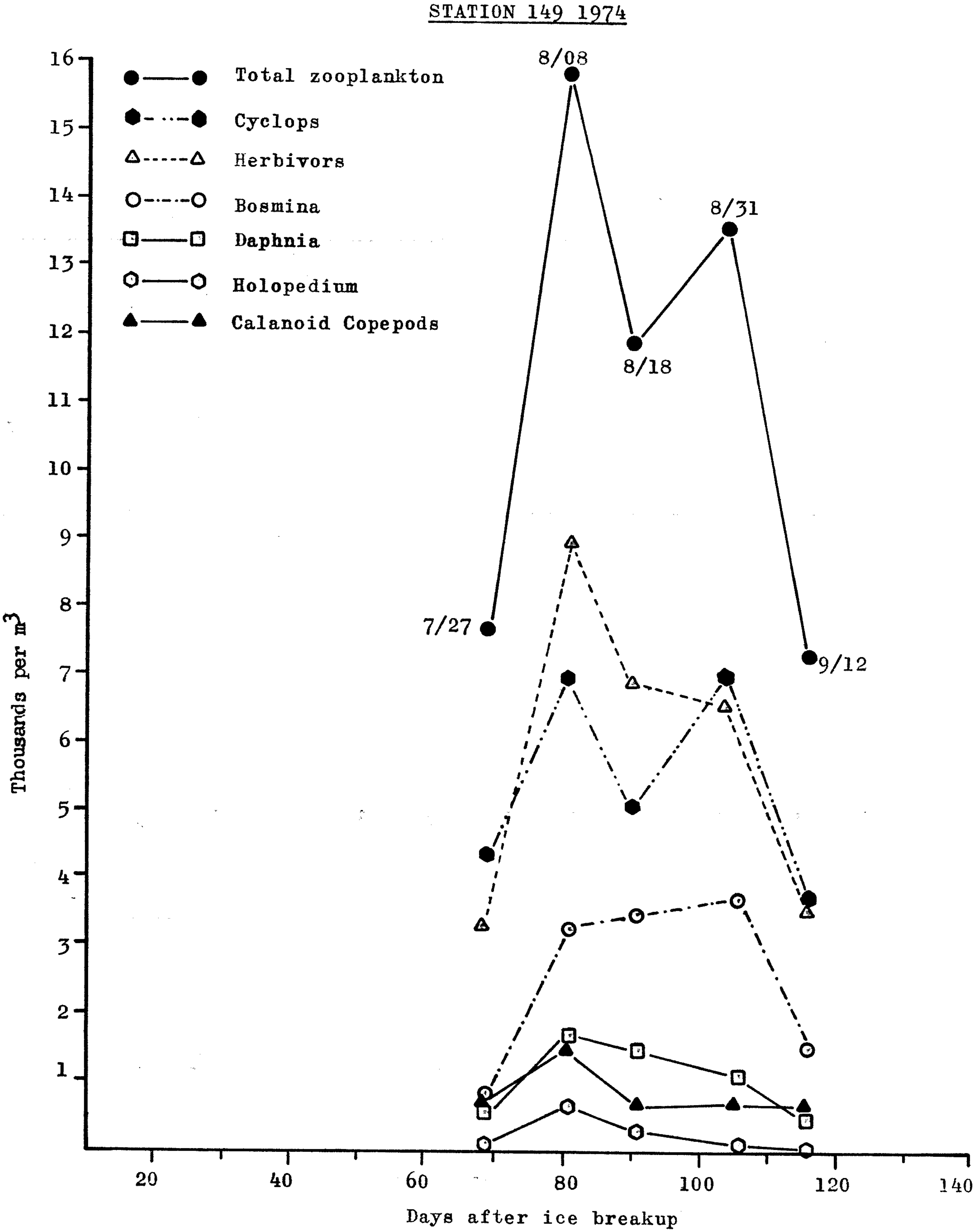

Fig. 33. Relative abundance of total zooplankton, Cyclops scutifer, Bosmina coregoni, total herbivors, Daphnia longiremis, Holopedium gibberum, and Calanoid Copepods, from No. 6 net sampling at Station 149, by days after the estimated breakup of lake ice, 1974.

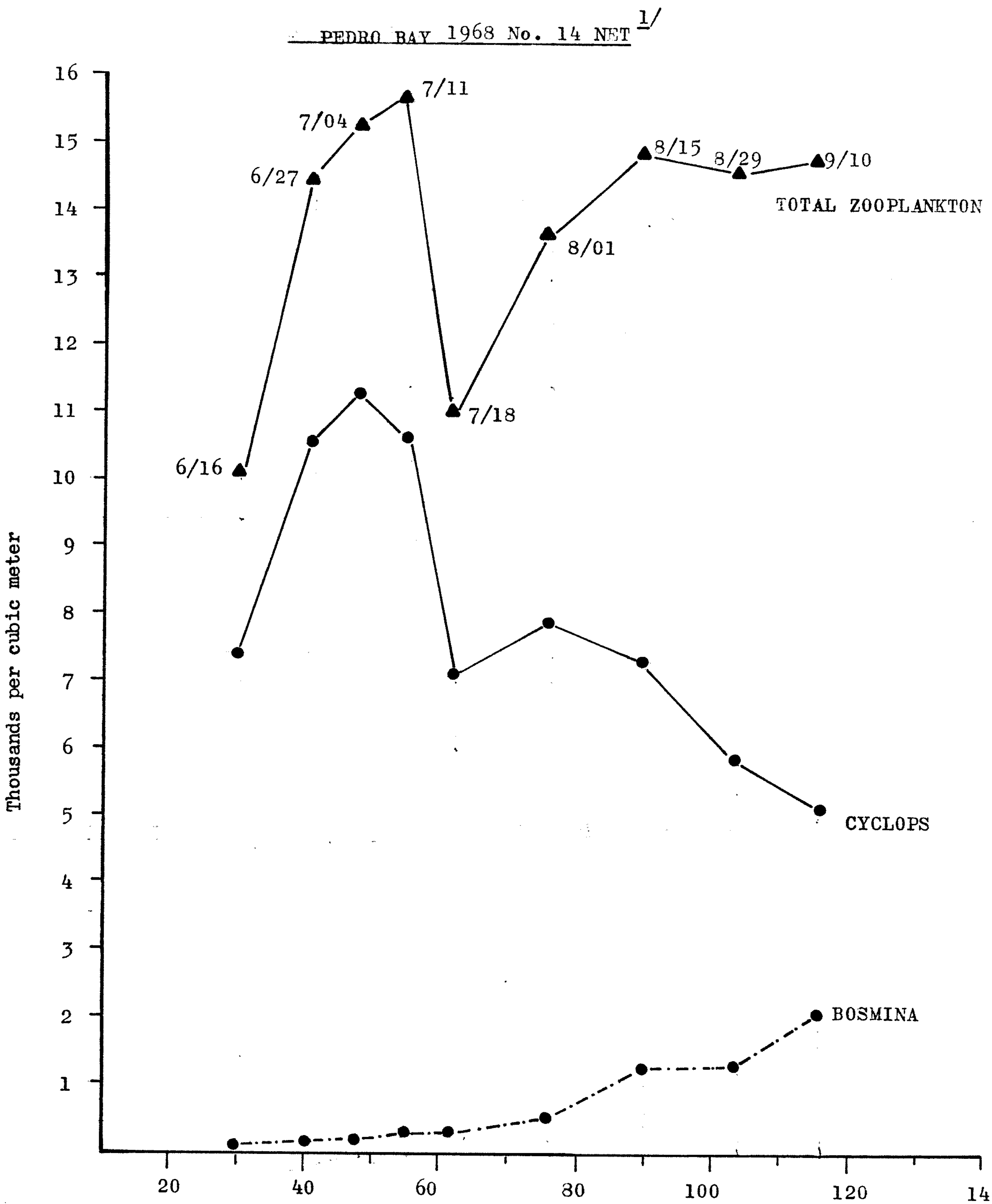

Fig. 34. Abundance of total zooplankton, Cyclops scutifer Sars, and Bosmina coregoni Baird, from No. 14 net sampling in Pedro Bay by Gunnerod (1969), by days after the breakup of lake ice, 1968.

1/ Numbers plotted represent geometric means of the 18 stations sampled on each date.

STATION 149 1972

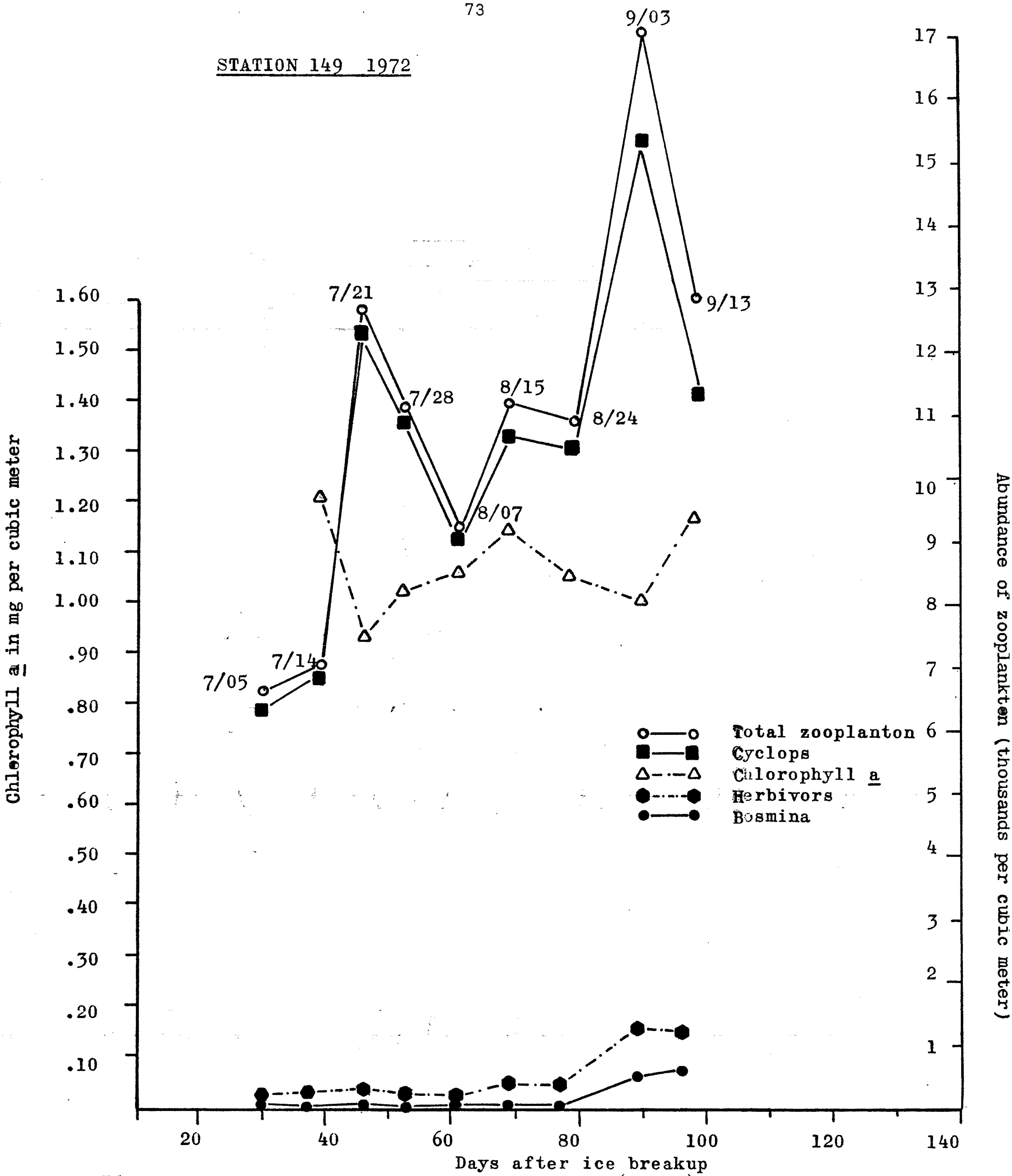

Fig. 35. The mean concentration of chlorophyll a (0-45m), the abundance of total zooplankton, *Cyclops scutifer* Sars, total herbivorous zooplanton, and *Bosmina coregoni* Baird, from No. 6 net sampling, by days after the break-up of lake ice, Station 149, Iliamna Lake, 1972.

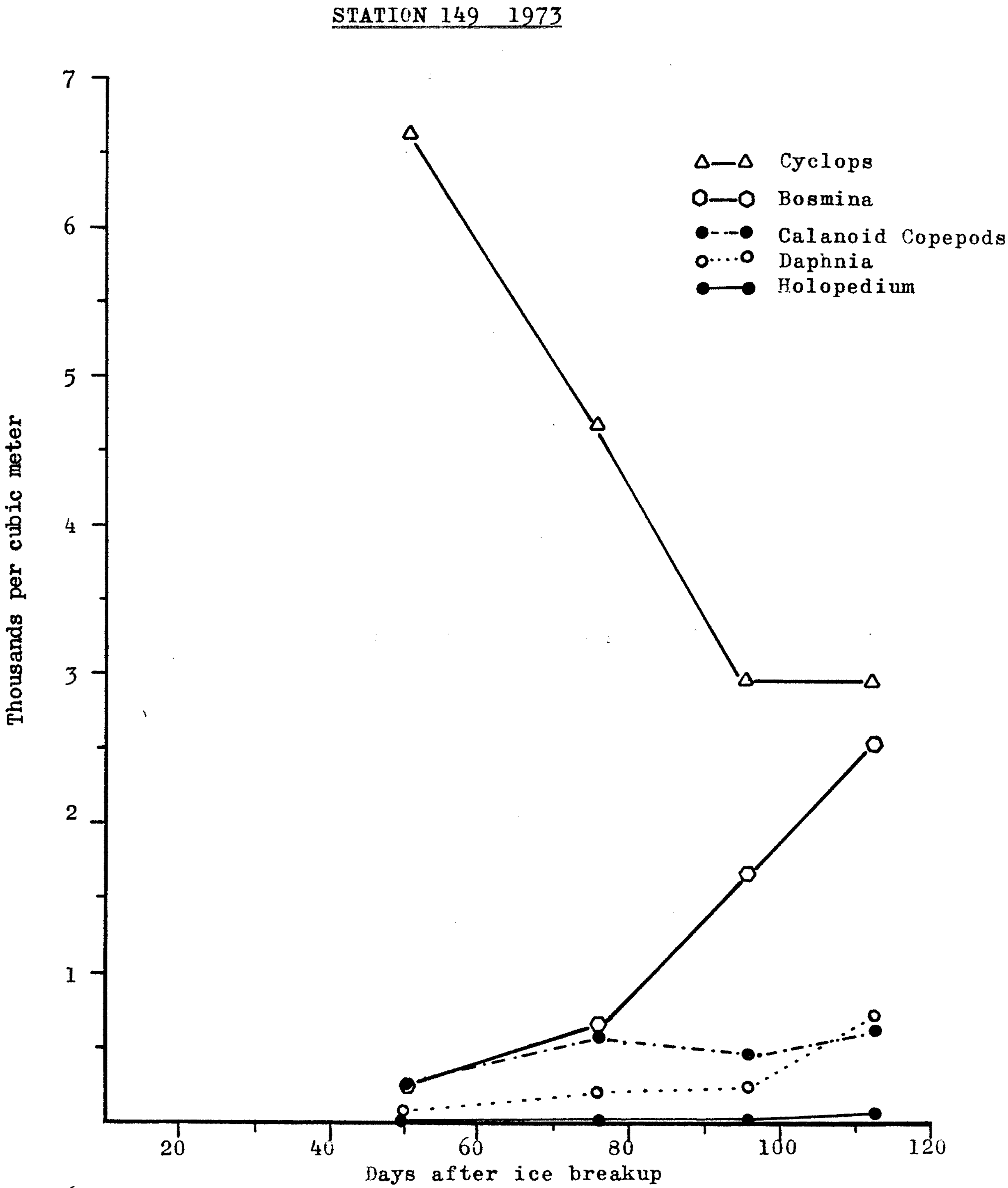

Fig. 36. Abundance of Cyclops scutifer Sars, Bosmina coregoni Baird, Calanoid Copepods (Diaptomus gracilis Sars and Eurytemora yukonensis Wilson), Daphnia longiremis Sars, and Holopedium gibberum Zaddach, from No. 6 net sampling at station 149, by days after ice breakup, 1973.

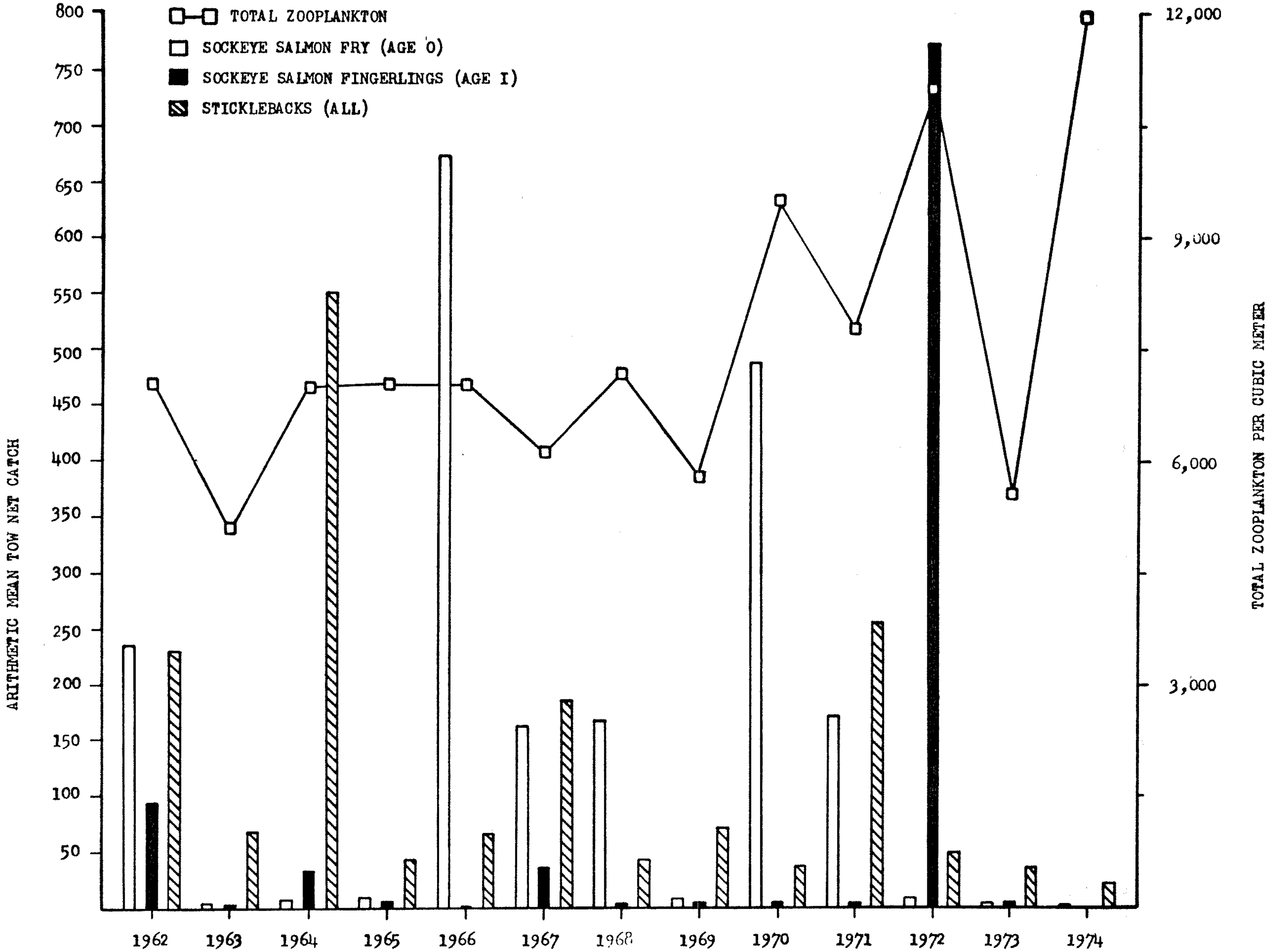

Fig. 37. **Arithmetic mean tow net catch of juvenile sockeye salmon and sticklebacks, and abundance of total zooplankton in August from No. 6 net sampling, Pedro Bay (Section 8), Iliamna Lake, 1962-1974.**

STUDIES OF JUVENILE SALMON AND MAJOR COMPETITOR SPECIES

Continued monitoring of juvenile salmon abundance, growth and distribution fulfills two essential purposes in the total study of the sockeye salmon production in the Kvichak system. First, this monitoring provides the first indication of the success of spawning each year. Second, continuous, comparable data over several life cycles is essential when evaluating the productive capacity of salmon producing systems and formulating management decisions. Maintenance of these studies through tow-netting, limited beach seining, and acoustic assessment where applicable is needed to further define and measure the interactions between juvenile sockeye salmon and biotic and abiotic factors limiting production of the Kvichak system.

Tow-Netting

Indices of relative abundance, distribution, and growth of juvenile sockeye salmon and threespine sticklebacks in Iliamna Lake and of juvenile sockeye salmon and least ciscos in Lake Clark have been determined since 1962. In 1974 the regular index towing was conducted between August 8-11 in Lake Clark and August 14 - September 7 in Iliamna Lake. The distribution of the tow-netting effort in 1974 is shown in Fig. 38a. The towing sections and normal track lines are shown in Fig. 38b.

Abundance

Tow net catches of the major groups of fishes in Iliamna Lake and Lake clark are presented in Table 24. The relative abundance, or biomass, of juvenile sockeye salmon and sticklebacks in the nursery lakes of the Kvichak system is the lowest observed during the period 1962-1974 (Fig. 39).

Prior to 1974 there had been three years during which the Iliamna Lake towing index had been expanded from an index value based on incomplete towing coverage of the lake. Since there was no tows made in lake section 1 during 1974, indices obtained (Table 25) were expanded to represent the the entire lake by using the following equation:

$$\text{Estimated total index} = \frac{\text{Observed index sections 2-11}}{\text{Mean \% from sections 2-11 from years of complete towing (see Appendix B)}}$$

The data used in expanding the Iliamna Lake towing indices in years of incomplete towing coverage are summarized in Table 26 and Appendix B. Indices for the years 1962-1974 are presented in Table 27.

Distribution

The distribution of the catch of each fish group in each lake section expressed as a percentage of the total catch of the respective fish groups for Iliamna Lake and Lake Clark are shown in Figs. 40 and 41.

Growth in Length

The daily growth rates of juvenile sockeye salmon and Age I threespine sticklebacks were computed as shown in Table 28a. Estimated daily growth rates of juvenile sockeye salmon and sticklebacks in the eastern portion of Iliamna Lake for the years 1962-1974 are summarized in Table 29. Growth curves established for sockeye salmon fry, sockeye salmon yearlings, and Age I threespine sticklebacks are illustrated in Fig. 42.

Mean live lengths of juvenile salmon and major competitors by lake section are presented in Table 30 . The weighted mean lengths of juvenile salmon and competitors in Iliamna Lake and Lake Clark for the years 1962-

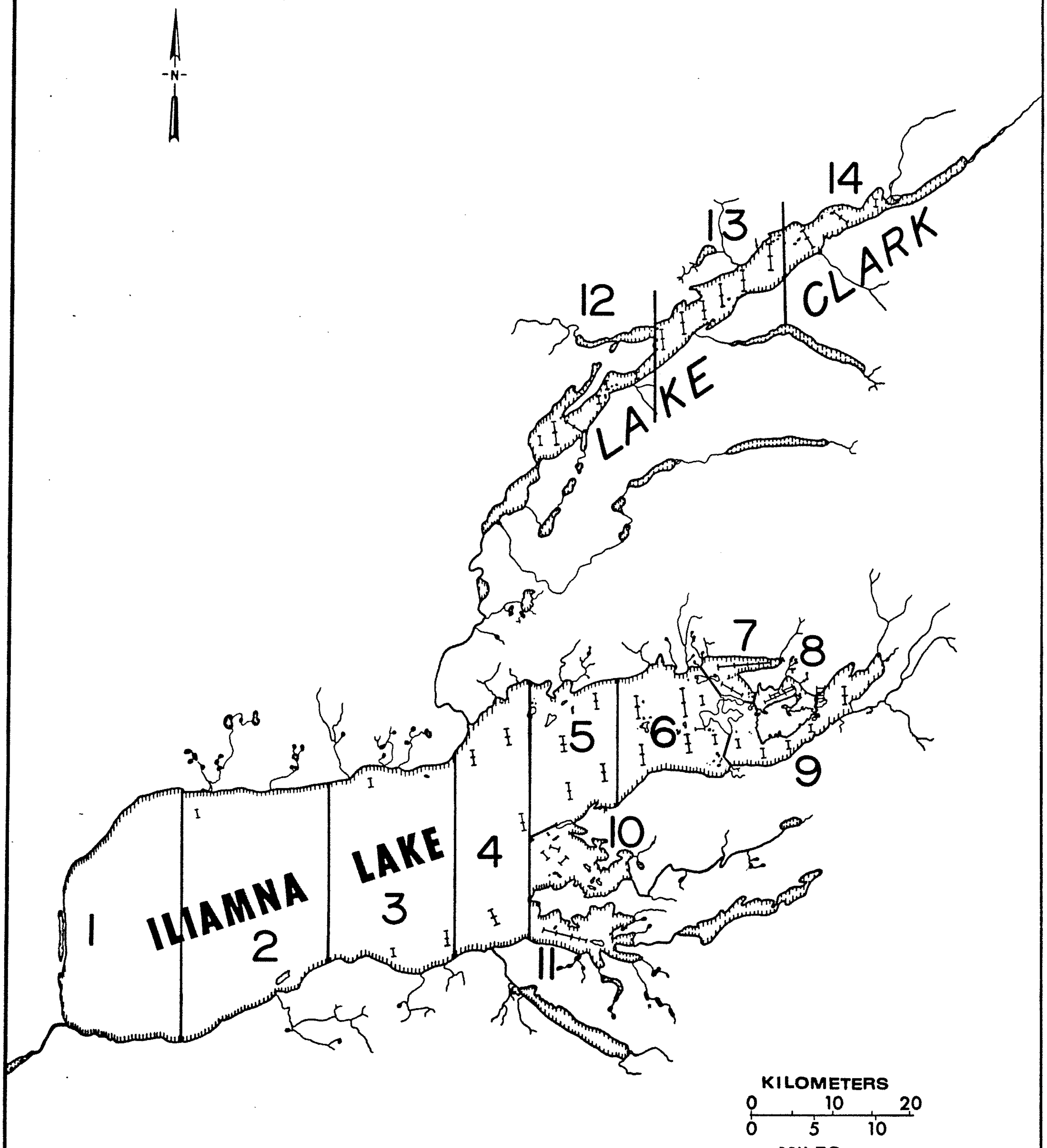

Fig. 38a. Distribution of the tow-netting survey in the nursery lakes of the Kvichak River system, 1974.

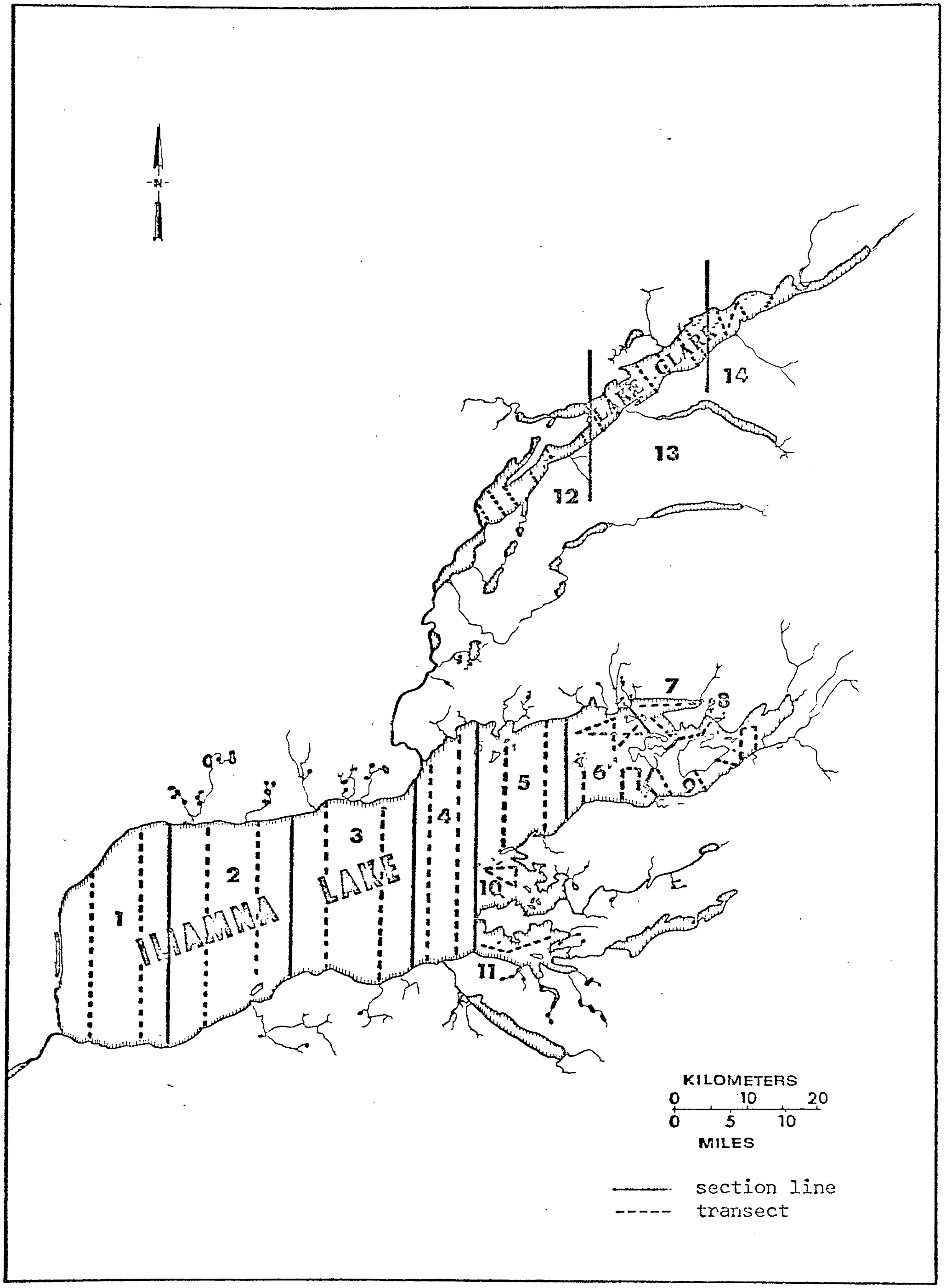

Fig. 38b. Map of Iliamna Lake and Lake Clark, showing the towing division of lake sections and the normal track lines of towing surveys.

Table 24. **Tow net catches of resident fishes in Iliamna Lake and Lake Clark, 1974**

Section	Sockeye salmon Fry	Sockeye salmon Yearlings	Sticklebacks Threespine	Sticklebacks Ninespine	Least Cisco	Number of index tows
			Iliamna Lake			
1	-	-	-	-	-	0
2	0	0	2	0	0	1
3	0	0	2	0	0	4
4	10	0	16	4	1	8
5	6	7	25	5	0	8
6	126	23	210	10	0	11
7	35	8	420	41	0	6
8	3	2	80	8	0	4
9	21	3	43	11	0	6
10	22	0	91	16	0	3
11	25	0	58	32	0	4
Total:	228	43	947	127	1	55
			Lake Clark			
12	376	37	0	0	3	8
13	163	31	0	0	151	12
14	19	1	0	8	233	5
Total:	558	69	0	8	387	25

Data Source: FRK 317R computer output for 1974.

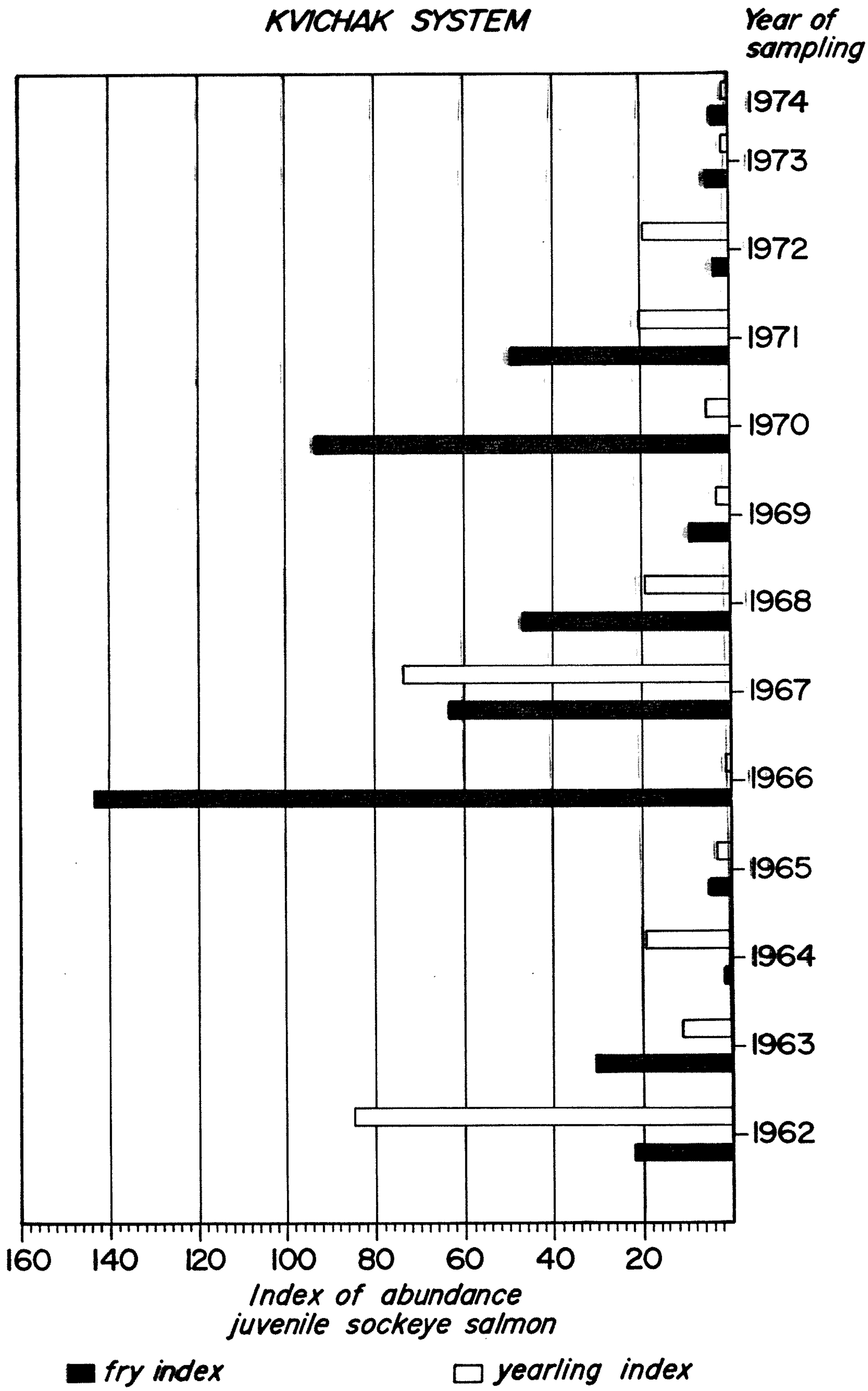

Fig. 39. Weighted mean catches of sockeye salmon fry and yearlings per standard tow, Kvichak system 1962-1974.

Table 25. Weighted mean catches of resident fishes from index towing for Iliamna Lake, Lake Clark, and the Kvichak system, 1974

Section	Sockeye salmon Fry	Sockeye salmon Yearlings	Sticklebacks Threespine	Sticklebacks Ninespine	Least Ciscos	Weighting factor	Number of tows
			ILIAMNA LAKE				
1	-	-	-	-	-	0.2130	0
2	0.000	0.000	0.367	0.000	0.000	0.1837	1
3	0.000	0.000	0.097	0.000	0.000	0.1935	4
4	0.166	0.000	0.266	0.066	0.017	0.1328	8
5	0.072	0.083	0.298	0.060	0.000	0.0954	8
6	0.782	0.143	1.304	0.062	0.000	0.0683	11
7	0.065	0.015	0.784	0.077	0.000	0.0112	6
8	0.006	0.004	0.168	0.017	0.000	0.0084	4
9	0.127	0.018	0.261	0.067	0.000	0.0364	6
10	0.241	0.000	0.998	0.175	0.000	0.0329	3
11	0.153	0.000	0.355	0.196	0.000	0.0245	4
Total:	1.613	0.264	4.898	0.720	0.017	1.0001	55
Expanded[1/]	1.665	0.266	5.023				
			LAKE CLARK				
12	17.898	1.761	-	0.000	0.143	0.3808	8
13	5.758	1.095	-	0.000	5.334	0.4239	12
14	0.742	0.039	-	0.312	9.101	0.1953	5
Total:	24.398	2.895	-	0.312	14.578	1.0000	25
			KVICHAK SYSTEM[2/]				
Iliamna Lake							
Sections 2-11	1.464	0.240	4.445	0.653	0.015	0.9075	55
Expanded to represent entire lake	1.511	0.241	4.558				
Lake Clark	2.257	0.268	-	0.029	1.348	0.0925	25
Total (unexpanded)	3.721	0.508	4.445	0.682	1.363	1.0000	80
Expanded	3.768	0.509	4.558				

1/ Since there were no tows made in lake section 1 during 1974, indexes of juvenile sockeye salmon and threespine sticklebacks (sections 2-11) were expanded to represent the entire lake by using the following equation: (Roger, MS 1973)

$$\text{Estimated total index} = \frac{\text{Observed index sections 2-11}}{\text{Mean \% from sections 2-11 from years of complete towing (see Table)}}$$

2/ Weighted mean catches = (Iliamna Lake index)(0.9075) + (Lake Clark index)(0.0925) for Kvichak system.

Table 26. Summary of weighted mean catches and percentages of total lake index of sockeye salmon fry, sockeye salmon yearlings and threespine sticklebacks by lake section, and number of tows in each lake section from index towing in Iliamna Lake, 1962-1974

Year	Section 1 Index	Section 1 %	Section 2 Index	Section 2 %	Section 3 Index	Section 3 %	Section 4 Index	Section 4 %	Section 5 Index	Section 5 %	Section 6 Index	Section 6 %	Section 7 Index	Section 7 %	Section 8 Index	Section 8 %	Section 9 Index	Section 9 %	Section 10 Index	Section 10 %	Section 11 Index	Section 11 %	TOTAL Index	TOTAL %
1962 Fry	.38	1.76	1.38	6.38	1.13	5.22	7.46	34.47	3.35	15.48	1.41	6.52	1.34	6.19	1.95	9.01	2.56	11.83	.55	2.54	.13	.60	21.64	100.00
Yearlings	3.12	3.55	35.03	39.90	7.15	8.14	13.88	15.81	13.43	15.30	6.73	7.67	.98	1.12	.78	.89	.79	.90	3.71	4.23	2.19	2.49	87.79	100.00
3-sp. stkb.	.50	.38	6.30	4.76	11.76	8.89	44.31	33.48	26.03	19.67	8.65	6.54	2.77	2.09	1.85	1.40	6.40	4.84	1.15	.87	22.60	17.08	132.32	100.00
No. tows	(9)		(14)		(20)		(11)		(14)		(6)		(8)		(9)		(10)		(4)		(4)			(109)
1963 Fry	.04	.15	2.40	8.47	1.55	5.47	3.26	11.53	9.22	32.56	1.04	3.68	.27	.96	.02	.08	1.16	4.08	6.00	21.21	3.34	11.81	28.31	100.00
Yearlings	0.00	0.00	.40	3.57	.40	3.58	3.40	30.14	6.07	54.41	.72	6.43	.16	1.41	.02	.16	0.00	0.00	0.00	0.00	0.00	0.00	11.16	100.00
3-sp. stkb.	0.00	0.00	.28	1.04	.59	2.23	1.61	6.06	9.87	37.08	2.92	10.97	1.12	4.21	.53	1.98	.17	.65	5.28	19.83	4.25	15.97	26.63	100.00
No. tows	(5)		(18)		(16)		(7)		(8)		(4)		(6)		(6)		(4)		(2)		(2)			(76)
1964 Fry	.04	3.89	.02	2.56	.02	2.11	.01	1.44	.01	1.22	.02	1.89	.10	11.22	.07	8.22	.24	26.67	.14	15.56	.23	25.22	.90	100.00
Yearlings	.07	.34	.57	2.72	.79	3.75	3.43	16.22	10.74	50.82	3.79	17.94	.05	.23	.27	1.28	.17	.79	1.08	5.10	.17	.81	21.13	100.00
3-sp. stkb.	20.59	21.60	.16	.17	1.08	1.14	24.25	25.43	1.47	1.54	13.69	14.36	.80	.84	4.42	4.63	.97	1.02	.54	.57	27.36	28.70	95.34	100.00
No. tows	(6)		(8)		(10)		(10)		(9)		(8)		(4)		(5)		(5)		(4)		(4)			(73)
1965 Fry	.71	16.35	.14*	3.51	.32	8.31	.17	4.41	.16	4.10	.20	5.29	.09	2.27	.08	2.09	.07	1.88	0.00	0.00	1.93	49.79	3.87	100.00
Yearlings	0.00	0.00	.22*	8.40	0.00	0.00	.49	18.49	.71	26.80	.47	17.73	.06	2.26	.05	1.89	.15	5.66	.34	12.83	.16	6.04	2.65	100.00
3-sp. stkb.	0.14	.16	1.28*	1.40	.16	.18	23.58	25.86	18.44	20.22	.23	.25	.04	.05	.28	.30	.21	.23	3.09	3.39	43.73	47.96	91.18	100.00
No. tows	(6)		***		(6)		(7)		(9)		(6)		(6)		(8)		(4)		(4)		(4)			(60)
1966 Fry	2.29	1.56	.71	.49	5.32	3.63	1.46	1.00	6.45	4.40	44.49	30.37	3.59	2.45	5.64	3.85	74.74	51.03	.26	.18	1.52	1.04	146.47	100.00
Yearlings	0.00	0.00	.05	5.00	.02	2.61	.12	13.37	.42	45.76	.20	21.52	.02	2.61	.002	.22	.005	.54	.08	8.37	0.00	0.00	.92	100.00
3-sp. stkb.	.05	.14	.57	1.56	.24	.66	15.18	41.41	3.29	8.97	8.40	22.91	1.78	4.85	.56	1.54	1.20	3.26	2.79	7.61	2.60	7.08	36.66	100.00
No. tows	(4)		(8)		(8)		(13)		(12)		(10)		(8)		(11)		(14)		(6)		(6)			(100)
1967 Fry	.37	.56	6.59	9.99	4.36	6.60	7.19	10.89	12.08	18.30	18.15	27.50	1.87	2.83	1.35	2.05	2.67	4.04	2.25	3.41	9.13	13.82	66.01	100.00
Yearlings	2.05	2.72	12.88	17.11	9.58	12.74	5.68	7.55	11.04	14.67	30.97	41.16	.41	.55	.30	.40	.98	1.30	1.33	1.77	.02	.03	75.24	100.00
3-sp. stkb.	.53	1.44	1.34	3.62	2.94	7.94	3.94	10.64	3.89	10.50	6.40	17.29	1.24	3.35	1.44	3.88	6.50	17.55	1.23	3.31	7.58	20.48	37.03	100.00
No. tows	(8)		(10)		(15)		(9)		(8)		(12)		(14)		(8)		(8)		(4)		(4)			(100)
1968 Fry	1.22	3.15	.85	2.20	10.98	28.27	4.11	10.57	3.53	9.09	8.36	21.53	.55	1.42	1.40	3.61	2.64	6.81	3.12	8.04	2.06	5.31	38.82	100.00
Yearlings	.21	1.04	.34	1.66	15.71	76.44	2.00	9.74	.86	4.18	.14	.67	.01	.04	.02	.09	.05	.24	1.15	5.60	.06	.30	20.55	100.00
3-sp. stkb.	.19	.21	.47	.52	15.64	17.33	48.39	53.62	4.54	5.03	2.23	2.47	.77	.86	.21	.23	1.66	1.84	1.45	1.60	14.70	16.29	90.25	100.00
No. tows	(8)		(14)		(12)		(13)		(9)		(14)		(5)		(9)		(11)		(3)		(4)			(102)
1969 Fry	.08	1.04	.06	.75	.21	2.58	.24	2.98	.20	2.44	1.16	14.26	2.17	26.60	.07	.87	3.01	36.92	.11	1.41	.83	10.15	8.14	100.00
Yearlings	0.00	0.00	.06	2.49	.05	2.07	.33	13.69	.76	31.55	.49	20.33	.50	20.75	.02	.83	.15	6.22	.02	.83	.03	1.24	2.41	100.00
3-sp. stkb.	.06	.08	.14	.17	.31	.38	11.01	13.67	1.84	2.28	26.19	32.51	12.72	15.79	.49	.60	7.88	9.78	6.46	8.02	13.47	16.72	80.57	100.00
No. tows	(10)		(12)		(12)		(12)		(12)		(12)		(5)		(4)		(7)		(4)		(4)			(94)
1970 Fry	.43	.43	.98	1.00	6.53	6.65	13.36	13.61	7.76	7.90	21.43	21.84	5.66	5.76	4.10	4.18	33.98	34.61	2.62	2.67	1.32	1.35	98.16	100.00
Yearlings	0.00	0.00	.12	2.54	.07	1.52	.95	19.73	.46	9.48	1.26	26.11	.18	3.74	.03	.60	1.73	35.95	.02	.33	0.00	0.00	4.82	100.00
3-sp. stkb.	.18	.57	.24	.79	1.38	4.46	8.71	28.17	5.14	16.63	3.38	10.92	.27	.86	.26	.83	1.55	5.00	1.58	5.11	8.24	26.66	30.93	100.00
No. tows	(4)		(12)		(8)		(14)		(9)		(18)		(11)		(2)		(6)		(4)		(4)			(94)
1971 1/ Fry	***		***		9.96		***		***		17.21		3.31		1.44		2.92		***		***			
Yearlings	***		***		.90		***		***		5.23		.23		.02		.28		***		***			
3-sp. stkb.	***		***		.39		***		***		4.59		1.16		2.10		.87		***		***			
No. tows	***		***		(6)		***		***		(11)		(8)		(4)		(6)		***		***			(35)
1972 Fry	0.00	0.00	0.00	0.00	.06	3.49	.13	7.56	.13	7.56	.08	4.65	.07	4.07	.08	4.65	.04	2.33	.75	43.60	.38	22.09	1.72	100.00
Yearlings	.11	.52	0.00	0.00	.58	2.80	1.04	5.01	.39	1.89	2.28	11.02	8.81	42.48	6.49	31.28	.27	1.29	.68	3.28	.09	.43	20.74	100.00
3-sp. stkb.	0.00	0.00	0.00	0.00	.15	2.63	2.12	36.07	.36	6.11	.57	9.69	.15	2.48	.36	6.20	.25	4.23	.42	7.08	1.50	25.51	5.88	100.00
No. tows	(4)		(3)		(10)		(6)		(9)		(11)		(5)		(7)		(6)		(3)		(3)			(67)
1973 Fry	***		***		.14		.46		.05		.03		.08		.01		.09		.01		.82		1.71	
Yearlings	***		***		.05		.02		.91		.37		.06		.03		.19		.02		.08		1.73	
3-sp. stkb.	***		***		.53		10.39		.71		.20		.29		.31		.21		1.37		3.13		17.15	
No. tows	***		***		(4)		(13)		(10)		(11)		(8)		(10)		(6)		(3)		(3)			(68)
1974 Fry	***		0.00		0.00		0.17		0.07		0.78		0.07		0.01		0.13		0.24		0.15		1.61	
Yearlings	***		0.00		0.00		0.00		0.08		0.14		0.01		0.004		0.02		0.00		0.00		0.264	
3-sp. stkb.	***		0.37		0.10		0.27		0.30		1.30		0.78		0.17		0.26		1.00		0.35		4.90	
No. tows	***		(1)		(4)		(8)		(3)		(11)		(6)		(4)		(6)		(3)		(4)			(55)

* No tows were made in lake section 2 in 1965. The indexes for each fish species for section 2 was estimated through determining the mean percent of the Iliamna Lake index contained in sections 1 plus 3-11 for the years 1962-1964, 1966-1970, and 1972.

*** No tows were made.

1/ I[illegible] from [illegible] egnd [illegible] se to[illegible] unds [illegible] mna L[illegible] 1971. [illegible] 1971 [illegible] were [illegible] ed fr[illegible] incom[illegible] towing [illegible] iamna [illegible] n

Table 27. Relative abundance of juvenile sockeye salmon, threespine sticklebacks and least ciscos in the Kvichak River system and the relative production of Age 0 sockeye, 1962-1974

Year of sampling	Index of abundance[1]								
	Iliamna Lake			Lake Clark			Kvichak system[2]		
	Age 0	Age I	Threespine sticklebacks	Age 0	Age I	Least ciscos	Age 0	Age I	Mean catch of Age 0 per million spawners
1962	21.6	87.8	132.3	22.3	0.0	2.4	21.7	79.7	5.84
1963	28.3	11.2	26.6	72.9	1.5	4.5	32.4	10.3	12.56
1964	0.9	21.1	95.3	6.5	0.9	3.6	1.4	19.2	4.11
1965	3.9	2.7	91.2	2.2	1.2	2.4	3.7	2.6	3.85
1966	146.5	0.9	36.7	51.4	0.7	10.6	137.7	0.9	5.66
1967	66.0	75.3	37.0	22.5	3.5	13.6	62.0	68.7	16.40
1968	38.8	20.5	90.3	84.7	19.8	12.6	43.0	20.4	13.35
1969	8.1	2.4	80.6	22.1	11.6	22.5	9.4	3.3	3.67
1970	98.2	4.8	31.0	17.4	12.1	17.4	90.7	5.5	10.81
1971[3]	55.4	20.7	39.5	25.3	5.5	16.4	52.6	19.3	3.77
1972	1.7	20.7	5.9	23.3	6.4	6.1	3.7	19.4	1.54
1973[3]	1.8	1.9	17.8	36.7	2.2	2.1	5.0	1.9	4.95
1974	1.7	0.3	5.0	24.4	2.6	14.9	3.8	0.5	16.52
Mean 1962-1973	39.3	22.5	57.0	32.3	5.4	9.5	38.6	20.9	7.21

[1] Weighted mean catches of juvenile sockeye salmon, threespine sticklebacks, and least ciscos per standard tow (all the above indices are derived from the computer program FRK317R which uses the 1968 method of computing indices of abundance and defining lake sections.)

[2] Iliamna index given a weight of 0.9075 and Lake Clark index a weight of 0.0925 based on total surface area.

[3] Indices estimated from incomplete towing.

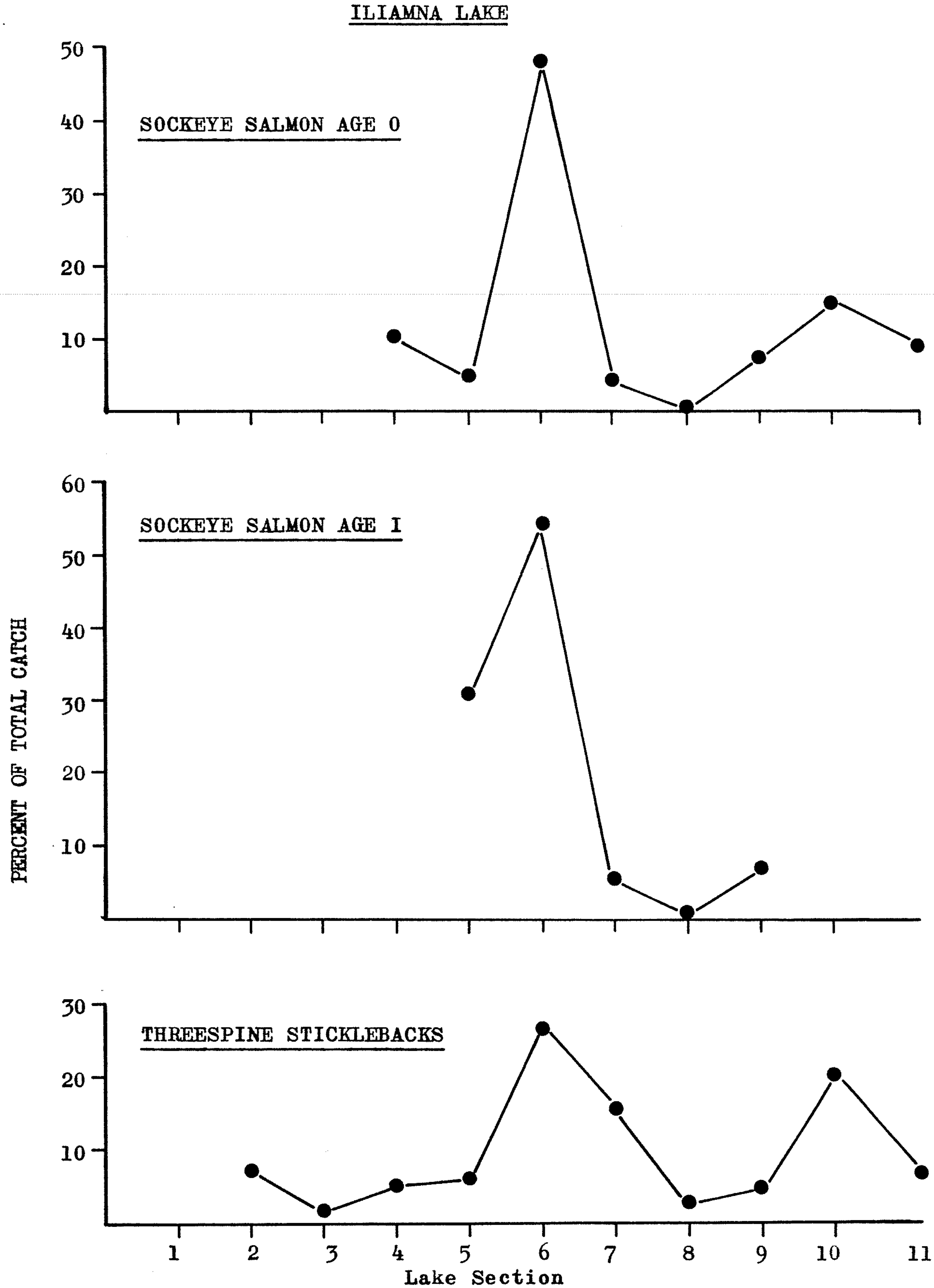

Fig. 40. Distribution of juvenile sockeye salmon and threespine sticklebacks in Iliamna Lake, 1974.

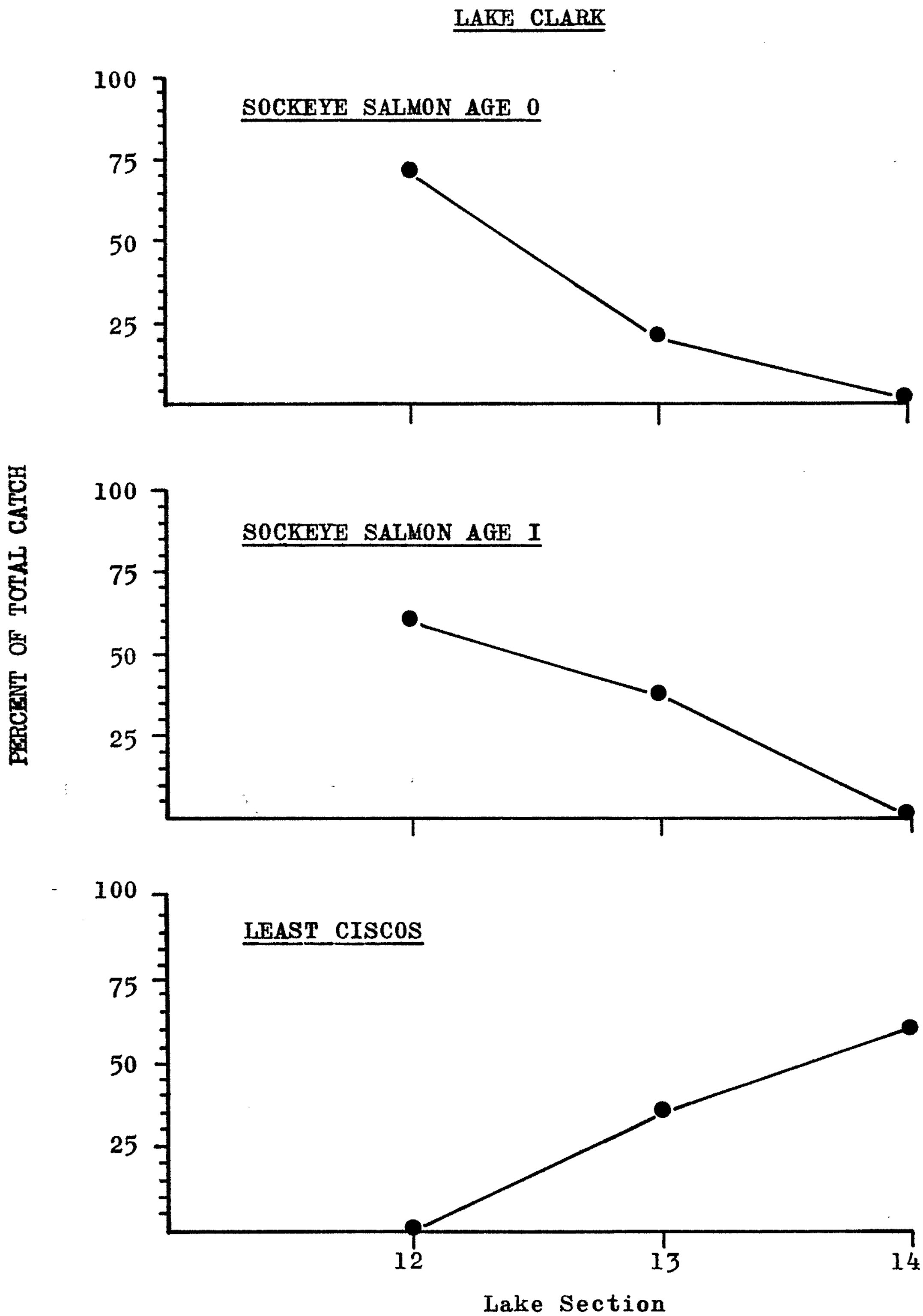

Fig. 41. Distribution of juvenile sockeye salmon and least ciscos in Lake Clark, 1974.

Table 28. Daily growth rates (in mm) of juvenile sockeye salmon and Age I threespine sticklebacks in the eastern portion of Iliamna Lake, 1974

Fish species	Date	Sample size	Mean live length	Length increment	#days between sampling	Average increase/ day
Sockeye salmon fry (Age 0)	7/04	187	36.76			
	9/07	32	74.59	36.90	66	0.57
Sockeye salmon yearlings (Age I)[1]						
Section 6 & 7	8/31	8	104.87			
	9/06	15	110.27	5.40	7	0.77
Big Chutes	8/03	87	79.07			
Section 9	8/12	14	87.21	8.14	10	0.81
			Section 6 & 7 & Big Chutes average			0.79
Threespine sticklebacks (Age I)	7/04	51	32.80			
	9/06	27	52.30	19.50	65	0.30

Length-weight sampling information, 1974.

	Date	Type of sampling	Sampling area	Mean live length	Sample size
Sockeye Age 0	7/04	beach seine	P3	36.76	187
	8/02	tow net	Pedro Bay Area 149	55.44	9
	8/03	" "	Big Chutes Area 151	52.96	216
	8/12	" "	" "	56.60	78
	8/21	" "	" "	61.36	47
	8/31	" "	Area 142	70.82	11
	9/06	" "	Area 140	72.32	71
	9/07	" "	Area 139	74.59	32
Sockeye Age I	8/03	" "	Area 151	79.07	87
	8/12	" "	" "	87.21	14
	8/21	" "	" "	88.75	4
	8/31	" "	Area 142 & 143	104.87	8
	9/06	" "	Area 140	110.27	15
	9/07	" "	Area 139	108.67	3
Threespine Sticklebacks Age I	7/04	beach seine	P3	32.80	51
	8/02	tow net	Area 149	42.70	291
	8/03	" "	Area 151	39.11	137
	8/21	" "	" "	52.27	235
	9/06	" "	Area 140	52.30	27

1/ Due to small sample sizes and the apparent intralake movements of concentrations of Age I sockeye fingerlings, the estimated growth rates of fingerlings in lake sections 6, 7, and 9 were averaged.

Table 29. Estimated daily growth rates (in mm) of juvenile sockeye salmon and sticklebacks in the eastern portion of Iliamna Lake, 1962-1974 [1]

Year of towing	Sockeye salmon Age 0	Sockeye salmon Age I	Sticklebacks
1962	.33	.18	.09
1963	.30	.20	.18
1964	.43	.37	.24
1965	.51	.58	.12
1966	.42	.56	.22
1967	.50	.27	.17
1968	.45	.33	.02
1969	.54	.31	.04
1970	.36	.53	.09
1971	.26	.21	.06
1972	.29	.30	.29
1973	.37	.46	.17
1974	.57	.79	.30
1962-1973 mean:	.40	.36	.14

[1] Sources of data for estimated daily growth rates (in mm) of juvenile sockeye salmon and Age I 3-spine sticklebacks for the years 1962-1973 are Kerns (1965, 1966, and 1968), Mathisen (1970), Mathisen, Poe, and Roger (1971), Roger (MS, 1973), and Poe (MS, 1975).

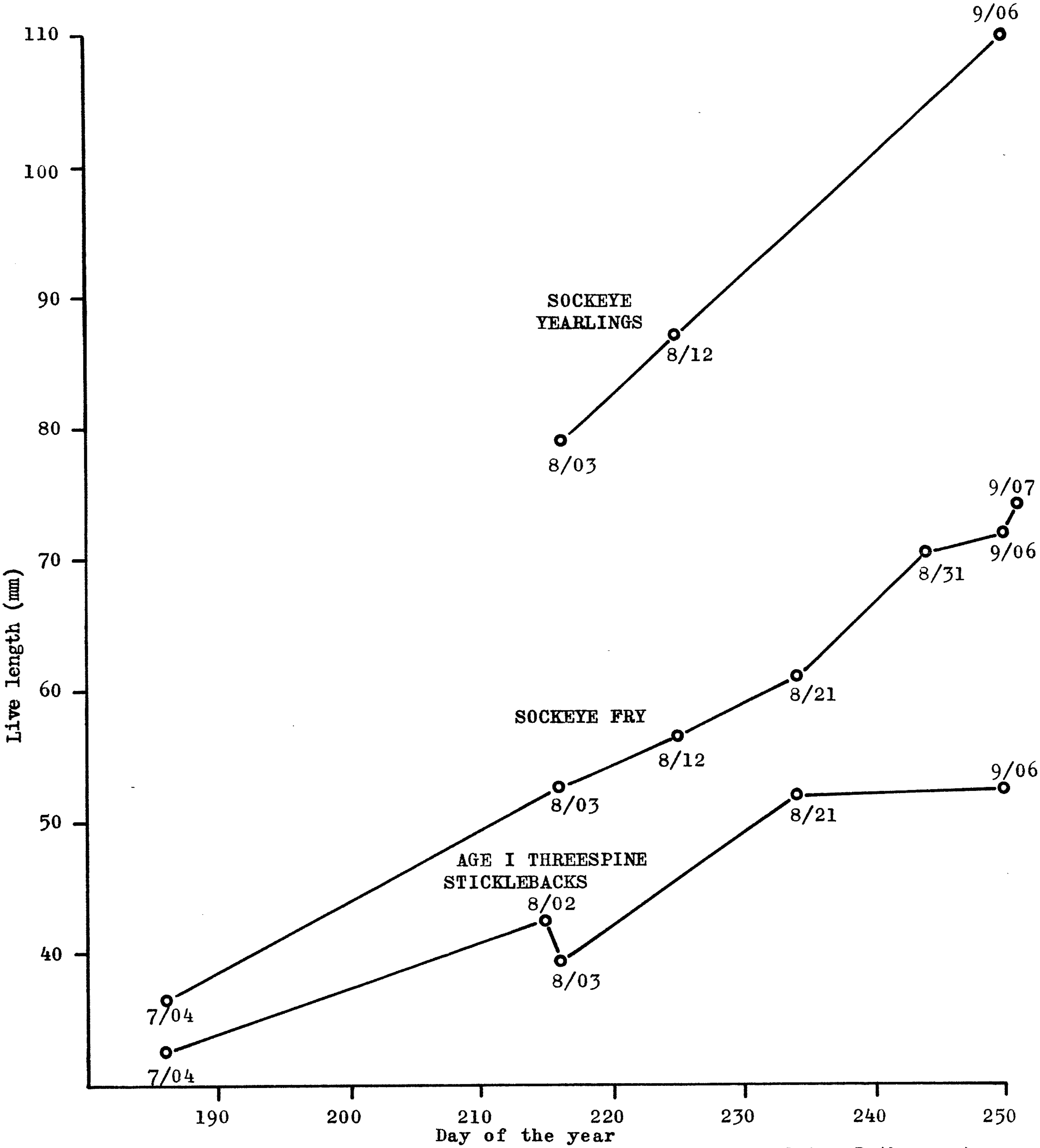

Fig. 42. Increase in length of juvenile sockeye salmon and Age I threespine sticklebacks in sections 6, 7, and 9, Iliamna Lake, 1974 (sample sizes less than 10 not included).

Table 30. Mean live lengths[1] (in mm) and numbers measured of juvenile sockeye salmon, total threespine sticklebacks, ninespine sticklebacks, and least ciscos, Iliamna Lake and Lake Clark, 1974 (lengths adjusted to Sept. 1 for all species except least ciscos)

Lake Section	Sockeye salmon Fry (age 0)[2] Size	#meas.	Yearlings[3] Size	#meas.	Threespine sticklebacks[4] Size	#meas.	Ninespine sticklebacks[4] Size	#meas.	Least ciscos[5] Size	#meas.
Iliamna Lake										
1	****	-	****	-	****	-	****	-	****	-
2	-	-	-	-	32.6	(2)	-	-	-	-
3	-	-	-	-	51.3	(2)	-	-	-	-
4	66.8	(10)	-	-	52.4	(10)	62.8	(4)	113.0	(1)
5	61.1	(6)	122.9	(7)	44.8	(25)	60.7	(5)	-	-
6	69.5	(126)	108.4	(23)	44.6	(210)	52.4	(10)	-	-
7	71.3	(35)	105.7	(8)	51.4	(420)	56.1	(41)	-	-
8	72.2	(3)	99.0	(2)	55.8	(80)	57.9	(8)	-	-
9	62.1	(21)	101.8	(3)	45.5	(43)	58.9	(11)	-	-
10	69.2	(22)	-	-	33.0	(91)	51.3	(16)	-	-
11	67.4	(25)	-	-	48.6	(58)	51.7	(32)	-	-
Lake mean[6]	68.1	(248)	112.2	(43)	43.7	(941)	54.7	(127)	113.0	(1)
Lake Clark										
12	56.3	(376)	110.3	(37)	-	-	-	-	144.7	(3)
13	60.4	(163)	108.3	(31)	-	-	-	-	152.9	(60)
14	57.8	(19)	118.2	(1)	-	-	48.8	(8)	170.0	(51)
Lake mean[6]	57.3	(558)	109.6	(69)	-	-	48.8	(8)	163.5	(114)

Data Source: FRK 317R computer output (arithmetic mean run)

[1] Mean live lengths for all species except least ciscos (preserved lengths). Most of the measurements taken from catches from index tows in 1974 were taken from fish that had been preserved in formalin and preserved lengths were converted to live lengths by multiplication with the following factors (Rogers, 1964).

Sockeye fry k = 1.031
Sockeye yearlings k = 1.042
3-sp. sticklebacks k = 1.015
9-sp. sticklebacks k = 1.015

[2] Lengths adjusted to September 1 by addition or subtraction of 0.57 mm/day.

[3] Lengths adjusted to September 1 by addition or subtraction of 0.79 mm/day.

[4] Lengths adjusted to September 1 by addition or subtraction of 0.30 mm/day.

[5] Preserved lengths.

[6] Lake mean is total of section means weighted by section indexes.

1974 are presented in Table 31. In 1974 the mean length of Age 0 and Age I juvenile sockeye salmon on September 1 was 19 and 15 per cent greater, respectively, than the mean length for the years 1962-1973.

Weight

Low fish densities and lack of a stable platform prevented weighing of fish from lake sections other than 7, 8, and 9. Therefore, only the length-weight relationships of juvenile sockeye salmon in the eastern portion of Iliamna Lake were studied. The length-weight relationships of juvenile sockeye salmon in 1974 were as follows:

Fry	Yearlings
$W = 4.3860 \times 10^{-6} \times L^{3.1750}$	$W = 4.2329 \times 10^{-6} \times L^{3.1749}$

Beach Seining

Limited sampling by beach seine was conducted in the eastern portion of Iliamna Lake to monitor the early size and growth of sockeye salmon fry and sticklebacks and to monitor the timing of the movement of these fishes from the littoral area into the pelagic zone. The 1974 sampling stations are shown in Fig. 43 and the catch data from two rounds of sampling are summarized in Table 32. The catch data indicate that the movement of juvenile salmon and sticklebacks into the pelagic zone was virtually complete before the commencement of towing operations.

Relationship Between the Different Indices of Freshwater Survival

Indices of the relative production of juvenile sockeye salmon obtained from the tow-netting operations in the nursery lakes and from the trunk stream indexing of emigrating smolts have generally shown the same trends. There are now a sufficient number of years of observation to make resonable comparisons between these two indices of the freshwater production of juvenile sockeye salmon.

The yearling index from tow-netting studies in Iliamna Lake and Lake Clark is compared with the smolt index of Age II fish in Fig. 44. The residual variance in the established regression line reflects sampling variability in both measures and a differential natural mortality between years from September in one year to late May of the following year. In spite of this both indices reflect the same pattern, and lend both consistency and reliability to past sampling efforts.

Table 31. Weighted mean live lengths[1/] (in mm) of juvenile sockeye salmon, threespine sticklebacks, and weighted mean preserved lengths of least ciscos, 1962-1974[2/]

Year of sowing	Iliamna Lake				Lake Clark			Kvichak system	
	Sockeye salmon		Threespine sticklebacks		Sockeye salmon		Least	Sockeye salmon	
	Fry	Yearlings	Total	Age I[3/]	Fry	Yearlings	Ciscos	Fry	Yearlings
1962	55.1	89.9	52.0	42.8	50.3	86.3	----	54.6	89.9
1963	58.4	97.6	54.8	44.0	49.9	86.2	165.0	56.7	97.5
1964	55.5	95.8	54.3	45.1	50.4	83.3	153.9	54.0	95.9
1965	62.7	108.6	56.5	44.3	50.2	80.0	-----	61.3	106.7
1966	53.3	112.0	59.2	44.0	52.5	100.7	136.4	53.1	108.9
1967	60.8	89.9	51.3	43.7	44.7	94.1	159.9	60.2	89.9
1968	64.1	109.6	50.6	47.3	59.3	99.0	157.2	63.3	108.8
1969	58.1	98.2	54.6	47.9	50.4	95.5	166.1	56.4	95.9
1970	63.2	100.8	52.9	44.9	55.4	108.6	171.5	63.1	101.9
1971	45.5	92.8	54.8	37.3	38.0	88.3	156.8	45.1	92.7
1972	52.4	74.0	51.5	44.4	40.6	83.7	146.7	45.5	74.2
1973	57.5	100.6	60.1	45.4	47.8	93.9	167.4	51.2	99.9
1974	68.1	112.2	43.7	50.6	57.3	109.6	163.5	61.6	110.9
1962-1973 mean:									
	57.2	97.5	54.4	44.3	49.1	91.6	158.1	55.4	96.8

1/ Lengths adjusted to September 1 for all species except least ciscos (data were not available on the effect of formalin on least ciscos nor on the growth rates of least ciscos with age).

2/ Source of data for all weighted mean lengths except those of Age I threespine sticklebacks for the years 1962-1970 and 1972 are from the arithmetic mean computer output from program No. FRK 317R (Roger, 1972).

3/ Sources of data for weighted mean lengths of Age I threespine sticklebacks for the years 1962-1970 and 1972 are Kerns (1965, 1966, and 1968), Mathisen (1970), Mathisen, Poe, and Roger (1971), and Roger (MS, 1973).

4/ Weighting procedure:

$$\left[\frac{(\text{Iliamna Lk. index})(0.9075)}{\text{Kvichak system index}}\right] \text{mean live length Iliamna Lake} + \left[\frac{(\text{Lk. Clark index})(0.0925)}{\text{Kvichak system index}}\right] \text{mean live length Lk. Clark}$$

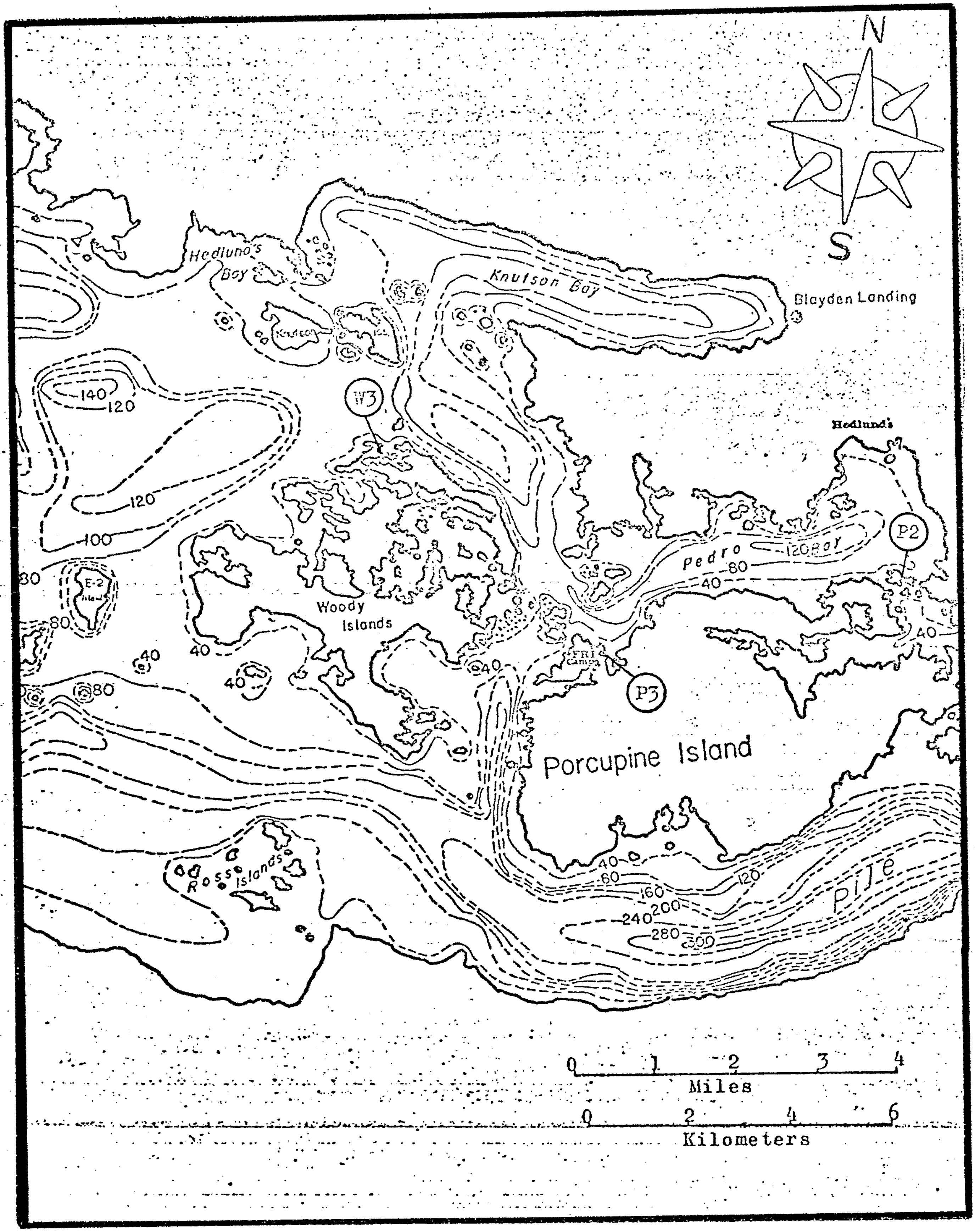

Fig. 43. Beach seine sites during the 1974 field season.

Table 32. **Catches of resident fishes from beach seine sampling in the eastern end of Iliamna Lake, 1974**

Date	Area	Sample #	Sockeye salmon Age 0	Sockeye salmon Age I	Sticklebacks 3-spine	Sticklebacks 9-sp.	Sculpins	Arctic char fry
7/04	84 (P3)	701	408	-	82	3	2	-
7/21	74 (W3)	702	-	-	13	-	1	1
7/21	83 (P2)	703	-	-	7	-	-	-
7/21	84 (P3)	704	-	-	24	-	2	1

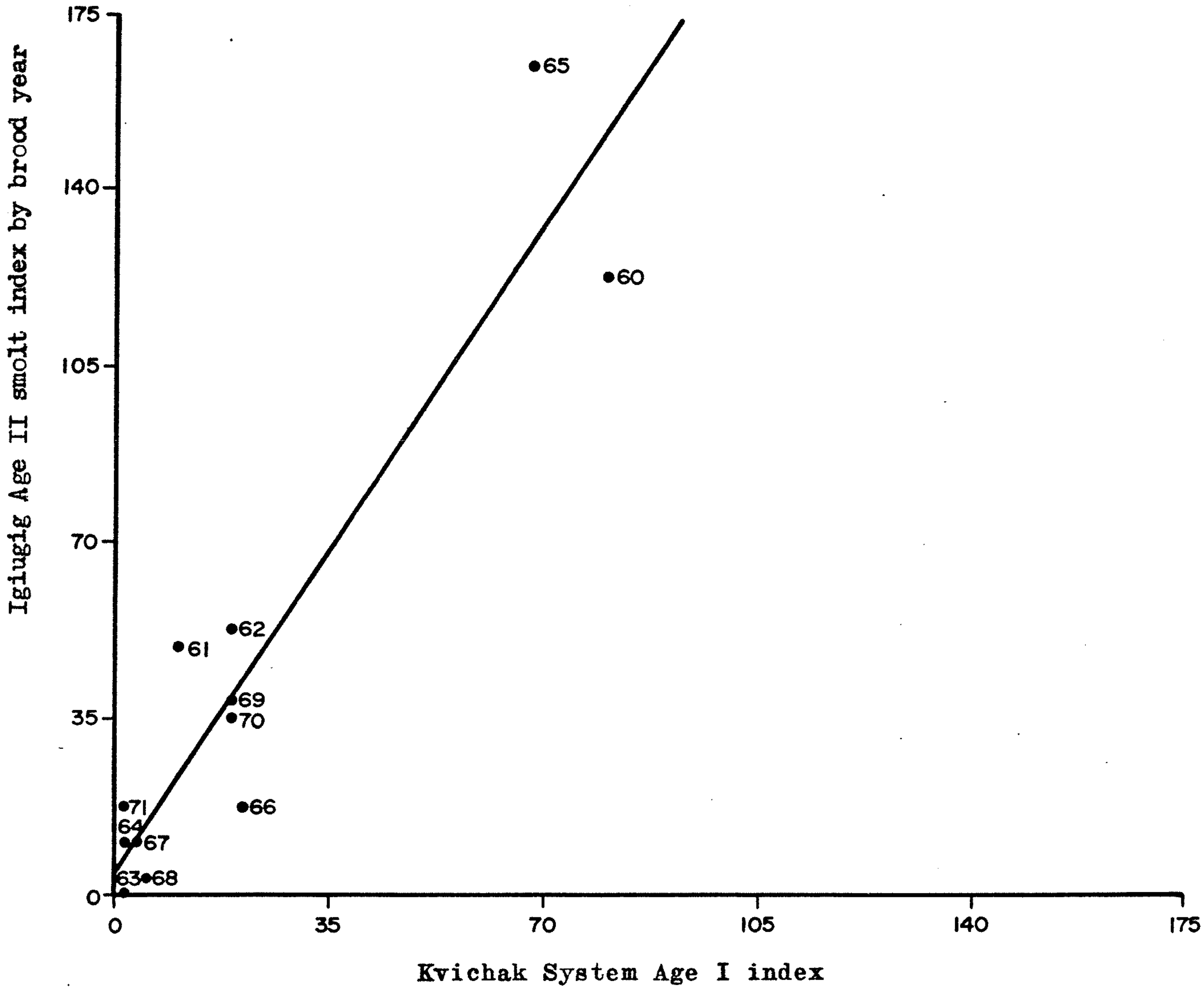

Fig. 44. Regression line of the Igiugig Age II smolt index by brood year on preceding Kvichak System Age I tow net index, brood years 1960-1971 (dates on graph represent brood years). The equation for the regression line is $y = 4.81215 + 1.82147X$.

The fry index from tow-netting operations in Iliamna Lake and Lake Clark is compared with the Age I smolt index the next year in Fig. 45. An added element due to varying proportions migrating as Age I and Age II smolts is now included in the residual variance of the regression line. Still the net implication is one of consistency in the two measures.

The fry index from tow-netting operations is compared with the total smolt index of each brood year in Fig. 46. The residual variance associated with the established regression line is less than the residual variance associated with the regression of Age I smolt index on the preceding tow net fry index but is more than the residual variance associated with the regression of Age II smolts on the preceding yearling index. Still the consistency in the two measurements persists. The index values used in the above regressions are summarized in Table 33.

Relative Production

Although the combined tow-netting and hydroacoustic program conducted in Iliamna Lake in 1974 showed the relative abundance of juvenile salmon to be the lowest observed since studies began in 1961, the relative production of Age 0 sockeye salmon per million spawners was the highest observed to date (Table 27). This high relative production of Age 0 from the 1973 brood year was associated with a low density of spawners and favorable environmental conditions during the period of emergence from the gravel and movement into the littoral areas of the nursery lakes.

Results from tow-netting operations in Lake Clark show the index of abundance to be much nearer the 1962-1973 mean for that system, whereas the index of abundance of least ciscos was above average (Table 27).

HYDROACOUSTIC SURVEYS

Regional Surveys of Juvenile Sockeye Salmon

Since 1971 systematic hydroacoustic surveys have been conducted in Iliamna Lake during the summer field season to estimate the distribution and relative density of juvenile sockeye salmon and sticklebacks. Since most of the Age 0 and Age I juvenile salmon are located in close proximity to the surface during August in Bristol Bay lakes, they are largely inaccessible for acoustic assessment. There are indications that during some years Age I juvenile sockeye salmon are deeper in the water column during the early part of the summer. During these times it may be possible to realistically assess the relative densities of Age I juvenile sockeye salmon.

The hydroacoustic surveys conducted in Iliamna Lake during the 1974 field season showed the expected very low densities of juvenile salmon.

Regional Surveys of Resident Fish

Through the course of conducting regional acoustic surveys in Iliamna Lake numerous distinct resident fish populations have been observed. The most prominent stock in terms of total biomass is distributed throughout the western and central limnetic portions of Iliamna Lake.

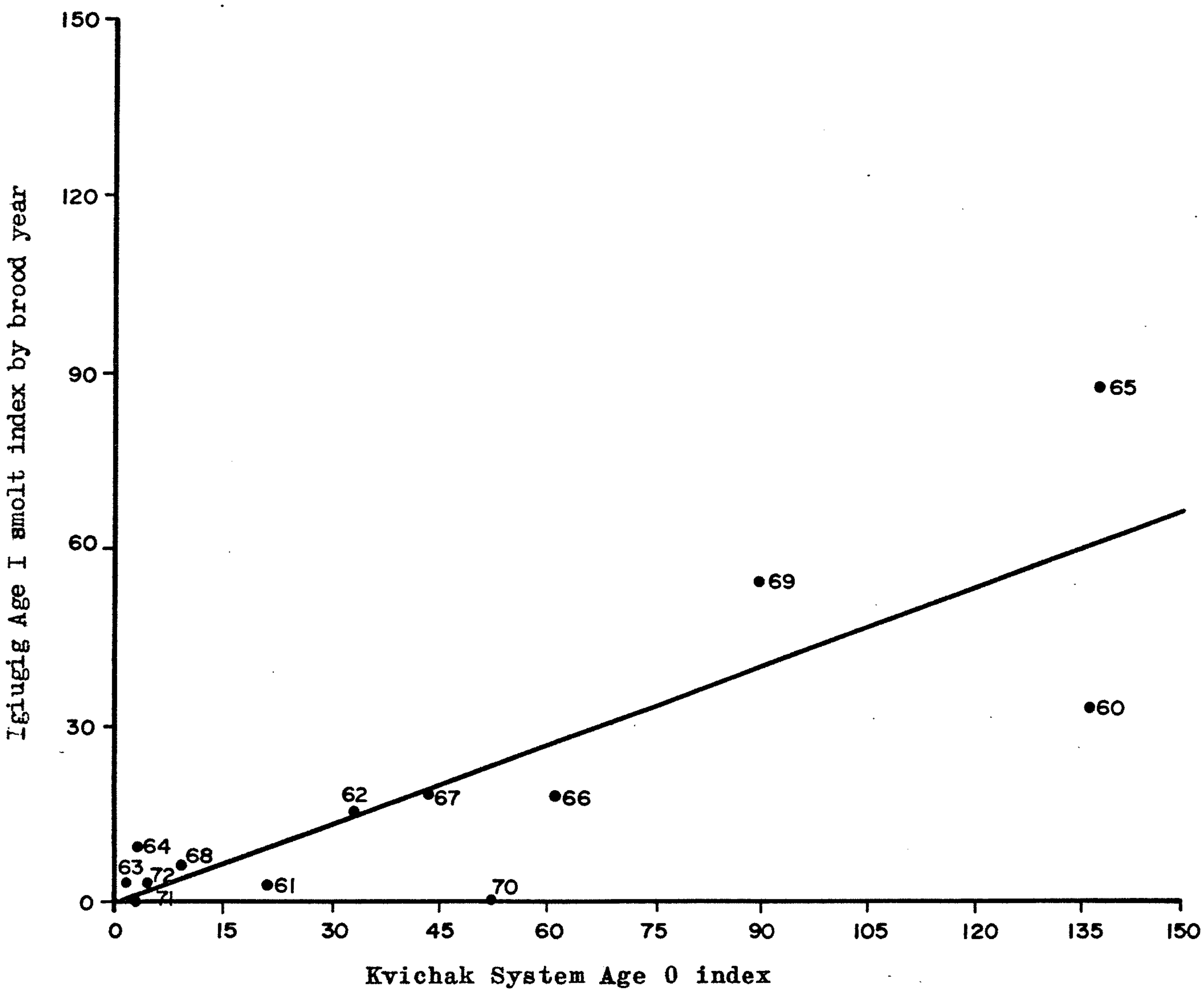

Fig. 45. Regression line of the Igiugig Age I smolt index by brood year on preceding Kvichak System Age 0 tow net index, brood years 1960-1972 (dates on graph represent brood years). The equation for the regression line is $y = -1.56762 + .44458X$.

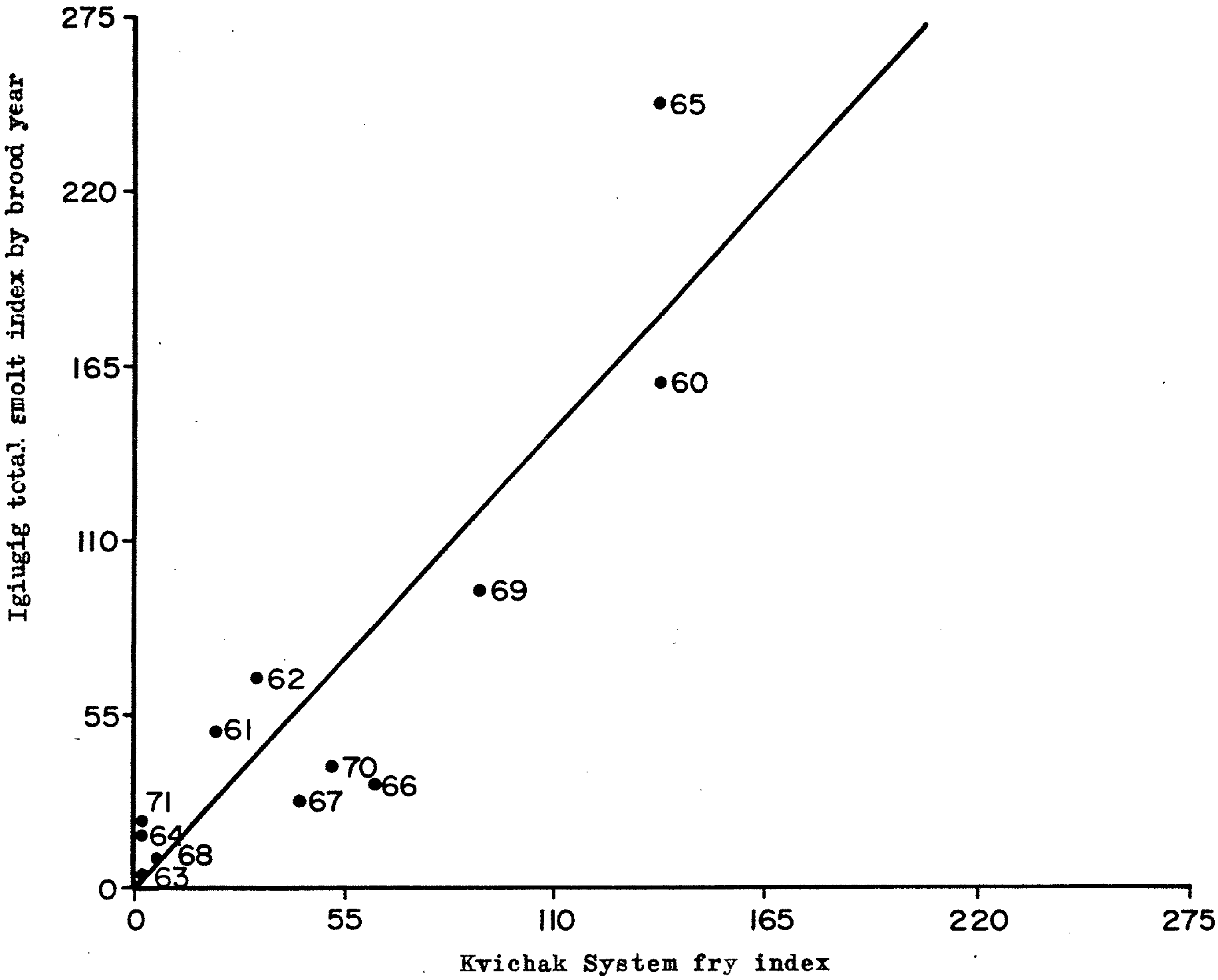

Fig. 46. Regression line of the Igiugig total smolt index by brood year on preceding Kvichak System fry index, brood years 1960-1971 (dates on graph represent brood years). The equation for the regression line is y = -2.65859 + 1.33076X.

Table 33. Abundances, sizes, and relative production of juvenile salmon in freshwater and adult escapements, total inshore returns, returns per indexed smolt ratio, and returns per spawner ratio for sockeye salmon of the Kvichak River system, brood years 1952 through 1973

Brood year	Index of abundance: By tow net[1] Age O	Index of abundance: By tow net[1] Age I	Index of abundance: By fyke net[2] Age I	Index of abundance: By fyke net[2] Age II	Index of abundance: By fyke net[2] Total	Average length (mm): By tow net[3] Age O	Average length (mm): By tow net[3] Age I	Average length (mm): By fyke net Age I	Average length (mm): By fyke net Age II	Escapement x 10^6	Relative production: By tow net Mean catch Age O per million spawners	Relative production: By fyke net Total smolt index per million spawners	Adult return: Total inshore return x 10^6	Adult return: Ret./smolt (indexed)	Adult return: Ret./spawn
1952				7.3					109.0	5.97			15.6		2.[illegible]
1953			0.6	1.4	2.0			89.0	116.0	.32		6.25	0.5	7.9	1.[illegible]
1954			0.9	0.3	1.2			92.0	120.0	.24		5.00	0.7	19.3	3.1
1955			0.7	2.0	2.7			96.0	114.0	.25		10.80	1.3	14.4	5.1
1956			98.0	83.3	181.3			84.0	99.0	9.44		19.21	33.1	5.5	3.5
1957			2.6	16.6	19.2			80.0	108.0	2.96		6.49	3.6	5.7	1.3
1958			1.8	0.3	2.1			91.0	117.0	.53		3.96	0.3	3.5	0.5
1959			0.8	2.2	3.0			92.0	110.0	.68		4.41	0.5	5.1	0.7
1960	137.0	79.7	33.9	123.5	157.4		89.9	82.0	98.0	14.63		10.76	48.9	9.3	3.3
1961	21.7	10.3	3.4	48.1	51.5	55.1	97.6	83.0	108.0	3.71	5.84	13.88	3.1	1.8	0.8
1962	32.4	19.2	13.7	52.4	66.1	58.4	95.8	87.0	109.0	2.58	12.56	25.62	4.8	2.2	1.9
1963	1.4	2.6	1.9	0.7	2.6	55.5	108.6	90.0	114.0	.34	4.11	7.65	0.9	9.7	2.5
1964	3.7	0.9	7.6	6.7	14.3	62.7	112.0	94.0	118.0	.96	3.85	14.90	4.9	10.3	5.1
1965	137.7	68.7	86.0	164.2	250.2	53.3	89.9	86.0	104.0	24.33	5.66	10.28	40.1	4.8	1.7
1966	62.0	20.4	19.4	16.2	35.6	60.8	109.6	88.0	109.0	3.78	16.40	9.42	5.6	4.7	1.5
1967	43.0	3.3	17.8	9.0	26.8	64.1	98.2	92.0	110.0	3.22	13.35	8.32	1.3	1.5	0.1
1968	9.4	5.5	5.6	3.7	9.3	58.1	100.8	91.0	111.0	2.56	3.67	3.63	0.4	1.2	0.2
1969	90.7	19.3[5]	54.1	42.2	96.3	63.2	92.8	90.0	106.0	8.39	10.61	11.48	5.6	1.7[4]	0.6
1970	52.6[5]	19.4	0.3	35.9	36.2	45.9	74.0	80.0	97.1	13.94	3.77	2.60			
1971	3.7	1.9[5]	1.3	18.0	19.3	52.4	100.6	85.6	115.0	2.39	1.54	8.08			
1972	5.0[5]	0.5[5]	1.5			57.5	112.3	93.0		1.01	4.95				
1973	3.8[5]					68.1				.23	16.52				

[1] FRI weighted mean catches of juvenile sockeye salmon Age O and Age I per standard tow.
[2] ADF&G Igiugig 24-hr indices of smolt abundance (one index point = 33,340 smolts).
[3] Lengths adjusted to September 1.
[4] Estimated returns of six year-old fish determined from average percentage that returned after six years in past years.
[5] Indices estimated from incomplete towing.

During the 1974 field season this population was identified from mid-water trawl catches as pygmy whitefish (Coregonus coulteri). The areal distribution in August was mapped from acoustic transects run orthogonal to the longitudinal axis of the lake (Fig. 47). In regions of highest concentration a maximum density of 75 fish/10^3m^3 was calculated and the fish were generally stratified between depths of 20 m and the bottom which usually does not exceed 45 m.

The pygmy whitefish must be important in the trophic system of Iliamna Lake. They are a small, abundant primary carnivore and consequently must be an important food source for the secondary carnivores such as lake trout (Salvelinus namaycush) and Arctic char (Salvelinus alpinus) which have been sampled by horizontal gill nets in areas of high pygmy whitefish concentration. In addition, rainbow trout (Salmo gairdneri) may also utilize pygmy whitefish during periods of their lake residency.

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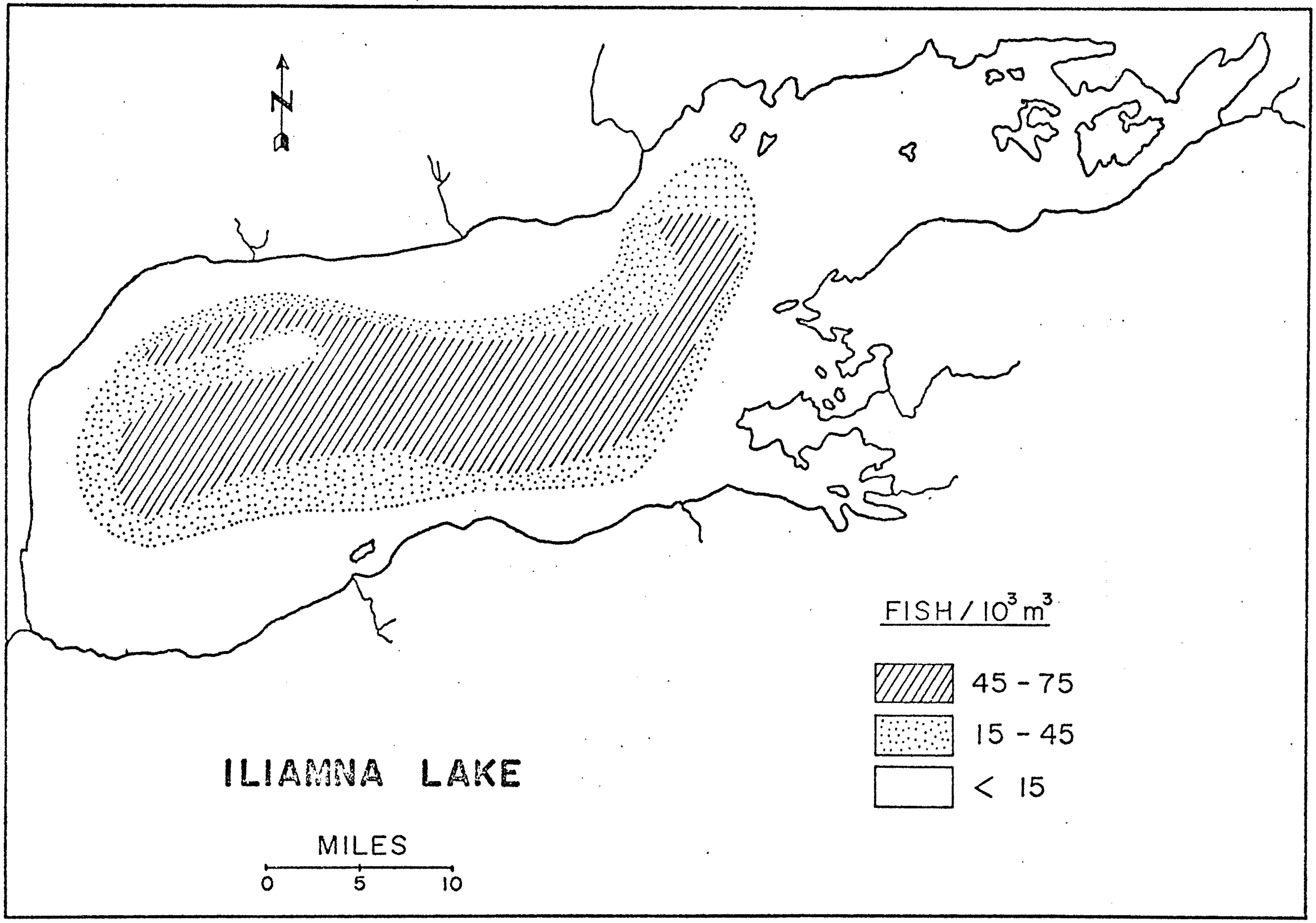

Fig. 47. Pygmy whitefish distribution and density in Iliamna Lake during August, 1974.

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APPENDICES

Appendix A. Standing crop of zooplankton (geometric means in number/m^3) by sampling period and lake section, and weighted lake mean[1] (in number/m^3) total zooplankton, Iliamna Lake, 1963-1974

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
JUNE												
1	1,938	7,394	6,900	7,294	5,495	6,335	6,614	6,770	3,383	5,080	*	*
2	2,755	6,308	5,663	7,570	4,776	6,875	5,039	6,109	3,950	4,259	*	*
3	2,048	4,078	4,407	5,210	4,086	4,293	4,695	8,744	2,778	2,851	*	*
4	1,802	874	4,137	4,137	3,051	5,409	2,676	5,320	2,494	2,545	6,336	*
Lake mean	2,155	5,174	5,430	6,269	4,534	5,704	5,072	7,013	3,210	3,827	X	*
JULY												
1	8,394	10,583	7,043	11,377	8,163	10,945	8,138	*	*	*	9,318	*
2	5,794	9,015	6,161	13,183	7,179	8,621	8,101	*	*	*	12,786	*
3	5,351	5,986	5,408	6,546	4,529	5,889	5,222	*	3,547	*	4,928	*
4	5,410	3,978	4,269	8,720	1,982	3,778	4,140	*	3,375	*	5,018	7,773
Lake mean	6,385	7,835	5,925	9,950	5,918	7,788	6,659	*	X	*	8,206	X
AUGUST												
1	8,513	9,025	11,186	13,828	9,015	8,730	11,052	10,428	8,463	14,107	12,629	16,447
2	9,141	7,853	10,011	10,762	6,774	8,537	8,097	10,987	6,915	15,977	11,620	17,722
3	6,931	8,027	6,015	7,159	6,651	8,301	6,315	10,454	5,015	8,521	7,338	12,749
4	4,336	2,853	4,429	5,907	4,448	6,021	4,861	6,490	4,532	8,069	8,752	10,741
Lake mean	7,888	7,552	8,336	9,881	7,081	8,166	7,976	10,017	6,455	11,983	10,190	14,808
SEPTEMBER												
1	*	*	*	*	*	*	*	*	*	*	*	11,703
2	*	*	*	*	*	*	*	*	*	*	*	9,496
3	*	*	*	*	*	*	*	*	4,838	*	8,043	9,145
4	*	*	*	*	*	*	*	*	4,861	*	7,456	6,727
Lake mean	*	*	*	*	*	*	*	*	X	*	X	9,660

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

* Data not taken.

X Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963- Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964- Vertical samples were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974- Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix A. Geometric means (number/m^3) by sampling period and Iliamna Lake section, and weighted lake mean (in number/m^3) Cyclops scutifer Sars, Iliamna Lake, 1963-1974 regional sampling rounds

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
						JUNE						
1	1,264	5,633	4,371	5,059	3,970	4,678	4,687	4,695	2,167	3,106	*	*
2	1,777	4,972	4,044	5,574	3,747	4,039	3,572	4,429	3,194	2,802	*	*
3	1,160	2,746	3,101	3,868	3,486	3,613	3,964	6,951	2,492	2,115	*	*
4	1,143	632	2,960	3,078	2,746	4,608	2,336	4,378	2,382	2,200	5,023	*
Lake mean	1,341	3,866	3,697	4,537	3,592	4,180	3,854	5,284	2,552	2,595	X	*
						JULY						
1	2,877	7,857	4,370	6,878	4,183	3,770	4,205	*	*	*	3,924	*
2	2,520	6,636	3,622	8,227	2,105	2,616	3,941	*	*	*	4,619	*
3	2,509	4,610	3,665	4,723	2,585	3,487	3,697	*	3,263	*	2,508	*
4	3,672	3,332	2,870	4,018	1,426	2,791	3,182	*	3,140	*	3,416	4,390
Lake mean	2,787	5,908	3,754	6,138	2,785	3,258	3,837	*	X	*	3,585	X
						AUGUST						
1	1,740	4,718	4,602	5,703	2,268	1,540	3,730	2,147	5,196	5,601	2,630	6,489
2	1,952	4,422	4,292	4,298	744	1,291	2,305	1,750	4,449	5,423	2,545	5,173
3	904	5,107	2,625	3,328	2,485	1,864	2,733	2,823	3,599	5,526	2,276	5,368
4	631	2,030	2,508	3,657	1,922	2,642	2,726	2,986	2,941	6,222	2,869	5,740
Lake mean	1,376	4,385	3,616	4,330	1,910	1,735	2,927	2,377	4,197	5,622	2,533	5,710
						SEPTEMBER						
1	*	*	*	*	*	*	*	*	*	*	*	3,830
2	*	*	*	*	*	*	*	*	*	*	*	2,679
3	*	*	*	*	*	*	*	*	2,949	*	1,844	3,034
4	*	*	*	*	*	*	*	*	3,014	*	1,903	2,960
Lake mean	*	*	*	*	*	*	*	*	X	*	X	3,176

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

*Data not taken.

X Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963 - Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964 - Vertical hauls were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974 - Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix A. Geometric means (number/m^3) by sampling period and Iliamna Lake section, and weighted lake mean[1] (in number/m^3) *Bosmina coregoni*, Iliamna Lake, 1963-1974

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
					JUNE							
1	168	275	454	731	296	392	160	533	119	439	*	*
2	191	204	279	535	139	392	128	396	195	309	*	*
3	119	93	275	307	38	94	57	359	80	167	*	*
4	23	11	224	232	21	106	27	61	56	69	189	*
Lake mean	133	164	323	480	138	259	101	378	117	270	X	*
					JULY							
1	2,913	749	1,240	2,946	2,030	3,907	1,186	*	*	*	2,497	*
2	1,603	577	1,103	3,194	1,701	2,610	1,158	*	*	*	4,492	*
3	768	213	743	1,100	390	694	395	*	142	*	853	*
4	112	76	587	874	42	231	195	*	160	*	585	361
Lake mean	1,528	445	960	2,142	1,174	2,070	794	*	X	*	2,210	X
					AUGUST							
1	3,012	2,810	4,033	5,014	2,936	3,934	4,357	6,021	1,361	5,520	5,874	4,215
2	4,525	1,707	3,026	4,303	2,950	4,698	3,070	6,618	877	7,256	4,624	5,789
3	2,819	823	2,187	2,680	1,760	4,077	1,745	5,088	399	1,686	3,179	3,469
4	821	103	1,009	1,424	897	1,945	659	2,021	342	699	3,178	1,896
Lake mean	3,016	1,538	2,784	3,606	2,286	3,886	2,705	5,313	799	4,078	4,348	4,044
					SEPTEMBER							
1	*	*	*	*	*	*	*	*	*	*	*	4,135
2	*	*	*	*	*	*	*	*	*	*	*	3,403
3	*	*	*	*	*	*	*	*	1,004	*	3,933	3,263
4	*	*	*	*	*	*	*	*	666	*	3,631	2,040
Lake mean	*	*	*	*	*	*	*	*	X	*	X	3,387

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

[*] Data not taken.

[X] Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963 - Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964 - Vertical hauls were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974 - Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix A. Geometric means (number/m^3) by sampling period and Iliamna Lake section, and weighted lake mean (in number/m^3) Holopedium gibberum Zaddach, Iliamna Lake, 1963-1974 regional sampling rounds

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
					JUNE							
1	0	2	393	4	280	34	299	386	2	362	*	*
2	0	1	77	38	192	142	266	196	3	199	*	*
3	3	0	42	8	81	9	97	114	1	2	*	*
4	0	0	1	7	9	1	9	17	1	1	0	*
Lake mean	1	1	151	14	158	48	187	202	2	159	X	*
					JULY							
1	341	240	13	135	427	634	1,172	*	*	*	590	*
2	129	37	26	200	1,013	938	1,029	*	*	*	597	*
3	85	4	11	44	161	177	152	*	10	*	52	*
4	11	5	11	26	15	6	81	*	5	*	14	139
Lake mean	163	83	15	107	431	479	666	*	X	*	343	X
					AUGUST							
1	697	244	276	641	730	811	1,272	588	207	1,197	1,487	1,248
2	564	241	207	407	545	376	799	502	146	1,544	1,453	1,967
3	603	208	105	95	285	330	221	281	44	338	350	978
4	53	33	110	37	211	136	86	77	8	23	331	410
Lake mean	544	202	182	328	473	459	661	399	113	850	962	1,223
					SEPTEMBER							
1	*	*	*	*	*	*	*	*	*	*	*	128
2	*	*	*	*	*	*	*	*	*	*	*	41
3	*	*	*	*	*	*	*	*	55	*	196	32
4	*	*	*	*	*	*	*	*	25	*	151	14
Lake mean	*	*	*	*	*	*	*	*	X	*	X	61

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

*Data not taken.

X Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963 - Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964 - Vertical hauls were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974 - Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix A. Geometric means (number/m^3) by sampling period and Iliamna Lake section, and weighted lake mean (in number/m^3) <u>Daphnia longiremis</u> Sars, Iliamna Lake, 1963-1974

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
					JUNE							
1	41	20	300	135	83	92	19	34	91	24	*	*
2	68	13	233	158	69	147	20	60	43	2	*	*
3	62	2	143	106	30	40	11	111	49	3	*	*
4	41	2	112	53	4	19	10	55	18	2	106	*
Lake mean	54	10	208	120	52	79	15	68	56	9	X	*
					JULY							
1	339	176	353	391	252	689	143	*	*	*	738	*
2	216	110	264	437	469	769	182	*	*	*	1,031	*
3	413	54	229	190	148	234	50	*	60	*	289	*
4	103	3	124	140	23	74	64	*	17	*	216	602
Lake mean	298	97	260	305	241	431	113	*	X	*	597	X
					AUGUST							
1	724	214	890	931	886	1,132	263	295	565	353	1,304	1,354
2	640	220	1,085	752	915	868	236	432	507	300	1,285	1,645
3	1,259	232	429	371	509	743	217	614	159	90	550	879
4	760	17	253	221	380	402	167	327	124	41	820	936
Lake mean	874	193	705	613	705	843	228	432	362	214	997	1,219
					SEPTEMBER							
1	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	1,172
3	*	*	*	*	*	*	*	*	*	*	*	1,131
4	*	*	*	*	*	*	*	*	226	*	962	548
									252	*	719	440
Lake mean	*	*	*	*	*	*	*	*	X	*	X	877

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

[*] Data not taken.

[X] Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963 - Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964 - Vertical hauls were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974 - Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix A. Geometric means (number/m^3) by sampling period and Iliamna Lake section, and weighted lake mean (in number/m^3) Calanoid Copepods (*Diaptomus gracilis* Sars and *Eurytemora yukonensis* Wilson), Iliamna Lake, 1963-1974 regional sampling rounds

Lake section	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
						JUNE						
1	415	1,263	1,296	1,218	705	329	1,308	823	892	837	*	*
2	620	956	964	1,116	519	1,216	942	730	998	749	*	*
3	436	1,143	722	846	347	421	481	1,016	650	440	*	*
4	495	176	778	725	178	545	231	688	338	155	686	*
Lake mean	484	996	963	1,008	473	607	809	841	765	596	X	*
						JULY						
1	1,086	1,405	957	740	557	1,272	1,058	*	*	*	1,171	*
2	776	1,201	806	828	777	935	1,174	*	*	*	1,392	*
3	944	966	656	409	719	623	568	*	728	*	921	*
4	1,244	468	563	650	334	280	489	*	420	*	539	781
Lake mean	988	1,086	771	646	630	847	854	*	X	*	1,059	X
						AUGUST						
1	612	673	1,064	951	1,415	890	800	1,005	1,111	990	733	1,148
2	744	927	869	680	1,077	306	921	1,179	759	063	769	1,168
3	546	1,266	500	469	1,377	907	859	1,053	509	631	579	768
4	996	521	389	403	868	646	749	780	395	526	917	677
Lake mean	679	898	745	657	1,242	840	841	1,031	736	806	720	968
						SEPTEMBER						
1	*	*	*	*	*	*	*	*	*	*	*	1,016
2	*	*	*	*	*	*	*	*	*	*	*	952
3	*	*	*	*	*	*	*	*	454	*	791	803
4	*	*	*	*	*	*	*	*	619	*	639	508
Lake mean	*	*	*	*	*	*	*	*	X	*	X	862

[1] Section values weighted by the percentage of the total lake volume represented by the section volume.

[*] Data not taken.

[X] Data insufficient for determination of lake mean.

Data source: FRM 298 computer output, Iliamna Lake zooplankton.

Notes on methods of sampling:

(1) 1963 - Vertical hauls were taken from 30 m to the surface or the bottom to the surface if the station depth was less than 30 m.

(2) 1964 - Vertical hauls were taken from the bottom to the surface or 40 m to the surface if the station was deeper than 40 m.

(3) 1965-1974 - Vertical hauls were taken from the bottom to the surface or 100 m to the surface if the station was deeper than 100 m.

Appendix B. Calculation of Section 2 indexes for juvenile salmon and threespine sticklebacks, Iliamna Lake, 1965.

	Percentage of Iliamna Lake index contained in lake sections 1 + 3 - 11									
	1962	1963	1964	1966	1967	1968	1969	1970	1972	Mean %
Fry (Age 0)	93.6	91.5	97.4	99.5	90.0	97.8	99.2	99.0	100.0	96.5
Yearlings (Age I)	60.1	96.4	97.3	95.0	82.9	98.3	97.5	97.5	100.0	91.
Sticklebacks (3-spine)	95.3	99.0	99.8	98.4	96.4	99.5	99.8	99.2	100.0	98.

The 1965 indexes for each species were then expanded accordi to the equation:

$$\text{Estimated total index} = \frac{\text{Observed index Sections } 1 + 3 - 11}{\text{Mean \% from sectio } 1 + 3 - 11}$$

Appendix B. Calculation of 1971 indexes for each species.

	Percentage of Iliamna Lake index contained in lake sections 6 - 9									
	1962	1963	1964	1965	1966	1967	1968	1969	1970	Mean %
Fry	33.5	8.8	48.0	11.5	87.7	36.4	33.4	78.6	66.4	44.9
Yearlings	10.6	8.0	20.2	27.6	24.9	43.4	1.0	48.1	66.4	27.
Sticklebacks	14.8	17.8	20.9	0.8	32.6	42.1	5.4	47.3	17.6	22.

The 1971 second round indexes for each species were then expanded according to the equation:

$$\text{Estimated total index} = \frac{\text{Observed index sections } 6-}{\text{Mean \% from sections } 6-9}$$

Appendix B. Calculation of 1973 indexes for juvenile sockeye salmon and threespine sticklebacks from incomplete towing of Iliamna Lake.

	Percentage of Iliamna Lake index contained in lake sections 3-11										
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1972	Mean
Fry	91.8	91.4	93.6	78.1	98.0	89.4	94.6	98.2	98.6	100.0	93
Yearlings	56.5	96.4	96.9	91.6	95.0	80.2	97.3	98.0	97.5	99.5	90
Sticklebacks	94.9	99.0	78.2	98.4	98.3	94.9	99.3	99.7	98.6	100.0	96

The 1973 indexes for each species were then expanded accord to the equation:

$$\text{Estimated total index} = \frac{\text{Observed index sections } 3 - 1}{\text{Mean \% from sections } 3 - 11 \text{ f years of complete towing}}$$

Appendix B. **Calculation of 1974 indexes of juvenile sockeye salmon and threespine sticklebacks from incomplete towing of Iliamna Lake**

Fish species	Percentage of Iliamna Lake index contained in lake sections 2-11 (for years of complete towing + 1965)										Mean %
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1972	
Sockeye Fry	98.2	99.9	96.1	81.7	98.4	99.4	96.8	99.0	99.6	100.0	96.9
Yearlings	96.4	100.0	99.7	100.0	100.0	97.3	99.0	100.0	100.0	100.0	99.2
Sticklebacks	99.6	100.0	78.4	99.8	99.9	98.6	99.8	99.9	99.4	100.0	97.5

The 1974 indexes for each species were then expanded according to the equation:

$$\text{Estimated total index} = \frac{\text{Observed index sections 2-11}}{\text{Mean \% from sections 2-11 for years of complete towing + 1965}}$$