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FERTILIZATION OF LITTLE TOGIAK LAKE

by

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FINAL REPORT

For the Period April 10, 1975 to April 15, 1976
Alaska Department of Fish and Game

Approved

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Robert L. Burgner
Director

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FERTILIZATION OF LITTLE TOGIAK LAKE

Final Report for the Period April 16, 1975 to April 15, 1976

INTRODUCTION

The Wood River lake system is the major producer of sockeye salmon in the Nushagak District of Bristol Bay. The catches in the Nushagak have declined greatly since the initial buildup of the fishery in the late 1800's. The most recent decline, from an annual average catch of near 3 million (1919-1948) to just under 1 million (1949-present), occurred when five successive brood years with above average escapements (1944-1948) produced very small returns.

The Fisheries Research Institute has been investigating the sockeye salmon populations in the Nushagak since 1946. Our major concern has been with identifying the factors which limit or control the production of salmon from the Wood River lakes. We have identified freshwater growth of juveniles as one important controllable factor in the production of adult salmon and this report is concerned with the use of artificial fertilization to increase the growth of juveniles by increasing their food supply.

Three fertilization experiments had been conducted in the Wood River lakes prior to 1975. Two of these resulted in significant increases in primary production; however, the effect on fish growth could not be evaluated because of the small size of the areas fertilized relative to the distribution of fish. We originally proposed to fertilize all of Little Togiak Lake in 1975 so that we could better evaluate the effect on fish growth; but the Alaska Department of Fish and Game requested (1) that we wait until 1976 to do this, and (2) that we collect another year of baseline data in Little Togiak Lake. Subsequent to our proposal to ADF & G on March 21, 1975 we received permission to add a smaller amount of fertilizer to the upper end of Little Togiak Lake in 1975 than we had added in 1974.

Our objectives in 1975 were:

(1) Construct a cold-weather facility at the Lake Nerka station (near Little Togiak Lake).

(2) Measure the abundance, age composition, and size of smolts migrating from Little Togiak Lake.

(3) Enumerate the adult escapement into Little Togiak Lake and compare to aerial estimate by ADF & G.

(4) Continue measurements of chlorophyll, zooplankton, insects, and fish abundance and size in Little Togiak Lake.

(5) Evaluate effect of fertilization in upper end of Little Togiak Lake in 1974 on food supply and fish growth during 1975.

A progress report was submitted to ADF & G on October 30, 1975. That report presented summaries of statistics on physical measurements (e.g., water temperature and solar radiation), abundance of emergent insects, density of chlorophyll, volume of zooplankton, and the abundance and size of fish from beach seine sampling. This final report is being prepared two months prior to the end of the contract period as requested by ADF & G; thus there has been a limited time for analysis of the data collected in 1975. This report presents summaries of data not included in the progress report and tentative conclusions regarding our objectives for 1975-1976.

METHODS

The spring of 1975 was colder than average and ice breakup was late. We opened up the Nerka camp on June 16. Ice breakup on Little Togiak Lake occurred on June 15, although some ice remained on the upper end of the lake until June 20. We began construction of a new cabin about June 21 and work was nearly completed by mid-July. This occupied much of our effort in the early summer.

Insect traps were placed in the lake at five stations as soon as they were clear of ice. The traps were checked at two-three day intervals until the end of September. Limnological measurements were begun on June 20 and were continued at about one-week intervals until October 2. Water temperature was measured from 60 m to the surface at three stations (Nos. 1, 3, and 5 in Fig. 1), chlorophyll was measured at two stations (Nos. 1 and 5), and zooplankton (vertical hauls from 60 m or lake bottom, 1/2-m net of No. 6 mesh) and secchi depth were measured at six stations.

The abundance of benthic organisms was measured near insect traps Nos. 1 and 7. A weighted Ekman sampler with an opening of 225 cm^2 was used to collect samples from about 3, 5, 10, and 15 m at approximately two-week intervals between June 21 and September 26.

The relative abundance and average size of fish in the littoral zone during the early summer was measured from beach seine hauls at seven stations. Hauls were made at weekly intervals between June 27 and July 31. The relative abundance and size of pelagic fish was measured from tow-net sampling conducted druing the nights of August 16 and 30. Nine 5-min tows were made each night between limnology stations 1 and 6.

Sockeye salmon smolts migrating out of Little Togiak Lake were sampled during the spring with a 9 x 9-ft tow net that was used as a fyke net in Little Togiak River. The net was fished every other night between June 22 and July 9. Arctic char were also caught by hook and line fishing in Little

Togiak River and their stomach contents were examined. Length and weight were measured and the number of juvenile sockeye (fry and smolts) in the stomachs were counted.

A commercial fertilizer, diammonium phosphate, was added to the upper end of Little Togiak Lake in mid-August (Fig. 2). The fertilizer was dissolved in water and then sprayed over the surface from a moving boat. Applications were made on August 13 (400 lb), August 17 (300 lb), and August 20 (300 lb). The total amount added in 1975 was one-third of the amount added between August 13 and 29, 1974.

We planned to continue field work through October and to make three or four trips to sample during the winter; however, we had to terminate field work in early October because of a lack of funds. Costs for supplies, materials for the new cabin, and freight costs were underestimated in the budget.

RESULTS

Sockeye Smolts from Little Togiak

Samples of smolts migrating out of Little Togiak Lake were collected in 1954-1957, 1961, and 1973-1975 (Tables 1 and 2). An estimate of the total number of smolts was made only in 1961 (Tables 3 and Aspinwall 1963). Smolts begin migrating out of Little Togiak about the time of ice breakup and reach the outlet of the lake system, a distance of about 40 miles, in approximately 11 days (Burgner 1962). In 1961, the majority of the smolts from Little Togiak Lake had migrated out of the lake during the first 20 days following breakup and they probably migrated out of the lake system during June 21 to July 6 (Fig. 3). The total abundance of sockeye in Little Togiak Lake is small relative to the populations in the other, much larger, lakes of the system and the smolts migrating out of Little Togiak probably become mixed with smolts from the upper lakes (Beverley and Kulik) during their migration through Lakes Nerka and Aleknagik.

The size of age I smolts migrating out of Little Togiak tends to decrease from the beginning of the migration to the peak and then increase towards the end of the migration (Fig. 4). Also the larger age II smolts tend to migrate earlier than the age I fish. The samples of smolts collected in 1973 and 1974 were probably taken too late in the migration and thus did not include the true proportion of age II smolts in those migrations. Samples of the juveniles in Little Togiak Lake during 1972 and 1973 indicated a very high abundance of yearlings (Fig. 5).

The abundance of yearlings in Little Togiak Lake is directly related to the abundance of parent spawners and the size of yearlings is inversely related to the parent escapement (Fig. 6). Our estimates of the abundance of fry (age 0) in Little Togiak Lake from tow-net sampling are not as precise as the estimates of yearling abundance because of year-to-year variation in the inshore-offshore distribution of fry in this lake; however, size of fry in the lake is inversely related to parent escapement (Fig. 7). One result of the density-dependent growth in this lake is an older age of return for the progeny of large escapements (Fig. 8). An increase in growth rate would probably result in an earlier age of return and higher survival.

Of particular interest is the size of the smolts that migrated out of the lake in 1975 since we had added fertilizer in August of 1974. The area fertilized was very small relative to the total lake so we wouldn't expect a pronounced effect on fish growth. The age I smolts were above average in size in 1975, whereas these fish were well below average in size when they were fry in 1974 (Figs. 4 and 5). However, the size of the age I smolts in 1975 was about as expected from the relatively small parent escapement in 1973.

We do not have a direct estimate of the abundance of smolts in 1975 although the abundance appeared to be low from our relatively poor fishing success and as judged from the abundance of smolts found in char stomachs (Table 4). A correlation is evident between the number of smolts in char stomachs and the abundance of parent spawners after adjustment for time and method of sampling (Table 5). Our fishing success for char in Little Togiak River was very poor in 1975. This suggests that the abundance has declined since 1972. Note also, that the average size of char caught by hook and line has declined. However, the number of fish removed seems too small relative to the estimated population in 1972 to have had a significant effect on the abundance in and about the river.

Adult Escapement to Little Togiak Lake

The escapement into Little Togiak Lake was estimated by three methods in 1961: sample counting in the river, tag and recapture, and aerial survey. All three methods gave nearly identical results (Finn 1962 and Kim 1962). In all other years since 1946 estimates of the escapement have been made by aerial surveys. In 1975 we estimated the escapement into the lake by sample counting in the river to provide an additional comparison with the aerial method. The enumeration data are given in Table 6. Counts were made from a cliff overlooking the river for half-hour periods and then doubled to estimate the hourly totals.

The daily estimates are shown in Fig. 9 and the accumulative estimates in Fig. 10. About 99 percent of the fish migrated into the lake in a 7-day period (7/10-16) and almost 50 percent in two days (7/12-13). Our final estimate of the escapement (30,000) is believed to be much higher than the aerial estimate; however, a final aerial estimate is not presently available.

Samples from the beach spawning grounds in the lake indicated that 95 percent of the fish were five years old (from the 1970 brood year) and about 61 percent were age 2.2 (5_3). This agrees closely with the high abundance of yearlings in Little Togiak during 1972 and further indicates that our sampling of the smolts in 1973 missed the main migration.

Primary Productivity

The seasonal variation in the density of phytoplankton, as measured by chlorophyll a, was shown in the Progress Report (October 1975). In the spring of 1975 there was a greater bloom of phytoplankton than had occurred in the two previous years. Since water temperatures and solar radiation were generally less in the spring of 1975, the higher density of phytoplankton was attributed to a higher density of nutrients from both the fertilizer added in 1974 and the number of adult salmon which was about 3.5 times greater in 1974 than in 1972-1973.

The responses of the phytoplankton to fertilization in August were different in 1974 and 1975. There was an almost immediate two-fold increase in chlorophyll in the upper 10 m after the initial application of fertilizer in 1974 (960 lb) and a seven-fold increase by eight days later when 2,500 lb had been added. There was a 50 percent increase in the density of chlorophyll in the upper 10 m four days after 400 lb had been added in 1975. An additional 600 lb was added shortly thereafter and the density of chlorophyll remained at about the same level until our last measurement was made on October 2. At that time the density was twice as high as the density immediately prior to fertilization. The differences between the years were attributed to the different amounts of fertilizer and different amounts of solar radiation at the time of fertilization; both were lower in 1975.

Secchi depths indicated that the fertilizer affected phytoplankton outside the area of application, but only within the upper basin of the lake (Stations 1 and 2 in Area A).

The fertilizer was applied over a surface area of about 1 km^2 and the surface area in the upper basin is about 1.7 km^2 or about 28 percent of the surface area in the lake. Some phytoplankton samples were prescribed and we plan to identify species and make some cell counts during 1976.

Secondary Productivity

The purpose of artificial fertilization is to increase the food supply for juvenile sockeye, i.e., zooplankton and aquatic insects (primarily chironomids). The standing crop of these invertebrates is controlled by their rates of reproduction, growth, and mortality. The mortality rate is frequently determined by the abundance of their predators (primarily fish). For example, there is an inverse relationship between the abundance of juvenile sockeye and the late-summer abundance of zooplankton in Lake Aleknagik. As was the case with primary production, we are estimating secondary production from changes in standing crop with time, although the changes are the result of both reproduction and mortality.

Zooplankton

The abundance of zooplankton in Area A and Areas B and C combined are given as number per m^2 in Table 7. The seasonal abundances of the four major categories of zooplankton are shown in Figs. 11-14. The hauls in Area A were made from a depth of 20 m (maximum depth in this area is 25 m), whereas hauls in Area BC were made from an average depth of 55 m (maximum depth of 80 m). Observations from Lake Aleknagik are shown for comparison with Area BC of Little Togiak as the depth of hauls are similar.

Most cyclopoid copepods are predaceous, therefore any effect of fertilization on their abundance would have to be indirect, i.e., through an increase in smaller forms of zooplankton. The abundance of cyclopoids subsequent to fertilization did not appear to be significantly higher; however, considering the much greater abundance of fish in 1975 we would expect a much lower abundance of zooplankters in 1975 given that reproduction rates were similar in all years. Cyclopoids occur deeper in the water column than the other zooplankters and their life span is much greater. They are the dominant zooplankter in the early summer.

Calanoid copepods are generally most abundant in late summer or fall. Their peak abundance each year may well be after our sampling has terminated and we can see no increase in Area A that is attributable to fertilization. The same conlusion was reached concerning the abundances of Bosmina and Daphnia. The latter species is particularly vulnerable to fish predation as the very low abundance in 1975 attests.

The seasonal abundances of phytoplankton and herbivorous zooplankton are shown in Fig. 15. The peak abundance of zooplankton follows the peak abundance of phytoplankton in the spring by over one month. If the increased phytoplankton abundance in Area A during late-August to late-September was followed by a second peak in zooplankton abundance such a peak would occur in October after our sampling had terminated.

Bottom Fauna

The densities of the dominant bottom organisms near insect traps No. 1 (west end, Area A) and No. 5 (east end, Area C) are given in Table 8. Bottom samples were also collected at the three insect traps in the east end of Lake Aleknagik. These traps are located in rather shallow areas so the bottom samples were from depths of 3 to 4 m. The bottom fauna in the Wood River lakes is most abundant in shallow water and abundance declines with increasing depth. Below 25 m, the density is very low.

The densities of oligochaete worms in 1974-1975 are shown in Fig. 16. After fertilization in mid-August 1974, there was no apparent increase in the density of oligochaetes at the west end of Little Togiak; however, the densities at the beginning and end of the summer in 1975 were considerably greater in the area fertilized.

The density of gastropods increased nearly four-fold following the fertilization in 1974 but there was no comparable increase in 1975 (Fig. 17). Snails and worms are not major food items for juvenile sockeye in the Wood River lakes, but snails are a major food item for Arctic char and a minor item in the diet of threespine stickleback (Rogers 1968).

Chironomids (midges) are the major food items for juvenile sockeye and threespine stickleback during the early summer. They are generally more abundant in Lake Aleknagik than in Little Togiak Lake and, in the former lake, the early summer growth of sockeye fry is density dependent which implies a limited food supply (Rogers 1973). The density of chironomid larvae appeared to increase following fertilization in 1974 and was very high in the spring of 1975 (Fig. 18). The density was relatively high in the fertilized area at the end of September 1975 even with the much greater density of fish in that year.

Emergent Chironomids

Catches of emergent chironomids by 5-day periods during 1973-1975 in Little Togiak Lake are shown in Fig. 19. The average catches at trap No. 1 are greater than the average for all traps in the lake, but are considerably less than the average catches in Lake Aleknagik (Fig. 20). The seasonal patterns of emergence are also different in the two lakes. The emergence in Lake Aleknagik during 1975 was atypical of past years because of the high emergence following the late ice breakup. In previous years, an early emergence occurred only when there was an early and warm spring (e.g., 1970 and 1974). Ice breakup in 1975 was late yet the highest emergence occurred about 10 days after breakup.

The relative abundance of emergent chironomids in Little Togiak Lake was less in 1975 than in the previous two years. This again corresponds to the higher fish density in that year. Sockeye fry feed predominantly on the pupae and emergent adults, whereas threespine stickleback feed predominantly on the larvae.

Stomach contents of the sockeye salmon and other species will be examined to determine the amount and composition of food for fish caught in the fertilized and unfertilized areas of the lake. We are also working on the taxonomy of the chironomids. This is a complete group of organisms with a large number of species.

Fish Abundance and Size

Statistics from beach seine sampling were given in the progress report. We estimate the number of pelagic fish in each of the Wood River lakes from the tow-net catches and counts from echograms. This has been done each year since 1958 (Rogers 1975). At present we have not processed the echograms collected in 1975; however, the mean catches from the tow-net sampling are generally proportional to the estimated total abundance. The catch statistics for Little Togiak Lake in 1973-1975 are shown in Fig. 21, and a summary of catches from all of the lakes is given in Table 9.

The catches of sockeye fry in 1975 were particularly large in Lakes Beverley and Kulik. These lakes also had very large escapements in 1974. The escapement to Little Togiak was also high in 1974 and the beach-seine catches of fry were high in 1975 but the tow-net catches were lower than average. The fry in Little Togiak may have been concentrated inshore or below 3 m when we were sampling in the upper 3 m. After we process the echograms we should have a better estimate of their abundance. Catches of threespine stickleback were large throughout the lake system in 1975 and particularly large in Little Togiak Lake. The stickleback were primarily age I from the spawning in the spring of 1974.

Growth of sockeye fry was generally poor throughout the lake system in 1975 as a result of the large escapement in 1974 (1.7 million). Mean lengths are given in Table 10. Sockeye fry in Areas B and C of Little Togiak Lake were the smallest recorded since 1958. The fry in Area A were also small but were slightly larger than those in the other areas and on the average they are usually smaller in Area A. In past years when the parent escapement was above average (greater or equal to 20,000), the fry in Area A averaged 2.4 mm shorter than those in Area B and 4.0 mm shorter than those in Area C. If the relatively larger size of fry in Area A on September 1, 1975 was caused by fertilization, then it would have been mainly the fertilization in 1974. The fertilization in 1975 would more likely affect their growth after September 1.

There are, of course, some serious problems in estimating the growth of fish from changes in size with time, e.g., we must assume that we are sampling the same population in each area throughout the summer. Larger fish may move from Area A to Area B during the summer and emergence appears to be later in Area A than emergence from spawning grounds in the remainder of the lake. The time of spawning is also later on the spawning grounds at the west end of the lake. We are considering the use of RNA/DNA ratios to estimate the instantaneous growth of the fish. This measurement (a measure of protein synthesis) could provide a measure of growth immediately preceding the time that the fish was caught and thus provide us with a better measure of the possible effect of fertilization.

When we fertilize the entire lake or at least a much larger portion of the lake then we should be able to measure the effect on growth by measuring the size of smolts migrating out in the following spring.

SUMMARY

Diammonium phosphate was added to the upper end of Little Togiak Lake in August of 1974 and 1975 to determine whether artificial fertilization would increase productivity and hence fish growth.

We sampled the sockeye salmon smolts migrating from Little Togiak in the spring of 1975 and determined that they were primarily age I and were slightly above average in size. Their size was about as expected from the relatively low abundance of the parent spawners.

We estimated an escapement of 30,000 sockeye into Little Togiak in July 1975 by visual counts in the outlet river. Sampling on the spawning grounds indicated a predominance of 5-year-old fish (61 percent were age 2.2).

Fertilization greatly increased primary productivity in the west end of the lake as judged by the increase in chlorophyll density in the upper 10 m. We were not able to detect an increase in zooplankton abundance; however, there was a higher fish desnity in 1975 which probably reduced the standing crop in that year. Significant increases in the abundance of oligochaetes, gastropods, and chironomid larvae were indicated following fertilization. The size of sockeye fry in 1975 was small as a result of the large escapement in 1974. The fry in the fertilized area were also small, but not as small as in past years of high abundance. Their slightly larger size than expected may have been the result of fertilization. A larger area of the lake needs to be fertilized to fully evaluate the effect on fish growth.

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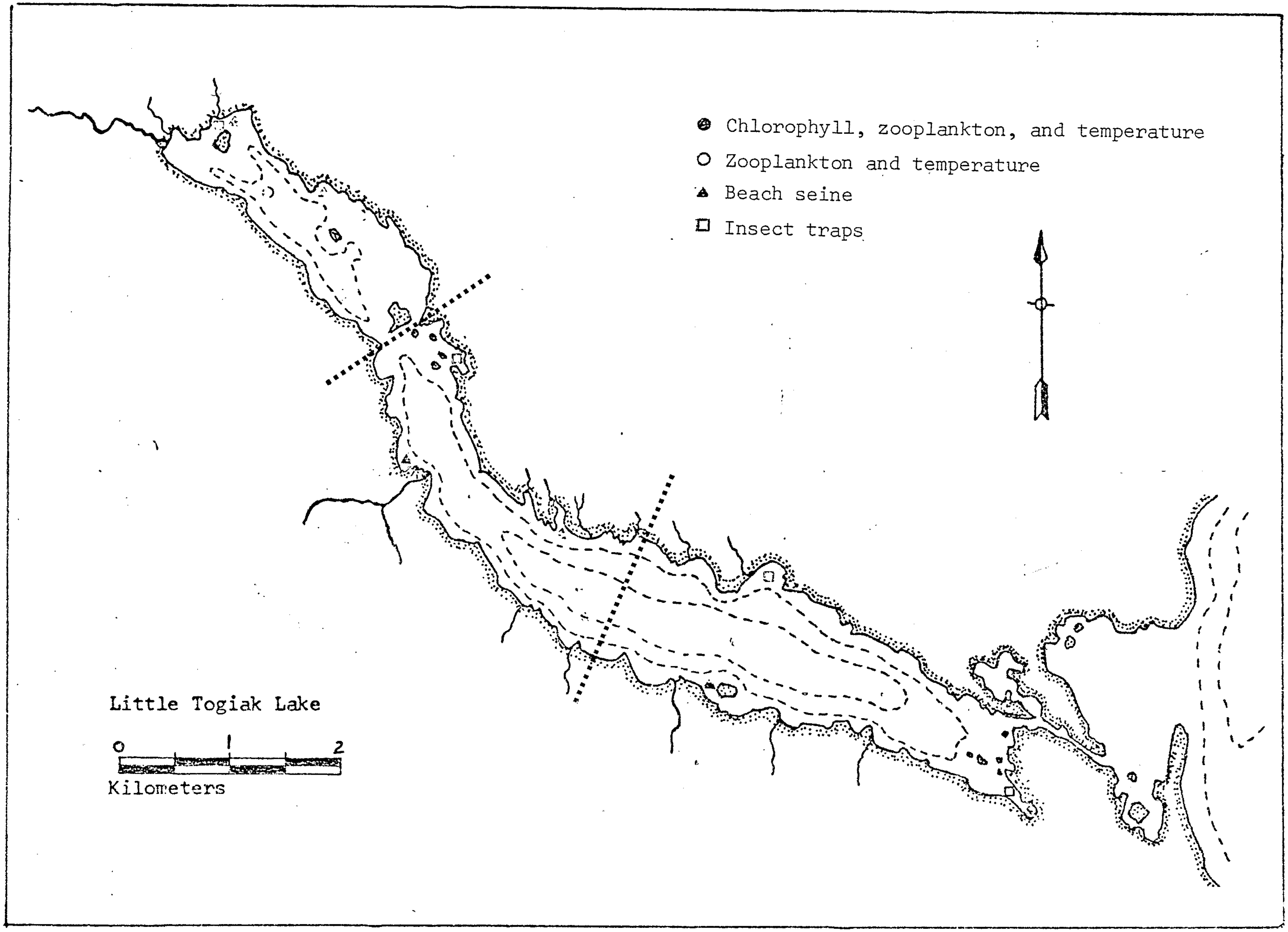

Fig. 1. Sampling stations in Little Togiak Lake. Depth contours at 20 m and 60 m indicated by dashed lines.

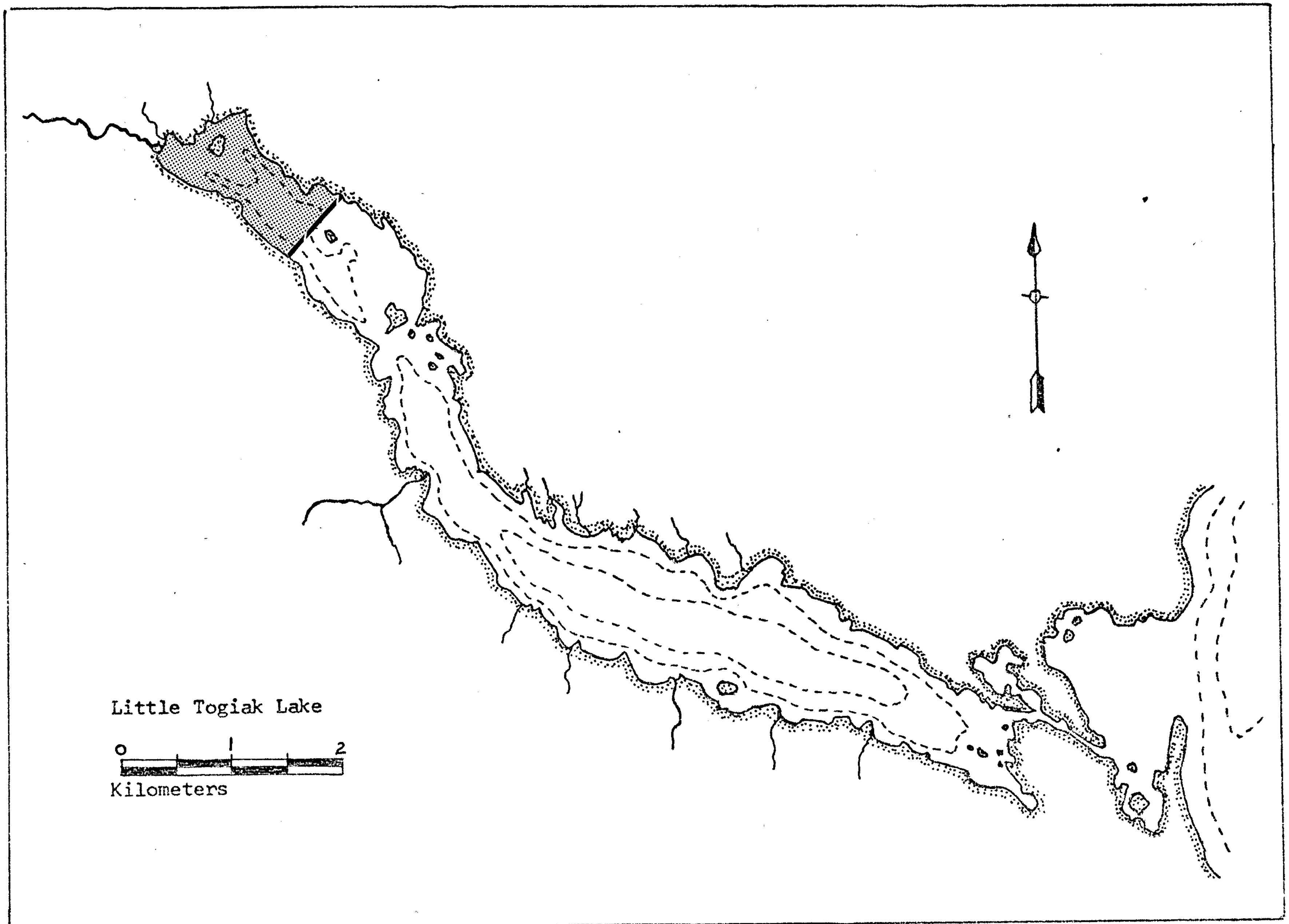

Fig. 2. Area in which fertilizer was added (shaded) in August of 1974 and 1975.

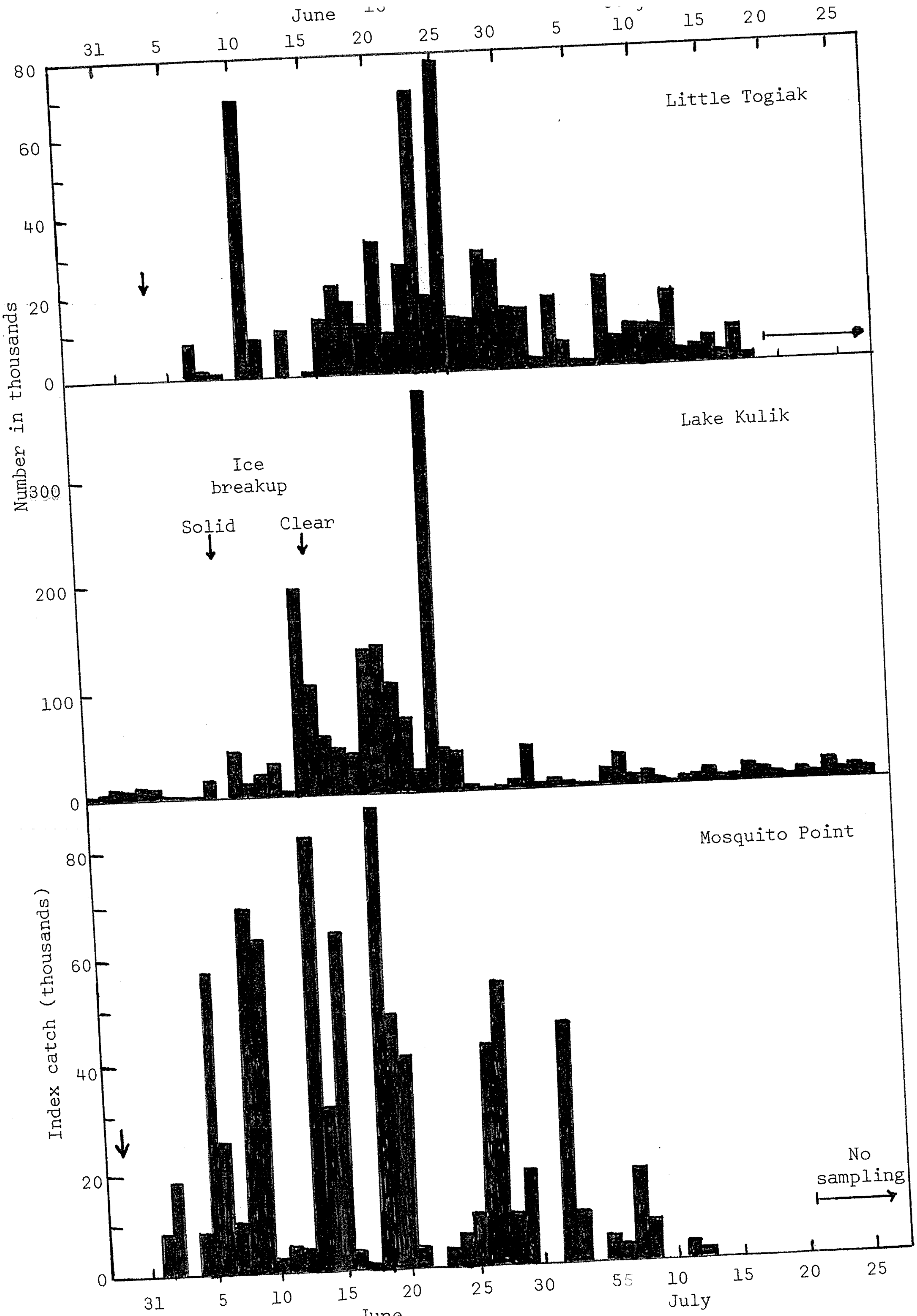

Fig. 3. Estimates of the daily smolt migrations from Little Togiak Lake, Lake Kulik, and Mosquito Point (outlet of lake system) in 1961.

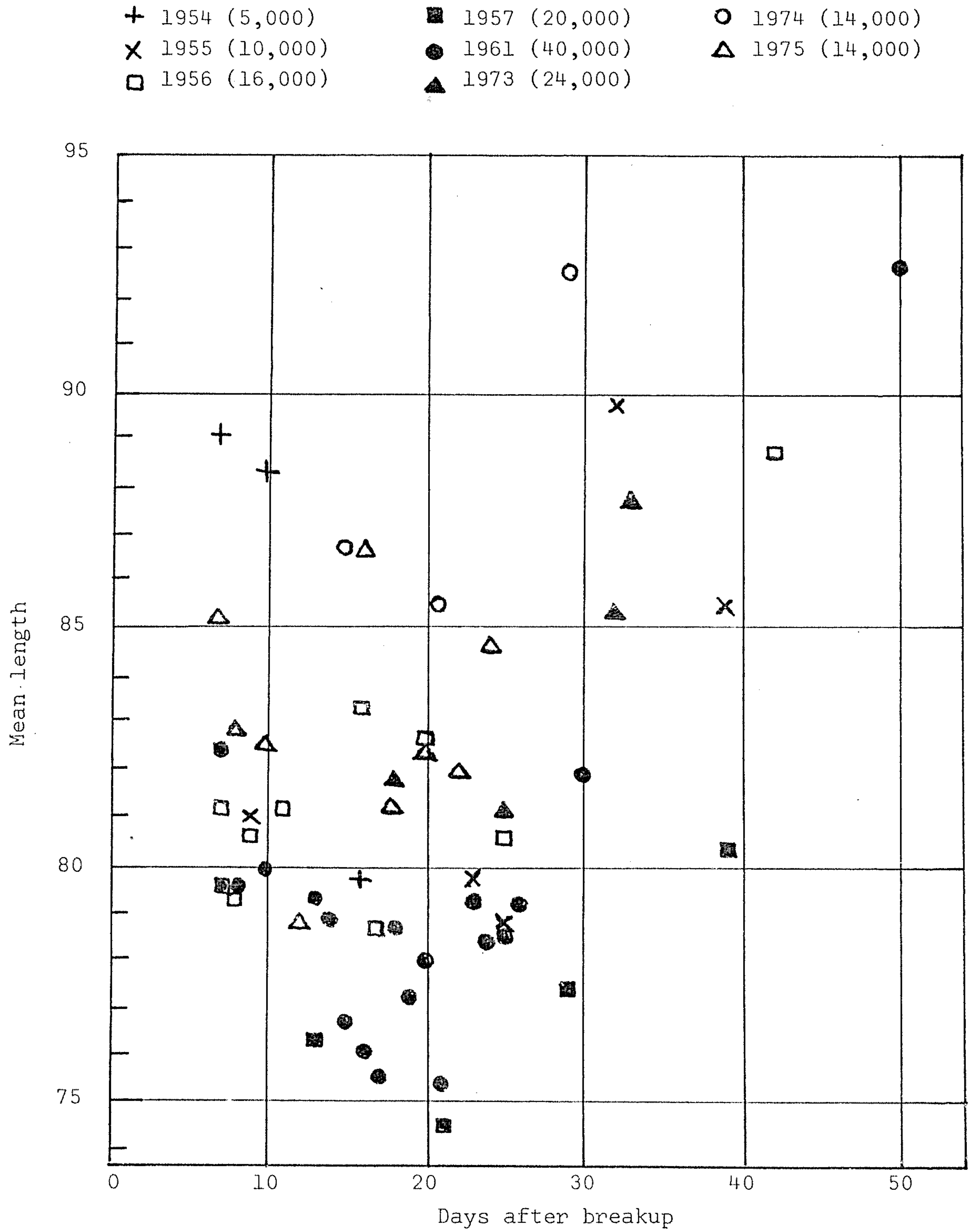

Fig. 4. Mean lengths of age I smolts from Little Togiak River by days after breakup. Parent escapements given in parentheses.

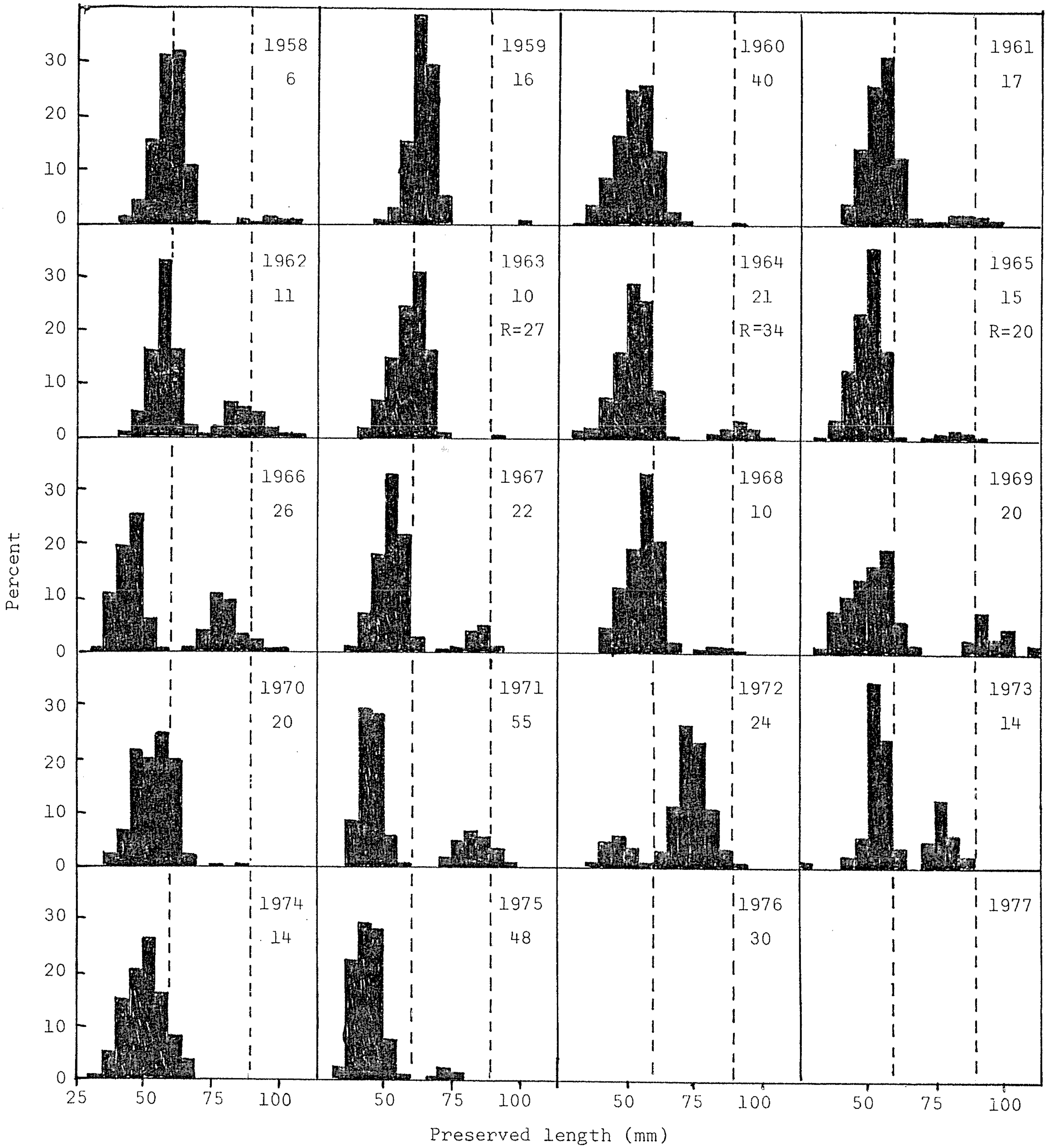

Fig. 5. Length frequencies of juvenile sockeye salmon on September 1 in Little Togiak Lake by year of sampling. Parent escapement for age 0 fish given below year. Dashed lines at the mean lengths for the Wood River lake system, 1958-1974 (56 mm for age 0 and 90 mm for age 1).

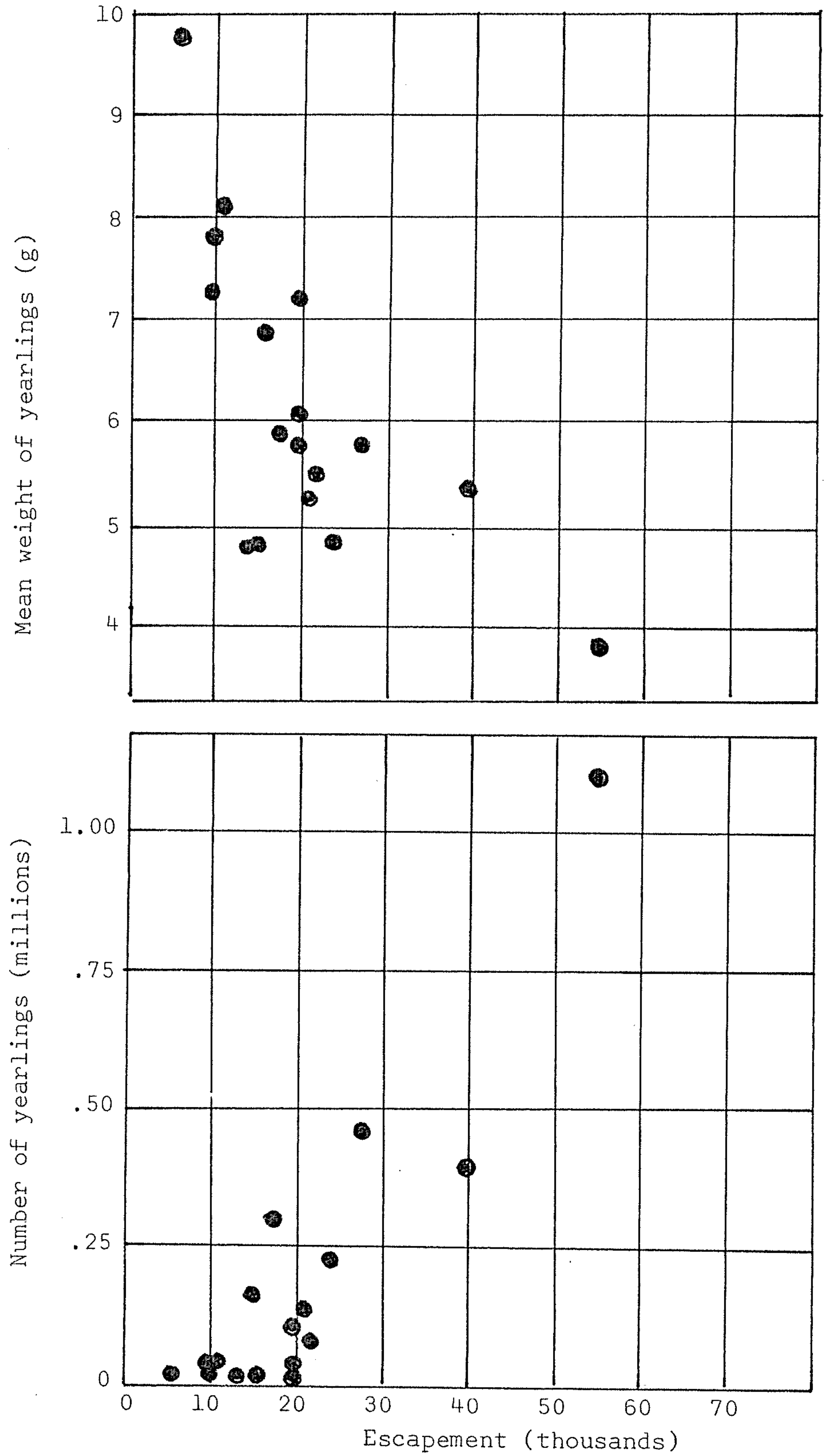

Fig. 6. Plots of escapement vs. mean weight of yearlings on September 1 two years later (top) and escapement vs. estimated number of yearlings two years later (bottom) in Little Togiak Lake, 1956-1972 brood years.

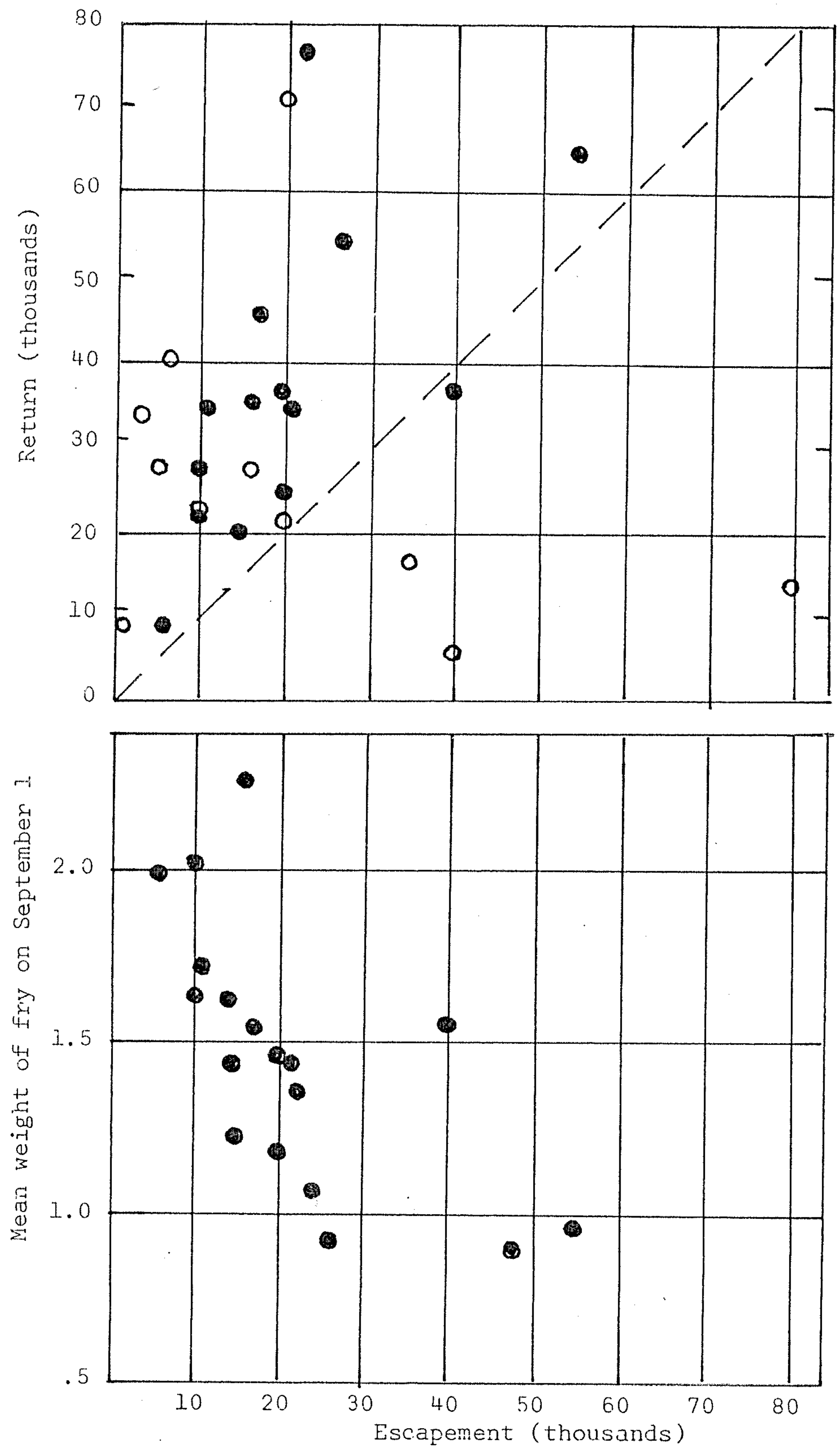

Fig. 7. Plots of escapement vs. return (top) and escapement vs. mean weight of fry on September 1 in the following summer (bottom) for Little Togiak Lake. Open circles for 1946-1956 brood years and closed circles for 1957-1974 brood years.

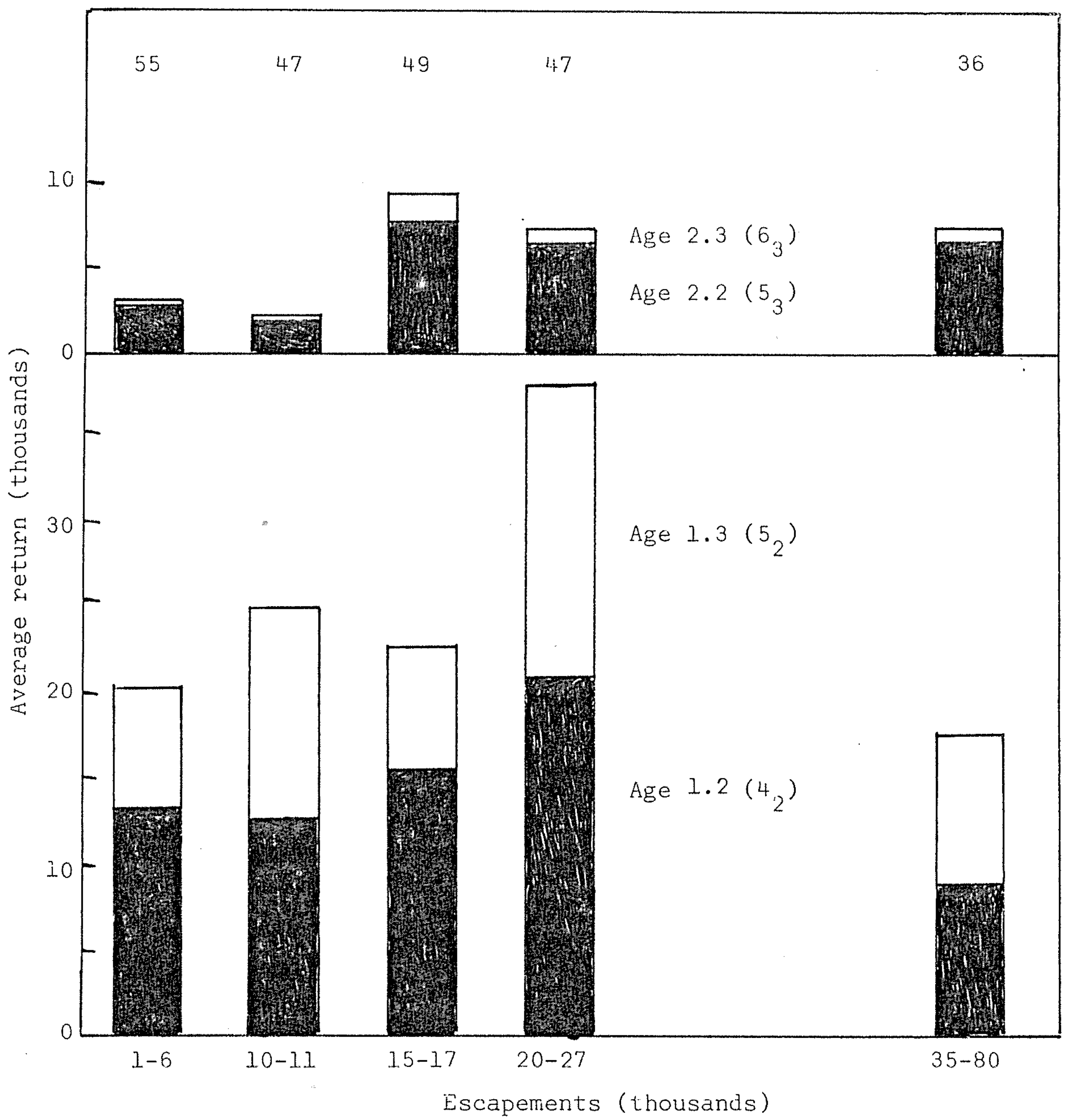

Fig. 8. Average returns by age group to Little Togiak Lake from various levels of escapements. The average percentage returning after 4 years (age 1.2) is given at the top.

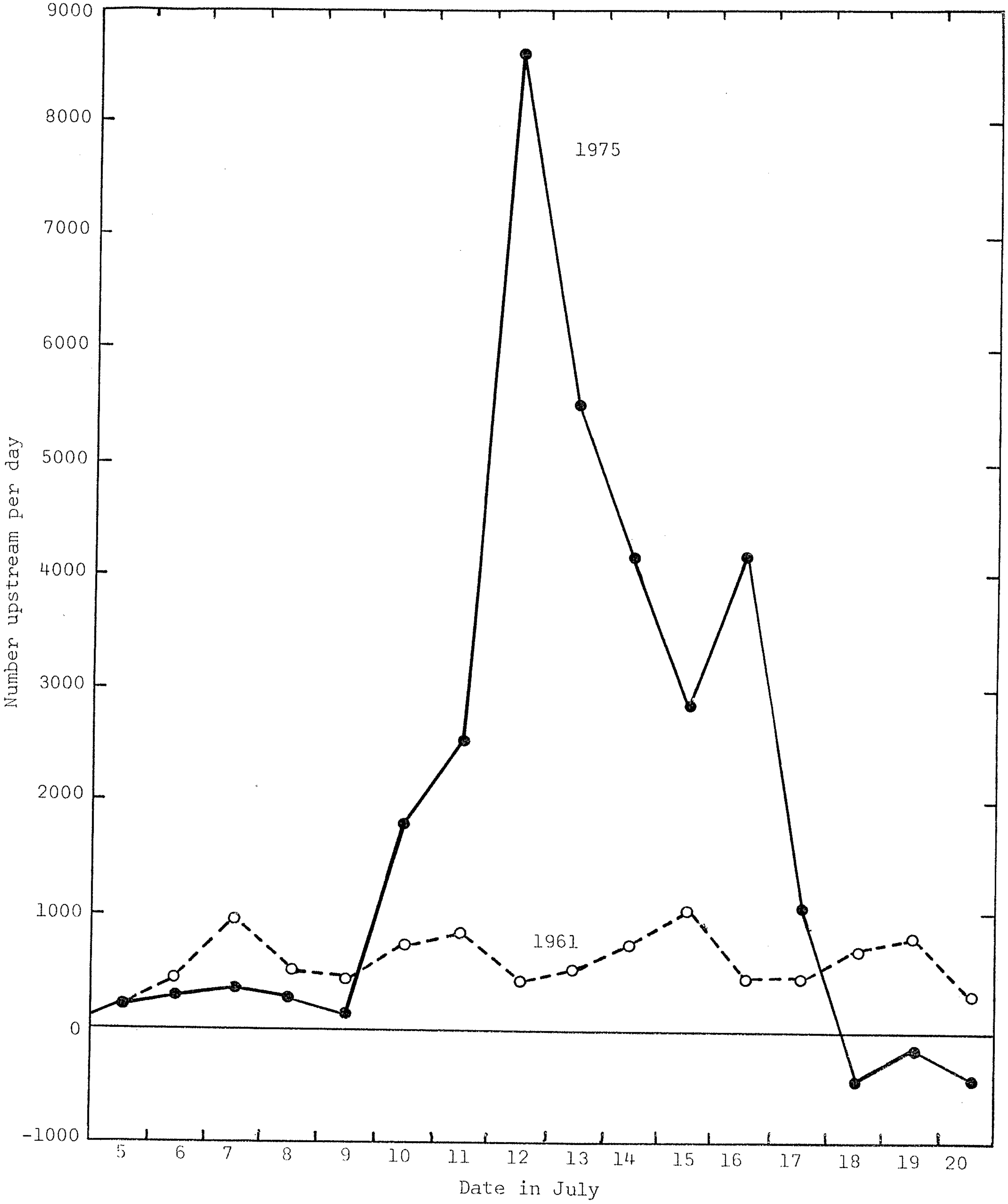

Fig. 9. Daily escapement into Little Togiak Lake in 1961 and 1975.

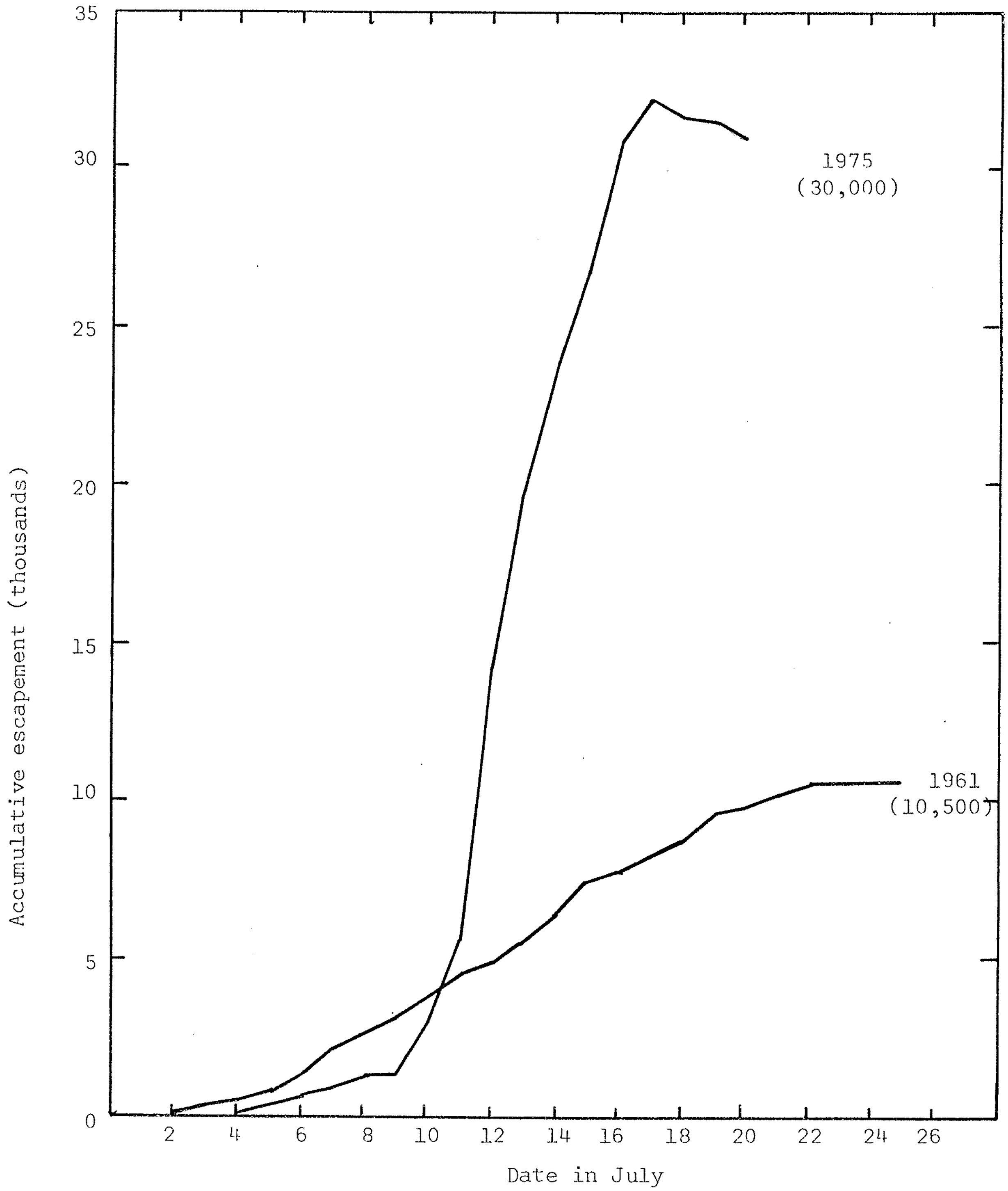

Fig. 10. Accumulative escapement into Little Togiak Lake in 1961 and 1975.

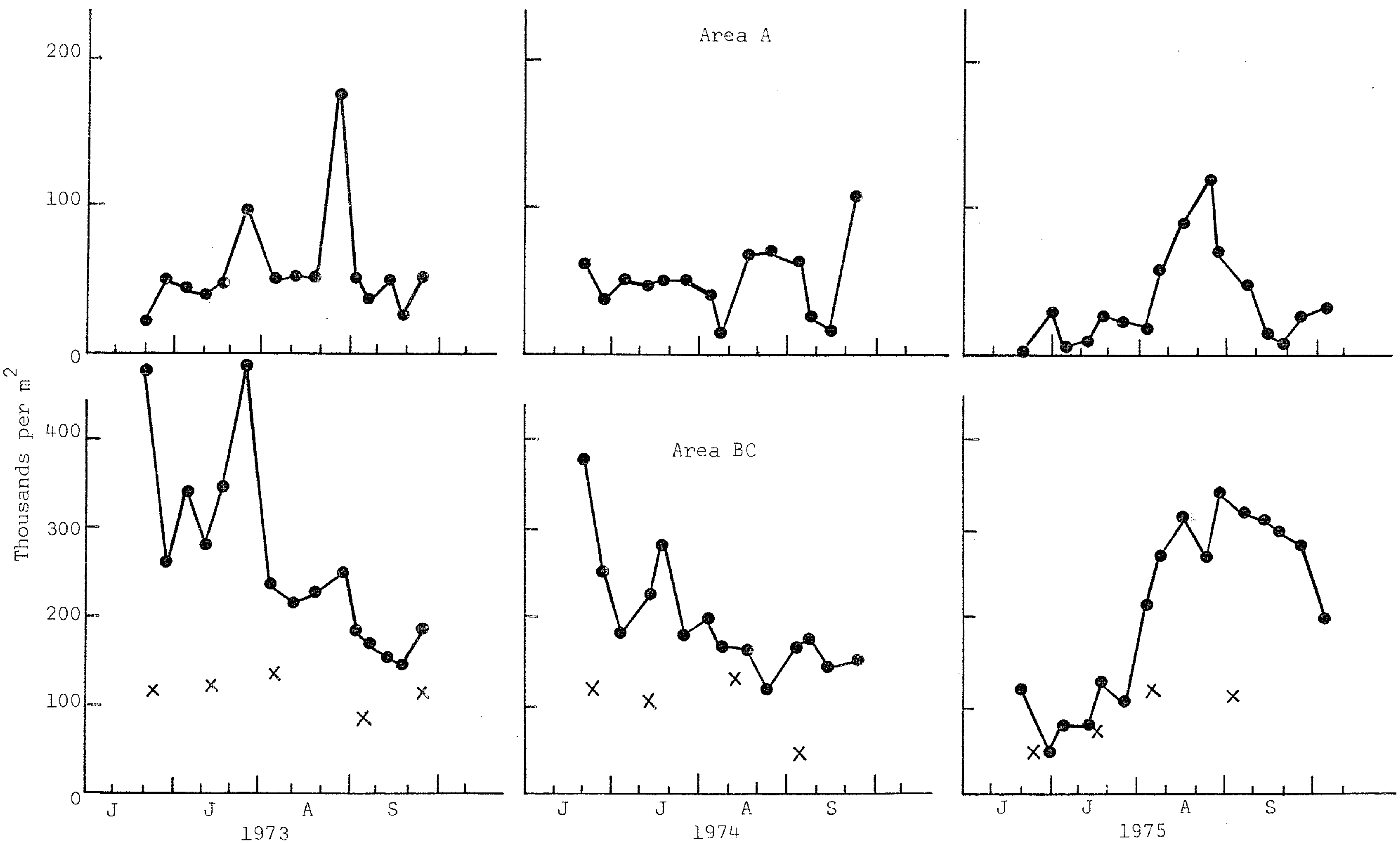

Fig. 11. Abundance of cyclopoid copepods in Little Togiak Lake and Lake Aleknagik (x).

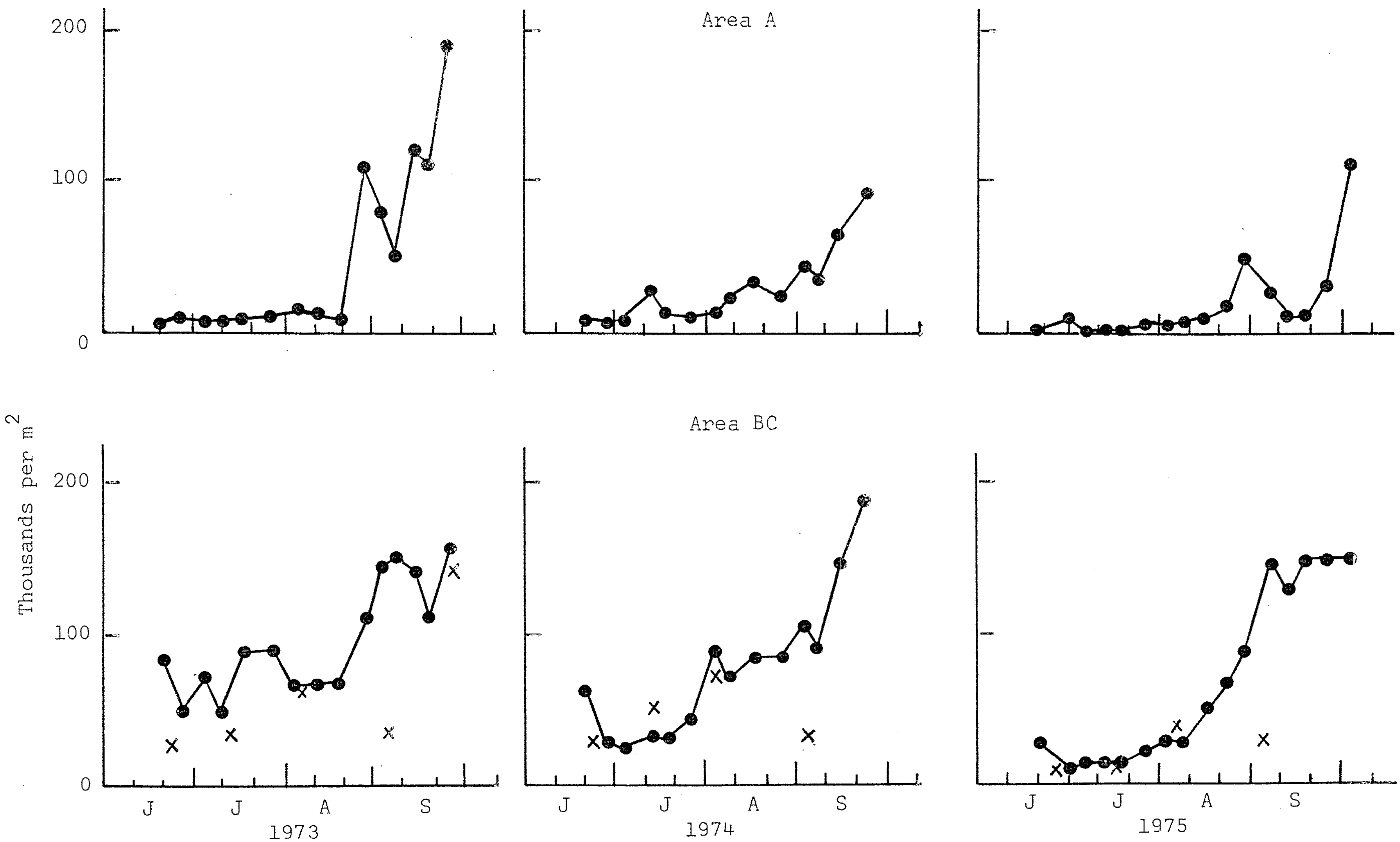

Fig. 12. Abundance of calanoid copepods in Little Togiak Lake and Lake Aleknagik (x).

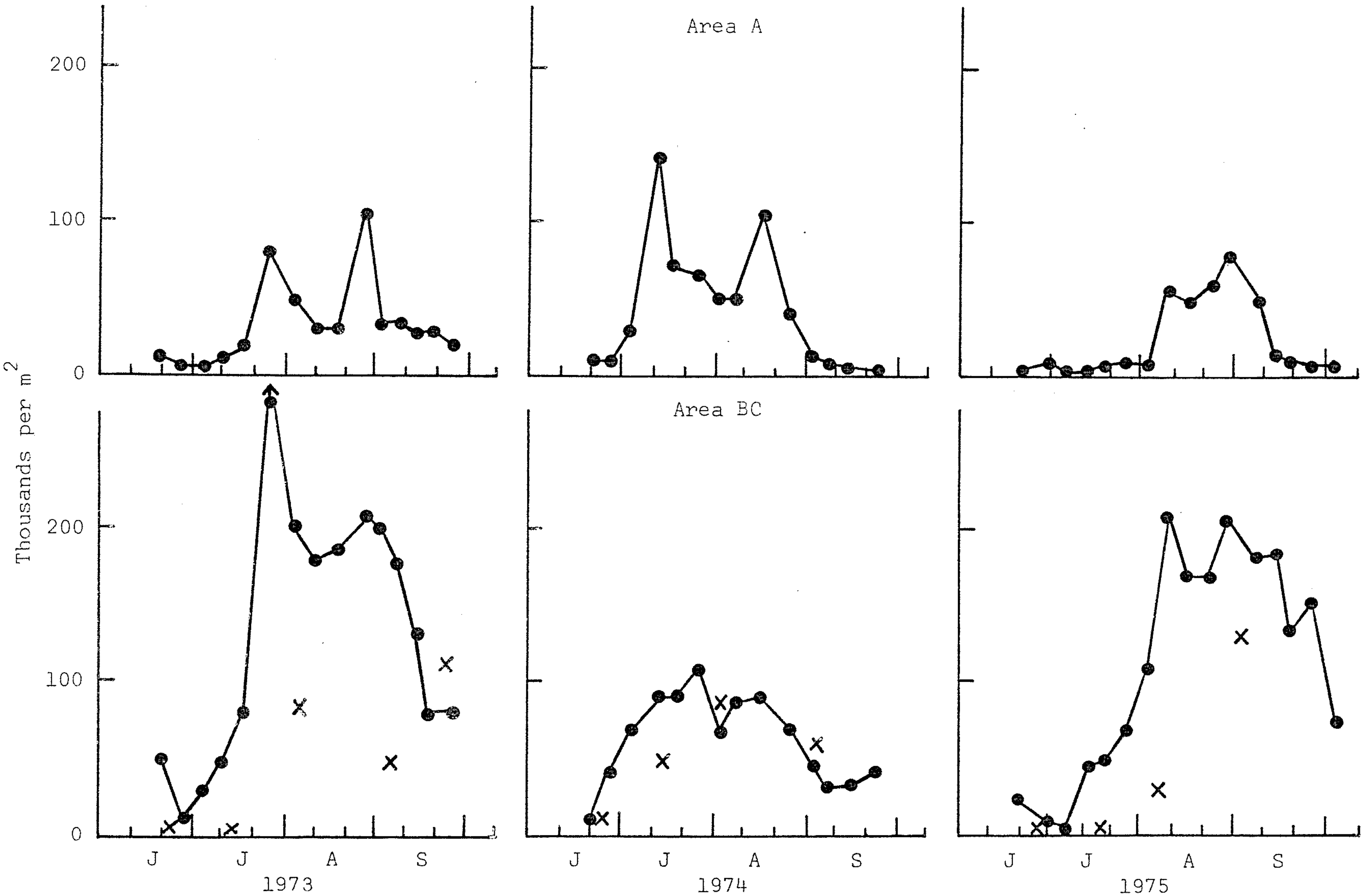

Fig. 13. Abundance of <u>Bosmina</u> in Little Togiak Lake and Lake Aleknagik (x).

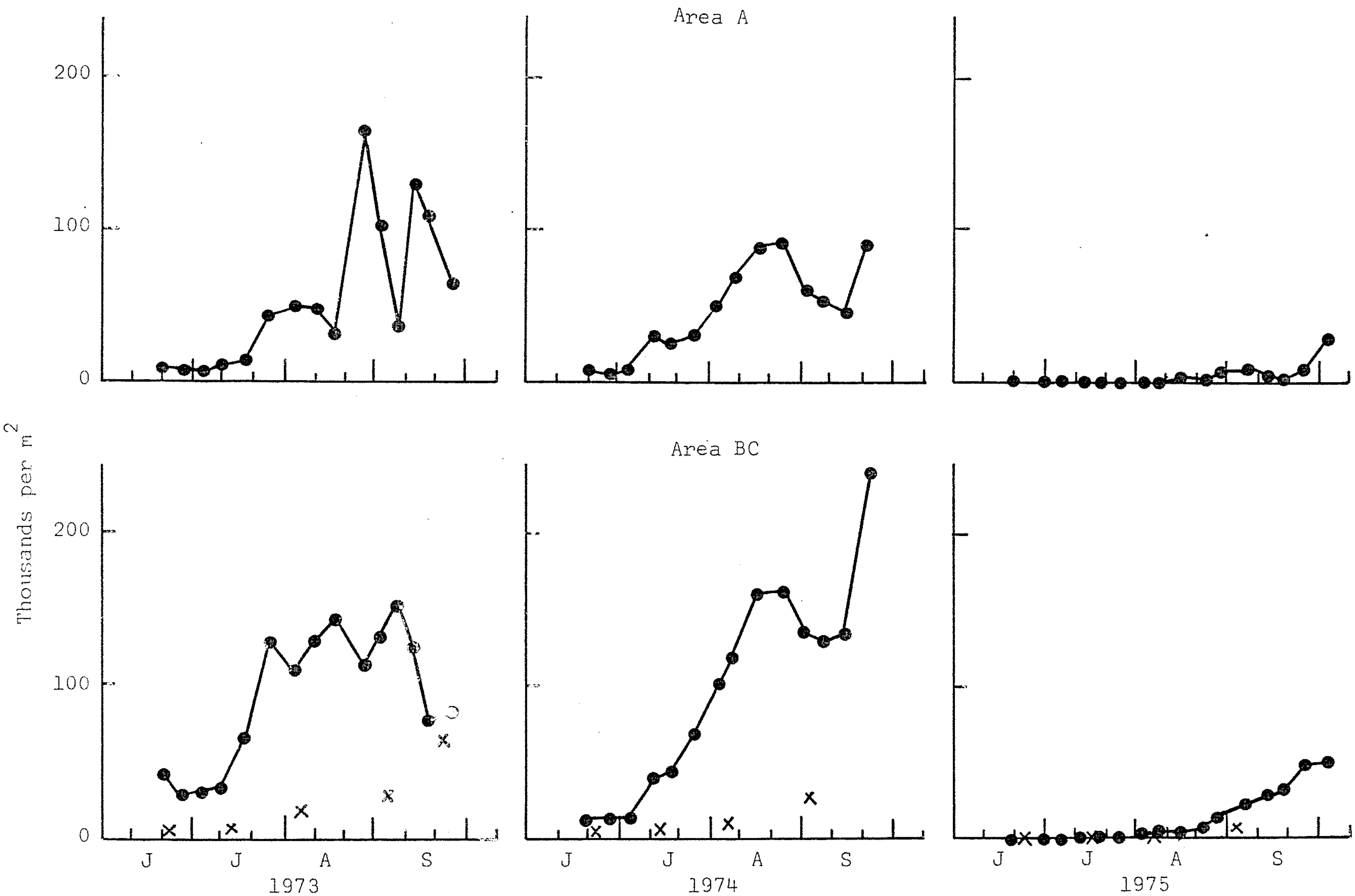

Fig. 14. Abundance of Daphnia in Little Togiak Lake and Lake Aleknagik (x).

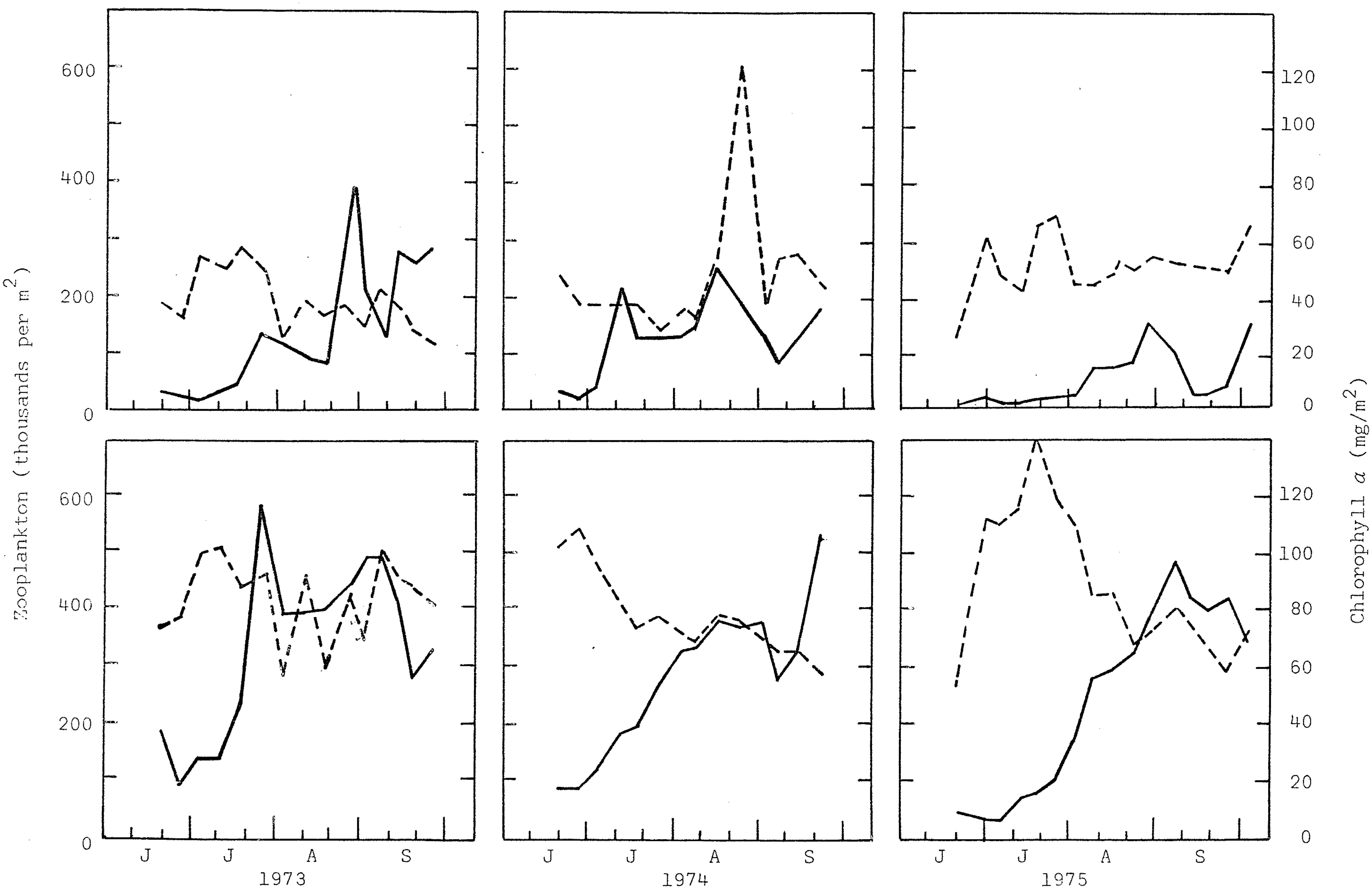

Fig. 15. Seasonal abundance of phytoplankton and herbivorous zooplankton in two areas of Little Togiak Lake during 1973-1975. Area A in upper graphs and Area BC in lower graphs, dashed line chlorophyll and solid line zooplankton.

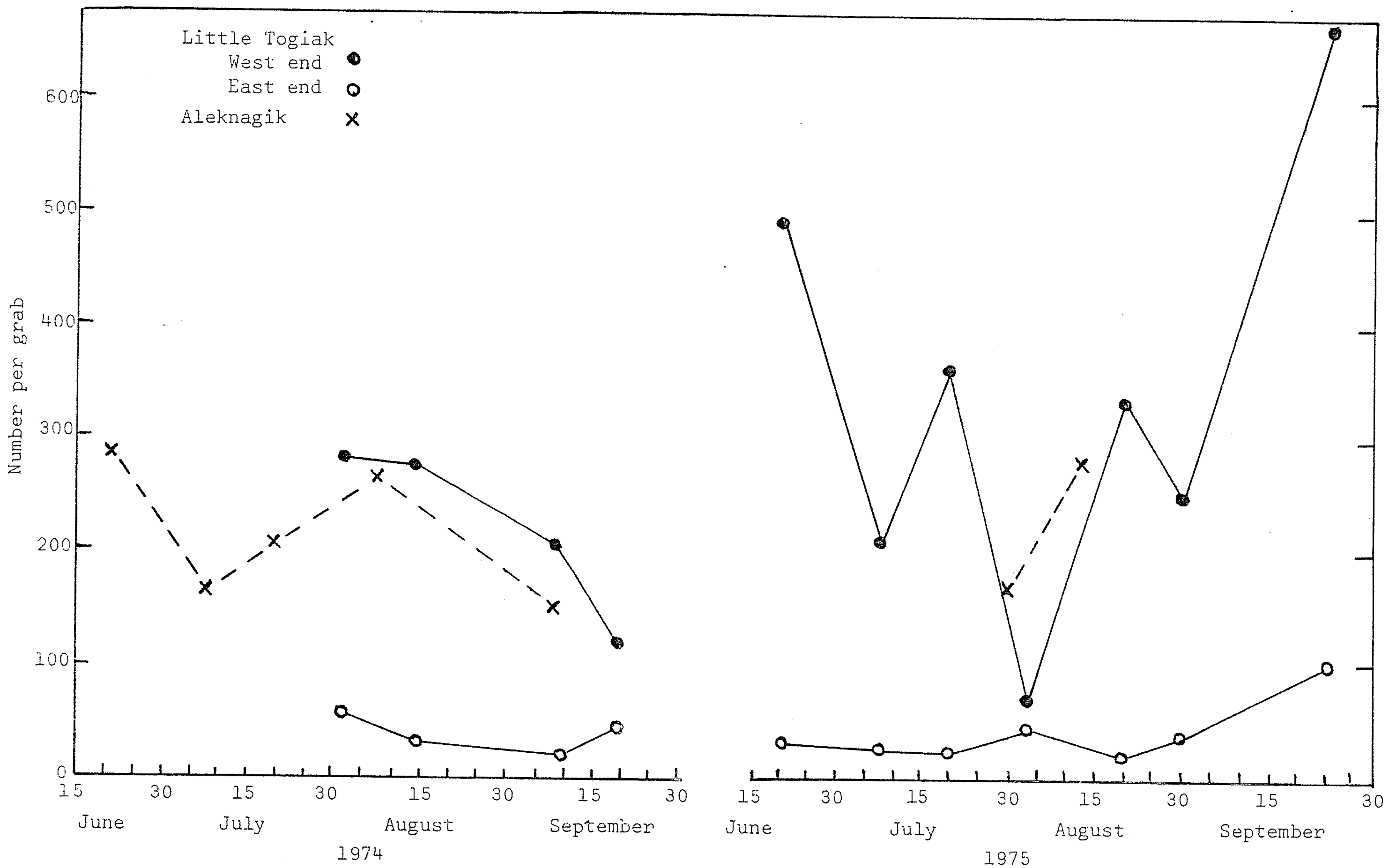

Fig. 16. Density of oligochaetes at 3-8 m, 1974-1975.

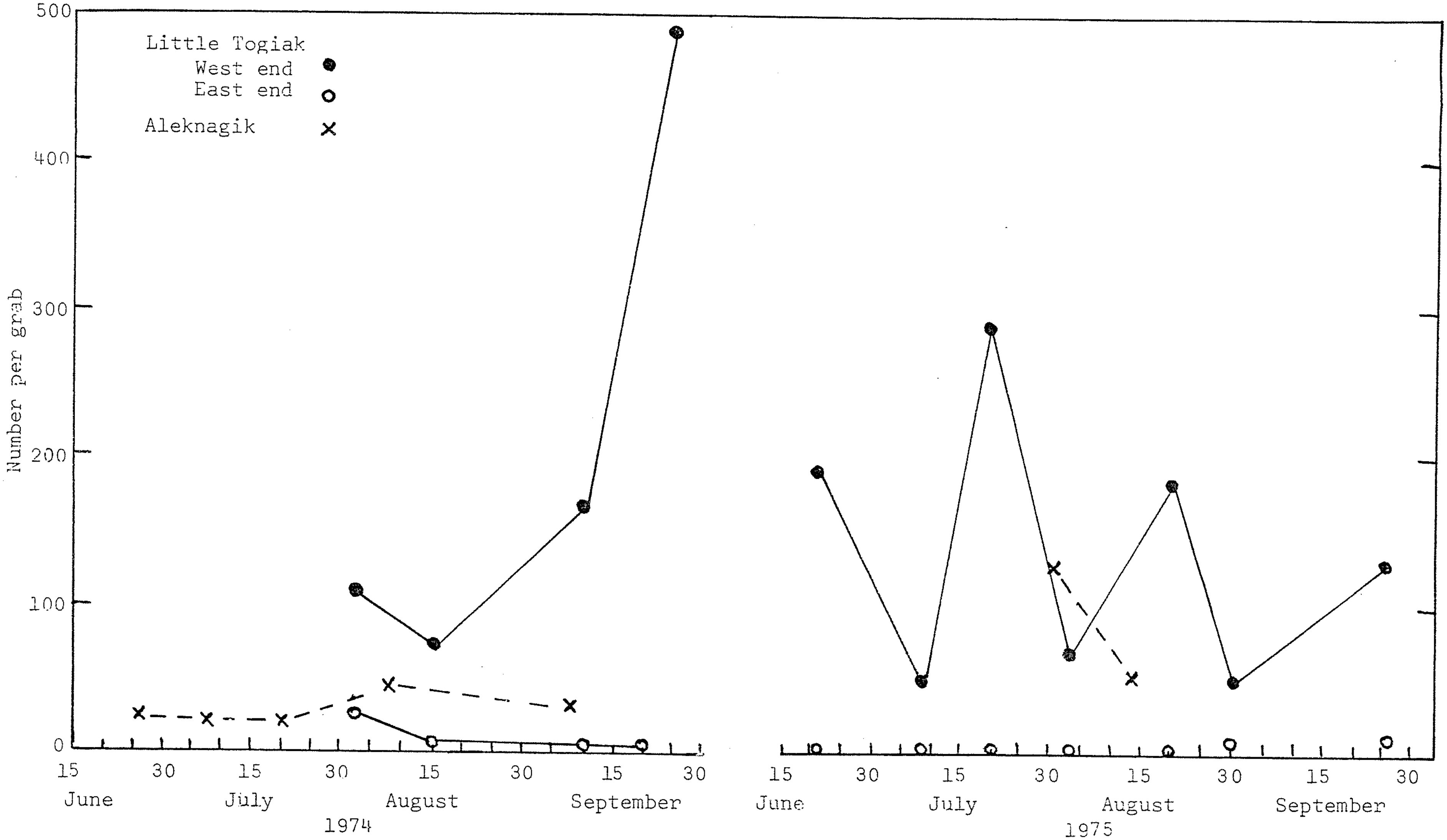

Fig. 17. Density of gastropods at 3-8 m, 1974-1975.

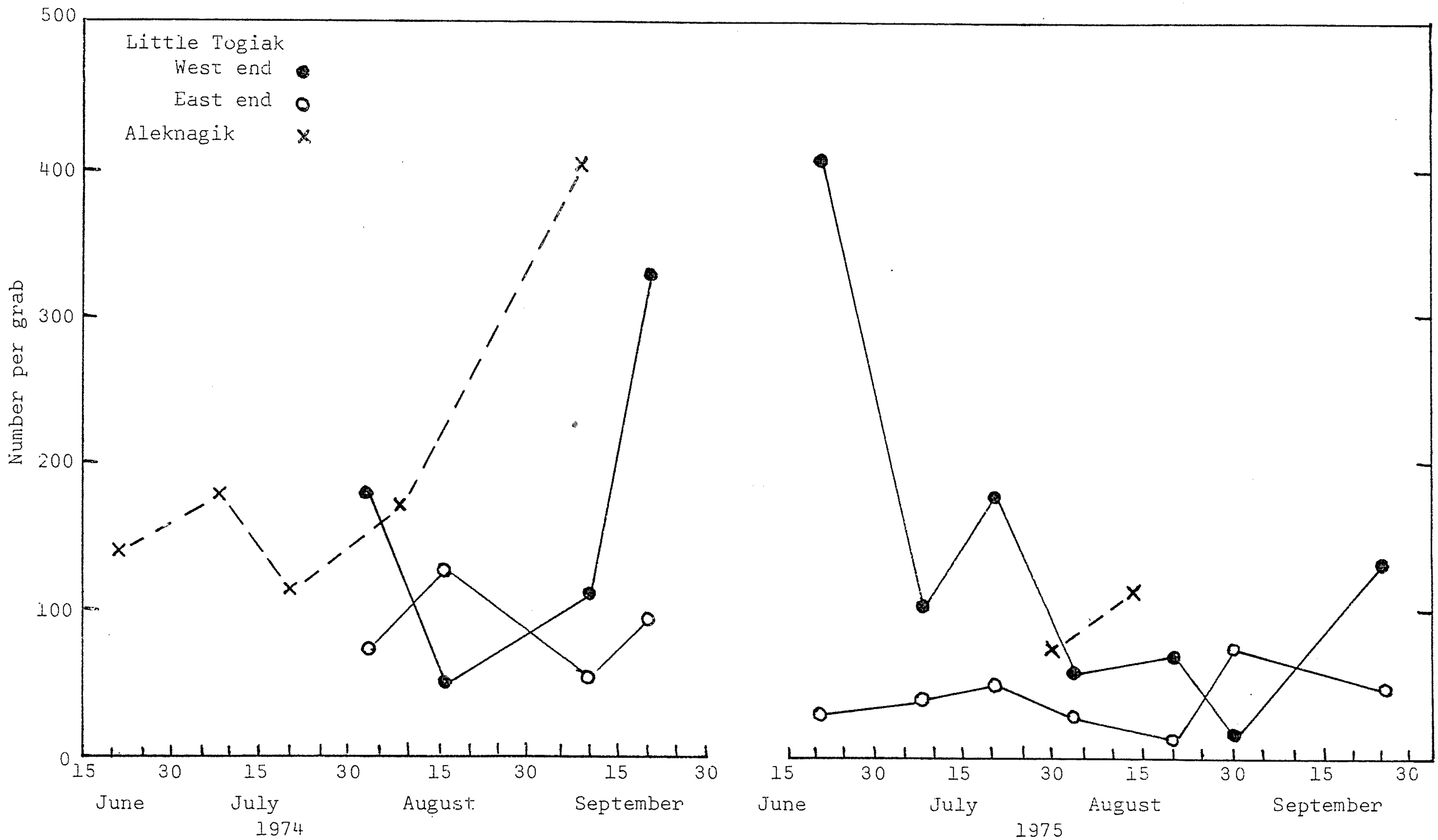

Fig. 18. Density of chironomid larvae at 3-8 m, 1974-1975.

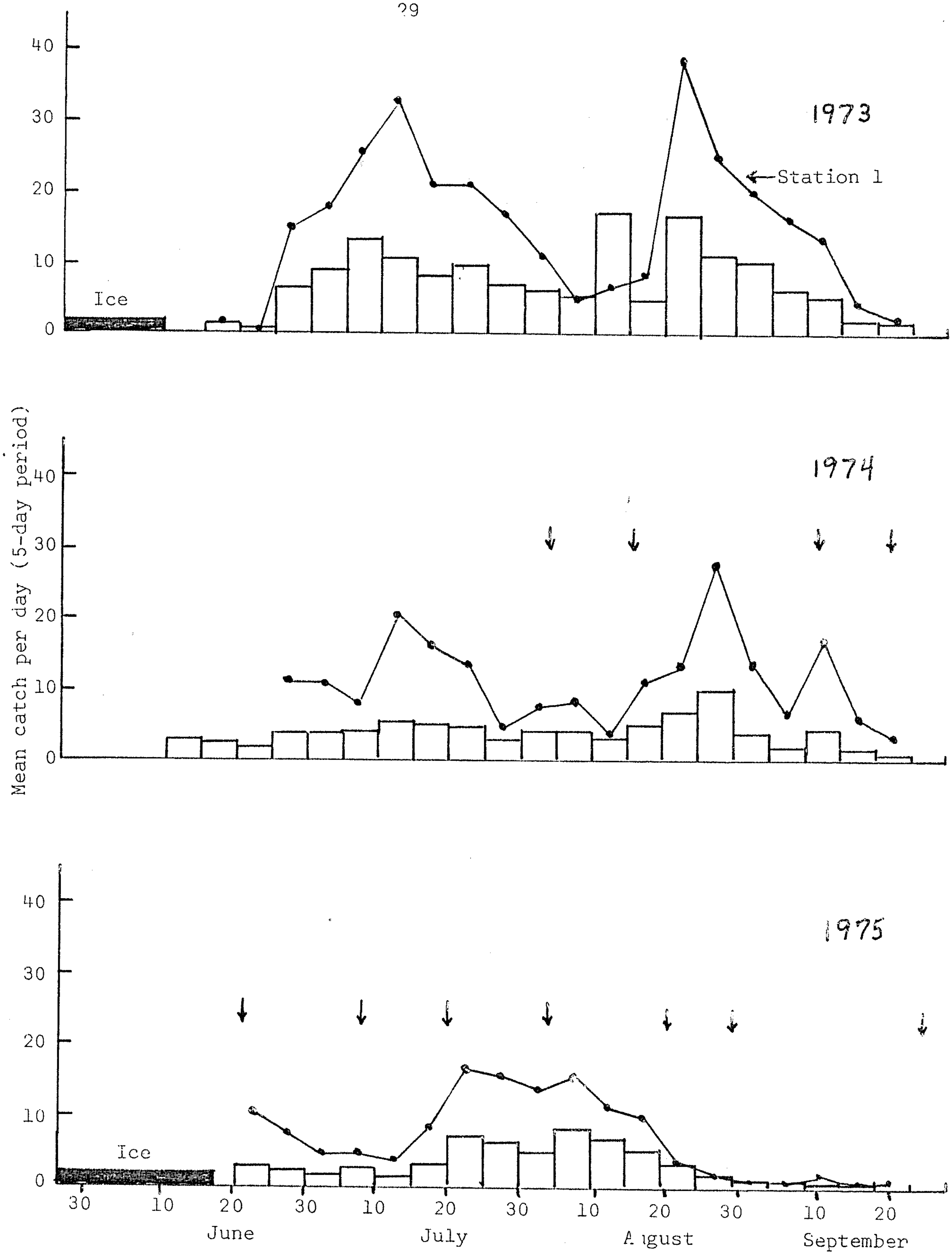

Fig. 19. Average catches of emergent chironomids in Little Togiak Lake (bars) and at Station 1 (line), 1973-1975. Arrows indicate dates when bottom samples were collected.

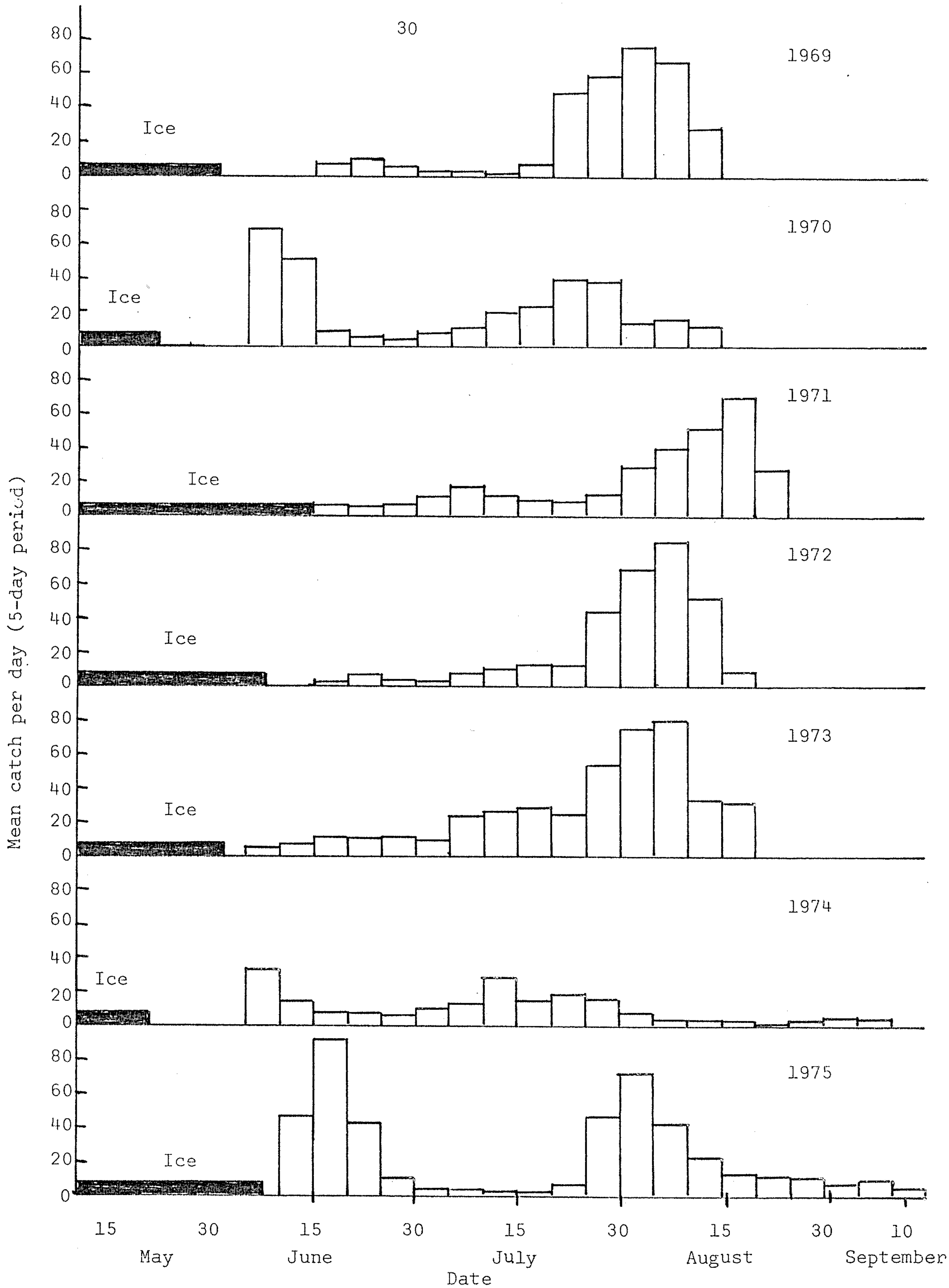

Fig. 20. Average catches of emergent chironomids in Lake Aleknagik by 5-day periods, 1969-1975.

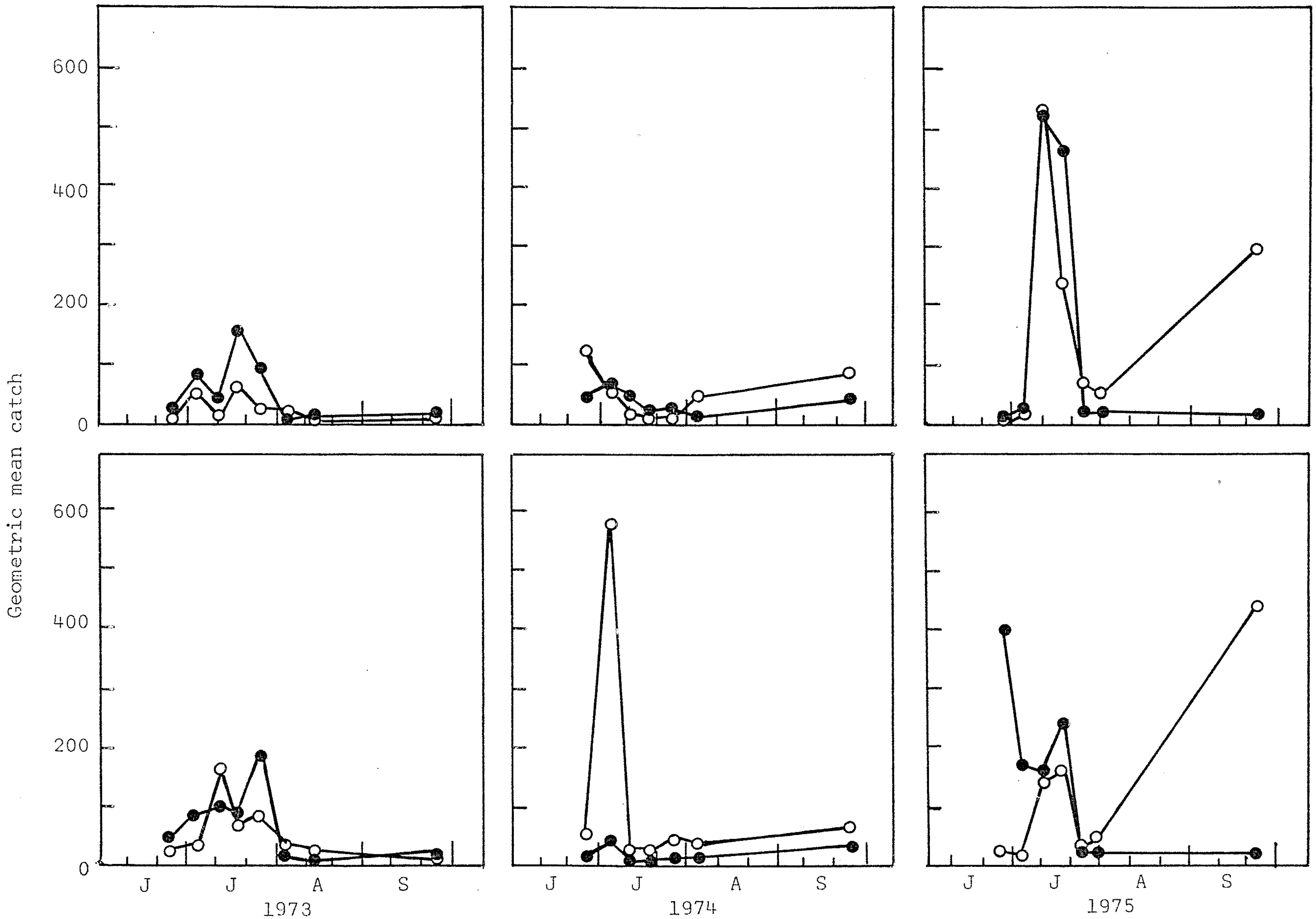

Fig. 21. Mean catches of sockeye salmon fry (solid points) and threespine stickleback (open points) in Little Togiak Lake. Beach seine hauls in June-August and tow net hauls in September, Area A in upper graphs and Area BC in lower graphs.

Table 1. Size of sockeye salmon smolts from Little Togiak Lake (live measurement), 1954-1974

Date		Days after breakup[1]	Age I n	Age I mean length	Age II n	Age II mean length	Percent Age I	Percent Age II
1954								
June	7	7	33	89.0	15	109.3	69	31
	10	10	95	88.3	5	103.8	93	7
	16	16	123	79.7	0		100	0
1955								
June	26	9	151	81.0	1	101.1	99	1
July	11	23	84	80.1	0		100	0
	13	25	158	78.7	0		100	0
	20	32	89	89.8	14	102.5	86	14
	27	39	149	85.4	11	104.0	93	7
1956								
June	15	7	111	81.2	33	101.8	77	23
	16	8	130	79.3	21	100.6	86	14
	17	9	130	80.6	21	101.3	86	14
	19	11	128	81.2	22	102.0	85	15
	24	16	294	83.5	7	105.4	98	2
	25	17	174	78.5	0		100	0
	28	20	261	82.8	38	105.0	87	13
July	3	25	107	80.5	5	110.2	96	4
	20	42	173	88.7	3	114.3	98	2
1957								
June	9	7	127	79.4	20	95.0	86	14
	15	13	106	76.3	1	94.0	99	1
	23	21	97	74.4	0		100	0
July	1	29	28	77.5	2	115.7	93	7
	11	39	36	80.4	2	111.5	95	5
1961								
June	10	7	200	82.4	4	108.0	98	2
	11	8	111	79.4	0		100	0
	13	10	110	79.9	0		100	0
	16	13	106	79.4	0		100	0
	17	14	116	78.9	0		100	0
	18	15	121	76.6	0		100	0
	19	16	123	76.0	0		100	0

[1]Estimated from breakup in Lake Aleknagik except for 1961 and 1975.

Table 1. Size of sockeye salmon smolts from Little Togiak Lake (live measurement), 1954-1974 - (continued)

Date	Days after breakup	Age I n	Age I mean length	Age II n	Age II mean length	Percent Age I	Percent Age II
1961 (cont'd.)							
June 20	17	121	75.5	0		100	0
21	18	114	78.8	1	115.0	99	1
22	19	121	77.2	0		100	0
23	20	120	78.0	0		100	0
24	21	409	75.4	0		100	0
25	*	84	87.5	1	115.0	99	1
26	23	113	79.1	0		100	0
27	24	112	78.3	0		100	0
28	25	91	78.6	7	117.6	93	7
29	26	106	79.1	1	103.0	99	1
July 3	30	94	81.9	1	105.0	99	1
23	50	59	92.7	1	112.0	98	2
1973							
June 26	18	56	81.9	8	102.8	87	13
July 3	25	183	81.1	12	99.9	94	6
10	32	90	85.4	11	104.7	89	11
11	33	121	87.8	15	105.0	89	11
1974							
June 11	15	67	86.7	9	108.3	88	12
17	21	19	85.5	1	106.0	95	5
25	29	28	92.5	3	106.3	90	10

*Sample from day-time migration.

Table 2. Sockeye salmon smolt samples from Little Togiak River, 1975 (days after breakup in parenthesis)

Date	Time fishes	Number of hours	Total catch	Length sample (live equivalent) Age I n	Age I mean	Age II n	Age II mean
June 22 (7)	0100-0230	1.5	300	136	85.1	4	104.7
23 (8)	2300-2400	1.0	1,000	125	85.8	0	--
25 (10)	2200-2300	1.0	3	--	--	--	--
	2330-2400	0.5	81	81	82.4	0	--
27 (12)	2350-2400	0.2	20	--	--	--	--
	2400-0100	1.0	40	20	78.8	0	--
July 1 (16)	2210-2310	1.0	0	--	--	---	--
	2310-0045	1.5	150	50	86.6	0	
3 (18)	2300-0025	1.5	2	0	--	--	--
	0025-0055	0.5	10	10	81.2	0	--
5 (20)	2215-2315	1.0	0	--	--	--	--
	2315-0035	1.3	300	80	82.5	1	106.0
7 (22)	2315-0035	1.3	56	56	82.0	0	--
9 (24)	2315-0035	1.3	24	24	84.6	0	--

Table 3. Estimates of sockeye salmon smolt abundance, age composition, and size in the 1961 migration from Little Togiak Lake

Dates	Number fish in migration (thousands)	Percent Age I	Percent Age II	Mean length (live) Age I	Mean length (live) Age II
6/06-10	78	98.0	2.0	82.4	108.0
6/11-15	21	100.0	0.0	79.7	--
6/16-20	96	100.0	0.0	77.1	--
6/21-25	203	100.0	0.0	76.6	--
6/26-30	96	97.4	2.6	78.8	109.1
7/01-05	42	98.9	1.1	81.9	105.0
7/06-10	54	--	--	--	--
7/11-15	40	--	--	--	--
7/16-20	18	--	--	--	--
7/21-25	(9)	--	--	92.7	112.0
Total migration	657	99.1	0.9	79.5	108.4

Table 4. Percentage occurrence and average number of juvenile sockeye salmon in stomachs of Arctic char at Little Togiak River by date in 1975 and by month 1972-1975. Sampling conducted at night unless indicated by (D)

				Sockeye salmon in stomachs			
				Percent occurrence		Mean number per stomach	
	Number	Length (mm)					
Date	examined	Mean	Range	Age 0	Age I+	Age 0	Age I+
6/22	3	386	377-404	0	0	0	0
6/23	6	424	386-440	0	67	0	1.5
6/24 (D)	3	460	428-491	0	100	0	14.3
6/24	4	414	399-427	0	0	0	0
6/25	3	443	428-470	0	67	0	6.3
6/27	2	478	389-567	0	0	0	0
6/29 (D)	4	450	382-528	0	25	0	0.5
6/29	4	430	380-462	0	25	0	0.5
7/1	5	368	230-518	60	20	1.0	0.6
7/2 (D)	2	458	457-460	50	50	0.5	2.5
7/3	2	378	344-412	0	100	0	3.0
7/4	1	386		0	0	0	0
7/5	15	402	278-520	7	7	0.1	0.1
7/6 (D)	1	465		0	0	0	0
7/7	4	440	365-484	0	100	0	6.3
7/8 (D)	4	428	357-475	0	25	0	0.2
7/9	1	403		100	100	2.0	1.0
7/10 (D)	1	465		0	100	0	5.0
7/13	3	281	231-349	0	0	0	0
7/13 (D)	3	446	443-450	0	67	0	1.3
1975							
June 22-29	29	433	377-567	0	38	0	2.6
July 1-13	42	403	230-520	14	33	0.2	1.2
1972							
June 24-25	46	455	310-595	54	72	4.9	6.0
July 5-8	96	438	160-580	7	44	0.2	2.5
1973							
June 19-27	94	454	275-590	38	52	2.1	3.6
July 3-11	79	431	230-590	6	39	0.2	1.0
1974							
June 11-25	214	438	275-575	7	44	0.4	2.7
July 3	9	390	318-463	0	44	0	0.9

Table 5. Summary of statistics on Arctic char from Little Togiak River, 1972-1975

	Year			
	1972	1973	1974	1975
Total number of char removed[1]	463	208	283	71
Total number measured	729	208	263	71
mean length (mm)	444	444	435	415
Number measured in June caught by hook and line	312	94	64	29
mean length (mm)	454	454	429	433
Stomach samples in June mean length of char from hook and line (night)	455	437	429	426
(morning)	--	470	--	454
gill net (overnight)	--	--	442	--
Number of sockeye smolts per stomach from hook and line (night)	6.0	2.3	1.6	1.4
(morning)	--	4.9	--	6.4
gill net (overnight)	--	--	3.2	--
Sockeye escapement to Little Togiak Lake in year-2 (thousands)	55	24	14	14

[1]A tag and recapture estimate of the number of Arctic char in the vicinity of Little Togiak River in 1972 was 3,500 with 95 percent confidence limits of 2,400 to 5,300.

Table 6, Little Togiak River adult enumeration - 1975 (number of fish per hour)

Time	7/5	7/6	7/7	7/8	7/9	7/10	7/11	7/12	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20
midnight-0100	(10)	(0)	(0)	(4)	(0)	(3)	(3)	(363)	(267)	(227)	(31)	(225)	(71)	(27)	(-3)	(-20)
0100-0200	(10)	(0)	(0)	(4)	(0)	(3)	(3)	(363)	(267)	(227)	(31)	(225)	(71)	(27)	(-3)	(-20)
0200-0300	(10)	(0)	(0)	(4)	(0)	(3)	(3)	(363)	(267)	(227)	(31)	(225)	(71)	(27)	(-3)	(-20)
0300-0400	(10)	0	(0)	(4)	0	(3)	(3)	(363)	(267)	(227)	(31)	(225)	(71)	(27)	(-3)	(-20)
0400-0500	(10)	0	0	8	0	6	0	134	252	(227)	0	364	58	-16	(-3)	(-20)
0500-0600	(10)	4	0	14	0	136	0	992	290	220	0	534	82	-24	(-3)	(-20)
0600-0700	(10)	28	0	44	0	122	48	566	330	218	48	256	28	22	(-3)	(-20)
0700-0800	(10)	20	42	46	0	254	14	334	210	132	124	342	40	-28	(-3)	(-20)
0800-0900	(10)	14	106	34	12	116	52	338	214	318	268	(230)	(38)	(-19)	-42	(-20)
0900-1000	(10)	6	18	0	4	(194)	48	144	136	494	156	118	36	-10	80	(-20)
1000-1100	(10)	0	0	40	20	272	18	354	166	344	226	92	-20	-72	-2	-88
1100-1200	(10)	0	0	0	0	166	42	492	108	194	176	-32	18	-48	60	-26
1200-1300	(10)	0	8	0	0	(154)	96	676	86	248	180	106	-50	40	-76	18
1300-1400	(10)	0	34	0	0	142	46	314	150	82	148	128	0	-266	0	10
1400-1500	20	0	0	28	8	66	60	364	36	208	96	76	0	-20	22	-54
1500-1600	0	14	0	0	0	48	30	166	284	62	90	292	100	-68	-54	42
1600-1700	0	14	44	16	0	82	0	392	124	74	58	196	138	8	-12	-44
1700-1800	0	124	0	0	18	(51)	6	210	562	128	174	30	0	(-20)	(-12)	(-20)
1800-1900	0	22	0	0	0	20	106	(232)	(335)	(98)	144	88	48	(-20)	(-12)	(-20)
1900-2000	0	0	0	0	0	26	420	254	108	68	118	122	66	(-20)	(-12)	(-20)
2000-2100	0	0	0	8	0	6	310	268	364	46	140	108	170	(-20)	(-12)	(-20)
2100-2200	74	0	44	0	8	(3)	324	386	234	62	86	84	70	(-20)	(-12)	(-20)
2200-2300	0	0	0	0	0	(3)	592	282	(227)	(31)	(225)	(71)	(27)	(-20)	(-12)	(-20)
2300-midnight	(0)	(0)	(4)	(0)	(3)	(3)	(363)	(267)	(227)	(31)	(225)	(71)	(27)	(-20)	(-12)	(-20)
Total	234	246	300	254	73	1882	2587	8617	5511	4193	2806	4176	1160	-493	-132	-482
Accumulative	234	480	780	1034	1107	2989	5576	14,193	19,704	23,897	26,703	30,879	32,039	31,546	31,414	30,932

Nighttime estimates from average of last count in evening and first count in morning.

Table 7. Geometric means from zooplankton hauls in Little Togiak Lake. Two hauls in Area A and four hauls in Area BC per date

		Thousands per m^2							
		Copepods		Cladocera					Volume
Date	Area	Cyclops	Calanoid	Daphnia	Bosmina	Holopedium	Total	Rotifers	(ml/m^2)
1973									
6/20	A	23	4	7	16	0	49	0	9
	BC	487	84	42	56	0	674	0	120
6/27	A	51	9	5	2	0	67	0	19
	BC	258	52	26	12	1	353	0	68
7/4	A	42	6	4	2	0	54	0	18
	BC	342	74	33	30	0	488	0	109
7/10	A	40	7	7	9	0	67	0	17
	BC	285	52	37	50	1	458	0	102
7/18	A	52	9	14	20	0	96	1	34
	BC	350	88	66	81	1	604	1	155
7/25	A	96	14	42	79	0	231	0	56
	BC	536	92	133	351	0	1172	0	226
8/3	A	51	18	45	45	0	160	0	41
	BC	233	63	112	200	2	615	0	155
8/10	A	56	14	43	31	0	168	0	27
	BC	211	65	133	178	1	607	0	142
8/18	A	55	6	32	28	0	120	0	28
	BC	229	66	142	184	1	641	0	166
8/28	A	177	111	164	108	6	573	1	84
	BC	251	110	116	209	1	752	1	148
9/1	A	50	79	101	34	0	277	0	51
	BC	173	143	135	199	2	646	0	121
9/7	A	39	53	37	35	0	168	0	30
	BC	164	147	156	178	2	653	0	163
9/13	A	53	121	133	26	3	368	0	63
	BC	153	141	124	132	10	597	0	131
9/19	A	23	113	107	28	3	283	1	75
	BC	146	115	78	79	0	443	1	92
9/25	A	57	194	64	20	6	344	1	77
	BC	187	158	84	82	2	527	1	121

Table 7. Geometric means from zooplankton hauls in Little Togiak Lake. Two hauls in Area A and four hauls in Area BC per date - continued

		Thousands per m^2							
		Copepods		Cladocera					Volume
Date	Area	Cyclops	Calanoid	Daphnia	Bosmina	Holopedium	Total	Rotifers	(ml/m^2)
1974									
6/20	A	62	7	6	9	0	99	0	25
	BC	379	64	12	11	0	472	2	137
6/27	A	38	3	3	5	0	50	0	16
	BC	255	32	16	42	2	354	1	106
7/4	A	52	7	6	27	2	94	2	21
	BC	182	22	16	69	2	295	2	111
7/11	A	45	31	30	141	1	262	16	41
	BC	223	36	40	86	4	402	11	116
7/17	A	51	16	25	71	0	167	13	43
	BC	286	32	42	93	4	474	17	123
7/25	A	49	9	30	63	2	156	19	39
	BC	182	43	69	109	8	422	27	123
8/2	A	40	14	49	46	1	153	23	38
	BC	199	87	102	66	21	513	42	152
8/9	A	16	21	71	48	1	167	7	41
	BC	168	73	121	86	14	357	34	163
8/16	A	68	34	86	108	0	295	21	48
	BC	159	84	160	89	11	531	29	172
8/24	A	70	24	88	40	1	229	24	46
	BC	111	84	161	70	15	460	30	186
9/1	A	63	42	58	14	2	186	14	47
	BC	162	106	137	45	10	486	69	160
9/7	A	21	38	36	6	0	103	1	32
	BC	169	93	129	33	7	439	11	150
9/14	A	18	65	43	2	0	132	3	27
	BC	142	147	137	35	4	473	2	151
9/21	A	107	92	87	1	0	292	3	36
	BC	150	186	241	41	1	634	65	139

Table 7. Geometric means from zooplankton hauls in Little Togiak Lake. Two hauls in Area A and four hauls in Area BC per date – continued

		Thousands per m^2							Volume
		Copepods		Cladocera					
Date	Area	Cyclops	Calanoid	Daphnia	Bosmina	Holopedium	Total	Rotifers	(ml/m^2)
1975									
6/20	A	0	0	0	2	0	2	0	5
	BC	121	26	1	22	0	100	0	44
6/30	A	30	11	0	8	1	49	1	17
	BC	45	12	0	9	2	65	1	31
7/5	A	4	0	0	1	0	5	0	7
	BC	86	16	1	5	2	111	1	47
7/11	A	10	1	0	1	0	12	0	5
	BC	81	17	1	45	5	158	1	43
7/18	A	26	2	0	4	0	32	0	5
	BC	130	17	2	48	4	207	3	71
7/25	A	24	4	0	5	0	34	1	10
	BC	105	23	2	68	6	204	2	71
8/1	A	19	4	0	6	1	30	4	12
	BC	214	26	2	111	11	373	9	99
8/8	A	60	5	0	59	2	126	3	25
	BC	270	26	6	214	17	549	14	115
8/15	A	95	11	2	47	2	157	6	38
	BC	317	52	5	169	44	631	23	142
8/22	A	121	19	2	60	1	209	7	50
	BC	268	65	6	166	50	589	30	173
8/29	A	72	46	5	78	14	224	8	61
	BC	343	87	15	209	43	727	28	252
9/7	A	53	27	5	51	5	169	10	62
	BC	327	144	22	182	58	798	75	251
9/12	A	14	9	2	14	1	41	2	13
	BC	316	125	30	183	23	688	64	214
9/19	A	9	9	1	8	0	28	3	5
	BC	300	150	34	138	13	643	65	159
9/25	A	28	31	7	7	0	74	1	14
	BC	291	151	51	155	15	672	52	167
10/2	A	37	116	28	6	1	191	0	33
	BC	198	154	52	78	4	515	61	128

Table 8. Density of bottom fauna at two locations in Little Togiak Lake by date and depth, 1975

Location	Date	Depth (m)	Number per grab (225 cm^2) Oligo- chaetes	Chiron- omids	Gastro- pods	Pelecy- pods	Nema- todes	Miscel- laneous	Total
West end	6/21	3	318	194	249	47	9	27	844
		5	678	620	136	16	64	76	1,590
		9	62	78	5	15	25	46	231
		14	33	22	2	2	31	24	114
	7/7	3	253	113	58	11	5	25	465
		5	160	78	40	7	9	9	303
		11	78	85	25	18	71	49	326
		15	66	43	1	2	15	32	159
	7/20	3	458	240	569	29	78	85	1,459
		4	278	116	9	11	15	25	454
		9	125	84	29	58	5	24	325
		16	118	58	0	53	0	42	271
	8/3	3	72	91	100	6	8	15	292
		5	62	24	27	20	62	15	210
		10	41	11	21	14	5	17	109
		15	27	34	3	8	0	0	72
	8/20	3	142	58	133	20	44	42	439
		6	522	86	233	87	27	10	965
		9	28	24	15	13	3	3	86
		14	29	55	4	16	27	13	144
	8/30	4	475	18	58	42	5	24	622
		6	16	8	46	4	8	28	110
		9	110	38	38	38	0	5	229
		16	85	27	2	18	22	24	178
	9/26	3	1,031	118	173	53	7	92	1,474
		5	324	145	82	4	11	38	604
		10	111	34	20	31	31	56	283
		14	109	18	0	44	13	44	228
East end	6/23	4	30	13	1	15	7	34	100
	6/21	6	31	47	3	24	0	4	109
		11	7	5	1	3	0	0	16
		15	11	28	0	25	0	15	79

Table 8. Density of bottom fauna at two locations in Little Togiak Lake by date and depth, 1975 - continued

Location	Date	Depth (m)	Oligo-chaetes	Chiron-omids	Gastro-pods	Pelecy-pods	Nema-todes	Miscel-laneous	Total
East end (cont'd.)	7/7	3	20	47	8	19	71	9	174
		5	30	33	2	10	0	12	87
		10	65	73	25	7	7	4	181
		15	31	27	2	43	5	13	121
	7/20	3	26	54	4	23	2	4	113
		5	13	41	0	5	0	5	64
		9	12	9	0	3	0	5	29
		16	7	7	1	5	0	2	22
	8/3	3	71	37	7	10	4	5	134
		5	19	20	4	20	2	10	75
		10							
		15	10	14	5	1	0	3	33
	8/20	3	23	15	4	9	27	2	80
		6	11	9	1	22	0	3	46
		10	7	4	16	2	4	2	35
		15	23	16	3	45	1	14	102
	8/30	3	32	35	2	24	49	41	183
		6	40	102	15	2	51	25	253
		9	60	31	1	11	1	17	121
		14							
	9/26	3	144	52	9	22	4	328	561
		5	70	46	14	31	4	139	304
		9	97	104	1	15	1	178	396
		15	8	0	0	0	1	1	10

Table 9. Geometric means of tow-net catches (5 min hauls) by sampling area in the Wood River lake system in 1975 compared to the means and ranges in means from previous years

		Sockeye fry (age 0)			Sockeye age I			Threespine stickleback		
		1975	1958-1974		1975	1958-1974		1975	1958-1974	
Lake		mean	Mean	Range	mean	Mean	Range	mean	Mean	Range
Aleknagik										
	A	9	25	1,377	0	1.4	0,42	295	40	2,377
	B	15	26	1,137	0	1.4	0,43	286	49	1,502
	C	21	35	5,261	0	1.4	0,31	159	63	7,195
South										
Nerka	A	28	8	0,260	0	1.7	0,12	456	3	0,67
	B	12	9	1,101	0.2	1.3	0,5	17	5	0,95
	C	1	4	0,15	0	0.9	0,7	3	2	0,16
Central										
Nerka	A	54	3	0,37	0	0.8	0,7	466	1	0,64
	B	12	10	2,62	0	1.4	0,13	47	5	0,125
	C	6	10	0,60	0	1.2	0,9	11	5	0,278
North										
Nerka	A	18	21	2,69	0	0.8	0,4	133	9	0,243
	B	6	31	3,490	0	0.4	0,2	50	8	0,112
	C	6	20	2,140	0	0.5	0,2	108	16	2,79
Beverley										
	A	57	13	0,163	0.3	1.3	0,11	61	12	0,68
	B	59	6	0,117	0	1.1	0,11	4	6	0,82
	C	185	5	0,68	0	0.6	0,7	456	8	1,46
Kulik										
	A	153	9	1,92	0.3	1.1	0,52	120	8	0,107
	B	91	8	0,42	3.9	1.2	0,28	54	5	0,63
	C	38	17	0,130	1.7	2.0	0,31	8	6	1,108
Little										
Togiak	A	17	45	0,550	3.5	5.1	0,15	310	19	2,126
	B	14	38	3,304	0.7	3.7	0,53	2036	49	4,152
	C	15	21	0,68	0.3	2.6	0,102	95	36	2,247

Table 10. Mean lengths (live equivalent in mm on September 1) by sampling area in the Wood River lake system in 1975 compared to the means and ranges in means from previous years

Lake	Sockeye fry (age 0)			Sockeye age I			Threespine stickleback (age I)		
	1975	1958-1974		1975	1958-1974		1975	1958-1974	
	mean	Mean	Range	mean	Mean	Range	mean	Mean	Range
Aleknagik									
A	54.4	54.5	42,62	-	87	70,108	40.7	41.8	39,49
B	56.6	57.6	44,65	-	90	70,112	43.3	43.3	40,51
C	54.4	58.9	44,69	-	93	86,107	43.0	44.5	40,51
South									
Nerka A	56.7	60.2	53,67	-	100	88,111	46.4	45.4	43,49
B	60.7	61.7	51,72	120	99	92,112	48.5	44.8	39,51
C	62.0	63.6	57,75	-	100	86,105	45.2	46.4	42,54
Central									
Nerka A	54.7	55.7	42,70	-	99	77,115	44.5	45.9	41,52
B	52.9	59.3	53,65	-	97	86,110	43.1	43.9	38,49
C	57.9	58.7	52,64	-	100	90,114	44.4	44.3	40,48
North									
Nerka A	54.8	58.1	51,65	-	96	85,115	41.9	43.6	41,50
B	47.7	60.0	52,69	-	94	83,114	40.9	43.5	37,51
C	54.2	58.9	51,67	-	97	90,105	42.9	44.7	41,52
Beverley									
A	42.8	54.4	43,61	103	91	75,104	47.4	43.6	38,48
B	44.8	55.9	45,66	-	89	77,112	46.2	43.8	35,49
C	57.9	61.4	48,69	-	91	81,98	47.1	43.5	39,48
Kulik									
A	45.6	58.0	50,69	87	90	81,105	41.6	43.7	39,52
B	48.3	57.4	46,72	91	91	82,99	45.0	44.1	40,48
C	41.3	59.1	49,66	85	91	80,106	39.9	43.6	38,47
Little									
Togiak A	44.9	53.2	44,63	79	91	76,107	40.1	41.8	37,48
B	44.8	54.5	45,62	77	93	79,105	41.1	43.2	36,48
C	43.2	56.2	49,66	90	91	77,104	41.6	43.6	39,49