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EVALUATION OF NUSHAGAK SOCKEYE ESCAPEMENTS

by

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INTRODUCTION

The 1980 sockeye salmon escapements to most of the Bristol Bay lakes were exceptionally large, particularly in the Nushagak District (Tables 1 and 2). The density of spawners in the Igushik lakes, nearly 27,000 per km^2 of lake surface area, was the highest density ever recorded in Bristol Bay. There are few observations on the relative production from large escapements or on the effects of large escapements on the lake ecosystems which provide the rearing areas for juvenile sockeye.

The impact of large escapements on the management of sockeye salmon runs can be profound because they may alter the spawner-return relationships that form the basis for escapement goals and forecasts of future runs. Extreme conditions, e.g., very low or very high abundance, growth, temperature, etc., also provide the most important information on the factors and mechanisms that regulate the abundance of sockeye salmon runs.

The objectives of this two-year research program are:

A. Monitor populations in the Wood River lakes to estimate 1) escapements and returns to individual lakes, 2) relative abundance and growth of juveniles, and 3) biological and physical parameters associated with the growth and production of juveniles.

B. Evaluate the impact of the record large escapements in the Igushik system by estimating 1) growth and relative abundance of juvenile salmon and competitor species, 2) densities of phytoplankton (chlorophyll *a*) and secondary producers (zooplankton and benthic organisms), 3) age composition of juvenile sockeye to determine holdover rate, and 4) optimum escapement based on freshwater data.

A preliminary report (October, 1981) summarized most of the data collected in the Wood River system in 1981. This report summarizes the observations made in the Igushik system and the results of zooplankton and benthic sampling in the Wood River system. In addition we examine the recent trends and variability in the runs of adult sockeye to the individual Wood River lakes. The final report of this project (Spring, 1983) will address the conclusions of the major objectives of the research.

RESULTS

Limnological Data

Limnological sampling in the Nushagak lake systems during the 1960's indicated that the Igushik lakes were the most productive (chlorophyll *a* and secchi depth) of the Nushagak lakes. The sampling in late July and early August, 1981, indicated that the Igushik lakes were similar in productivity to the Wood River lakes; however, the data were rather limited because the chlorophyll samples collected in July were erroneously processed (Table 3). Late July through early August is normally a time when phytoplankton standing crop is low and zooplankton standing stock is increasing.

The densities of zooplankton from individual vertical hauls in the Igushik lakes are given in Table 4. The hauls were made on different dates over the years and since there are pronounced changes in the abundances of zooplankters during the summer the data are not directly comparable between years. In lakes Aleknagik and Little Togiak *Daphnia* and calanoid copepods usually reach a peak abundance in September, *Eubosmina* in August or early September but *Cyclops* does not show a consistent pattern in abundance during the summer (Figs. 1 and 2).

In lakes Aleknagik and Little Togiak the abundances of zooplankton in 1981 were exceptionally high from late June through early August. Water temperatures were also exceptionally high during this period and chlorophyll densities were above average. In early September, however, most zooplankter densities had declined to very low levels. This decline was probably caused by the feeding of high densities of sockeye fry from the large 1980 escapements, e.g., Lake Aleknagik (Fig. 2).

In past years the abundances of zooplankton (particularly *Daphnia* and calanoid copepods) have been inversely related to the abundances of sockeye fry or parent spawners. However, in 1981 the abundances of *Daphnia* in the Wood River lakes were relatively high in spite of the high escapements in 1980 (Fig. 3 and Table 5). *Daphnia* was also exceptionally abundant in the few hauls made in Lake Ualik on August 9.

Benthic sampling in 1965 with a Peterson dredge indicated that the Igushik lakes contained the lowest density of benthic macroorganisms in the Nushagak District. The Igushik lakes were sampled with an Eckman grab (225 cm^2) in 1974 and 1981 and Little Togiak Lake has been sampled each summer since 1974. There have been significant differences in the abundances of benthic macroorganisms between the two ends of Little Togiak Lake, however in 1981 the densities were similar (Fig. 4). Densities in the Igushik Lakes were generally in between those in the two ends of Little Togiak Lake and not significantly different in 1974 and 1981, but in both years chironomid larvae were more abundant in Lake Ualik than in Lake Amanka.

Juvenile Fish Abundance and Length

The geometric means of the beach seine catches made in the Igushik lakes are presented in Table 6. Catches made before mid-July are expected to be higher than catches made later in the summer because both sockeye salmon fry and most of the threespine stickleback move offshore in mid-summer. In lake Aleknagik there has been a sharp decline in sockeye catches each year, except 1977 when water levels were abnormally high in mid-summer (Fig. 5).

The Igushik escapements in 1973 and 1980 were 60,000 and 1,988,000, respectively (a 33-fold difference), and there was about a five-fold difference in the catches of sockeye fry in August 1974 and 1981. In both years the catches of fry were much higher in Lake Amanka than in Lake Ualik, and the catches in Lake Amanka in August, 1981 were much higher than catches in lakes Aleknagik and Little Togiak in August, 1981.

The catches of Arctic char fry in Lake Ualik were high relative to the catches typically made in the Wood River lakes; otherwise beach seine catches in the Igushik lakes were similar to those in the Wood River system.

Lengths of Juvenile Fish

The mean lengths (preserved measurements) of sockeye salmon, threespine stickleback (age I) and Arctic char fry from beach seine sampling in the Igushik lakes are given in Table 7. The 1981 means lengths (adjusted to live measurements) are plotted in Figs. 6 and 7 along with data from Lake Aleknagik.

Date of ice breakup was early and summer water temperatures were warm in both 1974 and 1981 but the sockeye fry in the Igushik Lakes in mid-August were much smaller in 1981. The difference was most likely caused by the higher fish density in 1981. The growth of sockeye fry in June and early July, 1981 was exceptionally high in Lake Aleknagik, however growth from mid-July through August was quite low. This drop in growth coincided with the decline in zooplankton previously discussed. The lengths of sockeye fry in the Igushik lakes during late July to early August were similar to lengths in Lake Aleknagik and growth was also probably declining in the Igushik lakes at this time. If the growth trend observed in August continued through September-October then we would expect a high proportion of the fry to hold over in 1982 and migrate at age II in 1983.

Growth of Arctic char fry was above average in Lake Aleknagik in 1981, whereas lengths of char fry in the Igushik lakes were about average (for Lake Aleknagik). Age I threespine stickleback in Lake Aleknagik in June 1981 were the longest recorded in 20 years but their growth rate was poor so they were only a little above average in length about September 1. The age I sticklebacks apparently had good growth as age 0 fish in 1980 and/or an early beginning of growth in 1981. The age I threespine stickleback in the Igushik lakes in 1981 were smaller than those in Lake Aleknagik but still slightly above average in length during late-July to early August.

Wood River Adult Sockeye

The annual sockeye salmon runs to the Wood River lake system since 1953 have been estimated by adding the escapement (determined from expanded tower counts) and the catch of Wood River sockeye in the Nushagak fishery. The catch of Wood River sockeye was estimated by apportioning the Nushagak catch to the four lake systems according to the abundance of each age group in each of the lake system escapements. In a similar manner the Wood River catch has been apportioned to each of the Wood River lakes according to the abundance of each age group in each lake escapement (determined from aerial surveys and spawning ground sampling).

From 1953 through 1977 there was a cyclic pattern to the Wood River runs in which a low run occurred every four years (1953, 57, 61, etc.) and the majority of the fish in these years spawned in the two interconnecting rivers which drain into Lake Aleknagik and the north arm of Lake Nerka (Figs. 8 and 9).

Exceptionally large runs have returned to the Wood River lakes (and most other lakes in Bristol Bay) since 1978. Particularly unexpected was the run in 1981 because there had been consistently low runs in this cycle year; however, the distribution of the 1981 run was consistent with past years since the majority of the fish were in the two main rivers (Lakes Aleknagik and North Nerka).

There has been a greater increase in the abundance of river spawners which tend to spend three years at sea than in the abundance of creek and beach spawners which tend to spend two years at sea. The 3-ocean fish receive a higher rate of exploitation than the 2-ocean fish because the gillnets used in the domestic fishery are selective for the larger fish and 3-ocean fish have been subject to greater exploitation from high seas fishing (particularly between 1954 and 1973) than 2-ocean fish.

One important assumption in our estimates of the abundances of the runs to the individual lakes and spawning grounds is that the run timing of the various stocks is the same. The timing of the Wood River escapements has varied over the years largely in relation to the spring temperatures, i.e., cold spring late run and warm spring early run; however, most of the escapements have entered the lake system in about 10 days (Fig. 10). The timing of the escapements is also affected by the timing of the fishery. In the early period of the fishery (e.g., 1908-1919) there was a tendency to catch a much higher proportion of the early and middle portions of the run than the late portion. From the 1920's until the late 1950s fishing effort tended to be spread throughout the run with alternate open and closed periods of fishing, but since the 1960's there has been a variety of fishing patterns (Figs. 11-13).

A lack of or reduced early season fishing has been caused by a strike (e.g., 1959, 1969, 1980) or the anticipation (forecast) of a small run (e.g., 1974 and 1975). A lack of late season fishing has been caused by a weak run and the need to obtain an adequate escapement (e.g., 1972 and 1973). There is a delay of about three days between the date when fish are caught in the fishery and the date they are counted into the lake system.

The estimated daily catches of Wood River sockeye salmon were spread over three days (day of the catch, day before and two days before) and then lagged three days and added to the daily escapements to illustrate the hypothetical timing of the Wood River runs at the head of Wood River (outlet of Lake Aleknagik). The timing of the runs and the distribution of the catches are shown in Figs. 14 and 15.

In years with little or no early fishing the runs were much shorter in duration than in years when there was extensive fishing. This suggests that the fishery may delay the travel time to the lakes; however, it seems unlikely that the fishery caused the multimodal runs that have occurred in some years (e.g., 1976 and 1979) and these runs open the possibility for unequal timing of the various stocks which make up the Wood River run.

Another factor that may negate the assumption of equal timing is a change in age composition during the run. Data were examined for only three years but in two of the years there was a significant change in age composition during the escapement to the lake system (Figs. 16 and 17). In most years there have been significant differences in age composition among the escapements to the individual lakes and there have been consistent differences in age composition between river spawners and creek-beach spawners.

There was one tagging experiment conducted in the Wood River lakes (in 1961) to examine the timing of the various stocks in the system. Only minor differences in timing were detectable in that experiment and it was concluded that the various stocks were mixed during the run. The escapement in 1961 was small and the majority of the fish spawned in the two large interconnecting rivers. There was poor recovery of tags from beach spawning areas where there were relatively few fish that year.

Tagging should be conducted in 1982-84 to re-examine the assumption of equal timing of the stocks because if the stocks do not exhibit equal timing then there is a some opportunity to manage the Wood River run for individual lakes or spawning areas. In addition adjustments may be made to our statistics on the abundances of past runs to the individual lakes in the system. These statistics presently suggest that there are some differences in productivity among the various stocks (e.g., shape of spawner-return curve and average return per spawner).

Table 1. Densities of sockeye salmon escapements to Bristol Bay lake systems (number in thousands per km^2 of lake surface area).

Years	Kvichak	Naknek	Branch	Egegik	Ugashik	Wood	Nuyakuk	Igushik
1952-1976								
Median	.9	1.0	.6	.7	1.0	1.8	.4	2.6
Lowest	.1	.1	.1	.2	.1	.5	.1	.2
Highest	8.1	2.8	4.2	1.6	6.1	5.2	2.4	8.7
1977	.4	1.4	.3	.6	.5	1.3	.8	1.3
1978	1.4	1.0	.8	.8	.2	5.3	2.1	7.2
1979	3.7	1.2	1.0	.9	4.4	4.0	1.3	11.6
1980	7.5	3.3	1.0	.9	8.6	7.0	10.8	26.9
1981	.6	2.3	.3	.6	3.4	2.9	3.0	8.0

Table 2. Densities of sockeye salmon escapements to the Wood River lakes.

Year	Aleknagik	Nerka	Beverley	Kulik	Little Togiak
1949-1976					
Median	1.9	1.6	1.3	1.1	2.3
Lowest	.4	.3	.1	.1	.2
Highest	5.9	6.4	4.6	7.5	9.2
1977	1.8	1.5	.4	.8	4.3
1978	7.4	3.9	4.6	8.3	7.5
1979	4.3	3.4	4.0	4.9	7.3
1980	14.8	5.0	4.2	5.4	13.5
1981	5.5	3.0	.7	.9	10.0

Table 3. Comparative limnological measurements made in the Igushik lakes and the Wood River lakes in late July to early August, 1981.

Lake	Date	Density of chlorophyll a 0-20 m (mg/m^2)	Conductivity (micromhos/cm)	Secchi depth (m)	Inshore surface temperature
Amanka	7/28	--	34.0	7.8	15.7
	8/11	19.9	35.5	8.5	--
Ualik	7/27	--	34.3	9.7	14.0
	8/9	--	--	9.5	--
Aleknagik	8/2	25.3	36.2	9.4	14.2
Little Togiak	7/29	30.2	50.0	8.4	14.0
	8/14	23.0	--	8.8	--

Table 4. Zooplankton densities in the Igushik lakes.

Lake	Year	Date	Haul depth (m)	Thousands per m^2 Cyclops	Calanoid	Daphnia	Bosmina	Holopedium	Total	Rotifers	Volume (ml/m^2)
Amanka	65	7/8	35	25	7	3	7	42	84	--	143
			31	80	20	16	26	8	150	--	66
			35	111	73	11	32	20	247	--	132
			55	150	61	11	25	10	257	--	117
			25	58	34	11	8	4	115	--	56
		7/10	48	83	56	9	14	11	173	--	71
			38	68	6	4	7	10	133	--	76
	66	7/2	51	110	43	5	12	5	175	--	138
			41	49	21	4	6	35	115	--	168
	74	8/27	40	13	14	61	122	0	210	0	23
			20	+	1	5	7	+	14	0	3
			40	2	13	79	60	0	154	1	21
	81	7/28	40	147	14	32	166	8	367	18	143
			20	22	11	14	54	2	103	4	51
			40	79	73	58	426	6	642	45	132
		8/10	40	124	33	43	198	5	403	10	51
			20	6	8	33	51	4	102	4	25
Ualik	62	9/7	24	90	45	49	105	8	297	--	148
	65	7/9	28	152	40	28	51	15	286	--	143
			44	163	52	25	31	14	285	--	143
			60	270	37	18	25	23	373	--	224
			38	204	71	36	17	56	384	--	250
			20	57	13	8	15	10	103	--	61

Table 4. Zooplankton densities in the Igushik Lakes - cont'd.

Lake	Year	Date	Haul depth (m)	Thousands per m^2							Volume (ml/m^2)
				Cyclops	Calanoid	Daphnia	Bosmina	Holopedium	Total	Rotifers	
	66	7/4	47	100	32	2	10	20	164	--	117
		7/20	59	435	70	12	93	36	646	--	382
			55	450	42	4	77	20	593	--	234
	74	9/8	20	59	128	93	169	6	455	0	97
			35	46	160	85	73	5	369	0	92
			35	8	44	13	10	6	81	+	46
	81	7/27	40	86	25	83	84	44	322	30	173
			40	108	54	76	168	13	419	28	127
			20	6	4	17	39	3	69	5	31
		8/9	40	88	116	150	262	54	670	5	204
			40	26	43	177	193	40	479	5	153
			20	2	5	15	13	2	37	+	25

+ = less than 1,000 per m^2

Table 5. Geometric means from zooplankton hauls in the Wood River lakes in 1981 by lake and date (n = 6).

		Thousands per m^2							
		Copepods		Cladocera					Volume
Lake	Date	Cyclops	Calanoid	Daphnia	Eubosmina	Holopedium	Total	Rotifers	(ml/m^2)
Little Togiak	6/26	113	26	20	20	.1	183	5	57
	7/3	203	78	57	68	.7	431	10	106
	7/17	190	51	72	115	.7	439	33	93
	7/30	185	76	96	156	1.5	584	25	95
	8/14	104	59	84	131	.3	409	8	80
	8/29	68	22	40	48	.5	193	7	40
Aleknagik	6/24	163	13	4	9	5.2	197	29	91
	7/10	153	19	29	85	9.6	296	115	115
	8/4	77	14	22	69	2.0	191	18	69
	9/1	24	19	28	38	0	130	2	26
L. Nerka									
North	8/30	34	43	29	69	.3	166	0.3	42
Central	8/26	80	46	37	56	.6	230	2	64
South	8/31	55	56	86	87	.5	312	0.3	71
Beverley	8/23	80	28	30	50	.1	209	13	72
Kulik	8/22	139	82	61	158	8.8	471	6	192
Lake system average, 8/22-9/1 (weighted by area)		62	41	42	69	1	230	4	68
1967-1980									
System mean		97	46	28	79	4	266	9	90
Annual range LL		53	24	7	46	1	186	3	44
UL		166	64	70	111	9	376	15	126

Table 6. Geometric means of beach seine catches in the Igushik lakes.

Lake	Year	Date	Hauls (n)	Sockeye Salmon Age 0	Sockeye Salmon Age I+	Sticklebacks Threespine	Sticklebacks Ninespine	Sculpin	Arctic Char (age 0)
Amanka	1965	6/28-30	12	284	1.3	937	9	8	4
		7/25-27	6	34	.6	559	26	4	3
	1966	7/28	4	408	14	605	8	6	1
	1974	8/12	10	8	.2	467	31	29	.2
		8/30	10	5	.2	142	25	20	0
	1981	7/27	10	54	.1	187	8	8	.1
		8/10	8	38	.1	118	12	2	0
Ualik	1965	6/29	11	92	.3	165	2	22	12
	1974	8/15	10	1	.1	21	2	33	1
		8/27	9	1	.1	164	14	43	1
	1981	7/26	10	2	.1	169	3	2	18

Table 7. Mean lengths (preserved) from beach seine sampling in the Igushik lakes.

Lake	Year	Mean date	Sockeye Age 0 n	Sockeye Age 0 $\bar{L}$	Sockeye Age I n	Sockeye Age I $\bar{L}$	Threespine stickleback (age I) n	Threespine stickleback (age I) $\bar{L}$	Arctic char (age 0) n	Arctic char (age 0) $\bar{L}$
Amanka	1965	6/29	1031	31.6	91	63.7	1037	25.7	19	32.7
		7/26	215	40.9	18	88.1	492	29.8	150	28.0
	1966	7/28	211	31.1	190	60.3	437	25.7	1	27.0
	1974	8/12	-	51.4	-	-	-	42.6	-	46.0
		8/30	-	54.5	-	-	-	43.6	-	-
	1981	7/28	370	41.7	2	79.5	207	37.2	1	29.0
		8/10	164	42.8	1	60.0	72	39.2	18	37.5
Ualik	1966	6/29	450	28.4	23	82.6	86	25.7	281	28.4
	1974	8/15	-	42.1	-	-	-	37.3	-	41.1
		8/27	-	47.3	-	-	-	45.6	-	39.7
	1981	7/26	12	39.2	1	62.0	79	36.1	146	34.0

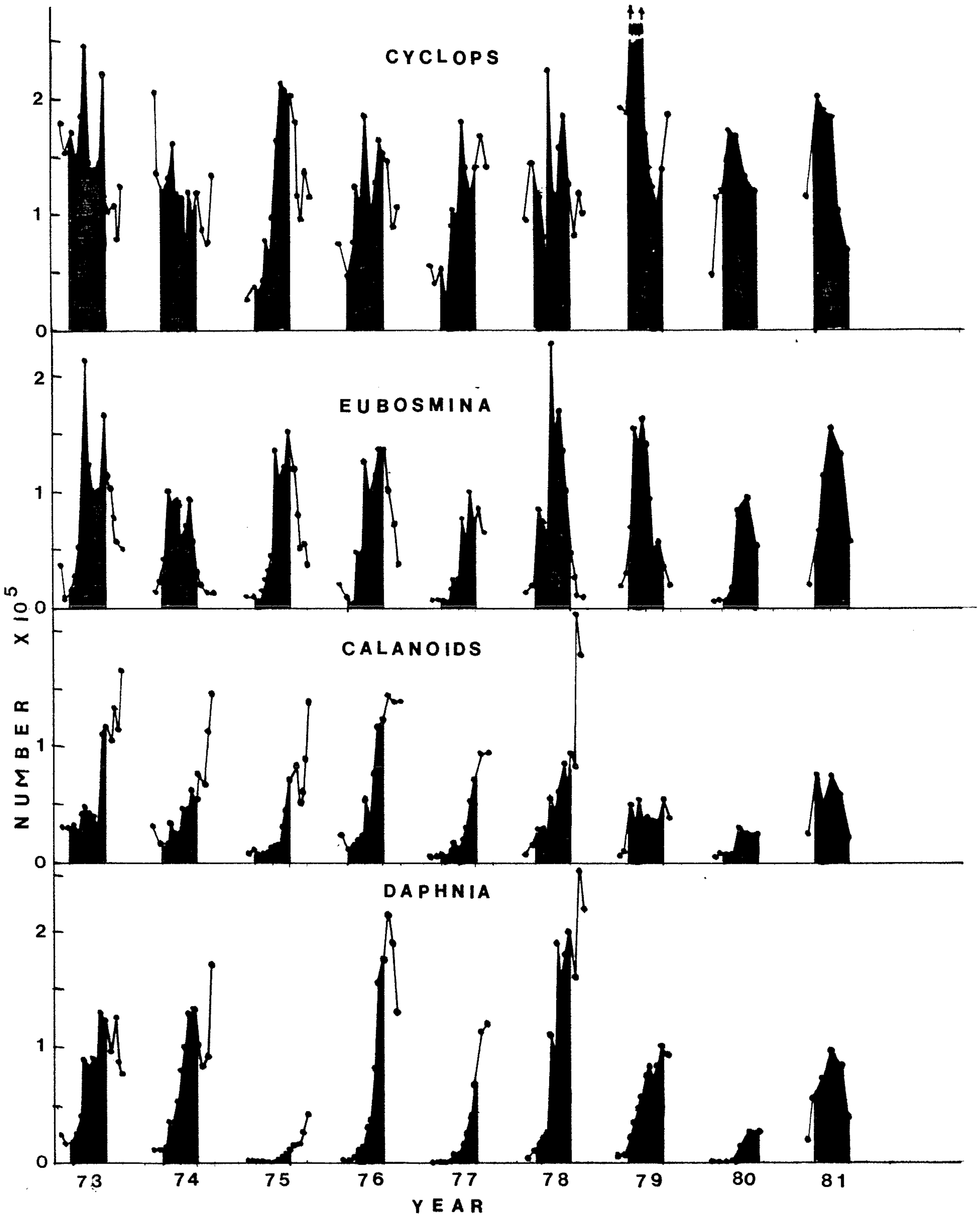

Fig. 1. Densities (thousands per m^2) of zooplankton in Little Togiak Lake during the summers 1973-1981. Geometric means from six hauls per date. Period July 1-August 31 shaded.

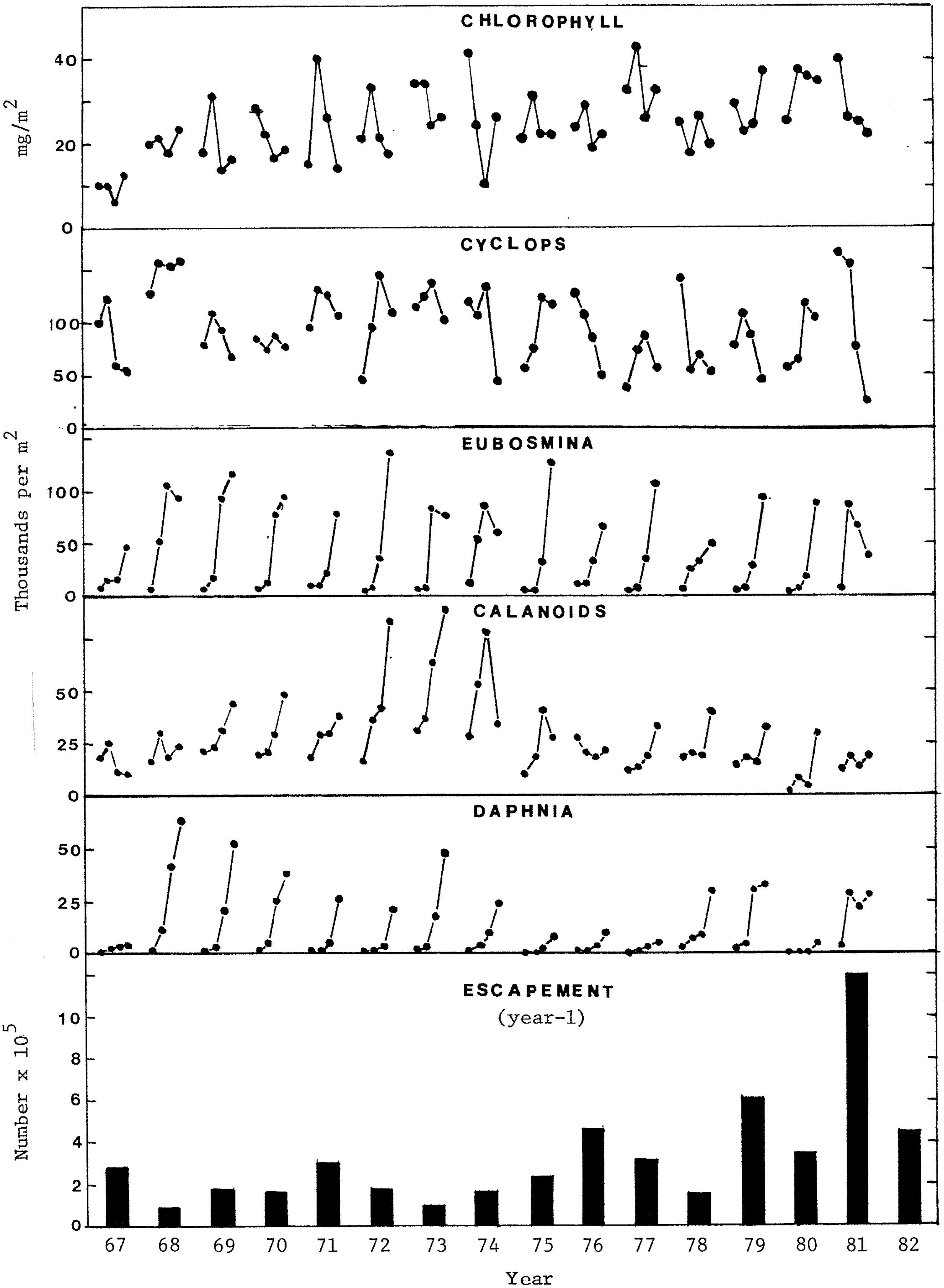

Fig. 2. Densities of chlorophyll a (0–20 m) and major zooplankters about June 24, July 15, August 5 and September 5, 1967-1981 in Lake Aleknagik and the sockeye escapement to the lake in the previous year.

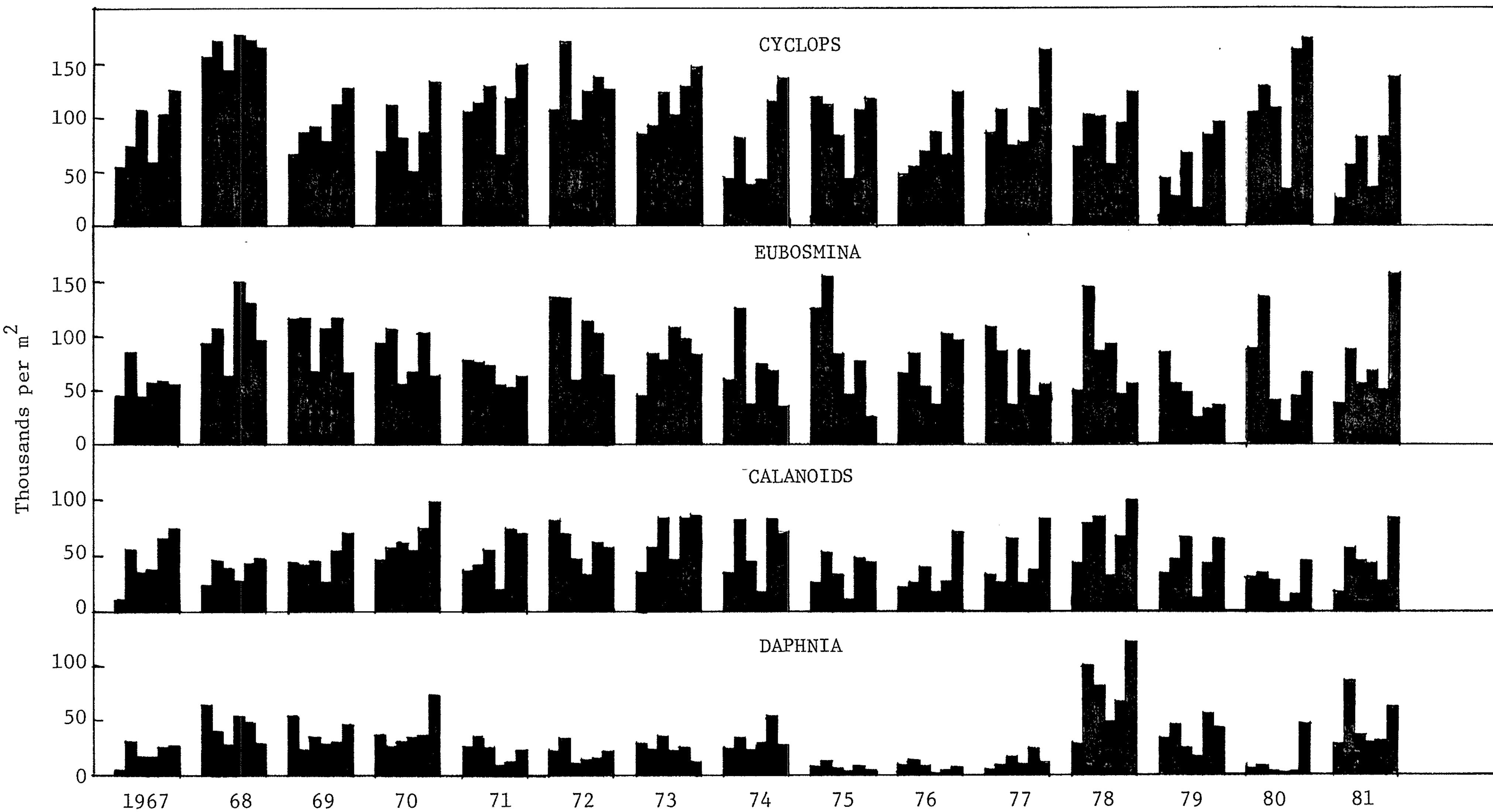

Fig. 3. Densities of major zooplankters (geometric means, n=6) in the Wood Rivers lakes during August 20-September 10, 1967-1981. Lakes in order from left to right: Aleknagik, South Nerka, Central Nerka, North Nerka, Beverley, and Kulik.

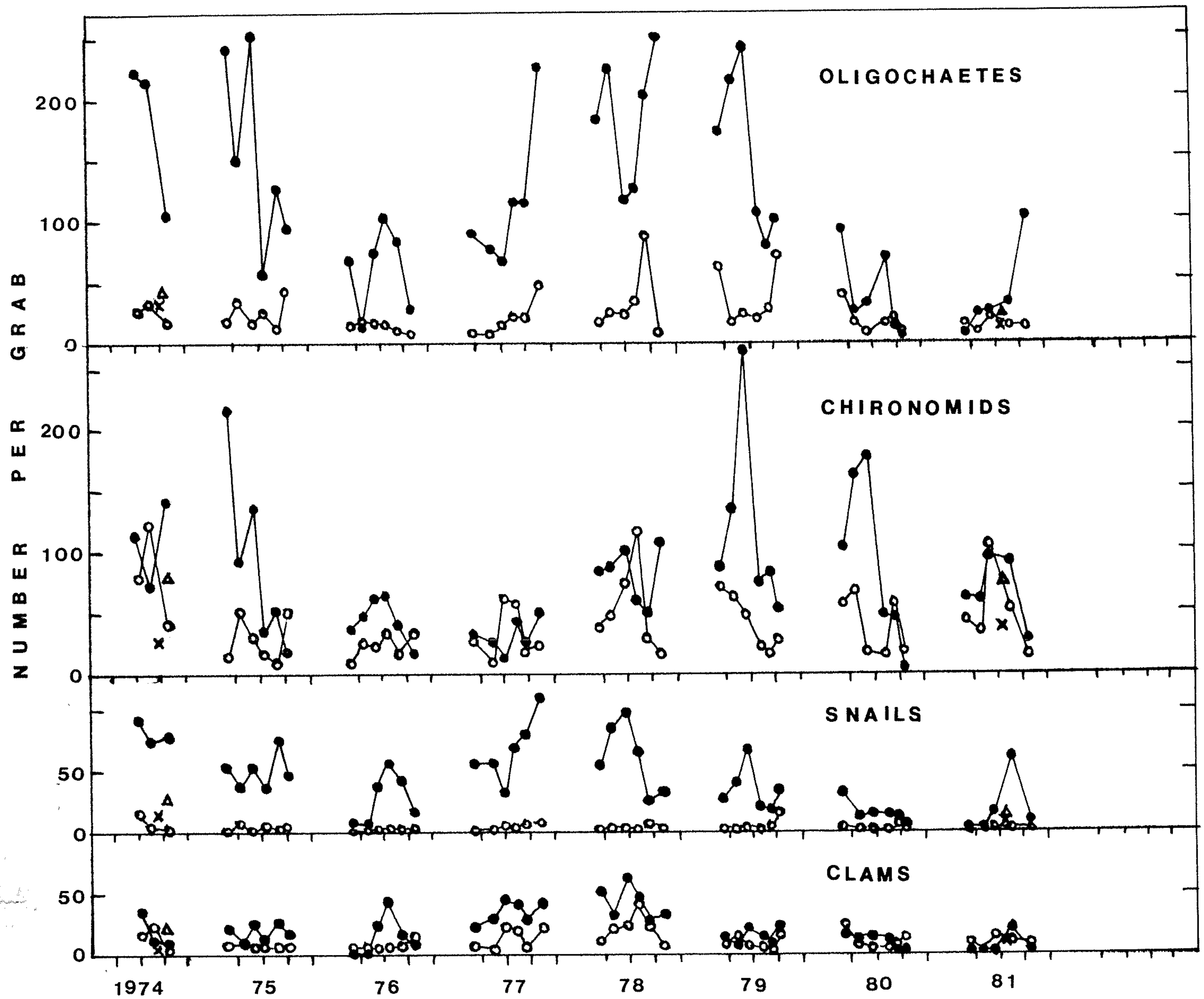

Fig. 4. Geometric means of the numbers of major benthic organisms (per 225 cm^2) from sampling between 3 and 10 m at the west end (solid) and east end (open) of Little Togiak Lake. From 1975 through 1981 sampling began about June 20 and ended about September 8 (4 samples per date). Densities for the Igushik lakes are indicated by a triangle and an X.

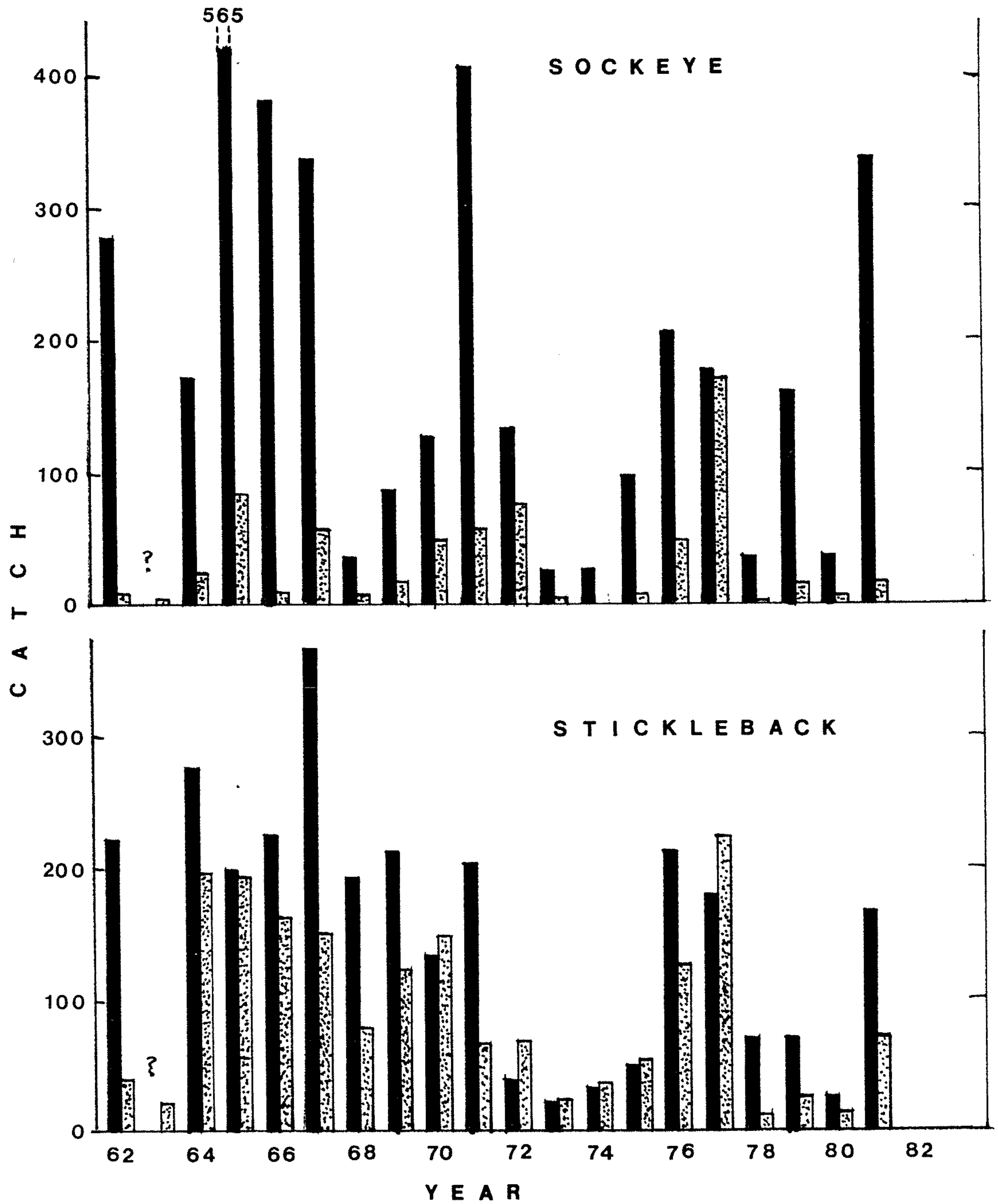

Fig. 5. Geometric means of beach seine catches of sockeye salmon fry and threespine stickleback in Lake Aleknagik, 1962-1981. Catches during June 20-July 15 shown by solid bars (n=40) and catches during July 20-August 5 by shaded bars (n=20).

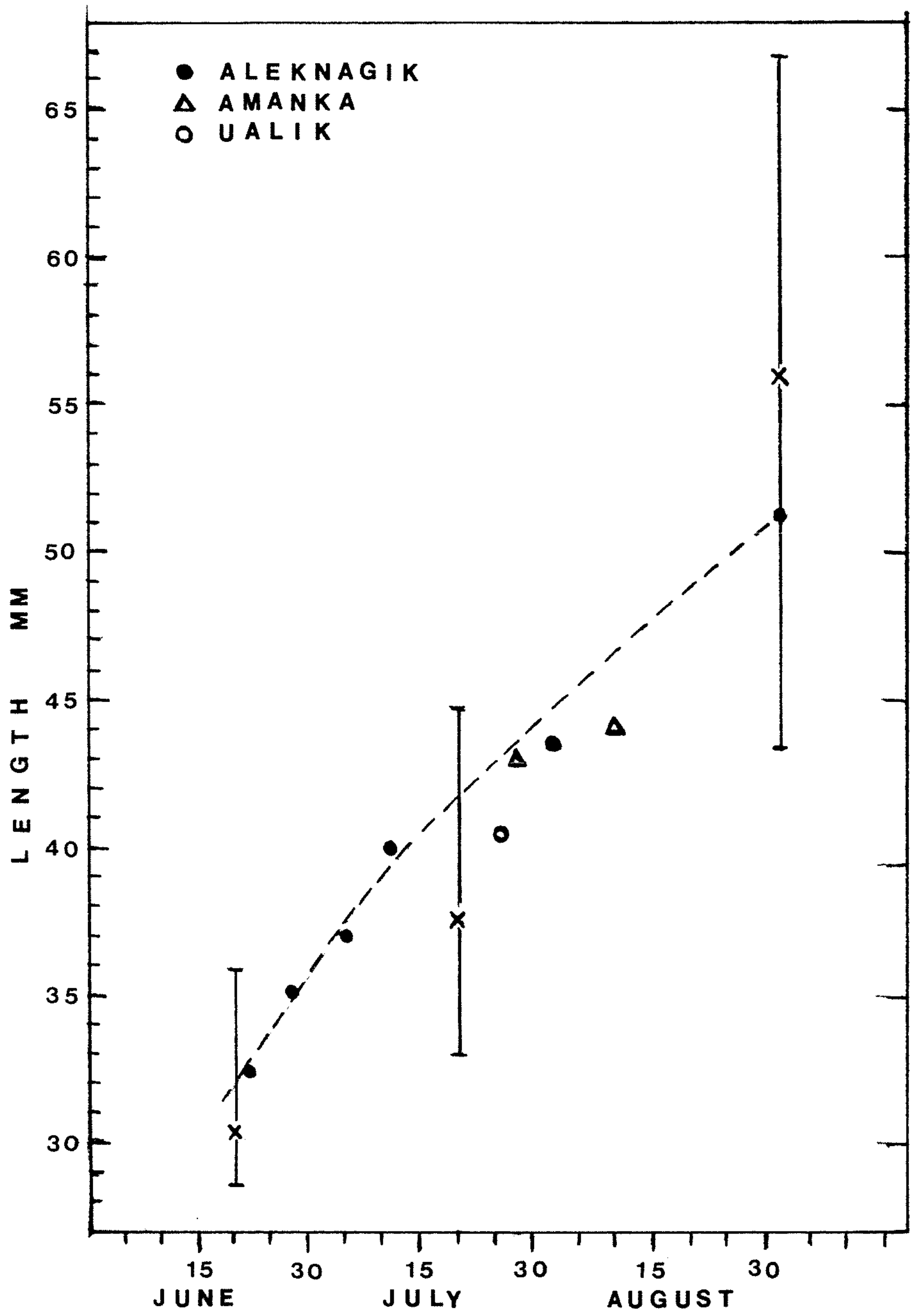

Fig. 6. Mean lengths of sockeye salmon fry in Lakes Aleknagik, Amanka and Ualik in 1981 and the averages and ranges in annual means in Lake Aleknagik on June 20, July 20, and September 1, 1962–1980. Dashed line is a freehand growth trajectory for Lake Aleknagik fry in 1981.

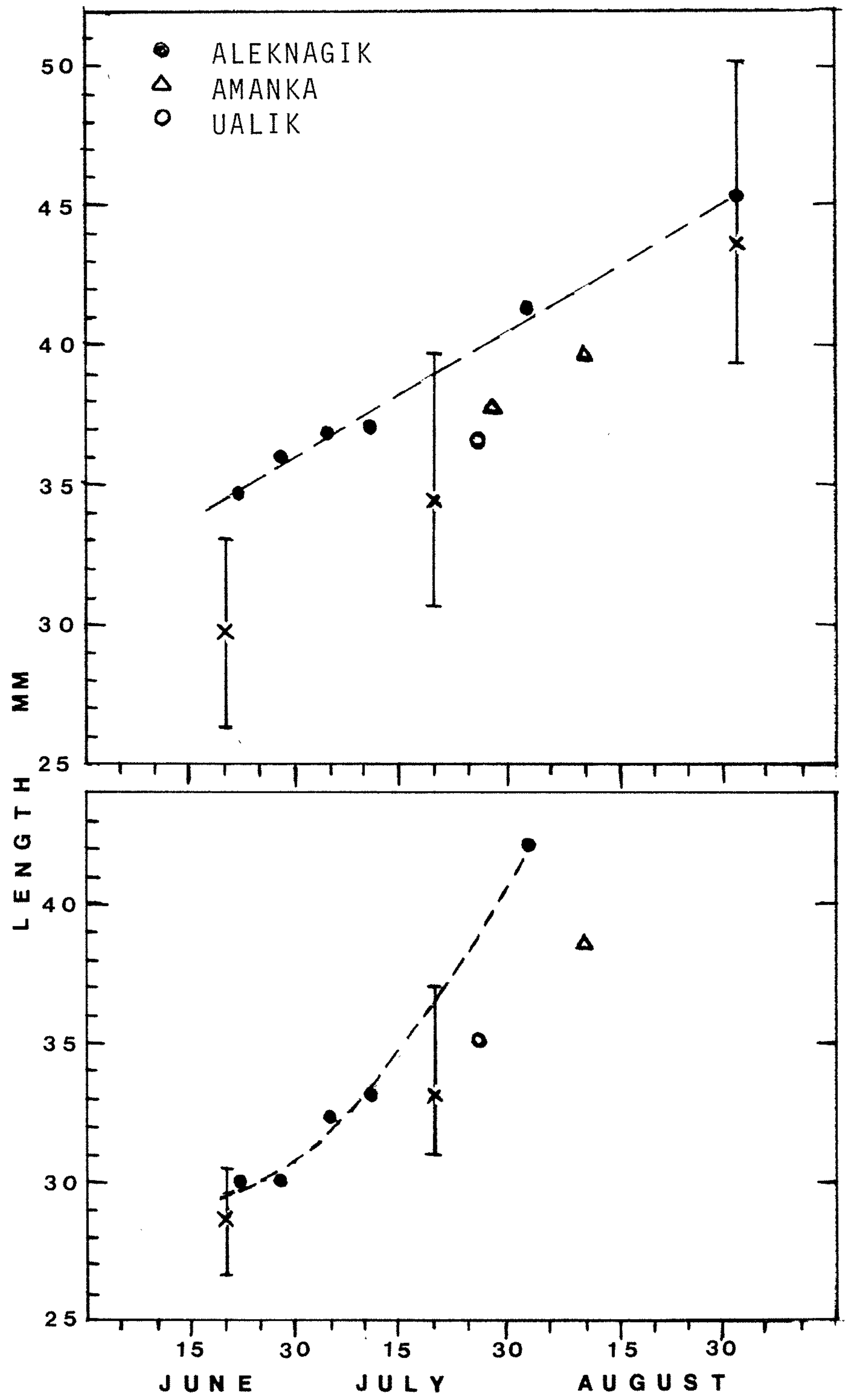

Fig. 7. Mean lengths of age I threespine sticklebacks (top) and Arctic char fry (bottom) in Lakes Aleknagik, Amanka and Ualik in 1981 and the averages and ranges in annual means in Lake Aleknagik on June 20, July 20, and September 1, 1962-1980.

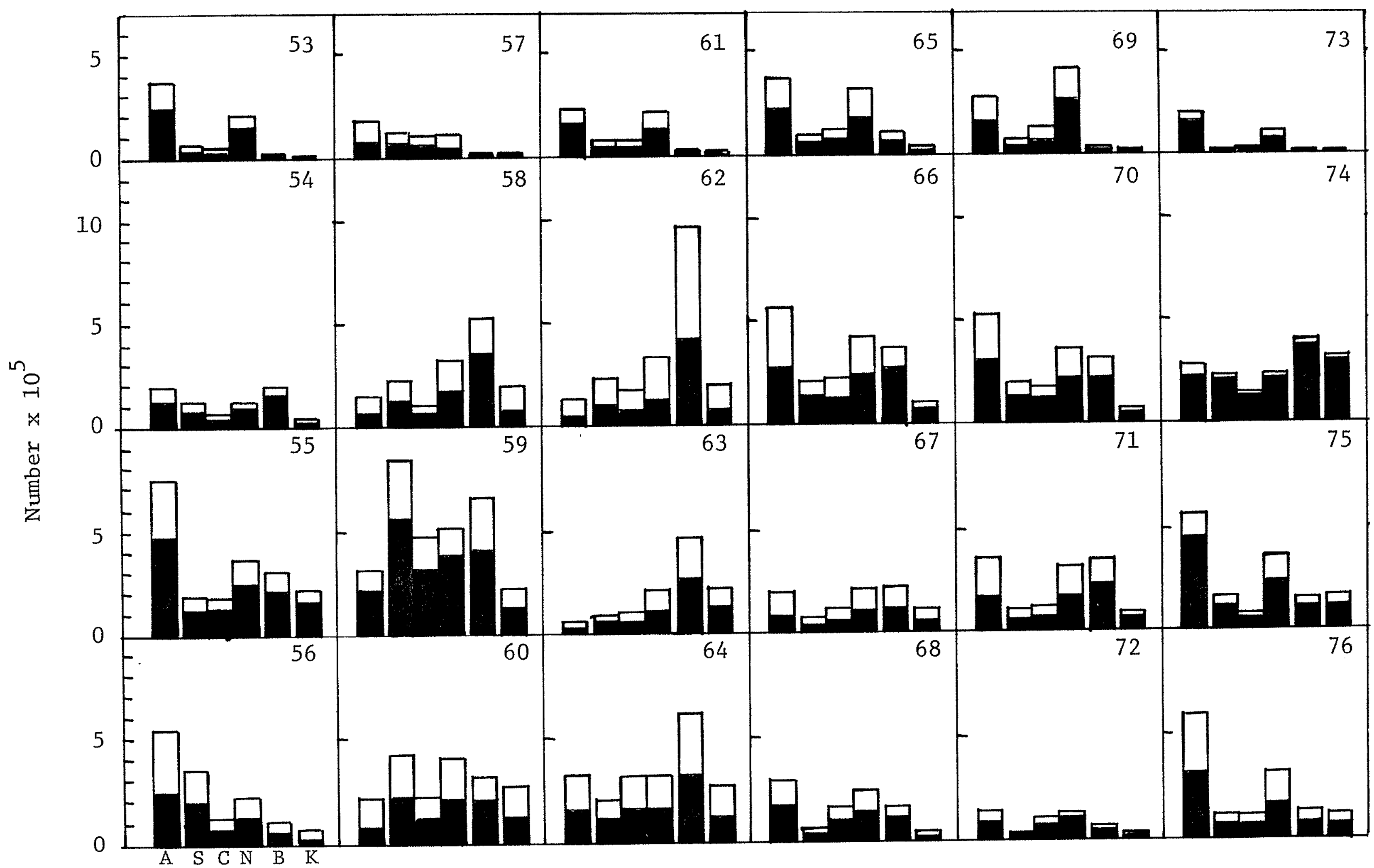

Fig. 8. Annual runs and escapements (shaded) to the major Wood River lakes: Left to right, Aleknagik (A), South Nerka (S), Central Nerka (C), North Nerka (N), Beverley (B), and Kulik (K), 1953-1976.

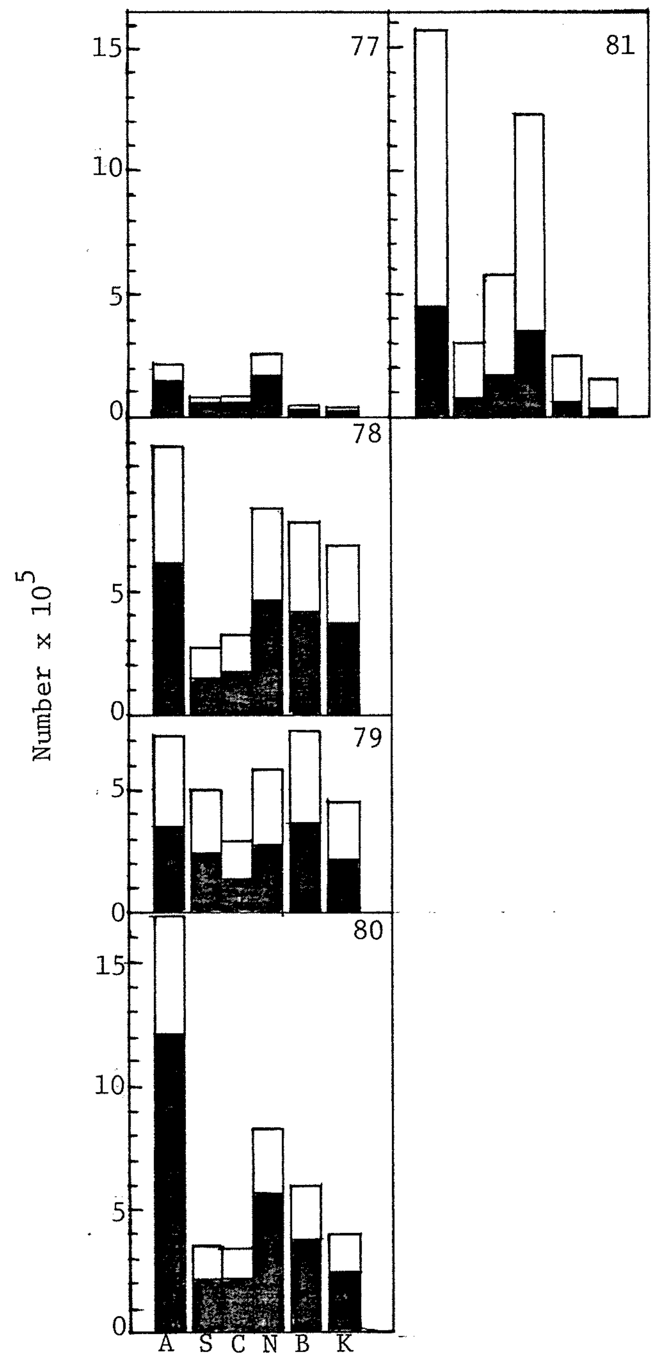

Fig. 9. Annual runs and escapements (shaded) to the major Wood River lakes, 1977-1981.

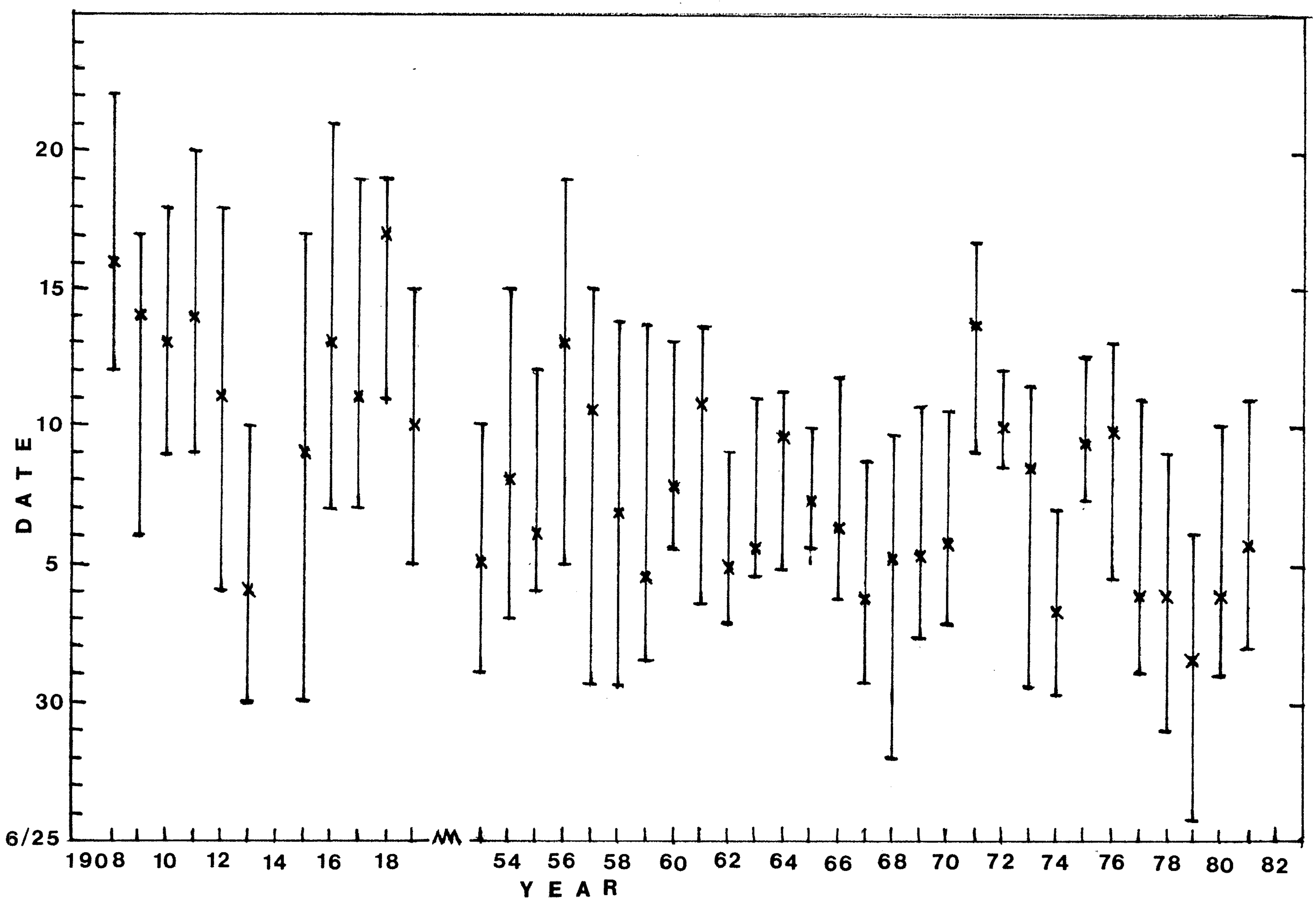

Fig. 10. Timing of the annual Wood River sockeye salmon escapements. Dates on which 10%, 50% (x), and 90% of the escapement entered the lake system at the head of Wood River, 1908-1919 (except 1914) and 1953-1981.

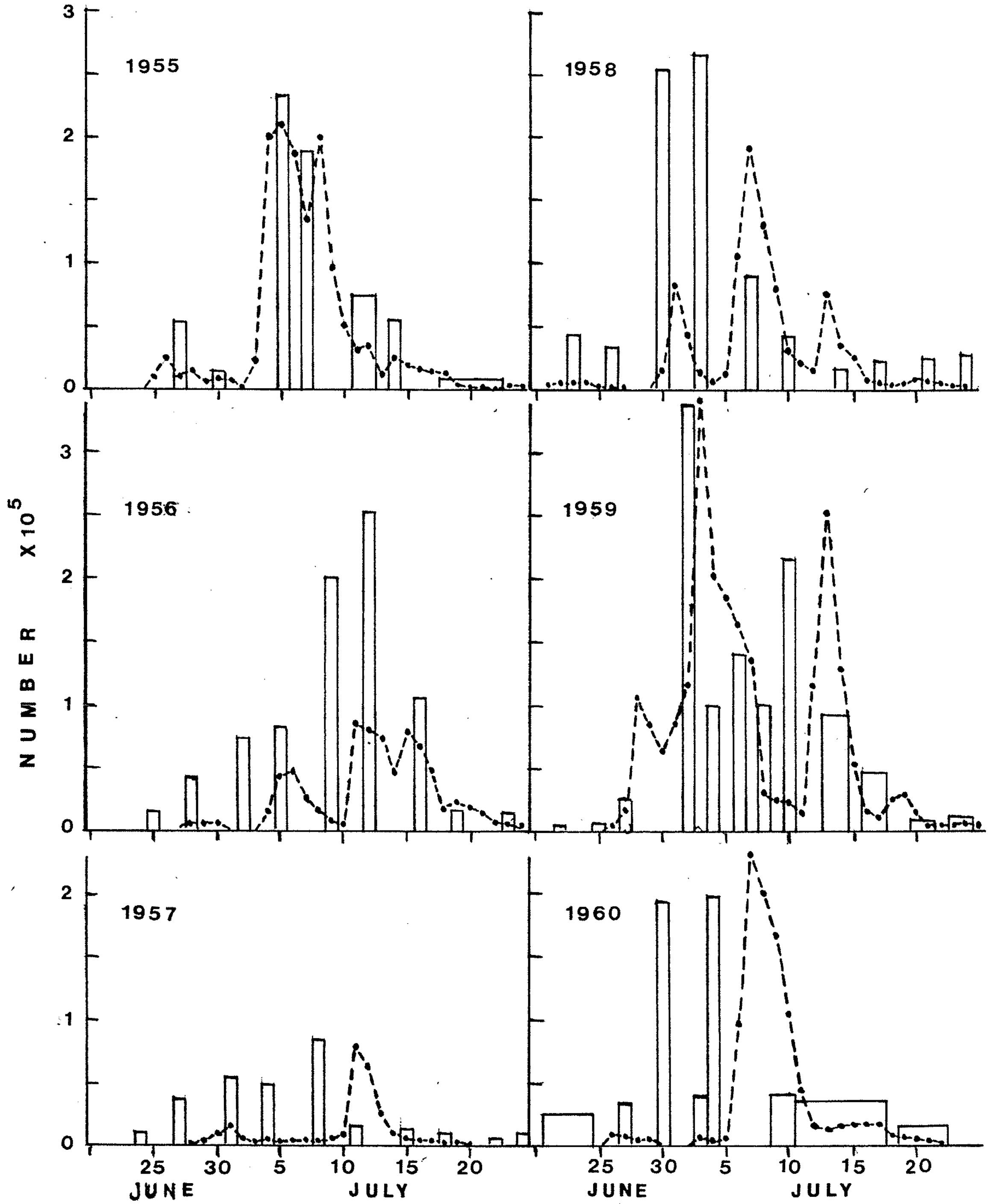

Fig. 11. Catches of Wood River sockeye salmon in Nushagak Bay (bars) and the escapements at the head of Wood River (dashed lines), 1955-1960.

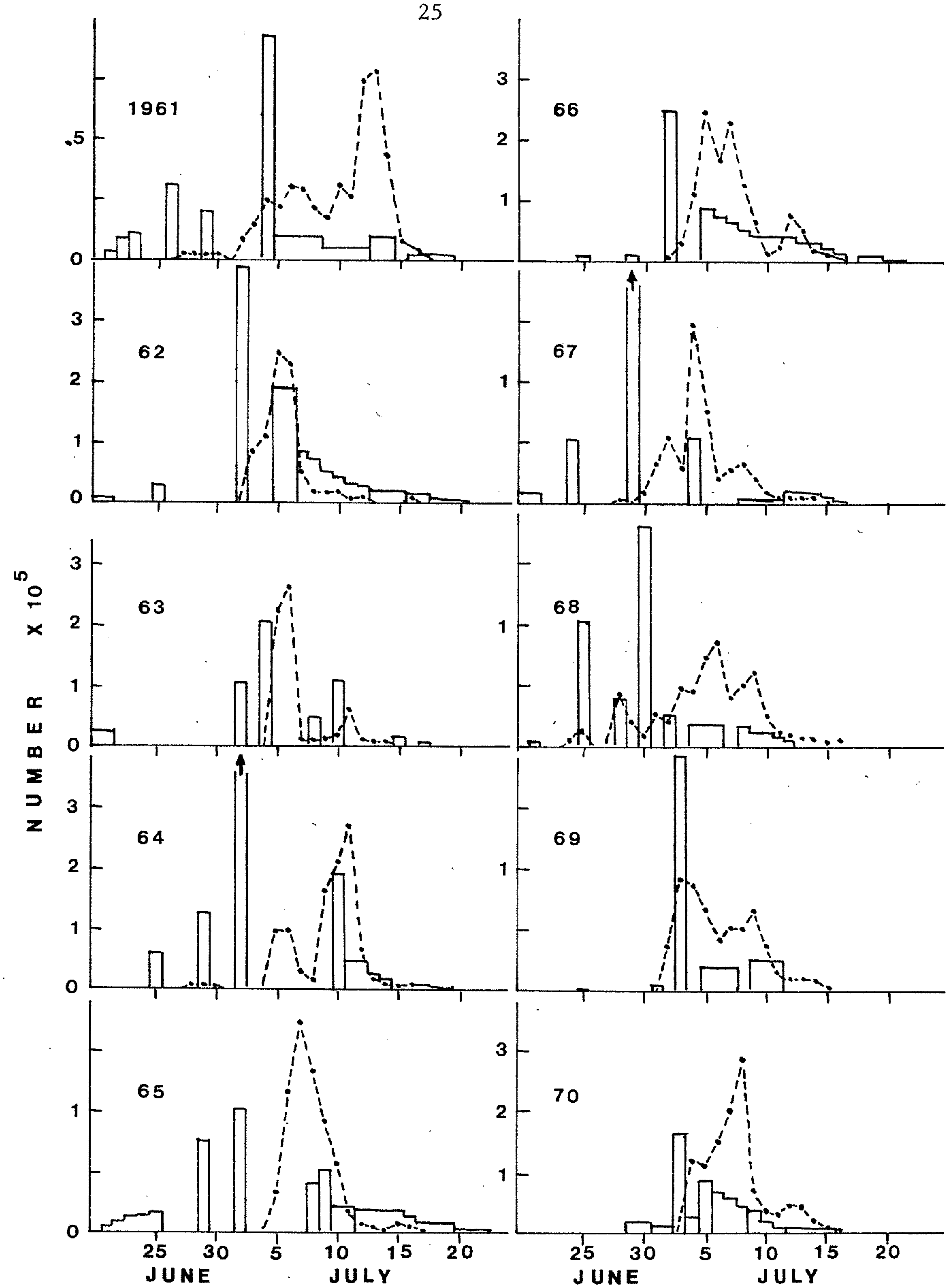

Fig. 12. Catches of Wood River sockeye salmon in Nushagak Bay (bars) and the escapements at the head of Wood River (dashed line), 1961-1970.

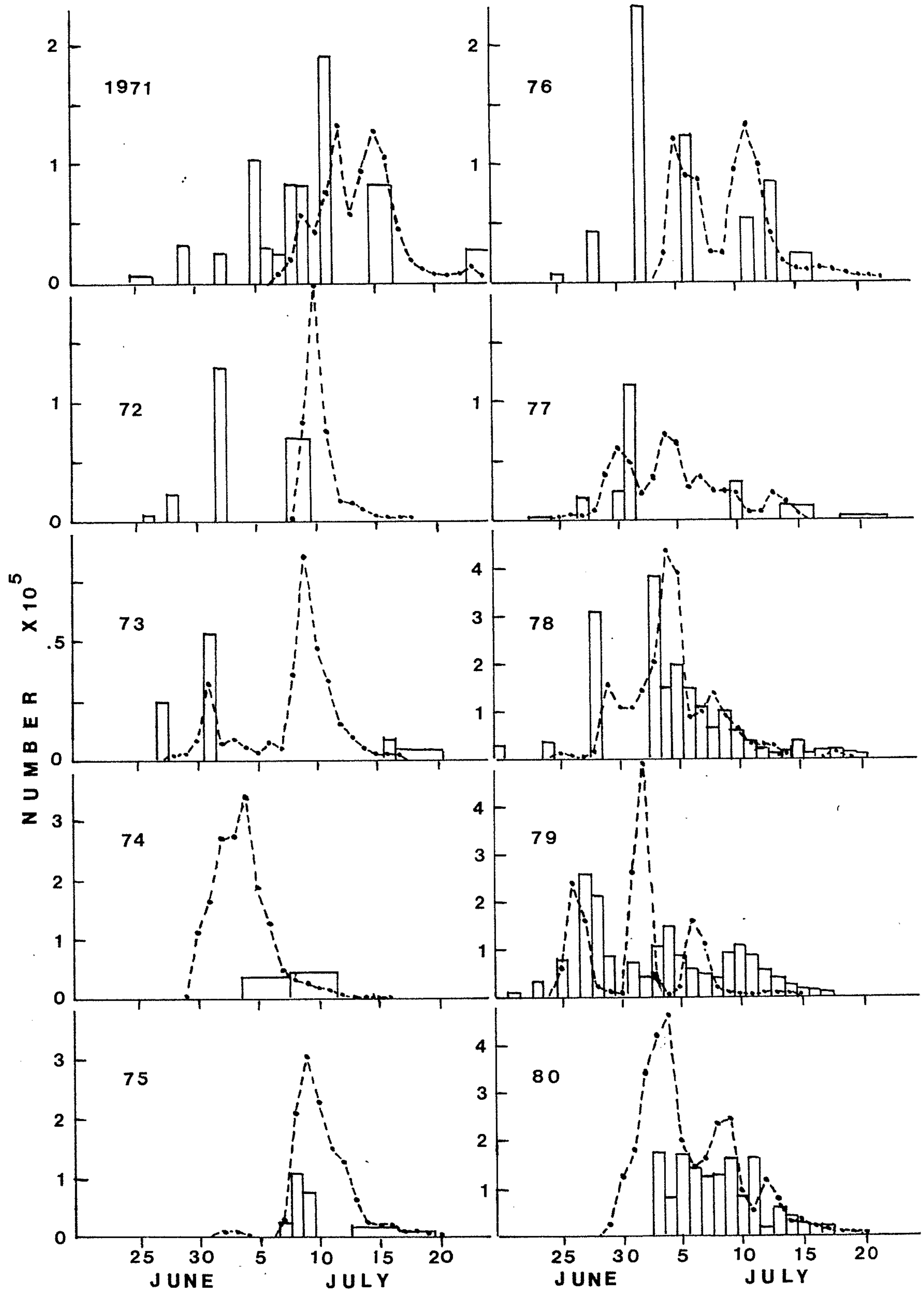

Fig. 13. Catches of Wood River sockeye salmon in Nushagak Bay (bars) and the escapements at the head of Wood River (dashed line), 1971-1980.

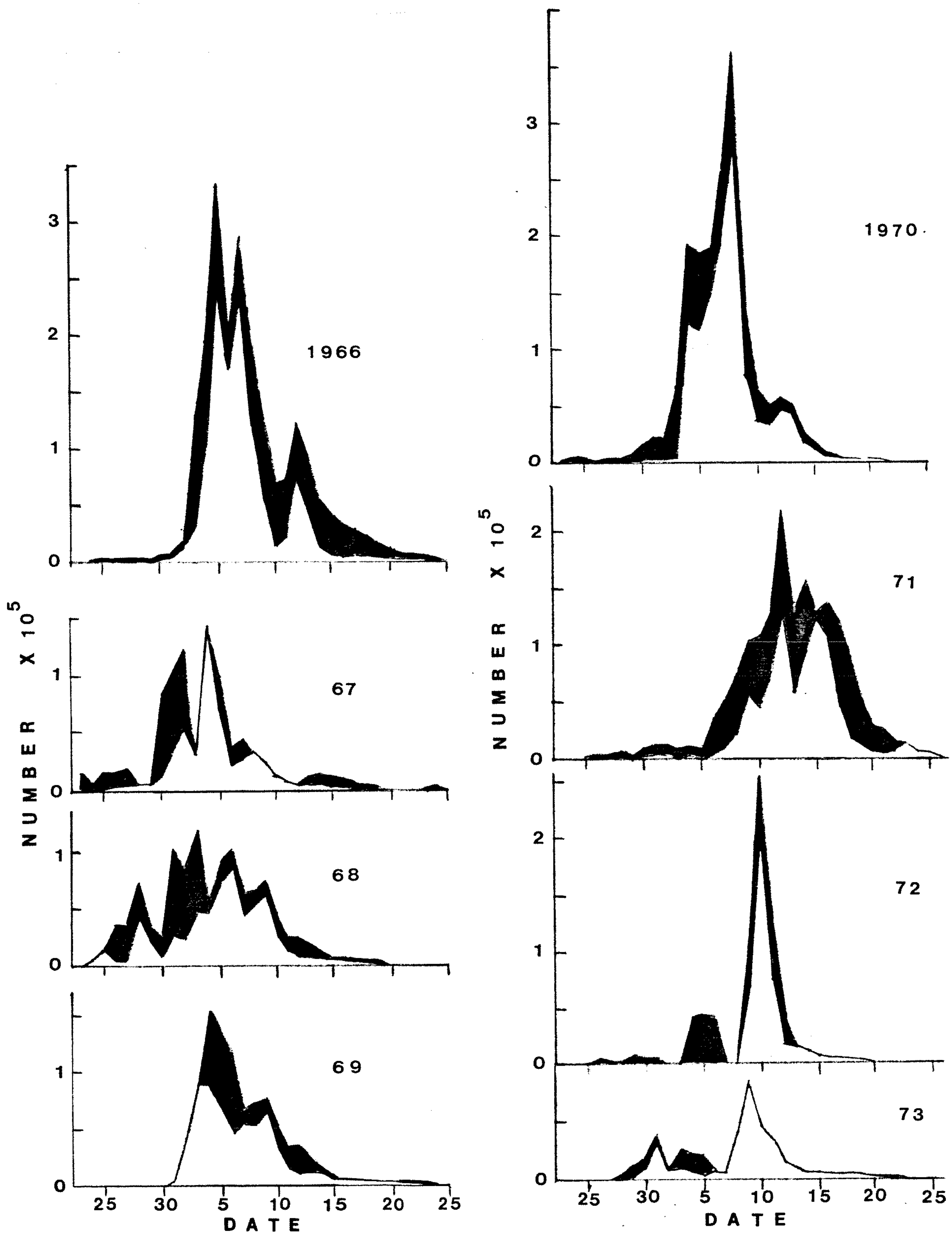

Fig. 14. Daily Wood River sockeye salmon runs at the head of Wood River. Shaded areas are commercial catches, 1966-73.

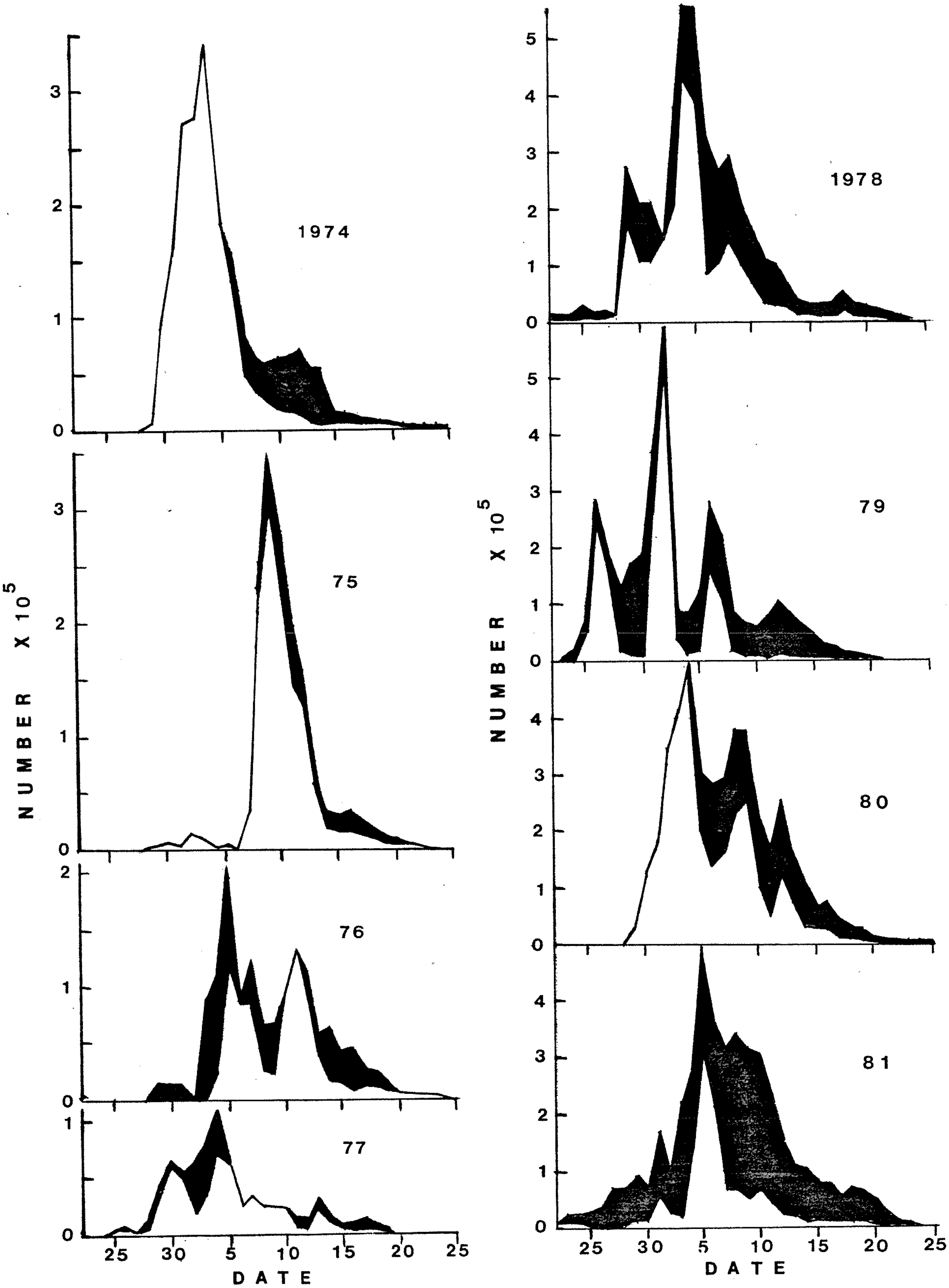

Fig. 15. Daily Wood River sockeye salmon runs at the head of Wood River. Shaded areas are commercial catches, 1974-81.

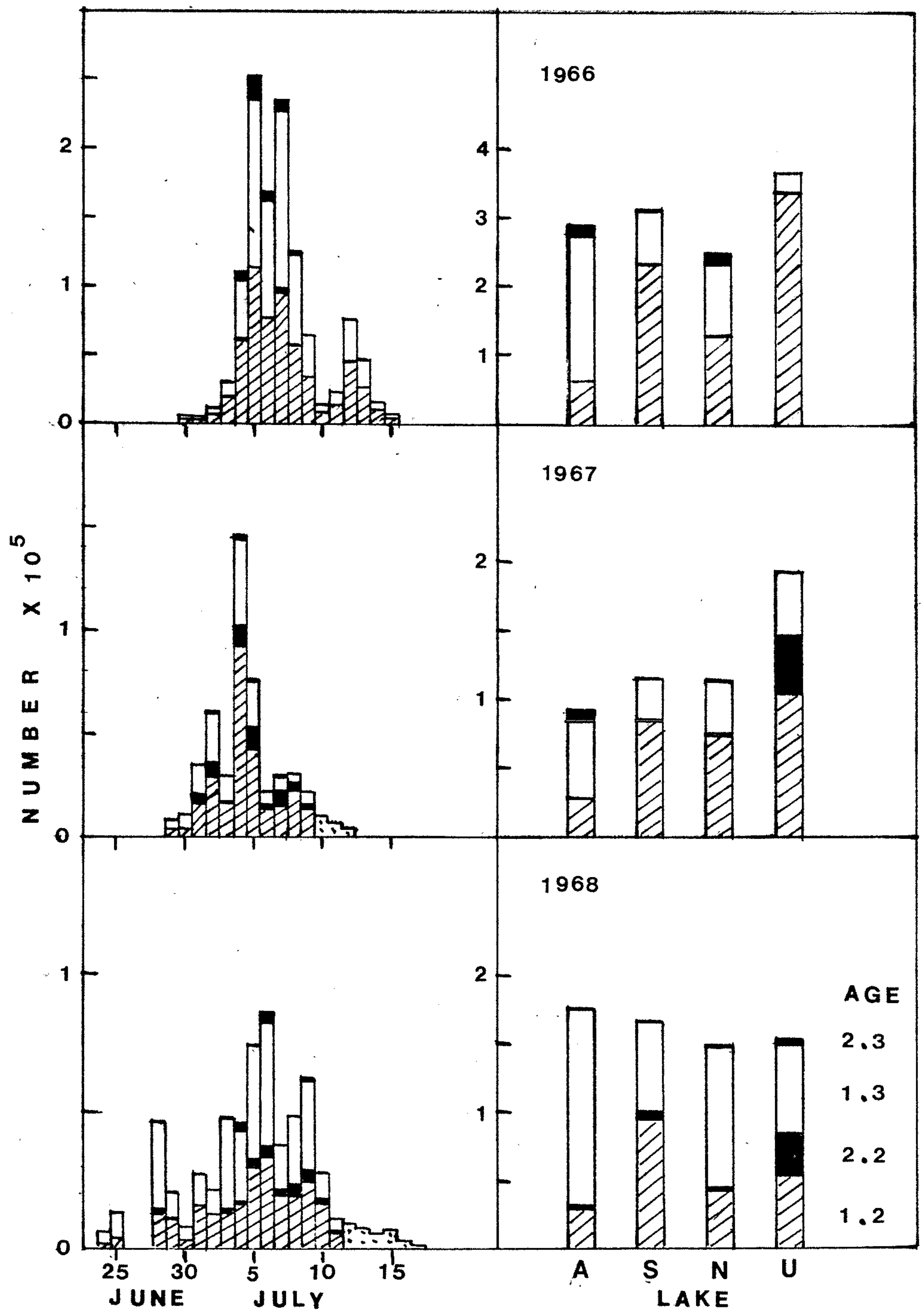

Fig. 16. Daily escapements to the Wood River lakes by age group (left) and the escapements by age group to Lakes Aleknagik (A), South and Central Nerka (S), North Nerka (N) and the upper lakes Beverley and Kulik (U), 1966-1968.

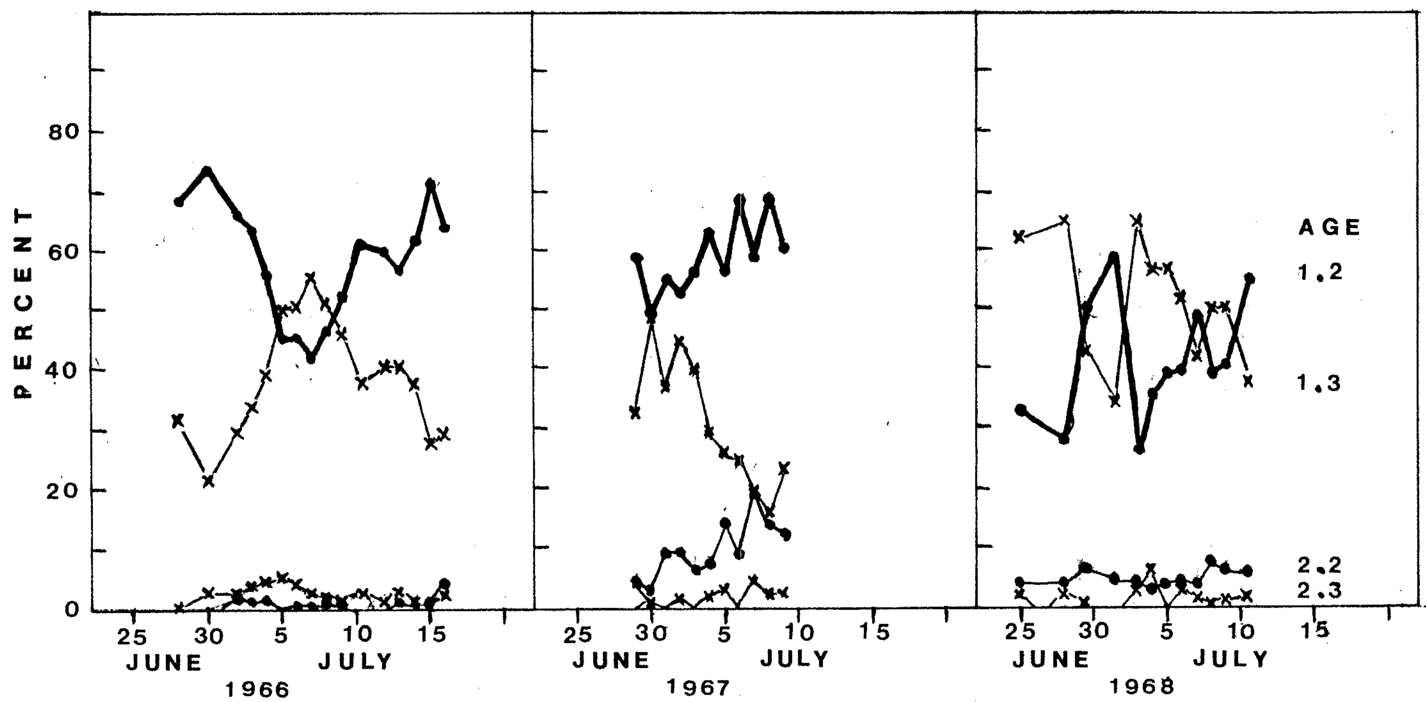

Fig. 17. Percentages of the four major age groups in the Wood River escapement by date, 1966-1968.