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ALASKA SALMON STUDIES

The Study of Red Salmon in the Nushagak District

by

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TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	ix
INTRODUCTION	1
RESULTS	1
Climatological Data	1
Sockeye Salmon Smolts	2
Char Predation on Smolts	2
Primary and Secondary Producers	3
Abundance and Size of Juvenile Sockeye	3
Abundance of Adult Sockeye Salmon	4

LIST OF TABLES

Table		Page
1.	Summary of physical measurements in the Wood River lake system in 1981 and the long-term means and ranges from prior years	7
2.	Average water temperatures in Lake Aleknagik for 0-20 m and 0-60 m, 1958-1981	8
3.	Average water temperatures 0-20 m in Little Togiak Lake, 1973-1981	9
4.	Mean surface temperatures at 10 beach seine stations on Lake Aleknagik, 1962-1981	10
5.	Average surface temperatures at insect traps in Little Togiak Lake by 5-day periods, 1973-1981	11
6.	Daily estimates of the number and size of sockeye salmon smolts from Little Togiak River in 1981	12
7.	Estimates of the abundance and size of sockeye salmon smolts from Little Togiak Lake by 5-day periods in 1981	13
8.	Length-weight statistics for sockeye salmon smolts from Little Togiak River, 1981	14
9.	Percent occurrence and average number of juvenile sockeye salmon in stomachs of Arctic char from Little Togiak River by 5-day periods in 1981	15
10.	Statistics from stomach samples of Arctic char collected by hook and line from Little Togiak River during 30 days following ice breakup, 1972-1981	16
11.	Average conductivity and secchi depth during June 20 - September 10 in Lake Aleknagik and Little Togiak Lake	17
12.	Densities of chlorophyll "a" and volumes of zooplankton in Lake Aleknagik, 1967-1981	18
13.	Geometric means of beach seine catches and mean lengths by sampling area in Lake Aleknagik, 1981	19

Table | Page

14. Geometric means of beach seine catches and mean lengths by sampling area in Little Togiak Lake, 1981 20

15. Geometric means of beach seine catches in Little Togiak Lake and Lake Aleknagik for the periods June 20 - July 18 and July 24 - August 11 21

16. Geometric means of townet catches by sampling area in the Wood River lake system in 1981 and the means and ranges in means from previous years. 22

17. Mean lengths by sampling area in the Wood River lake system in 1981 and the means and ranges in means from previous years 23

18. Average townet catches of sockeye salmon fry 24

19. Average townet catches of sockeye salmon yearlings 25

20. Average townet catches of threespine stickleback 26

21. Ground survey counts of creek spawning populations in the Wood River lake system in 1981 27

LIST OF FIGURES

Figure		Page
1.	Deviations from 60-year monthly means of air temperature and precipitation at Dillingham from November 1968 through May 1981	28
2.	Abundance of sockeye salmon smolts from Little Togiak River, the mean lengths at age I smolts, and river water temperature by 5-day periods	29
3.	Amounts of chlorophyll "a" and volume of zooplankton in Little Togiak Lake during the summers of 1973-1981.	30
4.	Average emergent chironomid catches in June, July, and August in three bays in Lake Aleknagik and three sites in Little Togiak Lake	31
5.	Daily escapements to the Wood River lake system and to Little Togiak Lake	32
6.	Annual runs of sockeye salmon to the main river systems in the Nushagak District, 1946-1981	33
7.	Nushagak sockeye salmon runs of 2-ocean fish by 4-year lines	34
8.	Nushagak sockeye salmon runs of 3-ocean fish by 5-year lines	35
9.	Plot of return on escapement of Wood River sockeye salmon, 1946-1976 brood years	36
10.	Spawner densities and the mean weights of fry on September 1 of the following year for Wood River lakes, and the average water temperature from June 15 to August 31 in Lake Aleknagik	37
11.	Relationships between return per spawner and spawner density for the 1951-1976 brood years	38

THE STUDY OF RED SALMON IN THE NUSHAGAK DISTRICT

Annual Report for October 1, 1980 to September 30, 1981

INTRODUCTION

This study of the sockeye salmon populations in the Nushagak District of Bristol Bay is a continuation of a research program that began in 1946 with financial support from the Alaska Salmon Industry. It is currently supported by the National Marine Fisheries Service ($50,000) and the Alaska Department of Fish and Game ($30,000). The emphasis of the research is on a comparative ecological study of the lakes and lake systems to determine: 1) causes of annual and long-term variations in abundance of adult sockeye salmon; 2) the effects of abundance and age composition of spawners on the abundance of juveniles and adults in the Wood River lakes system; and 3) methods for management of the freshwater environment by enhancing growth and survival of juveniles to increase the production of adult salmon. Our present research is largely directed toward this last objective; however, we have continued to monitor several physical and biological parameters in the lake system. These long-term measurments are valuable for our study, e.g., to estimate optimum escapements to individual lakes, as well as for other research projects in southwestern Alaska.

Our main purpose in 1981 was to determine the subsequent effects of the fertilizations of Little Togiak Lake during 1974-1978. The specific objectives were to determine: 1) the predation by Arctic char on migrating sockeye salmon smolts; 2) the abundance and size of smolts; 3) the relative abundance of phytoplankton, zooplankton, and chironomids; 4) the relative abundance and growth of juvenile sockeye salmon and associated fishes; and 5) the abundance and age composition of sockeye salmon spawners.

This report summarizes observations from the 1981 field search with comparable data from prior years. Analysis and interpretation of the data will be presented primarily in our future reports (1982) because this report comes so soon after the field season.

RESULTS

Climatological Data

The winter and spring weather in 1980-1981 was exceptionally warm--the fifth consecutive warm winter and fourth consecutive warm spring (Fig. 1). Precipitation was below normal during the winter and spring, and the lake level was relatively low during the summer (Table 1). Ice breakup was approximately May 23 or about one week earlier than average;

however, the water temperatures in June were generally the warmest recorded over the past 19 years (Tables 2-5). Solar radiation was above average during the remainder of the summer; thus, temperatures in late summer were above average but not record highs. Since the warm winter of 1976-1977, the temperatures in the hypolimnion of the lakes have been exceptionally warm.

Sockeye Salmon Smolts

Our sampling of the smolt migration from Little Togiak Lake did not begin until June 16 which was nearly 3 weeks after ice breakup in the lake; thus, we probably missed a significant portion of the migration in 1981. The largest single day's migration occurred on July 15 when there was a drop in water temperature and an increase in water level from heavy rainfall (Table 6). The age I smolts were exceptionally small until the 26th of June when their size began increasing (Table 7).

The parent escapements for the 1980 and 1981 migrations were comparable (45,000 and 44,000), yet the abundance of smolts in 1981 was considerably lower. The small size of the smolts and the warm temperatures in mid-June further suggest that a large portion of the migration had taken place in early June (Fig. 2).

Length-weight statistics for smolts from the 1981 migration are given in Table 8. For the smolts sampled in June (prior to significant plus growth), those in 1980 and 1981 had similar condition factors. At 80 mm the age I smolts weighed about 4 g. Those in the 1976 migration (the lake was partially fertilized in 1975) averaged 4.3 g at 80 mm. Thus the fertilizations of the lake produced smolts that were larger and relatively heavier at a given length during the early part of the migration. In each year the length, weight, and condition of the smolts increased in July, presumably from plus growth.

Char Predation on Smolts

The average number of smolts in the stomachs of Artic char sampled from Little Togiak River was relatively high during June 12-15 (Table 9). After June 16 when our smolt sampling began, the number of smolts in char stomachs was significantly lower. So our estimate of the intensity of char predation on sockeye salmon smolts in the 1981 migration is undoubtedly low (Table 10). Char were noticeably less abundant after June 16, and this was probably caused by the low water level in the river and the relative scarcity of smolts. Those char that were caught in the river were much smaller than average.

The predator-prey relationship between sockeye salmon smolts and Arctic char in Little Togiak River was examined in a Master of Science thesis by Gregory Ruggerone, completed in June, 1981.[1]

Primary and Secondary Producers

Measurements of conductivity were low in both Lake Aleknagik and Little Togiak Lake during the summer of 1981 (Table 11). Secchi depths were slightly lower than average in Lake Aleknagik and quite low in Little Togiak Lake. Although conductivity seldom varies much during the summer, Secchi depths are typically lower in early and late summer and higher in mid-summer than the averages given in Table 11.

The density of chlorophyll "a" in Lake Aleknagik in June was the second highest average for June since 1967, whereas the densities for the remainder of the summer were about average (Table 12). The settled volumes of zooplankton were exceptionally high in June and July, and exceptionally low in August and September. A similar situation occurred in Little Togiak Lake where the volume of zooplankton in June was the highest recorded for this time of the summer, although our observations only began in 1973 (Fig. 3). In the years in which Little Togiak Lake was fertilized the volume of zooplankton increased during August, whereas in other years the volume did not change significantly (1973, 1979) or declined (1980, 1981).

Emergent chironomid catches were generally low in 1981 except for the trap in Whitefish Bay where there were large catches in August (Fig. 4). There were significant increases in chironomid catches in Little Togiak Lake (following fertilization) only at Station 3. This station in the only one on the lake where there are no sockeye spawning grounds in the vicinity. There could have been increases in chironomid production at other stations but these may not have been detected because the abundance of fry and presumably predation on chironomids also increased subsequent to fertilization. The catches in Lake Aleknagik have generally declined following the large escapements to the lake that began in 1978.

Abundance and Size of Juvenile Sockeye

The sockeye salmon escapements to Lake Aleknagik and Little Togiak Lake in 1980 were the largest recorded (1.2 million and 80,000, respectively). We thus expected that the abundance of fry would be high and the growth of fry low in 1981. Beach seine catches were exceptionally

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[1]Ruggerone, G. T. 1981. Arctic char predation on sockeye salmon smolts at Little Togiak River, Alaska. M.S. Thesis, Univ. Washington, Seattle. 57 pp.

large in June and early July but declined considerably by mid-July (Tables 13-14). The fry in Lake Aleknagik on June 22, 1981 were the third largest for that date since sampling began in 1961. Their growth during late June and early July was the highest ever observed in the lake; however, growth from mid-July to September 1 was the second poorest ever observed for the period. This good early-summer growth and poor late-summer growth corresponded to warm temperatures and high zooplankton volumes in early summer, and average temperatures and very low zooplankton volumes in late summer. For the first time since 1973 the fry on September 1 were larger in Little Togiak Lake than in Lake Aleknagik although in both lakes the fish were well below average in length on September 1.

Beach seine catches of sockeye fry were generally above average in Lake Aleknagik but below average in Little Togiak Lake because the fish moved offshore earlier (Table 15). Catches of Arctic char fry were high and catches of sculpins were low in both lakes. Townet catches were below average throughout the lake system except in central Lake Nerka and Little Togiak Lake (Table 16). About September 1 the smallest fish were in the upper end of Lake Aleknagik (Area A) where the escapement density was highest in 1980 and the largest fish were in the south arm of Lake Nerka where the escapement density was lowest (Table 17). Townet catches of sockeye fry and threespine stickleback were above average in central Lake Nerka but generally below average in the other lakes, whereas catches of sockeye yearlings were low in all lakes except Little Togiak (Tables 18-20). Our townet sampling in Lake Beverley was curtailed in 1981 from bad weather, and we only sampled the lower end of the lake which typically contains fewer and larger fish than the upper end.

Abundance of Adult Sockeye Salmon

We estimated the 1981 escapement to Little Togiak Lake as we had done for 7 past years by tower enumeration (1/2-hour counts out of each daylight hour). On the average the escapement to Little Togiak Lake has been 2.3% of the lake system escapement. The 1981 escapement was 60,000, which was 4.9% of the lake system escapement of 1.23 million (enumerated by ADF & G). The daily pattern of the escapement into Little Togiak Lake has generally followed the pattern of the escapement into the system (head of Wood River); however, in 1981 the escapement into Little Togiak Lake appeared to come from a larger proportion of the late escapement into the system (Fig. 5). This also appears to be the case in 1977. The rate of exploitation was especially high in 1981 as about 72% of the fish were caught. From 1952 through 1980 the rate of exploitation averaged 41% and ranged from 19% to 60%.

The run to the Wood River system was large in 1981 and marked the fourth consecutive year of high abundance (Fig. 6). Prior to 1978 the Wood River system produced about 67% of the Nushagak sockeye salmon

runs, but since 1978 it has produced only 47% of the district runs. The Igushik and Nuyakuk systems produce predominantly 3-ocean fish (mainly age 1.3 or 5_2). Prior to 1978 the Wood River runs contained about 63% 2-ocean fish, whereas since 1978 they have contained 53% 2-ocean fish (mainly age 1.2 or 4_2). Thus the large runs in recent years have come more from increases in the returns of 3-ocean fish than from 2-ocean fish.

The 2-ocean fish in the Nushagak District have generally followed a 4-year cycle, thus four lines can be distinguished (Fig. 7). The strengths of the runs since 1978 have generally followed the strengths of the lines, and the run of 2-ocean fish in 1981 was small relative to the runs in the previous 3 years as this has been the weakest line. Five lines can be distinguished in the runs of 3-ocean fish and the large runs in 1980 and 1981 came on the two strongest lines (Fig. 8). These runs are among the largest runs of 3-ocean fish in the history of the fishery, whereas the recent runs of 2-ocean fish have not been record runs.

The large runs to the Wood River system have come primarily from the 1974-1976 brood years in which escapements were near or slightly above the recent historical optimum (Fig. 9). The escapements in 1978-1980 were large and escapements of this magnitude have produced poorly in the past; however, generally cold weather prevailed during past years of large escapements and we are presently in a warm period. Therefore, it is difficult to predict the expected returns from the 1978-1980 escapements.

There has been considerable variation in the distribution of escapements throughout the Wood River system, so the densities of spawners and their progeny vary from year to year (Fig. 10). The growth of sockeye fry is inversely related to their abundance and directly related to temperature and food abundance (which are somewhat correlated). However, precise estimates of the abundance of juvenile sockeye are difficult to obtain because sampling error is often quite large. The annual size (length or weight) of sockeye fry, if adjusted for the effects of temperature and food abundance, may provide a better measure of their abundance that could be used to predict the abundance of future runs.

One of our main objectives in 1981 was to evaluate the effects of the Little Togiak fertilizations on the abundance of adult returns. We plan to do this by comparing the relative production from the affected brood years between Little Togiak Lake and the other lakes in the system. The most valid comparisons are between Little Togiak Lake and other lakes with a comparable high percentage of beach spawners and fish that typically spend 2 years at sea (part of Lake Nerka and Lakes Beverley and Kulik). The distribution of the 1981 escapement is not yet available; however, we can compare the relative production in Little Togiak lake with the lake system as a whole. Spawner density in Little Togiak Lake has generally been greater than for the entire lake system,

and the return per spawner also has been somewhat higher than for the entire system. Plots of return per spawner on spawner density are shown in Fig. 11. Curves have been fitted to the data by regressing ln R/S on spawner density.

Progeny from the 1973 and 1974 brood years were partially subjected to fertilization in Little Togiak Lake (only the upper end or about 20% of the lake). The entire lake was fertilized in 1976-1978 (1975-1977 broods). The relative reproduction from the 1975 and 1976 brood years is only slightly higher in Little Togiak Lake compared to the lake system. However, the return per spawner for the 1977 brood year with only 4-year-olds having returned is already greater than four per spawner in Little Togiak Lake, whereas for the lake system the 1977 brood year had a spawner density of 1.3 and the return per spawner with only 4-year-olds is just 1.7.

The majority of the fish in the 1981 escapement to Little Togiak Lake was age 1.2 from the 1977 brood year (58% of the females and 65% of the males). For the entire lake system fish of age 1.2 constituted only 25% of the escapement as most of the fish (46%) were age 1.3 (preliminary data from ADF&G).

Otoliths were collected from most of the major spawning grounds; however, only those from Little Togiak Lake have been aged so far. Ground survey counts of creek spawners are given in Table 21. These data will be used with the age composition from otoliths to estimate the returns by brood year for individual creeks and lakes.

Table 1. Summary of physical measurements in the Wood River lake system in 1981 and the long-term means and ranges from prior years.

Measurement	1981	Long-term Mean	Long-term Range	Number of years
Date of ice breakup in Lake Aleknagik	5/23*	6/1	5/14,6/16	32
Mean water temperature about 0-20 m in Lake Aleknagik on:				
June 24	8.2	5.5	3.6, 7.6	19
July 12	-	8.3	5.7,11.3	19
Aug. 4	12.2	10.8	7.7,14.0	19
Sept. 1	12.1	11.2	9.3,13.0	23
Mean water temperature about Sept. 1 in the lake system:				
0-20 m	11.4	10.9	8.6,12.4	22
Total water volume	7.9	7.2	6.1, 8.2	22
Mean daily solar radiation (g cal/cm^2) during:				
June 1-15	420	408	291,552	17
June 16-30	454	444	283,572	18
July 1-15	418	408	284,590	19
July 16-31	287	372	192,478	20
Aug. 1-15	350	310	230,402	20
Aug. 16-31	241	258	175,351	20
Sept. 1-15	178	219	114,300	20
Sept. 16-30	-	158	101,216	9
Mean lake level (cm) at Lake Nerka during:				
June 1-15	143	132	84,206	29
June 16-30	127	151	97,218	29
July 1-15	96	131	75,191	29
July 16-31	87	106	53,172	29
Aug. 1-15	76	85	34,173	29
Aug. 16-31	80	83	30,183	29
Sept. 1-15	92	80	43,130	29
Sept. 16-30	-	89	45,179	24

*Between May 20 and 26.

Table 2. Average water temperatures in Lake Aleknagik for 0-20 m and 0-60 m, 1958-1981.

Year	June 21-26		July 12-20		Aug. 3-11		Sept. 1-5	
	0-20	0-60	0-20	0-60	0-20	0-60	0-20	0-60
1958	-	-	-	-	-	-	11.3	9.4
59	-	-	-	-	-	-	12.0	8.7
60	-	-	-	-	-	-	11.3	8.4
61	-	-	-	-	-	-	11.1	8.0
62	6.6	5.3	10.3	7.0	(12.3)	(7.7)	12.4	8.7
63	5.5	5.1	8.6	6.4	10.9	7.4	11.5	8.2
64	(3.9)	(3.9)	7.1	5.5	10.5	7.1	10.6	8.5
65	4.2	4.1	8.4	6.5	10.6	7.8	11.2	9.4
66	5.3	4.3	7.2	6.2	9.8	7.4	10.0	8.0
67	6.6	4.9	9.6	6.4	11.6	8.0	12.0	7.8
68	7.2	5.5	11.3	7.4	12.2	7.5	12.4	7.9
69	5.0	4.7	7.9	6.2	10.3	7.3	10.5	7.8
70	6.6	5.8	7.6	7.1	10.6	8.2	10.7	8.4
71	3.7	3.6	5.7	5.0	7.7	6.3	9.3	7.2
72	3.7	3.5	6.6	5.3	8.3	6.2	9.9	7.2
73	4.1	3.9	6.9	5.7	10.0	7.8	9.8	7.2
74	7.2	6.1	9.4	7.7	13.1	9.0	13.0	9.3
75	3.7	3.6	7.7	6.0	10.3	7.6	11.6	8.5
76	5.1	4.9	(7.4)	(6.4)	9.7	7.7	10.0	8.0
77	5.0	4.6	8.2	6.9	(11.2)	(9.1)	12.3	10.5
78	7.8	6.8	8.7	7.7	12.3	9.9	12.5	10.2
79	7.3	6.4	9.8	7.6	14.0	10.6	12.2	10.4
80	6.1	5.6	8.4	7.3	10.5	8.5	10.6	8.6
81	8.2	7.1	(10.9)	(8.2)	12.2	9.5	12.1	10.0

Table 3. Average water temperatures 0-20 m in Little Togiak Lake, 1973-1981.

Date	1973	1974	1975	1976	1977	1978	1979	1980	1981
June 19-20	4.1	6.8	-	-	4.1	6.0	6.2	5.3	-
26-28	4.6	7.8	5.1	4.8	5.7	7.0	7.6	5.7	8.4
July 3- 5	5.5	9.4	5.2	-	7.0	7.0	9.0	7.0	9.1
9-11	6.5	9.8	6.8	6.1	7.3	7.7	9.2	-	-
16-18	8.3	-	7.8	-	8.1	8.4	10.3	8.3	10.5
23-26	9.9	11.5	8.5	7.6	9.7	9.1	11.5	-	-
Aug. 1- 3	9.8	11.8	9.6	8.6	-	10.5	11.2	9.6	10.7
7-10	10.2	11.5	9.8	9.4	-	11.1	12.3	-	-
13-18	10.6	11.4	9.7	9.8	-	11.3	11.7	10.0	11.7
21-24	-	11.9	10.4	10.5	-	10.7	11.5	-	-
28-29	9.7	-	10.5	10.1	-	11.6	11.3	10.4	11.0
Sept. 1- 4	9.1	11.5	-	-	10.9	-	-	-	-
5- 8	8.8	11.5	9.7	10.7	-	11.0	11.0	9.3	-
12-14	8.2	11.2	9.7	9.9	10.9	10.6	-	-	-
19-21	8.2	10.9	9.0	8.4	-	10.1	-	-	-
25	7.5	-	9.0	-	-	-	-	-	-
Oct. 2	-	-	8.8	-	-	-	-	-	-

Table 4. Mean surface temperatures at 10 beach seine stations on Lake Aleknagik, 1962-1981.

Year	Dates						
	6/21-26	6/30-74	7/6-11	7/14-17	7/21-26	7/31-8/5	6/21-7/17
1962	8.9	12.4	11.3	14.3	13.4	10.5	11.7
63	-	-	-	-	-	12.3	-
64	7.6	7.6	12.5	-	10.8	12.4	9.8
65	7.3	6.4	6.8	7.5	-	11.8	7.0
66	7.5	6.7	8.8	10.8	15.0	10.6	8.4
67	9.0	11.6	12.1	15.0	13.7	13.4	11.9
68	10.8	14.2	13.9	14.1	15.9	13.9	13.2
69	9.4	13.1	11.1	9.5	13.1	11.7	10.8
70	7.8	11.3	10.1	9.8	9.5	13.1	9.8
71	8.2	7.8	12.0	11.3	7.0	11.7	9.8
72	4.3	5.5	10.4	10.0	11.9	12.0	7.6
73	6.6	6.9	11.8	10.5	10.4	11.8	9.0
74	11.6	15.3	14.3	10.9	14.5	16.8	13.0
75	4.6	6.5	9.9	11.9	11.9	13.9	8.2
76	8.4	7.4	12.7	13.7	11.7	16.2	10.6
77	10.5	9.1	11.5	11.9	13.4	11.7	10.8
78	9.4	(8.5)	10.0	12.9	12.8	17.9	10.2
79	10.2	9.6	10.0	(11.6)	13.4	15.8	10.4
80	6.4	8.7	8.9	11.3	-	13.1	8.8
81	10.5	12.6	13.9	12.9	-	14.2	12.5

Table 5. Average surface temperatures at insect traps in Little Togiak Lake by 5-day periods, 1973-1981.

Mid-date of period		Year								
		1973	1974	1975	1976	1977	1978	1979	1980	1981
June	3	0.0	-	0.0	0.0	0.0	-	-	-	-
	8	0.0	-	0.0	0.0	0.0	-	-	-	-
	13	0.0	-	0.0	0.0	1.5	6.9	-	4.8	-
	18	3.2	8.6	4.0	1.0	6.0	7.2	8.2	6.2	10.0
	23	-	-	4.3	5.0	8.8	7.9	9.1	6.4	10.9
	28	8.2	11.6	5.7	8.4	10.7	8.2	9.3	7.8	12.0
July	3	10.7	15.9	6.2	7.9	9.2	7.5	11.3	7.8	10.4
	8	10.3	14.7	9.7	10.4	10.1	8.3	9.4	8.3	11.9
	13	10.2	12.8	11.4	11.6	12.1	10.3	-	10.1	12.7
	18	11.5	12.3	11.5	13.0	11.9	10.0	13.7	12.9	13.5
	23	13.1	15.7	13.0	11.7	12.3	11.1	12.4	15.0	13.9
	28	11.5	15.2	13.5	12.0	12.2	14.3	13.8	13.6	14.6
Aug.	2	13.5	13.6	13.7	13.7	11.2	17.6	-	13.6	14.3
	7	13.0	13.9	14.6	12.6	11.4	17.4	14.0	13.3	15.2
	12	13.1	14.4	14.9	13.1	11.3	15.4	13.3	12.5	-
	17	13.0	14.7	13.7	12.4	11.3	14.7	11.3	11.6	-
	22	12.2	13.8	13.8	13.5	13.2	14.5	11.8	11.1	-
	27	10.2	13.1	12.9	13.0	14.2	14.6	12.1	12.1	12.2
Sept.	1	10.0	13.2	11.5	11.2	13.8	14.0	10.9	11.6	-
	6	9.5	13.0	-	11.6	12.6	12.4	10.2	10.6	-
	11	9.4	12.3	10.5	10.4	12.2	11.7	-	-	-
	16	-	11.4	10.2	9.9	-	11.2	-	-	-
	21	-	10.1	9.9	8.1	-	-	-	-	-

Table 6. Daily estimates of the number and size of sockeye salmon smolts from Little Togiak River in 1981.*

Date	Number			Mean length (mm)	
	Total	Age I	Age II	Age I	Age II
June 16	1,700	1,600	100	71.6	95.3
17	1,900	1,900	0	74.4	-
18	1,900	1,500	400	74.9	98.5
19	4,200	3,600	600	74.6	92.5
20	2,600	2,600	0	70.0	-
21	1,500	1,400	100	71.5	115.7
22	600	600	+	72.3	-
23	600	600	0	73.1	-
24	400	400	+	74.1	97.9
25	800	800	0	72.7	-
26	7,700	6,000	1,700	81.7	93.9
27	500	400	100	-	-
28	500	400	100	-	-
29	1,200	1,100	100	76.9	96.4
30	600	500	100	77.1	95.1
July 1	800	700	100	-	-
2	(800)	(700)	(100)		
3	(600)	(600)	(0)		
4	(400)	(400)	(0)		
5	(200)	(200)	(0)		
6	200	200	0	78.4	-
7	200	200	0	80.0	-
8	100	100	0	81.6	-
9	200	200	0	80.1	-
10	200	200	0	-	-
11	600	600	0	-	-
12	300	300	0	83.3	-
13	800	700	100	89.3	108.4
14	2,600	2,200	400	92.4	114.3
15	25,100	24,400	700	90.0	106.3
16	4,100	4,100	0	86.1	-
17	2,900	2,600	300	88.3	106.6
18	200	200	+	88.0	106.6

* + = < 100 and numbers in ( ) are estimates for missing observations.

Table 7. Estimates of the abundance and size of sockeye salmon smolts from Little Togiak Lake by 5-day periods in 1981.

Dates	Numbers (hundreds)			Mean length (mm)		Mean weight (g)	
	Age I	Age II	Total	Age I	Age II	Age I	Age II
June 1- 5	No sampling						
6-10	No sampling						
11-15	No sampling						
16-20	112	11	123	73.1	94.9	3.3	8.0
21-25	38	1	39	72.4	108.9	3.2	12.8
26-30	84	21	105	80.6	94.2	4.1	7.9
July 1- 5	26	2	28	77.8	95.1	3.9	8.1
6-10	9	0	9	80.3	-	4.5	-
11-15	282	12	294	89.9	109.1	6.7	13.0
16-20	73	3	76	87.0	106.6	6.2	12.0
21-25	No sampling						
26-30	No sampling						
Total	624	50	674	83.6	99.0	5.3	9.5

Table 8. Length-weight statistics for sockeye salmon smolts from Little Togiak River, 1981.

Length interval (mm)	June 24			July 18		
	Mean length (mm)	Mean weight (gm)	Sample size	Mean length (mm)	Mean weight (gm)	Sample size
63- 67	66.0	2.88	1	-	-	-
68- 72	70.5	2.92	28	-	-	-
73- 77	74.9	3.49	17	-	-	-
78- 82	80.0	4.02	4	80.0	5.08	4
83- 87	-	-	-	85.0	5.84	23
88- 92	-	-	-	89.9	6.79	7
93- 97	-	-	-	95.5	8.14	8
98-102	-	-	-	99.2	8.91	4
103-107	-	-	-	104.0	11.19	2
109	-	-	-	109	13.36	1
114	-	-	-	114	14.16	1

Table 9. Percent occurrence and average number of juvenile sockeye salmon in stomachs of Arctic char from Little Togiak River by 5-day periods in 1981.

Date	Time collected	Arctic char: Number examined	Arctic char: Length (mm) Mean	Arctic char: Length (mm) Range	Sockeye salmon in stomachs: Percent occurrence Fry	Percent occurrence Smolts	Mean no. per stomach Fry	Mean no. per stomach Smolts
6/12-15	AM	20	433	301,527	15	50	0.6	4.6
	PM	19	439	327,533	0	58	0	1.7
16-20	AM	38	407	279,551	3	21	0.1	0.6
	PM	4	412	318,476	0	0	0	0
21-25	AM	43	404	271,532	0	21	0	0.7
26-30	AM	25	392	290,475	4	8	0.6	0.4
	PM	12	388	308,475	0	0	0	0
7/ 1- 5	AM	5	432	328,544	0	0	0	0
	PM	2	450	448,453	0	50	0	2.5
16-18	AM	13	374	311,500	0	31	0	0.8

Table 10. Statistics from stomach samples of Arctic char collected by hook and line from Little Togiak River during 30 days following ice breakup, 1972-1981.

	1972	1973	1974	1975	1976	1977	1978	1979	1980[2]	1981
Samples collected in the day:										
Number examined	—	49	--	18	49	206	170	50	122	101
Mean length (mm)	--	470	--	449	435	399	443	431	457	411
Percent containing smolts	--	67	--	50	61	21	42	38	80	27
Mean number of smolts	--	4.9	--	3.3	3.1	0.5	1.6	1.6	6.5	1.4
Samples collected at night:										
Number examined	82	72	64	53	47	119	146	128	156	23
Mean length (mm)	446	429	429	404	400	411	431	441	461	434
Percent containing smolts	60	29	39	31	51	11	42	20	82	48
Mean number of smolts	4.5	1.6	1.6	1.3	1.2	0.3	1.4	1.0	11.7	1.4
Sockeye escapement to Little Togiak Lake in year-2 (thousands)	55	24	14	14	48	30	18	26	45	44
Number of smolts migrating (hundreds)	--	--	--	--	1,438	3,036	4,582	3,588	9,813	267
Mean length of smolts in migration (mm)	—	83	90	84	84	88	84	85	76	75
Lake level (cm)	177	161	121	150	122	206	133	164	172	135
Total number of char removed	463	208	283	71[1]	113[1]	574	587	344	87	181
Total number of char measured	729	208	263	71	113	574	587	344	512	181
Mean length (mm)	444	444	435	415	427	388	432	427	456	408

[1]Char were also removed by the Alaska Department of Fish and Game; however, the total number removed in each of these years was less than 200.

[2]Sixty-nine percent of char were captured by 5 to 15 minute drift gillnet sets.

Table 11. Average conductivity and secchi depth during June 20 - September 10 in Lake Aleknagik and Little Togiak Lake.

Year	Conductivity (micromhos/cm)		Secchi depth (m)	
	Aleknagik	Little Togiak	Aleknagik	Little Togiak
1962	-	-	8.7	-
63	-	-	9.4	-
64	-	-	9.6	-
65	-	-	10.4	-
66	-	-	10.7	-
67	-	-	9.9	-
68	38.8	-	9.2	-
69	39.4	-	8.4	-
70	40.2	-	9.6	-
71	38.8	-	9.3	-
72	38.1	-	8.0	-
73	39.2	55.5	10.4	9.6
74	39.1	57.0	8.6	10.5
75	40.1	54.8	8.8	9.3
76	38.4	55.7	9.5	10.2
77	39.3	46.8*	8.0	6.1
78	43.6	53.1	9.6	8.2
79	38.1	52.9	7.3	8.8
80	37.2	51.2	7.6	10.1
81	35.4	50.2	8.9	7.4

*Values during the summer were highly variable ranging from an average of 35 in mid-July to 73 in early September.

Table 12. Densities of chlorophyll "a" (0-20 m) and volumes of zooplankton (0-60 m) in Lake Aleknagik, 1967-1981.

	Chlorophyll "a" (mg/m^2)				Zooplankton (ml/m^2)			
Year	June 21-25	July 10-16	Aug. 1-6	Sept. 1-5	June 21-25	July 10-16	Aug. 1-6	Sept. 1-5
1967	10	10	6	12	48	68	43	44
68	20	21	18	23	52	97	97	66
69	18	31	14	16	53	65	138	79
70	28	22	16	18	52	63	93	79
71	15	40	26	14	35	60	75	91
72	21	33	21	17	23	59	160	95
73	34	34	24	26	45	104	226	81
74	41	24	10	26	74	161	175	37
75	21	31	22	22	33	63	132	107
76	24	29	19	22	59	86	91	33
77	32	43	26	32	22	45	111	51
78	25	17	26	20	60	51	83	48
79	29	23	24	37	40	72	85	32
80	26	37	36	36	21	47	86	59
81	40	26	25	22	91	115	69	26

Table 13. Geometric means of beach seine catches and mean lengths (live equivalent, mm) by sampling area in Lake Aleknagik, 1981.

Date	Area A		Area B		Area C		Weighted mean	
	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$
				Sockeye salmon (age 0)				
6/22	2474	32.2	128	33.6	165	35.0	374	32.4
6/28	3265	34.6	298	34.1	741	37.1	897	35.0
7/5	1940	36.8	336	37.0	122	41.7	430	37.0
7/11	693	37.9	14	40.7	75	41.6	90	39.9
8/2	83	43.1	5	47.6	6	45.1	14	43.5
9/1*	3	46.1	10	52.4	4	51.4	5	51.1
				Threespine stickleback (age I)				
6/22	87	33.5	23	37.4	26	36.3	37	34.7
6/28	203	36.8	85	34.4	295	36.0	172	36.0
7/5	522	37.0	204	36.3	56	36.4	181	36.8
7/11	328	36.9	2	35.0	11	41.1	19	37.0
8/2	85	41.3	7	40.3	8	42.5	17	41.3
9/1*	8	43.7	15	45.9	5	46.5	8	45.4
				Arctic char (age 0)				
6/22	15	30.3	2	29.2	2	29.1	4	30.1
6/28	9	30.2	8	30.1	2	29.4	5	30.1
7/5	51	32.5	8	31.6	3	30.4	11	32.3
7/11	49	32.2	9	36.5	3	37.7	11	33.1
8/2	4	32.9	8	45.9	2	44.7	4	42.0

*Townet sampling.

Table 14. Geometric means of beach seine catches and mean lengths (live equivalent, mm) by sampling area in Little Togiak Lake, 1981.

Date	Area A		Area B		Area C		Weighted mean	
	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$
				Sockeye salmon (age 0)				
6/21	255	29.5	1556	30.7	360	31.7	523	30.7
6/28	767	30.0	89	30.5	221	34.8	247	31.0
7/6	212	30.1	30	31.8	10	33.3	39	30.4
7/13	11	30.0	1	28.9	0	-	2	29.9
7/29	8	29.6	1	29.2	4	52.2	3	36.5
8/28*	15	47.9	12	46.8	33	56.0	18	52.1
				Threespine stickleback (age I)				
6/21	3	26.4	56	27.2	88	28.6	25	28.0
6/28	16	28.4	268	28.8	23	30.8	46	28.9
7/6	14	27.9	40	29.2	25	31.9	24	29.8
7/13	0	-	1	27.4	.3	29.4	.4	27.9
7/29	1	29.0	1	29.4	1	43.0	1	33.8
8/28*	3	39.9	4	39.2	3	45.0	3	41.2
				Arctic char (age 0)				
6/21	45	29.7	535	30.3	128	30.6	146	30.3
6/28	149	30.4	86	30.6	50	30.4	86	30.5
7/6	35	30.3	30	30.7	25	31.3	32	30.7
7/13	4	32.6	36	31.1	3	31.9	7	31.3
7/29	0	-	12	35.9	11	36.0	4	35.9

* Townet sampling.

Table 15. Geometric means of beach seine catches in Little Togiak Lake and Lake Aleknagik for the periods (1) June 20 - July 18 and (2) July 24 - August 11.

	Sockeye salmon Age 0		Sockeye salmon Age 1		Threespine Stickleback		Ninespine Stickleback		Slimy Sculpin		Char fry Age 0	
Year	1	2	1	2	1	2	1	2	1	2	1	2
L.T.												
1973	63	14	0	0	34	18	2	1	17	5	19	5
74	12	5	1	0	35	27	7	3	7	4	12	2
75	135	24	0	0	65	78	6	12	17	16	39	15
76	125	20	0	0	87	108	9	9	9	2	22	7
77	118	38	2	6	58	146	4	11	8	5	15	3
78	99	11	0	0	21	51	1	12	5	4	16	6
79	94	2	0	0	112	40	8	7	4	3	13	5
80	77	27	0	0	18	122	2	38	10	9	25	7
81	56	3	0	0	73	42	5	4	7	2	73	4
Aleknagik												
1962	278	9	3	1	222	41	12	6	38	10	6	6
63	--	3	--	1	--	23	--	4	--	7	--	9
64	171	23	2	1	277	197	20	16	45	13	4	6
65	565	81	1	1	199	197	8	9	31	12	2	5
66	380	19	3	2	228	164	4	6	18	8	6	1
67	335	57	10	10	369	152	22	14	19	9	6	3
68	35	6	6	1	193	80	32	44	24	13	5	0
69	85	18	2	1	212	125	22	23	26	11	2	3
70	127	49	2	1	132	149	16	18	29	12	4	5
71	405	56	4	1	202	69	11	8	40	22	2	2
72	131	74	2	5	40	72	3	7	34	36	4	4
73	22	4	3	0	24	26	6	4	30	15	5	8
74	26	0	1	0	34	38	8	28	12	19	10	2
75	97	6	1	1	51	55	16	18	22	14	2	3
76	204	48	2	3	211	129	22	15	12	3	3	2
77	174	170	4	3	180	224	4	8	6	10	3	7
78	34	1	4	0	71	13	8	7	15	8	4	2
79	160	14	0	0	71	29	9	7	20	6	5	2
80	36	7	2	1	28	16	9	19	25	5	3	2
81	336	14	3	0	169	73	30	14	5	4	7	4

Table 16. Geometric means of townet catches by sampling area in the Wood River lake system in 1981 and the means and ranges in means from previous years.

		Sockeye fry (age 0)			Sockeye (age I)			Threespine stickleback		
		1981	1958-1980		1981	1958-1980		1981	1958-1980	
Lake		mean	Mean	Range	mean	Mean	Range	mean	Mean	Range
Aleknagik	A	3	21	1-377	0	1.3	0-42	9	34	+-377
	B	10	23	1-478	0	1.2	0-43	19	48	1-502
	C	4	32	5-521	0	1.3	0-31	7	52	7-196
South	A	5	7	*+-260	0	1.3	0-14	2	5	0-114
Nerka	B	3	6	+-101	0	1.0	0-12	3	7	+- 95
	C	0	3	0- 15	0.3	0.8	0- 5	1	2	0- 26
Central	A	3	4	0- 74	0.3	1.0	0-15	0	2	0- 99
Nerka	B	23	10	+- 65	0	1.0	0-13	20	7	+-125
	C	15	9	+- 60	0.2	0.9	0- 8	5	6	0-278
North	A	18	22	0-107	0.2	0.7	0- 4	7	15	+-243
Nerka	B	15	28	3-490	0	0.4	0- 5	7	9	0-112
	C	2	17	2-140	0	0.5	0- 3	8	15	0- 83
Beverley	A	--	13	+-163	--	1.4	0-10	--	14	+-117
	B	--	6	+-117	--	1.2	0-17	--	7	+-197
	C	1	5	0-158	0.2	0.6	0- 7	+	11	+-108
Kulik	A	0	10	1- 92	0	1.2	0-52	+	10	0-107
	B	5	10	+- 73	0.7	1.3	0-28	3	6	0- 63
	C	2	16	0-222	0.2	2.0	0-31	1	8	1-118
Little	A	37	37	+-550	1.9	4.5	0-15	14	20	2-252
Togiak	B	30	42	3-304	2.2	3.4	0-53	15	55	4-1657
	C	80	22	3-145	6.9	2.4	0-102	44	41	2-245

*+ = .1 to .4

Table 17. Mean lengths (live equivalent in mm on September 1) by sampling area in the Wood River lake system in 1981 and the means and ranges in means from previous years.

Lake		Sockeye fry (age 0)			Sockeye (age I)			Threespine stickleback		
		1981	1958-1980		1981	1958-1980		1981	1958-1980	
		mean	Mean	Range	mean	Mean	Range	mean	Mean	Range
Aleknagik	A	46.1	54	42-62	--	86	70-108	43.7	42	38-49
	B	52.4	56	44-65	--	88	70-112	45.9	43	40-51
	C	51.4	58	44-69	--	90	69-114	46.5	44	40-51
South Nerka	A	59.7	59	52-67	--	98	82-111	44.7	45	42-49
	B	58.8	60	46-72	--	96	74-120	46.2	46	39-51
	C	--	63	54-75	92.7	99	85-107	--	45	42-54
Central Nerka	A	58.9	55	42-70	83.2	94	77-115	--	44	39-52
	B	53.9	58	49-65	--	94	77-110	44.8	44	38-49
	C	56.4	58	48-64	89.9	99	80-114	46.7	43	40-48
North Nerka	A	55.7	57	46-65	89.1	93	73-115	46.4	43	39-50
	B	53.6	58	45-69	--	92	77-114	46.2	43	37-51
	C	52.5	58	44-67	--	94	77-105	46.8	45	40-52
Beverley	A	--	53	43-61	--	90	71-104	--	43	38-48
	B	--	55	43-66	--	88	70-112	--	44	38-48
	C	57.1	60	46-69	81.0	89	72- 94	--	43	37-47
Kulik	A	--	56	43-69	--	89	80-105	--	43	37-48
	B	59.7	57	46-72	87.5	90	81- 99	48.7	44	40-48
	C	53.0	57	41-66	92.7	90	80-106	44.4	43	37-47
Little Togiak	A	49.2	52	44-63	77.3	90	76-107	40.5	41	37-48
	B	48.0	53	45-62	93.5	92	77-105	39.7	43	36-48
	C	57.2	55	43-66	84.5	91	77-104	45.6	43	39-49

Table 18. Average townet catches (5-min tows) of sockeye salmon fry (age 0).

Year	Aleknagik (83)	South Nerka (63)	Central Nerka (51)	North Nerka (87)	Little Togiak (6)	Beverley (90)	Kulik (45)	Lake System
1958	14	4	4	10	38	1	3	7
1959	13	17	9	4	228	49	25	23
1960	111	62	42	42	138	42	66	62
1961	103	108	57	64	184	23	39	68
1962	54	2	7	26	21	2	10	19
1963	24	58	18	55	120	97	61	55
1964	24	3	7	44	36	29	55	27
1965	103	15	8	93	113	12	27	49
1966	219	4	7	70	15	3	2	60
1967	49	8	18	58	62	18	14	31
1968	10	4	11	8	66	16	18	31
1969	78	15	4	27	3	7	11	26
1970	43	2	5	21	120	2	1	16
1971	17	3	9	197	10	1	10	47
1972	10	2	11	8	21	2	15	8
1973	3	1	3	11	6	+*	24	6
1974	44	5	4	34	40	—	—	18
1975	8	7	15	9	24	35	26	17
1976	394	1	9	40	32	—	2	87
1977	25	19	50	143	28	5	6	45
1978	6	+	+	4	25	—	—	3
1979	130	3	17	50	138	—	36	53
1980	3	1	14	37	27	74	102	37
1981	6	3	16	13	53	(1)	3	7

* + <1

Table 19. **Average townet catches (5-min tows) of sockeye salmon yearlings.**

Year	Aleknagik	South Nerka	Central Nerka	North Nerka	Little Togiak	Beverley	Kulik	Lake System
1958	1.2	1.7	.8	.2	.1	1.1	.4	.7
1959	.3	0	.3	.1	1.4	.1	.3	.2
1960	.2	1.4	.9	.3	2.7	7.0	1.8	2.1
1961	13.8	10.3	3.5	1.7	19.5	5.1	21.0	8.6
1962	2.2	2.1	1.4	1.0	8.2	1.3	3.9	1.9
1963	.4	.4	.7	.4	1.7	.1	.5	.4
1964	.7	1.3	1.8	1.4	3.5	7.1	2.7	2.7
1965	.2	2.7	4.7	2.2	7.4	3.7	26.0	5.1
1966	38.9	5.1	8.6	2.8	6.9	3.0	1.4	10.8
1967	6.3	.9	1.2	.5	4.4	.5	.1	1.8
1968	.5	.1	.4	+*	4.8	.1	.3	.3
1969	.1	.3	.2	.1	1.2	.2	.1	.2
1970	.2	.1	+	0	.9	+	0	.1
1971	.4	.3	.4	.4	2.4	+	.1	.3
1972	1.3	3.9	4.2	.7	60.3	.5	1.0	2.5
1973	.9	2.5	1.9	.8	7.3	.3	8.5	2.0
1974	.1	.1	0	0	.5	—	—	.1
1975	0	+	0	0	2.5	+	.8	.1
1976	.9	.3	+	.2	3.1	—	.7	1.0
1977	7.7	2.8	2.9	4.1	5.9	1.5	6.9	4.2
1978	.5	+	.1	0	1.3	—	—	.2
1979	0	0	1.3	0	1.5	—	.8	.9
1980	1.1	.3	.3	.8	3.7	6.6	4.2	2.4
1981	0	.1	.1	.1	4.1	(.2)	.3	.2

* + < .1

Table 20. Average townet catches (5-min tows) of threespine stickleback.

Year	Aleknagik	South Nerka	Central Nerka	North Nerka	Little Togiak	Beverley	Kulik	Lake System
1958	36	11	4	51	82	53	77	40
1959	136	53	23	30	57	39	18	54
1960	53	7	6	18	18	30	9	23
1961	38	3	6	12	39	8	10	14
1962	139	6	8	5	41	2	4	31
1963	46	5	1	16	55	34	10	22
1964	272	2	12	11	78	8	11	61
1965	183	4	2	16	53	7	2	42
1966	150	1	2	12	55	8	+	35
1967	61	2	16	15	58	14	3	21
1968	268	15	60	11	161	12	35	73
1969	81	4	1	30	24	33	14	31
1970	87	3	2	9	63	4	3	22
1971	3	+	+	8	6	1	4	3
1972	11	2	11	11	155	9	11	11
1973	8	+	2	7	3	1	15	5
1974	119	20	167	143	70	—	—	89
1975	132	41	49	79	601	53	16	75
1976	30	10	22	19	42	—	10	18
1977	36	24	20	9	38	9	42	22
1978	21	4	7	35	33	—	—	19
1979	50	29	92	66	144	—	54	59
1980	24	28	13	48	22	108	61	50
1981	12	2	11	7	27	(1)	1	6

Table 21. Ground survey counts of creek spawning populations in the Wood River lake system in 1981 (number of fish in hundreds).

Location	Date of survey	Estimated off mouth	Number in creek Live	Dead	Total	1952-1980 Median	Range
Aleknagik							
Yako	8/2	10	15	8	33	9	1, 40
Hansen	8/1	1	2	9	12	30	2, 157
Eagle	8/3	1	5	+*	6	8	1, 67
Whitefish	8/4	1	6	+	7	8	1, 42
Happy	8/5	2	17	24	43	17	2, 57
Bear	8/6	3	50	23	76	30	12, 102
Ice**	8/7	3	66	77	146	66	22, 180
South Nerka							
Fenno	8/10	0	2	12	14	19	4, 170
Lynx	8/16	2	35	5	42	18	1, 170
Stovall**	8/19	0	8	10	18	23	3, 750
Central Nerka							
Elva	8/12	1	3	+	4	2	1, 15
Pick	8/15	+	69	45	114	94	24, 782
North Nerka							
Hidden Lake	8/18	0	2	6	8	17	1, 163
Kema**	8/20	0	1	6	7	26	2, 200
Beverley							
Moose**	8/17	0	2	2	4	23	3, 256
Kulik							
Grant River	8/22	0	32	21	53	70	9, 320

*+ less than 50 fish

**Entire creek is not surveyed.

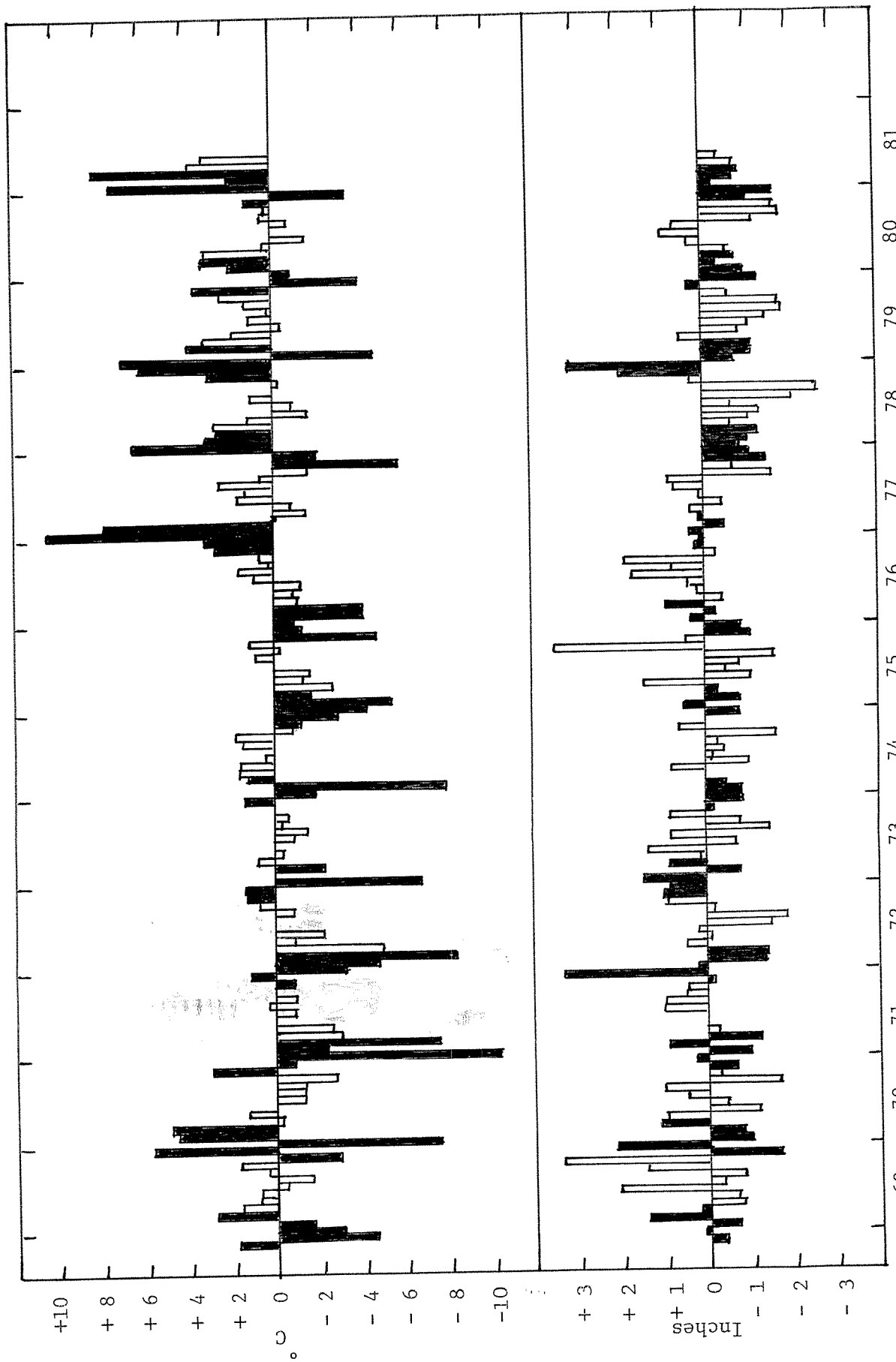

Fig. 1. Deviations from 60-year monthly means of air temperature (top) and precipitation (bottom) at Dillingham from November 1968 through May 1981. Solid bars for winter months (Nov.-Mar.).

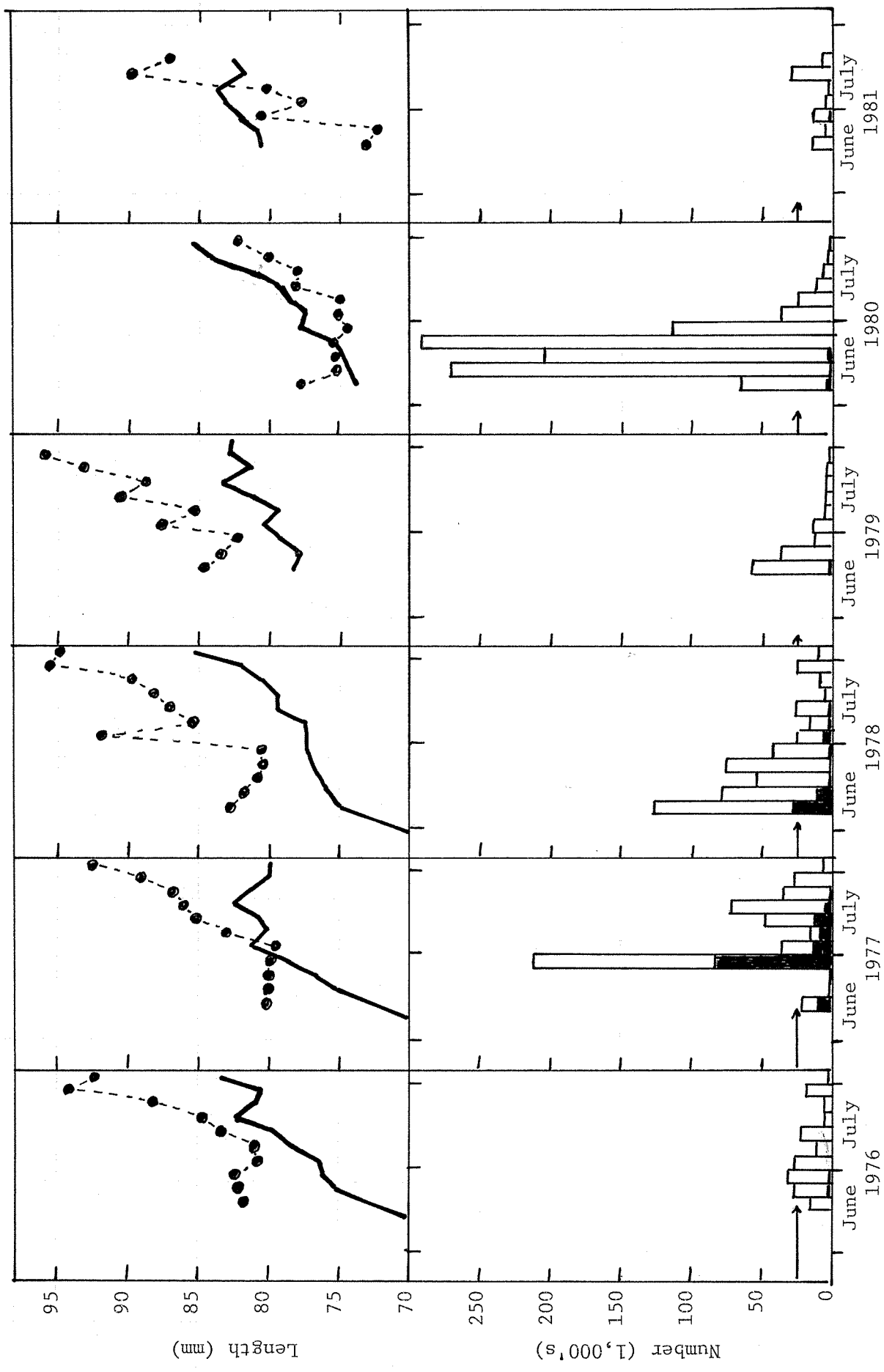

Fig. 2. Abundance of sockeye salmon smolts from Little Togiak River (age II shaded), the mean lengths at age I smolts, and river water temperature by 5-day periods (solid line).

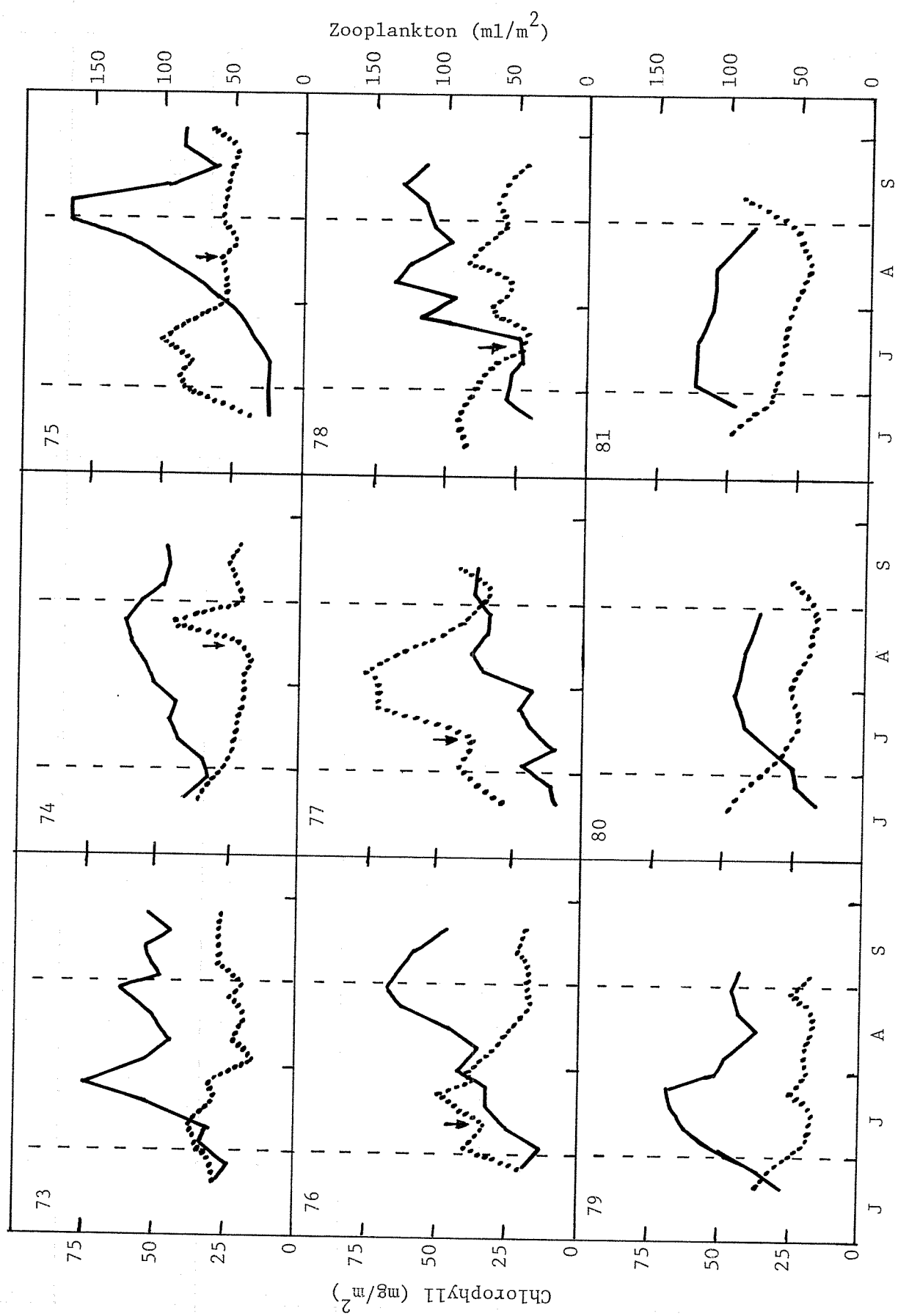

Fig. 3. Amounts of chlorophyll "a" and volume of zooplankton (solid line) in Little Togiak Lake during the summers of 1973-1981. Arrows indicate when fertilizer was added.

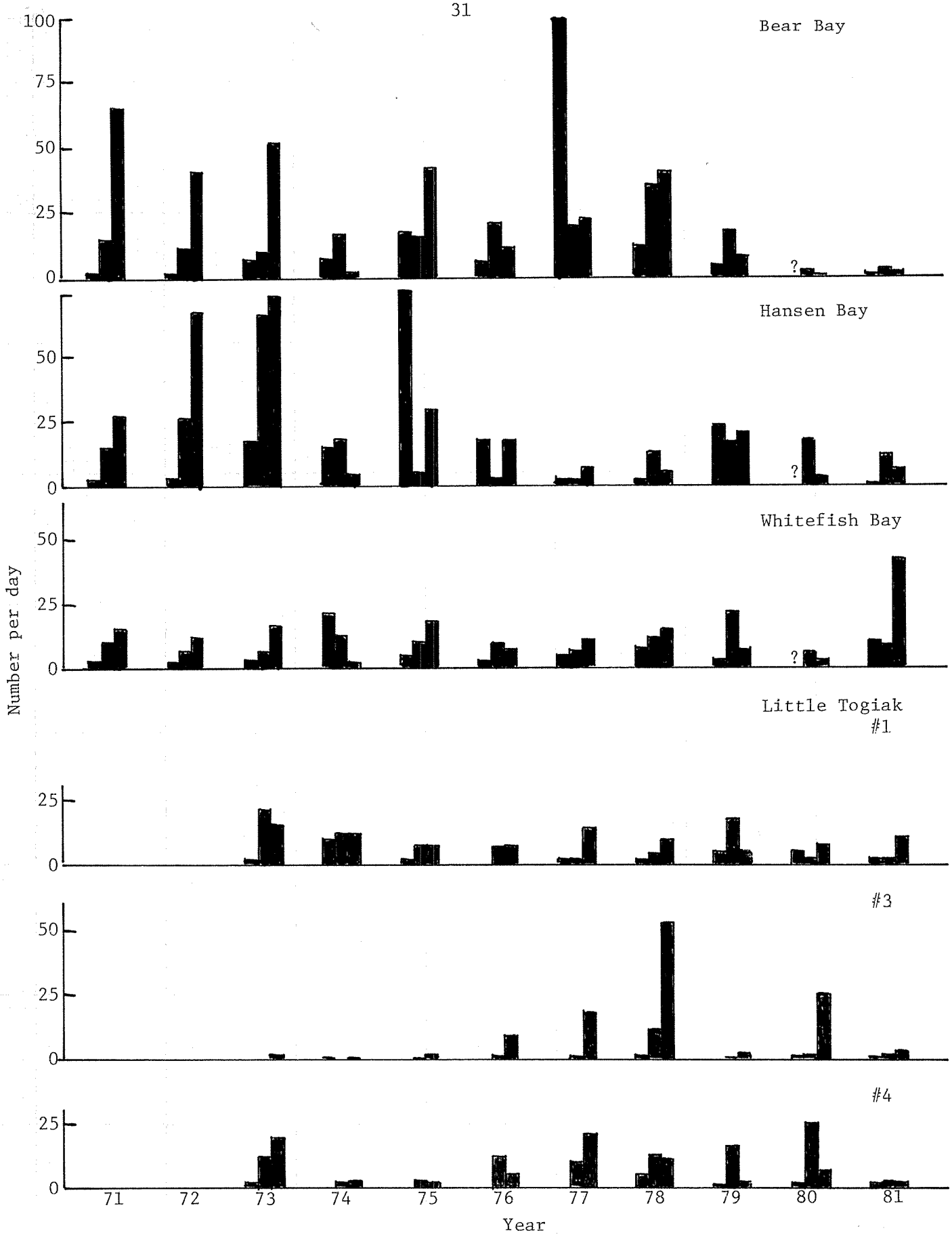

Fig. 4. Average emergent chironomid catches in June, July, and August in three bays in Lake Aleknagik and three sites in Little Togiak Lake.

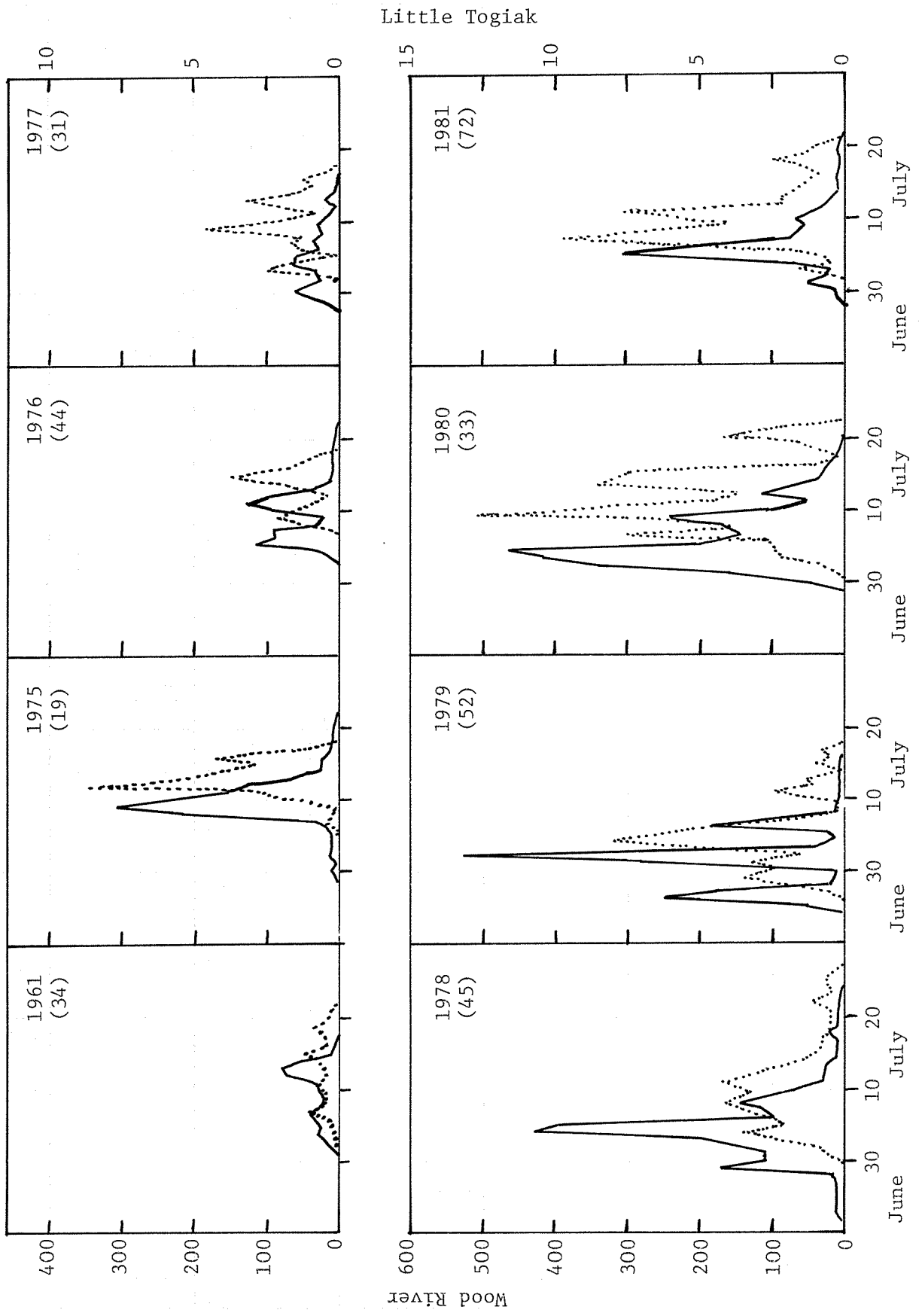

Fig. 5. Daily escapements to the Wood River lake system (solid) and to Little Togiak Lake (dotted). The rate of exploitation on the Wood River run in parenthesis.

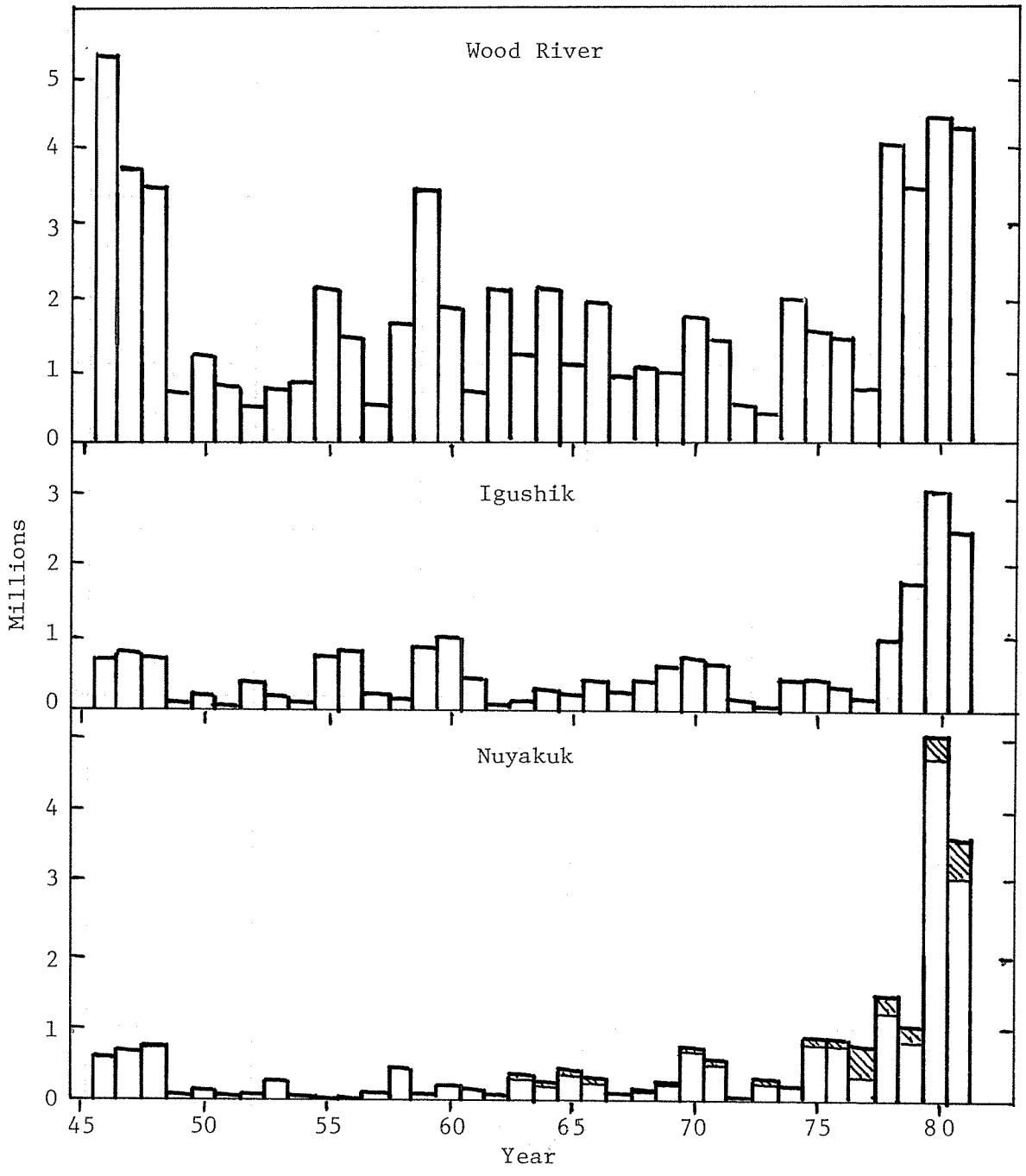

Fig. 6. Annual runs of sockeye salmon to the main river systems in the Nushagak District, 1946-1981. (Nushagak-Mulchatna runs added to the Nuyakuk.)

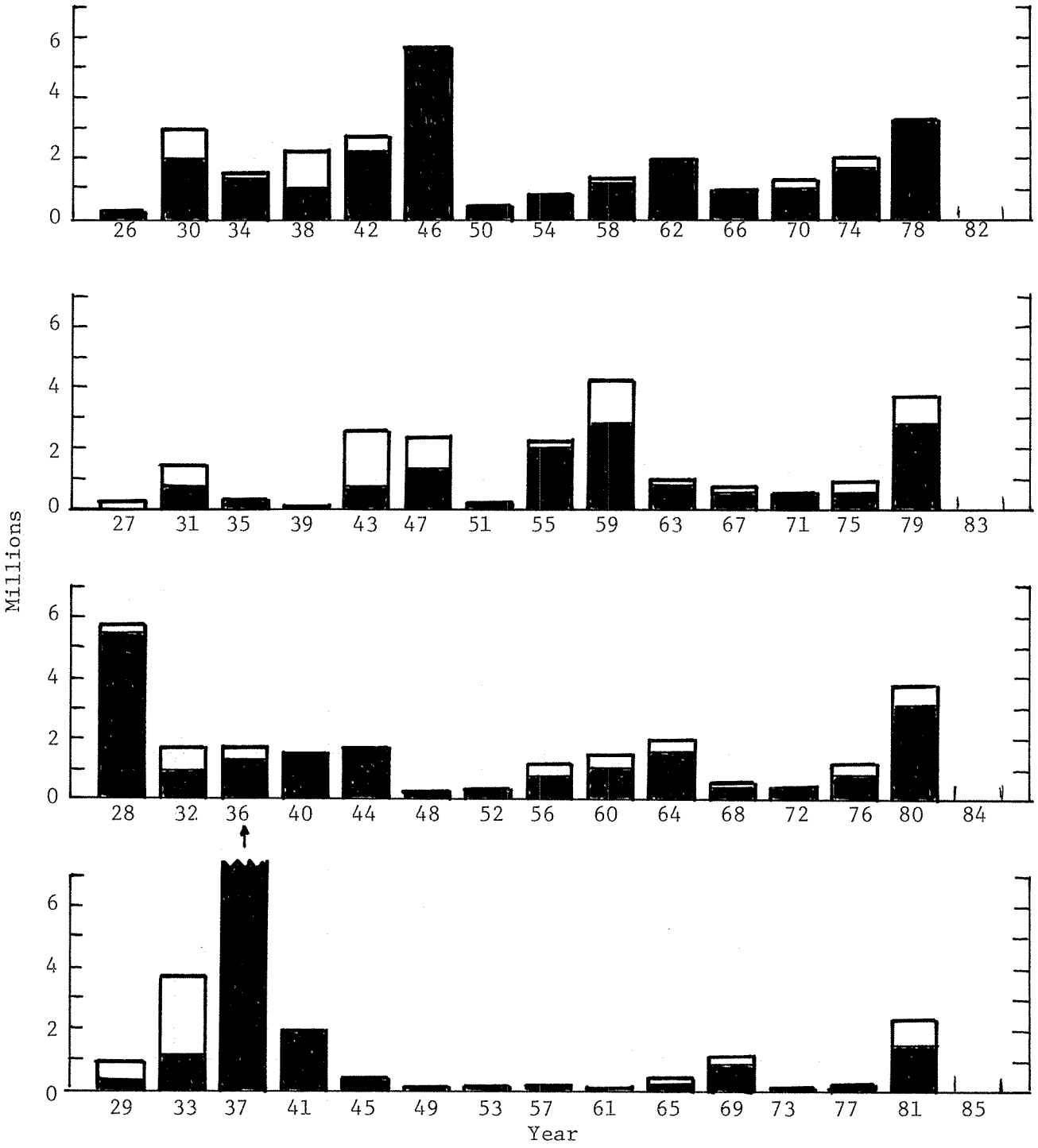

Fig. 7. Nushagak sockeye salmon runs of 2-ocean fish by 4-year lines. Age 1.2 (4_2) shaded and age 2.2 (5_3) unshaded.

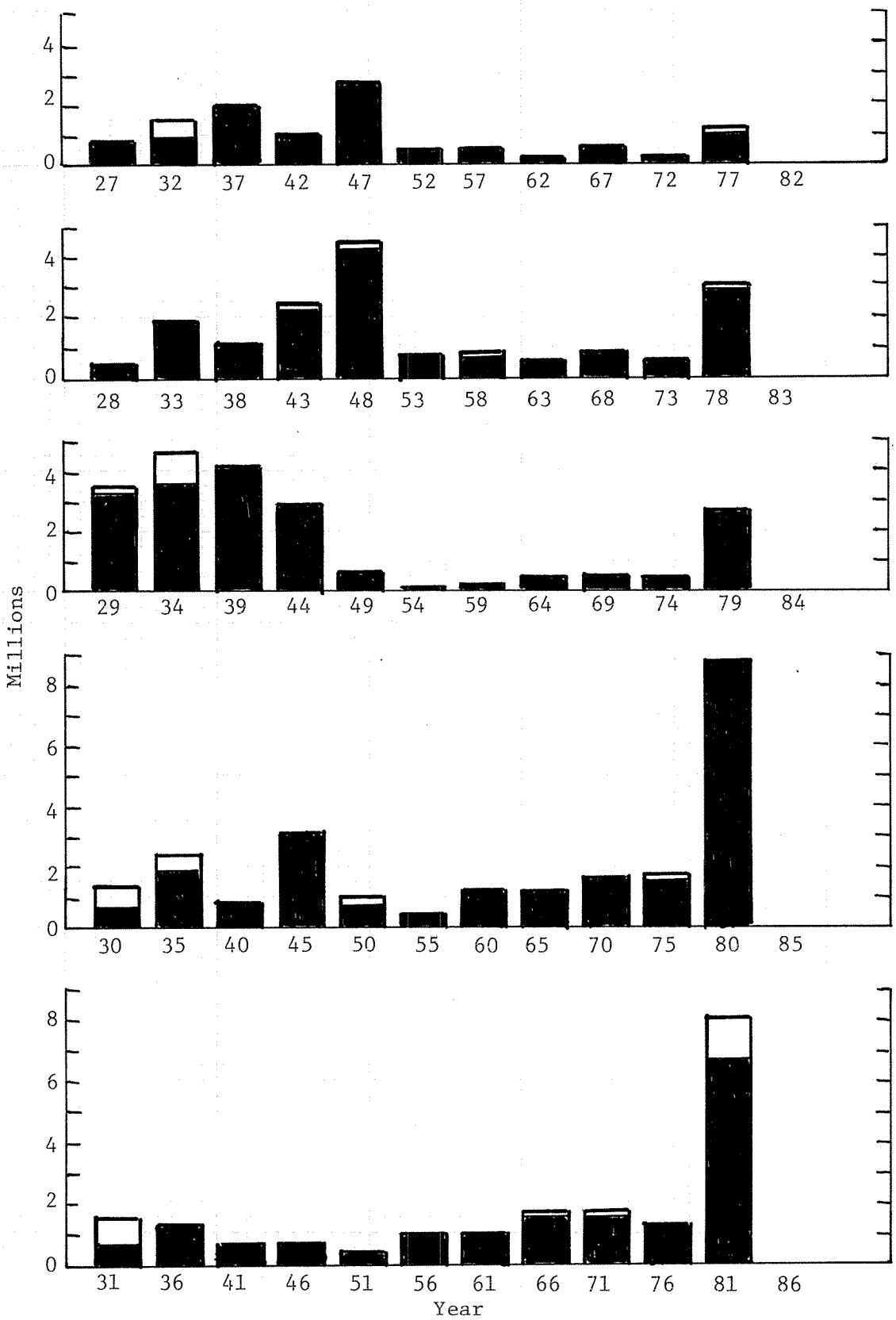

Fig. 8. Nushagak sockeye salmon runs of 3-ocean fish by 5-year lines. Age 1.3 (5_2) shaded and age 2.3 (6_3) unshaded.

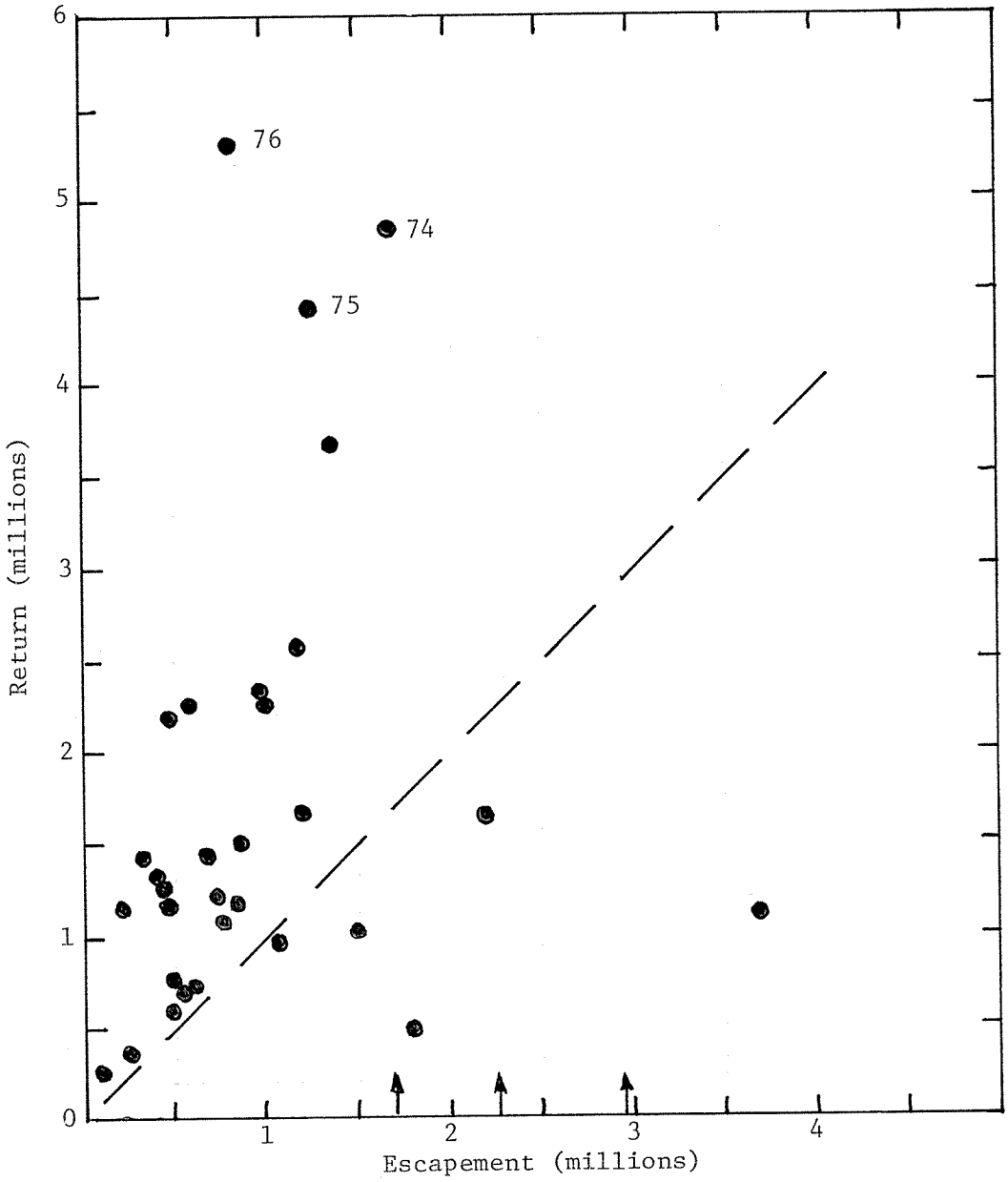

Fig. 9. Plot of return on escapement of Wood River sockeye salmon, 1946-1976 brood years. Arrows indicate escapements in 1978-1980.

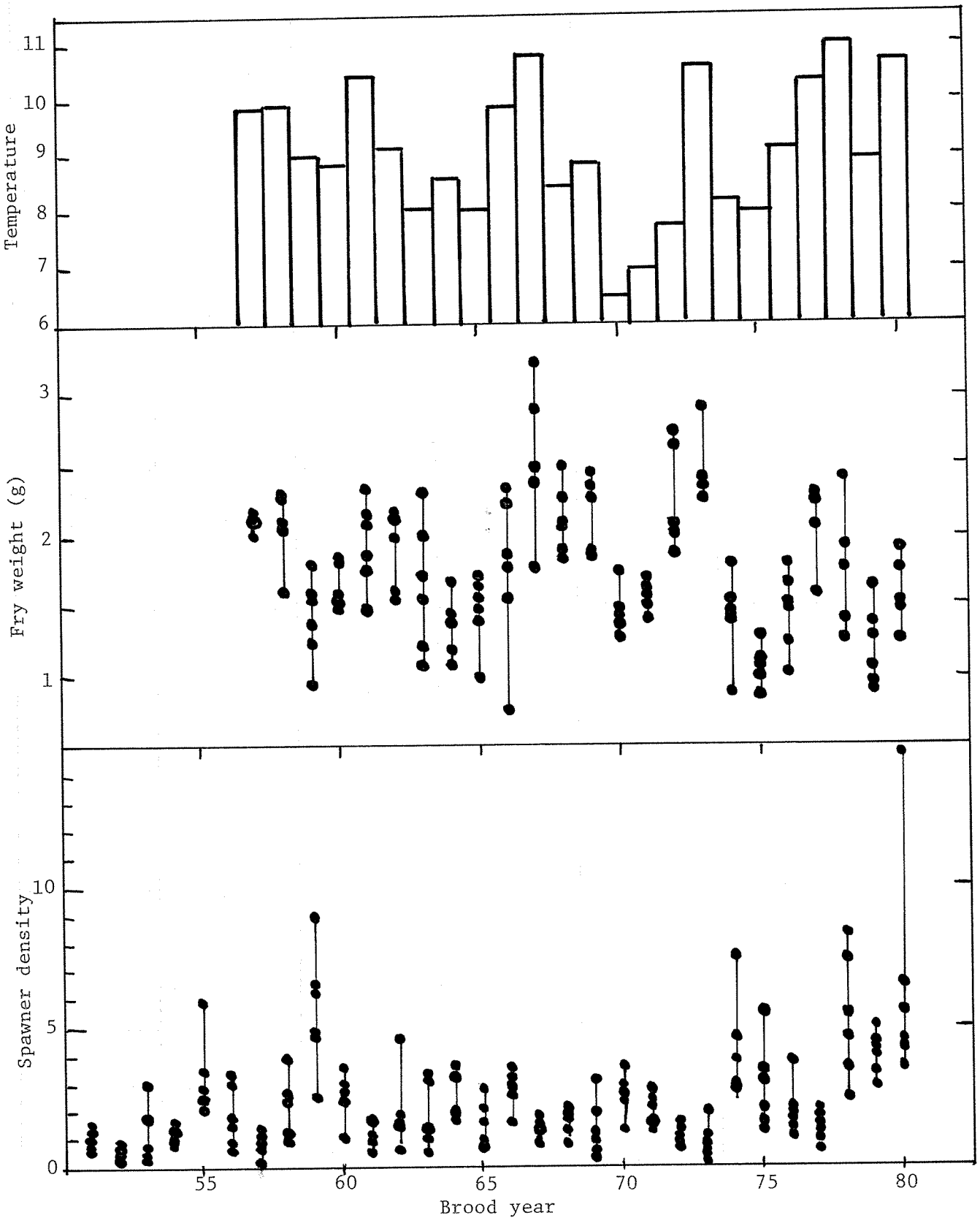

Fig. 10. Spawner densities (1000's/km^2) and the mean weights of fry on September 1 of the following year for the Wood River Lakes, and the average water temperature (0-20 m) from June 15 to August 31 in Lake Aleknagik.

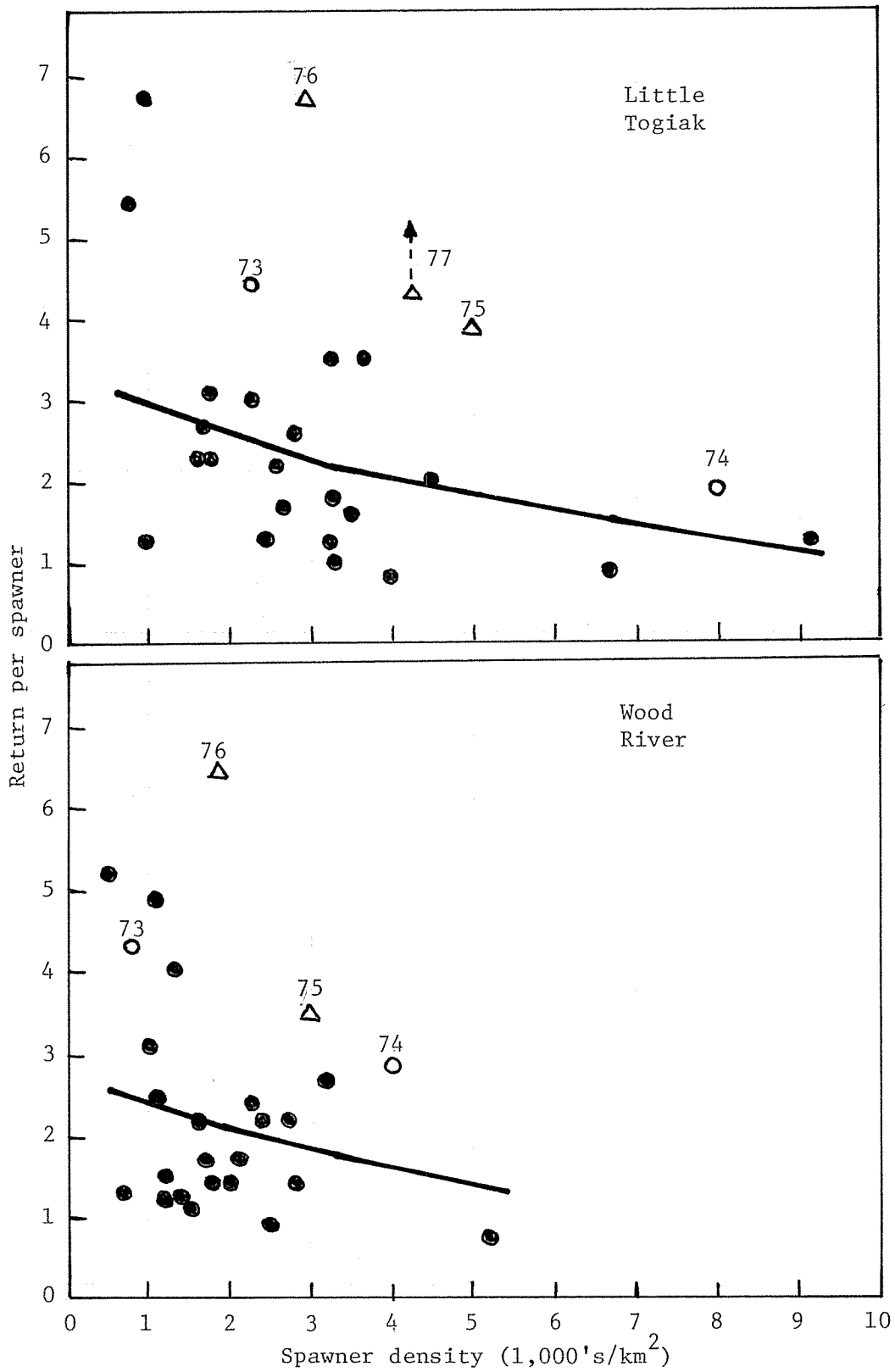

Fig. 11. Relationships between return per spawner and spawner density for the 1951-1976 brood years.