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ESCAPEMENT GOALS FOR THE KVICHAK RIVER SYSTEM

by

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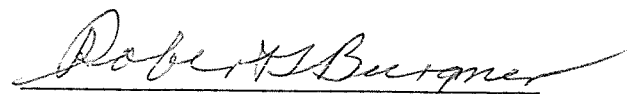
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## ABSTRACT

This report represents a synthesis of information relating to the evaluation of sockeye salmon escapement goals for the Kvichak River system. It was concluded that the Kvichak cycle since the 1940's has been caused by a combination of weather and small escapements in non-peak years which were often caused by excessive exploitation by domestic and foreign fisheries. There appears to be little evidence of an inherent cause for the Kvichak cycle as the reproductive capacity does not appear to differ significantly among brood lines.

It seems imperative for future good production in the fishery to obtain escapements of 6-10 million in 1984 and 1985, and that as much as possible exploitation should be spread out over the course of the run to insure that the fish in the escapement come from all segments of the run and are in relatively good health. The best escapement sequence for future production would be three successive (or nearly so) large (6-10 million) escapements.

Key words: Kvichak cycle, selectivity of the fishery, rate of exploitation, escapement goals, forecasts, management strategies.

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## ESCAPEMENT GOALS FOR THE KVICHAK RIVER SYSTEM

### INTRODUCTION

The Kvichak River system is the largest producer of sockeye salmon in Alaska and also one of the most variable producers with annual runs since 1950 ranging from 300,000 to 42 million. The Kvichak sockeye are fished in the Naknek-Kvichak district of Bristol Bay along with the usually less abundant and less variable stocks from the Branch and Naknek River systems (Fig. 1). After the buildup of the fishery in the early 1900's, the Naknek-Kvichak stocks produced about three consecutive large catches out of every five years until the 1940's. After that, the stocks produced only one or two large catches or runs each four or five years until 1978. Since then the pattern has been similar to the earlier historical catches.

Management strategy for the Kvichak stock since the 1960's has been to obtain a large escapement (10-15 million) for the peak-cycle run, an intermediate escapement (4-6 million) for the adjacent years, and small escapements (1-2 million) for the other cycle years. From the 1950's to the early 1970's, only the peak-cycle year produced large (over 10 million) returns and the relative production (R/E) from the other cycle years was typically lower than from the peak-cycle year. However, in recent years this pattern has changed coincidentally with the increase in salmon abundance throughout Western Alaska that has been associated with a warming trend in the weather and a reduction in high seas salmon fishing. With the change in the Kvichak cycle some of the forecasts of the Kvichak runs in recent years (1979, 1982 and 1983) were greatly in error (the actual return of age 4<sub>2</sub> fish was 8 million less than expected in 1982 and 11 million more than expected in 1983) and past management strategy was questioned after the large run in 1983 of 20 million was heavily fished with a resulting escapement of 3.6 million (since 1983 was a mid-cycle year the escapement goal was 2 million).

The purpose of this report is to provide a synthesis of information relating to the evaluation of sockeye salmon escapement goals for the Kvichak river system. The objectives were to: 1) analyze the Kvichak cycle to address the response of limnological factors to level of escapement and juvenile sockeye salmon abundance, cyclic aspects of the distribution of spawning populations, and the response of growth and age at seaward migration to abundances of juveniles and parent spawners; 2) determine likely mechanisms responsible for changes in the Kvichak cycle, e.g., climatic conditions and escapement pattern, so cycle changes can be forecast in time to implement escapement goal policy; and, 3) evaluate the optimal level of escapement by cycle year and the best escapement goal policies for various scenarios of run strength in 1984 and 1985 in view of the low escapements obtained in 1981-1983.

Our work began with the 2nd objective and then the 3rd objective, which we considered most important, received most of our effort. Finally, we worked on the 1st objective, but it received relatively little attention, particularly in regard to the response of limnological factors to abundance of salmon.

#### METHODS

The following statistics were examined to determine the extent to which they explained the variation in the Kvichak cycle:

1. Historical (i.e., pre-1952) Naknek-Kvichak catches by age and brood year. Data collected by the Bureau of Commercial Fisheries and summarized by Mathisen (1964).<sup>1</sup>
2. Recent (post-1952) escapement-return data, including length, weight and sex-age composition statistics from catches and escapements. Data collected by BCF, FRI and ADF&G and summarized in FRI and ADF&G reports.
3. Annual estimates of the abundance, age composition and size (length and weight) of Kvichak smolts. Data collected by FRI and ADF&G and summarized in ADF&G Informational Leaflets.
4. Annual estimates of the relative abundance and mean length of fry from townet sampling in Iliamna Lake and Lake Clark. Data collected and summarized by FRI.
5. Annual environmental parameters, e.g., monthly air temperature for Bristol Bay from Weather Bureau records and water temperatures, solar radiation, chlorophyll concentration, and zooplankton abundance from FRI observations.
6. Escapement counts for the Newhalen River (1979-80 and 1982-83) and aerial survey estimates of spawners (1955-83) made by FRI.
7. Annual age compositions of spawners on selected spawning grounds within the Kvichak system that were calculated from scale and otolith samples collected by FRI.

The analysis of the data was largely by graphics and statistical correlation. Most parameters were grouped by cycle year and visually examined. Only when there were obvious differences between cycle years

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<sup>1</sup>Mathisen, Ole A. 1964. Escapement pattern of the sockeye salmon runs to the Kvichak River, Bristol Bay, Alaska. Unpublished manuscript. Fish. Res. Inst., Univ. Washington, Seattle.

did we conclude that there was a significant effect or association between the parameter and the Kvichak sockeye salmon cycle.

Statistical sets 1-4 were analyzed by D. Rogers and sets 5-7 were analyzed by P. Poe. Mean weights of sockeye salmon in the Naknek-Kvichak District were calculated by D. Rogers from data supplied by ADF&G. The mean weights are given in Table 1 and were used to examine production statistics in terms of weight as well as number in the runs.

## RESULTS

### Historical Catches and the Kvichak Cycle

Since 1956 when run statistics became available for the three Naknek-Kvichak District lake systems, the Kvichak stock has greatly predominated in the District runs and the Branch stock has been relatively minor.<sup>1</sup> It has been generally assumed that the Kvichak stock was likewise predominant in earlier years, therefore the historical catches were assumed to reflect the pattern of the annual runs to the Kvichak. However, the recent large runs to the Naknek (1980-83) and the fact that the age composition of the early historical catches was more similar to the Naknek run age composition than the Kvichak run age composition make this assumption somewhat questionable (Fig. 2). It seems quite likely that production from the Naknek stock prior to the 1940's was similar to that observed in the most recent years, because comparable changes in abundance have occurred for many of the other Bristol Bay stocks. Still the Kvichak stock must have been predominant in the historical Naknek-Kvichak District catches that exceeded 10 million.

When the historical catches are arranged by brood year (return catches, Fig. 2), it is evident that consecutive brood years often produced large returns until the late 1930's. Then the pattern changed to the single dominant year. The lack of a single large catch of age 4<sub>2</sub> (1.2) fish is puzzling, since there have been at least four broods since 1952 that produced large enough returns to produce a catch of at least 5 million. The larger mesh size used in earlier years (5 3/4", 1913-26 and 5 1/2", 1927-60) undoubtedly selected for 3-ocean fish to a greater extent than the 5 3/8" nets used now, but that should not have significantly affected the freshwater age composition in the catch.

Dr. Ole Mathisen attributed the historically higher percentage of 2-freshwater-aged fish (age 2.) to the assumption that escapement levels were historically greater, juvenile densities were greater, and

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<sup>1</sup>The Branch River stock is largely ignored in the rest of the report because it contributes so little.

density-dependent growth resulted in consistently poor growth and a high proportion of age 2+ smolts. However, in recent years the growth of juveniles in the Kvichak has been influenced as much or more so by spring-summer temperatures as by abundance.<sup>1</sup>

The pattern of the Kvichak cycle since the mid-1930's can be largely explained on the basis of escapement size and weather. Large returns are produced from large escapements (small returns are produced from small escapements but can also be produced from large escapements). Since the Kvichak sockeye tend to mature after 2 years at sea, the year of return is mainly determined by freshwater age, or year of seaward migration. Freshwater age (smoltification) is determined by the growth of juveniles, i.e., they must reach a threshold size to smoltify. Growth is greatly influenced by water temperature, which, in turn, is correlated with air temperature. Whether juveniles from a given brood year will migrate at age 1.+ or 2.+ is primarily determined by the weather from spring through fall (for the fry) and secondly, by the weather in the following spring (when they would smoltify as age 1.+).

The Naknek-Kvichak brood year returns by freshwater age were graphed with the mean summer and spring air temperature deviations for Bristol Bay (Dillingham and King Salmon averages) and temperatures following years with large escapements were distinguished from other years by solid bars (Fig. 3). The spring and summer temperatures since the 1940's have been somewhat below normal (1920-1982) but particularly so for the years when there were large escapements, with the exception of those years following the 1952, 1956 and 1979 escapements. The Kvichak cycle shifted from five to four years with the warm summers in 1953 and 1957, then each year with a large escapement was followed by a cool summer until the 1979 escapement and this produced the large run of 1.2 (4<sub>2</sub>) fish in 1983. The very cold summers and springs following the 1969 and 1970 brood years caused an unusually high percentage of age 3. fish and probably contributed to the poor production from those brood years.

#### Recent Escapement-Return Statistics

Escapement statistics for the Naknek-Kvichak District, including lengths, age and sex composition are fairly complete since 1956. The commercial catches are prorated to the river systems on the basis of the age compositions and numbers of fish in the escapements (Naknek, Branch and Kvichak). This procedure assumes that fish of a given age are equally exploited by the fishery regardless of their origin, i.e., whether bound for the Kvichak, Naknek or Branch rivers. It has also been assumed that there is little if any difference in the timing of

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<sup>1</sup>The regulation of growth and freshwater age will be discussed later in the report in more detail.

the stocks or spawning populations within the stocks contributing to the District fishery. Therefore rates of exploitation during a run or from year to year would be expected to affect the contributing stocks about equally, provided the age compositions were similar in the runs.

### Selectivity of the Fishery

The average size of a sockeye salmon in the Naknek-Kvichak runs not only depends on ocean age, sex and the abundance of the run (fish are usually smaller in large runs), but also on the stock. Naknek 2-ocean sockeye (especially males) are significantly smaller than Kvichak 2-ocean sockeye (Fig. 4). The fishery selects the larger individuals in the 2-ocean run and the size selection is greatest for Naknek males then Naknek females, Kvichak females and, lastly, Kvichak males. This selectivity probably causes some error in the prorated catches, i.e., too few fish assigned to the Kvichak and too many to the Naknek. However, this would cause a relatively small amount of error in the return statistics for the Kvichak because the Kvichak sockeye were very predominant in all but 3 of the past 28 runs of 2-ocean fish. It is of interest to note that the one year when fishing was largely restricted to the Naknek section of the District (1977) the mean lengths in the catch were closest to the means in the Naknek escapement.

Naknek 3-ocean fish were more often more abundant than Kvichak 3-ocean fish in the runs, and there was little difference in the mean lengths in the escapements to the two systems (Fig. 5). The fishery tends to select the larger individuals of the 3-ocean females, but the size selection of 3-ocean males is not so evident.

### Rate of Exploitation

Rates of exploitation in the Naknek-Kvichak District have been higher for 3-ocean fish than 2-ocean fish, highest for 3-ocean females and lowest for 2-ocean females (Fig. 6). There has not been a significant correlation between rate of exploitation for all fish and the size of the run, but some correlation is evident between the rate of exploitation on the weight of females in a run and the total weight of fish in the run (Fig. 7, Table 2). Rate of exploitation was particularly high in the most recent three years.

Rates of exploitation calculated for the Kvichak annual runs and returns from brood years likewise indicate little correlation between size of run and exploitation (Figs. 8 and 9). Small returns (less than 5 million) were fished from very light to very heavily, intermediate returns (5-10 million) were fished above 50%, whereas large returns (10-40+ million) were generally fished below 50%.

Rates of exploitation on the Kvichak runs and returns were arranged by cycle years, and means and standard deviations were calculated (Tables 3 and 4). Rates of exploitation were significantly

higher on the runs in the sub-, or post-peak, years and also higher on the adult returns from the sub-peak broods, whereas rates of exploitation on the other cycle years were similar. It is of interest to note that the relative production (R/E) from the sub-peak years was generally lower than for other cycle years until 1976.

The commercial fishery not only affects the size and age of fish in the spawning escapement but also the sex composition in the escapement. Because they grow faster and thus tend to mature earlier, males usually predominate in the 2-ocean runs and females in the 3-ocean runs of sockeye salmon, but some spawning populations are also predominantly 2-ocean fish (males and females) and others 3-ocean fish (males and females).

When the percentage of females in the Naknek-Kvichak runs of 2-ocean fish was below 50%, the percentage in the catch was much lower, whereas when the percentage of females in the runs was over 50%, the percentage in the catch was similar (Fig. 10). This would suggest that if there is a low percentage of females (high percentage of males) in the run, the fishery takes a higher percentage of the females and thus exaggerates the unbalanced sex ratio in the spawning escapement. For runs of 3-ocean fish, when the percentage of females in the run was low, the percentage in the catch was similar, but when the percentage in the run was high, then the percentage in the catch was even higher. Females were predominant in the escapements of 2-ocean fish to the Kvichak whereas males were predominant in the 2-ocean escapements to Naknek (Fig. 11). This may indicate that the small Naknek 2-ocean males tend to escape the fishery; however the sex ratios in the runs to the Kvichak and Naknek may also be quite different. For 3-ocean fish, which are of similar size for both stocks, females predominate in the Naknek and males in the Kvichak escapement.

Sex ratios (percent females) for Naknek-Kvichak catches and runs and the Naknek and Kvichak escapements were arranged by Kvichak cycle years (Table 5, 6 and 7). The percentage of females was lower in the catches made from peak-year runs, but similar for other cycle years. In the Kvichak escapements, the percentage of females was lower in the pre-peak years, higher in the sub-peak years, and similar for other cycle years, but the differences do not appear to be significant.

We did not examine within-run variation in age-sex composition, nor the question of possible different run timing for component stocks of populations so we could not address the possible effects on the stocks of differing rates of exploitation during the course of a run. In the early 1900's the fishery probably took a higher percentage of the early run and fished rather lightly on the late part of the run. During the 1940's and 1950's, fishing was spread out over the course of the run with alternating openings and closure of the fishery. Since the 1960's there has been a tendency to fish more on the late portion of the run than on the early portion except in cases of very small runs, e.g., 1972 and 1973 (Fig. 12). Lacking evidence that there are

no differences in run timing or stock composition during the run, it would seem best to distribute exploitation on the stocks evenly throughout the run. It may not be a wise practice to obtain the required escapement from the beginning of the run and then have continuous heavy exploitation on the late portion although this makes the job of management somewhat easier.

### Escapement Goals

Escapement goals were determined from the escapement-return (in-shore) statistics and then the goals were evaluated with respect to escapement-smolt and smolt-return statistics. It is obvious from the Kvichak data that small escapements produce small returns and large escapements usually produce large returns (Fig. 13 and 14). It is not so obvious what the optimum escapement should be, i.e., the escapement that on the average would produce the largest sustainable catch, other than it is somewhere between 5 and 15 million, and there have been only 6 escapements in that range for which we have returns. When the returns are plotted on the weight of females in the escapement (a better measure of reproductive potential) the returns appear to decline at higher escapements and both the 1979 and 1980 escapements (arrows in Fig. 13) are at that level. However, it is impractical at present to manage the fishery for metric tons of females, so an escapement goal in numbers is needed and the question of the escapement goals for the years of the cycle needs to be resolved.

The relative production (R/E) for the other major Bristol Bay systems with comparable statistics was compared to the Kvichak production by cycle years (Fig. 15). The post-peak cycle production in the Kvichak has been generally lower (except 1976) than the average for other years, but in general the relative production for the other systems shows a similar pattern, thus there is little evidence that there is an inherent inequality in the productive capacity of the Kvichak cycle years. It would seem that any year could produce a large return if the escapement was sufficient.

The average R/E for the Kvichak has been lower than the average for other Bristol Bay systems, but the relative (% of Kvichak mean R/E and % of expected R/E for other systems) production has been similar. A disturbing trend is evident in that the R/E for the Kvichak is quite low compared to other systems for the last four brood years (Fig. 16).

In order to get a better picture of the underlying escapement-return relationship for the Kvichak system, the recent Kvichak data were plotted along with the recent data from five other large lake systems adjusted to number per km<sup>2</sup> of lake surface area (Fig. 17). The optimum escapement for the Kvichak appears to be between 6 and 10 million (following a curve connecting the points for the 1974, 56, 75, and 65 broods). The optimum escapement for the other systems appears to also fall in this range (in terms of density). We took the midpoint of the range, so the optimum escapement for the Kvichak is about

8 million. Since we concluded that there was not strong evidence for differential productivity among cycle years, then this escapement goal (6-10 million or 8 million mid-point) should apply to any large run. Obviously the escapement goal should not be 8 million if a run of only 1-2 million is expected. For years with very small runs we recommend a goal of 40 to 50% of the expected run. The important thing is that when there are large runs, and we can expect 2-3 out of every 4-5 years, there should be large escapements if the optimum production from the system is to be realized.

#### Smolt Production

Estimates of the annual abundances and sizes of Kvichak smolts are available since the 1950's; however, the method of estimating abundance changed between 1970 and 1971 (from fyke net catches to sonar estimates). The earlier catch indices were adjusted to make them equivalent to recent estimates of total numbers in migrations. The adjustment was based on the average ratios of smolts to escapement and returns to smolts. Emphasis in the analysis of smolt statistics was still placed on the more recent years as these data were considered more accurate.

Small escapements produced few smolts and large escapements produced large numbers of smolts, but with considerable annual variation (Fig. 18). An escapement of 8 million would be expected to produce an average of 220 million smolts and this number of smolts would on the average produce about 22 million adults. There was relatively little increase in the number of smolts produced on the average when escapements exceeded about 10 million.

Since there is an inverse relationship between escapement and mean weight of smolts, the biomass (number in millions x mean weight in gms) of smolts tends to decrease slightly at large escapements (It would decrease much more except that past large escapements have produced a majority of older thus larger smolts.). The maximum biomass of smolts produced, on the average, changed very little from escapements of 5 to 15 million. The adult returns increased in a more linear manner (than with number of smolts) with increasing biomass. Maximum adult returns could be realized from escapements as low as 6 million.

In past sub-cycle years, the mean weights of age 1 smolts were smaller than expected from the number of fish in the escapement (Fig. 19). This may indicate a competitive interaction with the peak-cycle year. However, the age 2 smolts from the sub-cycle years were not much smaller than expected and, as will be shown next with the fry statistics, growth can be significantly affected by the temperatures.

### Fry Abundance and Growth

Townet sampling to estimate the relative abundance and size of juvenile sockeye in the Kvichak system has been conducted annually since 1961. However, sampling has not been continuous in the lower part of Iliamna Lake where yearling fish are usually concentrated so continuous statistics are only available for fry (Age 0). Fry growth is known to be influenced by temperature and there are several measurements of spring-summer temperatures. Some of these were standardized (deviations from long-term means relative to the standard deviation of the measurement) and averaged to obtain temperature indices (Tables 8 and 9).

The annual growth of fry in Iliamna Lake, as estimated by their mean length on September 1, was more closely related to temperature than to the size of the parent escapement (Fig. 20). The observed reduction in growth of smolts from the sub-peak years is partially explained by the fact that temperatures were generally cooler for those fry.

The fry were more abundant in the larger Iliamna Lake than in Lake Clark but Lake Clark contained consistently smaller fish. It has been hypothesized that Lake Clark has received a higher proportion of the system escapement in the pre-peak cycle years; however this is not substantiated by the catch or length data (Table 10). The ratio of catches between Lake Clark and Lake Iliamna was not significantly different in the pre-peak years and the fry in those years were actually somewhat larger in Lake Clark (they would be expected to be smaller if the density was significantly greater). It may be that a high proportion of the fry produced in Lake Clark drop down into Iliamna Lake during the summer. There is some recent evidence for this hypothesis from sampling conducted in the Newhalen River, but much more data are needed.

### Forecasts

Management of the Kvichak stock requires a relatively accurate forecast of the run (small, medium, large) not only for the next year but also for at least the succeeding two years. The runs can largely be forecasted from abundance of parent spawners (escapement), abundance of smolts and the return of jacks, since the adults typically return after two years at sea. There has been only one large run of 3-ocean fish, i.e., over 5 million since 1960 (however, there may be another in 1984). The large errors that have occurred in past forecasts have been in the forecasts of 2-ocean fish, either 4<sub>2</sub> or 5<sub>3</sub> age groups (Table 11).

The smolt and jack abundances offer the best means of forecasting a run; however, there are relatively few observations for large runs (i.e., greater than 5 million). In addition, both the return of jacks and the survival of smolts may vary from year to year because of environmental fluctuations (for example, temperature effects on growth, and thus on the proportion of fish maturing as jacks; temperature effects on early marine survival of smolts) and because of mortality from high seas fishing which has been significantly lower since 1978.

The adult and jack returns have been ordered according to the estimated abundance of smolts in Figures 21 and 22, and two measures of spring temperatures are included: May-June air temperature deviations in Bristol Bay and the mean water temperature during the peak (one week) of the smolt migration. The recent years of smolt to adult survival statistics are presented in Table 12 in order of the size of parent escapements. The 2-ocean fish returning in 1984 will come from the 1982 smolt migration. Temperatures were colder than normal in 1982 and the smolts were smaller than average so we would expect a lower than average return of jacks in 1983, and a lower than average survival of at least the age 1 smolts.

Figures 23 and 24 show data available to forecast the freshwater age composition of the 2-ocean fish returning in 1984 and 1985.<sup>1</sup>

In 1984 we can expect a run of about 4 million age 4<sub>2</sub>, 8 million age 5<sub>3</sub>, 7 million age 5<sub>2</sub> and a small number of age 6<sub>3</sub> plus jacks for a total run of about 19 million. The run in 1985 will probably be smaller (jack returns in 1984 should provide a better forecast) at about 10-12 million.

#### Distribution and Age of Spawners

Aerial surveys of the spawning escapements have been conducted by FRI in the Kvichak system each year since 1955; in addition, the escapement into Lake Clark has been estimated by visual enumeration since 1979 in the Newhalen River. The aerial survey estimates were grouped by type of spawning ground and are presented in Table 13. A relatively small percentage of the escapement to the Kvichak system is accounted for by the aerial estimates, however there is still an obvious correlation between the aerial estimates and the enumeration estimates from Igiugig. Of particular concern at present is that the island beach component of the Iliamna Lake system, which in past large escapements had high numbers of spawners, apparently received relatively few spawners in 1979 and 1980. In contrast the 1979 and 1980 escapements to the Newhalen River-Lake Clark system were very large (about 9 and 7.5 million).

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<sup>1</sup>A discussion of forecast procedures was felt unnecessary because ADF&G uses these same statistics to forecast the runs.

There is concern that the major portion of the 1984 run to the Kvichak system may be bound for the Newhalen River-Lake Clark area and that a large escapement, e.g., 10 million, might be wasteful in the case that crowding on the spawning grounds might result in lower returns than would be realized from a lower escapement level. The relative magnitude and the proportion of the Kvichak system escapement at Igiugig that is bound for the Newhalen River can be estimated from 10-hour index counts near the mouth of the Newhalen River (River Mile 1). Counts during past years at Newhalen were lagged back to Igiugig for the beginning days of the escapement. Day 1 was defined as the first day when the accumulative escapement at Igiugig was over 100,000 (Table 14). The formulae, bottom of Table 14, can be used to project the Newhalen-Lake Clark escapement for the season based on the first few days of index counting. The timing of the early Kvichak escapement is related to spring temperatures; e.g., the dates of 1% and 10% of the accumulative escapement were correlated with the date of ice breakup in Lake Aleknagik in the Wood River system.

We plan to enumerate the sockeye salmon in the Newhalen River in 1984 and use these data to provide an indication of the distribution of the escapement. The information will be reported to ADF&G early enough to hopefully be of value in management.

#### Age Composition on Spawning Grounds

Age composition data for a selected few major Kvichak spawning grounds for which there are continuous records are compared to Kvichak escapement age composition data collected at Igiugig in Tables 15-21. Within the group of interconnecting river systems sampled, Copper River and Gibraltar Creek show a higher proportion of 3-ocean fish, while the Newhalen River and Lake Clark, as represented by the sampling of the Nondalton subsistence fishery, show a higher proportion of age 2. adult sockeye than the Kvichak escapement as a whole. Data for the Iliamna River system, the only major runoff stream for which we have continuous records, indicates that this system produces a higher proportion of five-year-old, 2. adult returns than the Kvichak system as a whole. Within the beach spawning category, Woody Island beaches seem to produce more 4-year-old fish while Knutson Bay shows the least deviation from age composition data collected at Igiugig during the Kvichak River escapement.

#### Limnological Data

##### Phytoplankton

The food chain leading from inorganic nutrients to production of juvenile salmon is complicated by many factors. Studies at the primary trophic level have sought to determine how changes in escapement level affect the food base and hence the survival rate and growth of juvenile salmon.

Since 1961 measurements of the relative standing crop of limnetic phytoplankton in Iliamna Lake during the period June-September have been made through determinations of the concentration of chlorophyll a. The data representative of the three distinct physical regions in Iliamna Lake are presented in Figure 25. While salmon carcasses certainly represent an important source of biogenic N and P in the nutrient loading of Iliamna Lake, a complex of environmental and biological factors such as water temperature and degree of stratification, surface run off, and number of zooplankton, confound the definition of the fertilization effects linking the level of escapement to primary productivity in the limnetic zone of Iliamna Lake (Fig. 25). A primary example is the perturbation of the physical and biological environment caused by the ash fallout from the 1976 eruptions of nearby Augustine Volcano. This low-level ash fall contributed amounts of water-soluble N, P, and Si to the Kvichak watershed, and a low-level increase in the standing crop of limnetic phytoplankton was indicated, especially in the eastern, or upper portion, of Iliamna Lake where the ash fall was heaviest.

While it is difficult to demonstrate the fertilization effects of salmon carcasses on the production of limnetic phytoplankton, biogenic elements brought into the Iliamna Lake ecosystem by decomposing spawners appear to be bound in part by the littoral periphyton community. Statistical analyses of monitoring data and qualitative observations particularly indicate a direct relationship between the input of P from salmon carcasses and the growth of littoral periphyton on the island beaches of Iliamna Lake.

The role of periphyton is related to the ability of this benthic nearshore community to initially and rapidly sequester the biogenic elements derived from the salmon carcasses via uptake and assimilation. During the winter and early spring large amounts of periphyton die and the nutrient elements incorporated into their algal biomass are potentially available for secondary benthic production in the region where salmon fry first emerge and where feeding commences. Indeed, any increase of benthic production in littoral nursery areas should provide a broader food base for young juvenile sockeye salmon fry. Dr. O. A. Mathisen of the University of Alaska-Juneau has recently submitted a proposal to the National Science Foundation which includes a study to clarify the role of periphyton in the food web transfer in Iliamna Lake.

### Zooplankton

Secondary production studies in Iliamna Lake have sought to determine the point at which zooplankton production becomes a limiting factor in the production of juvenile salmon.

Since 1961 measurements of the relative standing crop of limnetic zooplankton during the period June-September have been made through vertical hauls with a No. 6 mesh (aperture 223 microns), conical plankton net with a mouth opening of 1/2 m diameter. Data taken at the

standardized primary production stations of Iliamna Lake are presented in Figure 26. Corresponding temperature, and size and relative abundance data for sockeye fry, are also presented for the upper lake area (Fig. 26). The abundance of zooplankton is highest in the deeper mid and upper portions of Iliamna Lake. Of the two dominant zooplankters, Cyclops and Bosmina, Cyclops is numerically and proportionately most abundant in the upper lake, while Bosmina is proportionately most abundant in the lower lake, but numerically most abundant in the mid-lake area. While there is some suggestion that the abundance of zooplankton is linked to fry abundance, and hence parent escapement, other biological and environmental factors, such as water temperature, phytoplankton production, and fry growth, or feeding inhibiting factors related to population density, confound a clearer definition of this relationship.

## DISCUSSION

### Management Strategies for 1984-1985

We have concluded that the Kvichak cycle since the 1940's has been caused primarily by a combination of weather and small escapements in non-peak years which were often caused by excessive exploitation (domestic and foreign). There appears to be little evidence of an inherent cause for the cycle, i.e., the reproductive capacity does not appear to differ significantly among brood lines.

It has often been said that it would be better for the fishery to have two years with 12 million catches than one year with a 22 million catch and another with a 2 million catch. So a smoothing of the cycle would benefit the fishery provided the long term production level was not substantially reduced. A smoothing of the cycle should follow a smoothing of the escapements.

Two consecutive large (6-10 million) escapements with average R/E may produce future consecutive runs of large-small-large (if the first brood produced mostly 4-yr-olds and the second brood produced mostly 5-yr-olds), small-very large-small (if the first produced mostly 5-yr-olds and the second 4-yr-olds), or large-large if both broods produced mostly fish of the same age. The best escapement sequence for future production would be three successive (or nearly so) large escapements.

The escapements in 1981 and 1982 were quite small with little potential to produce 2 large runs, so the outlook for 1986 is only fair. The 1983 escapement of 3.6 million may produce a return of 7-10 million, but these fish may be spread out over 1987 and 1988 or come mostly in 1988. It seems imperative for future good production in the fishery to obtain escapements of 6-10 million in 1984 and 1985. The escapement in 1984 should be 8 million if 1) there is a strong return of jacks, 2) there is not an exceptionally high proportion of the fish returning to Lake Clark, and 3) the run appears to be much less than 20 million. If these conditions are not met, the escapement should be 10-15 million.

If there are few jacks in 1984, given the warm spring in 1983, this would certainly indicate a poorer than expected run in 1985 and it would be wise to obtain a larger escapement in 1984. If the 1984 run appears to be 20 million or more, then we would not be concerned about the level of escapement into Lake Clark, since, if it was large, it would mean that the large escapement there in 1979 had produced quite well.

Finally, we recommend that, as much as possible, exploitation should be spread out over the course of the run by periodic openings and closures. This is to insure that the fish in the escapement come from all segments of the run (early, middle and late) and are in relatively good health. In recent years when there has been continuous fishing, we have noted an apparent decline in the condition of the fish in the escapement; although we have no evidence that this will affect the reproductive capacity of the escapement.

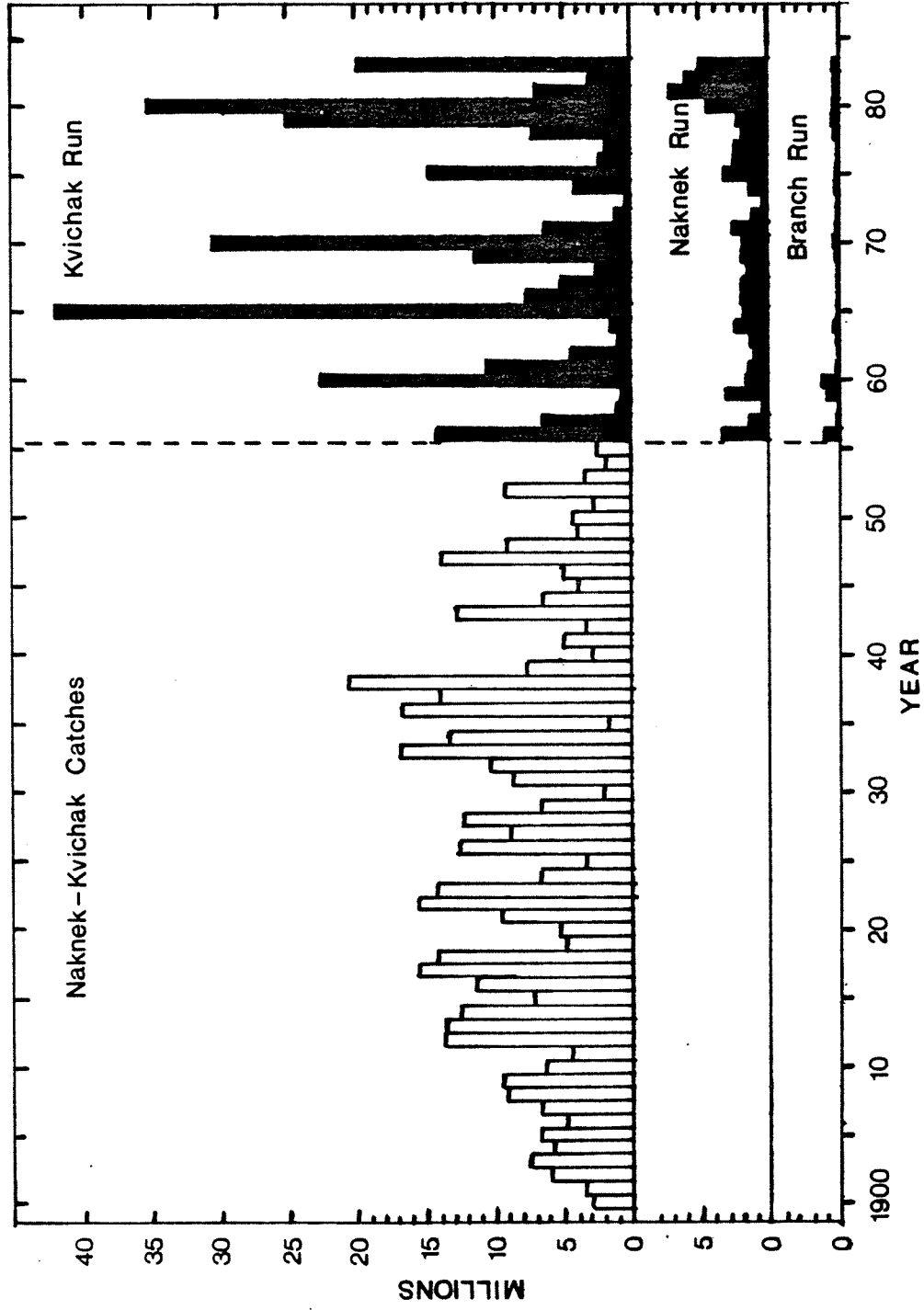


Fig. 1. Sockeye salmon catches in the Naknek-Kvichak, 1900-1955, and the runs (catch + escapement) to the Kvichak, Naknek, and Branch systems, 1956-1983.

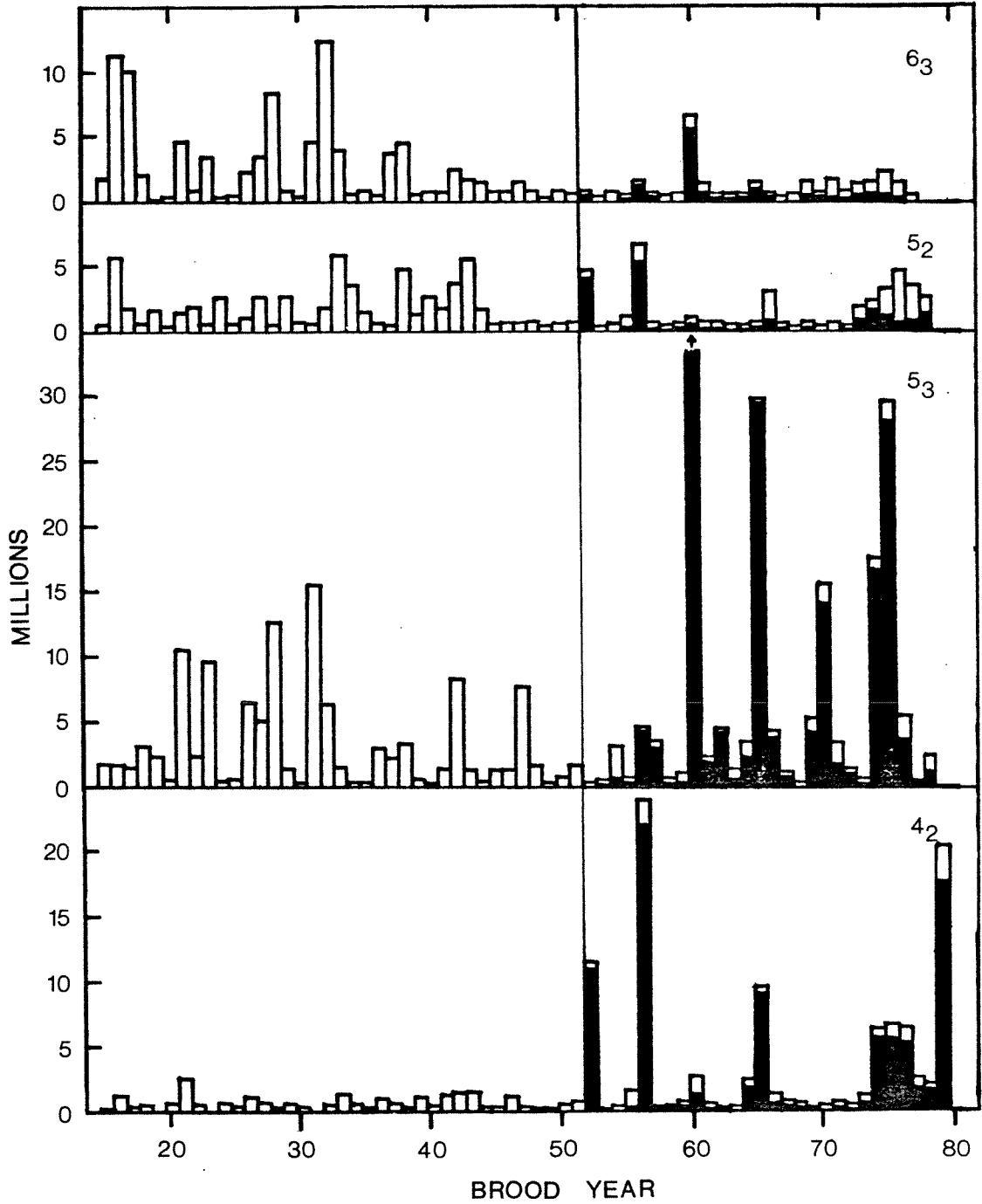


Fig. 2. Returns by age from brood years; Naknek-Kvichak catches from the 1915 to 1951 broods and Naknek-Kvichak runs from the 1952 to 1979 broods (solid bars for the Kvichak and open for Naknek plus Branch).

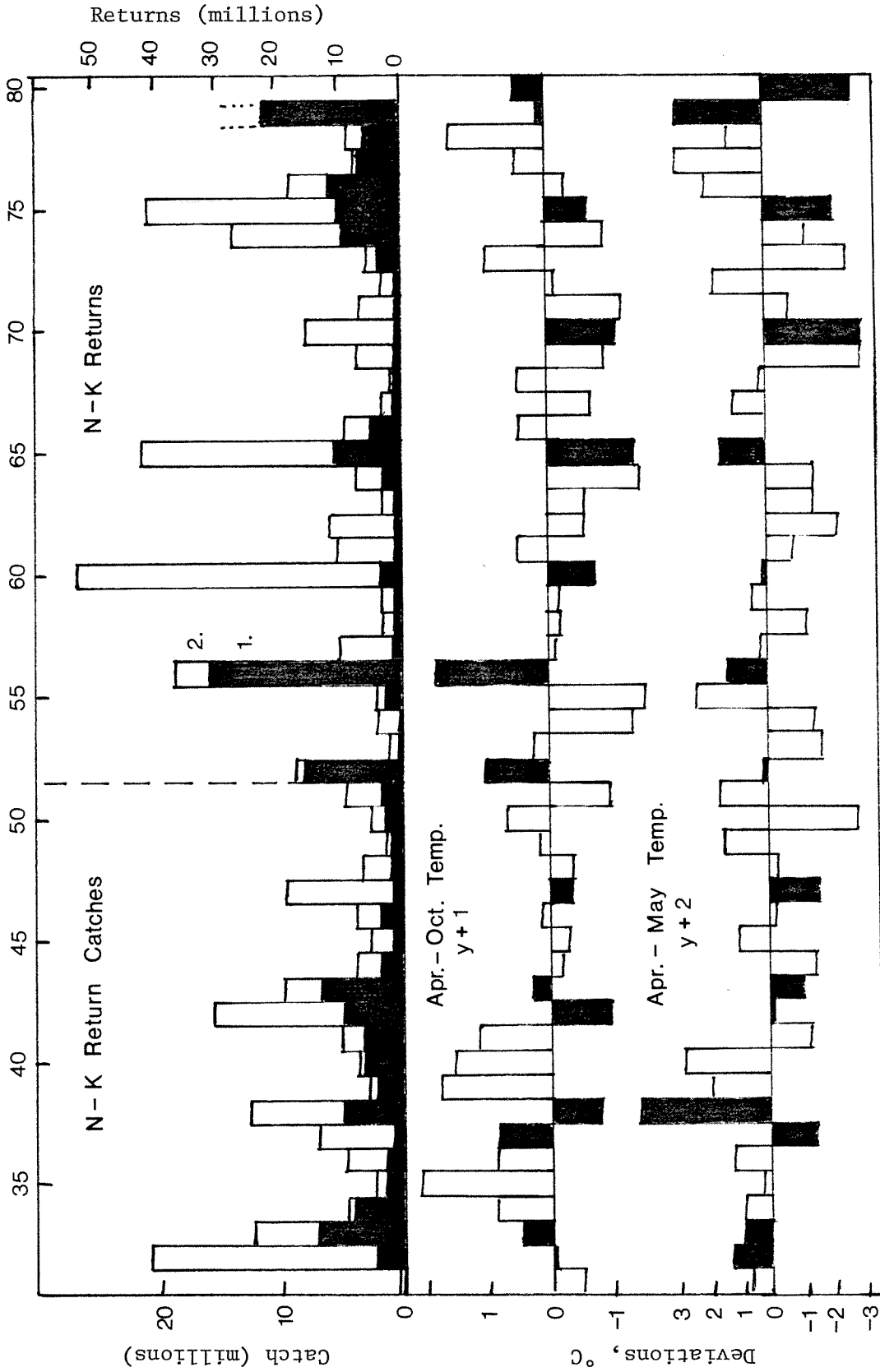


Fig. 3. Naknek-Kvichak return catches (1931-51 broods) and returns--catch plus escapement (1952-79 broods) by freshwater age and the mean monthly air temperature deviations for summer months (fry) and spring months (yearling).

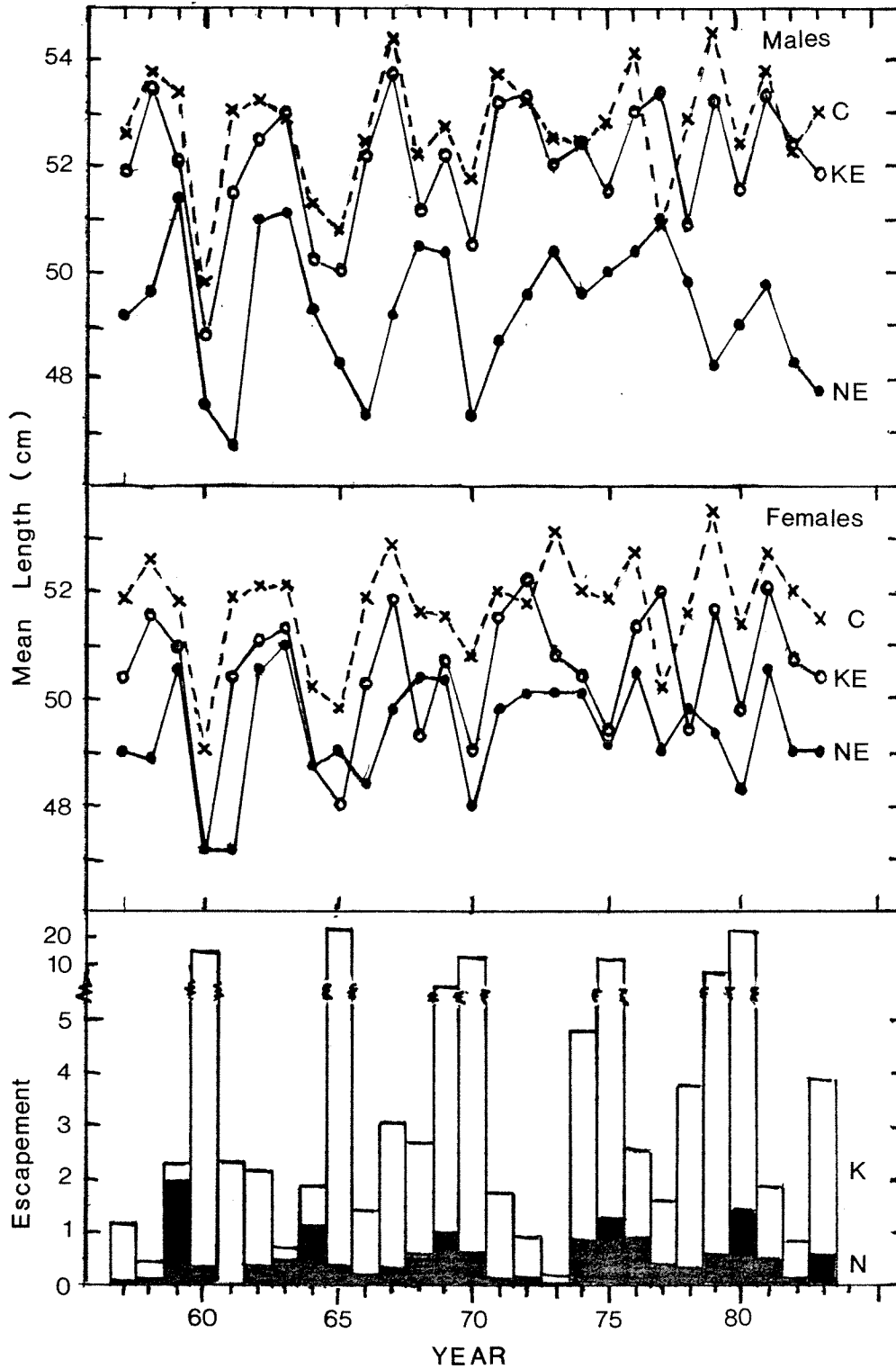


Fig. 4. Escapements of 2-ocean-age sockeye to the Kvichak and Naknek (solid) systems and the mean lengths in the catch (C) and escapements by sex.

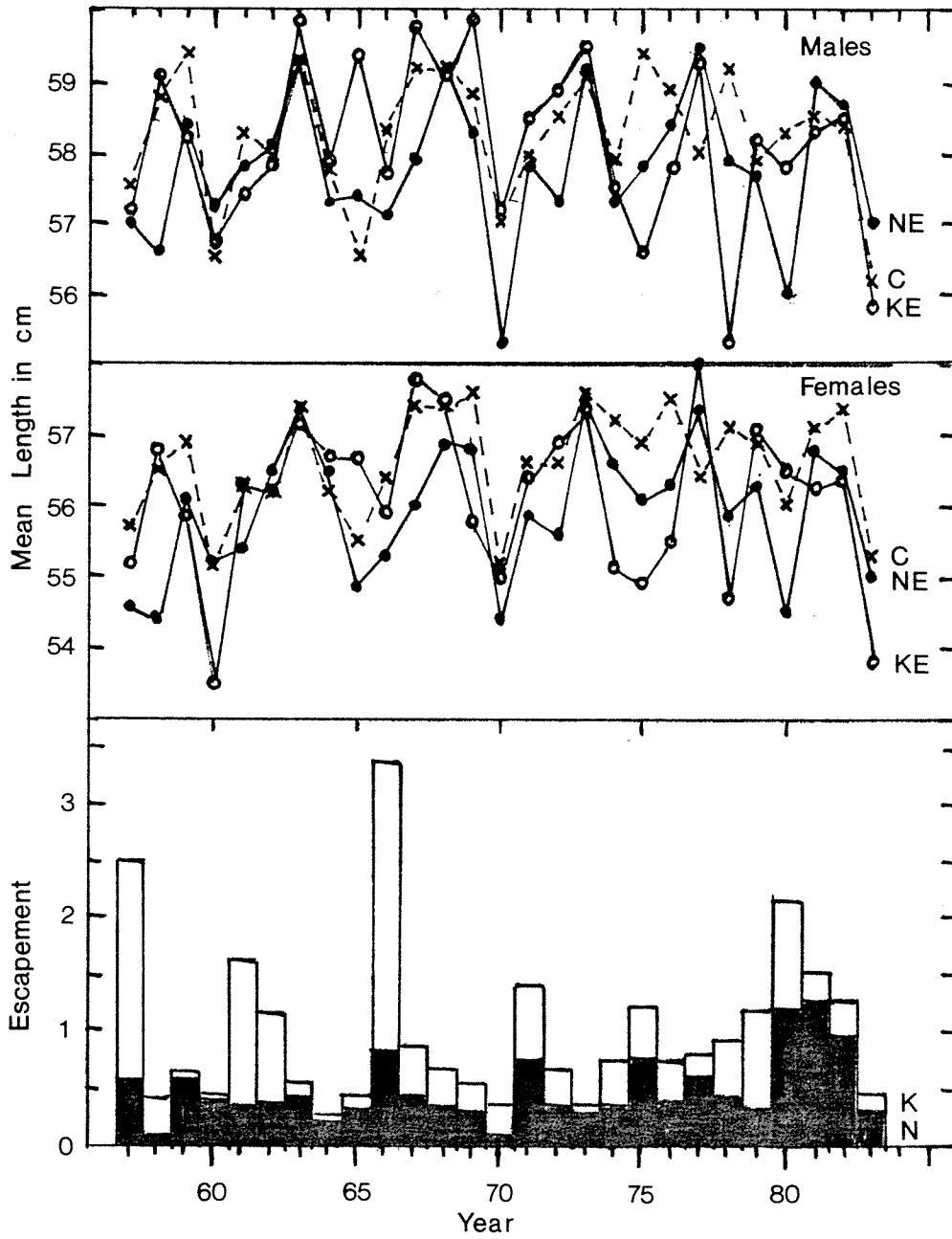


Fig. 5. Escapements of 3-ocean-age sockeye to the Kvichak and Naknek (solid) systems and the mean lengths in the catch (C) and escapements by sex.

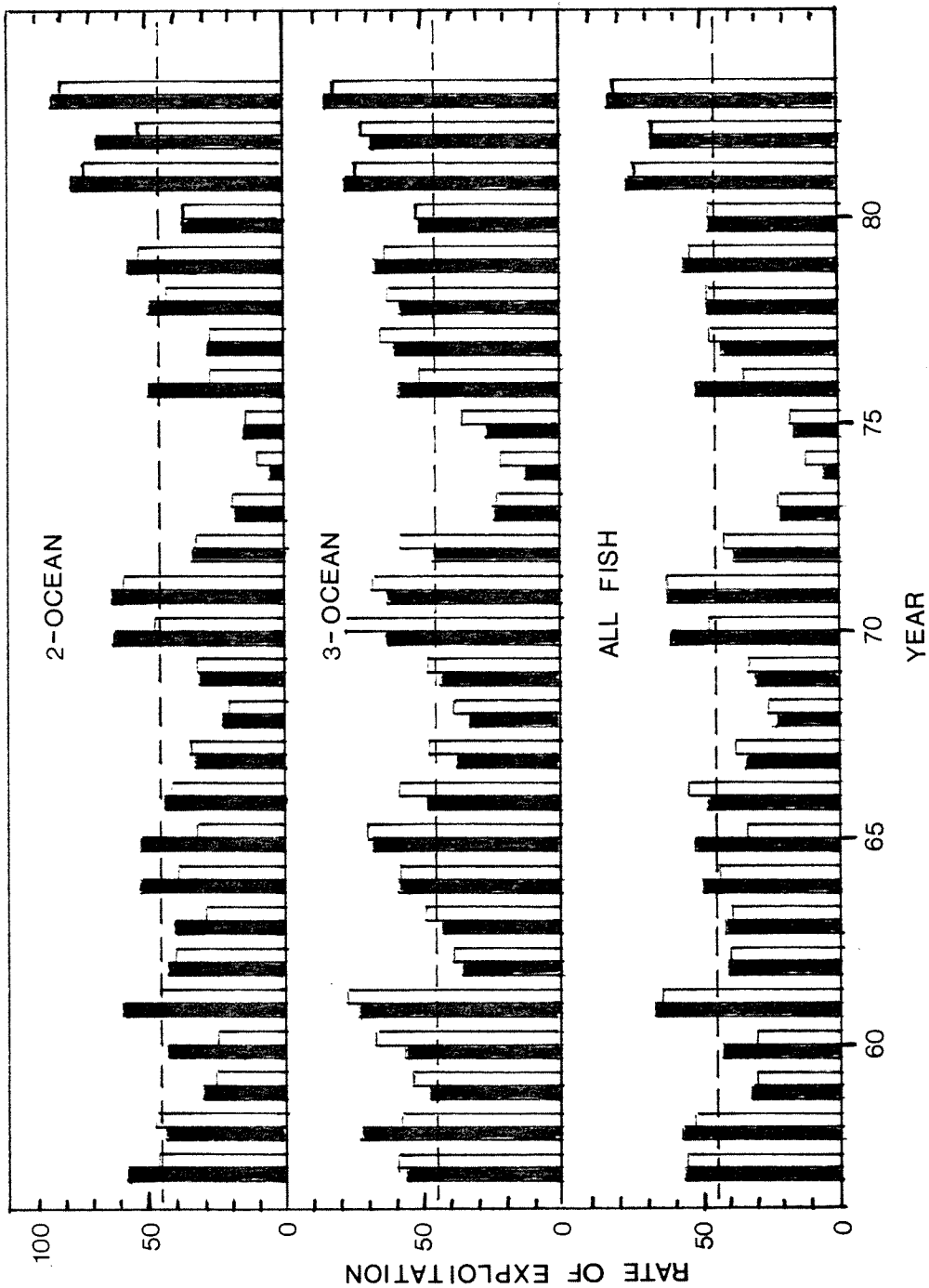


Fig. 6. Rates of exploitation on the Naknek-Kvichak District runs (males, solid bars; females, open bars).

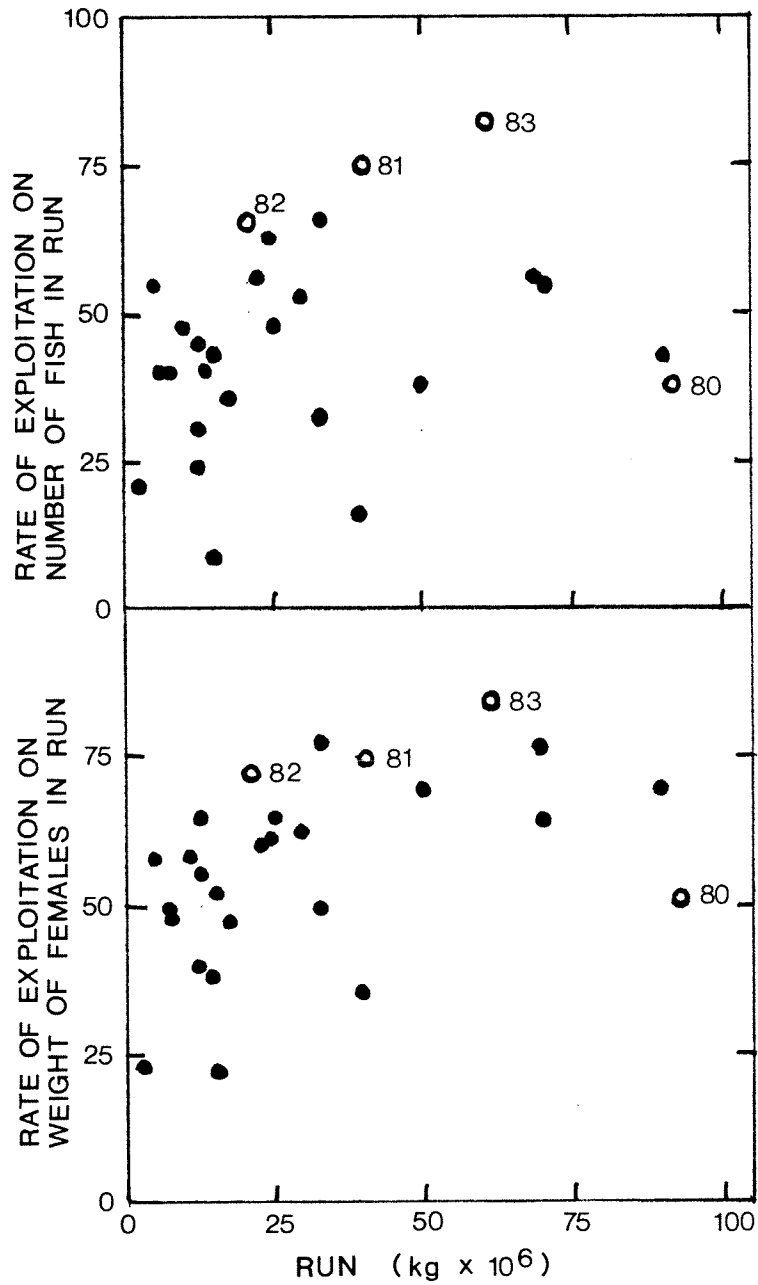


Fig. 7. Rates of exploitation in the Naknek-Kvichak District plotted on the weight of fish in the run. Rate in number of fish (top) and weight of females (bottom).

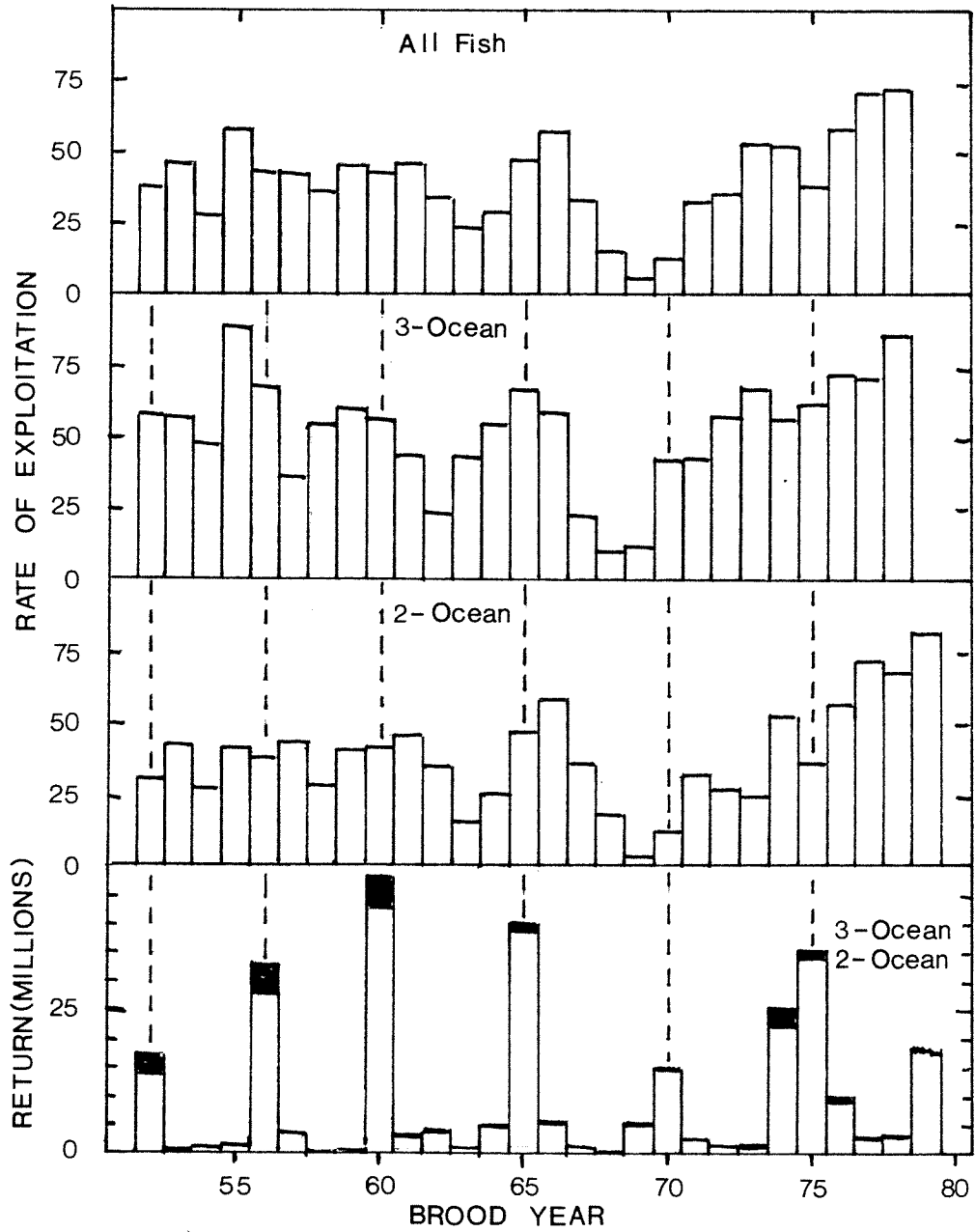


Fig. 8. Rates of exploitation on the returns by brood year for the Kvichak system.

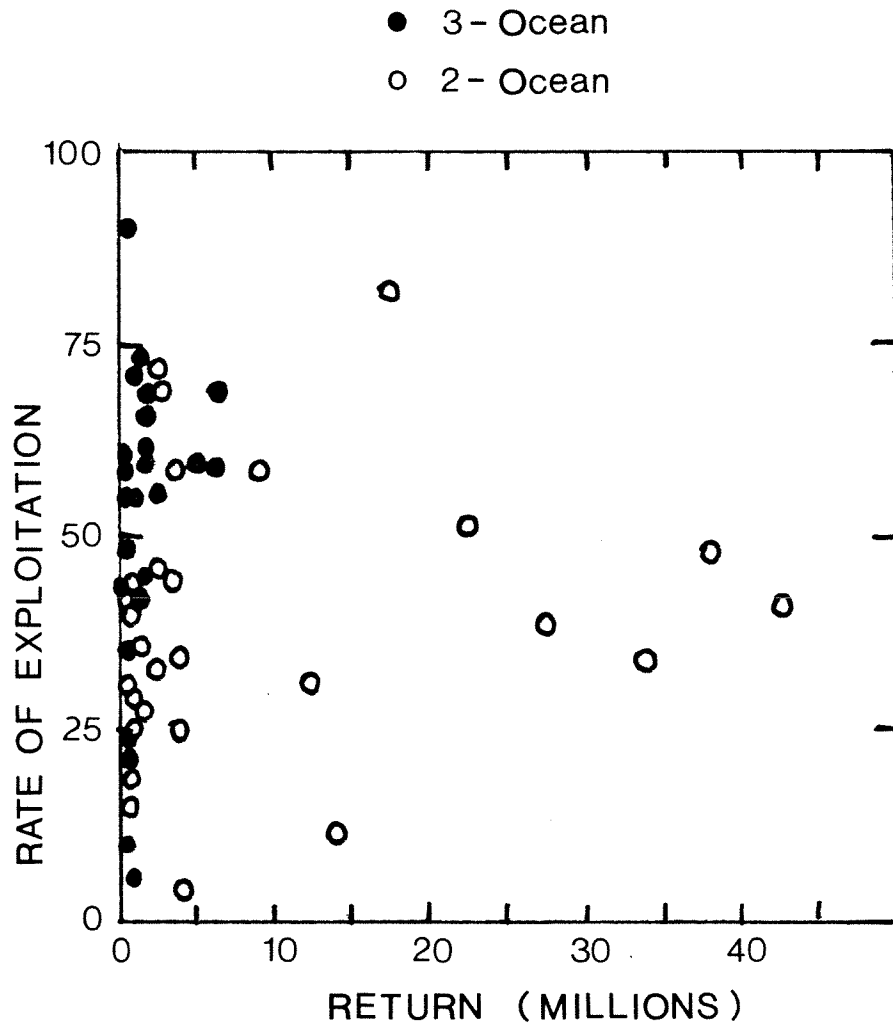


Fig. 9. Rates of exploitation on the returns by ocean age plotted on the returns to the Kvichak system.

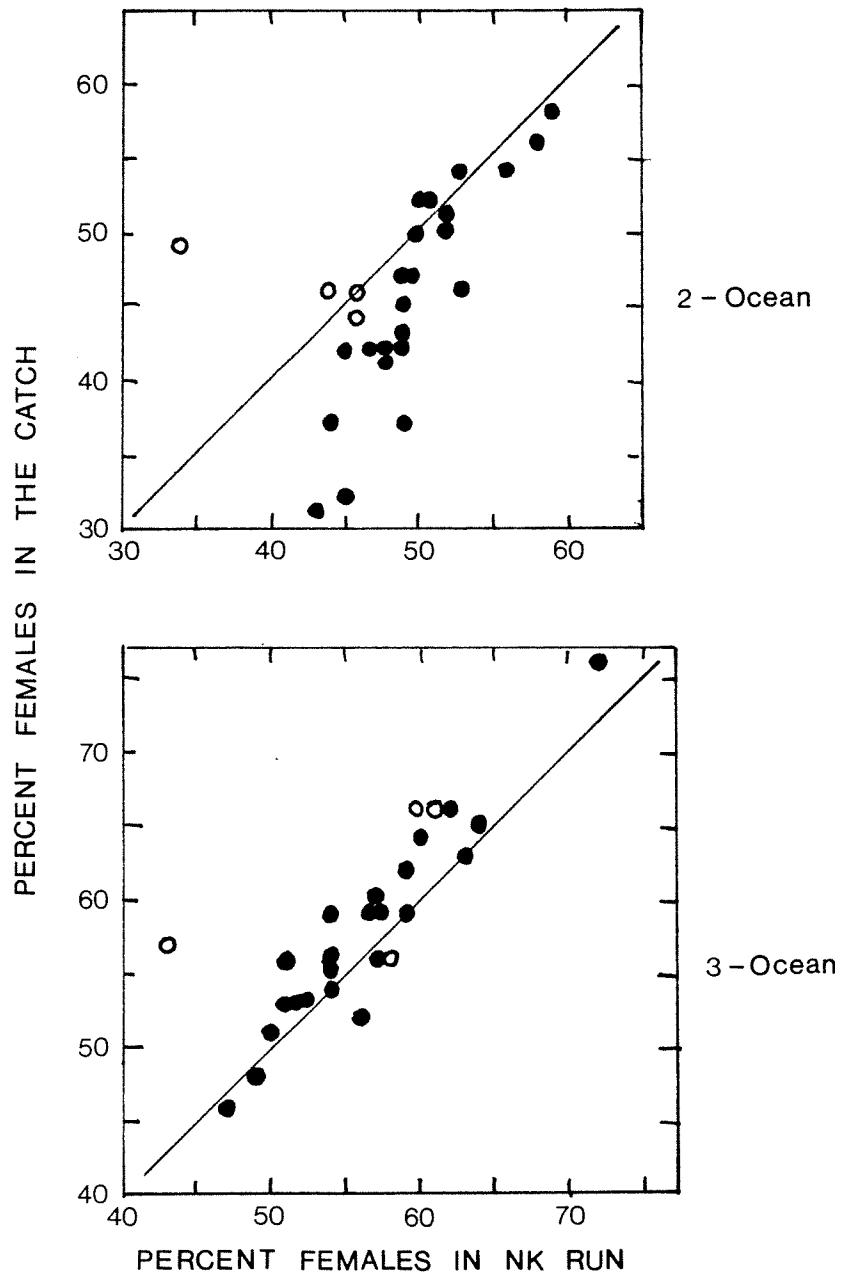


Fig. 10. Sex ratio (percent females) in the catch plotted on the sex ratio in the Naknek-Kvichak run by ocean age. Open circles for years in which rate of exploitation was less than .25.

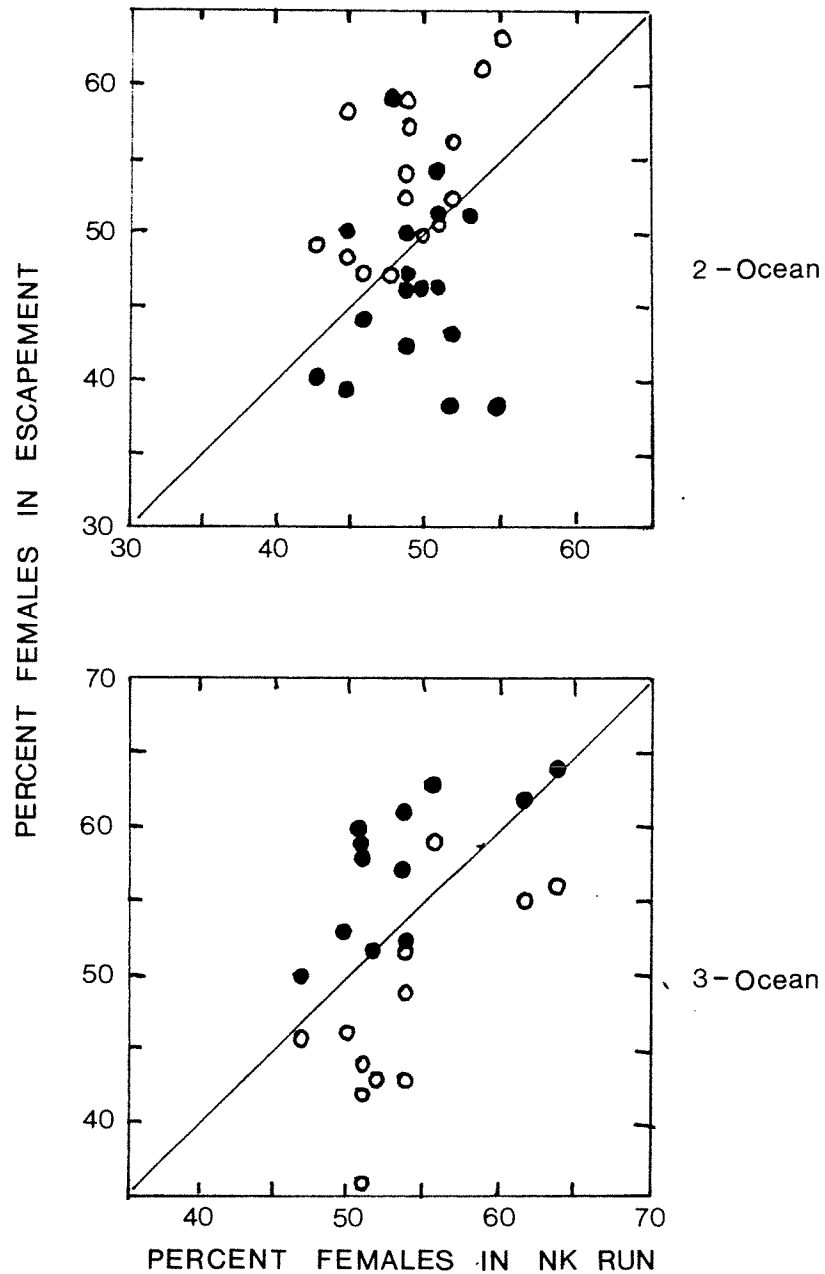


Fig. 11. Sex ratio (percent females) in the Kvichak (circles) and Naknek (solid) escapements plotted on the sex ratio in the Naknek-Kvichak run for years when escapements to both systems were greater than 300,000 and rate of exploitation was greater than .25.

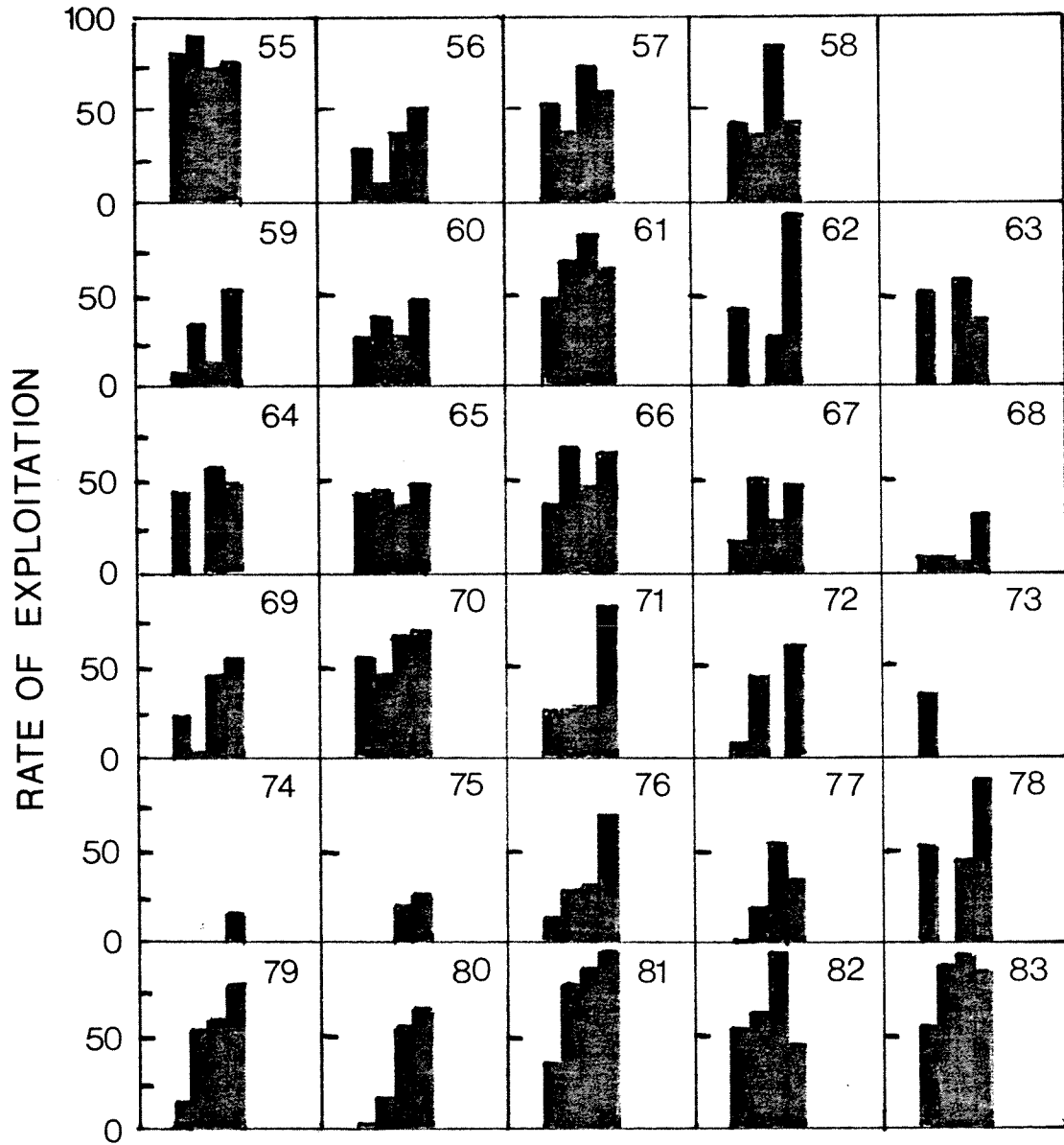


Fig. 12. Rates of exploitation on the Kvichak sockeye salmon runs by quartile of the run (1st-25% to last 25%, left to right).

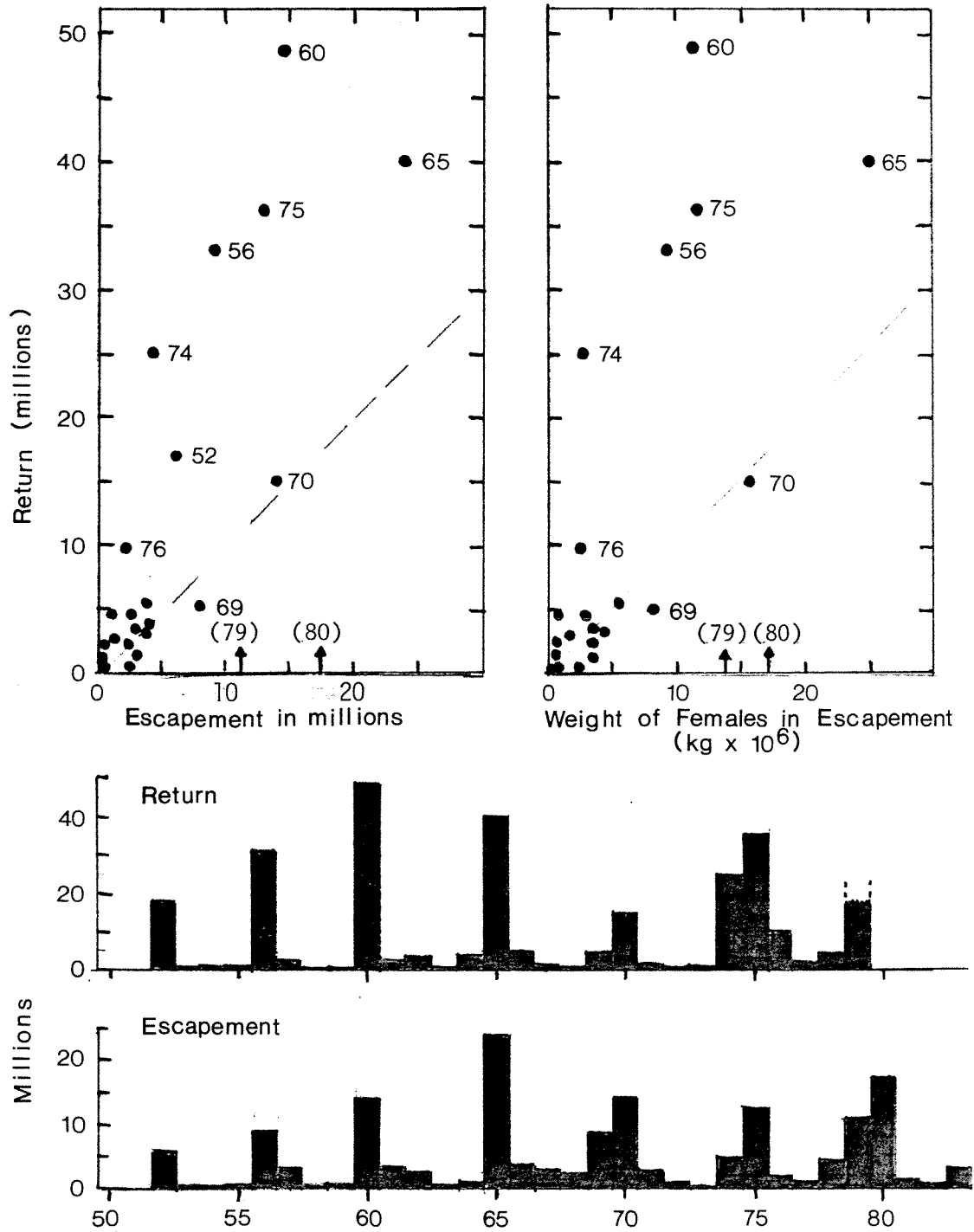
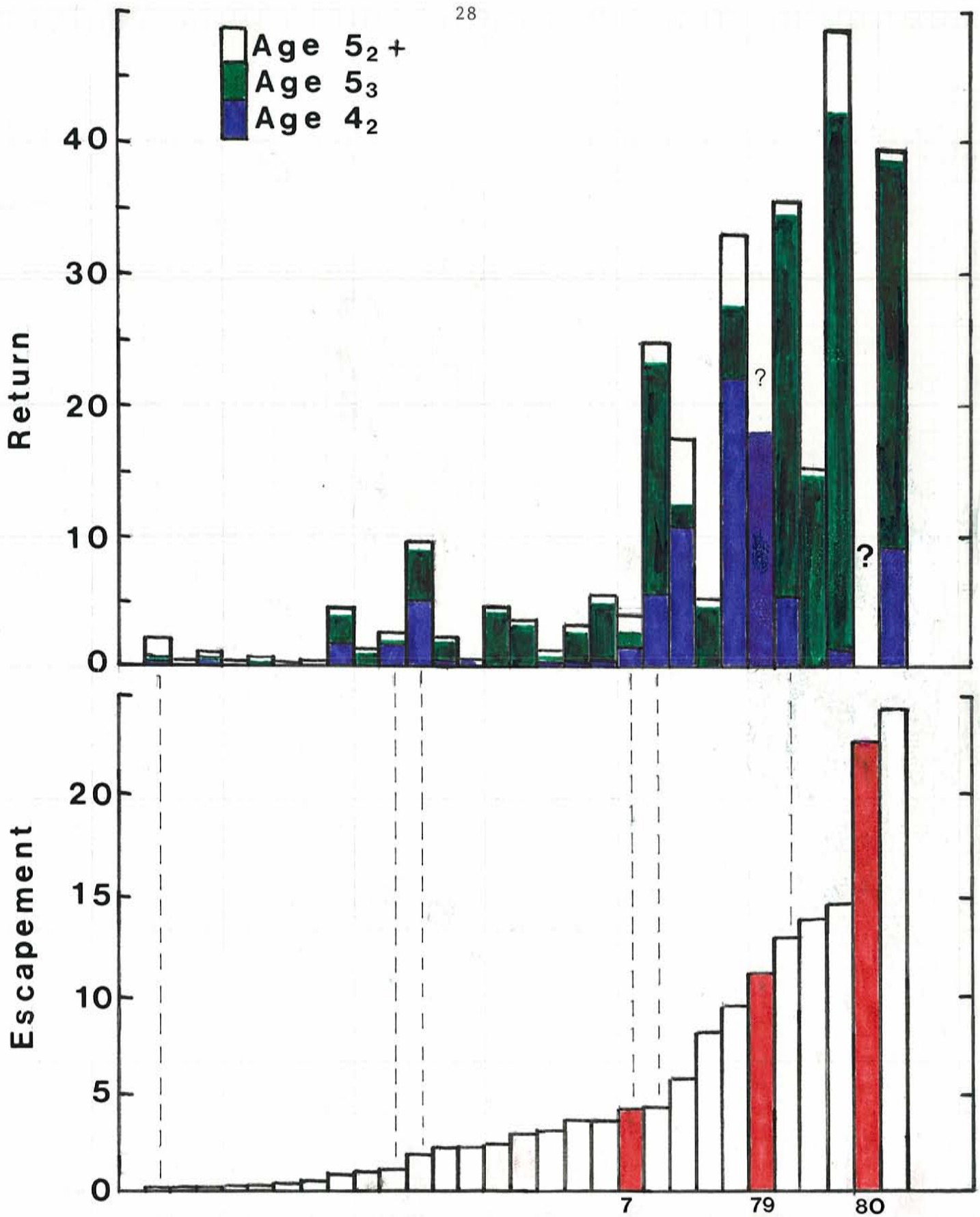


Fig. 13. Escapements and returns to the Kvichak system since the 1952 brood year.



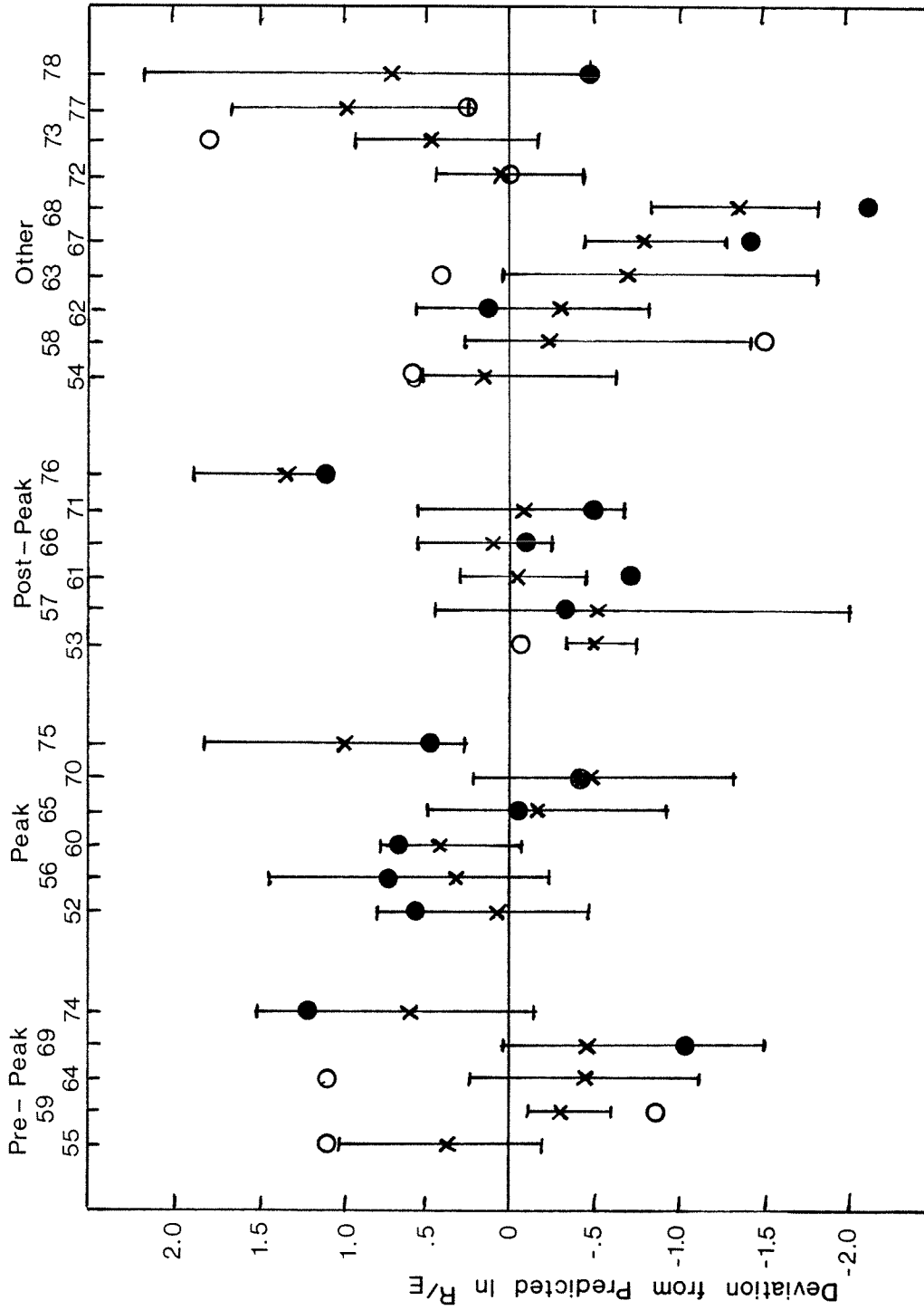


Fig. 15. Means (X) and ranges in deviations from predicted return per escapement for the Naknek, Egegik, Ugashik, Wood, and Igushik systems and the deviations for the Kvichak system by Kvichak cycle year (open circles for Kvichak escapements less than 1.3 million).

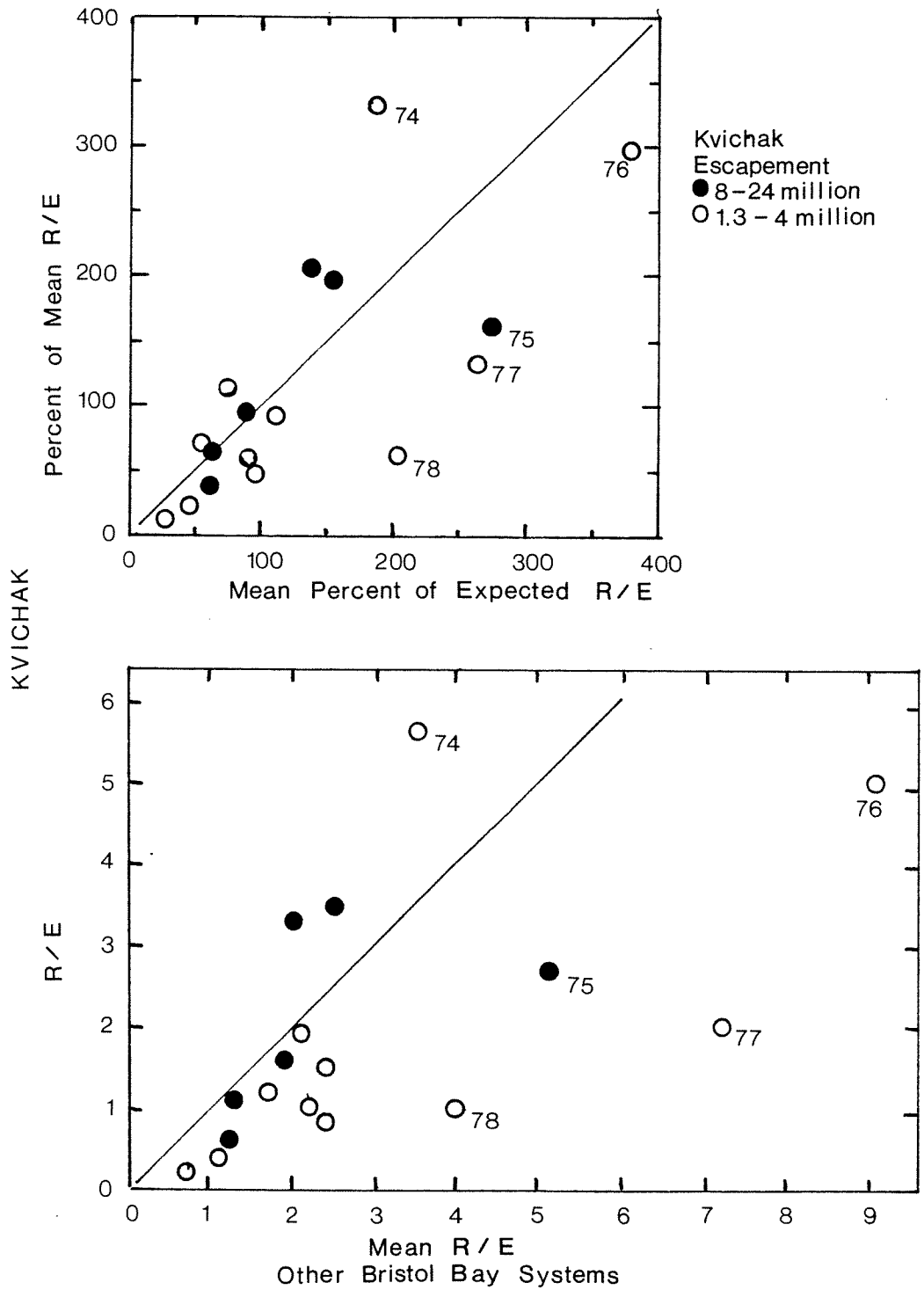


Fig. 16. Return per escapement for the Kvichak system plotted on the mean for other Bristol Bay systems.

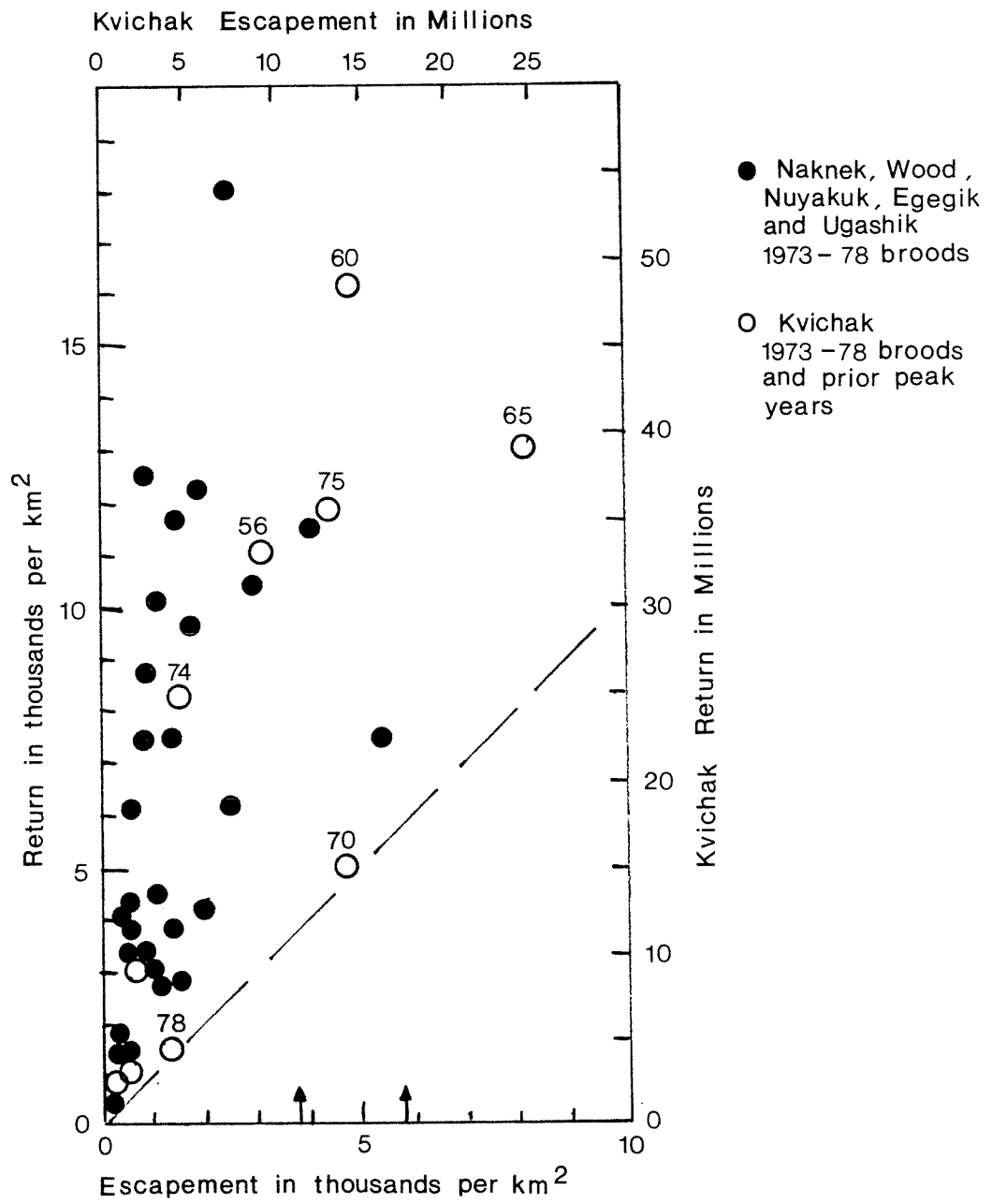


Fig. 17. Escapements and returns per lake surface area for Bristol Bay lake systems.

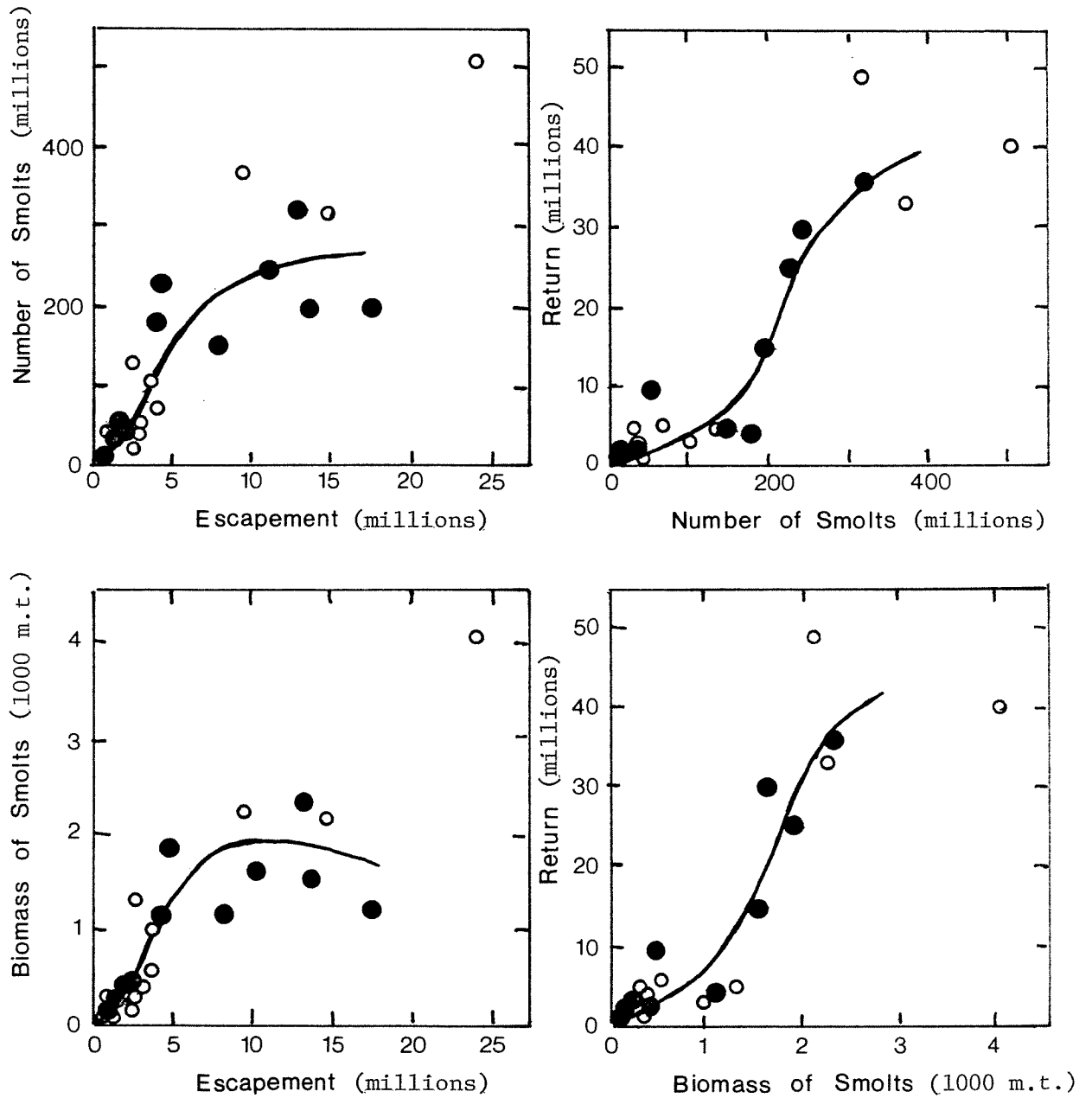


Fig. 18. Escapement-smolt and smolt-return relationships for the Kvichak system (large points, 1969-80 broods; small circles, 1955-68 broods). Freehand curves.

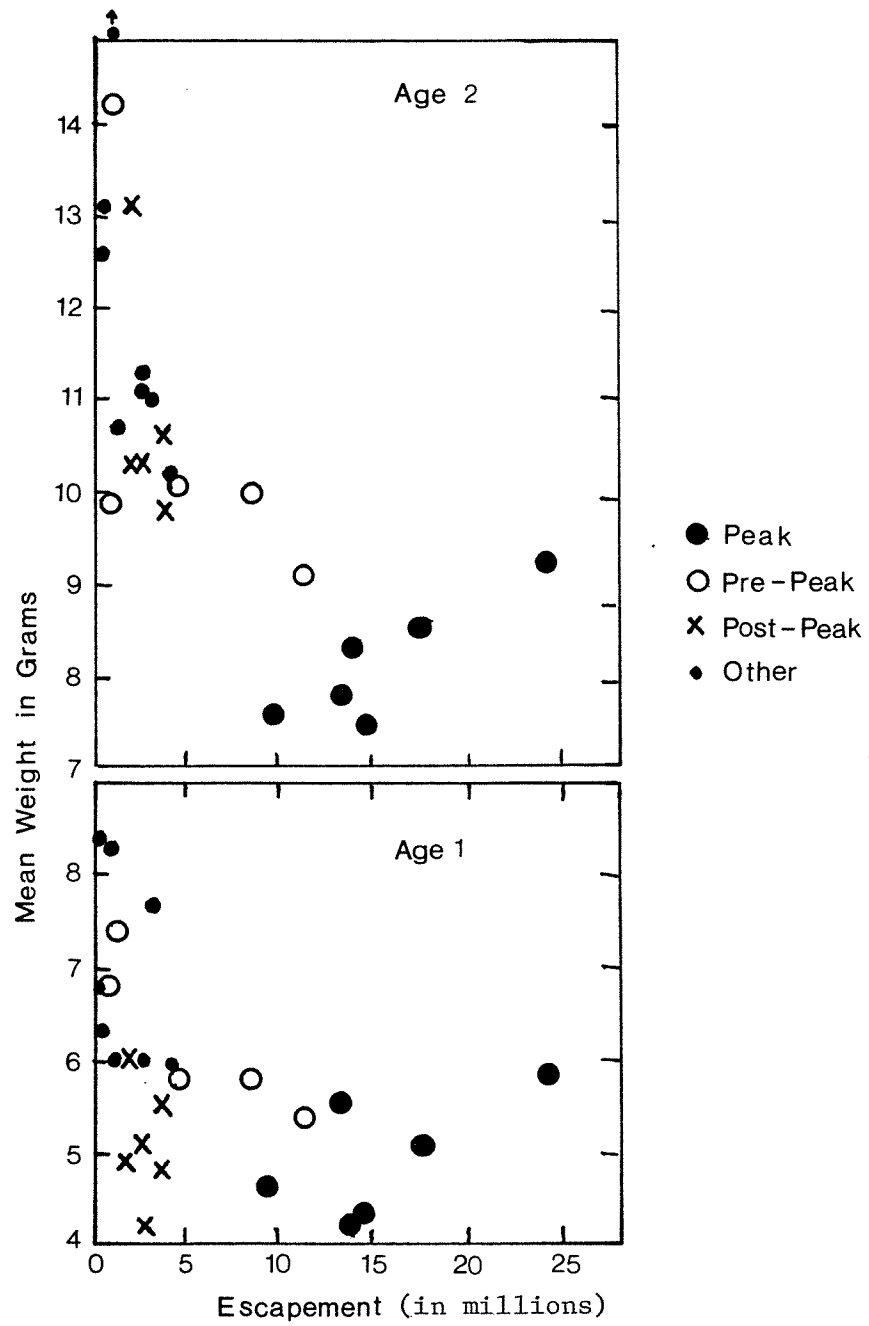


Fig. 19. Mean weights of Kvichak smolts plotted on escapement.

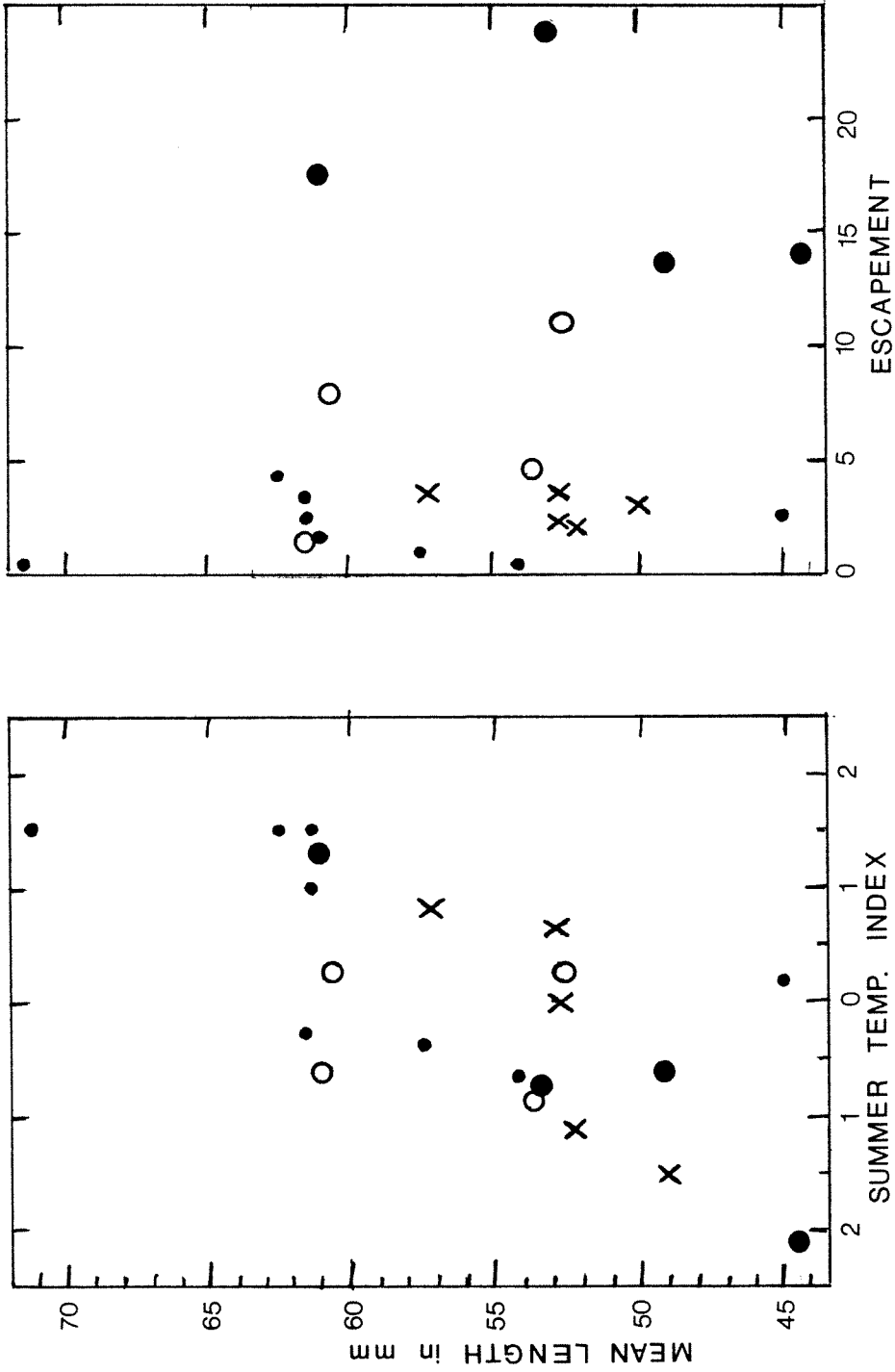


Fig. 20. Mean length of fry in Lake Iliamna on Sept. 1 plotted on summer temperature index and parent escapement (symbols same as in Fig. 19).

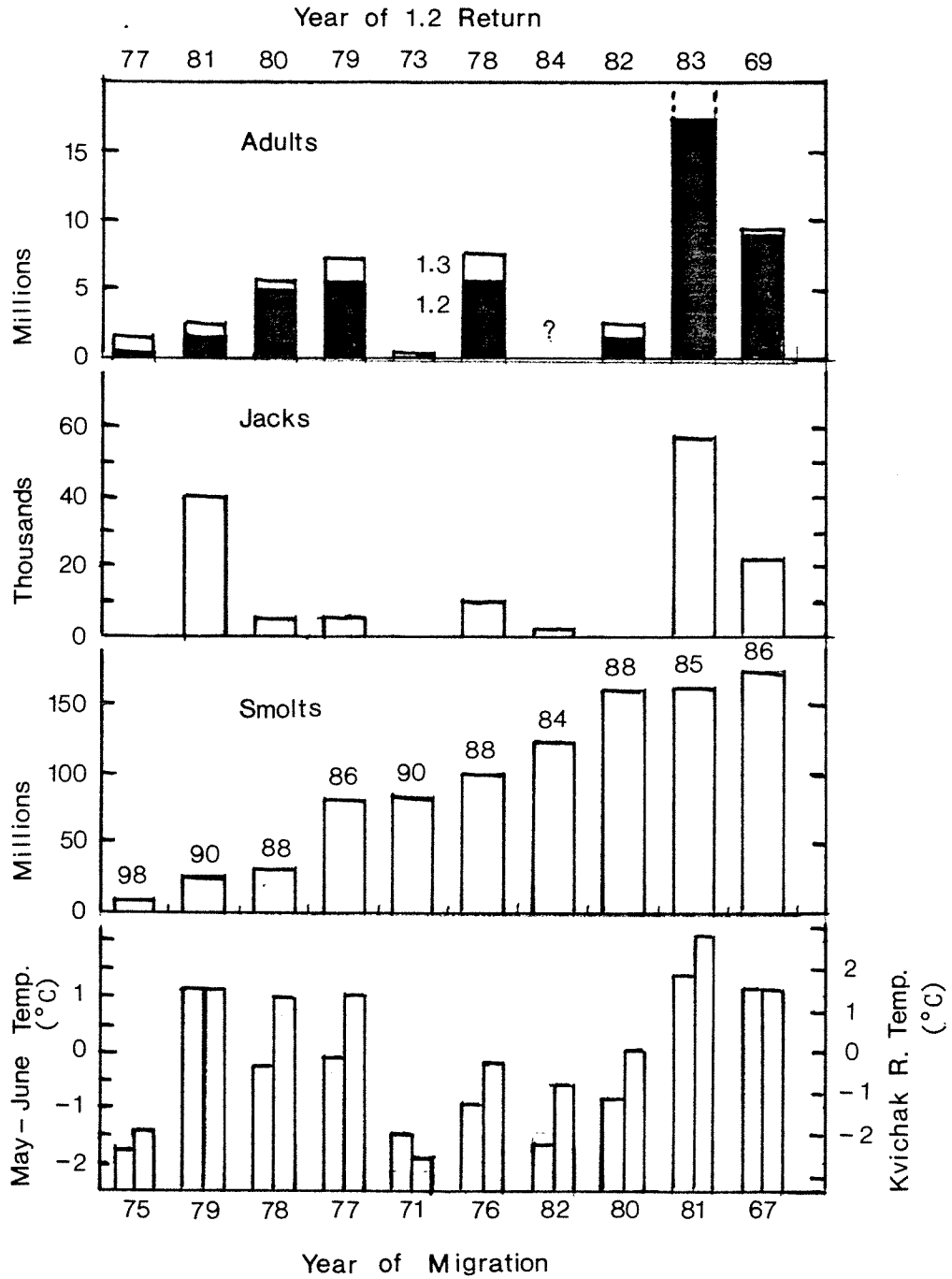


Fig. 21. Age 1. smolts, jacks and adult (1.2 + 1.3) returns ordered by abundance of smolts. Mean length of smolts is given above each bar. (Includes only years with age 1. smolt migrations greater than 10 million.)

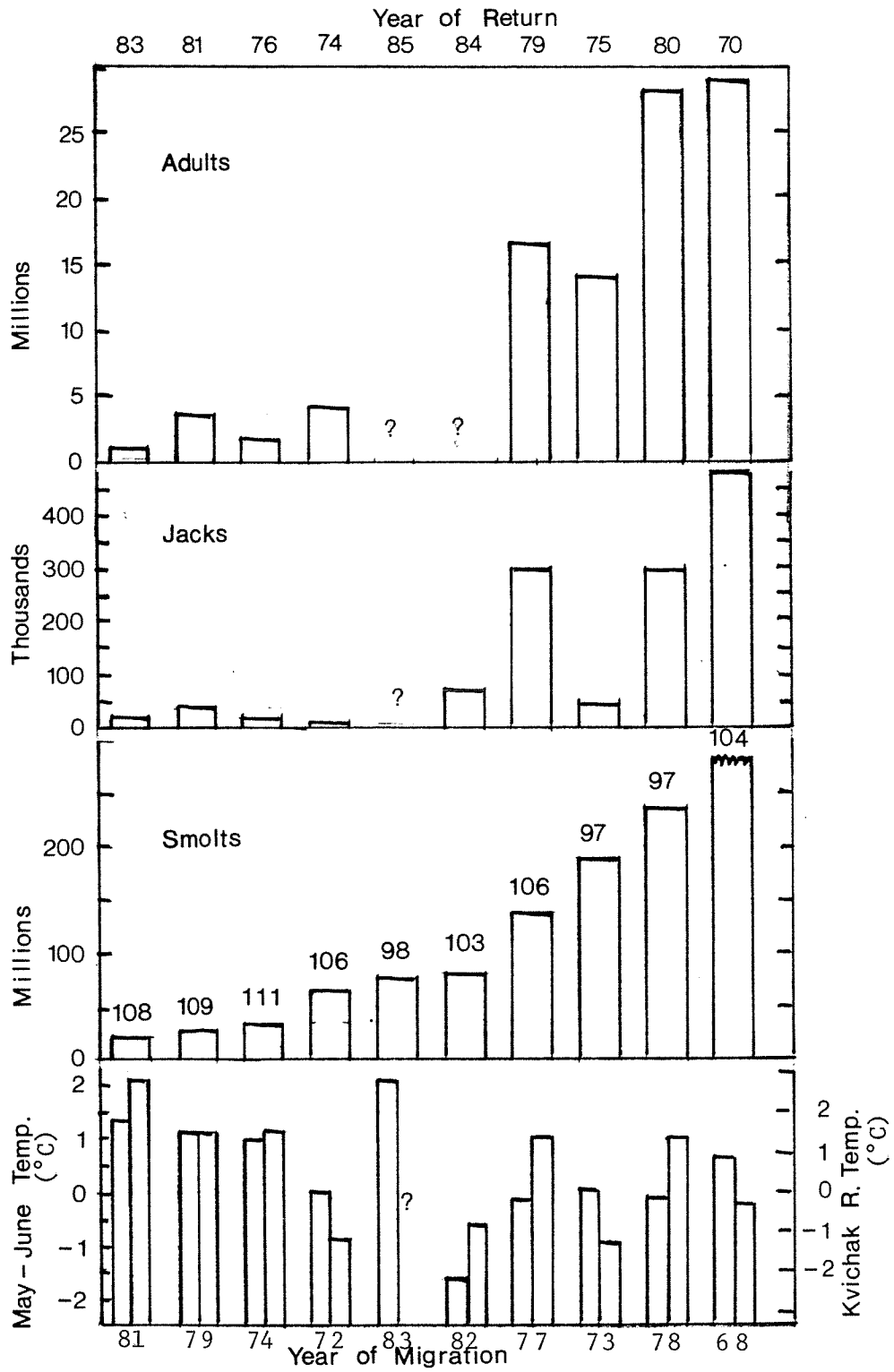


Fig. 22. Age 2. smolts, jacks and adult (2.2) returns ordered by abundance of smolts. Mean length of smolts is given above each bar. (Includes only years with age 2. smolt migrations greater than 10 million.)

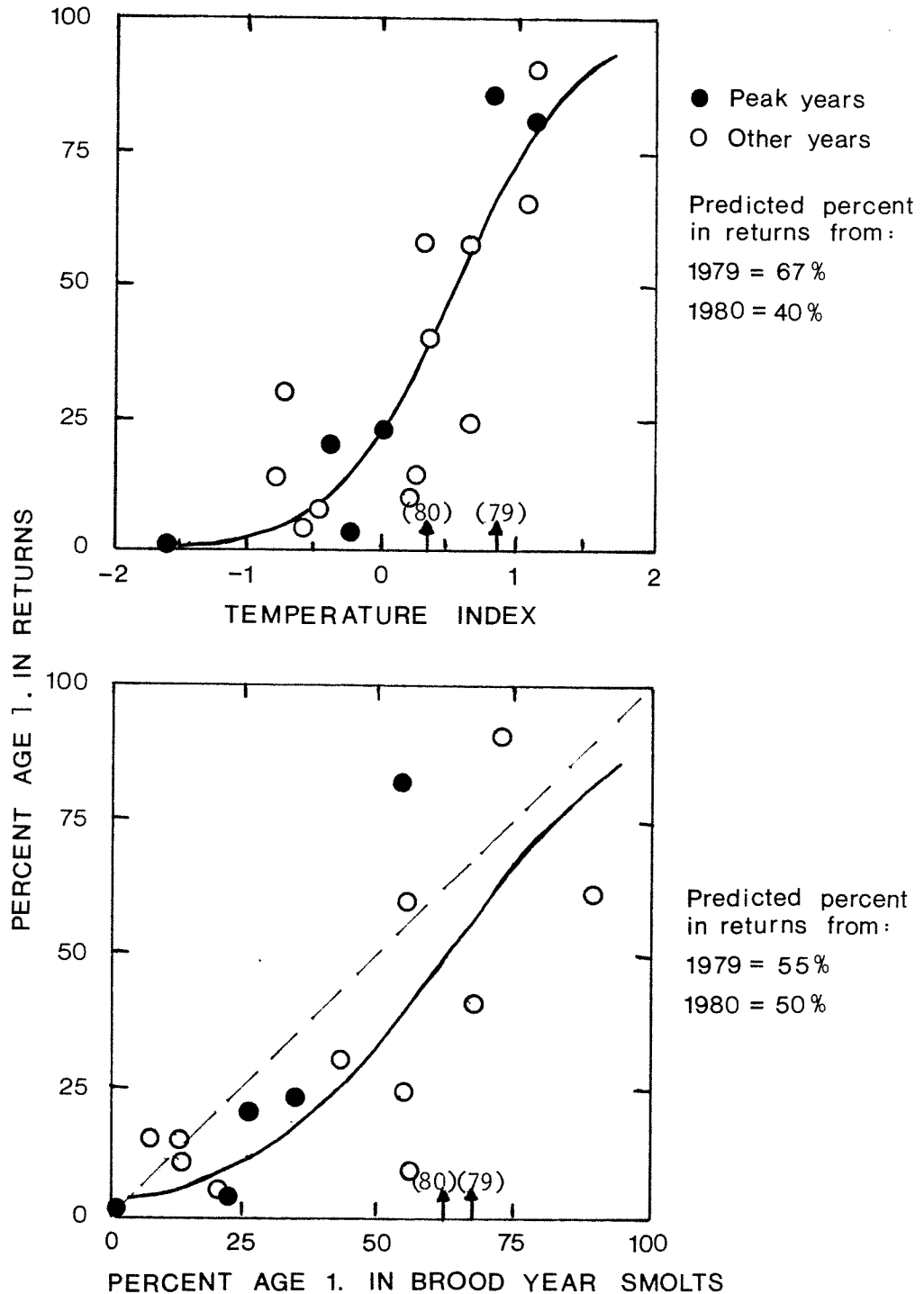


Fig. 23. Relationships between freshwater age composition of Kvichak returns and temperature (top) and composition in smolts from brood year (bottom). ["Temperature index" is the average of the summer temperature index during the fry stage and the spring temperature index the following spring (See last columns, Tables 9 and 8, respectively).]

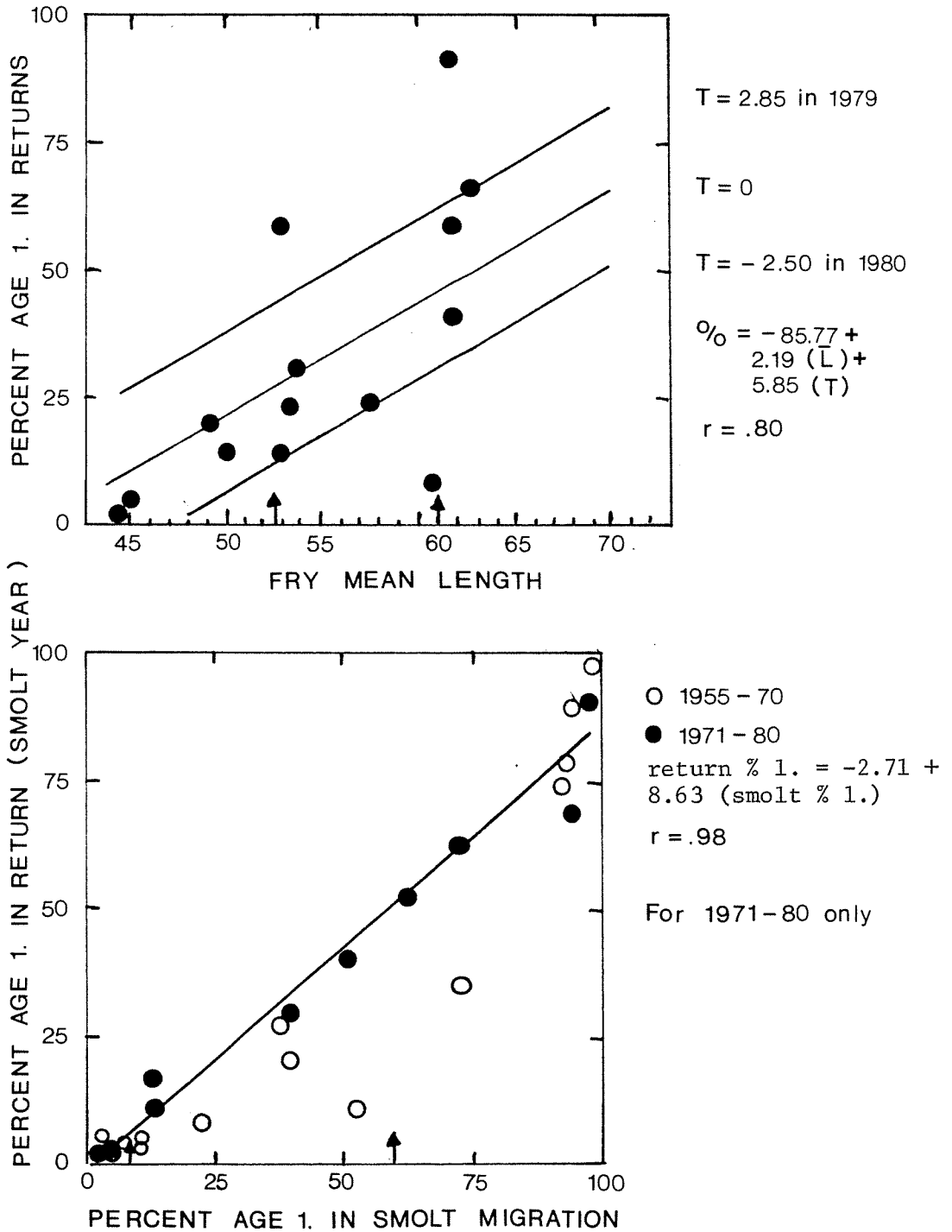


Fig. 24. Relationships between freshwater age compositions of Kvichak returns and mean length of fry (top) and composition in smolt migration (bottom). [T = deviation from long term mean April-May air temperature the following spring, e.g. + 2.58° in spring 1981, potentially affecting smoltification of 1979 brood fry.]

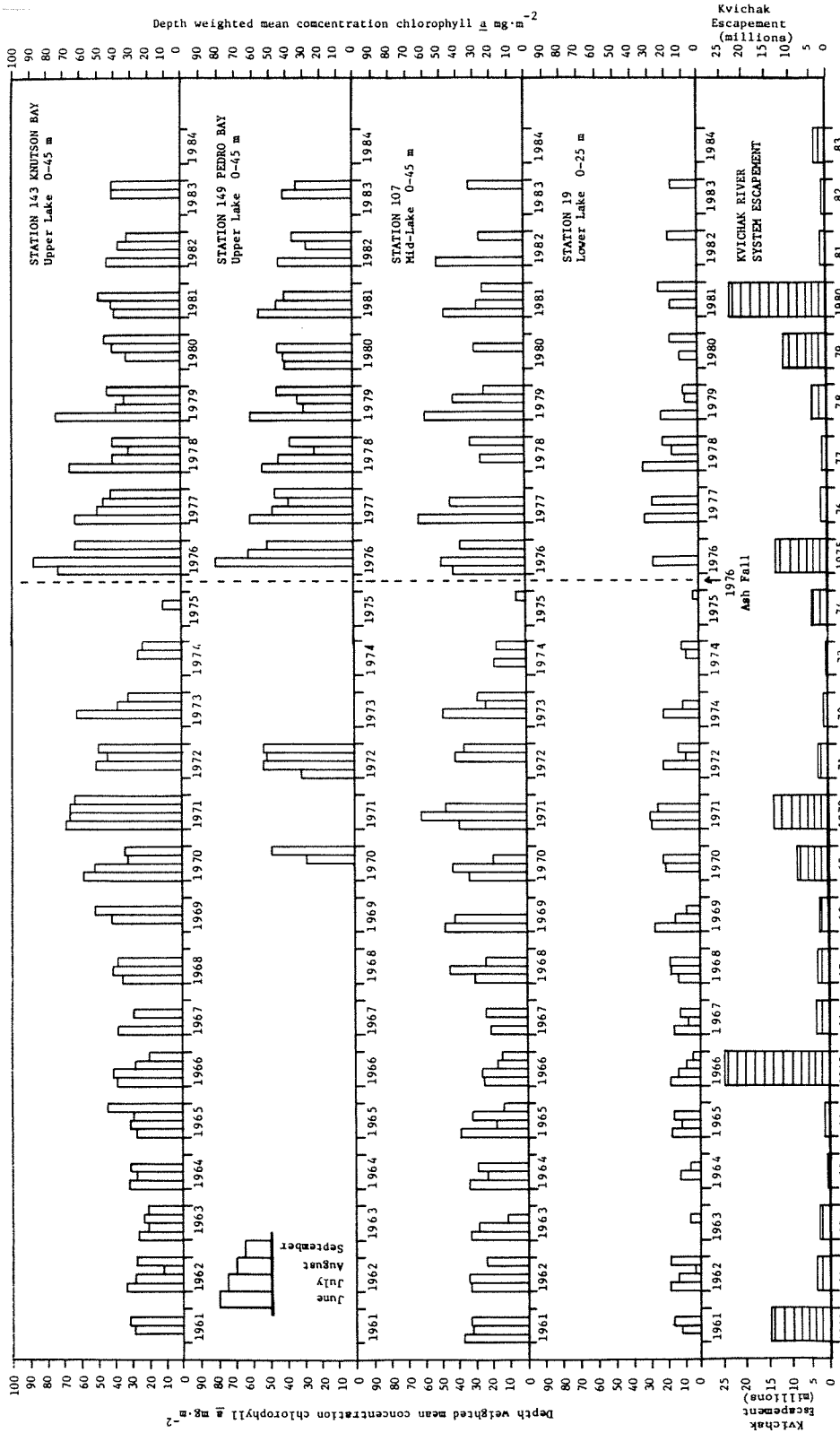


Fig. 25. Kvichak escapements and limnetic phytoplankton abundance as measured by the concentrations of chlorophyll *a* ( $\text{mg}\cdot\text{m}^{-2}$ ) at Stations 19, 107, 143 and 149, Iliamna Lake, 1961-1983.

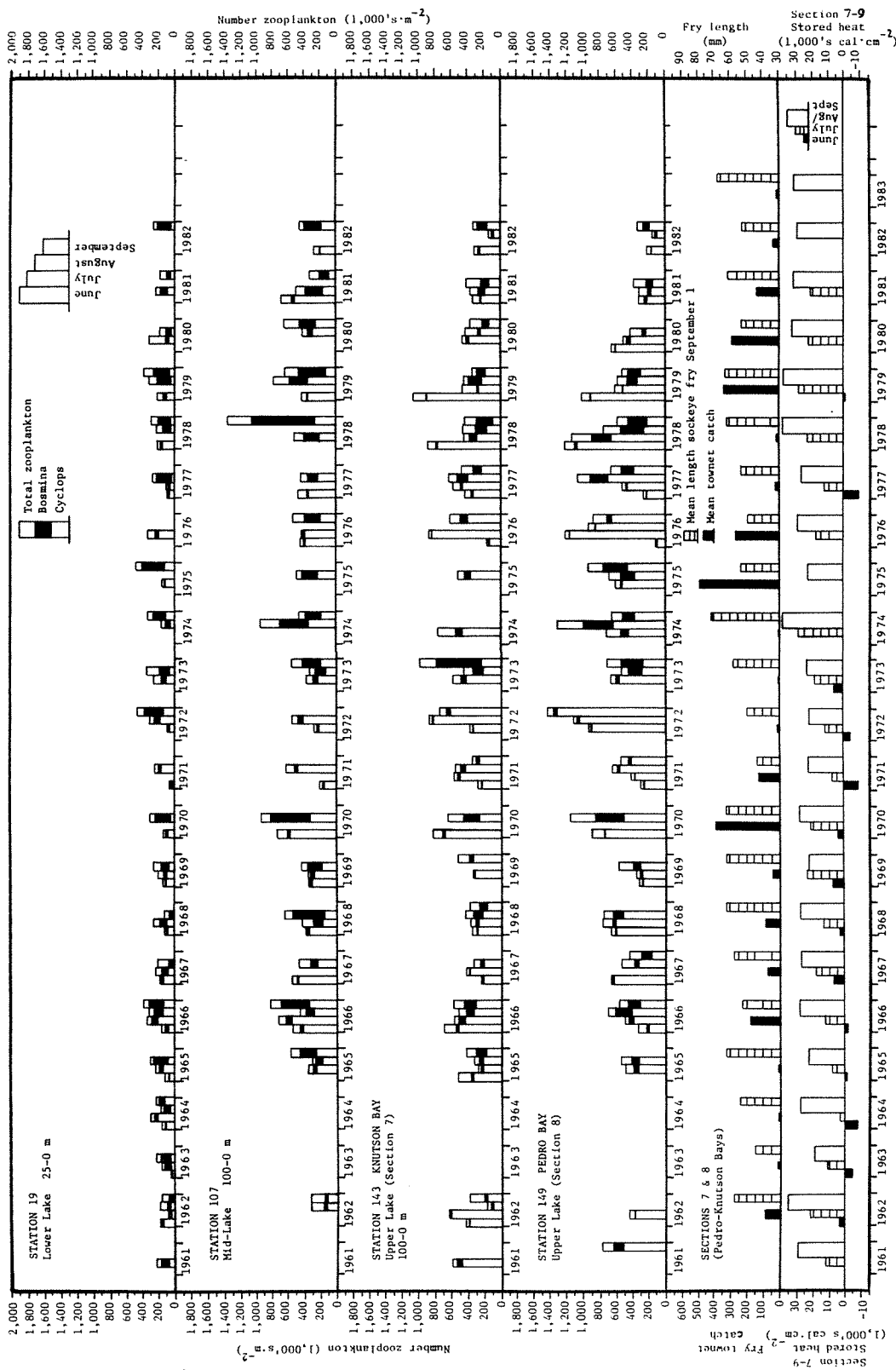


Fig. 26. Seasonal limnetic zooplankton abundance in three distinct physical regions in Iliamna Lake and relationships between temperature regimes and sockeye fry relative abundance and size in the eastern portion of Iliamna Lake, 1961-1983.

Table 1. Mean weights (kg) of sockeye salmon in the Naknek-Kvichak District catches and escapements (E).

Year	Males										Females						Both sexes	
	All .1		1.2		2.2		All .2		1.3		2.3		All .3		All			
1957	Catch	-	2.39	2.40	2.40	2.40	3.14	3.22	3.17	2.96	2.09	2.17	2.17	2.74	2.73	2.74	2.62	2.79
	Nak. E	-	1.78	1.97	2.03	3.09	3.17	3.13	3.05	3.05	1.83	1.85	1.85	2.50	2.66	2.58	2.53	2.77
	Kvi. E	-	2.36	2.39	2.39	3.13	3.39	3.17	2.94	2.94	2.44	2.03	2.66	2.81	2.68	2.68	2.43	2.69
	Total E*	-	2.26	2.37	2.38	3.12	3.27	3.16	2.96	2.96	2.27	2.02	2.63	2.72	2.65	2.45	2.45	2.71
	Run	-	2.32	2.39	2.39	3.13	3.24	3.16	2.96	2.96	2.19	2.08	2.69	2.73	2.70	2.54	2.54	2.75
1958	Catch	-	2.41	2.59	2.65	3.27	3.43	3.40	3.08	3.08	2.09	2.26	2.26	2.77	2.85	2.83	2.63	2.82
	Nak. E	-	1.88	2.05	2.14	2.88	3.20	3.05	2.42	2.42	1.78	1.84	1.84	2.37	2.63	2.54	2.23	2.32
	Kvi. E	-	2.34	2.64	2.73	3.20	3.55	3.52	3.16	3.16	1.86	2.23	2.18	2.81	2.95	2.94	2.58	2.85
	Total E	-	2.08	2.37	2.49	2.95	3.50	3.40	2.90	2.90	1.84	2.13	2.08	2.53	2.87	2.81	2.47	2.67
	Run	-	2.22	2.47	2.56	3.13	3.46	3.40	3.00	3.00	1.96	2.21	2.17	2.68	2.86	2.82	2.56	2.76
1959	Catch	-	2.48	2.54	2.61	3.59	3.55	3.57	2.70	2.70	2.11	2.15	2.15	2.86	2.94	2.89	2.34	2.53
	Nak. E	.61	2.20	2.32	2.35	3.39	3.39	3.39	2.41	2.41	1.91	2.09	2.05	2.81	2.87	2.83	2.14	2.27
	Kvi. E	.70	2.23	2.43	2.50	3.26	3.41	3.36	2.49	2.49	2.04	2.13	2.10	2.76	2.81	2.79	2.14	2.30
	Bran. E	.56	2.20	2.20	2.19	2.90	-	2.90	2.26	2.26	1.66	1.74	1.69	2.01	-	2.01	1.70	1.97
	Total E	.68	2.20	2.31	2.36	3.19	3.39	3.27	2.39	2.39	1.81	2.06	1.98	2.70	2.86	2.76	2.05	2.22
	Run	.68	2.31	2.38	2.42	3.38	3.47	3.41	2.49	2.49	1.90	2.09	2.02	2.79	2.90	2.83	2.14	2.32
1960	Catch	-	2.06	2.07	2.40	2.77	3.21	2.91	2.10	2.10	1.75	2.02	1.76	2.63	2.70	2.66	1.97	2.05
	Nak. E	-	1.42	1.46	1.60	3.05	3.28	3.17	2.13	2.13	1.56	1.73	1.61	2.61	2.76	2.68	2.31	2.22
	Kvi. E.	.61	1.93	1.93	1.99	3.07	-	3.07	1.93	1.93	1.61	1.83	1.61	2.40	-	2.40	1.61	1.77
	Bran. E	-	2.08	2.08	-	3.36	3.51	3.37	2.20	2.20	1.66	1.60	1.66	2.56	2.45	2.50	1.74	1.90
	Total E	.61	1.93	1.92	1.88	3.14	3.29	3.20	1.95	1.95	1.61	1.79	1.61	2.59	2.68	2.63	1.66	1.80
	Run	.61	1.98	1.98	2.10	2.92	3.25	3.04	2.02	2.02	1.65	1.90	1.65	2.62	2.69	2.65	1.75	1.89
1961	Catch	-	2.41	2.46	2.46	3.34	3.43	3.35	2.99	2.99	2.22	2.14	2.15	2.82	2.88	2.83	2.66	2.83
	Nak. E	-	1.51	1.96	1.96	3.28	3.32	3.28	3.16	3.16	1.61	-	1.61	2.71	2.78	2.71	2.67	2.89
	Kvi. E	-	2.05	2.35	2.35	3.20	3.45	3.20	2.66	2.66	2.03	2.03	2.03	2.86	2.89	2.86	2.32	2.49
	Bran. E	-	2.19	-	-	3.36	3.03	3.34	3.31	3.31	1.91	-	1.91	2.73	2.73	2.73	2.71	2.98
	Total E	-	1.92	2.35	2.35	3.22	3.40	3.22	2.71	2.71	1.98	2.03	2.03	2.82	2.86	2.82	2.36	2.53
	Run	-	2.25	2.42	2.42	3.31	3.43	3.32	2.90	2.90	2.09	2.08	2.08	2.82	2.88	2.83	2.55	2.73

\*When length-weight samples were not available for the Branch escapement, the mean weights for the Kvichk were used with age-sex composition of Branch escapement to calculate the means for the total escapement.

Table 1. Mean weights (kg) of sockeye salmon in the Naknek-Kvichak District catches and escapements (E) - cont'd.

Year		Males										Females					Both sexes
		All .1	1.2	2.2	All .2	1.3	2.3	All .3	All	1.2	2.2	All .2	1.3	2.3	All .3	All	
1962	Catch	-	2.35	2.51	2.51	2.51	3.34	3.22	3.24	2.72	2.14	2.18	2.82	2.78	2.79	2.39	2.56
	Nak. E	-	2.12	2.32	2.26	3.36	3.30	3.33	2.74	1.86	2.10	2.91	2.86	2.89	2.54	2.64	
	Kvi. E	-	2.35	2.49	2.49	3.32	3.28	3.28	2.77	2.16	2.11	2.91	2.83	2.84	2.32	2.55	
	Total E	-	2.23	2.47	2.45	3.34	3.28	3.29	2.76	1.94	2.10	2.91	2.84	2.86	2.7	2.56	
	Run	-	2.25	2.49	2.48	3.34	3.26	3.27	2.75	1.98	2.13	2.88	2.81	2.83	2.38	2.56	
1963	Catch	-	2.50	2.53	2.51	3.49	3.60	3.57	2.93	2.21	2.28	2.86	3.05	3.00	2.71	2.82	
	Nak. E	.61	2.11	2.41	2.28	3.37	3.60	3.57	2.77	1.98	2.10	2.85	3.08	3.03	2.56	2.66	
	Kvi. E	-	2.43	2.79	2.56	3.84	3.66	3.68	3.08	2.00	2.14	2.99	3.00	3.00	2.46	2.78	
	Bran. E	-	2.50	2.69	2.52	3.60	4.00	3.76	2.67	1.99	2.00	2.97	2.11	2.73	2.04	2.29	
	Total E	.61	2.30	2.49	2.38	3.51	3.63	3.61	2.843	1.99	2.08	2.88	3.06	3.02	2.46	2.64	
	Run	.61	2.38	2.50	2.43	3.50	3.62	3.60	2.88	2.05	2.14	2.87	3.06	3.01	2.56	2.71	
1964	Catch	-	2.24	2.35	2.26	3.30	3.25	3.29	2.43	1.96	2.10	2.81	2.87	2.83	2.27	2.36	
	Nak. E	-	2.05	1.93	2.00	3.18	3.20	3.18	2.18	1.75	1.94	2.86	2.97	2.89	1.97	2.06	
	Kvi. E	.80	2.12	2.25	2.14	3.22	3.51	3.30	1.86	1.80	1.98	2.89	3.10	2.92	1.93	1.89	
	Bran. E	.56	2.66	2.55	2.62	3.94	3.74	3.91	2.87	2.36	2.15	2.80	2.63	2.77	2.54	2.67	
	Total E	.78	2.11	2.04	2.10	3.42	3.30	3.38	2.08	1.79	1.98	2.84	2.89	2.85	2.02	2.05	
	Run	-	2.18	2.19	2.18	3.35	3.27	3.33	2.25	1.85	2.03	2.83	2.88	2.84	2.13	2.19	
1965	Catch	-	2.06	2.14	2.14	2.78	2.99	2.86	2.17	1.86	1.91	2.54	2.70	2.61	1.97	2.09	
	Nak. E	-	2.04	1.74	1.80	3.15	3.24	3.20	2.23	1.83	1.74	2.46	2.70	2.57	2.18	2.20	
	Kvi. E	-	2.49	2.14	2.14	3.52	3.57	3.52	2.15	1.77	1.81	2.81	2.87	2.81	1.81	1.96	
	Bran. E	.06	2.41	2.24	2.30	3.47	3.39	3.45	2.28	1.94	1.84	2.75	2.83	2.77	2.22	2.25	
	Total E	.60	2.30	2.13	2.13	3.39	3.26	3.35	2.16	1.82	1.81	2.61	2.71	2.65	1.82	1.97	
	Run	.60	2.14	2.14	2.14	2.98	3.07	3.02	2.16	1.85	1.84	2.57	2.70	2.62	1.87	2.02	
1966	Catch	-	2.41	2.33	2.34	3.42	3.42	3.42	3.15	2.03	2.15	2.86	2.87	2.87	2.74	2.89	
	Nak. E	.68	1.60	1.73	1.70	3.15	3.15	3.15	2.70	1.49	1.81	2.67	2.78	2.69	2.59	2.64	
	Kvi. E	.66	2.08	2.45	2.44	3.55	3.26	3.26	3.02	1.90	2.03	3.02	2.74	2.76	2.49	2.72	
	Bran. E	-	2.05	2.41	2.06	3.57	3.52	3.57	2.91	1.85	2.15	2.94	2.76	2.92	2.43	2.64	
	Total E	.67	1.88	2.31	2.26	3.28	3.25	3.25	2.95	1.84	2.01	2.78	2.75	2.75	2.51	2.70	
	Run	.67	2.05	2.32	2.29	3.35	3.33	3.33	3.04	1.91	2.07	2.82	2.82	2.82	2.64	2.80	

Table 1. Mean weights (kg) of sockeye salmon in the Naknek-Kvichak District catches and escapements (E) - cont'd.

Year		Males										Females										Both sexes						
		1.2		2.2		All .2		1.3		2.3		All .3		1.2		2.2		All .2		1.3		2.3		All .3		All	All .3	
		All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2	All .1	All .2					
1967	Catch	-	2.35	2.70	2.68	3.58	3.42	3.45	2.89	2.12	2.29	2.28	2.98	3.00	2.99	2.50	2.68											
	Nak. E	.70	1.69	2.15	1.99	3.24	3.32	3.30	2.63	1.69	2.05	1.95	2.76	2.83	2.81	2.50	2.56											
	Bran. E	.51	2.32	2.67	2.34	3.45	-	3.45	2.53	1.84	-	1.84	.00	-	3.00	2.31												
	Total E	.62	2.06	2.64	2.59	3.45	3.53	3.51	2.79	1.83	2.20	2.17	2.86	2.95	2.92	2.33	2.56											
	Run	.62	2.12	2.66	2.62	3.49	3.49	3.49	2.82	1.88	2.23	2.21	2.92	2.97	2.95	2.39	2.61											
1968	Catch	-	2.36	2.49	2.42	3.40	3.71	3.59	2.71	2.05	2.26	2.17	2.96	3.18	3.08	2.58	2.64											
	Nak. E	.74	1.99	2.32	2.19	3.39	3.68	3.55	2.48	1.88	2.09	2.03	2.87	3.03	2.95	2.43	2.46											
	Kvi. E	.82	2.21	2.52	2.28	2.92	3.66	3.52	2.26	1.83	2.11	1.89	2.84	3.07	3.05	2.07	2.17											
	Bran. E	.53	2.28	2.45	2.30	3.52	3.55	3.52	2.73	1.95	2.08	1.99	3.08	3.08	3.08	2.55	2.63											
	Total E	.79	2.18	2.42	2.26	3.36	3.66	3.53	2.34	1.84	2.10	1.92	2.93	3.06	3.01	2.19	2.27											
	Run	.79	2.21	2.44	2.29	3.37	3.68	3.55	2.43	1.87	2.15	1.97	2.94	3.10	3.04	2.29	2.36											
1969	Catch	-	2.46	2.54	2.48	3.30	3.47	3.39	2.57	2.17	2.35	2.23	3.00	2.96	2.98	2.32	2.44											
	Nak. E	.62	2.02	2.26	2.17	3.24	3.43	3.37	2.28	1.91	2.08	2.03	.87	2.97	2.94	2.23	2.25											
	Kvi. E	.75	2.41	2.56	2.44	3.52	3.83	3.68	2.29	2.04	2.15	2.06	2.86	2.61	2.78	2.08	2.19											
	Bran. E	.59	2.26	2.58	2.41	3.36	3.32	3.36	2.32	1.99	1.95	1.96	2.94	-	2.94	2.13	2.22											
	Total E	.73	2.39	2.47	2.41	3.41	3.59	3.52	2.29	2.03	2.12	2.05	2.87	2.87	2.87	2.11	2.20											
	Run	.73	2.41	2.49	2.43	3.36	3.56	3.47	2.37	2.07	2.20	2.11	2.92	2.93	2.92	2.18	2.27											
1970	Catch	-	2.27	2.33	2.32	2.55	3.35	2.86	2.34	1.99	2.09	2.09	2.44	2.67	2.54	2.13	2.24											
	Nak. E	.69	1.63	1.79	1.70	2.79	2.96	2.81	1.83	1.66	1.79	1.73	2.45	2.68	2.54	1.86	1.85											
	Kvi. E	.57	1.87	2.17	2.17	3.55	3.05	3.17	2.20	1.76	1.85	1.85	2.45	2.79	2.64	1.86	1.99											
	Bran. E	.50	1.96	2.52	1.97	3.36	3.32	3.36	2.05	1.71	1.91	1.73	2.71	2.87	2.73	1.93	1.98											
	Total E	.55	1.76	2.16	2.14	3.23	3.05	3.11	2.18	1.70	1.85	1.84	2.49	2.76	2.62	1.86	1.99											
	Run	.55	2.3	2.26	2.25	2.72	3.20	2.95	2.28	1.83	1.96	1.96	2.45	2.69	2.56	1.99	2.13											
1971	Catch	-	2.21	2.49	2.44	3.06	3.16	3.09	2.73	2.10	2.11	2.11	2.68	2.62	2.66	2.40	2.53											
	Nak. E	.73	1.79	2.00	1.86	3.31	3.21	3.30	2.93	1.91	1.97	1.93	2.82	2.79	2.82	2.67	2.77											
	Kvi. E	.71	2.34	2.59	2.57	3.44	3.30	3.36	2.82	2.23	2.18	2.19	3.06	2.86	2.95	2.39	2.56											
	Bran. E	.69	2.32	2.28	2.32	3.31	3.29	3.31	2.64	1.83	1.71	1.83	2.79	2.75	2.79	2.21	2.41											
	Total E	.71	2.14	2.56	2.48	3.35	3.28	3.33	2.84	2.01	2.17	2.15	2.89	2.84	2.87	2.46	2.61											
	Run	.71	2.18	2.52	2.46	3.17	3.21	3.18	2.77	2.06	2.14	2.13	2.74	2.69	2.73	2.42	2.56											

Table 1. Mean weights (kg) of sockeye salmon in the Naknek-Kvichak District catches and escapements (E) - cont'd.

Year		Males						Females						Both sexes			
		1.2		2.2		All		1.3		2.3		All					
		All	1.2	All	2.2	All	1.3	All	1.3	All	2.3	All	2.3		All		
1972	Catch	-	2.25	2.46	2.40	3.39	3.34	3.36	2.90	2.05	2.14	2.13	2.89	2.82	2.85	2.59	2.75
	Nak. E	-	1.80	2.17	2.05	3.16	3.20	3.18	2.68	1.77	2.07	1.99	2.64	2.75	2.74	2.51	2.59
	Kvi. E	-	2.37	2.68	2.61	3.50	3.48	3.48	2.91	1.98	2.26	2.26	2.94	2.95	2.95	2.52	2.75
	Bran. E	-	2.24	2.17	2.22	3.30	3.32	3.30	2.55	1.76	1.65	1.74	2.81	3.05	2.84	1.90	2.21
	Total E	-	2.20	2.55	2.44	3.32	3.37	3.34	2.81	1.89	2.19	2.10	2.75	2.84	2.82	2.45	2.64
	Run	-	2.22	2.52	2.43	3.35	3.36	3.35	2.84	1.91	2.17	2.11	2.82	2.83	2.83	2.51	2.69
1973	Catch	-	2.36	2.42	2.40	3.52	3.48	3.50	3.14	2.28	2.37	2.35	.02	2.97	2.98	2.82	2.97
	Nak. E	.61	2.10	2.21	2.16	3.52	3.55	3.54	3.17	1.93	2.03	1.99	3.00	3.08	3.05	2.89	3.01
	Kvi. E	.73	2.32	2.58	2.40	3.28	3.70	3.60	2.65	1.98	2.20	2.07	2.94	3.08	3.04	2.45	2.56
	Bran. E	.56	1.51	3.24	2.08	4.06	3.83	4.02	3.53	2.21	2.78	2.40	3.13	3.15	3.14	3.01	3.28
	Total E	.69	2.25	2.44	2.32	3.60	3.60	3.60	2.97	1.98	2.14	2.05	3.01	3.08	3.05	2.76	2.86
	Run	.69	2.26	2.44	2.34	3.58	3.57	3.57	3.01	2.01	2.20	2.11	3.01	3.05	3.04	2.77	2.88
1974	Catch	-	2.39	2.45	2.44	3.29	3.19	3.26	2.64	2.19	2.17	2.17	2.82	2.99	2.93	2.40	2.52
	Nak. E	.68	2.02	2.05	2.05	3.07	3.34	3.18	2.27	1.78	2.01	1.98	2.59	2.91	2.74	2.26	2.27
	Kvi. E	.59	2.35	2.47	2.47	3.18	3.32	3.22	2.51	2.00	2.03	2.03	2.69	2.61	2.67	2.08	2.37
	Bran. E	.52	2.17	2.41	2.31	3.28	4.72	3.34	2.53	1.86	2.08	1.96	2.66	No 2.3s	2.66	2.06	2.48
	Total E	.62	2.11	2.41	2.40	3.16	3.35	3.22	2.47	1.86	2.03	2.02	2.63	2.83	2.72	2.13	2.35
	Run	.62	2.14	2.42	2.40	3.18	3.32	3.22	2.48	1.91	2.04	2.03	2.66	2.88	2.76	2.16	2.37
1975	Catch	-	2.39	2.46	2.46	3.42	3.42	3.42	2.59	2.03	2.11	2.11	2.85	2.89	2.88	2.31	2.45
	Nak. E	.71	2.06	2.12	2.11	3.24	3.28	3.27	2.41	1.76	1.88	1.86	2.81	2.83	2.82	2.31	2.36
	Kvi. E	.76	2.43	2.10	2.10	2.52	3.07	3.05	2.13	1.80	1.91	1.91	2.25	2.63	2.62	1.93	2.04
	Bran. E	.48	2.49	1.88	2.44	3.37	3.51	3.41	3.13	1.83	2.03	1.89	3.03	2.87	2.99	2.63	2.92
	Total E	.73	2.25	2.10	2.10	3.24	3.17	3.18	2.17	1.78	1.91	1.91	2.83	2.76	2.77	1.99	2.08
	Run	.73	2.30	2.15	2.16	3.27	3.24	3.24	2.24	1.83	1.94	1.94	2.84	2.80	2.81	2.05	2.15
1976	Catch	-	2.59	2.64	2.63	3.40	3.38	3.39	2.84	2.23	2.30	2.30	2.95	2.98	2.98	2.62	2.75
	Nak. E	.80	2.29	2.15	2.17	3.45	3.24	3.40	2.45	1.88	2.08	2.05	2.81	2.91	2.85	2.32	2.38
	Kvi. E	.81	2.34	2.56	2.56	3.18	3.28	3.28	2.69	1.99	2.16	2.15	2.81	2.71	2.72	2.26	2.44
	Bran. E	-	2.89	2.70	2.84	3.91	No 2.3s	3.91	2.96	2.32	2.32	2.32	3.04	2.54	2.97	2.44	2.73
	Total E	.81	2.42	2.39	2.41	3.44	3.27	3.35	2.60	1.99	2.13	2.12	2.82	2.78	2.79	2.29	2.43
	Run	.81	2.50	2.51	2.52	3.42	3.34	3.37	2.72	2.04	2.18	2.17	2.88	2.89	2.89	2.40	2.56





Table 2. Weights ( $\text{kg} \times 10^6$ ) of sockeye salmon in the Naknek-Kvichak District catches and escapements by sex, 1957-83.

Year	Catch		Escapement		Total run
	Males	Females	Males	Females	
1957	6.84	5.94	5.35	4.38	22.51
58	1.20	1.39	1.39	1.13	5.11
59	2.35	1.92	4.33	3.90	12.50
60	13.25	6.97	16.26	13.87	50.35
61	12.38	10.56	5.49	5.00	33.43
62	3.13	2.68	4.66	4.00	14.47
63	1.35	1.36	1.88	2.35	6.94
65	25.48	14.58	23.45	26.11	89.62
66	6.11	9.48	6.28	7.14	29.01
67	3.15	3.12	5.86	4.82	16.95
68	1.57	1.63	4.65	3.92	11.77
69	5.63	5.59	11.81	10.15	33.18
70	22.09	17.81	12.90	16.57	69.37
71	6.14	8.66	3.92	5.23	23.95
72	1.65	1.37	2.49	1.84	7.35
73	.25	.25	.90	.87	2.27
74	.69	.65	9.60	4.26	15.20
75	3.96	3.49	17.42	14.33	39.20
76	4.46	2.62	3.82	4.33	15.23
77	2.86	3.18	2.98	3.30	12.32
78	7.51	5.71	6.54	5.09	24.85
79	20.99	19.78	14.60	14.94	70.31
80	18.62	17.02	30.19	25.73	91.56
81	17.11	13.34	5.24	4.63	40.32
82	7.54	6.94	3.58	3.22	21.28
83	26.27	25.31	4.40	5.42	61.40



Table 4. Means and standard deviations of the rates of exploitation on Kvichak sockeye salmon by cycle year.

	Escape (millions)	% age .3	$\mu$ (%)	Return (millions)	R/E	$\mu\%$ on returns		% age .3 in returns
						.2	.3	
Peak cycle	15.1	15.1	35	34.6	2.4	35	59	37
1956-75	5.5	1.4	15	12.4	1.1	14	11	14
S.D.								
Pre- peak	3.0	8.8	35	7.4	3.4	33	54	38
1955-74	3.5	6.7	26	10.2	2.6	19	28	21
S.D.								
Post- peak	3.0	43.1	54	4.9	1.9	47	51	48
1957-76	.8	22.5	12	3.0	1.8	11	15	11
S.D.								
Other years	1.5	29.0	30	1.8	2.4	32	44	38
1958-77	1.2	15.1	13	1.5	3.2	18	23	17
S.D.								

Table 5. Sex ratios (% females) in the Naknek-Kvichak catches and runs by Kvichak cycle years.

	Brood year	2-ocean		3-ocean		Total <sup>1</sup>		$\mu$ <sup>2</sup> (%)
		Catch	Run	Catch	Run	Catch	Run	
Peak	1960	31	43	76	72	36	45	37
	65	37	49	59	59	39	49	43
	70	46	53	64	60	47	53	55
	75	46	46	66	60	50	48	17
	80	<u>50</u>	<u>50</u>	<u>54</u>	<u>54</u>	<u>51</u>	<u>51</u>	<u>37</u>
	Means	42	48	64	61	45	49	38
Pre-peak	1959	45	49	60	57	48	50	31
	64	41	48	63	63	46	51	48
	69	52	51	56	54	52	52	33
	74	49	34	57	43	51	36	8
	79	<u>50</u>	<u>52</u>	<u>56</u>	<u>57</u>	<u>51</u>	<u>53</u>	<u>56</u>
	Means	47	47	58	55	50	48	35
Post-peak	1957	43	49	51	50	49	50	56
	61	37	44	55	54	49	50	66
	66	56	58	66	62	64	61	52
	71	58	59	65	64	62	61	63
	76	32	45	52	56	39	49	43
	81	<u>48</u>	<u>49</u>	<u>46</u>	<u>47</u>	<u>47</u>	<u>48</u>	<u>75</u>
Means	46	51	56	56	52	53	59	
Other years	1958	54	53	59	57	57	55	52
	62	47	49	53	51	49	50	40
	63	42	49	62	59	52	53	40
	67	53	51	56	51	54	51	36
	68	44	46	66	61	52	50	25
	72	42	47	53	51	48	47	40
	73	46	44	56	57	53	52	22
	77	51	52	59	57	56	54	45
	78	42	45	55	54	46	47	50
	82	42	48	53	52	51	51	67
	83	<u>54</u>	<u>55</u>	<u>48</u>	<u>49</u>	<u>53</u>	<u>54</u>	<u>83</u>
Means	43	49	56	50	52	51	45	

<sup>1</sup>Excluding jacks.<sup>2</sup>Rate of exploitation, excluding jacks.

Table 6. Sex ratios (% females) in the Kvichak and Naknek escapements by Kvichak cycle years.

	Brood year	2-ocean		3-ocean		Total <sup>1</sup>	
		Kvichak	Naknek	Kvichak	Naknek	Kvichak	Naknek
Peak	1960	49	39	29	65	48	53
	65	57	43	43	64	57	52
	70	61	51	41	60	61	52
	75	47	44	45	64	47	51
	80	<u>50</u>	<u>46</u>	<u>43</u>	<u>61</u>	<u>50</u>	<u>53</u>
	Means	53	45	40	63	53	52
	Pre-peak	1959	59	50	51	53	53
64		47	59	64	59	48	59
69		50	54	47	56	50	55
74		32	42	28	58	32	47
79		<u>53</u>	<u>38</u>	<u>47</u>	<u>95</u>	<u>57</u>	<u>58</u>
Means		48	49	47	64	48	54
Post-peak	1957	56	52	46	53	49	53
	61	52	39	49	57	51	56
	66	63	32	55	62	58	56
	71	63	56	56	64	61	62
	76	58	50	59	63	58	54
	81	<u>54</u>	<u>46</u>	<u>46</u>	<u>50</u>	<u>53</u>	<u>49</u>
	Means	58	46	52	58	55	55
Other years	1958	58	42	51	61	54	50
	62	52	47	44	60	49	53
	63	52	50	42	62	48	55
	67	51	46	36	59	49	54
	68	49	40	62	56	50	46
	72	39	43	42	58	40	52
	73	42	47	50	60	44	58
	77	56	43	55	53	56	49
	78	48	39	52	52	49	46
	82	61	38	43	52	56	50
	83	<u>63</u>	<u>38</u>	<u>51</u>	<u>52</u>	<u>63</u>	<u>43</u>
Means	52	43	48	57	51	51	

<sup>1</sup>Excluding jacks.

Table 7. Escapements (millions) by ocean age for the Kvichak and Naknek systems by Kvichak cycle year.

	Brood year	2-ocean		3-ocean	
		Kvichak	Naknek	Kvichak	Naknek
Peak	1960	14.59	.39	.03	.44
	65	24.18	.42	.14	.30
	70	13.53	.46	.27	.11
	75	12.66	1.24	.46	.76
	80	21.46	1.44	.96	1.19
Pre- peak	1959	.61	2.00	.04	.23
	64	.77	1.14	.05	.20
	69	7.69	1.01	.26	.28
	74	4.01	.85	.38	.37
	79	10.06	.60	.88	.31
Post- peak	1957	.97	.04	1.87	.59
	61	2.37	.02	1.34	.33
	66	1.22	.20	2.55	.81
	71	1.71	.17	.68	.76
	76	1.59	.94	.37	.38
81	1.44	.52	.31	1.27	
Other years	1958	.23	.14	.29	.12
	62	1.75	.34	.83	.36
	63	.20	.50	.14	.40
	67	2.77	.31	.43	.44
	68	2.13	.65	.31	.35
	72	.58	.22	.32	.37
	73	.14	.07	.08	.29
	77	1.15	.46	.18	.62
	78	3.38	.38	.46	.43
	82	.74	.14	.32	.99
83	3.33	.57	.18	.29	

Table 8. Spring temperature indices (x minus the mean over years divided by the standard deviation).

Year	x1 Air temp.	x2 Ice out	x3 Water temp.	x4 River temp.	x5 River temp.	Average
1952	-1.4	- .7	- .5	- .5	- .8	- .8
53	.9	.6	.3	.2	.5	.5
54	.1	.7	.2	.1	.3	.3
55	-1.9	-1.1	- .7	- .7	-1.0	- .9
56	- .8	- .1	- .4	-1.4	- .6	- .7
57	1.3	.5	.5	1.0	.8	.8
58	.8	1.7	- .1	1.0	.8	.8
59	.2	.6	.5	1.1	.8	- .1
60	- .6	- .2	- .1	.6	- .1	- .1
61	.4	.4	.1	.6	.2	.3
62	.2	0	.7	- .6	- .3	0
63	- .4	- .1	- .1	.3	- .4	- .1
64	-1.2	-1.7	-1.1	-1.7	-1.0	-1.3
65	- .8	- .5	- .9	-1.6	-1.2	-1.0
66	-1.6	- .6	- .2	- .8	- .1	- .7
67	.9	.5	.7	.5	.7	.7
68	.2	.1	1.1	.2	.9	.5
69	.6	- .1	- .4	- .2	- .7	- .2
70	.2	1.1	.7	1.7	.9	.9
71	-1.6	-1.8	-1.2	-1.8	- .7	-1.4
72	-1.6	- .8	-1.2	-1.1	- .9	-1.1
73	.4	- .1	- .9	.1	- .2	- .1
74	1.0	1.2	1.0	.7	3.7	1.3
75	-1.3	- .8	-1.2	-1.0	-1.1	-1.1
76	- .7	-1.1	- .3	-1.0	- .6	- .7
77	- .4	0	- .4	.5	- .5	- .2
78	1.1	1.2	1.4	1.2	.6	1.1
79	1.6	1.9	1.1	1.0	.3	1.2
80	.7	1.8	.3	.2	.1	.6
81	1.6	1.1	1.7	1.2	1.4	1.4
82	-1.3	- .6	- .7	0	- .6	- .6
83	1.4	1.7	.4			

x1 Mean Bristol Bay air temp. deviation for Apr-May.

x2 Date of ice breakup in L. Aleknagik (minus = late, plus = early).

x3 Average water temp. 0-20 m in L. Aleknagik, June 20-24.

x4 Kvichak River water temp. during 6/1-15.

x5 Wood River water temp. during 6/1-15.

All temperatures in °C.

Table 9. Summer temperature indices (x minus the mean over years divided by the standard deviation).

Year	x1 Water temp.	x2 Solar radiation	x3 Heat Budget	x4 Air temp.	Average
1953	1.6	1.5	1.4	.5	1.3
54	.2	.1	.1	0	.1
55	-.7	-.6	-.7	-.4	-.6
56	-1.0	-.9	-1.0	-1.0	-1.0
57	1.7	1.6	1.5	1.4	1.6
58	.5	.4	.3	.9	.5
59	-.4	-.4	-.5	-.7	-.5
60	.2	.1	.1	-.4	0
61	-.4	-.4	-.5	-.5	-.5
62	1.2	.7	.4	.1	.6
63	.2	.4	-.3	-.1	.1
64	-.7	-.6	-.2	.1	-.4
65	-.2	-.4	-1.2	.1	-.4
66	-.7	-.1	-.5	-1.3	-.7
67	.8	1.3	.2	.9	.8
68	1.5	.8	.5	.6	.9
69	-.4	-1.0	-.7	.8	-.3
70	-.1	.7	.3	.8	.4
71	-2.0	-2.0	-2.6	-1.9	-2.1
72	-1.5	-1.2	-.9	-2.3	-1.5
73	-.9	-.2	-.4	0	-.4
74	1.3	2.1	1.8	.7	1.5
75	-.5	-.9	-.6	-1.2	-.8
76	-.7	-.7	.2	-1.0	-.6
77	.2	.1	.2	-.5	0
78	1.1	.3	1.7	1.7	1.0
79	1.6	1.6	1.5	1.3	1.5
80	0	.6	-.1	.6	.3
81	1.6	.8	1.1	1.8	1.3
82	-1.2	-1.4	-1.1	-.6	-1.1
83	-.1	1.4	1.4	1.5	1.1

x1 Average water temperature (0-20 m) in L. Aleknagik during 6/15-8/31.

x2 Accumulative solar radiation from L. Aleknagik ice breakup to 8/31.

x3 August heat budget in L. Iliamna.

x4 Mean of air temperature deviation for Bristol Bay, Mar-Jun.

All temperatures in °C.

Table 10. Mean townet catches and mean lengths of sockeye salmon fry in Lake Iliamna and Lake Clark by Kvichak cycle year.

	Brood year	Escapement (millions)	L. Iliamna		L. Clark	
			$\bar{C}$	$\bar{L}$	$\bar{C}$	$\bar{L}$
Peak	1965	24.3	154.6	53.2	2.1	52.5
	70	13.9	115.3	44.4	1.9	38.0
	75	13.1	228.7	49.1	9.7	48.7
	80	<u>17.5</u>	<u>121.5</u>	<u>61.0</u>	<u>2.4</u>	<u>59.3</u>
	Mean	17.2	155.0	51.9	4.0	49.6
Pre-peak	1964	1.0	5.9	61.5	.2	50.2
	69	8.4	350.4	60.6	.2	50.2
	74	4.4	445.5	53.6	7.4	54.8
	79	<u>11.2</u>	<u>256.4</u>	<u>52.6</u>	<u>5.5</u>	<u>47.5</u>
	Mean	6.2	246.6	57.1	3.5	52.0
Post-peak	1961	3.7	81.9	52.7	1.2	50.3
	66	3.8	61.1	57.3	1.4	44.7
	71	2.4	3.6	49.9	1.4	40.6
	76	2.0	14.1	52.7	-	-
	81	<u>1.8</u>	<u>33.4</u>	<u>52.3</u>	<u>5.3</u>	<u>46.2</u>
Mean	2.7	38.8	53.0	2.3	45.4	
Other years	1962	2.6	11.3	45.0	6.7	49.9
	63	.3	4.4	54.1	.3	50.4
	67	3.2	71.1	61.6	4.4	59.3
	68	2.6	38.9	61.6	.8	50.4
	72	1.0	2.5	57.5	1.6	47.9
	73	.2	1.5	71.3	1.1	57.3
	77	1.3	9.8	61.3	-	-
	78	<u>4.2</u>	<u>307.8</u>	<u>62.5</u>	<u>6.0</u>	<u>56.3</u>
Mean	1.9	55.9	59.4	3.0	53.1	

$\bar{C}$  = mean townet catch x .9075 for Iliamna and x.0925 for Clark.

$\bar{L}$  = mean length of fry on Sept. 1 (mm).

Table 11. Differences between the actual runs and the forecasted runs  
(by age) for Kvichak sockeye salmon.

Year	Total <sup>1</sup> run (millions)	Absolute difference (millions) <sup>2</sup>				Relative difference (%) <sup>3</sup>			
		4 <sub>2</sub>	5 <sub>3</sub>	5 <sub>2</sub>	6 <sub>3</sub>	4 <sub>2</sub>	5 <sub>3</sub>	5 <sub>2</sub>	6 <sub>3</sub>
1970	30.5	- .4	-10.8	-2.2	.1	-48	-27	-85	-28
71	6.1	-1.4	2.7	.7	-2.2	-82	231	439	-69
72	1.4	- .7	- 1.6	- .1	- .2	-74	-70	-33	-46
73	.3	-5.8	- 1.0	- .2	- .4	-98	-94	-90	-84
74	4.5	- .1	1.4	.1	0	-74	53	95	83
75	15.9	.3	8.2	- .1	0	3300	132	-87	0
76	2.7	- .2	- .6	- .1	-1.4	-45	-24	-62	-71
77	1.8	.1	- .4	0	- .3	45	-25	-21	-64
78	7.3	1.2	.1	.8	.2	27	44	278	116
79	24.6	1.3	10.0	.6	.4	31	151	48	245
80	35.1	3.2	- 6.1	-1.0	-1.1	179	-18	-45	-61
81	7.0	.4	- 1.2	- .7	-2.0	27	-24	-48	-78
82	2.9	-8.1	- 1.9	.3	- .4	-83	-91	43	-60
83	19.9	11.0	- .6	.1	- .3	166	-33	8	-78

<sup>1</sup>Excluding minor age groups that are not forecasted.

<sup>2</sup>Run-Forecast.

<sup>3</sup>Run-Forecast/Forecast x 100.

Table 12. Kvichak smolt-adult returns by size of parent escapement (numbers in millions).

Escapement	Brood year	Age I		s %	Kvichak temp.	Age II		s %	Kvichak temp.
		Smolts	Adults			Smolts	Adults		
.2	1973	10	1.5	15.3	-1.7	3	.7	25.8	.3
1.0	72	4	.3	7.5	1.5	6	.4	24.1	-1.7
1.1	82	--	--	--	--	--	--	--	--
1.3	77	27	2.7	10.2	1.5	10	.3	2.7	.0
1.8	81	6	--	--	--	--	--	--	--
2.0	76	31	5.8	18.5	1.3	26	4.1	15.8	1.5
2.4	71	5	.3	6.0	-1.3	34	2.0	5.9	1.5
3.6	83	--	--	--	--	--	--	--	--
4.1	78	163	2.6	1.6	0	21	1.2+	6+	2.8
4.4	74	100	7.6	7.6	.3	132	17.3	13.2	.8
8.4	69	86	.4	.5	-2.4	67	4.7	7.0	-1.1
11.2	79	163	17.7+	11+	2.8	81	--	--	-.7
13.1	75	82	6.8	8.3	1.3	238	29.0	12.2	1.3
13.9	70	1	.1	9.3	-1.1	195	14.6	7.7	-1.3
17.5	80	123	--	--	-.7	76	--	--	--

Kvichak temperature = deviation from mean water temperature in the Kvichak River during the week of peak migration ( $^{\circ}\text{C}$ ).

1. For age 1 smolt migrations greater than 10 million, survival was correlated with temperature ( $r = .77$ ).  $\hat{s} = 6.7 + 2.98(\tau)$  and  $\hat{s} (79) = 15\%$  for a return of 24.5 million. Since 17.7 million have returned, the expected return of 1.3 in 1984 is 6.8 million. The predicted survival for the 1980 brood is 4.6% for a return of only 5.7 million (1.2 in 1984 and 1.3 in 1985).
2. For age 2 smolt migrations, the adult returns were correlated with the number of smolts ( $r = .96$ ) and temperature had a minor effect on survival. Adults =  $-.4 + 1.08$  (smolts). The predicted returns for both the 1979 and 1980 broods are about 8 million each (returns in 1984 and 1985).

Table 13. Aerial survey estimates and the annual escapements of sockeye salmon to the Kvichak Lake system.

Year	Number of areas surveyed	Aerial estimates of spawners (1,000s)			Total escapement	Percent of total escapement	
		Streams & ponds	Mainland beaches	Island beaches			
1955	35	29	4	-	33	251	13
56	36	1,023	265	43	1,331	9,443	14
57	52	269	80	5	354	2,843	12
58	43	68	27	4	99	535	19
59	47	100	11	18	128	680	19
60	45	1,362	489	1,000	2,851	14,630	19
61	44	395	152	107	654	3,706	18
62	64	230	46	10	286	2,581	11
63	64	39	8	5	52	339	15
64	72	73	7	15	95	957	10
65	78	1,333	387	1,958	3,678	24,326	15
66	75	436	134	49	619	3,776	16
67	73	366	150	19	535	3,216	17
68	89	224	36	77	337	2,557	13
69	96	434	114	132	680	8,394	8
70	86	1,441	546	643	2,630	13,936	19
71	65	324	51	61	436	2,387	18
72	83	149	27	10	186	1,010	18
73	93	58	10	7	75	227	33
74	96	635	121	140	896	4,433	20
75	113	1,671	423	557	2,651	13,140	20
76	not analyzed						
77	"						
78	80	696	176	6	878	4,149	21
79	86	2,072	681	101	2,854	11,218	25
80	56	1,631	135	205	1,971	22,505*	9
81	75	285	28	23	336	1,754	19
82	83	368	40	11	419	1,135	37
83	100	991	139	9	1,139	3,570	32

\* An estimated 5 million fish died at a river blockage before reaching spawning grounds, thus actual escapement to spawning areas was 17,505.

Table 14. Accumulative escapements at Igiugig and index escapements at Newhalen (RM 1) in thousands.  
Final escapement to Newhalen River-Lake Clark in parenthesis.<sup>1/</sup>

	1979				1980				New/ Igiug.	
	Igiugig Date	Esc.	Newhalen Date	Esc.	Igiugig Date	Esc.	Newhalen Date	Esc.		
Day 0	6/24	2	6/26	23	Day 0	6/26	8	6/28	5	-
1	25	359	27	76	1	27	156	29	88	.56
2	26	1,046	28	169	2	28	981	30	136	.14
3	27	1,896	29	245	3	29	2,072	7/1	201	.10
4	28	2,783	30	376	4	30	3,078	2	258	.08
5	29	2,798	7/1	507	5	7/1	4,433	3	337	.08
6	30	4,774	2	660	6	2	5,954	4	417	.07
7	7/1	5,331	3	762	7	3	7,315	5	518	.07
Final		11,218		3,385 (9,000)	Final		22,505		2,523 (7,500)	.11 .11

	1982				1983				New/ Igiug.	
	Igiugig Date	Esc.	Newhalen Date	Esc.	Igiugig Date	Esc.	Newhalen Date	Esc.		
Day 0	7/6	46	7/8	1	Day 0	6/27	3	6/29	+	
1	7	138	9	4	1	28	142	30	29	.20
2	8	421	10	9	2	29	521	7/1	46	.09
3	9	551	11	11	3	30	943	2	58	.06
4	10	598	12	13	4	7/1	1,366	3	74	.05
5	11	631	13	15	5	2	1,683	4	95	.06
6	12	680	14	22	6	3	1,779	5	109	.06
7	13	697	15	30	7	4	1,865	6	120	.06
Final		1,135		86 (276)	Final		3,570		328 (1,109)	.09

Day 1	New.-L. Clark escapement <sup>2/</sup>	-.11	+ .097	(Accum. Newhalen Index)	r =	.975
2	"	-.78	+ .058	"	"	.991
3	"	-.58	+ .039	"	"	.995
4	"	-.23	+ .026	"	"	.985
5	"	-.12	+ .019	"	"	.982

<sup>1/</sup>No Newhalen RM 1 index program in 1981. Final escapement estimate (in thousands) to Newhalen River-Lake Clark system in 1981 = 264.

<sup>2/</sup>Escapement in millions; Newhalen index in 1000's.

Table 15. Deviation (%) of Nondalton Fishery from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	*	*	*	*	*	*
63	-26.51	19.54	6.66	.30	53.01	106
64	-27.33	20.98	2.26	4.08	54.65	208
65	*	*	*	*	*	*
1966	-1.62	.06	-1.36	2.82	5.86	218
67	-.96	5.58	-2.00	-2.61	11.15	618
68	-49.26	2.25	-1.44	48.43	101.38	419
69	16.70	-14.08	-1.70	-.92	33.40	404
70	-1.04	1.88	-.61	-.24	3.77	175
1971	-3.03	-10.54	15.59	-2.02	31.18	50
72	-17.00	-9.31	5.64	20.68	52.63	152
73	-17.38	-11.95	10.57	18.77	58.67	109
74	6.37	-2.63	-4.93	1.19	15.12	82
75	-1.62	-.15	-.08	1.84	3.69	133
1976	-4.10	-2.78	-1.35	8.22	16.45	100
77	-28.47	28.14	-5.68	6.02	68.31	80
78	11.24	-.43	-8.19	-2.62	22.48	158
79	3.80	-6.15	3.09	-.73	13.77	202
80	-10.50	1.04	11.23	-1.77	24.54	124
1981	-19.49	2.41	10.71	6.37	38.98	276
82	5.60	.27	-10.63	4.77	21.27	815
83	1.12	2.17	-3.01	-.29	6.59	604
Mean deviation (%) from Igiugig age composition	-8.17	1.32	1.24	5.62	31.85	

\*No age sampling.

Table 16. Deviation (%) of Newhalen River from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	-2.21	9.52	-6.05	1.27	19.05	93
63	*	*	*	*	*	*
64	*	*	*	*	*	*
65	-0.41	-0.11	0.58	1.09	2.19	87
1966	-1.12	-5.64	-2.26	9.02	18.04	200
67	-1.12	7.64	-2.15	-4.36	15.27	200
68	-33.31	7.97	-0.95	26.28	68.51	204
69	12.01	-10.09	-1.20	-0.72	24.02	286
70	-1.64	2.58	0.39	-1.34	5.95	100
1971	3.47	-1.84	-3.91	2.28	11.50	82
72	-19.60	13.69	-1.56	7.48	42.33	40
73	*	*	*	*	*	*
74	-0.91	5.87	-2.43	-2.51	11.72	54
75	-1.62	5.15	-0.08	-3.46	10.31	49
1976	-9.10	-4.66	-0.02	13.78	27.56	43
77	-26.30	23.83	-4.13	6.60	60.86	107
78	14.12	-2.56	-8.94	-2.62	28.24	194
79	*	*	*	*	*	*
80	*	*	*	*	*	*
1981	-19.99	15.71	0.31	3.97	39.98	141
82	33.28	-6.95	-19.94	-6.38	66.55	196
83	27.30	3.7	-2.62	-0.49	34.11	212
Mean deviation (%) from Igiugig age composition	-1.60	3.75	-3.30	2.79	28.60	

\*No age sampling.

Table 17. Deviation (%) of Copper River from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	.39	-28.98	-4.75	33.33	67.45	76
63	-26.71	-12.26	-3.44	42.40	84.81	185
64	-17.24	8.48	3.54	5.20	34.46	156
65	-.41	-.11	-.58	1.09	2.19	88
1966	-1.12	-21.14	-2.26	24.52	49.04	199
67	-1.12	6.52	-.11	-5.28	13.03	197
68	-45.03	9.22	-1.01	36.82	92.08	234
69	-53.07	24.25	12.39	16.44	106.15	196
70	5.08	-3.14	-.61	-1.34	10.17	119
1971	*	*	*	*	*	*
72	-19.60	-21.01	-7.16	47.78	95.55	144
73	-38.38	-12.45	1.77	49.07	101.67	70
74	-.93	-11.53	-2.33	14.79	29.58	52
75	-.82	-13.85	-.08	14.74	29.49	121
1976	20.80	-2.58	-.85	-17.28	41.51	67
77	-10.07	-6.31	2.07	14.42	32.87	67
78	-10.35	4.54	6.80	-.99	22.68	123
79	-13.40	9.73	4.13	-.45	27.71	128
80	-10.42	5.57	.84	4.02	20.85	121
1981	-15.39	22.25	-7.99	1.12	46.75	129
82	-11.01	12.27	-1.54	.28	25.10	223
83	-2.80	-.62	3.90	-.49	7.81	214
Mean deviation (%) from Igiugig age composition	-11.98	-1.48	.13	13.34	44.81	

\*No age sampling.

Table 18. Deviation (%) of Gibraltar Creek from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	-2.21	6.13	-2.68	-1.25	12.27	89
63	-29.71	-10.66	-2.54	42.90	85.81	97
64	15.28	-12.67	-2.56	-.06	30.57	174
65	-.41	.99	-.58	-.01	1.99	37
1966	-1.57	-24.14	-2.26	27.52	55.49	200
67	-.62	-12.86	2.85	10.64	26.97	200
68	-15.73	.49	.29	14.94	31.45	231
69	-16.91	11.94	2.76	2.21	33.82	193
70	.36	-.92	.89	-.34	2.51	200
1971	*	*	*	*	*	*
72	-16.30	-41.21	-7.56	65.08	130.15	92
73	-26.28	13.65	12.87	-.23	53.03	40
74	.87	-16.33	1.27	14.19	32.66	108
75	-1.62	-4.35	-.08	6.04	12.09	95
1976	1.64	10.39	-2.35	-9.69	24.07	121
77	-15.87	11.79	-2.23	6.32	36.21	86
78	-51.00	12.65	36.69	1.65	101.99	117
79	-13.69	9.52	3.88	.30	27.39	131
80	*	*	*	*	*	*
1981	4.81	-15.89	10.11	.97	31.78	184
82	-17.23	-1.06	20.49	-2.19	40.97	234
83	-30.08	-.83	29.69	1.21	61.81	240
Mean deviation (%) from Igiugig age composition	-10.81	-3.17	4.95	8.7	41.65	

\*No age sampling.

Table 19. Deviation (%) of Iliamna River from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	-2.21	27.52	-6.05	-19.27	55.05	89
63	4.52	-4.94	-1.38	1.80	12.64	94
64	-47.14	38.86	8.81	-.53	95.34	295
65	-.41	.99	-.58	-.01	1.99	160
1966	3.94	-2.47	-2.16	.70	9.27	1026
67	1.88	10.14	-2.65	-9.36	24.03	200
68	-54.66	26.70	-.68	28.63	110.67	394
69	-12.82	14.15	-1.24	-.09	28.30	301
70	-1.64	3.58	-.61	-1.34	7.17	100
1971	8.66	-7.02	-10.62	8.98	35.28	168
72	-15.90	45.39	-14.06	-15.42	90.77	191
73	* *	* *	* *	* *	* *	* *
74	*	*	*	*	*	*
75	-1.62	.04	-.08	1.65	3.39	137
1976	-9.10	-8.67	-2.35	20.11	40.23	54
77	-10.27	19.99	-6.93	-2.78	39.97	82
78	-2.20	6.55	-3.18	-1.17	13.10	207
79	-23.50	29.95	-6.01	-.43	59.89	125
80	*	*	*	*	*	*
1981	-15.99	30.01	-11.09	-2.93	60.02	161
82	* *	* *	* *	* *	* *	* *
83	4.97	7.10	-2.13	-.01	14.21	210
Mean deviation (%) from Igiugig age composition	-10.19	13.22	-3.50	.47	38.96	

\*No age sampling (flood 1980).

\*\*Sample size too small for comparative purposes.

Table 20. Deviation (%) of Woody Island from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	.04	-35.38	-3.55	38.63	77.59	79
63	34.69	-1.36	-2.34	-30.90	69.29	180
64	7.92	-9.08	2.35	-1.21	20.56	167
65	-.41	.99	-.58	-.01	1.99	84
1966	-.76	4.19	-2.05	-1.39	8.39	933
67	-1.12	-31.36	0.35	32.24	65.07	202
68	28.72	-16.34	-1.44	-10.94	57.44	189
69	3.81	-.49	-1.90	-1.42	7.62	205
70	-.64	.58	1.39	-1.34	3.95	100
1971	-2.03	-7.64	-1.71	11.38	22.76	168
72	54.60	-43.81	-4.06	-6.72	109.19	120
73	-14.38	38.15	-.23	-23.53	76.29	171
74	-.93	4.37	-2.43	-1.01	8.74	135
75	-1.62	3.25	-.08	-1.56	6.51	104
1976	3.77	-17.30	-2.35	15.87	39.29	101
77	30.13	-19.41	-6.23	-4.48	60.25	149
78	.78	1.37	-.59	-1.56	4.30	282
79	1.93	-1.70	1.02	-1.23	5.88	115
80	-12.90	16.34	-1.67	-1.77	32.68	126
1981	58.21	-47.19	-11.09	.07	116.56	179
82	-17.02	5.73	16.49	-5.19	44.43	235
83	8.76	-4.83	-3.46	-.49	17.54	285
Mean deviation (%) from Igiugig age composition	8.25	-7.31	-1.10	.16	38.92	

Table 21. Deviation (%) of Knutson Bay from Kvichak escapement (Igiugig sampling) age composition, sexes combined, 4 major age groups, 1962-1983.

Year	Age class				Absolute value difference [1]+[2]+[3]+[4]	Otolith sample size
	4 <sub>2</sub> (1.2) [1]	5 <sub>3</sub> (2.2) [2]	5 <sub>2</sub> (1.3) [3]	6 <sub>3</sub> (2.3) [4]		
1962	-1.11	-30.18	-6.05	37.23	74.57	87
63	13.58	1.27	3.45	-18.32	36.62	99
64	-37.68	34.26	3.51	-.09	75.54	179
65	-.41	-.31	-.58	1.29	2.59	75
1966	1.38	-7.94	-1.46	8.02	18.80	396
67	-1.12	-15.86	1.85	15.14	33.97	200
68	11.79	-3.41	-1.44	-6.95	23.59	199
69	14.82	-12.00	-1.39	-1.42	29.63	197
70	*	*	*	*	*	*
1971	1.87	8.16	2.49	-12.62	25.14	87
72	*	*	*	*	*	*
73	**	**	**	**	**	**
74	-.93	6.71	-4.23	-1.56	13.43	105
75	-1.62	-1.45	-.08	3.14	6.29	76
1976	-9.10	7.36	-2.35	4.08	22.89	35
77	2.33	8.29	-6.93	-3.78	21.33	147
78	8.42	.76	-7.29	-1.90	18.37	138
79	-17.93	15.83	2.61	-.51	36.88	138
80	-12.90	9.51	3.46	-.08	25.95	118
1981	27.11	-19.29	-8.99	1.17	56.56	142
82	*	*	*	*	*	*
83	5.92	-2.73	-3.31	.11	12.07	171
Mean deviation (%) from Igiugig age composition	.24	-.06	-1.49	1.28	29.68	

\*No age sampling.

\*\*Sample size too small for comparative purposes.