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ALASKA SALMON RESEARCH

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GRADUATE STUDENTS

ANNUAL REPORT - 1990

to

PACIFIC SEAFOOD PROCESSORS ASSOCIATION

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Director

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ALASKA SALMON RESEARCH

INTRODUCTION

The Fisheries Research Institute was established in 1946 with the financial support of the major Alaskan salmon processors to (1) investigate the causes of the declines in production that had occurred in most stocks since the 1930s, (2) work with the government management agency to increase our knowledge of the biology of salmon and the effects of the fisheries on the stocks, and (3) assist salmon processors by providing a second opinion on matters of salmon fisheries management. These objectives are still valid today, but with the high levels of production since the 1980s, our primary objectives now are to determine how to maintain the high production (what has caused year-to-year variation) and how to harvest/process salmon most efficiently, e.g., accurate forecasts and fishing evenly distributed throughout the run.

We presently have salmon research projects in Bristol Bay, Southeast Alaska and Chignik that are funded in part or entirely by the industry. In addition, we have a federally funded high seas salmon project that is concerned with the oceanic distribution of salmon and the vulnerability of North American stocks to foreign fisheries. Also, a project is beginning, in conjunction with the School of Oceanography and School of Marine Affairs, to investigate how changes in the dynamics of large-scale North Pacific atmospheric and physical oceanographic features relate to time and space dynamics of the biological production of salmon. In recent years we have also worked at Kodiak, the Alaska Peninsula and on the Yukon stocks. All of these projects have been carried out in cooperation with the Alaska Department of Fish and Game (ADF&G) or the National Marine Fisheries Service (high seas), and we have also had cooperative research projects with salmon biologists from Japan and the U.S.S.R.

This report will focus on our 1990 Bristol Bay research with emphasis on salmon forecasting and research relevant to escapement policies to maximize production. The Southeast pink salmon research will be reported in a separate report from the University of Alaska and our Chignik salmon research is reported to the National Marine Fisheries Service.

FORECASTING

Pre-season Forecasts

Forecasts of the 1990 Bristol Bay sockeye runs and catches were provided to participating processors at our October 1990 meeting. They are presented in Table 1 with the ADF&G forecasts and the past forecasts and runs beginning in 1985. The two river system forecasts (by FRI and ADF&G) are based on the same data sources but different analytical methods have often been used. Both 1990 forecasts were for an average to below average run and catch, whereas the actual run was well above average and the catch was the second largest on record! Since 1985, the actual catch has been between the two forecasted catches only once. In the other five years the catch was either higher (4) or lower (1) than both forecasts.

Prior to the 1990 run, the FRI forecasted catches had been within 13 to 33% (average = 25%) of the actual catches; however, the forecasted catch for 1990 was off by 74% (ADF&G by 125%). This is an unacceptable accuracy for processor planning and would have been disastrous for the 1990 plant operations had it not been for the in-season Port Moller program.

PORT MOLLER FORECAST

The Port Moller in-season test fishery was conducted by ADF&G from 1968 through 1985 with a change in gear in 1985.. There was no test fishery in 1986 and, beginning in 1987, we have conducted the test fishery each year. The accuracy of the forecasts during 1987-1989 was outstanding, within 4% of the actual runs. We were not so close in 1990 (24%); however, the 1990 forecast was probably more valuable to the industry because it was for a large run and catch when a small to average run was expected.

The test fishery at Port Moller employs a 200-fathom gill net that is 60 meshes deep and has 5-inch stretched mesh. The web is multistrand monofilament (center core). We have used a 70-ft vessel (Nettie H) and fished each day from June 11 through about July 5 (weather permitting). Four stations are fished (Fig. 1) and one station is usually repeated each day for a total of five drifts. Catches, mean lengths and water temperatures are sent daily by radio to Port Moller and then faxed into Bristol Bay. The vessel comes into port every other day to deliver fish and salmon scales collected by the two biologists on board. In 1990, we had a third biologist stationed at Port Moller to age the sockeye salmon scales and report the age composition of the catches every other day.

The statistics from Port Moller in 1990 were a real challenge to interpret. The early catches and age compositions (June 11-20) indicated a run very similar to the pre-season forecasts; however, over the next 10 days, catches increased significantly and yet there was a higher percentage of 3-ocean sockeye which is usually associated with small runs (Table 2). Nevertheless, by June 25 the test fishery was projecting a run of 42 million and processors were warned to prepare for a larger catch than previously planned for.

ADF&G provided preliminary daily catches and escapements for 1990 and from these data as well as published statistics (e.g., Stratten 1990), we reconstructed the run timing in the Bristol Bay fishing districts to compare with past years and with the Port Moller index catches (Figs. 2 and 3). The timing of the 1990 run was unusual because it was somewhat late in starting but about average at the mid point. Timing of the escapements to Naknek and Ugashik were average, whereas the timing of the other escapements was 1-2 days later than average (1981-89). The timing of the mid point of the runs (50%) ranged from one day late (Nushagak and Ugashik) to three days late (Egegik) in 1990.

The timing and magnitude of the 1990 run was fairly well predicted by the Port Moller catches except that in the last week of fishing at Port Moller, the catch rate (catch per number of sockeye in the run) was unusually high. The change in catch rate may have been caused by the change in age composition during the run and the small size of the sockeye for a given age and sex in 1990. ADF&G provided preliminary length and weight statistics for 1990 and statistics from prior years were available (e.g., Yuen et al. 1981 and Stratten 1990) so we could calculate mean lengths in the runs and mean weights in the catches (Tables 3 and 4). Sockeye in the 1990 run were among the smallest recorded and smaller than the fish in the 1985-1989 runs for which we have comparative Port Moller index catches.

We are presently unable to predict the effect of variation in fish size on the selectivity of the Port Moller gill net; however, the small size of the sockeye in 1990 was not unusual given the large run. Large runs typically contain smaller fish because of density-dependent growth in their final spring at sea (Rogers 1980).

The Port Moller test fishery in 1990 also provided an early indication to ADF&G management that a large run was on the way, especially to the Kvichak. This information contributed to excellent management of the Kvichak run in 1990; unfortunately, there was a large over-escapement in the Naknek River caused partly by an earlier timing of the run and very small 2-ocean fish (Table 5). A large over-escapement also occurred in the Egegik River, but this was the result of management decisions to have closures in the face of the largest run ever recorded for Egegik (Fig. 4). In all, the excess escapements (over the point goals) in 1990 totalled more than the False Pass catches of Bristol Bay sockeye in 1989 and 1990 combined (Shaul et al. 1990). Of course in only three cases (Naknek, Egegik and Igushik) were the 1990 escapements excessive. In the other systems, escapements were well within management ranges and the Kvichak could have even received another million fish.

To insure that the test fishery continues to provide an accurate forecast, Doug Helton in his Master's thesis examined factors that influenced the operation of the test fishery and the efficiency of the gill net. Annual run timing of sockeye to Port Moller and Bristol Bay was positively correlated with sea surface temperature—warmer temperatures and earlier runs. reduction of the gill net mesh size from 5 3/8 inches to 5 inches increased net efficiency in capturing the predominant size group of sockeye (2-ocean fish) and improved the accuracy of the test fishery forecast relative to that prior to 1987. Forecast accuracy was also improved by reducing the number of stations so that all stations could be sampled each day. Sockeye catch per unit net length declined as net length was shortened; therefore, the standard net length (200 fathoms) should not be modified. Wind velocities exceeding 15 knots reduced catches of sockeye salmon; strong winds also stressed the gear and could cause lost fishing time from damaged gear. Fish depth of capture varied with location, time of season and tidal stage. The most effective means for insuring continued high accuracy of the test fishery would be to increase the number of drifts made during the season. This could be accomplished by a fast, reliable fishing vessel.

LAKE RESEARCH

During the summer of 1990, we continued our long-term studies of spawner distribution, growth and abundance of fry, and the physical and biological environment for the sockeye salmon of the Wood River (Nushagak) and Kvichak lake systems. Most of our annual observations in the Wood River Lakes extend over more than 30 years and constitute the longest continuous biological and environmental record on any salmon stock in Alaska. In 1990, we also conducted special studies of bear predation on spawning sockeye salmon, stock-specific traits of sockeye spawning populations, and freshwater and marine growth of Nushagak sockeye salmon through scale measurements on samples dating back to the early 1900s (funded jointly by NOAA and industry).

KVICHAK SYSTEM

Our 1990 field season in the Kvichak system (lakes Iliamna and Clark) consisted of estimating the sockeye escapement into the Newhalen River in late-June and July; townetting for juvenile sockeye and threespine stickleback in upper Lake Iliamna and Lake Clark in August; and spawning ground surveys in late August-early September to collect otoliths for age determination.

Newhalen River Escapement

The annual escapements of sockeye salmon to the Kvichak lake system are estimated from expanded 10-min counts on each bank of the river at the outlet of Lake Iliamna (Igiugig) by ADF&G. In addition, since 1979 we have estimated the escapements up the Newhalen River by expanding 20-min counts on one bank, for each of ten daylight hours, to a daily count for both banks. We count when and where the visibility is best and assume that thew fish utilize both banks equally and that their migratory rate does not change at night. The daily counts at Newhalen are compared to the counts at Igiugig to estimate a travel time and then by lagging the Newhalen counts back to Igiugig the appropriate number of days, we can calculate the daily proportions of the Kvichak run that went up the Newhalen River.

The cumulative daily escapements for the two rivers, timed to the Kvichak, are given in Table 6 for 1984-1990 (no Newhalen counts for 1987). In mid-July, milling fish often swim upriver along the banks of the Newhalen and are counted, and then drift downriver in the middle where they cannot be seen, only to swim up river again. This inflates the counts for the escapement; therefore, we have used the average proportion of Newhalen count to Kvichak count for day 5 to day 16 (day one equals the first day of 100,000 in the Kvichak) and the season's total Kvichak escapement to estimate the Newhalen/Lake Clark escapement.

In 1990, we estimated that 1.1 million of the Kvichak escapement of 7.0 million (about 16%) ended up in the Newhalen/Lake Clark system (Table 7). This percentage was similar to that which occurred in the main parent brood year for the 1990 run (1985, 22%). The aerial surveys conducted by ADF&G in 1990 did not include an estimate for the Newhalen River, which is needed to estimate the Lake Clark escapement. However, that escapement was probably small because the aerial estimate of the spawners in the Tazimina River (major spawning ground in Lake Clark) was one of the lowest ever (4,000).

Spawning Ground Surveys

We have collected scales or otoliths from spawned-out sockeye salmon from several major spawning grounds in the Kvichak system each year since 1956. In 1990, six spawning grounds were sampled and the age compositions from the samples provided an unusual pattern when compared to the age composition in the lake system escapement. The sockeye spawning in the creeks and rivers had an age structure different from those spawning on the beaches and in the lake system escapement (Table 8). The age compositions of the beach spawners with a high percentage of age 2.2 sockeye, matched the age composition in the system escapement, whereas the other spawning grounds contained high percentages of age 2.3 sockeye. This would seem to indicate that the great majority of sockeye in 1990 spawned on the lake beaches, which might be expected from the distribution of the spawners in 1985 (Table 9).

We began aerial surveys of the Kvichak spawning grounds in 1956, but counts of beach spawners did not begin until 1961. ADF&G took over the annual surveys in 1988 as part of their aerial survey program in Bristol Bay (Bill et al. 1987). Survey conditions in 1990 must have been poor because only about 3% of the escapement was accounted for by the survey estimates.

It was especially surprising that there were such low counts for the beach spawning areas where our field crew noted more spawners than in any year since 1985. Aerial surveys can provide a good estimate of the escapement provided that the major spawning grounds are included, the observer is experienced, and 20% or so of the fish are seen (Rogers 1984).

Sockeye Fry Abundance and Size

We have sampled the sockeye fry (age 0) in the Kvichak system each year since 1962 (1961 brood year) by townetting at night. However, only the upper end of Iliamna Lake, where most of the fry are concentrated, has been sampled consistently. We have usually not sampled the fry in Six-mile Lake (upper end of the Newhalen River) where fry from the Tazimina River are likely to concentrate. The geometric means of the catches provide a measure of the relative density (number per 5-min tow) and the mean lengths of the fry are adjusted each year, based on their daily growth rate, to September 1 (Table 10).

The sockeye fry are usually smaller in Lake Clark than in Lake Iliamna (as was the case in 1990) because temperatures are usually colder and there is a shorter ice-free period in Lake Clark. In both lakes, the annual growth of the fry is correlated with water temperatures which are mostly influenced by spring weather. Cold temperatures typically result in small fry (40-50 mm) which then spend two years in the lake before seaward migration and tend to return as adults five years after their parents. Warm temperatures usually result in large fry (over 60 mm) which tend to migrate to sea after one year and mostly return four years after their parents.

The tow net sampling has been useful in predicting, three years in advance, the main age at return from the larger Kvichak escapements by utilizing the relationship between age at return and mean length of fry in Lake Iliamna (Fig. 5). Fry from the 1984 brood year averaged only 46 mm in 1985 and we predicted that 85% (19 million) of the total return would return in 1989. The actual return in 1989 was 18 million. The majority of the production from the 1985 brood year (mean length of 54 mm) should have returned in 1990 and that appears to be the case with a preliminary return of 13 million compared to 2 million return in 1989 (Table 11). The small escapement in 1986 is unlikely to produce much; however, the 1987 brood with fry averaging 63 mm should produce a large return in 1991 (four years later). The 1992 and 1993 runs are likely to be smaller, with the next large run to the Kvichak coming in 1994 (from the 1989 brood year).

Wood River System

The Bristol Bay research program of FRI began with spawning ground surveys in the Wood River Lakes in 1946 to determine where, when and how many sockeye spawned there. During the early 1950s, methods were established to enumerate and sample the commercial catches, escapements (towers) and the smolts produced. By the late 1950s we had established several important measurements which we have maintained to the present in order to characterize each year's environment for spawning adults and rearing juveniles.

Environmental Observations

The spring of 1990 was warmer than average in Bristol Bay and ice breakup was 13 days earlier than average in Lake Aleknagik (Table 12). With the early ice breakup, water temperatures were warmer than average in June and July but not as warm as in past years with comparable breakup dates. This was because solar radiation (sunlight) was below average. Lake levels were well above normal in early June, but then dropped sharply until the end of July when rainfall increased and lake level held steady until the middle of September. Lake level in early July 1990, when the adult salmon were migrating into the lakes, was the third lowest recorded for that period, whereas water levels during salmon spawning (late August and early September) were very average. Standing crops of phytoplankton and zooplankton were a little above average in 1990, as was the growth of sockeye fry in Lake Aleknagik.

Historical Sockeye Growth

The sockeye salmon runs to the Nushagak have been exploited since the late 1800s. Their abundance peaked in the early 1900s and then periodically declined until the late 1970s, when runs unexpectedly increased and surpassed historical levels. We hypothesized that changes in sockeye abundance may be correlated with changes in growth at different periods of their lives. To test this hypothesis, measurements of the widths of freshwater and saltwater annual growth zones were made from scales taken from the Nushagak commercial fishery representing brood years of 1907 to 1984. ADF&G provided the scales from 1961 to 1984, whereas scales from earlier years had been collected by FRI or the Bureau of Commercial Fisheries (now NMFS). We also utilized Wood River smolt length statistics published by ADF&G since 1962 (e.g., Woolington et al. 1990).

Scale growth of sockeye during the first year in freshwater was directly correlated with mean lengths of fry from our tow net sampling in the Wood River Lakes (1958 to present), and these mean lengths were correlated with the mean lengths of age 1 smolts (Table 13). This demonstrated that scale measurements were accurate estimates of juvenile lengths. Freshwater scale growth was also negatively correlated with the density of parent spawners indicating density-dependent growth, and positively correlated with weather variables representing spring and summer growing conditions.

In general, total growth of the sockeye salmon in the Nushagak District lakes and in the ocean, as indicated by scales, tended to be relatively low and variable during brood years 1907 to 1945 and consistently greater during the 1946 to 1984 brood years. Growth was lowest during the 1934 to 1945 brood years. These trends were especially represented by growth during freshwater and the first year at sea. In contrast, scale growth of age 1.2 and 1.3 sockeye during the second year at sea was consistently low from the 1938 to 1956 brood years and the growth of age 1.3 sockeye during their third year at sea was above average during 1940 to 1948.

The relationship between scale growth, Bristol Bay air temperature and sockeye abundance was initially examined by multiple regression analysis for brood years 1920 to 1984. Total return of sockeye was positively correlated with scale growth during the first and second years at sea and negatively correlated with growth in freshwater. Strong density-dependent growth in freshwater explains the inverse relationship between return and freshwater growth. In general the distribution of scale measurements within each brood year was not skewed to the right, which indicated that size-selective predation on smaller sockeye did not influence the growth estimates. Analysis is continuing with time series analysis and the incorporation of other variables such as total salmon abundance in the North Pacific and sea surface temperature.

Char Predation

We have sampled the Arctic char in Little Togiak River each spring since 1972 to follow the rate of predation on juvenile sockeye, especially smolt. This short river flows from Little Togiak Lake into Lake Nerka and the smolts are very vulnerable to the char for the few minutes it takes them to move from one lake to the next. Large char usually eat more juvenile sockeye than small char and the char caught in 1990 were generally small as was the case in 1989 (Table 14). There are about 5,000 char in and around the river mouth, so that at just one sockeye smolt per char per night for a migration of 20 to 30 days, a significant number of smolts are lost from the production of this small lake in the system.

Bear Predation

The abundance of brown bears in the Wood River Lakes has increased since 1978 along with the increase in salmon escapements (personal observations from bear sightings on stream surveys). Because bears could have a significant effect on the number of spawning sockeye, especially in small creeks, we examined the effect of bear predation on spawning sockeye salmon in a small spring-fed creek in Lake Aleknagik (Hansen Creek). Daily count and removal of sockeye killed by bears indicated that 1,334 (20%) of 6,583 spawners were killed by bears in 1990 (Table 15). Up to 157 salmon were killed per night. Preliminary analysis suggests that female sockeye were preferred over males during the early spawning, but this preference switched to a strong preference for males later in the spawning period. Examination of female sockeye spawning condition indicated that sockeye spawned within a few days after entering the creek and that the majority of females killed by bears were spent. Analysis of tag and recapture data will determine whether the bears were size-selective. In general, the potential influence of bears on spawning sockeye is great but sockeye apparently reduce the effect by spawning soon after entry into the creek.

Six different bears were observed near the creek, including two cubs. A large proportion of the sockeye killed by bears had either little or no flesh removed. Teeth and bite marks indicated that male fish were generally attacked from the top, whereas females were usually attacked from beneath. This latter observation was surprising because it was assumed that bears attack all fish from the top, then turn the fish over to open the body cavity. Future research will examine the influence of bear predation on sockeye morphology and the time spent on the spawning ground prior to spawning.

Spawner Morphology

This year Susan Bishop completed her Master's thesis on variation in sockeye morphology (body size and shape) among spawning populations in the Wood River lake system. For sockeye spawning in rivers and streams, body shape was related to water depth and velocity. Fish spawning in small shallow creeks were small and narrow-bodied compared to sockeye spawning in deep, fast-flowing rivers. Beach spawners had the deepest body shape among all spawning ground types.

We have continued this line of research by studying some stock-specific traits of sockeye spawning populations in the Wood River Lakes. Homing of salmon to their natal stream suggests that salmon have evolved stock-specific traits that enhance their survival in unique environments. We tested for stock-specific traits among spawning stocks through genetic (electrophoresis) and phenotypic (external morphology, fecundity, egg size and egg caloric content) measurements. Information on the environmental influence on these traits will enhance our understanding of evolutionary processes. These data should strengthen the stock concept for Wood River sockeye and emphasize the need to manage the fishery accordingly. The results of this investigation will be presented in a Master's thesis to be completed in 1991.

Spawning Ground Surveys

Sockeye salmon spawning surveys are conducted annually in the Wood River lake system. We collect otoliths from the major spawning grounds for age determination and make ground counts of the number of spawners in the small streams. ADF&G estimates the numbers of spawners on the lake beaches and in the interconnecting rivers by aerial surveys. The total escapement to the lake system can then be apportioned to the individual lakes or type of spawning ground (creek, river and beach).

We have not yet received the aerial survey estimates from ADF&G for 1990; however, the age compositions on the spawning grounds are given in Table 16. Although the escapement to the lake system contained about equal numbers of ages 1.2 and 1.3, on the individual spawning grounds one age or the other was predominant, usually age 1.2 in the creeks and age 1.3 in the larger rivers. This is typical of the age compositions in past years (Rogers 1987). Beach spawners in the past have contained a majority of age 1.2, but in 1990 there was a majority of age 1.3 on the three beach areas that were sampled. During the past decade there appears to be a shift to more 3-ocean fish in the beach spawners.

The distribution of the escapement among the lakes of the Wood River system affects the relative production (return/spawner) from the escapement. Escapements that were evenly distributed among the lakes generally produced a greater rate of return than escapements that were unevenly distributed (Fig. 6). Of immediate importance is the distribution of the 1987 escapement of 1.34 million that will produce most of the 2-ocean return in 1991. This escapement was one of the most evenly distributed escapements recorded (Sum d^2*Esc = 80) and should produce a high return/escapement and thus a large run in 1991.

During our foot surveys of sockeye spawning streams in 1990, we encountered an unusually high occurrence of pink salmon (Table 17). The main spawning grounds for pink salmon in the Nushagak District are the Nuyakuk and Tikchik rivers. The lesser numbers that typically spawn in the Wood River system are usually concentrated in the two large rivers (Agulowak and Wood) and one long creek tributary of Lake Aleknagik (Youth Creek). No aerial estimates were made of pink salmon spawners in 1990; however, our personal observation of the number of pink salmon in the Agulowak River in 1990 was that there were more than we had ever seen (since 1960), including 1978 when the Nushagak pink salmon run was nearly 14 million. It is likely that the number of pink salmon in the Wood River system in 1990 was at least as numerous as in 1978 (200,000).

One new project undertaken in 1990 by Dr. Tom Quinn was a study of the spawning behavior of sockeye on Iliamna Lake beaches. These beaches are very different from typical sockeye spawning grounds, and the beach spawning populations are sufficiently large to warrant special attention. Preliminary data analysis indicates that spawning site preferences of females are related to depth and circulation. Reproductive success of males is related to large size, both in length and hump. Our previous studies have demonstrated that male beach spawners have proportionately larger humps than males from streams. We hope to relate these studies to the variations in shape and size of sockeye as they pass through the fisheries to determine if differential mortality may be occurring on certain populations.

We also initiated the first phase of a program to monitor the beach spawning environment and the variability in spawner abundance among sites both within and between years. A continuous (12-month) recording thermograph was installed at one of the beaches and we hope to deploy a second thermograph in 1991. We will also document the patterns of gravel stability, depth of spawning, spawning density, and timing at selected beaches. The abundance data will provide an index to improve aerial estimates, and the environmental data may assist in estimating egg-fry survival.

NUSHAGAK PINK AND CHINOOK SALMON

The Nushagak District usually produces the majority of pink, chinook and chum salmon returning to Bristol Bay (ADF&G 1990). The chum salmon return along with the more abundant and valuable sockeye so that management regulations are not directed towards chums; however, pink and chinook salmon return mostly later and earlier than the sockeye and are managed separately to achieve an estimated escapement (e.g., Nelson 1987).

The 1990 pink salmon run to the Nushagak was unexpectedly small (about 1 million) considering that the parent escapement of about 0.5 million was near the optimum (Table 18 and Fig. 7). Very little fishing time was permitted in late July and early August (during the peak of the run), and as a result the preliminary catch of 53,000 was the smallest in 30 years. The 1990 escapement to the Nushagak River was estimated by the Portage Creek sonar as has been the case since 1986. During 1980-1984, there was both a sonar count and a tower count of the pink salmon escapement. In 1980, the tower escapement only through August 11 was used to compare with the sonar counts that were made only through August 6 (allowing for a 5-day travel time). For the three even years, the sonar counter underestimated the escapement by an average of 28%; however, that is not likely to apply to the sonar estimates for 1986-1990 because the runs were obviously smaller in those years and there have been improvements in the sonar system.

The 1990 chinook salmon run to the Nushagak was not fished during the peak of the run, i.e., no June fishery, and there was very little fishing during the early part of the sockeye season when significant numbers of chinook salmon are still available (Table

20). In past years, there was a good correlation between the number of fish in the chinook run and the catch per day in the June fishery (R^2 = .58), whereas the correlation between run size and the catch per day during the early sockeye season was rather poor (R^= 0.17) and there was no correlation with run size during the late sockeye season (July 5-15). Unfortunately, for the years since 1987, there is no other independent estimate of the chinook run size other than the Nushagak sonar estimate of escapement and the incidental catch of chinook salmon during the sockeye season.

The escapement/return statistics for Nushagak chinook salmon were examined for density dependence, and a Ricker curve (Ricker 1958) was fitted by a least-squares iterative procedure (Fig. 7). The most recent brood years exhibit a strong density dependence (reduced production at high escapements). The optimum escapement is just below 50,000 with peak production from 50,000 to about 70,000 spawners.

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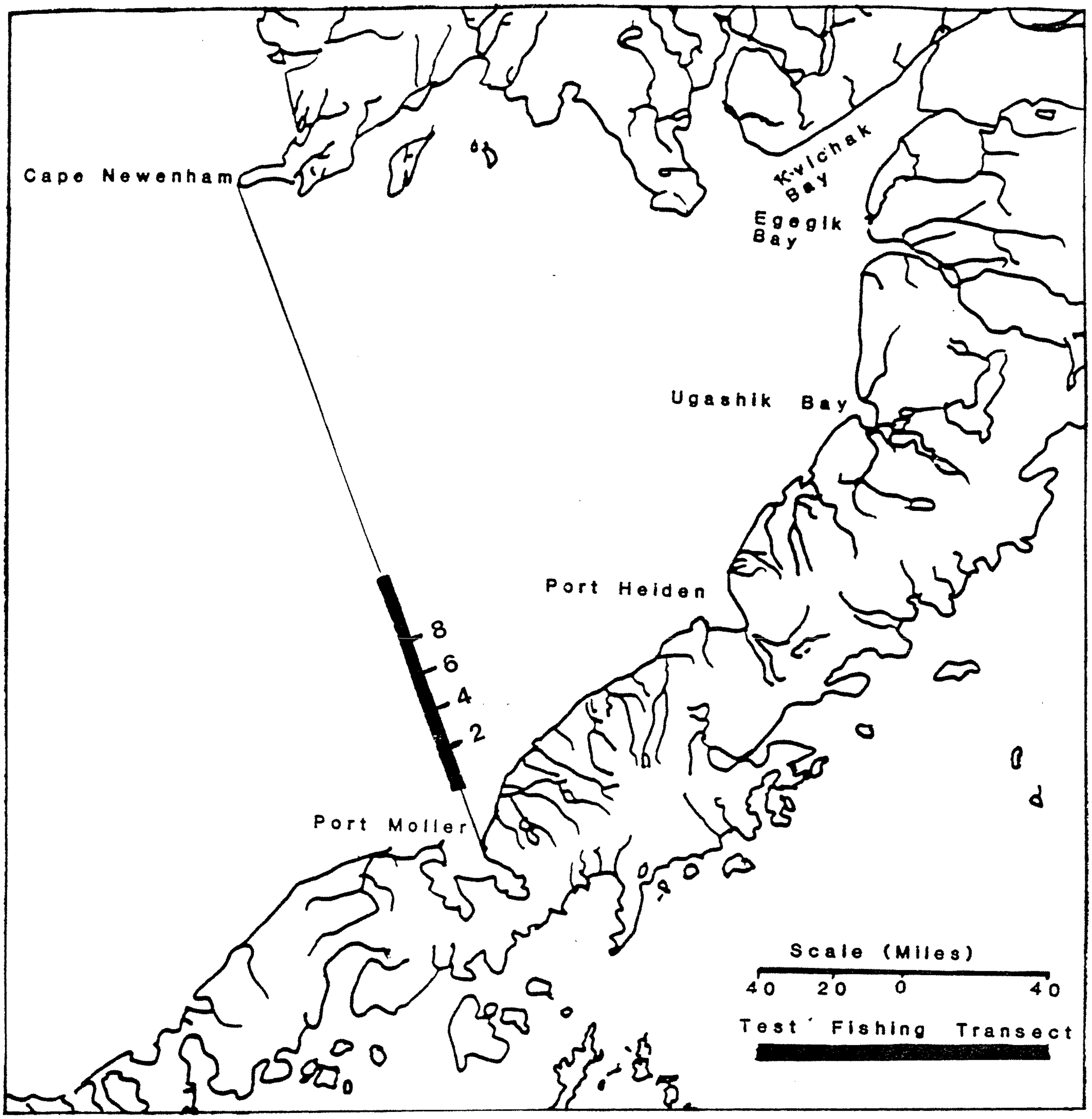
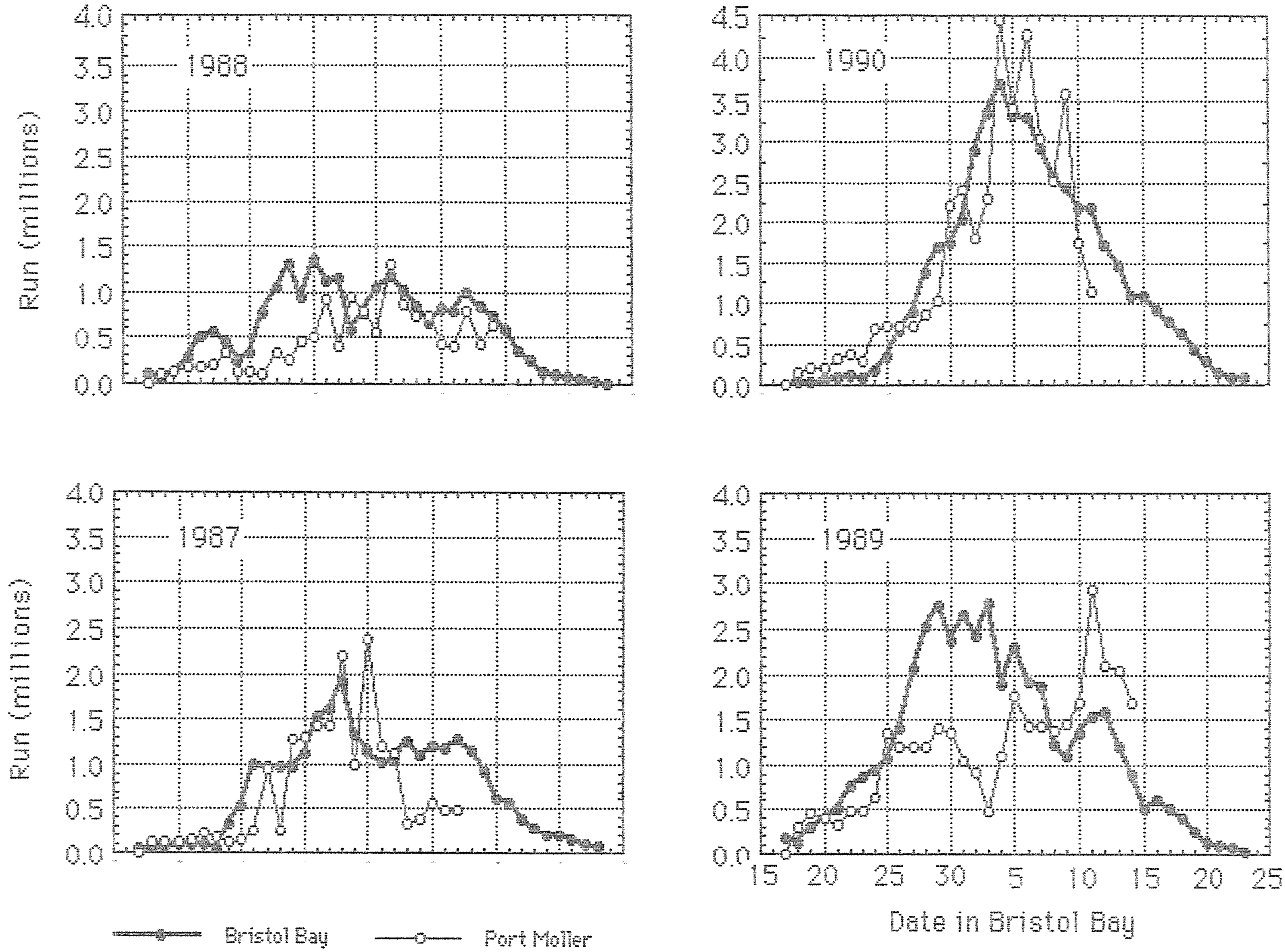


Fig. 1. Location of the Port Moller test fishery.



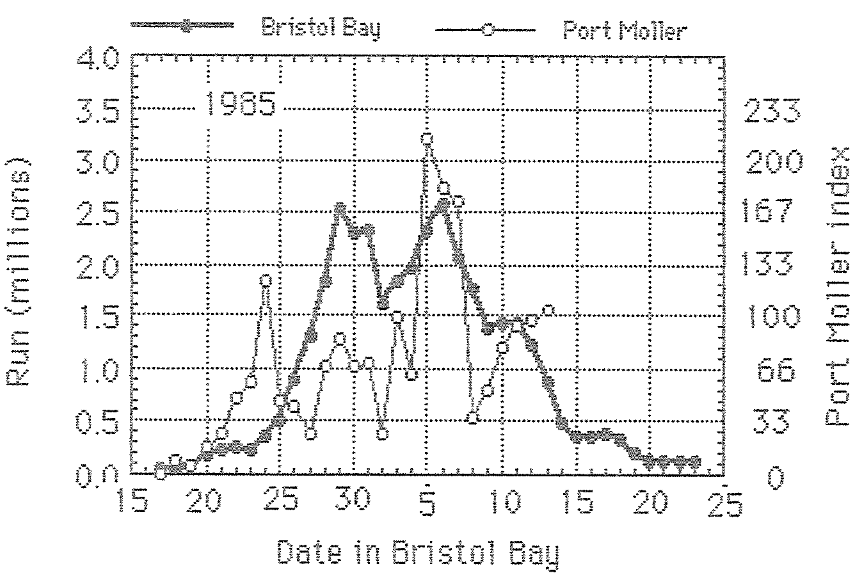


Fig. 2. Daily Bristol Bay sockeye runs and the daily Port Moller index catches lagged 7 days and scaled to 1 index= 15,000 in the run.

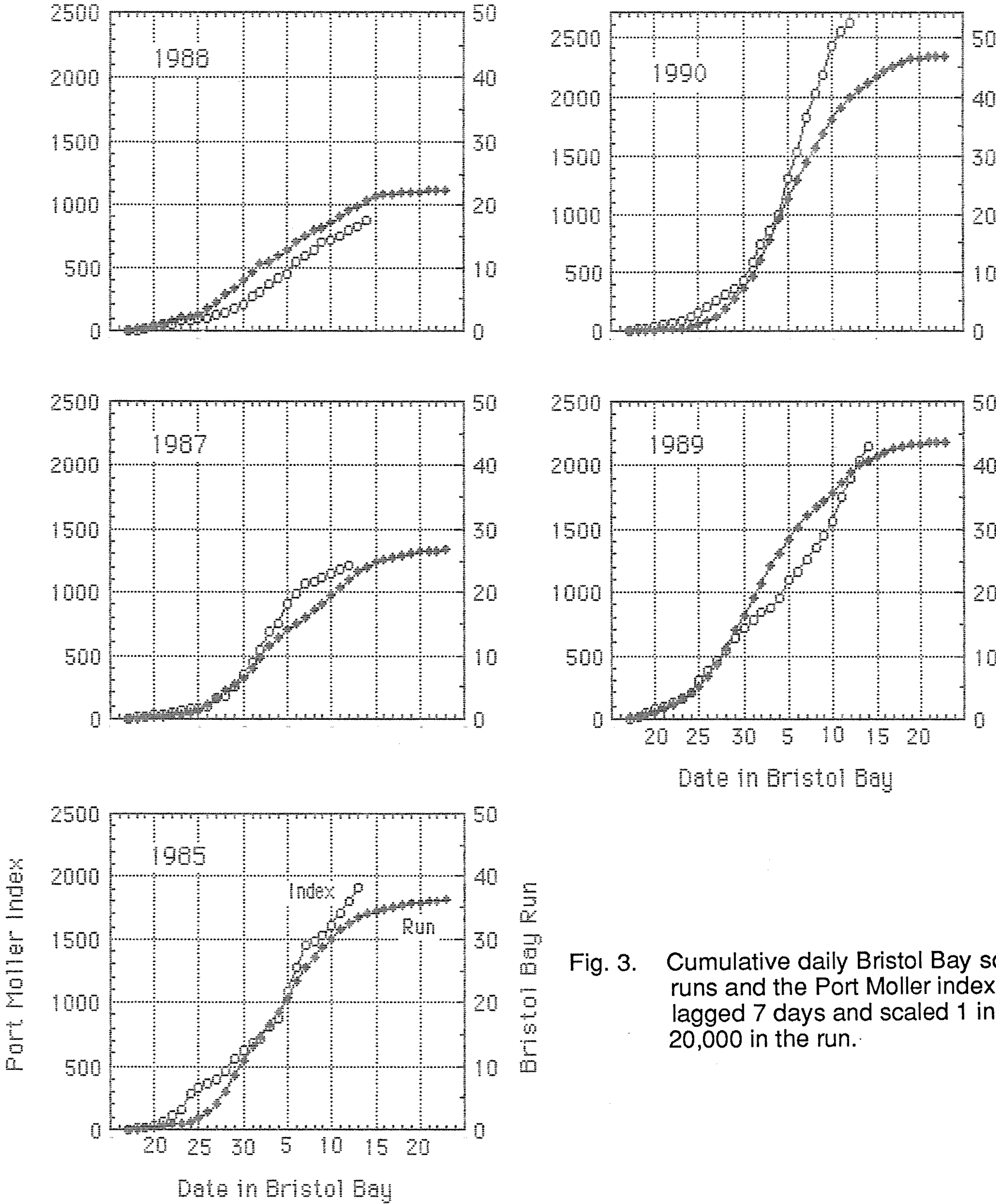


Fig. 3. Cumulative daily Bristol Bay sockeye runs and the Port Moller index catches lagged 7 days and scaled 1 index = 20,000 in the run.

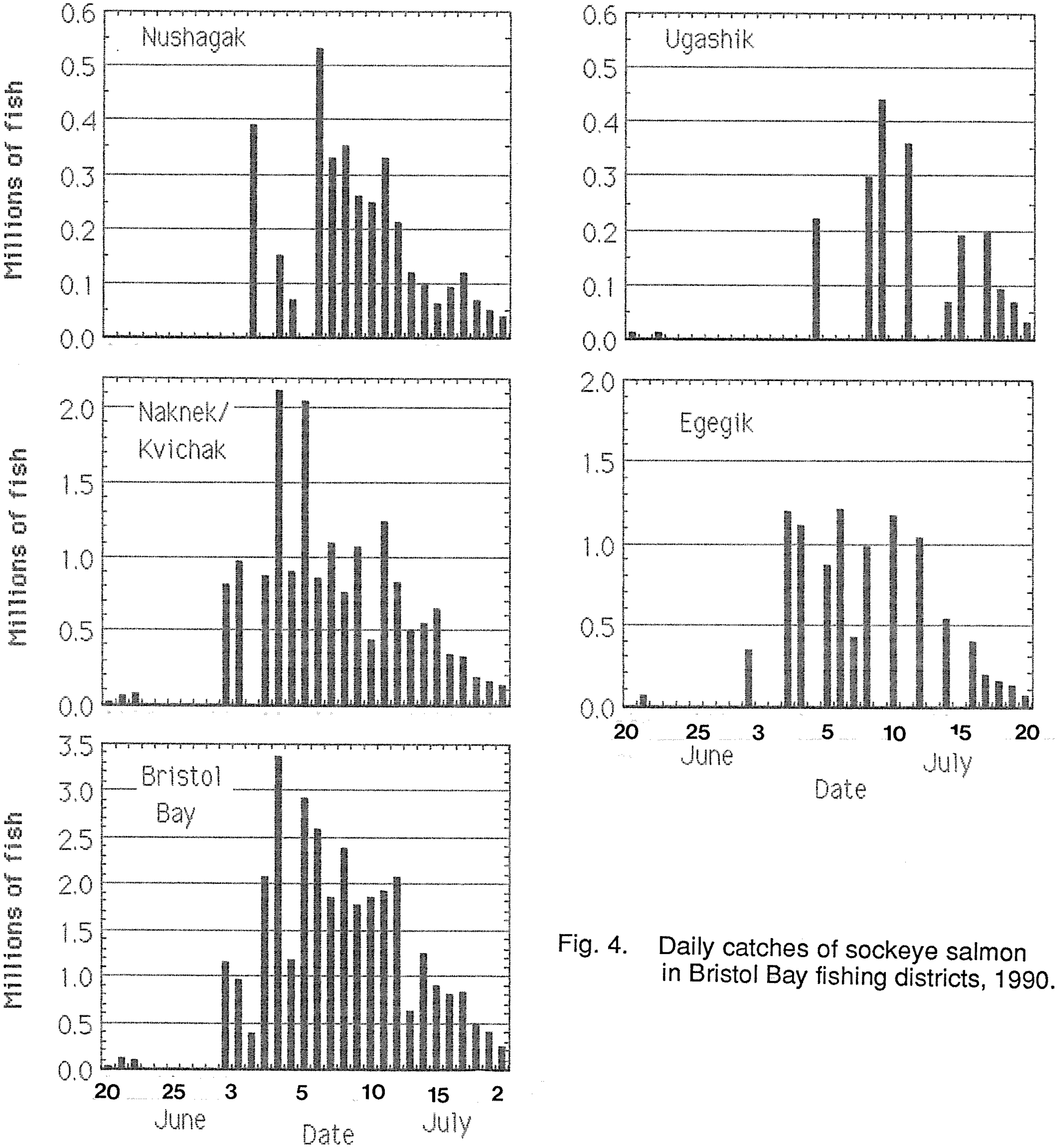
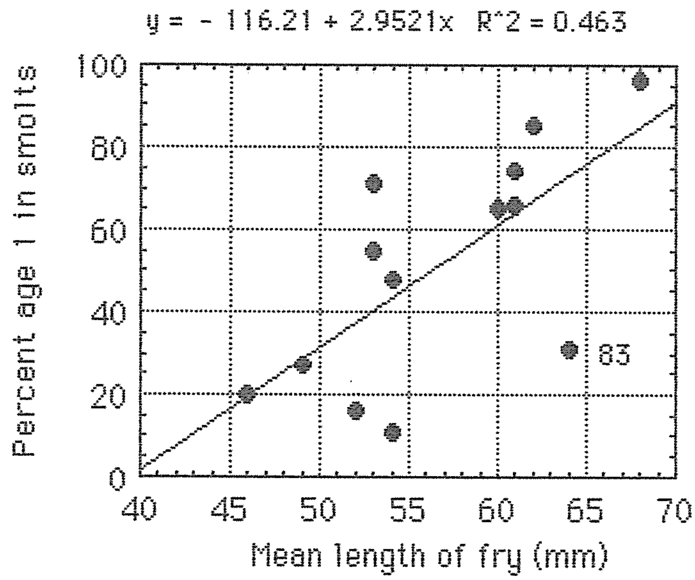
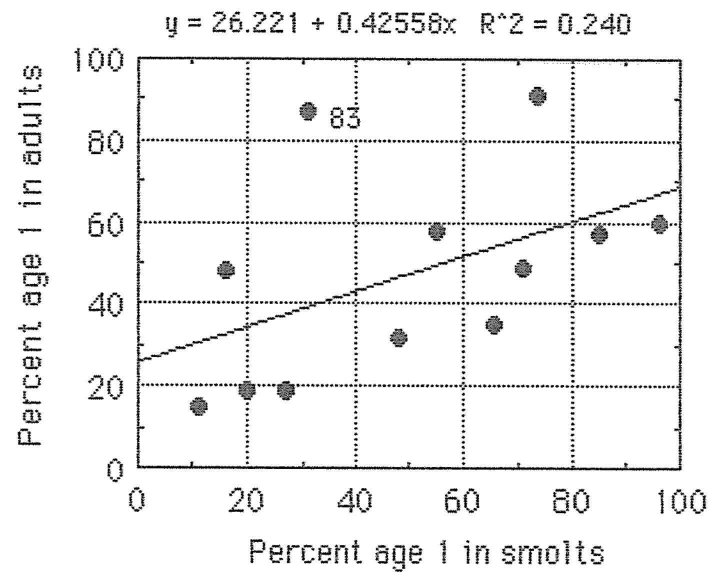
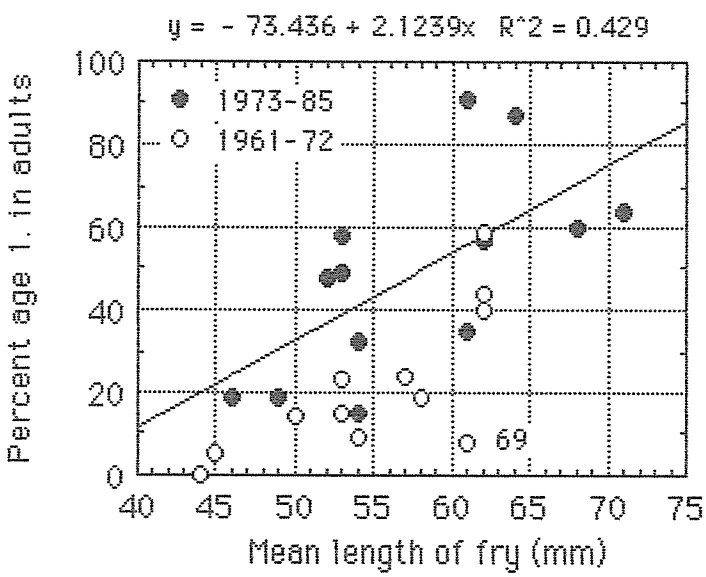


Fig. 4. Daily catches of sockeye salmon in Bristol Bay fishing districts, 1990.







Brood year	Mean length
87	63
88	58
89	55

Fig. 5. Regressions of the percentage of age 1. in adult returns to the Kvichak on the mean length of fry (bottom) and the percent of age 1 in the smolts (upper right); and the percent age 1 in smolt migrations on the mean length of fry (upper left).

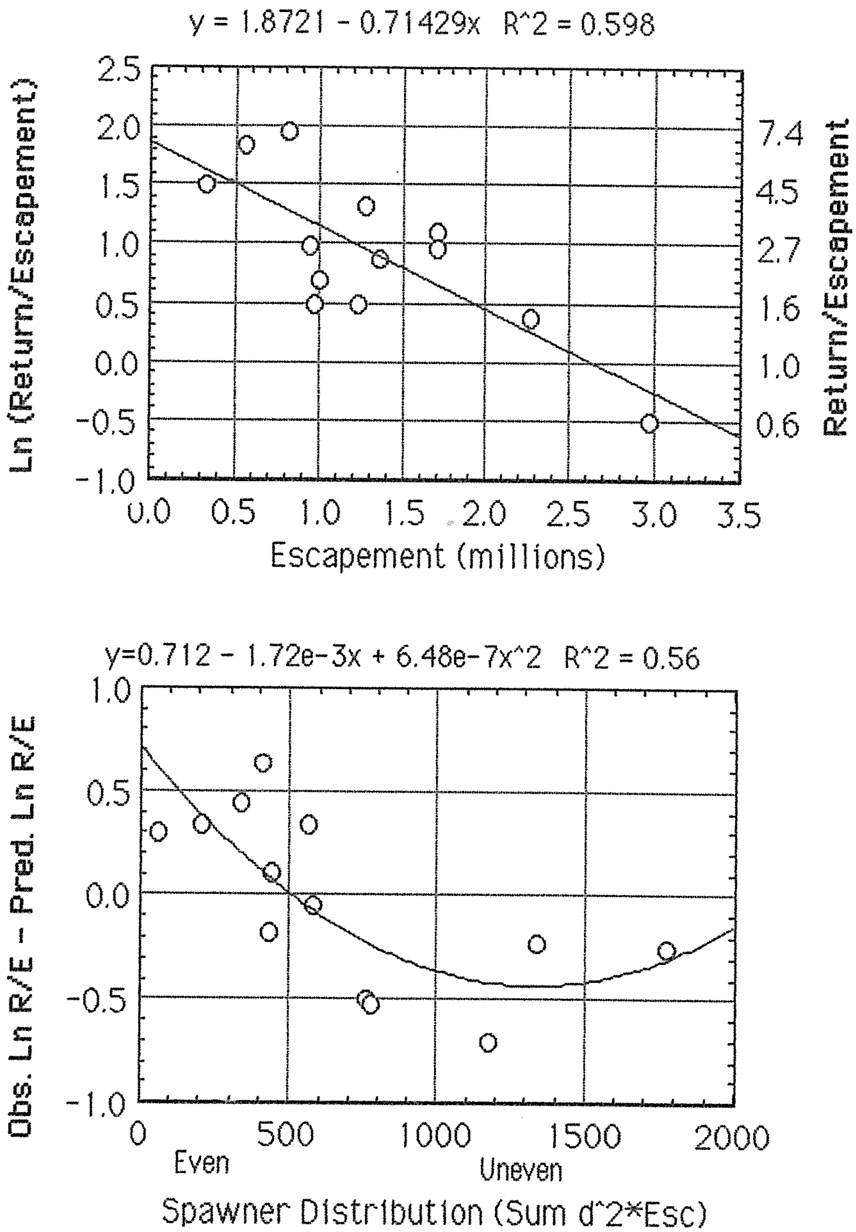


Fig. 6. Regression of relative production of Wood River sockeye (return per escapement) on escapement for the 1973-1985 brood years (top) and the deviations from that regression on the distribution of the escapement among the lake system (bottom).

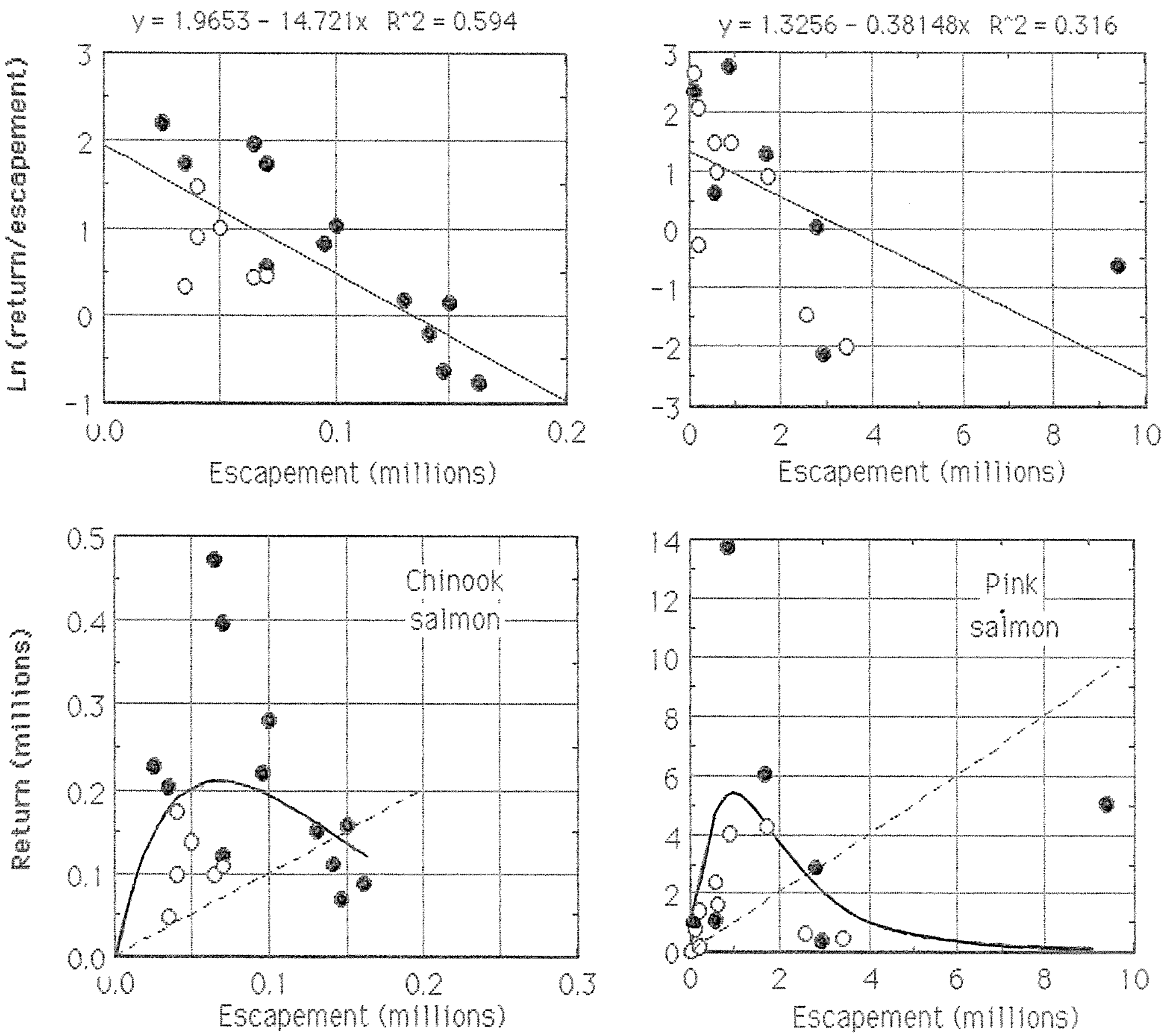


Fig. 7. Linear regressions of the relative production (ln return/escapement) on escapement (top) and plots of return on escapement with least-squares Ricker curves (bottom) for Nushagak chinook and pink salmon stocks. Solid points for the 1972-83 chinook brood years and the 1976-88 pink salmon brood years.

Table 1. Pre-season Bristol Bay sockeye forecasts and the actual inshore runs (millions).

Year	Forecast/run	Kvichak	Naknek	Egegik	Ugashik	Nushagak	Total run	Catch	% Error
1985	FRI	12.2	5.3	5.8	4.4	4.3	33.0	18.2	29
	ADFG	12.2	4.9	6.6	5.6	4.3	35.0	20.3	
	Japan CPUE						38.0		
	Actual run	13.4	3.7	8.6	7.4	3.0	36.6	23.5	
1986	FRI	9.2	4.5	5.9	6.7	4.8	32.1	19.4	19
	ADFG	4.5	3.2	5.4	4.9	3.8	22.5	13.3	
	Japan CPUE						31.7		
	Actual run	2.0	3.9	6.2	5.9	4.9	23.7	15.8	
1987	FRI	2.8	2.0	5.8	3.1	5.1	19.5	12.4	29
	ADFG	2.7	2.1	4.9	3.1	3.3	16.8	9.3	
	Japan CPUE						17.0		
	Actual run	9.6	2.4	6.7	2.8	5.1	27.3	16.0	
1988	FRI	12.3	3.1	6.2	3.1	5.0	30.6	20.8	33
	ADFG	9.3	2.5	5.6	3.2	5.6	26.5	16.8	
	Japan CPUE						18.5		
	Actual run	6.8	1.8	8.0	2.2	3.2	23.4	14.0	
1989	FRI	20.4	3.6	6.7	3.0	3.4	38.0	25.4	13
	ADFG	12.5	3.1	5.6	3.6	3.1	28.9	16.2	
	Japan CPUE						26.9		
	Actual run	19.8	3.2	10.3	4.9	5.0	43.9	28.7	
1990	FRI	10.1	4.8	6.6	3.0	4.6	29.8	19.0	
	ADFG	8.9	3.6	5.6	3.1	3.5	25.4	14.7	
	Japan CPUE								
	Actual run	17.4	8.4	12.3	2.9	5.7	47.6	33.1	74
1991	FRI	12.0	4.6	8.9	3.6	6.9	36.7	25.0	
	ADFG	7.6	6.0	8.2	3.5	3.8	30.0	21.2	
	Japan CPUE								
	Actual run								

Table 2. Age composition of sockeye at Port Moller by 5-day periods and in the Bristol Bay run.

Year	Dates	Age composition (%)							Mean daily	Mean
		Age 1.2	Age 2.2	Age 1.3	Age 2.3	Other	All .2	All .3	index catch	length
1985	6/11-15	14.0	45.5	28.0	9.6	2.9	59.5	37.6	21	540
	6/16-20	10.6	47.3	29.9	10.0	2.2	57.9	39.9	59	543
	6/21-25	8.4	36.4	37.9	14.9	2.4	44.8	52.8	63	549
	6/26-30	10.7	42.1	26.2	19.4	1.6	52.8	45.6	146	547
	7/01-05	15.4	37.5	27.9	18.4	0.8	52.9	46.3	72	552
	7/06-10	18.8	45.9	18.2	16.5	0.6	64.7	34.7		
	Combined	11.4	41.2	29.3	16.3	1.8	52.6	45.6	72	547
	BB run	12.7	45.6	25.1	15.7	0.8	58.6	41.1	36.8	542
1987	6/11-15	26.3	17.6	24.5	31.6	0.0	43.9	56.1	10	535
	6/16-20	38.1	18.3	21.4	20.6	1.6	56.4	42.0	22	540
	6/21-25	45.4	19.6	24.5	9.8	0.7	65.0	34.3	76	535
	6/26-30	55.2	19.7	14.2	9.3	1.6	74.9	23.5	105	527
	7/01-05	64.0	14.9	7.0	13.3	0.8	78.9	20.3	30	526
	Combined	45.8	18.0	18.3	16.9	1.0	63.8	35.2	49	531
	BB run	49.6	11.6	25.5	13.0	0.4	61.1	38.5	27.5	536
1988	6/11-15								11	562
	6/16-20	17.3	16.8	55.1	4.9	5.9	34.1	60.0	14	555
	6/21-25	18.2	22.6	47.0	9.3	2.9	40.8	56.3	34	553
	6/26-30	14.2	20.6	46.3	16.4	2.5	34.8	62.7	60	556
	7/01-05	23.7	17.4	47.3	10.1	1.5	41.1	57.4	42	552
	Combined	18.0	19.6	48.1	11.5	2.8	37.6	59.5	32	555
	BB run	21.3	22.2	42.2	13.0	1.3	43.5	55.2	23.2	554
1989	6/11-15	3.6	34.3	21.7	36.2	4.2	37.9	57.9	27	566
	6/16-20								67	562
	6/21-25	15.5	39.4	27.5	15.7	1.9	54.9	43.2	78	546
	6/26-30	12.9	57.0	14.0	12.9	3.2	69.9	26.9	83	538
	7/01-05	9.3	65.5	16.1	8.3	0.8	74.8	24.4	127	534
	Combined	12.0	51.6	20.4	14.0	2.0	63.6	34.4	76	544
	BB run	10.8	62.4	15.9	9.2	1.7	73.4	26.4	43.9	538
1990	6/11-15	10.6	50.6	21.1	16.5	1.2	60.9	39.1	14	529
	6/16-20	9.4	41.4	28.9	18.0	2.3	50.8	49.2	37	538
	6/21-25	12.6	38.0	19.1	26.7	3.6	51.6	48.4	97	544
	6/26-30	9.6	35.1	25.6	27.0	2.7	45.0	55.0	216	546
	7/01-05	10.2	34.4	19.0	32.7	3.7	45.0	55.0	159	546
	Combined	10.4	36.3	22.5	27.8	3.0	46.5	53.5	105	545
	BB run	14.1	41.4	20.7	20.3	3.5	56.4	43.2	47.6	528

Table 3. Mean lengths (live ME-TF, in mm) of sockeye salmon in the Bristol Bay runs.

Year	BB run (millions)	2-ocean Male	2-ocean Female	2-ocean Combined	3-ocean Male	3-ocean Female	3-ocean Combined	Both age groups	Percent 3-ocean
1960	36	496	480	489	580	553	562	498	12
1961	18	525	512	519	583	562	572	554	66
1962	10	527	508	518	582	566	574	535	30
1963	7	529	512	520	594	570	580	546	44
1964	11	517	499	508	584	564	571	522	22
1965	53	506	487	497	574	552	561	502	8
1966	18	514	503	508	581	561	569	554	75
1967	10	534	518	526	592	570	579	544	34
1968	8	516	503	510	594	572	581	535	36
1969	18	524	510	517	591	571	580	525	22
1970	39	511	497	504	572	549	558	509	9
1971	16	530	516	522	584	563	572	552	60
1972	5	521	505	514	583	562	572	543	51
1973	2	522	513	518	601	575	587	575	82
1974	11	525	508	518	581	566	574	528	19
1975	24	518	499	509	587	564	574	523	21
1976	12	531	514	523	592	568	578	543	36
1977	10	533	517	525	597	573	584	556	53
1978	19	520	502	512	595	570	582	539	38
1979	40	537	524	530	586	567	576	538	18
1980	62	519	503	511	583	553	567	525	26
1981	34	536	523	529	588	566	577	555	54
1982	22	522	508	515	587	566	576	561	75
1983	46	530	514	521	574	557	565	529	17
1984	41	515	501	508	580	561	570	526	30
1985	37	527	512	520	583	567	575	543	41
1986	24	535	521	528	583	561	571	553	58
1987	27	521	506	513	590	567	577	538	39
1988	23	525	513	519	592	571	581	554	56
1989	44	525	507	515	586	564	575	538	27
1990	48	507	491	499	578	557	566	528	43
Averages									
60-76	18	520	505	513	586	564	573	535	37
77-90	34	525	510	518	586	564	574	542	41

Table 4. Average weights of sockeye (kg) in the Bristol Bay commercial catches.

Year	BB catch (millions)	2-ocean Male	2-ocean Female	2-ocean Combined	3-ocean Male	3-ocean Female	3-ocean Combined	All males	All females	All fish	Percent 3-ocean
1960	14	2.12	1.81	2.02	3.29	2.75	2.95	2.25	2.12	2.20	20
1961	12	2.47	2.15	2.35	3.37	2.84	3.08	3.05	2.69	2.87	71
1962	5	2.56	2.19	2.39	3.35	2.88	3.08	2.74	2.41	2.58	27
1963	3	2.60	2.22	2.43	3.59	2.98	3.21	3.02	2.50	2.74	51
1964	6	2.47	2.14	2.33	3.50	2.97	3.17	2.66	2.43	2.55	27
1965	24	2.16	1.92	2.07	3.13	2.69	2.86	2.23	2.05	2.16	11
1966	9	2.32	2.12	2.22	3.43	2.86	3.06	3.13	2.74	2.89	80
1967	4	2.56	2.24	2.39	3.51	2.94	3.15	2.88	2.55	2.69	39
1968	3	2.46	2.17	2.33	3.64	3.03	3.26	2.91	2.65	2.77	47
1969	7	2.49	2.23	2.36	3.38	2.92	3.12	2.61	2.35	2.48	15
1970	21	2.30	2.07	2.20	3.04	2.58	2.75	2.35	2.14	2.26	10
1971	10	2.43	2.12	2.25	3.27	2.74	2.95	2.93	2.51	2.68	62
1972	2	2.44	2.14	2.32	3.45	2.88	3.15	2.99	2.63	2.82	60
1973	1	2.52	2.33	2.43	3.80	3.11	3.43	3.60	3.02	3.29	86
1974	1	2.52	2.21	2.36	3.43	3.02	3.23	2.75	2.44	2.59	27
1975	5	2.47	2.14	2.33	3.52	2.93	3.16	2.72	2.45	2.59	32
1976	6	2.60	2.22	2.45	3.62	3.03	3.28	2.93	2.62	2.78	40
1977	5	2.51	2.23	2.38	3.78	3.11	3.40	3.20	2.80	2.99	60
1978	10	2.48	2.14	2.33	3.71	3.00	3.32	2.94	2.57	2.76	44
1979	21	2.66	2.38	2.52	3.38	2.89	3.11	2.79	2.49	2.64	20
1980	24	2.39	2.10	2.25	3.35	2.74	3.02	2.65	2.30	2.47	29
1981	26	2.60	2.28	2.43	3.46	2.90	3.17	3.05	2.61	2.82	53
1982	15	2.40	2.17	2.30	3.42	2.90	3.15	3.17	2.75	2.96	77
1983	37	2.58	2.20	2.38	3.25	2.80	3.01	2.70	2.31	2.49	18
1984	25	2.34	2.07	2.22	3.29	2.85	3.06	2.64	2.37	2.51	35
1985	24	2.46	2.13	2.31	3.31	2.90	3.10	2.81	2.49	2.66	44
1986	16	2.61	2.24	2.42	3.38	2.84	3.07	3.02	2.60	2.79	57
1987	16	2.40	2.17	2.29	3.40	2.98	3.16	2.85	2.59	2.72	49
1988	14	2.44	2.14	2.31	3.47	3.02	3.25	3.03	2.69	2.87	60
1989	28	2.43	2.09	2.25	3.37	2.80	3.08	2.72	2.28	2.49	29
1990	33	2.30	2.09	2.20	3.36	2.80	3.03	2.77	2.48	2.62	50
Averages											
60-76	8	2.44	2.14	2.31	3.43	2.89	3.11	2.81	2.49	2.64	41
77-90	21	2.47	2.17	2.33	3.42	2.90	3.14	2.88	2.52	2.70	45

Table 5. The 1990 sockeye salmon runs to Bristol Bay river systems and the escapements compared to the management goals (in millions).

River system	Run	Escapement	Escapement goal	Excess escapement	Percent of goal
Kvichak	17.48	6.97	6.00	.97	16
Naknek	8.37	2.09	1.00	1.09	109
Egegik	12.28	2.19	1.00	1.19	119
Ugashik	2.87	.73	.70	.03	4
Wood	2.65	1.07	1.00	.07	7
Igushik	1.27	.37	.20	.17	85
Nuyakuk/Nush.	1.77	.67	.50	.17	34
Togiak	.37	.19	.15	.04	27
Totals	47.06	14.28	10.55	3.73	

Table 6. Cumulative daily escapements of sockeye salmon in the Kvichak and Newhalen Rivers, 1984-1990. (Numbers in 1,000's and Newhalen escapements estimated from expanded counts lagged back 3 days for 1986 and 2 days for other years).

	1984		1985		1986		1988		1989		1990	
Date	Kvichak	Newhalen	Kvichak	Newhalen	Kvichak	Newhalen	Kvichak	Newhalen.	Kvichak	Newhalen	Kvichak	Newhalen
6/25	17	10					1	0	58	17	1	
26	86	34					4	5	298	97	2	
27	121	42	1	0			75	85	525	162	3	
28	133	75	113	14			264	128	653	200	5	0
29	804	258	362	38			313	140	892	454	8	1
30	1821	389	631	67			328	187	1509	641	39	2
7/1	2600	635	979	110			364	244	2052	712	46	37
2	3116	913	1216	192	1	0	778	456	2566	785	219	66
3	3630	1185	1337	278	8	3	1193	632	3287	892	825	90
4	4320	1385	1601	350	75	7	1598	676	4378	1185	1412	110
5	5113	1652	1907	451	212	8	1901	784	5418	1287	1874	139
6	5968	1899	2330	480	268	16	2079	1076	5947	1358	2399	204
7	6787	2232	2738	538	278	24	2189	1313	6611	1567	2901	304
8	7581	2474	3137	754	280	30	2232	1505	7182	1962	3509	375
9	8437	2669	3833	874	310	51	2272	1629	7518	2317	4061	459
10	8992	2887	4625	1138	442	72	2389	1721	7670	2478	4692	648
11	9222	3060	5327	1311	539	98	2775	1868	7708	2614	5081	790
12	9358		5800	1373	680	189	3473	2106	7755	2728	5388	961
13	9748		6067	1445	854	250	3753	2372	7806	2829	5803	1079
14	10032		6366		987	320	3840	2657	7860	2944	6208	1193
15	10111		6586		1080	359	3948	2848	7914		6418	1297
16	10172		6674		1012	382	3990	2976	8060		6510	
17	10270		6706		1110	391	4020	3094	8130		6603	
18	10360		6856		1115	397	4046	3203	8164		6674	
19	10430		6976		1119	406	4057	3313	8205		6733	
20	10455		7051		1122	410	4062	3435	8245		6781	
21	10467		7116		1130	420	4065		8273		6827	
22	10476		7171		1154	428	4065		8287		6876	
23	10485		7201		1169	441			8295		6915	
24	10490		7211		1174	450			8302		6941	
25	10491				1177	454			8312		6970	

Table 7. The Kvichak lake system escapements and the percentages going to the Newhalen River and Lake Clark.

Year	Kvichak System Escapement (millions)	Newhalen/Lake Clark Escapement (millions)	Percent of Kvichak (%)	Newhalen River Spawners (millions)	Lake Clark Escapement (millions)	Percent of Kvichak (%)	Tazimina River Aerial count (thousands)
1979	11.22	9.00	80	0.56	8.44	75	504
1980	22.51	7.50	33	2.64	4.86	22	128
1981	1.75	0.26	15	0.03	0.23	13	28
1982	1.14	0.34	30	0.13	0.21	18	31
1983	3.57	1.08	30	0.41	0.67	19	212
1984	10.49	3.20	31	0.67	2.53	24	366
1985	7.21	1.62	22	0.15	1.47	20	186
1986	1.18	0.29	25	0.01	0.28	24	7
1987	6.07	- - -	- -	1.46	- -	- -	246
1988	4.06	2.41	59	0.29	2.12	52	83
1989	8.32	2.59	31	0.06	2.53	30	30
1990	6.97	1.09	16	- -	- -	- -	4

Newhalen River spawners estimated by two times the aerial survey estimate.

Table 8. Age compositions of sockeye salmon on Kvichak spawning grounds in 1990.

Spawning ground	Sex	Sample size (n)	Age composition (%) 1.2	2.2	3.2	1.3	2.3	Escapement (1,000s)
Gibralter Creek	M	95	0.0	50.5		1.1	48.4	20
	F	96	3.1	50.0		1.0	45.9	
Copper River	M	97	0.0	46.4	0.0		53.6	51
	F	92	2.2	50.0	6.5		41.3	
Chinkelyes Creek	M	78	2.6	60.2	0.0	7.7	29.5	2
	F	92	6.5	57.6	1.1	5.4	29.4	
Tazimina River	M	62	1.6	53.2		4.9	40.3	4
	F	12	8.3	41.7		0.0	50.0	
Woody Is. beaches	M	91	3.3	95.6		1.1		15
	F	88	0.0	100.0		0.0		
Knudson Bay beach	M	89	5.6	80.9		0.0	13.5	6
	F	85	4.7	90.6		1.2	3.5	
Kvichak escapement	M	1178	3.1	85.6		3.7	7.1	6987
(ADF&G,Igiugig)	F	1732	3.2	89.6		2.6	4.4	

Table 9. Aerial survey counts and tower count escapements of sockeye to the Kvichak lake system.

Year	Aerial survey counts (1,000s) Rivers	Creeks	Beaches Mainland	Beaches Island	Total	Tower count escapement (1,000s)	Aerial count/ Escapement (%)	Aerial observer
56	775	- -	- -	- -		9443		1
57	170	- -	- -	- -		2843		1
58	44	- -	- -	- -		535		1
59	84	- -	- -	- -		680		1
60	841	- -	- -	- -		14630		1
61	246	40	50	127	463	3706	12.5	2
62	140	52	21	12	225	2581	8.7	2
63	31	13	5	7	56	339	16.5	2
64	36	38	3	21	98	957	10.2	2
65	734	538	261	1352	2885	24326	11.9	2
66	248	153	134	46	581	3776	15.4	2
67	370	63	85	16	534	3216	16.6	3
68	131	64	14	64	273	2557	10.7	3
69	192	168	40	102	502	8394	6.0	3
70	790	574	216	506	2086	13935	15.0	3
71	177	194	27	50	448	2387	18.8	3
72	89	50	15	9	163	1010	16.1	3
73	35	18	6	6	65	227	28.6	3
74	294	269	72	122	757	4433	17.1	3
75	936	440	225	412	2013	13140	15.3	3
76	144	55	19	45	263	1965	13.4	3
77	124	20	88	28	260	1341	19.4	3
78	510	100	42	6	658	4149	15.9	3
79	1424	372	252	81	2129	11218	19.0	3
80	2189	317	77	201	2784	22505	12.4	3
81	187	85	16	20	308	1754	17.6	3
82	255	68	27	9	359	1135	31.6	3
83	743	123	75	9	950	3570	26.6	3
84	1902	359	597	84	2942	10491	28.0	4
85	672	296	260	247	1475	7211	20.5	4
86	57	16	12	5	90	1200	7.5	5
87	1313	111	397	123	1944	6100	31.9	5
88	481	94	116	15	706	4065	17.4	6
89	396	111	31	8	546	8318	6.6	6
90	141	47	19	25	232	6970	3.3	6
61-90 Means	500	162	107	125	893	5899	16.3	

Table 10. Mean tow net catches and lengths (on Sept. 1 in mm) of sockeye fry in Lakes Iliamna and Clark.

	Kvichak	Lake Iliamna		Lake Clark	
Brood Year	Escapement (millions)	Mean Catch	Mean Length	Mean Catch	Mean Length
61	3.7	90	53	13	50
62	2.6	12	45	54	50
63	0.3	5	54	3	50
64	1.0	7	62	2	50
65	24.3	170	53	23	52
66	3.8	67	57	15	47
67	3.2	78	62	47	59
68	2.6	43	62	9	50
69	8.4	386	61	11	55
70	13.9	127	44	20	38
71	2.4	4	50	15	41
72	1.0	3	58	17	48
73	0.2	2	71	12	57
74	4.4	491	54	80	55
75	13.1	252	49	105	49
76	2.0	16	53	- -	- -
77	1.3	11	61	- -	- -
78	4.1	339	62	65	56
79	11.2	282	53	60	48
80	22.5	134	61	26	59
81	1.8	37	52	58	46
82	1.1	9	68	18	57
83	3.6	242	64	40	56
84	10.5	147	46	84	51
85	7.2	63	54	16	49
86	1.2	10	60	- -	- -
87	6.1	79	63	11	56
88	4.1	22	58	21	48
89	8.3	356	55	23	47
90	7.0				

Table 11. Kvichak sockeye salmon freshwater production statistics, 1973-1989 brood years.

Brood	Run (millions)		Fry (age 0)		Smolts (millions)			Adult returns (millions)		
			Index	Mean						
year	Total	Escape.	catch	length	Age 1	Age 2	Total	From age 1	From age 2	Total
73	0.3	0.2	3	65	- -	3		1.4	0.8	2.3
74	4.6	4.4	453	54	108	114	223	8.1	17.4	25.5
75	14.9	13.1	238	49	78	213	292	6.7	29.0	35.8
76	3.0	2.0	21	50	32	26	58	5.8	4.1	9.9
77	1.8	1.3	15	58	29	10	39	2.7	0.3	3.0
78	8.0	4.1	314	62	182	32	215	2.7	2.0	4.7
79	24.6	11.2	262	52	220	89	309	19.8	20.4	40.2
80	35.2	22.5	124	61	150	76	226	4.3	8.2	12.5
81	7.0	1.8	39	51	7	38	45	1.0	1.1	2.1
82	3.0	1.1	9	66	52	2	54	1.0	0.6	1.6
83	20.1	3.6	223	64	24	53	77	11.4	1.7	13.1
84	22.8	10.5	141	46	83	330	413	4.3	18.8	23.1
85	12.2	7.2	59	54	11	87	98	2.2	13.1+	15.3+
86	2.0	1.2	10	60	13	7	20	0.7+		
87	9.4	6.1	79	63	152					
88	6.8	4.1	22	58						
89	19.8	8.3	356	55						
90	17.4	7.0								
91										

Table 12. Summary of 1990 measurements in Lake Aleknagik (Wood River Lakes).

Measurement and years measured	Dates	1990	Past years Average	Past years Range
1. Date of ice breakup 1949-		19-May	1-Jun	14 May, 16-Jun
2. Water temperature, 0-20m (C) 1958-	25-Jun	6.1	5.7	3.7, 9.2
	15-Jul	9.1	8.4	5.7, 12.0
	5-Aug	10.7	10.7	7.7, 14.0
	1-Sep	10.5	11.1	9.3, 13.0
3. Water transparency Secchi depth (m) 1962-	25-Jun	6.8	8.3	5.5, 10.5
	15-Jul	9.2	8.4	5.0, 10.9
	5-Aug	9.2	9.5	6.3, 11.9
	1-Sep	6.8	9.4	5.8, 12.1
4. Average daily solar radiation (gm/cal/cm) 1964-	June 16-30	420	427	283, 572
	July 1-15	385	405	284, 543
	July 16-31	344	358	192, 485
	Aug. 1-15	297	311	203, 386
	Aug. 16-31	263	260	165, 420
	Sept. 1-15	200	216	114, 300
5. Lake level (cm) 1952-	June 1-15	161	138	84, 222
	June 16-30	123	149	102, 218
	July 1-15	90	130	75, 191
	July 16-31	73	105	54, 172
	Aug. 1-15	81	84	34, 173
	Aug. 16-31	81	80	30, 184
	Sept. 1-15	84	80	29, 131
6. Chlorophyll "a", 0-20m (mg/m2) 1963-	25-Jun	30	27	10, 45
	15-Jul	24	27	10, 43
	5-Aug	23	21	6, 36
	1-Sep	20	22	12, 37
7. Zooplankton volume (ml/m2) 1967-	25-Jun	56	52	20, 168
	15-Jul	80	82	45, 161
	5-Aug	156	121	67, 226
	1-Sep	76	65	26, 107
8. Mean length of sockeye fry (mm) 1958-	1-Sep	57.7	56.8	43.4,66.7

Table 13. Mean lengths (live,mm) of sockeye fry (Sept. 1) and age 1 smolts from the Wood River system.

		Fry mean length 9/1		Age 1 smolt mean lengths				
					Through 7/20		Through 7/31	
Brood year	Smolt year	Lake Aleknagik	Lake system	1st 20 days of migration	Mean	Range	Mean	Upper range
49	51						91.0	
50	52						87.0	
51	53						86.0	
52	54			87.0	87.5	86.4-91.9		
53	55			87.4	85.7	82.3-89.2	86.0	89.2
54	56			78.6	82.1	76.9-83.3	82.7	90.2
55	57			75.5	76.7	67.2-84.4		
56	58				82.0			
57	59	62.1	61.7	85.0	87.0	83.5-99.5		
58	60	62.7	60.1	88.5	88.0	86.3-89.7	88.0	95.4
59	61	55.5	53.9	80.3	81.7	79.3-88.3		
60	62	58.4	56.8	78.9	80.1	76.3-88.5	80.1	93.1
61	63	54.1	56.7	81.9	82.8	79.6-91.9		
62	64	62.1	58.6	85.9	83.7	80.8-88.1		
63	65	60.4	56.0	84.7	85.4	83.7-87.8		
64	66	53.6	53.4	77.1	77.1	74.2-80.3		
65	67	47.5	49.5	78.6	77.7	75.5-78.6		
66	68	43.4	54.3					
67	69	57.9	64.1	88.9	89.1			
68	70	61.4	61.3	87.2	86.7			
69	71	59.0	60.4					
70	72	54.6	57.2					
71	73	54.8	54.5					
72	74	66.7	60.6					
73	75	62.8	63.6	83.2	82.5	81.2-88.8		
74	76	55.3	51.9	80.1	82.3	76.8-84.7	83.5	87.5
75	77	49.8	49.4	68.6	68.9	63.6-77.9	69.2	77.9
76	78	48.0	51.9	72.4	78.3	66.8-85.0	79.0	89.1
77	79	62.7	61.6	83.6	87.6	83.3-95.5	89.6	97.4
78	80	51.5	54.2	69.8	76.6	66.3-82.0	77.0	82.0
79	81	56.4	48.7	79.3	84.4	78.0-91.9	86.6	94.9
80	82	51.3	54.6	76.6	77.9	72.6-82.1	78.0	82.1
81	83	52.2	52.7	78.1	85.5	77.0-92.1	86.0	93.9
82	84	63.9	61.1	86.8	90.5	84.5-112.1	90.8	112.1
83	85	64.2	62.7	89.2	90.2	87.9-94.4	90.9	99.6
84	86	56.3	55.0	86.8	86.5	84.8-91.2		
85	87	58.4	54.7	83.9	86.0	82.0-85.6	85.6	93.5
86	88	57.5	54.8	77.5	82.2	76.0-94.5	84.4	100.1
87	89	58.8	56.9				91.0	
88	90	55.4	56.2					
89	91	57.7	58.5					
90	92							

Table 14. Occurrance and numbers of juvenile sockeye in stomachs of Arctic char collected by hook and line from Little Togiak River during about 30 days after ice out.

Year	Date of ice out	Range in sampling dates	Number of char examined	Mean length (mm)	Percent of char with: Fry	Smolt	Mean number per char Fry	Smolt	Sockeye escape. year-2
72	6/17	6/26-7/10	82	446	34	60	2.8	4.5	55
73	6/08	6/19-7/03	121	446	34	44	1.9	2.9	24
74	5/27	6/11-25	64	429	19	39	0.8	1.6	14
75	6/15	6/22-7/13	71	415	9	36	0.2	1.8	14
76	6/17	6/19-7/13	96	418	11	56	0.4	2.2	48
77	6/13	6/11-7/11	325	403	30	17	7.0	0.4	30
78	6/02	6/07-25	316	437	7	42	0.2	1.5	18
79	5/24	6/06-22	178	438	32	25	1.8	1.2	26
80	5/27	6/09-25	278	459	27	81	1.4	9.4	45
81	5/28	6/12-25	124	415	3	31	0.1	1.4	44
82	6/15	6/17-7/05	105	450	18	61	1.8	6.4	81
83	5/27	6/19-7/03	78	424	0	14	0.0	0.3	60
84	5/26	6/20-7/02	56	408	0	18	0.0	0.4	36
85	6/17	6/15-7/06	60	437	22	30	1.6	1.2	31
86	6/04	6/16-7/05	61	437	21	56	0.4	2.7	17
87	6/01	6/14-7/05	51	451	6	78	0.1	4.9	21
88	6/05	6/16-29	43	431	7	26	0.1	0.8	21
89	6/17	6/20-7/15	105	388	37	38	2.2	1.3	15
90	5/28	6/07-24	72	391	35	11	1.8	0.3	19
91									15

Table 15. Daily counts of sockeye salmon spawners in Hansen Creek (Lake Aleknagik) in 1990. Dead fish were marked and removed on each survey.

		In creek				
Date	Estimated off mouth	Live	Natural dead	Bear-kill dead	Cumulative dead	Live plus cumulative dead
7/27	Too many	0	0	0	0	0
28	"	453	9	0	9	462
29	"	1562	2	4	15	1577
30	"	1961	4	0	19	1980
31	"	3027	10	157	186	3213
8/1	"	3380	6	9	201	3581
2	"	3416	15	107	323	3739
3	50?	3386	8	57	388	3824
4	50	- -	31	118	537	- -
5	50	- -	46	58	641	- -
6	25	3825	55	47	743	4593
7	25	- -	95	77	915	- -
8	100	3226	112	132	1159	4485
9	50	- -	173	79	1411	- -
10	no survey					
11	no survey					
12	20	2951	947	104	2462	5433
13	no survey					
14	0	2812	835	35	3332	6144
15	no survey					
16	no survey					
17	0	1284	1586	210	5128	6412
18	2	951	365	139	5632	6583

Table 16. Age compositions (%) of sockeye spawners in the Wood River Lakes in 1990.

	Males						Number	Females					Number
Location	1.1	1.2	2.2	1.3	2.3	1.4	of fish	1.2	2.2	1.3	2.3	1.4	of fish
Hansen	3.8	87.9		8.3			240	93.3		6.7			327
Happy		73.0		27.0			100	58.1		41.9			124
Bear		77.6		22.4			98	81.7		18.3			104
Ice		62.9		37.1			105	50.5		49.5			99
Agulowak		24.8		75.2			105	15.9		81.8	2.3		132
Wood		66.3		33.7			83	85.0		15.0			100
Fenno		22.2	1.0	76.8			99	34.8		65.2			92
Stovall		58.2		41.7			103	69.9		30.1			103
Lynx		13.7		86.3			95	18.5		81.5			124
Pick		35.3		64.7			102	43.3		56.7			127
LT River		22.0	2.4	74.0	1.6		127	17.8	1.9	80.3			107
N4-N6 beach		43.1	1.0	55.9	1.0		102	28.6	5.1	65.3	1.0		98
Kema		78.6	3.6	17.9			28	88.2		11.8			17
Hidden Lake		78.0	1.0	21.0			100	76.5		23.5			102
Anvil Bay beach		27.4	0.8	71.8			117	30.8	3.8	64.7	0.7		133
Agulukpak		14.1	2.3	79.7	2.3	1.6	128	5.1	0.9	88.9	5.1		117
LT beaches		47.2	11.1	38.9	2.8		36	39.5	9.9	50.6			81
Moose		76.0		24.0			100	76.7		23.3			103
Grant River		82.7	1.0	16.3			104	69.1	1.8	29.1			55
Wood River ADF&G tower		45.3	0.5	51.4	0.3	1.1	753	50.8	0.6	45.5	0.6	0.8	1001

Table 17. Numbers of pink salmon observed on sockeye spawning streams in the Wood River Lakes.

Lake/stream	Year 68	70	72	74	76	78	80	82	84	86	88	90
Aleknagik												
Mission	- -	- -	- -	- -	- -	- -	- -	1	0	0	0	0
Whitefish	- -	0	0	0	0	0	0	51	0	0	0	0
Eagle	- -	0	0	0	- -	0	0	0	0	0	0	0
Yako	- -	0	0	0	0	0	0	0	0	0	0	0
Hansen	0	0	0	0	0	0	0	0	0	0	0	0
Bear	0	0	0	0	0	0	2	0	0	0	0	0
Happy	0	0	0	0	0	0	0	0	0	0	0	1
Ice	98	20	0	0	++	0	0	0	++	0	++	50
Nerka												
Fenno	0	0	0	0	0	7	0	5	0	0	0	20
Stovall	19	0	0	0	0	0	0	2	0	0	0	10
Lynx	1	0	0	0	0	0	0	0	1	1	0	75
Pick	0	0	0	0	0	0	0	0	0	0	0	10
Elva	- -	0	0	0	0	0	0	0	1	0	0	38
Hidden	0	0	1	0	0	0	0	8	0	0	0	20
Kema	0	0	0	0	0	0	0	0	3	0	0	15
Beverley												
Moose	0	0	0	0	0	0	- -	1	- -	0	0	0
Kulik												
Grant	0	0	0	0	1	0	- -	0	2	- -	0	- -
Total observed	118	20	1	0	3+	7	2	68	7+	1	1+	239
Aerial count in 1,000s for Wood River, Agulowak River, and Youth Creek	- -	- -	- -	45	20	205	31	37	81	- -	- -	- -
Nushagak catch in 1,000s	1705	418	68	414	741	4369	2311	1286	3154	281	249	53

++= numerous, i.e. no count but more than 10 fish.

Table 18. Even-year pink salmon runs to the Nushagak District, in thousands of fish.

		Escapement							
Year	Catch	Nuyakuk tower	Other Nushagak(1)	Total Nushagak(2)	Wood River	Igushik River	Snake River	Total District	Run
58	1114	- -	- -	3300	(99)	(28)	(5)	3432	4546
60	290	146	(20)	166	(4)	(1)	(4)	175	465
62	880	494	6	500	25	12	6	543	1423
64	1498	743	165	908	2	1	+	911	2409
66	2337	1442	(202)	1644	(49)	(14)	(3)	1710	4047
68	1705	2161	(303)	2464	(74)	(22)	(4)	2564	4269
70	418	153	(21)	174	(5)	(2)	+	181	599
72	68	59	(8)	67	(2)	(1)	+	70	138
74	414	456	76	532	45	8	1	586	1000
76	741	701	135	836	20	5	+	861	1602
78	4369	7190	1972	9162	205	16	3	9386	13755
80	2311	2537	213	2750	31	4	1	2786	5097
82	1286	1538	73	1611	37	8	1	1675	2943
84	3154	2602	231	2833	81	6	6	2926	6080
86	281	- -	- -	72	(2)	(1)	+	75	356
88	249	- -	- -	525	(14)	(5)	(1)	545	794
90	53	- -	- -	801	200	(8)	(2)	1011	1064

(1) Other Nushagak are aerial estimates of spawners in the Nuyakuk (below tower), Nushagak and Mulchatna Rivers. Numbers in parentheses are estimates based on mean percentages of the Nuyakuk escapement (14% for other Nushagak, 3% for Wood River, 1% for Igushik and 0.2% for Snake).

(2) Aerial estimates of the 1958 Nushagak escapement ranged from 2.5 to 4.0 million and the average is used here. The 1986,1988 and 1990 estimates are from the Portage Creek sonar and may be underestimates.

+ = less than 1,000.

Table 19. Comparison of Nushagak River pink salmon escapement estimates from sonar (Portage Creek) and tower counts plus aerial surveys (in thousands of fish).

Year	Nushagak "sonar" escapement (1)	Nuyakuk "tower" escapement	Nush/Mulchatna "aerial" escapement	Nushagak "tower+aerial" escapement (2)	Difference in escapement estimates (1-2)	Percentage difference (1-2)/(2) x100
1980	1136	1745	147	1892	-756	-40.0
1982	1425	1538	73	1611	-186	-11.5
1984	1905	2602	231	2883	-978	-33.9
Means	1489	1962	150	2129	-640	-28.5

Table 20. The Nushagak chinook salmon fishery-- fishing time, catch and catch per unit effort (days), 1972-1990.

	Chinook season and gear, 6/5-22			Early sockeye gear, 6/23-7/5			Late sockeye gear, 7/6-7/15					
Year	% of time open to fishing	Catch (100's)	Catch per day (100's)	% of time open to fishing	Catch (100's)	Catch per day (100's)	% of time open to fishing	Catch (100's)	Catch per day (100's)	Escape-ment 1,000's	Run 1,000's	Exploi-tation (%)
1972	78	301	22	19	101	34	5	39	39	25	71	65
1973	61	240	22	12	30	10	0			35	65	46
1974	50	244	27	23	31	10	70	24	3	70	102	31
1975	56	130	13	0			65	54	8	70	91	23
1976	44	296	37	15	218	54	20	44	15	100	161	38
1977	58	713	65	4	30	30	25	7	2	65	150	57
1978	53	822	82	23	136	27	90	32	3	130	249	48
1979	56	1082	83	69	306	28	100	31	3	95	252	62
1980	39	528	59	23	10	3	100	27	3	141	206	32
1981	19	656	131	54	844	106	100	94	9	150	343	56
1982	36	526	66	85	966	80	100	212	21	147	342	57
1983	36	571	71	38	516	74	100	174	17	162	299	46
1984	28	270	54	15	149	37	70	55	7	81	142	43
1985	22	179	36	12	351	117	5	7	7	116	184	37
1986	17	321	80	15	245	82	50	22	4	(43)	107	60
1987	0			13	228	76	80	161	18	(84)	132	36
1988	0			9	104	69	40	45	11	(57)	73	22
1989	0			31	135	23	100	35	4	(78)	96	19
1990	0			8	39	26	100	79	8	(64)	78	18
1991												

% of time open to fishing = hours open/hours in inclusive dates x 100.
In catch per day, days = number of days open when fishing occurred for 12 or more hours.
Catches and fishing time in "Igushik section only" openings were excluded.
Escapements estimated by aerial surveys (1972-1985) and then by sonar (1986-1990).