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REPORT TO THE ALASKA BOARD OF FISHERIES ON SPAWNING ESCAPEMENT GOAL EVALUATION FOR BRISTOL BAY SOCKEYE SALMON

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

A workshop was held on November 8-9, 1994 in Anchorage by the Alaska Department of Fish and Game to review sockeye salmon *Oncorhynchus nerka* escapement goals for major rivers in Bristol Bay. Spawner-return data were analyzed for Kvichak, Naknek, Egegik, Ugashik, Wood, and Igushik Rivers. In addition, smolt information was reviewed for Kvichak, Egegik, and Ugashik Rivers. Workshop participants recommended a point escapement goal of 10.0 million sockeye salmon for the Kvichak River in 1995. They also recommended for the Kvichak River an escapement goal range from 4 million to 8 million sockeye salmon for 1996-98, and an escapement goal range from 7 million to 10 million sockeye salmon for 1999 and 2000. No changes were recommended for point escapement goals for sockeye salmon returning to other rivers in Bristol Bay . Workshop members did recommend increasing the upper escapement goal range for Egegik River from 1.2 million to 1.4 million sockeye salmon, and increasing the upper escapement goal range for Ugashik River from 900 thousand to 1.2 million sockeye salmon.

KEY WORDS:Sockeye salmon *Oncorhynchus nerka*, Bristol Bay, Kvichak River, Naknek River, Egegik River, Ugashik River, Wood River, Igushik River, spawning escapement goal, Ricker stock-recruitment model, smolt

INTRODUCTION

Bristol Bay, Alaska, supports some of the largest sockeye salmon *Oncorhynchus nerka* runs in the world. Combined sockeye salmon runs to Bristol Bay have averaged 40.8 million for the last 10 years. Nine major river systems produce 98% of the sockeye salmon returning to Bristol Bay and include: Kvichak, Branch, Naknek, Egegik, Ugashik, Wood, Igushik, Nushagak, and Togiak Rivers. Management of Bristol Bay sockeye runs is based on achieving a specific escapement goal for each river. Individual escapement goals have been established for the major rivers since the early 1960's. Periodically, the Alaska Department of Fish and Game (ADF&G) reviews the escapement goals for Bristol Bay rivers and determines if they are still appropriate or if adjustments are required.

A formal evaluation of Bristol Bay sockeye escapement goals was conducted on November 8-9, 1994 at the ADF&G office in Anchorage. The escapement goal workshop was attended by 23 people which included representatives from the following organizations: ADF&G, Commercial Fisheries Management and Development Division (headquarters, regional, area, and limnology); University of Washington; and University of Alaska (Appendix A.1). The objectives of the escapement goal workshop were: 1) to establish a point escapement goal for the Kvichak River for 1995; 2) to outline the escapement goal policy for Kvichak River for the next five years; and, 3) to review the other rivers' escapement goals and recommend adjustments if necessary.

The objectives of this report are 1) to summarize pertinent information presented during the 1994 Bristol Bay escapement goal workshop; 2) to recommend a point goal for 1995 and escapement goal ranges for Kvichak River for 1996-2000; and, 3) to recommend adjustments in escapement goal ranges for Egegik and Ugashik Rivers.

METHODS

Spawner-Return Data

Spawner-return data by age were analyzed for brood years 1956-89 for Kvichak, Wood, and Igushik Rivers and for brood years 1956-88 for Naknek, Egegik, and Ugashik Rivers. Escapement goals for Nushagak and Togiak Rivers were not evaluated during the workshop. Return information for brood year 1989 were incomplete because the six-year-old age group will return in 1995. However, since this age group usually comprises less than 6% of Kvichak, Wood, and Igushik returns, the 1989 brood year was used for those systems.

Methods used to estimate total runs are described by Stratton and Crawford (1994). Numbers of spawners for each river are based on visual counts from towers located below lake outlets. Annual runs were the sum of tower counts and commercial harvests. Sport and subsistence

harvests were minor components of each river's run, therefore these catches were not included in estimates of total return.

We assumed that sockeye salmon harvested in each district originated from rivers within the district. Estimates of interceptions of stocks outside their district of origin were available for east side districts for 1983-94. These information were reviewed during the workshop and the degree interceptions affected spawner-return relationships was investigated. Although all east side stocks were intercepted outside their district of origin, spawner-return relationships were not changed significantly by taking them into account. Therefore, spawner-return data were analyzed excluding interception estimates.

Ricker stock-recruitment models (Ricker 1975) were fitted with linear and nonlinear techniques to each river's spawner-return data in an effort to estimate the number of spawners required to produce maximum sustained yield (MSY). However, results from these models were not given much weight during the escapement goal evaluation if they did not describe the observed relationship between spawners and returns i.e. model fits were not significant, or underlying assumptions were violated i.e. serially correlated residuals.

Hilborn and Walters (1992) have shown that results from stock-recruitment models can be misleading for the following reasons: 1) errors in measurement of spawners and returns; 2) lack of contrast in sizes of spawning stocks; 3) autocorrelated errors of the stock-recruitment model; and, 4) changes in spawner-return relationships through time and within stock subunits. In general, spawner-return data for east side Bristol Bay rivers (Kvichak, Naknek, Egegik, and Ugashik) did not exhibit density dependent mortality which is a basic assumption of most stock-recruitment models. Density dependent mortality may not be clearly evident in these river's spawner-return data for several reasons: 1) there are not enough data points from higher escapement levels to adequately describe reduction in returns from density dependent mechanisms; 2) freshwater and/or marine production has changed over time; and 3) factors in addition to numbers of spawners greatly affect returns. Because stock-recruitment models did not describe the relationships between numbers of spawners and numbers of returns for most east side rivers, we were unable to estimate the number of spawners required to produce MSY. Instead, spawner-return data were analyzed less formally to evaluate escapement goals (or ranges of escapements) which would produce high sustainable yields.

Brood Year Interaction

To evaluate the possible effects spawning numbers of one brood year had on the production for the following brood year within Kvichak River, we plotted the residuals (observed returns-per-spawner minus the predicted returns-per-spawner) against the number of spawners the previous brood year. This analysis was similar to the one performed by Eggers and Rogers (1987). Predicted returns-per-spawner were estimated from a linear Ricker stock-recruitment model using recent spawner-return data (1973-89). We displayed the residuals graphically to look for any trend. If the residuals were randomly distributed, similar numbers positive and negative for

given spawning numbers, we interpreted these as lacking trend, and would conclude that brood year interaction was not evident. If residuals were mostly negative or mostly positive for given escapement ranges, we interpreted this as displaying a negative or positive trend and evidence for brood year interaction. Residuals were identified by brood year and were coded by cycle year.

Distribution Of Spawners

The Kvichak River system is very complex with more than 100 different spawning areas including river, streams, and beaches. D.E. Rogers (University of Washington, Seattle, personal communication) compiled aerial survey counts from key index areas and classified them into four habitat types 1) rivers, 2) creeks and ponds, 3) mainland beaches, and 4) island beaches. Survey counts by habitat type were reviewed for trends through time.

Smolt Information

Numbers of smolt migrating from Kvichak River have been counted with hydroacoustic equipment since 1971, from Egegik River since 1982, and from Ugashik River since 1983 (Crawford and Cross 1994). The relationship between numbers of smolt and spawners and the relationship between adult returns and numbers of smolt were investigated. If the relationships were significantly correlated, simple linear regression models were built to describe them. For the Kvichak River, a regression model based on adult returns and numbers of smolt was used to estimate the numbers of smolt required to produce a 15-million sockeye return and a 20-million sockeye return. A regression model relating smolt and spawners was then used to estimate the number of spawners required for the two return sizes.

RESULTS

Kvichak River

Escapement Goal History

The management strategy for the Kvichak River from 1962 through 1984 was based on the occurrence of cyclic dominance in which some depensatory mechanism, independent of the fishery, suppressed production from small spawning escapements. Since the cycle was thought to be a naturally occurring phenomenon, management was based upon obtaining cyclic spawning goals. Fishing in the Naknek-Kvichak District was regulated to obtain large spawning escapements (10 million to 15 million) for the peak-cycle (dominant) run, an intermediate spawning escapement (4 million to 6 million) for the pre-peak (sub-dominant) run, and small

spawning escapements (1 million to 2 million) for the other three off-cycle years (Table 1 and Figure 1).

Changes in the Kvichak River run since 1978, particularly the occurrence of large runs during off-cycle years like 1983, prompted re-evaluation of management based on the cyclic dominance theory. Results from analyses conducted by Rogers and Poe (1984) and Eggers and Rogers (1987) suggested that Kvichak River run cycles were largely caused by a combination of: 1) weather; 2) small spawning escapements; and, 3) brood year interaction between the peak-cycle years which had very large escapements and the following brood years which experienced reduced production. Eggers and Rogers (1987) also suggested that the commercial fishery was the depensatory factor responsible for the recent pronounced cycle, because off-cycle runs were exploited at much greater rates than either pre-peak or peak runs.

In 1985, ADF&G began a transition from a cyclic goal policy to a more static goal policy (Fried 1984). The objective was to increase spawning escapements during off-cycle years, and decrease escapement during peak years to moderate the future fluctuations in production. Since the initial policy change in 1985, there have been three formal escapement goal evaluations for the Kvichak River; 1987, 1991, and the workshop held in 1994. Results from these escapement goal workshops have been reported each year to the Board of Fisheries (Cross 1991).

The escapement goal policy adopted in 1987 and 1991 was to allow annual spawning escapement goals to fluctuate within a range from 4 million to 10 million and to increase escapements during off-cycle years. A lower bound of 4 million spawners was established because escapements below this level had often produced poorly. An upper bound of 10 million spawners was established because escapements greatly above this level have been shown to reduce production the following brood year. A range of goals, rather than a single goal, was established to allow for 1) fluctuations in run sizes; 2) variations in spawner distribution; 3) potential effects of brood year interactions between progeny of successive spawning escapements; and, 4) limited observations of returns from spawning escapements between 4 million and 10 million.

Spawner-Return Data

The number of Kvichak River spawners has ranged from 227 thousand in 1973 to 24.3 million in 1965; while returns have ranged from 289 thousand for brood year 1958 to 55.0 million for brood year 1960 (Appendix Table A.1 and Figure 2). Returns-per-spawner for Kvichak River have varied from a low of 0.2 for brood year 1968 to a high of 10.8 for brood year 1973 and averaged 2.6 for all available brood years (Figure 3). Sockeye salmon production increased for Kvichak River after brood year 1972 as shown by increased numbers of returns-per-spawner (Figure 3). Returns-per-spawner averaged 1.9 from 1956-72 and increased to 2.8 from 1974-89. In addition, returns-per-spawner were below replacement six times from 1956-72; while returns-per-spawner were only below replacement once from 1973-89.

Although the annual number of sockeye salmon spawning in the Kvichak River has varied greatly, there were less than 4 million spawners for 19 out of 33 brood years (1956-89; Figure

4). For the 19 brood years with <4 million spawners, returns were below replacement for 5 years and just barely above replacement for 6 years. There have been 8 brood years from 1956-89 which have had spawners ranging from 4 million to 10 million and all these years have produced well except brood year 1969. Similarly, brood years with spawners >10 million (7 brood years) have produced well with the exception of 1970 and 1980. The two largest spawning escapements in Kvichak River occurred in 1965 (24.3 million) and 1980 (17.5 million). The 1965 spawning escapement produced a return of 45.0 million; while the 1980 spawning escapement failed to replace itself and produced only a 13.0 million return.

Stock-recruitment models did not explain the observed relationship between spawners and returns for the Kvichak River, therefore we were unable to precisely estimate the number of spawners required to produce MSY. However, from spawner-return information to date, it appears that spawning escapements from 4 million to 10 million consistently produce high returns. Escapements for the upcoming 5 brood years are from 4 million to 10 million (Figure 4).

Brood Year Interaction

Brood years interaction within Kvichak River was not evident for spawning escapements below 10 million, there was no trend evident in the residuals (observed returns-per-spawner minus predicted returns-per-spawner plotted against spawning escapements the previous year; Figure 5). However, for spawning escapements greater than 10 million the residuals were mostly negative especially for post-cycle years. This negative trend in the residuals supported the theory that very large escapements during peak-cycle years depressed the production from small escapements during post-cycle years. However, there was no evidence that brood year interaction had occurred for more recent brood years (1986-89) in which spawning escapements goals were from 4 million to 10 million.

Spawner Distribution

Distribution of spawners among spawning habitat types within the Kvichak River has varied throughout the years, however a couple of trends are evident (Figure 6). Cycles moderated after 1978 for all runs to the various spawning habitats except for runs to the island beaches which still show a strong 5-year cycle. Spawning occurred in appreciable numbers on the island beaches only during peak-cycle years. Also, there appeared to be a decreasing trend in the numbers of island beach spawners from 1965-94. Some of the decrease in the numbers of island beach spawners may have been due to a change in our aerial survey program in 1988. In the past, aerial surveys were conducted over a comprehensive time period each year, therefore the probability of surveying during peak spawning was high for all areas. In more recent years the number of replicate surveys has been reduced, and timing of the surveys became critical. An accurate aerial survey of beach spawners is only possible during peak spawning activity. Still a decline in beach spawners began prior to 1988 when surveys were reduced.

Smolt Information

There was a significant ($F=45$, $P<0.005$) positive relationship between total number of smolt and numbers of spawners in the Kvichak River (Figure 7). There was also a significant ($F=23$, $P<0.005$) positive relationship between numbers of adult returns and numbers of smolt. An estimate of the numbers of spawners required for a given return can be made using these relationships. Based on these relationships an estimated 5 million spawners would be required to produce a 10-million return, and an estimated 13 million spawners would be required to produce a 20-million return.

Escapement Goal Recommendations

There was unanimous agreement among all workshop participants that the current escapement goal policy for Kvichak River sockeye salmon should continue. They agreed that escapement goals should be from 4 million to 10 million with the objective of moderating Kvichak River cycles while maintaining overall sockeye production. Since 1987, ADF&G successfully increased off-cycle escapements from 2 million to 4 million to 5 million, and reduced pre-peak and peak cycle escapements from 14 million to 6 million to 10 million. The reduction of peak-cycle escapements to $\leq$10 million appears to have eliminated the negative effects of brood year interaction.

Although there are limited returns from escapements managed under the current escapement goal policy, it appears that off-cycle runs have increased and pre-peak and peak cycle runs have remained high (Figure 8). Off-cycle runs from 1976-89 which were produced from escapements managed under the cyclic goal policy averaged 5.7 million sockeye salmon. Off-cycle runs from 1991-93 which were produced from escapements managed under the current policy averaged 9.7 million sockeye salmon.

ADF&G has tried to increase off-cycle escapements gradually to minimize the effects on the fishery. The difference between allowable catches over time from the two escapement goal policies was compared for the years 1989-95 (Table 2). The total allowable catches which would have resulted under the two escapement goal policies were similar for years 1989-95 (66.3 million for cyclic goal policy, and 65.3 million for the current policy).

1995 Point Escapement Goal. An escapement goal range for 1995 from 7 million to 10 million was established for the Kvichak River during the 1991 Bristol Bay escapement goal workshop. All participants of the 1994 workshop agreed that the Kvichak River point escapement goal for 1995 should be 10.0 million sockeye salmon (Table 3). The decision for a 10.0 million point goal was based on the following: 1) 1995 is traditionally the peak-cycle year for Kvichak River; 2) good future production was expected from 10.0 million spawners; 3) current information indicated that brood year interaction was not a problem from spawning escapements $\leq$10.0 million; 4) 1995 is the cycle year in which island beach spawners traditionally returned in appreciable numbers and because their numbers were declining efforts should be made to assure

adequate escapement to this spawning area; and 5) the 1995 Kvichak forecast was good with a predicted total run of 26.7 million.

1996-2000 Escapement Goal Ranges. Workshop participants recommended an escapement goal range of 4 million to 8 million sockeye salmon for the years 1996 through 1998, and an escapement goal range of 7 million to 10 million sockeye salmon for 1999 and 2000 (Table 3). The group felt it was better to set ranges for future goals and to wait to establish the actual point goal until all possible information was available. Additional information which would be available the fall prior to the season included: smolt and sibling information for the run in question, information of spawning distribution and actual numbers of spawners the previous years, and a more accurate preseason forecast.

Naknek River

Spawner-Return Data

The current escapement goal for Naknek River is 1.0 million sockeye salmon and the escapement goal range is 800 thousand to 1.4 million. The numbers of Naknek River sockeye spawners have ranged from 278 thousand in 1958 to 3.6 million in 1991(Appendix Table A.2 and Figure 9). Escapements for the last 10 years have averaged 1.7 million sockeye salmon. Returns have ranged from 745 thousand for brood year 1968 to 13.7 million for brood year 1986. Returns-per-spawner for Naknek River have varied from a low of 0.7 for brood year 1968 to a high of 6.9 for brood year 1986 and averaged 3.2 for all available brood years (Appendix Table A.2 and Figure 10). Sockeye salmon production increased for Naknek River after brood year 1972 as shown by increased numbers of returns-per-spawner (Figure 10). Returns-per-spawner averaged 2.7 from 1956-72 and increased to 3.7 from 1973-88. Returns-per-spawner only fell below replacement twice, in 1959 and 1968.

Stock-recruitment models did not explain the observed relationship between spawners and returns for the Naknek River, therefore we were unable to precisely estimate the number of spawners required to produce MSY. However, from spawner-return information to date, it appeared that spawning escapements from 1 million to 2 million have on average produced high returns (Figure 11). Of the brood years available, 9 brood years had spawning escapements <800 thousand and returns from these escapements averaged 1.7 million; 15 years had spawning escapements from 1 million to 2 million and returns from these escapements averaged 4.5 million; and 3 years had spawning escapements >2.0 million and returns from these averaged 3.9 million.

Escapements for four out of the next six brood years are greater than 1.5 million, one of which is a record 3.6 million sockeye escapement (Figure 11). Returns from these upcoming escapements should provide more precise estimates of production levels from high numbers of sockeye spawners in the Naknek River.

Escapement Goal Recommendations

Workshop participants recommended no changes for the Naknek River sockeye salmon escapement goal. They agreed there was no compelling reason to change the goal at this time. Available spawner-return data does suggest that the point goal and/or the range could possibly be increased, however the group recommended waiting until returns from the next five brood years were analyzed before making any changes.

Egegik River

Spawner-Return Data

The current escapement goal for Egegik River is 1.0 million sockeye salmon and the current escapement goal range is 800 thousand to 1.2 million. The numbers of Egegik River sockeye spawners have ranged from 246 thousand in 1958 to 2.8 million in 1991(Appendix Table A.3 and Figure 12). Escapements during the last 10 years have averaged 1.7 million sockeye salmon. Returns to Egegik River have ranged from 459 thousand for brood year 1968 to 25.9 million for brood year 1987. Returns-per-spawner for Egegik River have varied from a low of 1.3 for brood year 1963 to a high of 20.3 for brood year 1987 and averaged 5.9 for all available brood years (Appendix Table A.3 and Figure 13). Sockeye salmon production increased significantly for Egegik River, beginning in brood year 1976. Returns-per-spawner averaged 3.1 from 1956-72 and increased to 8.9 from 1973-88. Returns-per-spawner have never been below replacement for Egegik River.

Stock-recruitment models did not explain the observed relationship between spawners and returns for the Egegik River. There was no evidence of density dependent mortality in the Egegik River spawner-return data. Consequently, we were unable to estimate the number of spawners required to produce MSY for Egegik River. However, from spawner-return information to date, it appeared that spawning escapements from 1.0 million to 1.6 million have on average produced high returns (Figure 14). Of the brood years available, 12 brood years had spawning escapements <800 thousand and returns from these escapements averaged 3.4 million; while 16 brood years had escapements ranging from 1.0 million to 1.6 million and returns from these escapements averaged 8.2 million.

Escapements for five of the next six brood years are greater than 1.6 million, and three escapements are greater than previously observed. Returns from these upcoming escapements should provide more precise estimates of production levels from high numbers of sockeye spawners in the Egegik River.

Smolt Information

The relationship between numbers of smolt and numbers of spawners for Egegik River was unclear (Figure 15). Numbers of smolt emigrating from Egegik River did not show an increasing trend with numbers of spawners, especially when numbers of spawners were greater than 1.6 million sockeye salmon. Numbers of smolt produced by brood years 1989-91 which had escapements greater than 1.6 million, did not increase as expected with the increase in numbers of spawners. Workshop participants viewed these data as the first possible indication of density dependent mortality for Egegik River. There was a significant ($F=25$, $P<0.005$) positive relationship between numbers of adult returns to Egegik River and numbers of smolt (Figure 15). Participants all agreed that returns from brood years 1989-94 were important to evaluate because they all had large escapements and should better define production levels from spawners in excess of 1.6 million.

Escapement Goal Recommendations

Workshop participants recommended the point escapement goal for Egegik River remain at 1.0 million sockeye salmon, but that the upper bound of the escapement goal range be raised from 1.2 million to 1.4 million sockeye salmon (Table 4). Participants felt there was no compelling reason to change the point escapement goal at this time, but that the escapement goal range was too narrow. Available spawner-return data suggested that escapements from 1.0 million to 1.6 million on average produced high returns, but smolt information indicated that escapements >1.6 million may not produce as well. Therefore the group felt the data supported escapements 800 thousand to 1.4 million, but thought upcoming brood years should be evaluated prior to changing the point escapement goal.

Ugashik River

Spawner-Return Data

The current escapement goal for Ugashik River is 700 thousand sockeye salmon and the current range is 500 thousand to 900 thousand. The numbers of Ugashik River sockeye spawners have ranged from 39 thousand in 1973 to 3.3 million in 1980 (Appendix Table A.4 and Figure 16). Escapements during the last 10 years have averaged 1.3 million sockeye salmon. Returns to Ugashik River have ranged from 39 thousand for brood year 1968 to 7.8 million brood year 1980. Returns-per-spawner for Ugashik River have varied from a low of 0.4 for brood year 1963 to a high of 25.2 for brood year 1978 and averaged 4.8 for all available brood years (Appendix Table A.4 and Figure 17). Sockeye salmon production increased significantly for Ugashik River beginning in brood year 1974. Returns-per-spawner averaged 2.1 from 1956-72 and increased to 7.7 from 1973-88. For brood years 1956-72, returns-per-spawner were below replacement seven times, but have not fallen below replacement for brood years 1973-88.

Stock-recruitment models did not explain the observed relationship between spawners and returns for the Ugashik River, consequently we were unable to estimate the number of spawners required to produce MSY. However, from spawner-return information to date, it appeared that Ugashik River production increased as spawning escapements increased from 40 thousand to 500 thousand and on average good returns were produced from escapements ranging from 700 thousand to 1.3 million (Figure 18). Of the brood years available, 18 brood years had spawning escapements <500 thousand and returns from these escapements averaged 1.3 million; while 12 brood years had escapements ranging from 500 thousand to 1.3 million and returns from these escapements averaged 3.6 million. Of the brood years with escapements >1.7 million, two out of three produced high returns.

Escapements for four out of the next six brood years are >1.3 million, and two of them are >2.0 million. Returns from these upcoming escapements should provide more precise estimates of production levels from high numbers of sockeye spawners in Ugashik River.

Smolt Information

The relationship between numbers of smolt and numbers of spawners for Ugashik River was unclear (Figure 19). Numbers of smolt emigrating from Ugashik River showed no discernable trend with numbers of spawners. There was a moderately significant($F=4$, $P<0.10$) positive relationship between numbers of adult returns to Ugashik River and numbers of smolt (Figure 19).

Escapement Goal Recommendations

Workshop participants recommended the point escapement goal for Ugashik River remain at 700 thousand sockeye salmon, but the upper bound of the escapement goal range be raised from 900 thousand to 1.2 million sockeye salmon (Table 4). Available spawner-return data suggested that escapements from 700 thousand to 1.3 million produced high returns on average. Returns from two of the three escapements greater than 1.3 million were also high. Although there were spawner-return data that indicated the point escapement goal could be raised, the group thought upcoming brood years of high escapements should be evaluated prior to changing the point goal.

Wood River

Spawner-Return Data

The current escapement goal for Wood River is 1.0 million sockeye salmon and the current escapement goal range is 700 thousand to 1.2 million. The numbers of Wood River sockeye spawners have ranged from 289 thousand in 1957 to almost 3.0 million in 1980 (Appendix Table A.5 and Figure 20). Escapements into Wood River during the last 10 years have averaged 1.1 million sockeye salmon. Returns to Wood River have ranged from 449 thousand for brood year 1957 to 5.7 million for brood year 1976. Returns-per-spawner for Wood River have varied from

a low of 0.5 for brood year 1980 to a high of 7.0 for brood year 1976 and averaged 2.6 for all available brood years (Appendix Table A.5 and Figure 21). Brood years 1972-78 showed increased production compared to earlier and later years. Returns-per-spawner averaged 2.1 from 1956-72 and increased to 3.1 from 1973-89. Wood River returns-per-spawner were less than one for only two brood years, 1959 and 1980, and those years both had escapements greater than 2.0 million.

Ricker stock-recruitment models explained the observed relationship between spawners and returns for Wood River fairly well. A Ricker stock-recruitment model fitted through the Wood River 1973-89 spawner-return data with linear techniques was significant ($F= 22$, $P<0.001$), and the estimate of spawning escapement required to produce MSY was 930 thousand. An estimate of the number of spawners required for Wood River for MSY from a nonlinear Ricker model was 980 thousand. Escapements within the 800 thousand to 1.6 million range have produced good returns, while those greater than 2.0 million have not (Figure 22).

Escapement Goal Recommendations

Workshop participants recommended no changes for the Wood River sockeye salmon escapement goal. Available spawner-return information supported the current escapement goal and escapement goal ranges.

Igushik River

Spawner-Return Data

The current escapement goal for Igushik River is 200 thousand sockeye salmon and the current escapement goal range is 150 thousand to 250 thousand. The numbers of Igushik River sockeye spawners have ranged from 16 thousand in 1960 to almost 2.0 million in 1980 (Appendix Table A.6 and Figure 23). Escapements into Igushik River during the last 10 years have averaged 360 thousand sockeye salmon. Returns to Igushik River have ranged from 76 thousand for brood year 1957 to 4.0 million for brood year 1975. Returns-per-spawner for Igushik River have varied from a low of 0.2 for brood year 1980 to a high of 21.0 for brood year 1977 and averaged 5.0 for all available brood years (Appendix Table A.6 and Figure 24). Brood years 1962-65, 1973-77, and 1985-88 showed increases in returns-per-spawner compared to other years. Returns-per-spawner averaged 3.3 from 1956-72 and increased to 6.6 from 1973-89. Igushik River returns-per-spawner were less than one for nine brood years, six of which had escapements greater than 200 thousand.

The linear Ricker stock-recruitment model of 1973-89 Igushik River spawner-return data was significant ($F=37$, $P<0.001$), and the estimated number of spawners required to produce MSY was 350 thousand. An estimate of spawners required for MSY from a nonlinear Ricker model was 220 thousand. Escapements within the 150 thousand to 300 thousand range have produced good returns, while those greater than 500 thousand have not (Figure 25).

Escapement Goal Recommendations

Workshop participants recommended no changes for the Igushik River sockeye salmon escapement goal. Available spawner-return information supported the current escapement goal and escapement goal ranges.

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Table 1. History of Kvichak River sockeye escapement goals set under the cyclic goal policy, 1969-85, and recent goals, 1986-94, set under the 4-10 million range policy.

Year	Policy	Goal	Actual	Percent Deviation[a]
1969	Cyclic	6,000,000	8,394,204	40
1970	"	19,000,000	13,935,306	-27
1971	"	2,500,000	2,387,392	- 4
1972	"	2,000,000	1,009,962	-49
1973	"	2,000,000	226,554	-89
1974	"	6,000,000	4,433,844	-26
1975	"	14,000,000	13,140,450	- 6
1976	"	2,000,000	1,965,282	- 2
1977	"	2,000,000	1,341,144	-33
1978	"	2,000,000	4,149,288	107
1979	"	6,000,000	11,218,434	87
1980	"	14,000,000	22,505,268	61
1981	"	2,000,000	1,754,358	-12
1982	"	2,000,000	1,134,840	-45
1983	"	2,000,000	3,569,982	78
1984	"	10,000,000	10,490,670	5
1985	"	10,000,000	7,211,046	-28
1986	4-10 Range	5,000,000	1,179,322	-76
1987	"	5,000,000	6,065,880	21
1988	"	5,000,000	4,065,216	-19
1989	"	8,000,000	8,317,500	4
1990	"	6,000,000	6,970,020	16
1991	"	4,000,000	4,222,788	5
1992	"	6,000,000	4,725,864	-21
1993	"	5,000,000	4,025,166	-19
1994	"	8,000,000	8,337,840	4
1969-94 Avg		6,000,000	6,000,000	- 1
1969-85 Avg		5,600,000	6,400,000	3
1986-94 Avg		5,800,000	5,300,000	-9

[a] Percent deviation = (Actual-Goal)/Goal

Table 2. Comparisons of catch and escapement scenarios for 1989-95 based on actual runs and escapements set under cyclic goal policy versus 4-10 million range policy.

Year	Actual Run	Cyclic Goal Policy		4-10 Million Range Policy	
		Escapement Goal	Allowable Catch	Escapement Goal	Allowable Catch
1989	19.8	6.0	13.8	8.0	11.8
1990	17.4	14.0	3.4	6.0	11.4
1991	8.1	2.0	6.1	4.0	4.1
1992	10.4	2.0	8.4	6.0	4.4
1993	9.3	2.0	7.3	5.0	4.3
1994	22.2	6.0	16.2	8.0	14.2
1995	25.1	14.0	11.1	10.0	15.1
1989-95 Total		46.0	66.3	47.0	65.3

Table 3. Recommended spawning escapement goals for sockeye salmon returning to Kvichak River, 1995-2000.

Year	Millions of Sockeye Salmon	
	Point Goal	Range
1995	10.0	7.0 - 10.0
1996	Finalize after forecast	4.0 - 8.0
1997	" "	4.0 - 8.0
1998	" "	4.0 - 8.0
1999	" "	7.0 - 10.0
2000	" "	7.0 - 10.0

Table 4. Current spawning escapement goals in millions of sockeye salmon for Bristol Bay Rivers and recommended changes.

River	Current Goals		Recommended Goals	
	Point	Range	Point	Range
Naknek	1.0	0.8 - 1.4	NO CHANGE	
Egegik	1.0	0.8 - 1.2	Same	0.8 - 1.4
Ugashik	0.7	0.5 - 0.9	Same	0.5 - 1.2
Wood	1.0	0.7 - 1.2	NO CHANGE	
Igushik	0.2	0.15 - 0.25	NO CHANGE	
Nushagak	0.55	0.34 - 0.76	NO CHANGE	
Togiak	0.15	0.14 - 0.25	NO CHANGE	

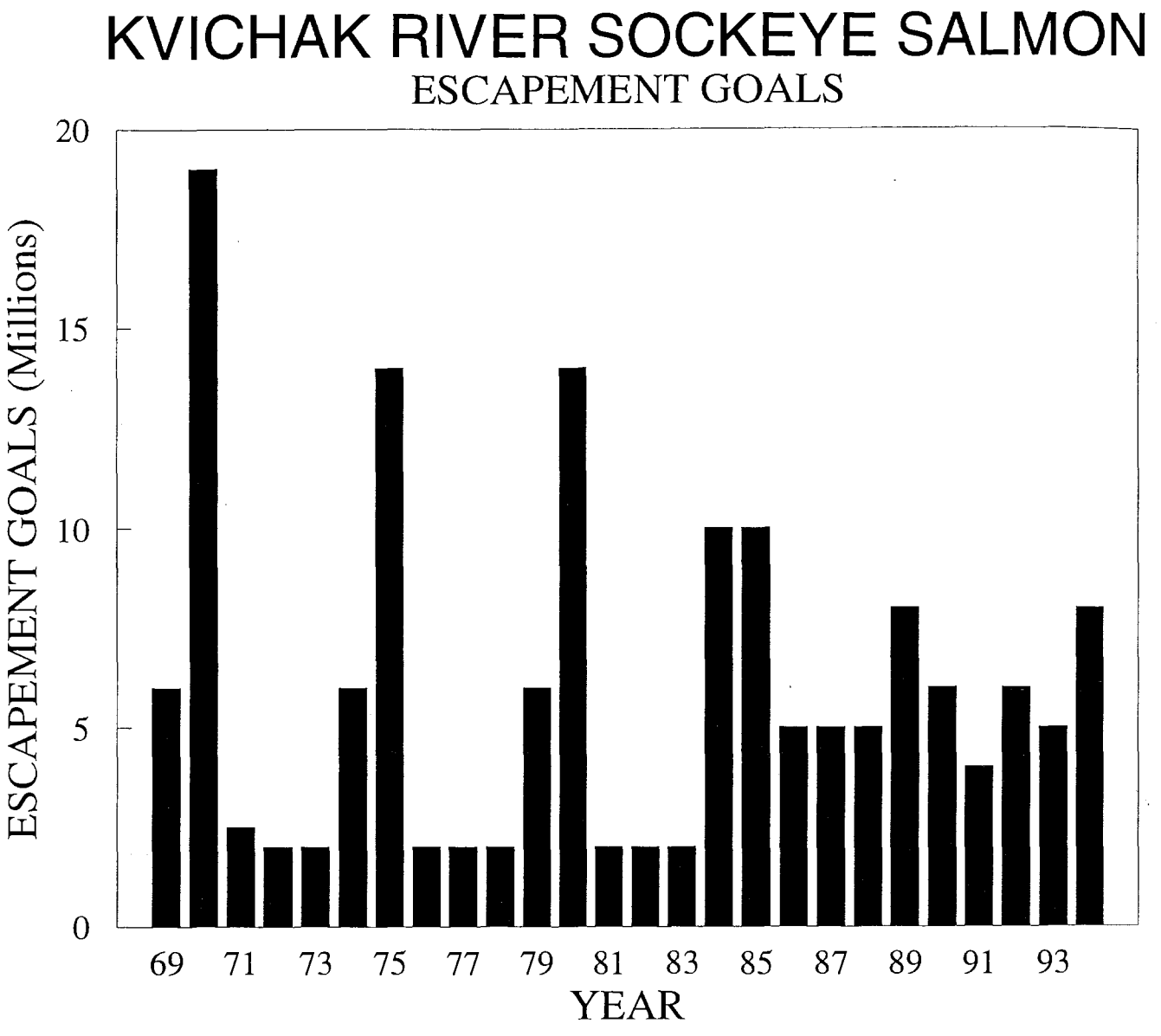


Figure 1. Spawning escapement goals for Kvichak River sockeye salmon, 1969-94.

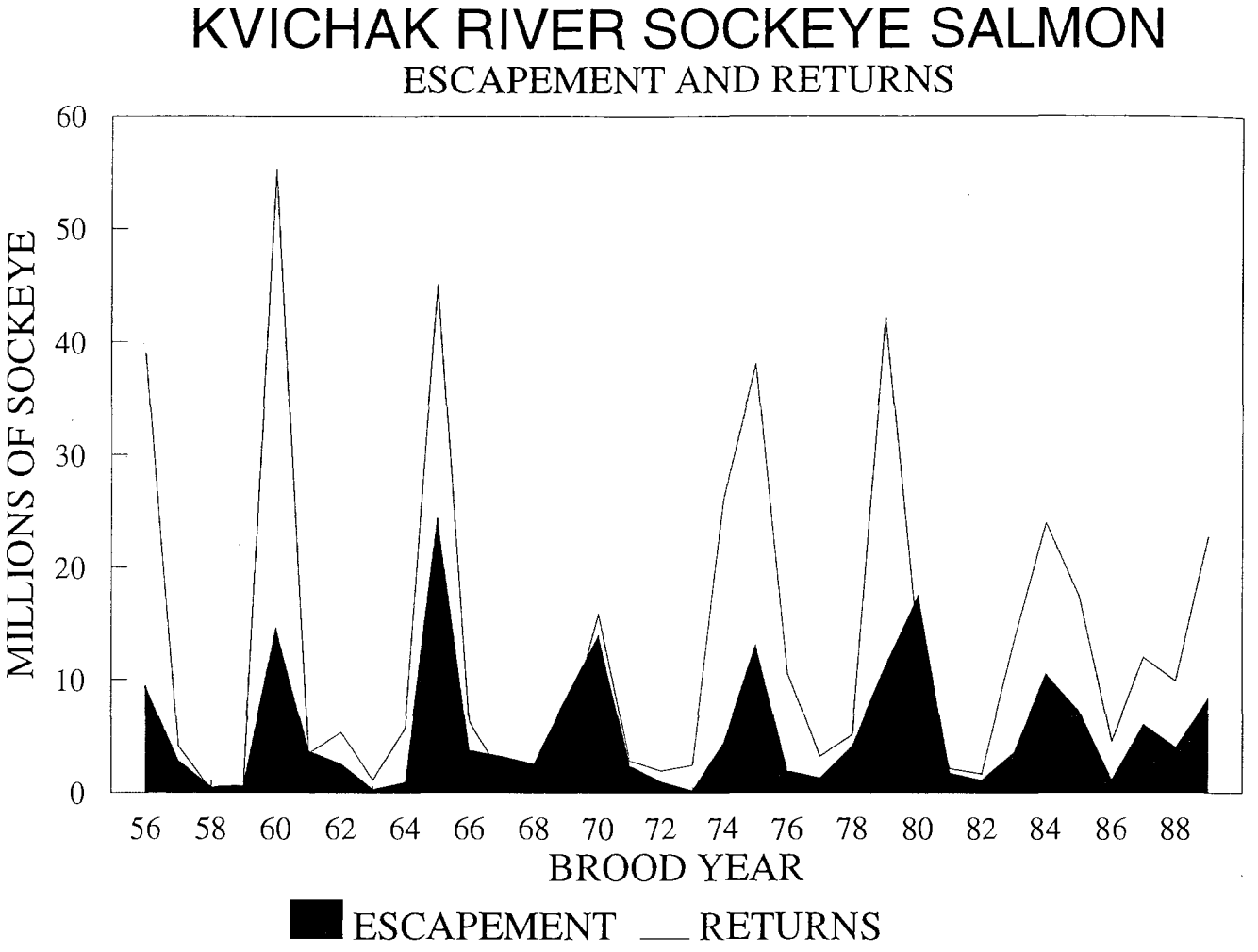


Figure 2. Kvichak River sockeye salmon escapement and returns by brood year, 1956-89.

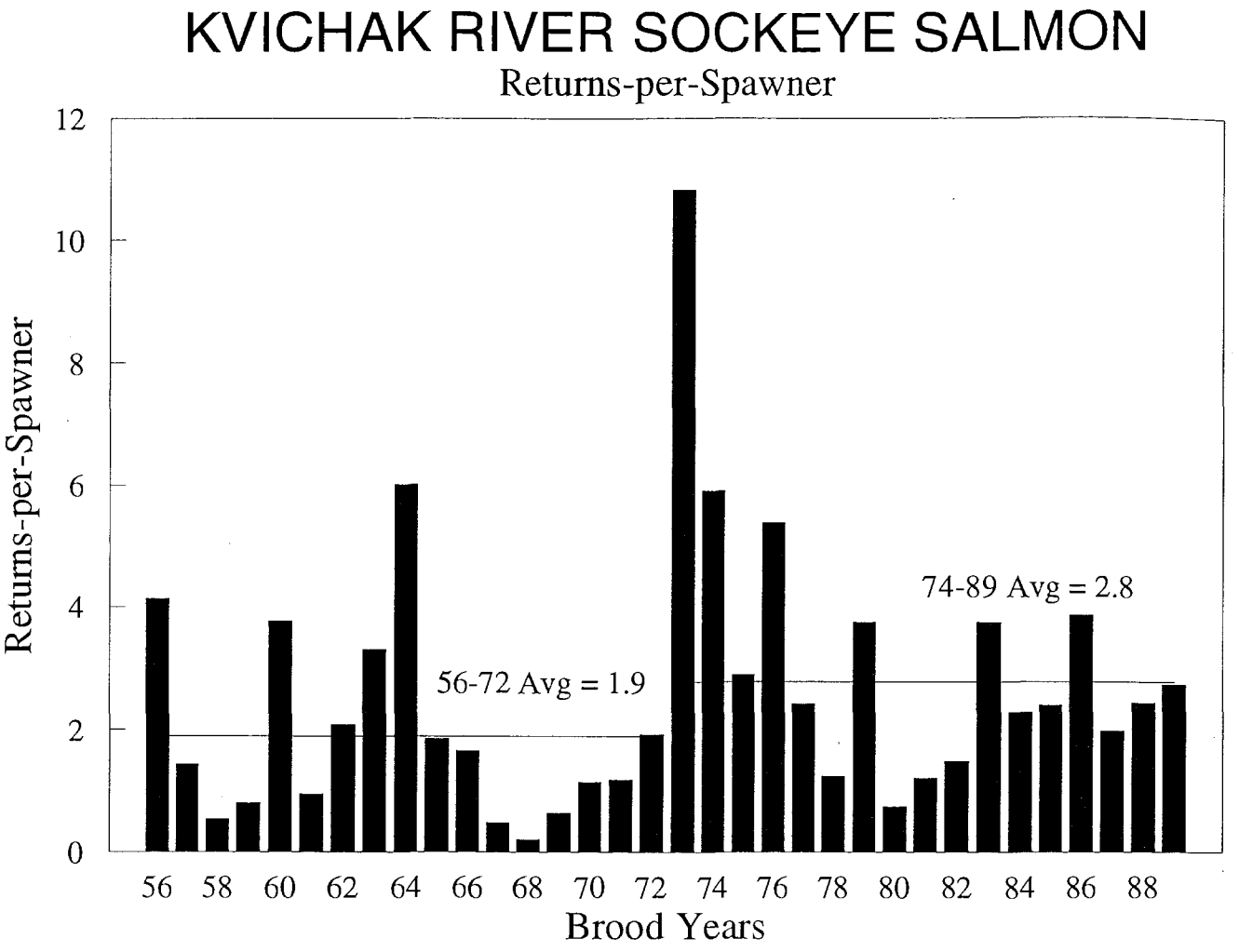


Figure 3. Returns-per-spawner for Kvichak River sockeye salmon by brood year, 1956-89.

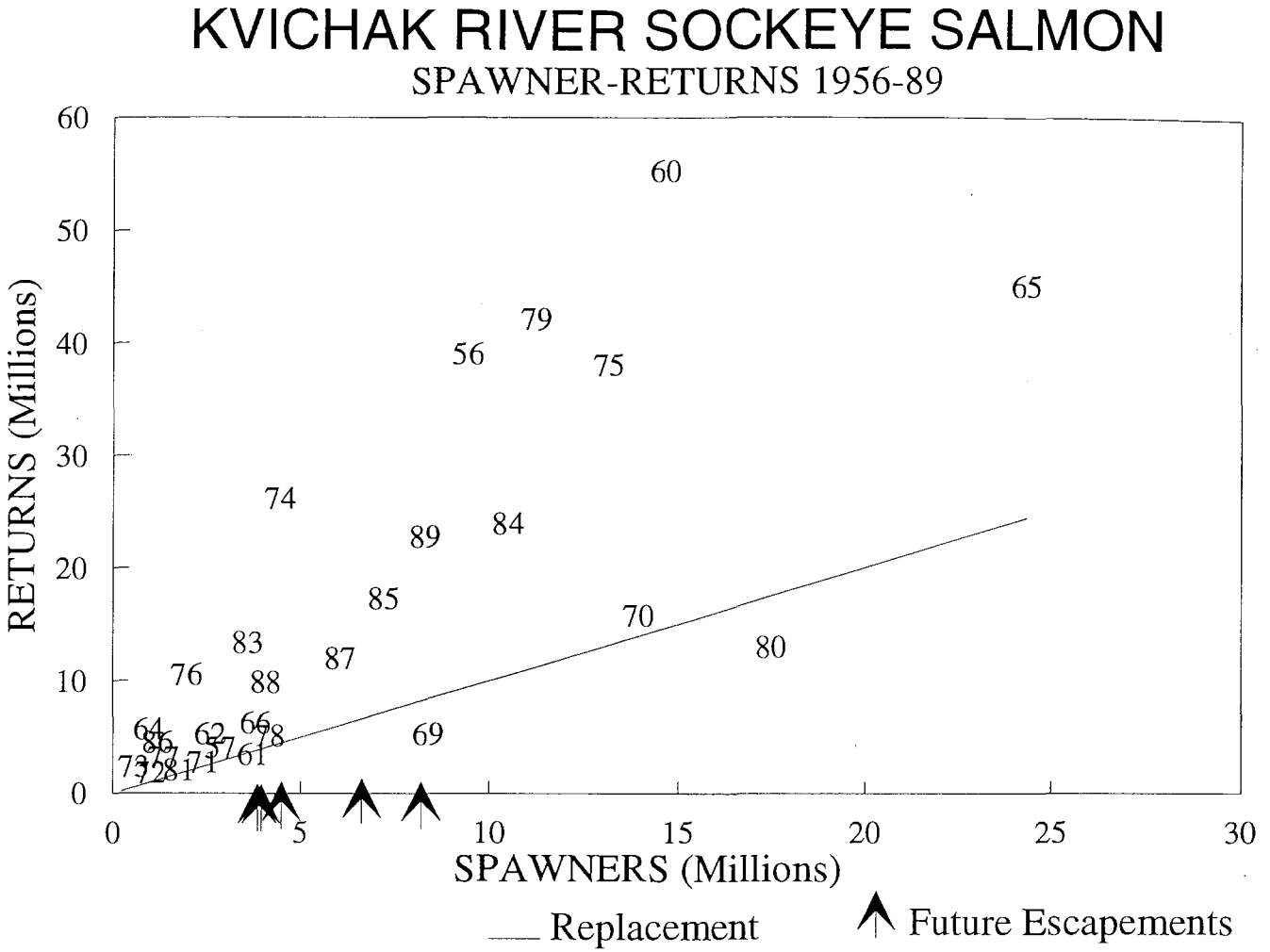


Figure 4. Kvichak River spawners and returns by brood year, 1956-89. Arrows represent numbers of spawners in 1990-94.

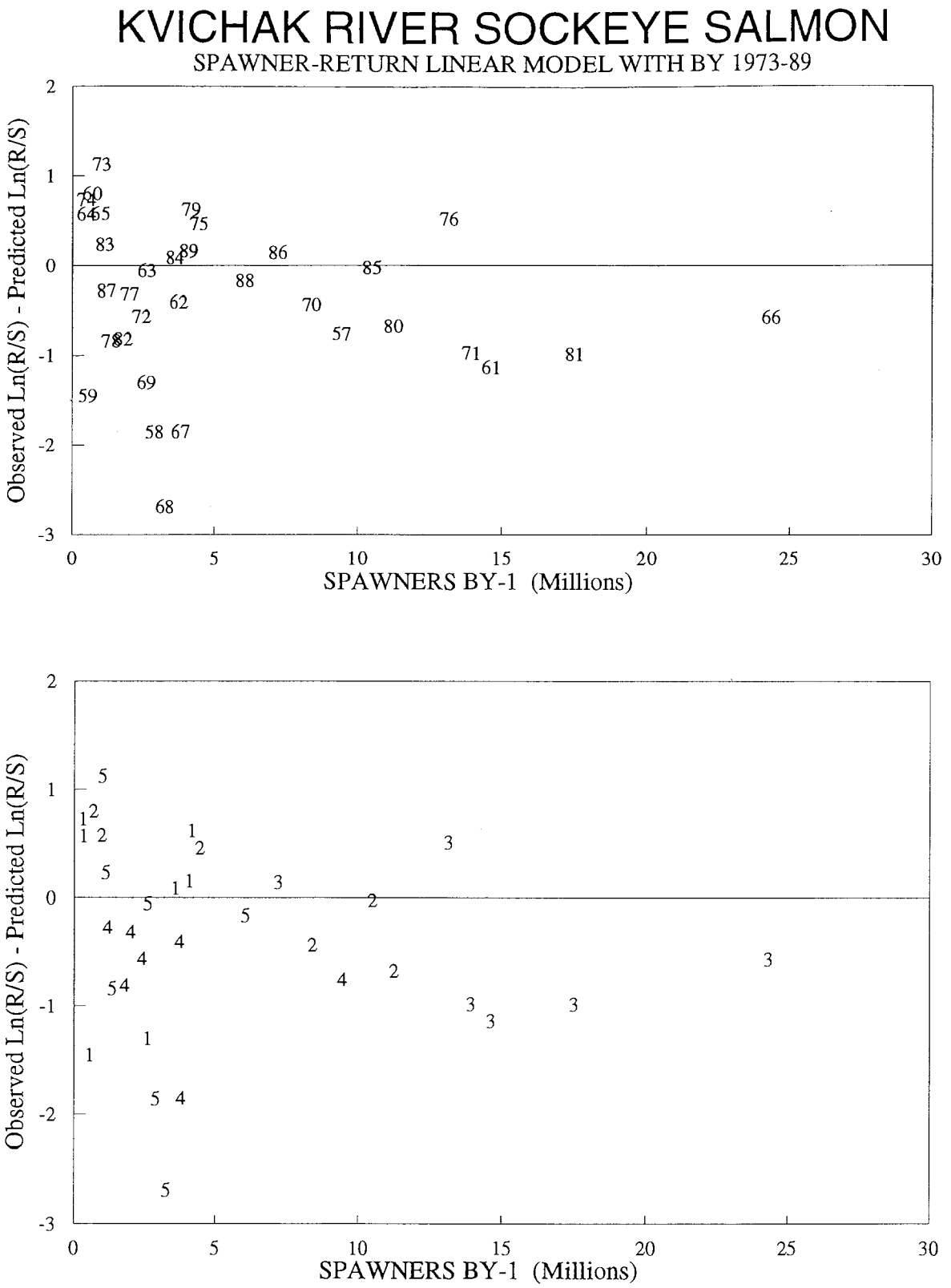


Figure 5. Residuals (observed-predicted) for a linear fit of a Ricker spawner-return model for 1973-89 brood years versus escapement the previous year. Data points are identified by brood year for the top figure and coded as (1) for pre-peak cycle, (2) for peak cycle, and (3,4,5) for post cycle brood year returns for the bottom figure.

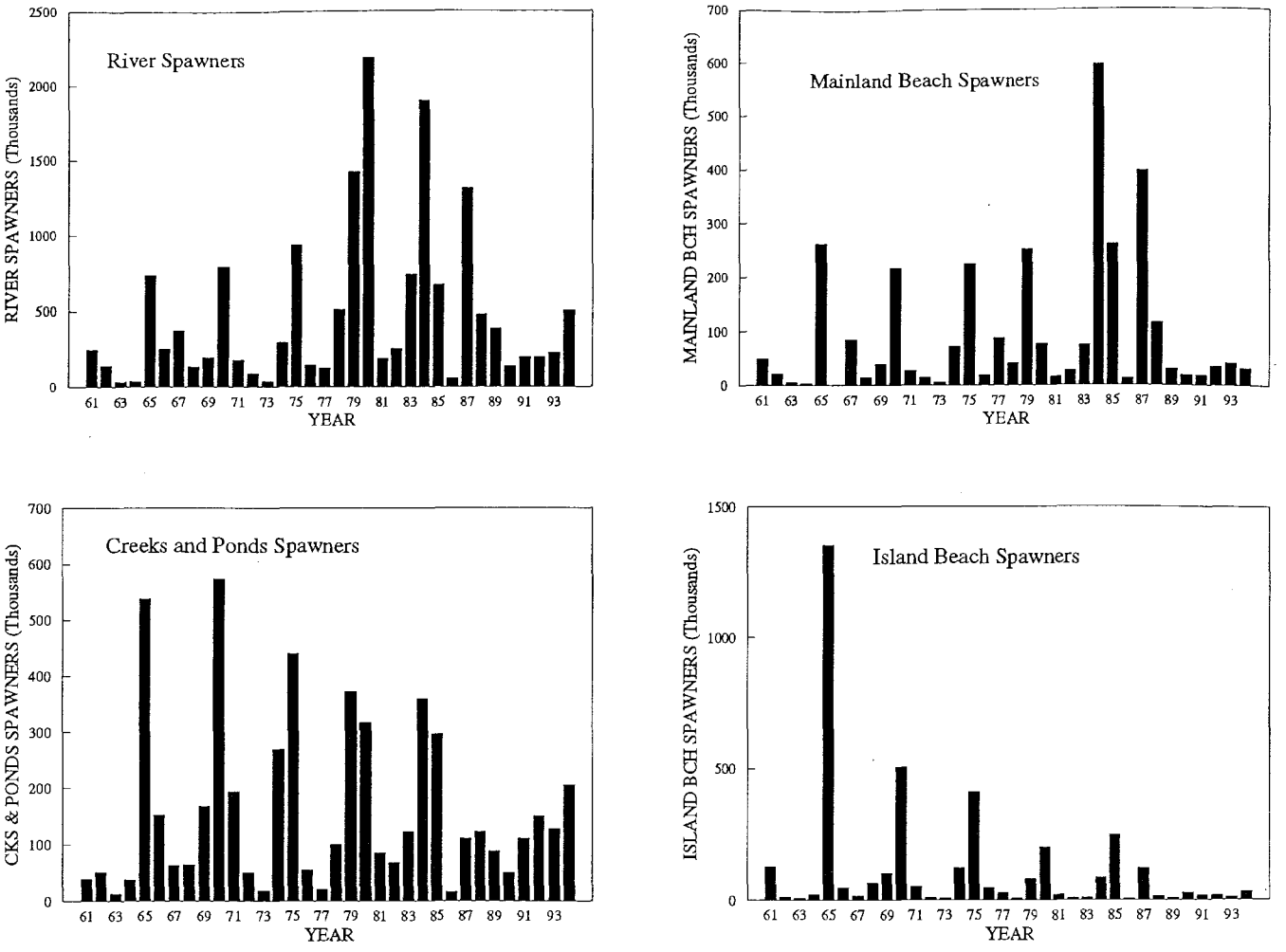
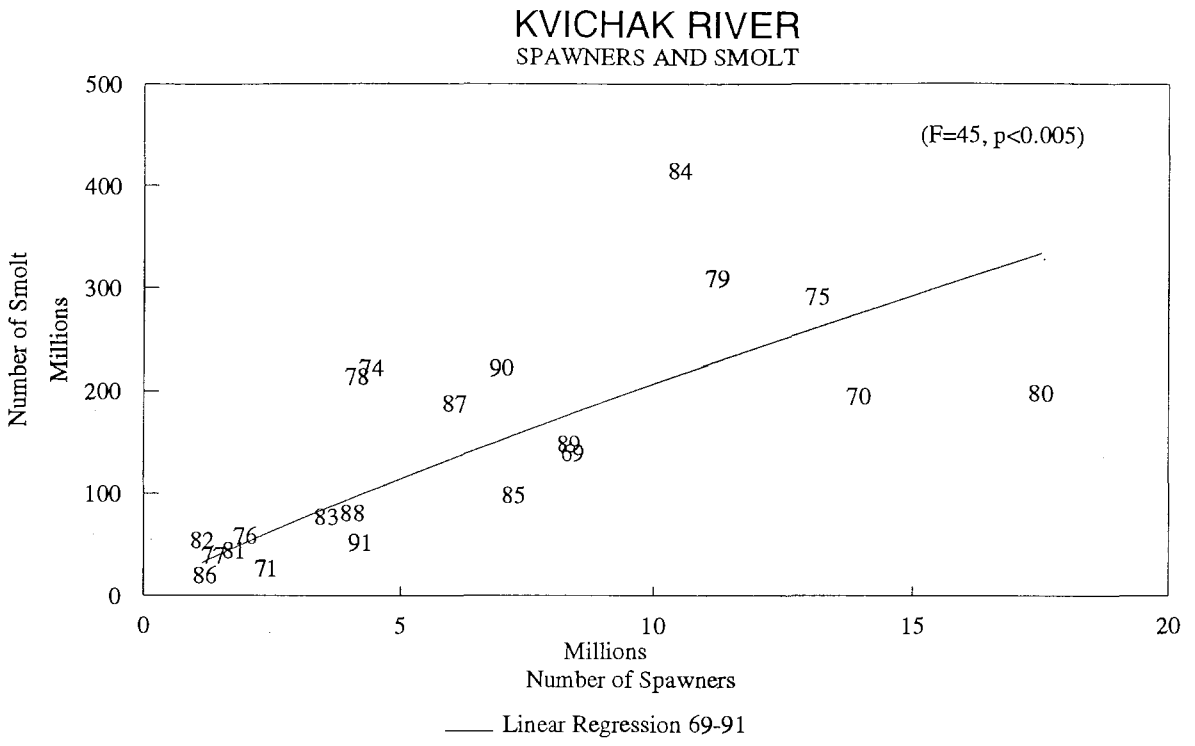


Figure 6. Numbers of sockeye salmon spawners by habitat type based on aerial surveys for Kvichak River, 1961-94.



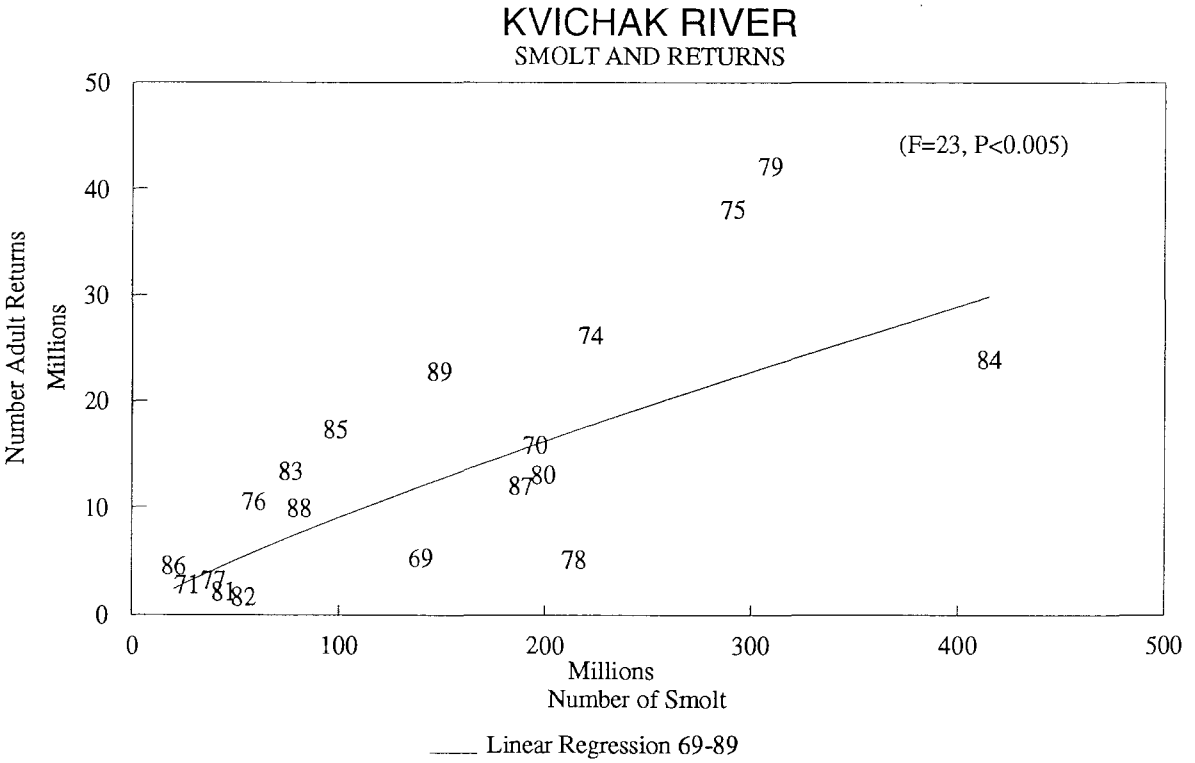


Figure 7. Relationships of spawners to smolt, and smolt to adult returns for Kvichak River sockeye salmon.

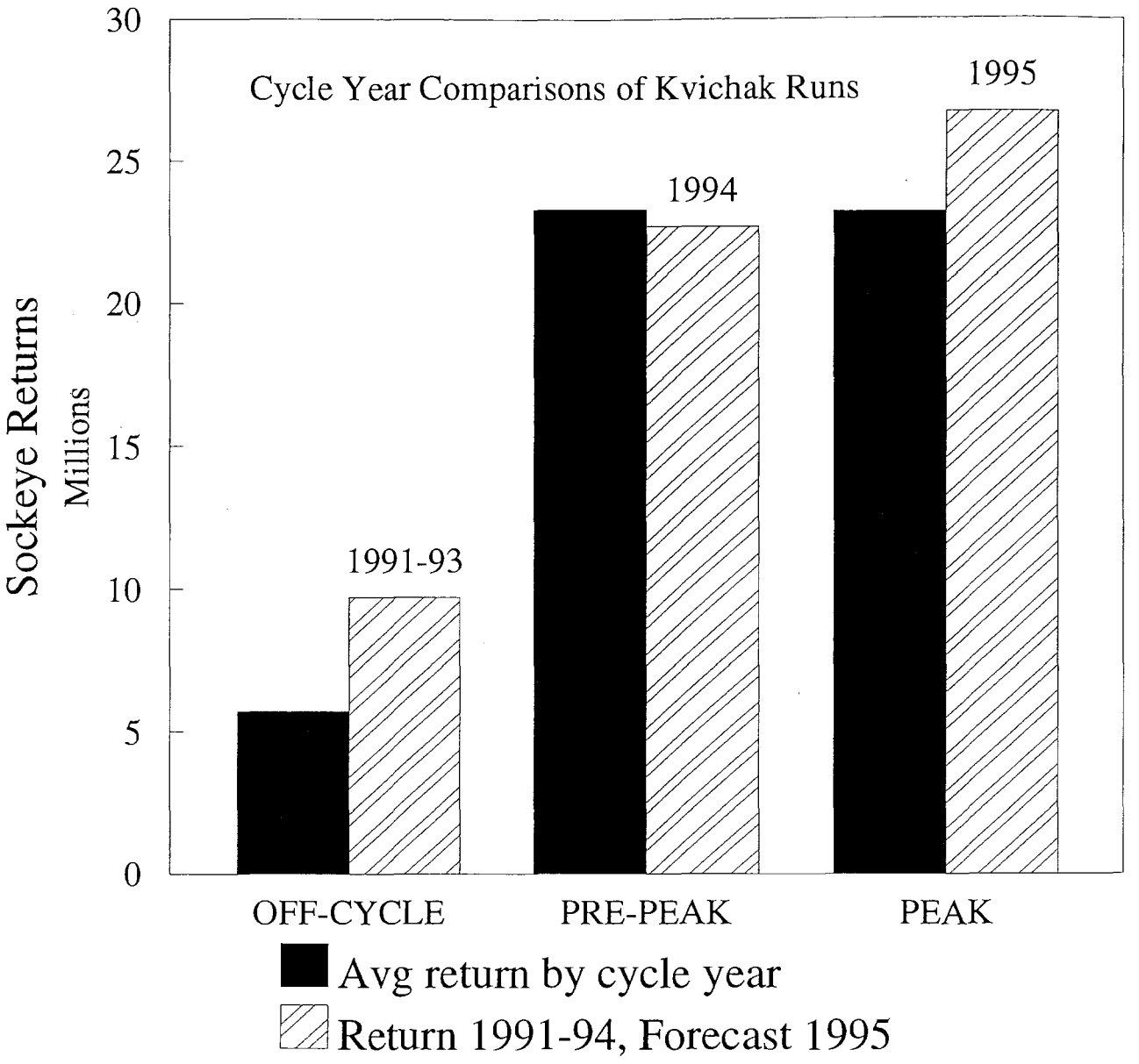


Figure 8. Cycle year comparisons of Kvichak River sockeye salmon runs. Return by cycle year is an average for 1976-89, excluding 1983.

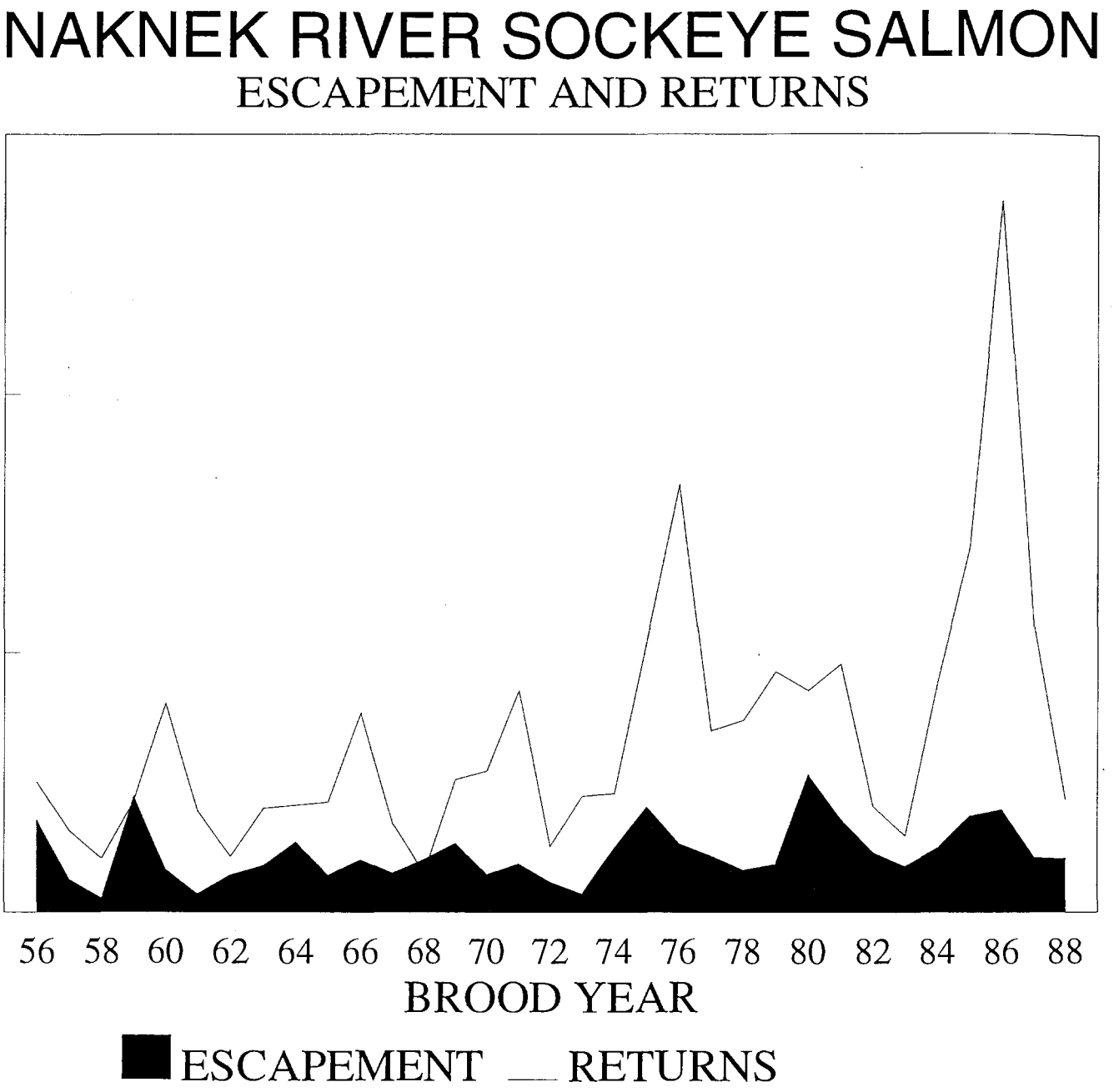


Figure 9. Naknek River sockeye salmon escapement and returns by brood year, 1956-88.

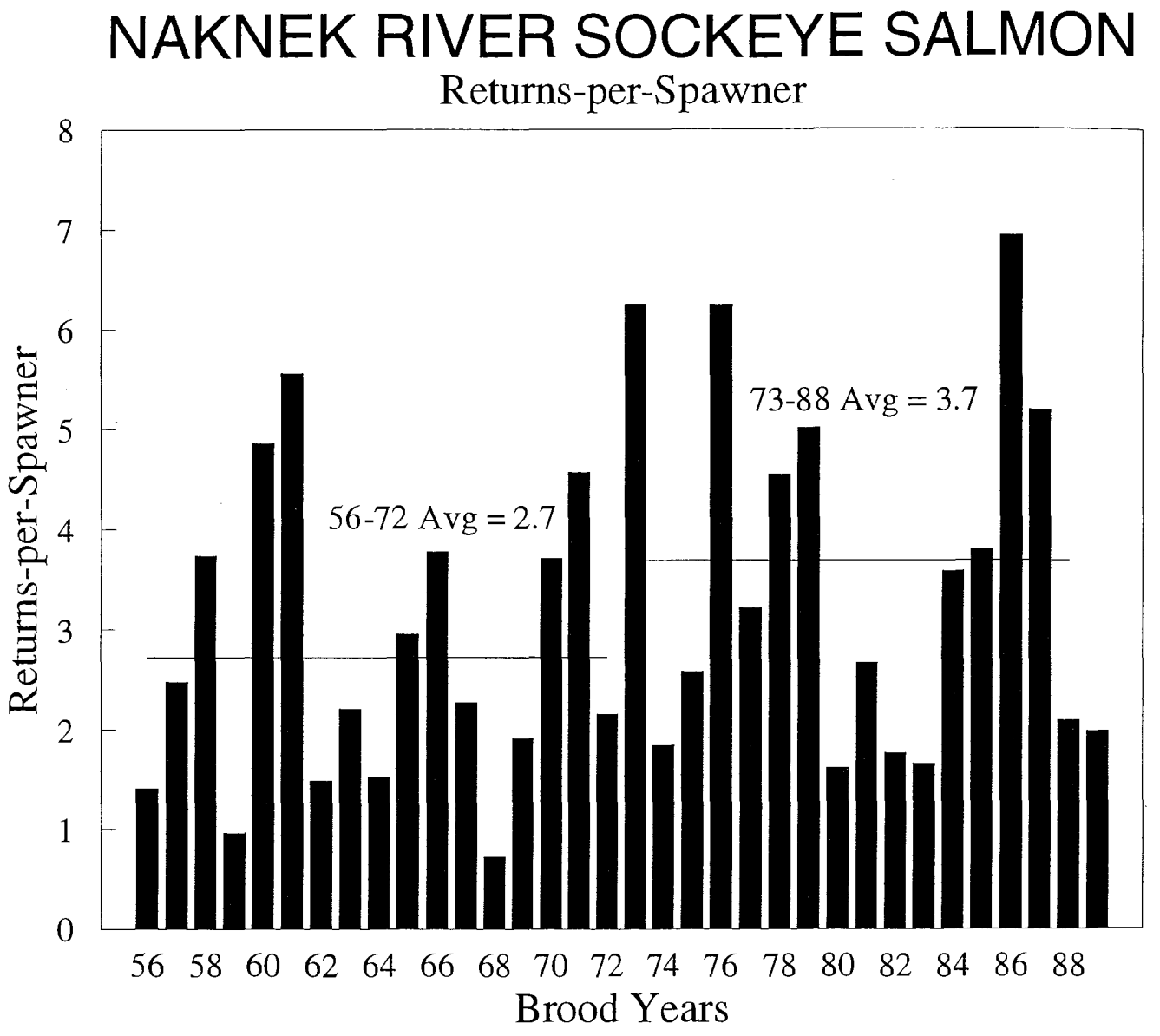


Figure 10. Returns-per-spawner for Naknek River sockeye salmon by brood year, 1956-88.

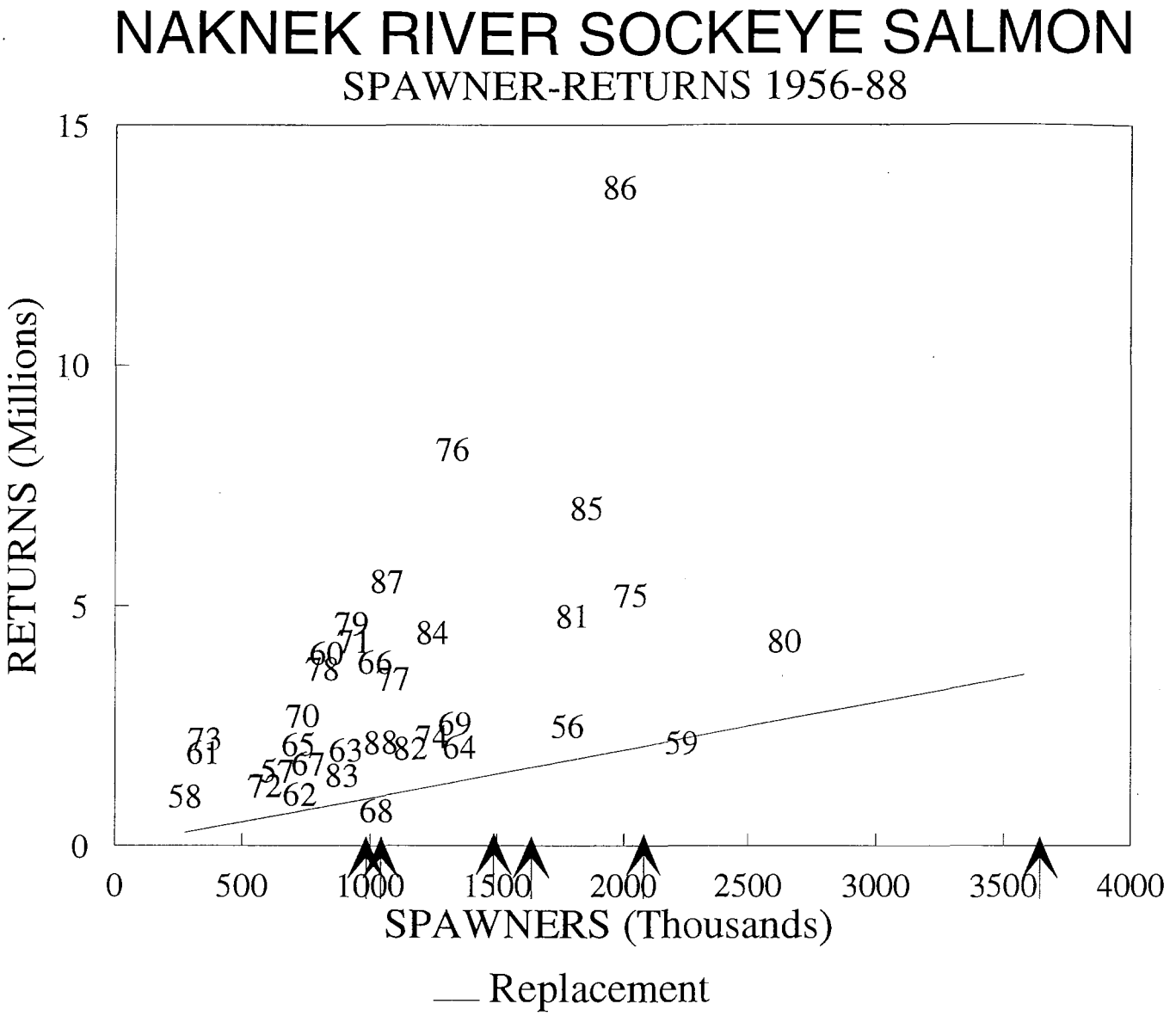


Figure 11. Naknek River spawners and returns by brood year, 1956-88. Arrows represent number of spawners in 1989-94.

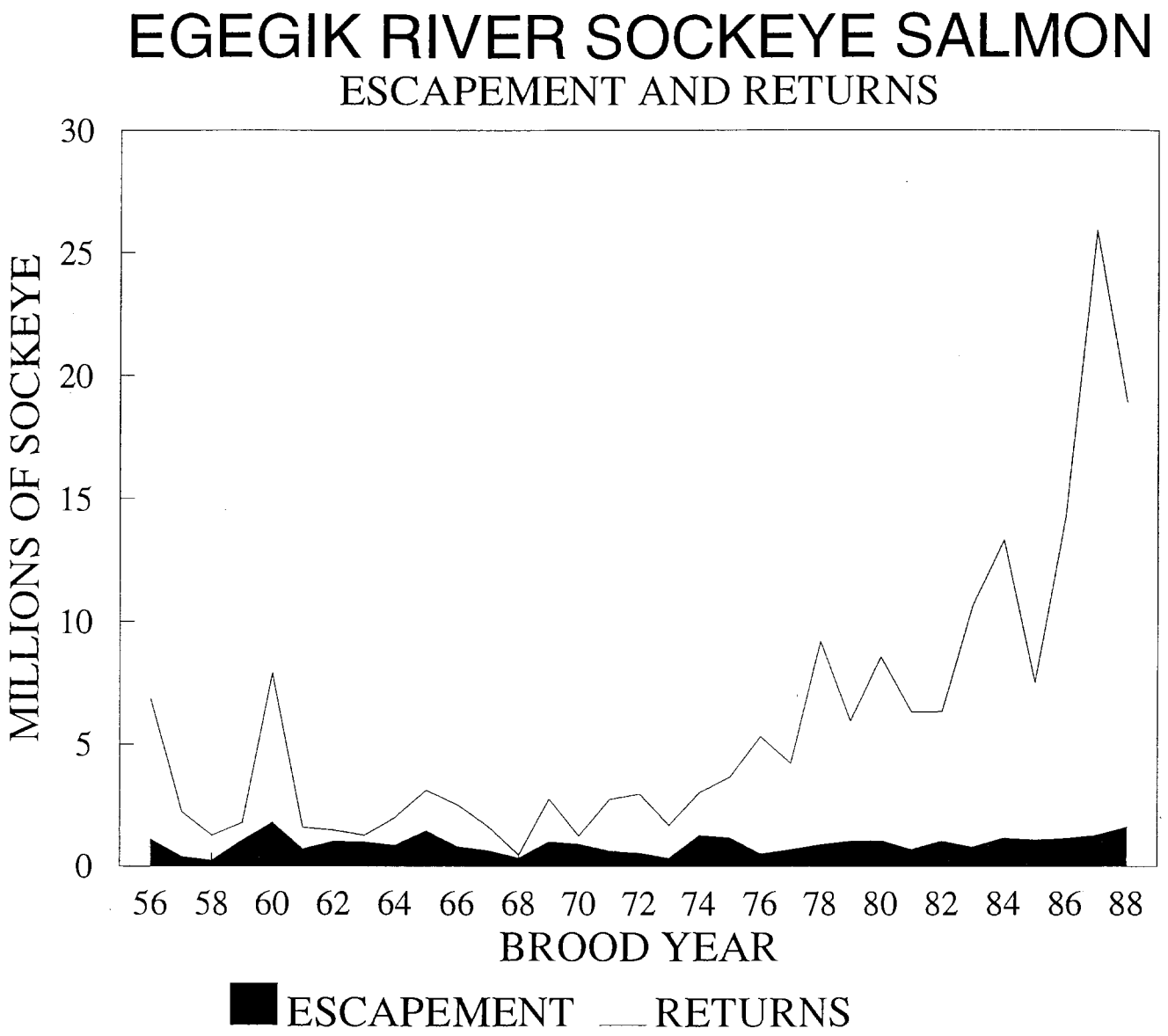


Figure 12. Egegik River sockeye salmon escapement and returns by brood year, 1956-88.

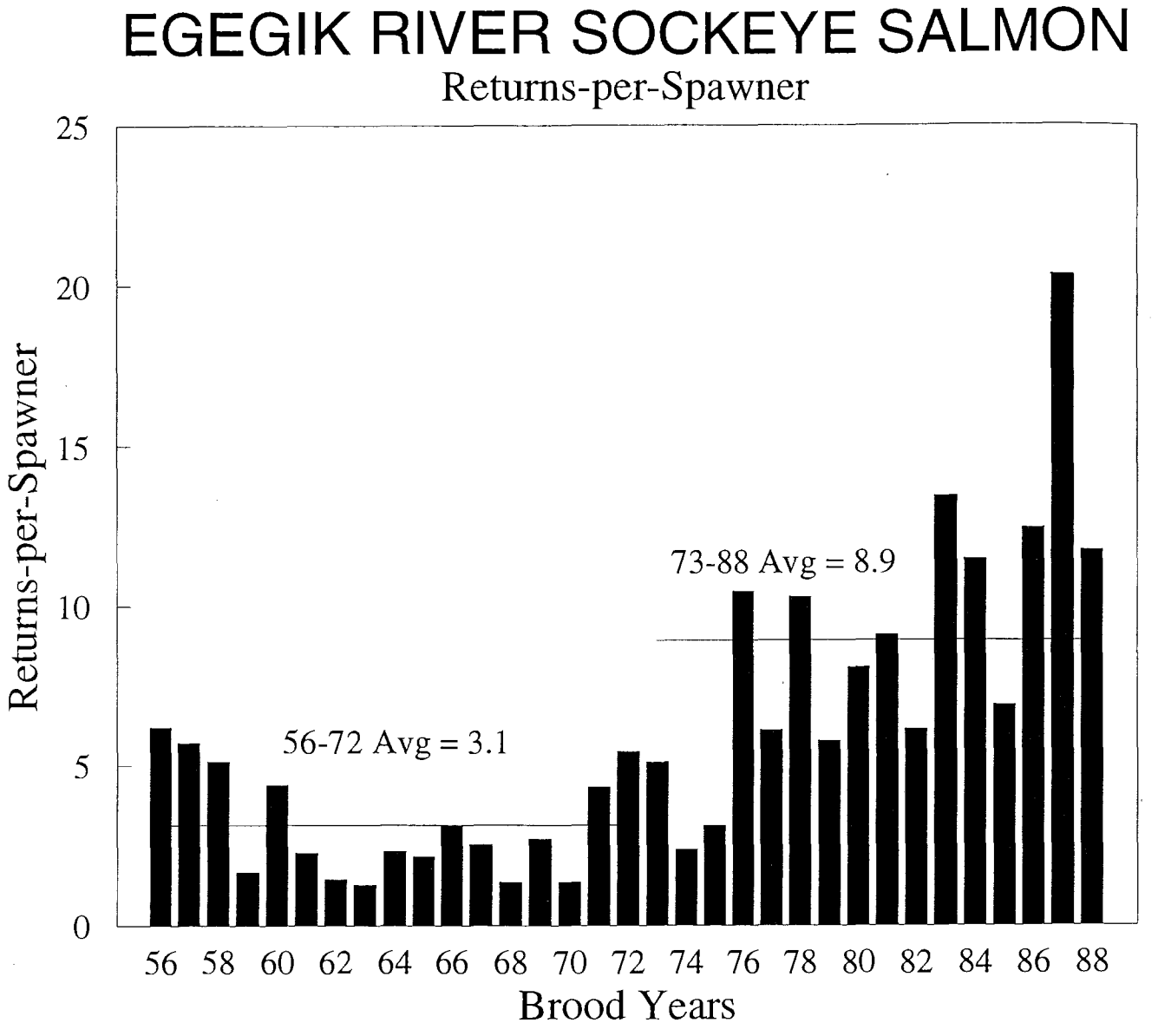


Figure 13. Returns-per-spawner for Egegik River sockeye salmon by brood year, 1956-88.

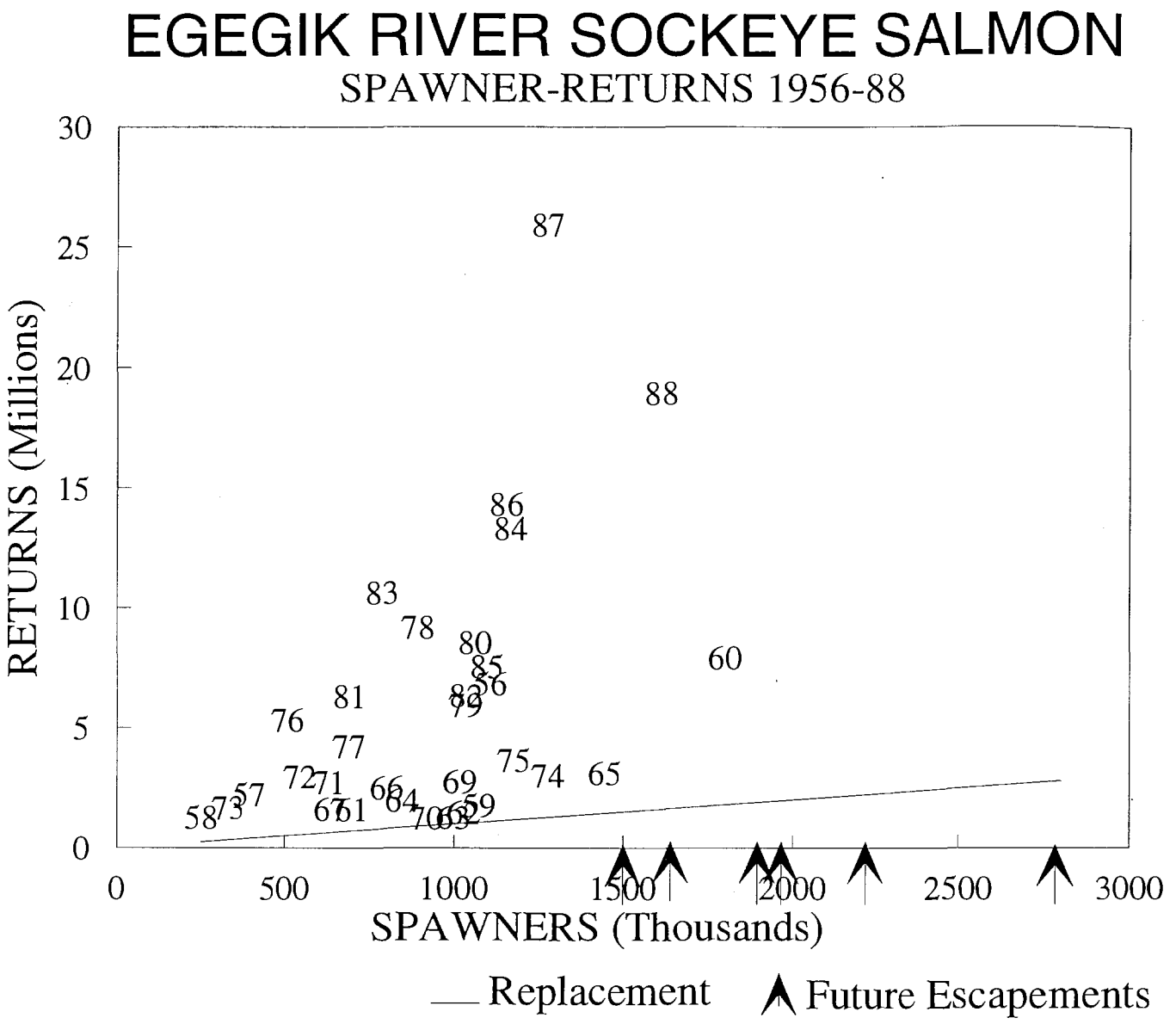
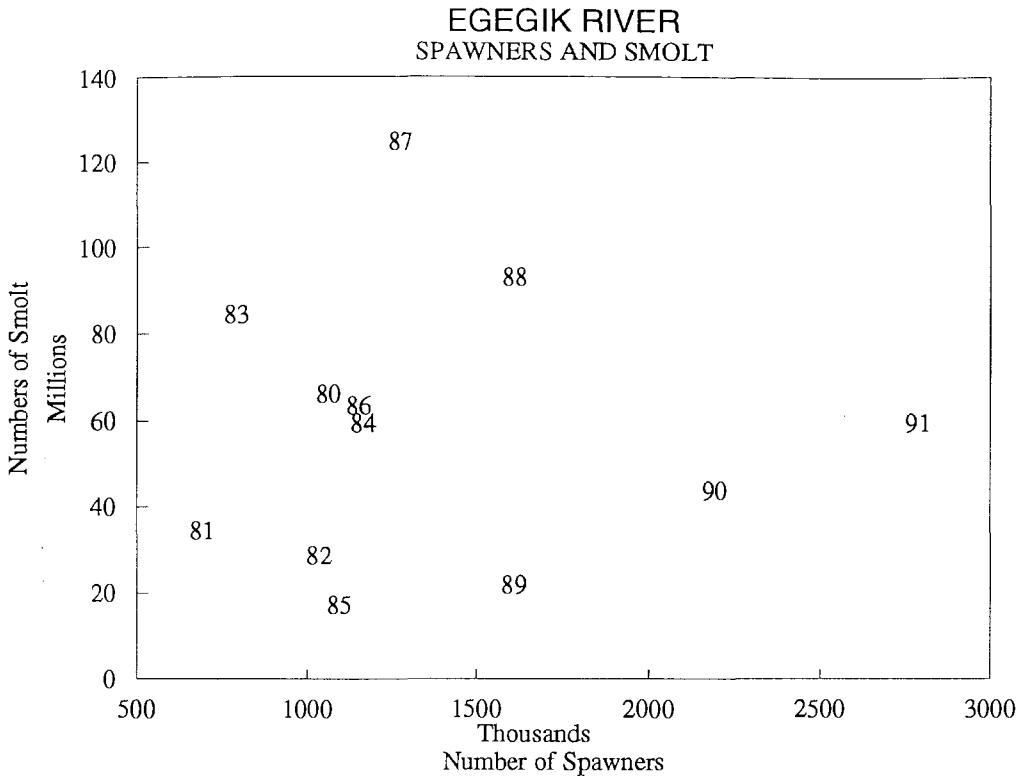


Figure 14. Egegik River spawners and returns by brood year, 1956-88. Arrows represent number of spawners in 1989-94.



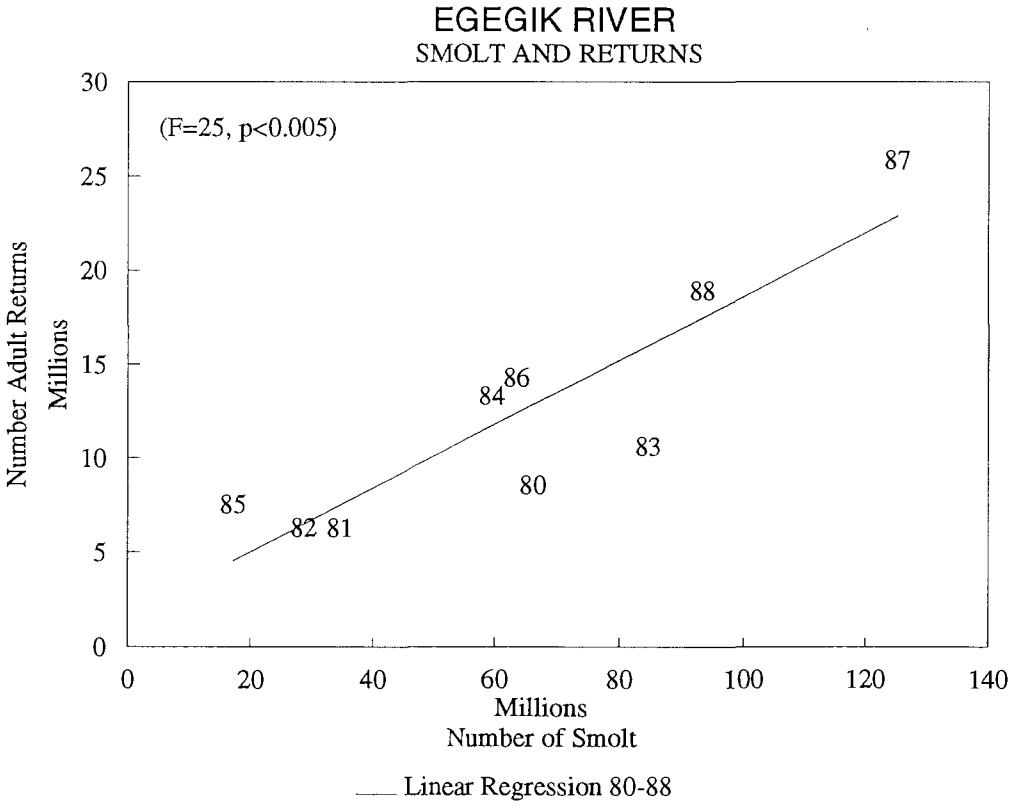


Figure 15. Relationships of spawners to smolt, and smolt to adult returns for Egegik River sockeye salmon.

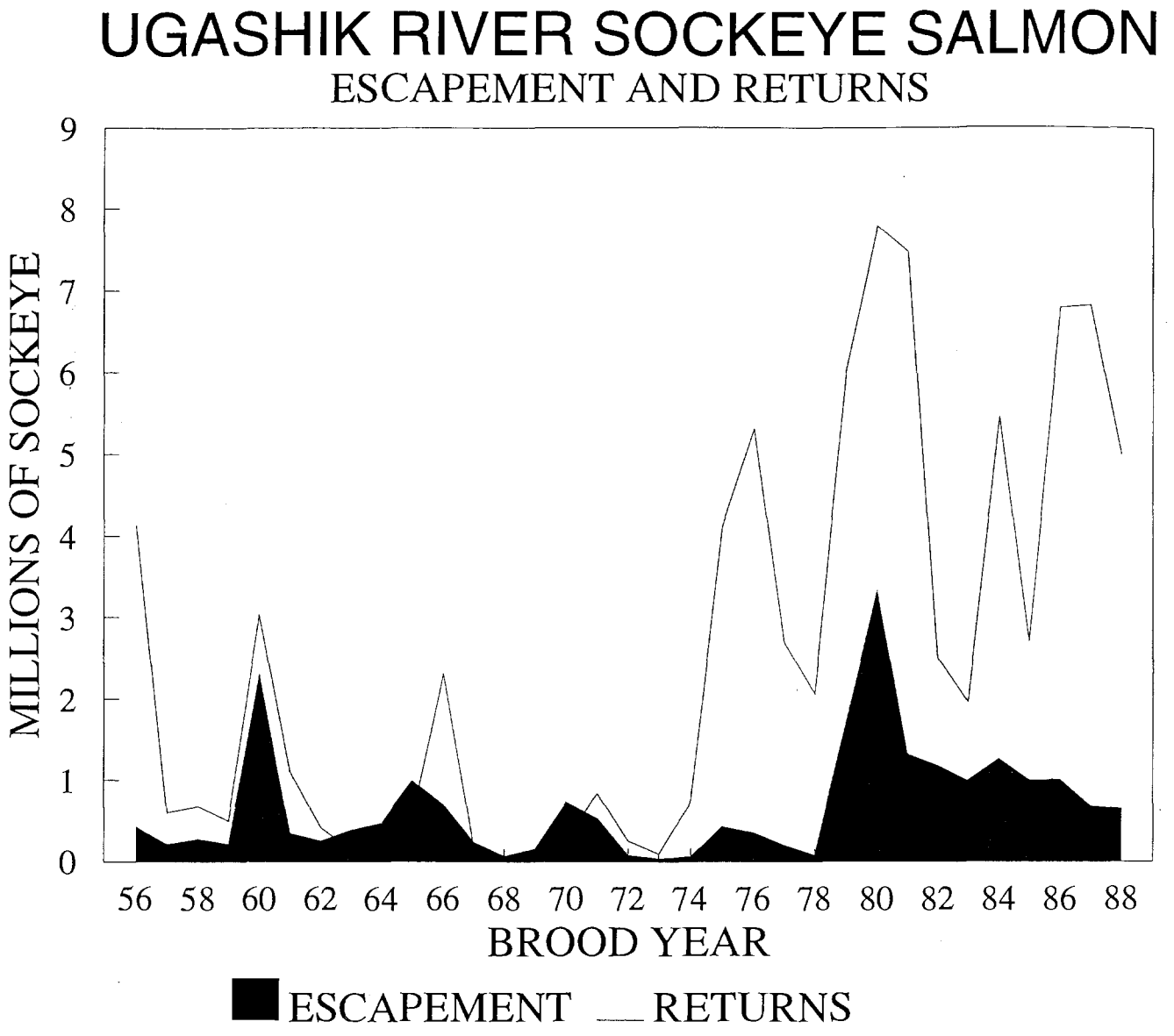


Figure 16. Ugashik River sockeye salmon escapement and returns by brood year, 1956-88.

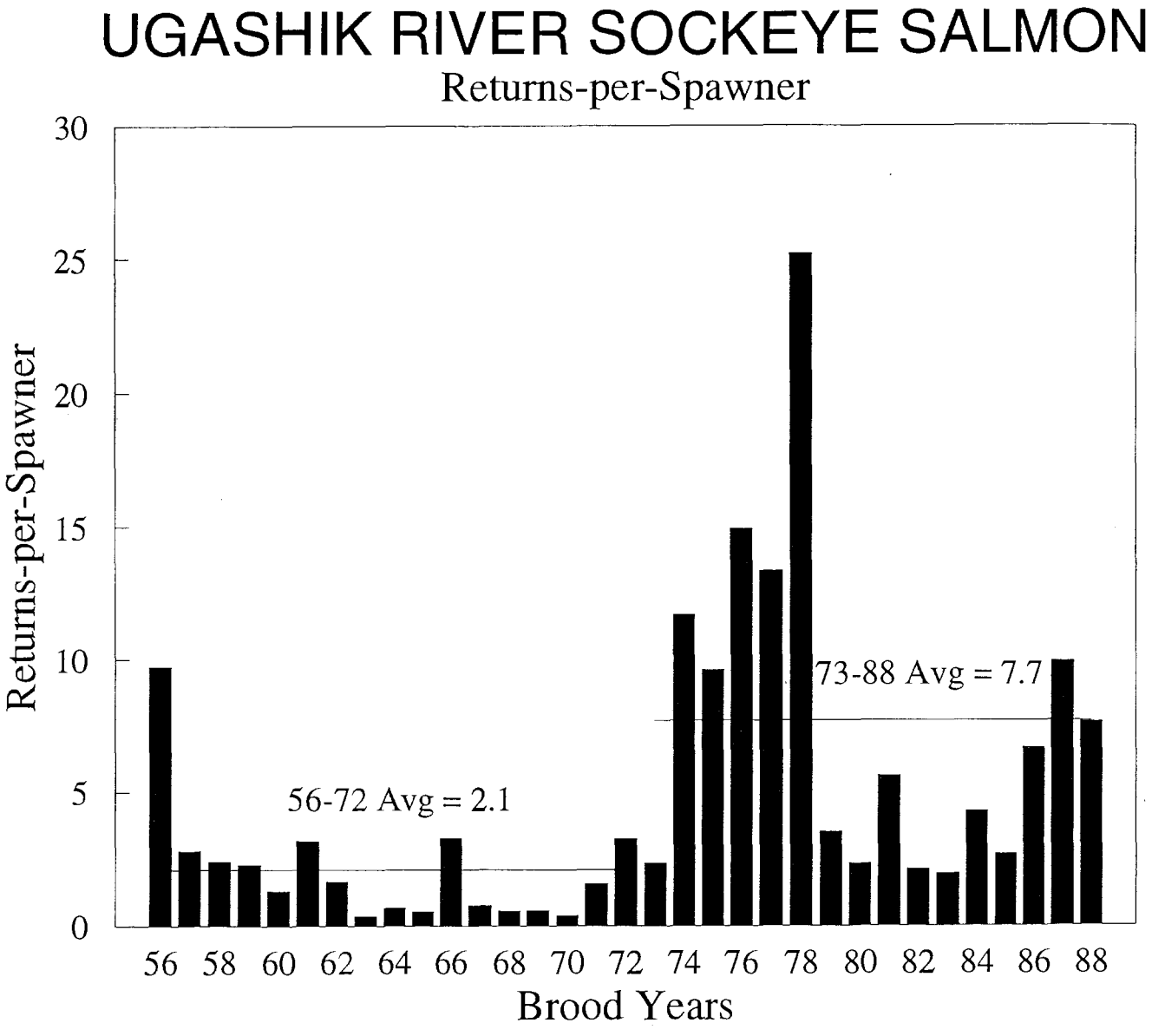


Figure 17. Returns-per-spawner for Ugashik River sockeye salmon by brood year, 1956-88.

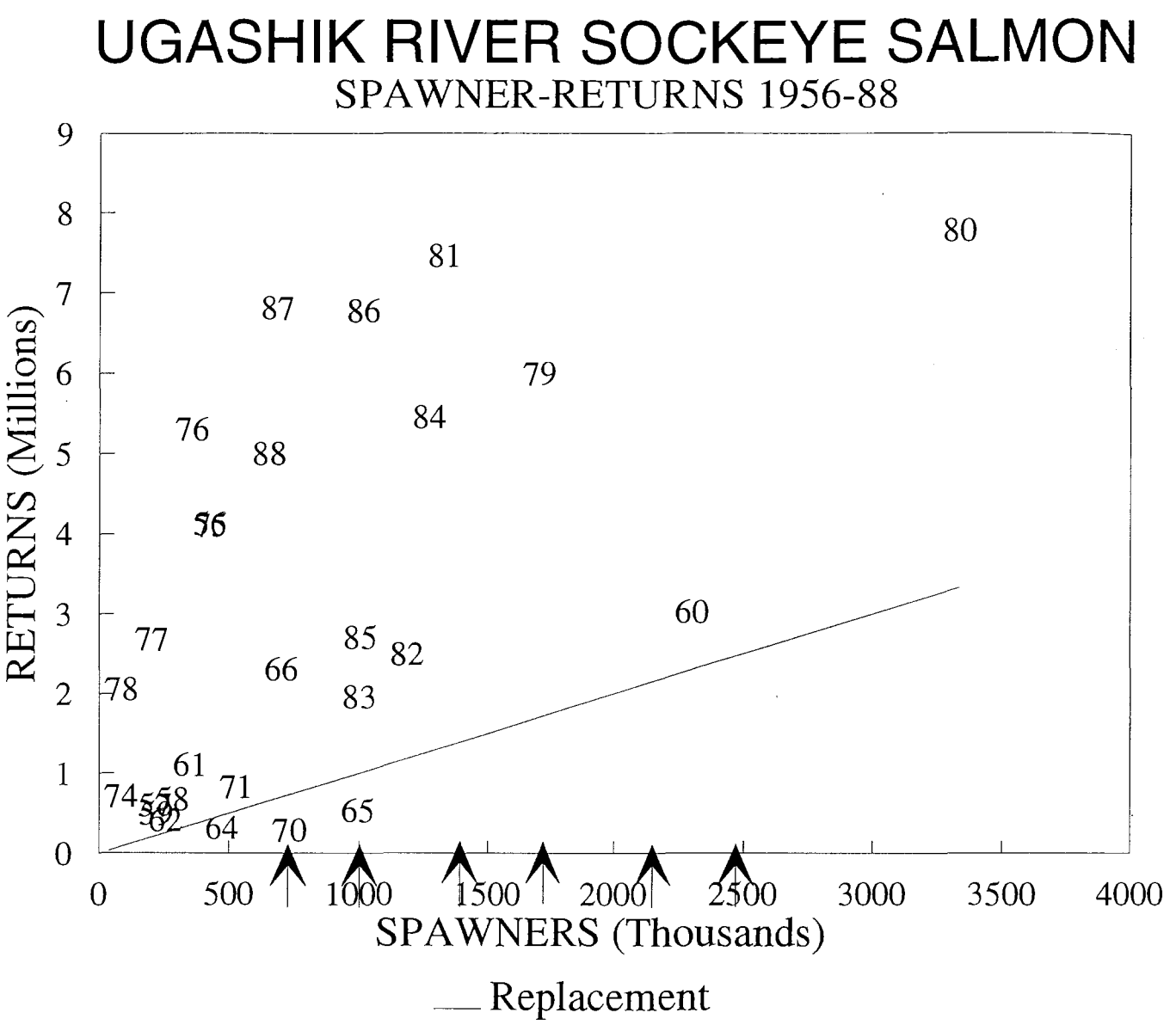
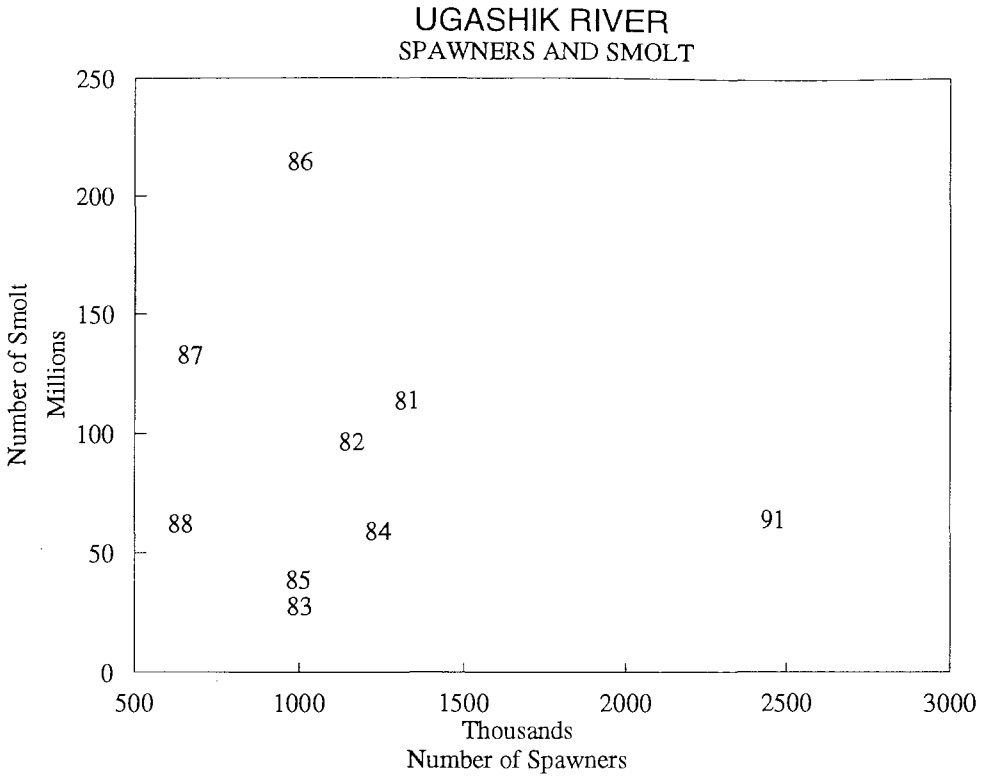


Figure 18. Ugashik River spawners and returns by brood year, 1956-88. Arrows represent numbers of spawners for 1989-94.



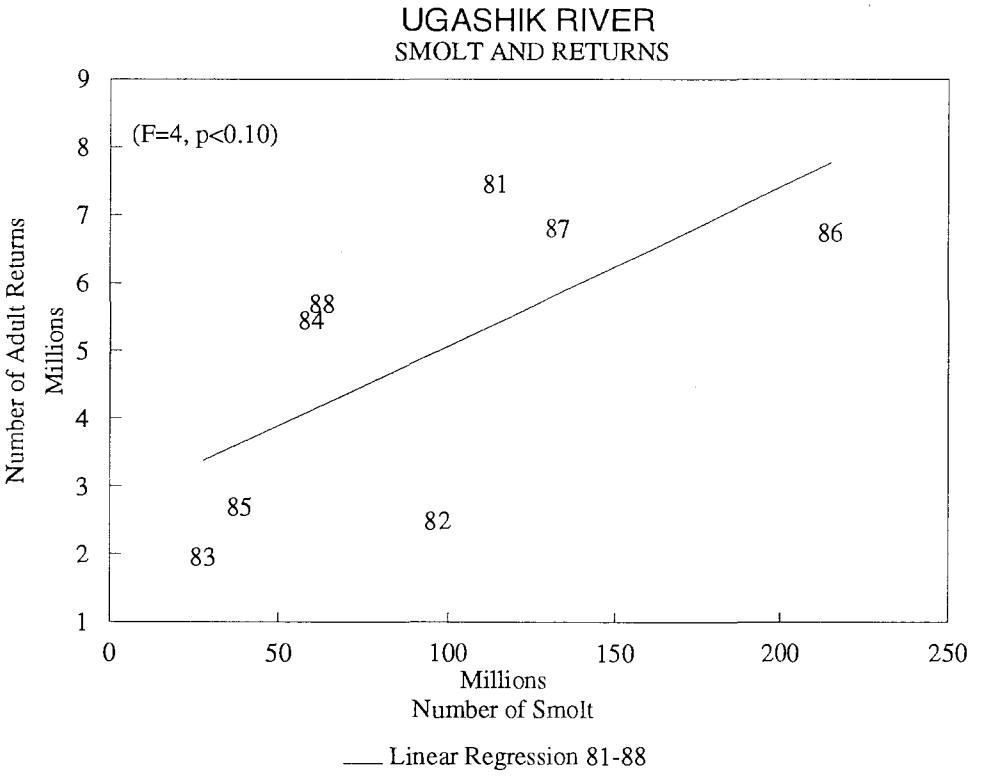


Figure 19. Relationships of spawners to smolt, and smolt to adult returns Ugashik River sockeye salmon.

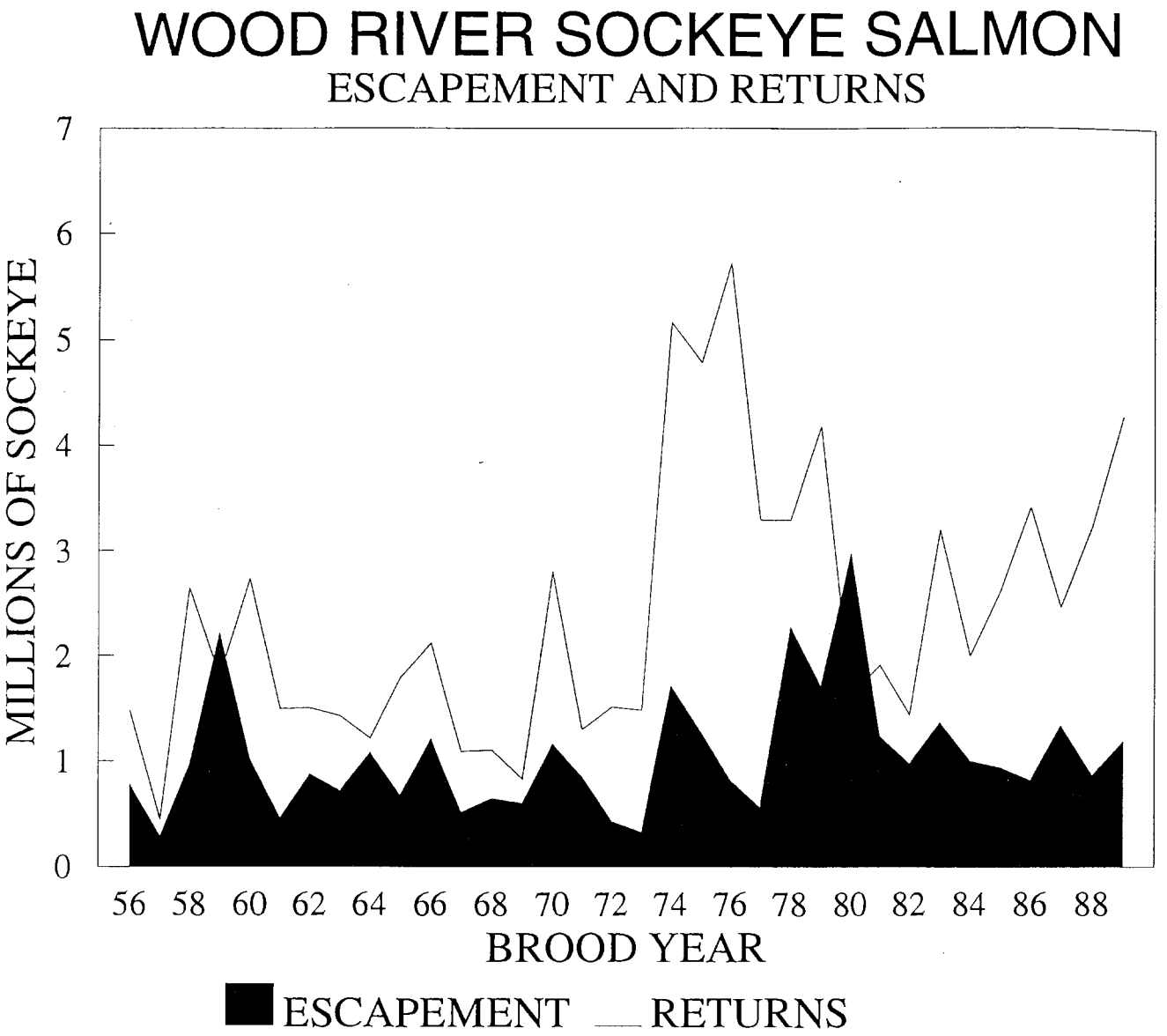


Figure 20. Wood River sockeye salmon escapement and returns by brood year, 1956-89.

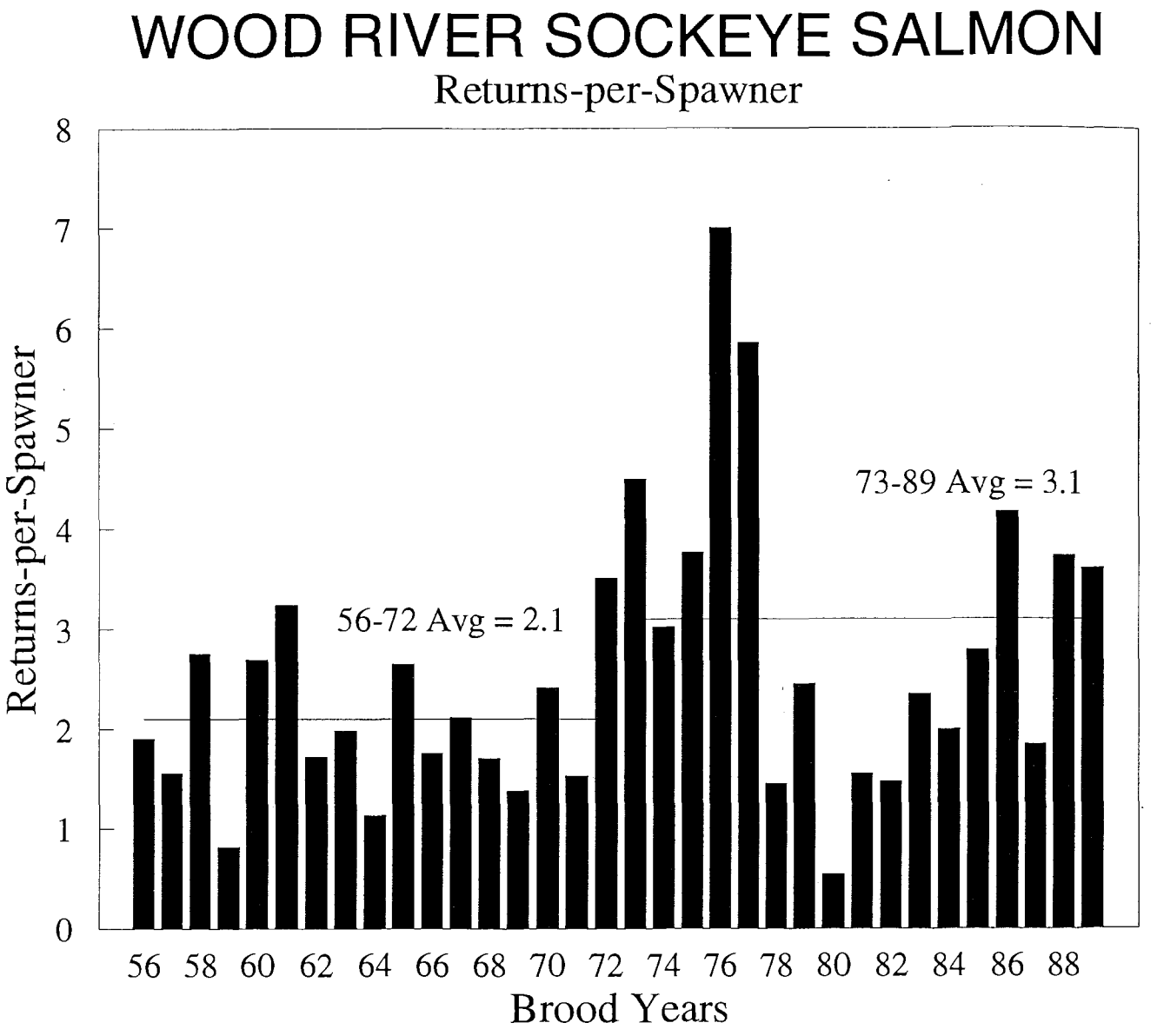


Figure 21. Returns-per-spawner for Wood River sockeye salmon by brood year, 1956-89.

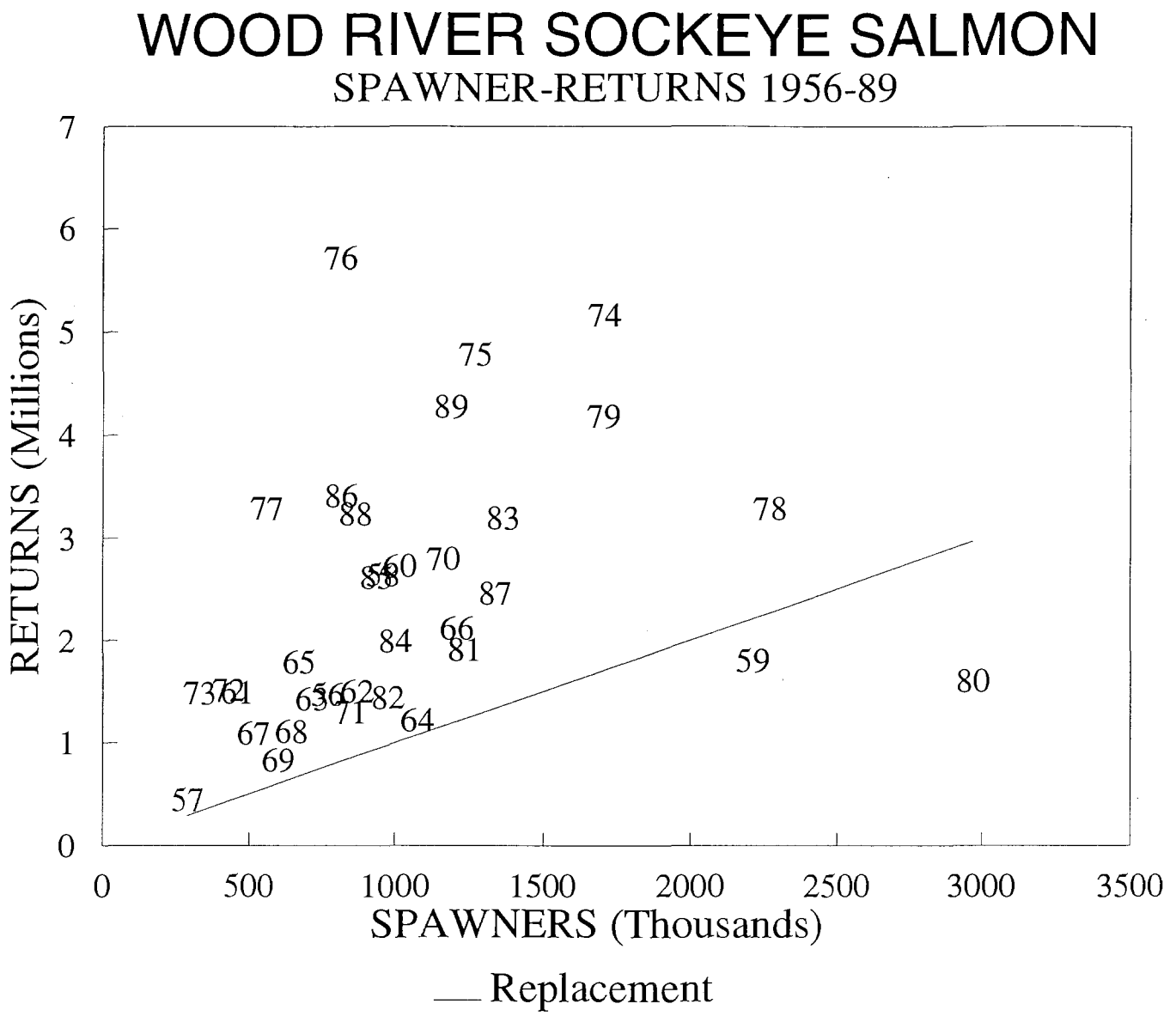


Figure 22. Wood River spawners and returns by brood year, 1956-89.

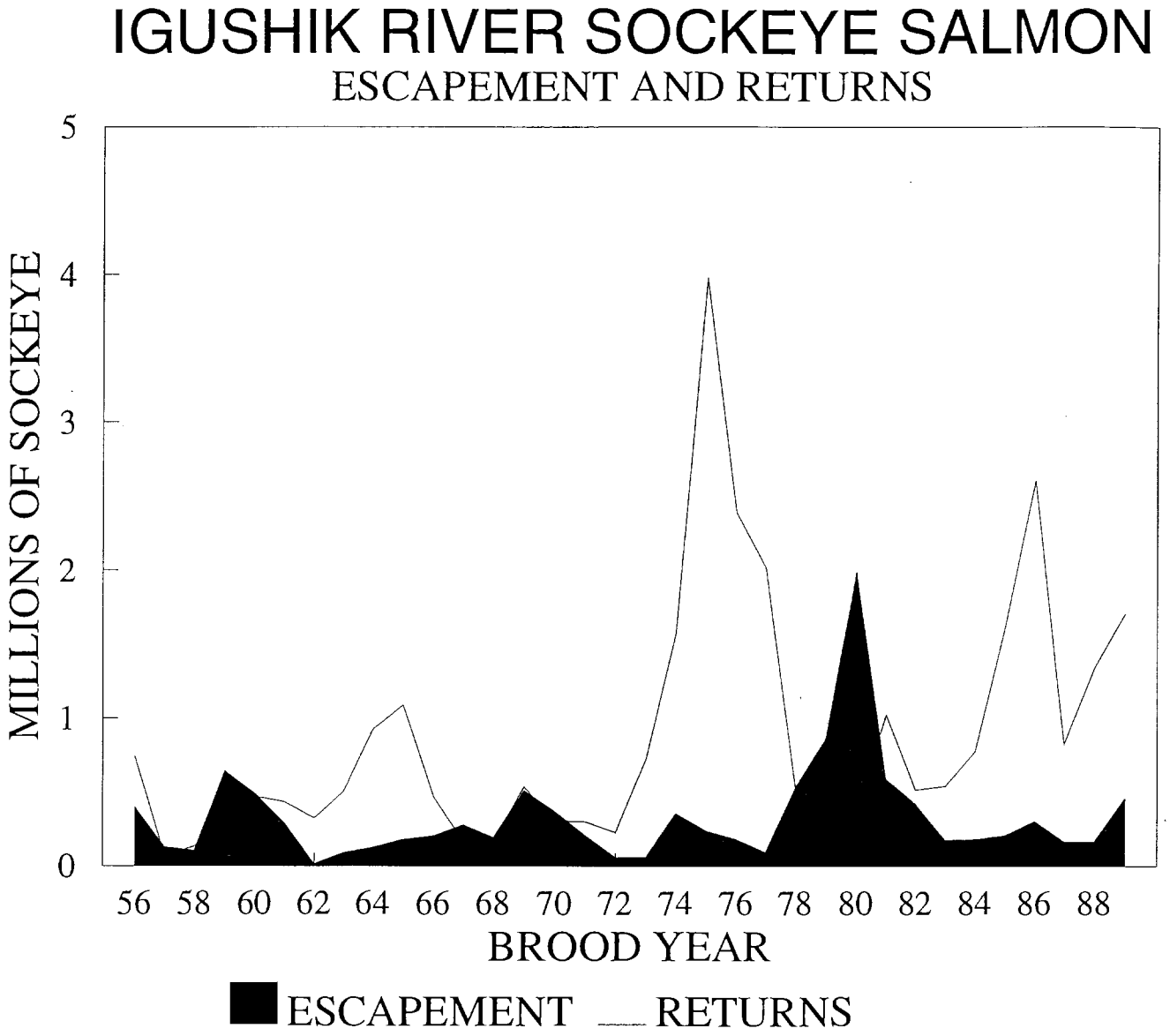


Figure 23. Igushik River sockeye salmon escapement and returns by brood year, 1956-89.

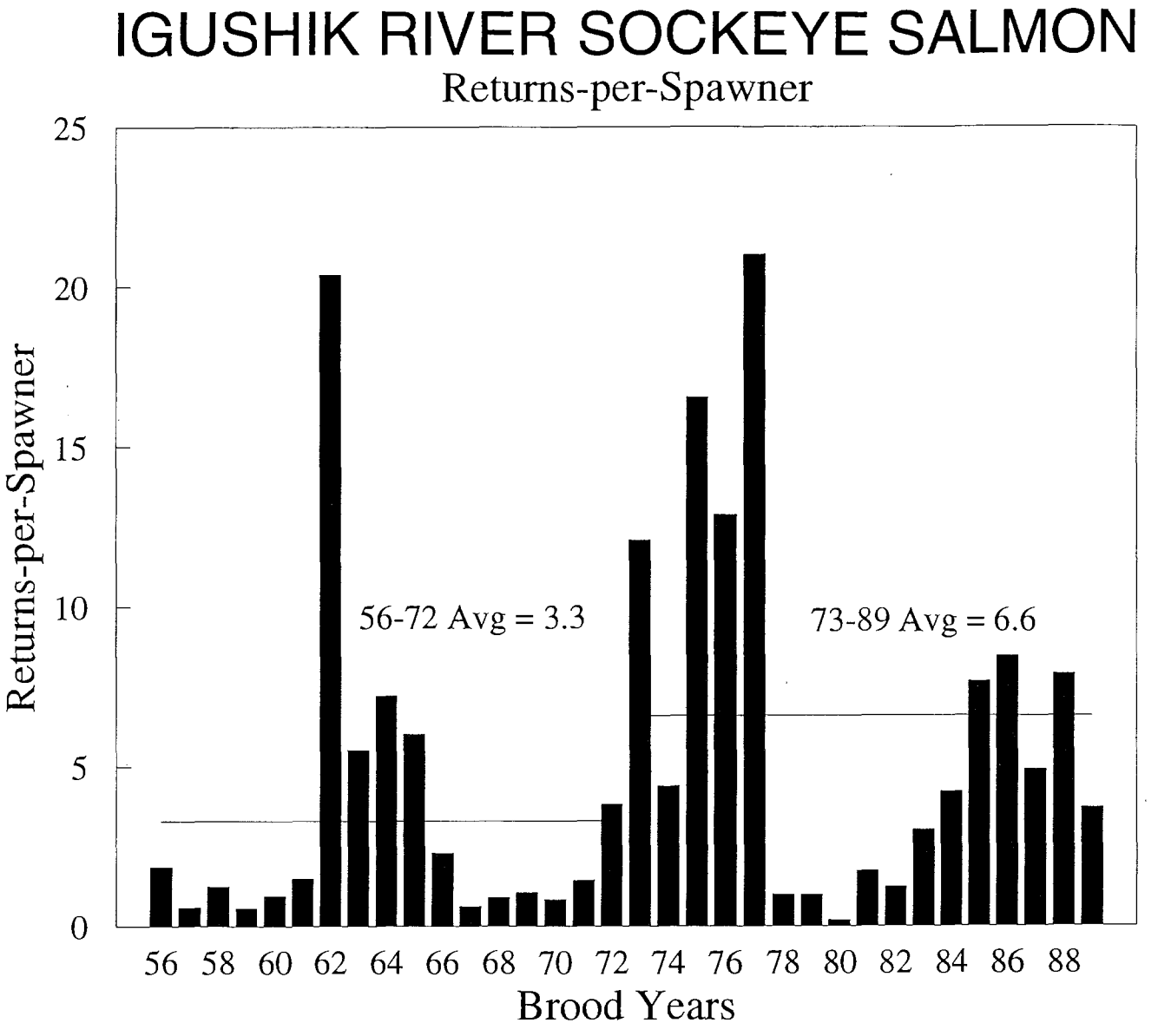


Figure 24. Returns-per-spawner for Igushik River sockeye salmon by brood year, 1956-89.

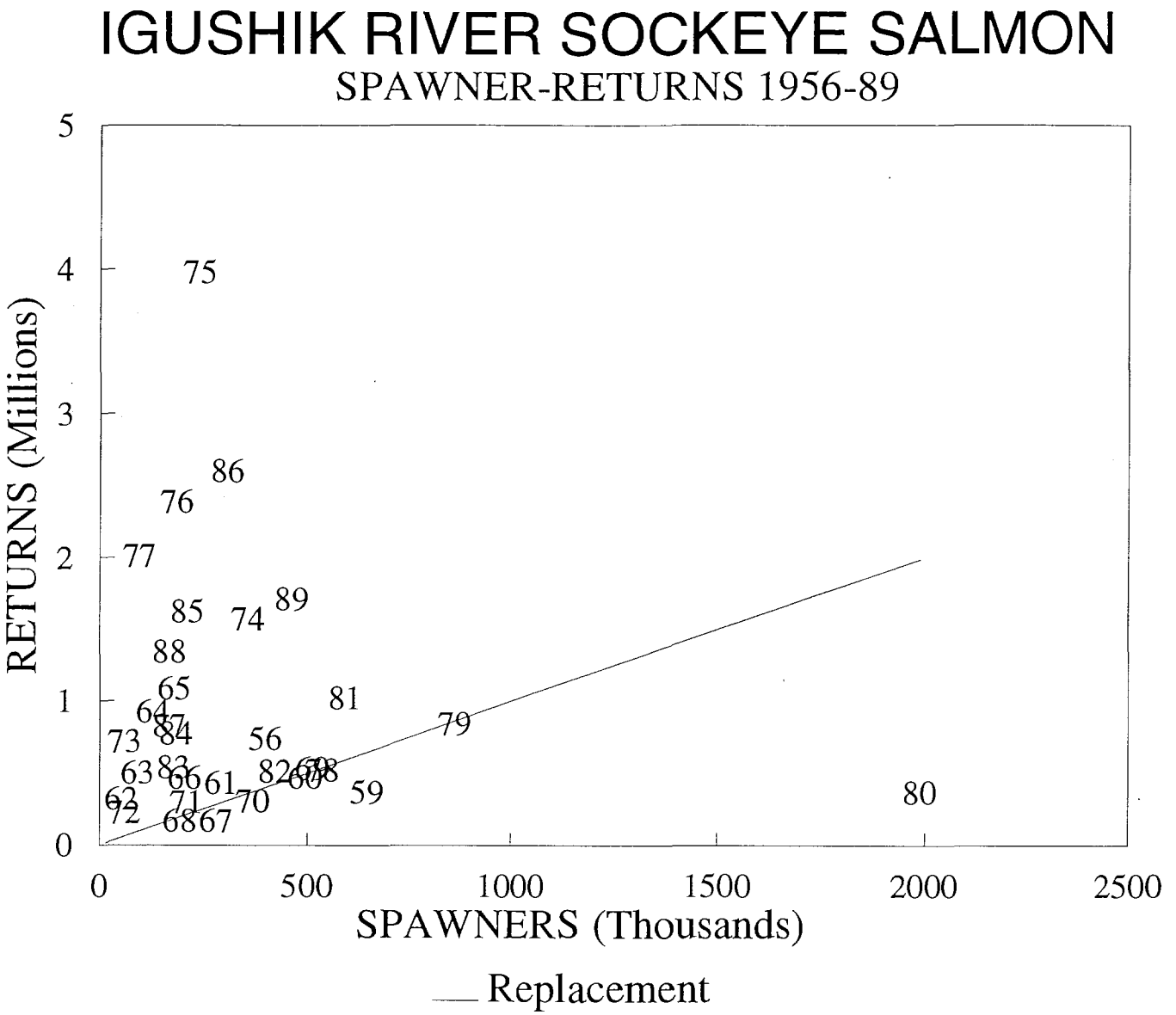


Figure 25. Igushik River spawners and returns by brood year, 1956-89.

APPENDIX A: WORKSHOP PARTICIPANTS

Appendix A.1. List of individuals attending the 1994 Bristol Bay sockeye salmon escapement goal workshop.

Name	Affiliation
James Brady	ADF&G, Division of Commercial Fisheries Management and Development
Linda Brannian	ADF&G, Division of Commercial Fisheries Management and Development
Tom Brookover	ADF&G, Division of Commercial Fisheries Management and Development
Jim Browning	ADF&G, Division of Commercial Fisheries Management and Development
Stan Carlson	ADF&G, Division of Commercial Fisheries Management and Development
Drew Crawford	ADF&G, Division of Commercial Fisheries Management and Development
Beverly Cross	ADF&G, Division of Commercial Fisheries Management and Development
Doug Eggers	ADF&G, Division of Commercial Fisheries Management and Development
Ed Farley	University of Alaska, School of Fisheries and Ocean Sciences
Chris Foote	University of Washington, Fisheries Research Institute
Stephen Fried	ADF&G, Division of Commercial Fisheries Management and Development
Dennis Haanpaa	ADF&G, Division of Commercial Fisheries Management and Development
John Hilsinger	ADF&G, Division of Commercial Fisheries Management and Development
Gary Kyle	ADF&G, Division of Commercial Fisheries Management and Development
Ole Mathisen	University of Alaska, School of Fisheries and Ocean Sciences
Jim Miller	ADF&G, Division of Commercial Fisheries Management and Development
Jeff Regnart	ADF&G, Division of Commercial Fisheries Management and Development
Donald Rogers	ADF&G, Division of Commercial Fisheries Management and Development
Richard Russell	ADF&G, Division of Commercial Fisheries Management and Development
Dana Schmidt	ADF&G, Division of Commercial Fisheries Management and Development
Keith Weiland	ADF&G, Division of Commercial Fisheries Management and Development
Attended Portions of the Meeting:	
Kelly Hepler	ADF&G, Division of Sport Fisheries
Charles Meacham	ADF&G, Commissioners Office
Eric Minard	ADF&G, Division of Sport Fisheries

APPENDIX B: BROOD TABLES

Appendix B.1. Kvichak River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-89.

BROOD YEAR	SPAWNERS	RETURNS BY AGE				TOTAL RETURN	RETURNS-PER-SPAWNER
		1.2	1.3	2.2	2.3		
56	9443	24273	6968	6472	1308	39036	4.13
57	2843	243	244	3333	259	4091	1.44
58	535	76	48	135	26	289	0.54
59	680	212	117	206	11	547	0.80
60	14630	1314	563	46746	6485	55259	3.78
61	3706	334	190	2293	679	3503	0.95
62	2581	104	152	4675	408	5357	2.08
63	339	49	50	639	366	1120	3.30
64	957	2232	407	2341	647	5751	6.01
65	24326	9853	471	32951	1239	45026	1.85
66	3775	497	1086	4262	385	6262	1.66
67	3216	349	272	812	86	1527	0.47
68	2557	293	34	77	132	543	0.21
69	8394	129	321	4221	595	5304	0.63
70	13935	43	13	14463	848	15834	1.14
71	2387	244	93	2169	303	2829	1.19
72	1010	255	159	1206	297	1941	1.92
73	227	576	1028	274	543	2457	10.82
74	4434	6328	2009	16725	763	26179	5.90
75	13140	5683	1232	30263	599	38087	2.90
76	1965	5298	826	4115	273	10575	5.38
77	1341	1934	935	208	99	3238	2.41
78	4149	1835	1157	1318	817	5160	1.24
79	11218	18331	2234	17931	3512	42142	3.76
80	17505	2889	1641	8076	413	13048	0.75
81	1754	789	231	931	167	2129	1.21
82	1135	445	544	524	139	1685	1.48
83	3570	8596	3010	1195	573	13392	3.75
84	10491	2532	1924	16952	2446	23913	2.28
85	7211	1024	1279	13375	1569	17337	2.40
86	1179	693	1085	1393	1326	4563	3.87
87	6066	4189	2507	4484	703	12030	1.98
88	4065	2494	2476	4329	554	9922	2.44
89	8318	2129	1669	18795		22798	2.74
90	6970						
91	4223						
92	4726						
93	4025						
94	8338						
56-89 AVG	5679	3125	1088	7879	866	13026	2.57
56-72 AVG	5607	2382	658	7471	828	11425	1.89
74-89 AVG	6096	4074	1547	8788	930	15387	2.78

Appendix B.2. Naknek River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-88.

BROOD YEAR	SPAWNERS	RETURNS BY AGE				TOTAL RETURN	RETURNS-PER-SPAWNER
		1.2	1.3	2.2	2.3		
1956	1773	473	1701	3	304	2499	1.41
1957	635	53	329	505	674	1572	2.48
1958	278	112	211	539	168	1039	3.74
1959	2232	349	351	742	705	2154	0.97
1960	828	1408	625	696	1278	4022	4.86
1961	351	239	744	315	640	1952	5.56
1962	723	76	230	351	397	1074	1.49
1963	905	136	390	833	627	2002	2.21
1964	1350	447	264	1135	177	2060	1.53
1965	718	540	360	732	437	2120	2.95
1966	1016	728	2304	167	630	3838	3.78
1967	756	326	625	401	356	1717	2.27
1968	1023	152	234	83	269	745	0.73
1969	1331	47	307	976	1211	2552	1.92
1970	733	154	318	1845	370	2719	3.71
1971	936	397	559	1428	1844	4273	4.57
1972	587	245	241	161	599	1265	2.16
1973	357	494	618	524	598	2234	6.26
1974	1241	232	228	1026	783	2285	1.84
1975	2027	425	1746	1393	1641	5226	2.58
1976	1321	1084	4048	1575	1491	8255	6.25
1977	1086	635	2272	95	401	3492	3.22
1978	813	331	1695	1121	530	3695	4.54
1979	925	2438	973	792	408	4636	5.01
1980	2645	723	1505	1192	828	4275	1.62
1981	1796	782	2568	473	937	4788	2.67
1982	1156	185	1172	191	457	2043	1.77
1983	888	163	484	336	480	1477	1.66
1984	1242	469	911	1214	1798	4448	3.58
1985	1850	656	3524	1284	1449	7024	3.80
1986	1978	1996	7207	1278	2804	13707	6.93
1987	1062	336	1245	563	3237	5510	5.19
1988	1038	272	797	509	541	2171	2.09
1989	1162	224	924	1153			
1990	2093	405					
1991	3579						
1992	1607						
1993	1536						
1994	991						
56-88 AVG	1139	518	1236	742	881	3420	3.19
56-72 AVG	951	346	576	642	629	2212	2.72
73-88 AVG	1339	701	1937	848	1149	4704	3.69

Appendix B.3. Egegik River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-88.

BROOD YEAR	SPAWNERS	RETURNS BY AGE 1.2	1.3	2.2	2.3	TOTAL RETURN	RETURNS-PER-SPAWNER
56	1104	2025	3190	925	685	6846	6.20
57	391	37	43	1096	927	2235	5.72
58	246	42	73	817	308	1261	5.13
59	1072	73	164	1037	467	1781	1.66
60	1799	447	328	4447	2560	7911	4.40
61	702	82	229	446	791	1590	2.26
62	1027	22	69	950	375	1474	1.44
63	998	16	112	538	506	1258	1.26
64	850	126	69	1454	242	1984	2.33
65	1445	104	72	2016	845	3104	2.15
66	804	249	752	600	890	2511	3.12
67	637	60	257	665	622	1612	2.53
68	339	41	56	87	258	459	1.35
69	1016	12	111	1096	1141	2755	2.71
70	920	59	89	796	175	1240	1.35
71	634	45	109	1477	970	2733	4.31
72	546	57	61	1508	1264	2959	5.42
73	329	76	135	578	851	1679	5.10
74	1276	131	99	2224	496	3025	2.37
75	1174	148	241	2449	797	3663	3.12
76	509	612	789	3003	846	5317	10.45
77	693	823	1969	688	655	4217	6.09
78	896	398	510	6071	2184	9208	10.28
79	1032	712	520	3036	1659	5946	5.76
80	1061	803	2225	4576	917	8574	8.08
81	695	544	953	3284	1438	6316	9.09
82	1035	988	1874	1796	1638	6340	6.13
83	792	1748	2763	3235	2822	10645	13.44
84	1165	608	978	6539	4846	13338	11.45
85	1095	567	1375	4263	1262	7548	6.89
86	1152	1846	3719	3927	4525	14333	12.44
87	1274	888	4564	8880	11163	25902	20.33
88	1613	413	1493	11038	5677	18944	11.74
89	1612	602	459	6088			
90	2192	406					
91	2787						
92	1945						
93	1517						
94	1968						
56-88 AVG	919	449	909	2592	1661	5718	5.94
56-72 AVG	855	206	340	1174	766	2571	3.14
73-88 AVG	987	707	1513	4099	2611	9062	8.92

Appendix B.4. Ugashik River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-88.

BROOD YEAR	SPAWNERS	RETURNS BY AGE 1.2	1.3	2.2	2.3	TOTAL RETURN	RETURNS-PER-SPAWNER
56	425	3165	837	80	35	4132	9.72
57	215	35	105	354	100	605	2.81
58	280	63	105	444	66	678	2.42
59	219	18	38	310	132	499	2.28
60	2304	674	296	1563	487	3031	1.32
61	349	240	500	247	120	1113	3.19
62	255	77	130	185	27	423	1.66
63	388	13	21	91	23	148	0.38
64	473	31	16	245	18	321	0.68
65	997	86	38	249	162	539	0.54
66	704	723	1478	90	21	2315	3.29
67	239	56	50	44	34	184	0.77
68	71	14	7	15	3	39	0.55
69	160	4	5	53	26	92	0.58
70	735	4	2	256	28	295	0.40
71	530	178	236	290	130	835	1.58
72	79	35	58	119	41	258	3.27
73	39	16	8	17	46	92	2.36
74	62	13	15	602	83	725	11.69
75	429	1484	575	1721	325	4115	9.59
76	356	2027	1527	1248	437	5309	14.91
77	202	585	1614	266	186	2692	13.33
78	82	247	413	863	523	2065	25.18
79	1707	3076	851	1471	562	6007	3.52
80	3335	1183	2309	3371	850	7781	2.33
81	1328	1603	2632	2278	933	7468	5.62
82	1186	423	713	606	737	2508	2.11
83	1001	650	342	632	319	1965	1.96
84	1270	472	568	3635	705	5458	4.30
85	1006	508	720	977	481	2707	2.69
86	1016	507	2472	1901	1762	6788	6.68
87	687	840	1635	1886	2355	6824	9.93
88	654	464	7.2	2187	2259	5007	7.66
89	1713	703	395	2470			
90	749	347					
91	2482						
92	2174						
93	1390						
94	1095						
56-88 AVG	690	591	616	857	425	2516	4.83
56-72 AVG	495	319	231	273	85	912	2.08
73-88 AVG	898	881	1025	1479	785	4219	7.74

Appendix B.5. Wood River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-89.

BROOD YEAR	SPAWNERS	RETURNS BY AGE 1.2	1.3	2.2	2.3	TOTAL RETURN	RETURNS-PER-SPAWNER
56	773	774	627	24	0	1473	1.91
57	289	136	257	35	0	449	1.55
58	960	2145	389	75	32	2643	2.75
59	2209	979	398	359	55	1805	0.82
60	1016	1474	1039	106	105	2733	2.69
61	461	255	1183	24	20	1496	3.25
62	874	992	340	116	43	1503	1.72
63	721	536	769	76	46	1428	1.98
64	1076	452	347	338	74	1220	1.13
65	675	472	999	90	213	1787	2.65
66	1209	974	988	46	69	2121	1.75
67	516	642	269	75	80	1092	2.12
68	649	514	565	5	19	1108	1.71
69	604	57	445	201	116	833	1.38
70	1162	1539	1002	231	26	2800	2.41
71	851	456	576	198	49	1301	1.53
72	431	779	631	32	27	1514	3.51
73	330	213	1148	74	44	1484	4.50
74	1709	2956	1698	421	71	5164	3.02
75	1270	1592	1977	406	734	4785	3.77
76	817	2278	2589	572	265	5720	7.00
77	562	1029	2173	40	26	3290	5.85
78	2267	1364	1029	784	96	3288	1.45
79	1706	2643	1491	24	13	4182	2.45
80	2969	453	978	72	101	1605	0.54
81	1233	626	1137	60	86	1909	1.55
82	976	522	765	121	14	1438	1.47
83	1361	1940	1154	15	75	3194	2.35
84	1003	586	1340	32	22	1997	1.99
85	939	1127	1418	30	13	2617	2.79
86	819	1215	2014	71	65	3413	4.17
87	1337	1411	777	100	94	2463	1.84
88	867	1633	1446	92	34	3237	3.73
89	1186	2300	1944	14		4279	3.61
90	1069	1112					
91	1160						
92	1286						
93	1176						
94	1472						
56-89 AVG	1054	1090	1056	146	83	2393	2.56
56-72 AVG	852	775	637	119	57	1606	2.05
73-89 AVG	1256	1405	1475	172	110	3180	3.06

Appendix B.6. Igushik River sockeye salmon spawners and returns in thousands of fish by brood year, 1956-89.

BROOD YEAR	SPAWNERS	RETURNS BY AGE 1.2	1.3	2.2	2.3	TOTAL RETURN	RETURNS-PER SPAWNER
56	400	169	523	12	36	743	1.86
57	130	2	35	19	20	76	0.58
58	107	14	71	20	28	134	1.25
59	644	101	155	93	22	371	0.58
60	495	61	310	44	57	473	0.96
61	294	33	364	20	17	436	1.48
62	16	20	280	9	9	326	20.38
63	92	254	190	36	25	508	5.52
64	129	162	585	133	49	930	7.21
65	181	371	436	203	80	1090	6.02
66	206	66	383	6	15	470	2.28
67	282	57	90	13	12	175	0.62
68	195	43	120	0	10	175	0.90
69	512	1	131	301	103	538	1.05
70	371	26	170	41	71	309	0.83
71	211	48	164	60	30	303	1.44
72	60	89	109	6	13	229	3.82
73	60	19	650	25	29	725	12.08
74	359	441	750	346	25	1574	4.38
75	241	783	2556	137	503	3981	16.52
76	186	551	1411	194	215	2394	12.87
77	96	294	1689	9	9	2015	20.99
78	536	96	330	84	15	526	0.98
79	860	422	406	13	5	846	0.98
80	1988	20	271	25	56	372	0.19
81	591	188	779	8	49	1025	1.73
82	424	57	434	9	10	519	1.22
83	180	151	353	8	29	544	3.02
84	185	41	641	56	35	779	4.21
85	212	515	933	86	79	1627	7.67
86	308	239	2276	27	31	2606	8.46
87	169	166	603	7	29	830	4.91
88	170	193	1069	41	36	1344	7.91
89	462	510	1126	60		1711	3.70
90	366	160					
91	756						
92	305						
93	406						
94	446						
56-89 AVG	334	182	600	63	53	903	4.96
56-72 AVG	254	89	242	60	35	429	3.34
73-89 AVG	413	276	957	67	72	1378	6.58

APPENDIX C: SMOLT INFORMATION

Appendix C.1. Kvichak River numbers of sockeye salmon smolt and adult returns by brood year, 1969-91.

Brood Year	Spawners	Total Smolt	Adult Return	Smolt/ Spawner	Marine Survival
69	8,394,204	139,882,770	5,304,000	16.66	0.04
70	13,935,306	195,225,917	15,834,000	14.01	0.08
71	2,387,392	26,546,646	2,829,000	11.12	0.11
74	4,433,844	222,626,740	26,179,000	50.21	0.12
75	13,140,450	291,672,721	38,087,000	22.20	0.13
76	1,965,282	58,649,892	10,575,000	29.84	0.18
77	1,341,144	39,168,658	3,238,000	29.21	0.08
78	4,149,288	214,737,076	5,160,000	51.75	0.02
79	11,218,434	309,228,935	42,142,000	27.56	0.14
80	17,505,268	199,172,858	13,048,000	11.38	0.07
81	1,754,358	44,145,112	2,129,000	25.16	0.05
82	1,134,840	53,833,461	1,685,000	47.44	0.03
83	3,569,982	76,975,111	13,392,000	21.56	0.17
84	10,490,670	414,898,140	23,913,000	39.55	0.06
85	7,211,046	98,212,937	17,337,000	13.62	0.18
86	1,179,322	19,957,080	4,563,000	16.92	0.23
87	6,065,880	188,037,688	12,030,000	31.00	0.06
88	4,065,216	80,835,990	9,922,000	19.88	0.12
89	8,317,500	148,505,069	22,798,000	17.85	0.15
90	6,970,020	222,799,579		31.97	
91	4,222,788	51,988,277		12.31	
AVG 69-89	6,434,707	148,542,779	14,219,211	26.15	0.11

Appendix C.2. Egegik River numbers of sockeye salmon smolt and adult returns by brood year, 1980-91.

Brood Year	Spawners	Total Smolt	Adult Return	Smolt/ Spawner	Marine Survival
80	1,060,860	66,179,555	8,574,000	62.38	0.13
81	694,680	34,530,912	6,316,000	49.71	0.18
82	1,034,628	28,669,681	6,340,000	27.71	0.22
83	792,282	84,655,055	10,645,000	106.85	0.13
84	1,165,320	59,483,908	13,338,000	51.05	0.22
85	1,095,204	17,236,372	7,548,000	15.74	0.44
86	1,151,320	63,469,761	14,333,000	55.13	0.23
87	1,272,978	125,153,934	25,902,000	98.32	0.21
88	1,612,680	93,318,905	18,944,000	57.87	0.20
89	1,610,916	21,895,567		13.59	
90	2,191,362	43,787,169			
91	2,786,880	59,362,288			
AVG 80-91	1,372,426	58,145,259	12,437,778	53.83	0.22

Appendix C.3. Ugashik River numbers of sockeye salmon smolt and adult returns by brood year, 1981-91.

Brood Year	Spawners	Total Smolt	Adult Return	Smolt/ Spawner	Marine Survival
81	1,326,762	113,954,425	7,458,294	85.89	0.07
82	1,157,526	96,899,011	2,491,735	83.71	0.03
83	1,000,614	27,881,406	1,954,395	27.86	0.07
84	1,241,418	59,383,477	5,453,448	47.84	0.09
85	998,232	38,700,560	2,699,044	38.77	0.07
86	1,001,493	214,998,421	6,742,039	214.68	0.03
87	668,964	132,908,766	6,808,308	198.68	0.05
88	642,972	62,551,046	5,698,446	97.28	0.09
89	1,681,302	-		-	-
90	730,038	-		-	-
91	2,457,306	64,057,099		26.07	
AVG 81-91	1,173,330	90,148,246	4,913,214	91.20	0.06