BIOLOGICAL ESCAPEMENT GOAL FOR SITUK RIVER SOCKEYE SALMON

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Regional Information Report No.[1] 1J95-22

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
Douglas, Alaska

September 1995

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ACKNOWLEDGEMENTS

The authors thank Craig Farrington and Benjamin Van Alen for providing 1989 through 1994 catch and escapement age composition information for Situk River sockeye salmon. Thanks to Gordon Woods for providing 1985 through 1994 Situk subsistence catch data and 1988-1994 escapement data. Thanks to Mike Mills for providing a preliminary estimate of the sport harvest of sockeye salmon from the Situk River in 1994. The authors thank John E. Clark for assisting with the bootstrap analysis. Robert D. Mecum provided helpful review comments on an early draft of this report.

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ABSTRACT

Commercial, sport, and subsistence/personal use catches, escapements, and age compositions of sockeye salmon *Oncorhynchus nerka* returning to the Situk River during the years 1976-1994 were analyzed to develop a spawner-recruit relationship. The independent variable in the relationship was based on counts of upstream migrating sockeye salmon made at a weir located in the lower Situk River. Total adult recruitments of Situk River sockeye salmon from the 1976 through 1989 brood years were estimated based on the sum of estimated age-specific catches and escapements in return years 1978 through 1994; these recruitment estimates represented the dependent variable in the spawner-recruit relationship. The regression based spawner-recruit relationship was used to estimate the escapement level (48,535) that on average will produce maximum sustained yield of sockeye salmon in Situk River fisheries (about 75,500). Based on this analysis, it is recommended that the Alaska Department of Fish and Game adopt 50,000 sockeye salmon as the biological escapement goal for sockeye salmon returning to the Situk River. A management range of 30,000 to 70,000 sockeye salmon counted past the Situk River weir is identified as the likely range of escapements that will produce 90% or more of the estimated maximum sustained yield of 75,500 fish to Situk River fisheries.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Situk River, brood table, spawner-recruit, escapement goal.

INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* returning to the Situk River, near Yakutat Alaska support commercial set gill net, sport, and subsistence/personal use fisheries. The commercial set gill net fishery (fishing district 182-70) takes place in the lagoon where the Situk and Ahrnklin rivers drain into the Gulf of Alaska (Figure 1). Commercial harvests of sockeye salmon in the Situk River set gill net fishery have been monitored in-season since Statehood through the use of fish tickets (receipts from sales of commercially caught fish). The age, sex, and size composition of sockeye salmon harvested in the Situk River commercial set gill net fishery have been annually monitored since 1982. The sport fishery takes place in freshwater, predominantly in the Situk River below the Alsek Road (Figure 1). Sport fishery harvests of sockeye salmon in the Situk River have been annually monitored since 1977 through the use of a post-season postal questionnaire. The subsistence/personal use fishery takes place both in the lagoon and in freshwater. The harvest of sockeye salmon in the Situk River subsistence/personal use fishery has been monitored since 1985 by tallying reported catches from permitted fishermen.

Documented spawning locations for sockeye salmon returning to the Situk River system include tributaries and beaches of Situk and Mountain lakes, the Situk River below Situk Lake, the Old Situk River, the West Fork of the Situk River and Redfield Lake (Figure 1). Most of the spawning population of sockeye salmon is believed to return to the portion of the drainage located upstream of the outlet of Situk Lake. In 1971, the escapement of sockeye salmon into the Situk River system was monitored with the aid of a weir located just downstream of the Alsek Road (Figure 1). The weir was again operated at this site during the years 1976 through 1987. In 1988 the weir was moved downstream and installed just above the area of tidewater influence. Annual escapements of sockeye salmon have been enumerated at this site from 1988 through the current year. The age, sex, and size composition of the annual sockeye salmon escapements into the Situk River have been monitored since 1982.

The purpose of this report is to analyze catch, escapement, and age composition information and develop a spawner-recruit relationship that can be used to establish a biological escapement goal for sockeye salmon returning to the Situk River.

METHODS

Data Sources

Estimates of the harvests by commercial, sport, and subsistence/personal use fisheries for the years 1976 through 1994 are included in this analysis. Commercial catch data presented in this report originated from fish tickets. Data obtained from fish tickets were entered into the Integrated Fishery Data Base (IFDB) maintained by the Douglas Office of the Commercial Fisheries Management and Development Division of the Alaska Department of Fish and Game (ADF&G). Annual commercial harvests reported herein are based on a July 28, 1995 IFDB computer run. Sport fishery harvests reported were obtained from

the 1977-1995 annual estimates developed by the Sport Fish Division of ADF&G through the use of post-season questionnaires annually sent to a random subset of all sport fish license holders (Mills {1979-1995} for the years 1977-1993 and Mills {personal communication} for 1994). Because the 1976 sport fishery was not monitored, the average sport harvest of sockeye salmon in the Situk River during the 5-year period of 1977-1981 was used as a proxy value for the 1976 Situk River sport fishery harvest of sockeye salmon. Annual subsistence/personal use fishery harvests reported herein are based on a tally of the number of sockeye salmon that permitted fishermen stated were harvested in their mandatory post-season reports. These annual data are available for the years 1985 through 1994 (Gordon Woods, personal communication). The average subsistence/personal use harvest during the 5-year period of 1985-1989 was used as a proxy value for the years 1976 through 1984 when the fishery was not monitored annually.

Annual escapements of sockeye salmon in the Situk River have been enumerated with the aid of a weir since 1976. The escapements reported herein for the years 1976 through 1987 were taken from IFDB. Escapements of sockeye salmon in the Situk River for the years 1988 through 1994 were provided by Gordon Woods (personal communication).

Age composition of sockeye salmon in the annual Situk River escapements and in the annual Situk River commercial set gill net fishery for the years 1982 through 1988 were taken from Rowse (1990). Mark Olsen and Benjamin Van Alen (personal communication) provided age composition estimates of Situk River escapements and commercial set gill net fishery harvests for the years 1989 through 1994. Average annual age composition of the Situk River sockeye salmon escapement during the years 1982 through 1994 was used as a proxy estimate of age composition of escapements for each of the years 1976 through 1981. Average annual age composition of sockeye salmon harvested in the Situk River commercial set gill net fishery during the years 1982 through 1994 was used as a proxy estimate of age composition of these harvests for each of the years 1976 through 1981. Because age composition of the sport fishery harvests and the subsistence/personal use fishery harvests are not monitored, annual age composition estimates for the commercial set gill net fishery were used as proxy estimates for the total annual harvests.

Total Harvests of Situk River Sockeye Salmon

Not all sockeye salmon harvested in the Situk River commercial set gill net fishery are fish returning to the Situk River to spawn. In addition, sockeye salmon returning to the Situk River to spawn are harvested at locations other than the Situk River. Therefore, available interception studies of Situk River sockeye salmon were reviewed and analyzed.

A mixed stock commercial set gill net fishery takes place in Yakutat Bay (Figure 2) that harvests Situk River origin sockeye salmon. The Situk River stock of sockeye salmon comprised an estimated 50.1% of the Yakutat Bay harvest of sockeye salmon in 1987 (McPherson and Clark 1995) with the percentage ranging from 19.5% early in the season (statistical week 25; June 14-20) to 73.1% late in the season (statistical week 30; July 19-25).

Although interception of Situk River origin sockeye salmon in the Yakutat Bay fishery is believed to occur each year, 1987 is the only year for which a quantified estimate is available. Some Situk River sockeye salmon are also believed to be harvested in the mixed stock commercial set gill net fishery located along Manby Shore (Figure 2); the interception rates are believed to be smaller than the Yakutat Bay interceptions, however quantitative estimates are not available. Also, it is likely that a few Situk River sockeye salmon are harvested in the nearby Lost River commercial fishery (Figure 1); quantitative estimates of these potential interceptions are not available.

The Situk River commercial set gill net fishery takes place in the lagoon that drains both the Situk River and the Ahrnklin River. Although the Ahrnklin River supports a spawning population of sockeye salmon, the annual abundance of this run is unknown. McPherson and Clark (1995) estimated that the Situk River stock of sockeye salmon comprised 73.1% of the Situk River commercial set gill net harvest in 1987 with the percentage ranging from zero early in the season (statistical week 24; June 7-13) to 90.8% later in the season (statistical week 31; July 26-August 1). Estimates of the proportion of the Situk River stock of sockeye salmon in the Situk River commercial set gill net fishery for other years are not available.

Based upon the available data, two courses of action can be taken to estimate annual harvests of Situk River sockeye salmon. One approach is to use the 1987 estimates of the proportion of Situk River sockeye salmon in the Yakutat Bay and Situk River commercial set gill net fisheries (Figure 3) and apply these rates to other years. One of the problems with this approach is that it only partially addresses the problem in 1987 because it is likely that a few Situk River sockeye salmon were also intercepted in the Manby Shore and Lost River set gill net fisheries; and, it may be that other interceptions also occurred. Further, there is little reason to believe that the interception rates documented in 1987 apply equally across years. Another approach is to use the harvests of sockeye salmon in the Situk River commercial, sport, and subsistence/personal use fisheries as estimates of the harvest of the Situk River stock of sockeye salmon. A comparison of the two approaches (Figure 4) indicates that the magnitude of the estimated harvests are similar on an annual basis. We chose the second approach and have used the annual harvests of sockeye salmon in the commercial, sport, and subsistence/personal use fisheries in the Situk River as our best estimates of the total annual harvests of Situk River origin sockeye salmon.

Age-Specific Estimates, Estimated Total Returns, and Spawner-Recruit Relationship

Age-specific estimates of the annual escapements of sockeye salmon in the Situk River were developed by multiplying the estimated annual age proportions by the annual escapements. Total annual harvest estimates of Situk River sockeye salmon were developed by adding annual harvests in the commercial, sport, and subsistence/personal use fisheries of the Situk River. Age-specific estimates of the harvests of Situk River sockeye salmon were developed by multiplying estimated annual age proportions by estimated total annual harvests.

Annual estimates of sockeye salmon escapements by age were added to estimates of the annual catch in the Situk fisheries by age to estimate annual total returns by age for the years 1976-1994. This information was then used to develop a paired data set consisting of estimated brood year escapements for each of the years 1976 through 1989 (*i*) and the resultant sum of recruits in the years *i+2*, *i+3*, *i+4*, *i+5*, *i+6*, and *i+7*. Because recruitment of age-7 fish from brood year 1988 and age-6 and age-7 fish from brood year 1989 could not be directly summed (return years = 1995 and 1996), average age-6 and age-7 contribution proportions from the entire data set were used to estimate these missing age-6 (for brood year 1989) and age-7 contributions (for brood years 1988 and 1989).

The paired data set consisting of the estimated escapements of Situk River sockeye salmon, and the estimated total returns produced from these escapements for brood years 1976-1989 (n = 14), was used to develop a spawner-recruit relationship by fitting these paired data with the following model:

$$R = S \exp[a(1-S/P_m)] \quad (1)$$

where: R = estimated total return;
S = spawning escapement;
exp = base of the natural system of logarithms;
a = intrinsic rate of population increase in the absence of density-dependent limitations; and,
P_m = carrying capacity.

This model, commonly referred to as a Ricker recruitment curve (Ricker 1975), estimates two parameters, a and P_m, given a series of spawner and recruit observations. We assumed the errors were log-normal (as is common for salmon returns), resulting in the log-transformed equation:

$$Ln(R/S) = a - a/P_m(S) + error. \quad (2)$$

Linear regression procedures provided estimates of the intercept (a) and the slope (a/P_m) of the equation. The estimated number of spawners that produce the maximum number of recruits is:

$$S_{max} = P_m/a; \quad (3)$$

and, the estimated number of spawners that produce the maximum harvestable surplus is estimated by iteratively solving the equation:

$$S_{msy} = P_m/a \{1-\exp[-a(1-S_{msy}/P_m)]\}. \quad (4)$$

Once the spawner-recruit relationship was calculated, a series of parameters were estimated including: (1) carrying capacity, or the point on the modeled spawner-recruit line where it intersects the replacement line; (2) the estimated escapement that produces the maximum recruits, or the highest point on the curve (estimated maximum recruitment escapement); and, (3) the optimum escapement, or the point on the modeled spawner-recruit line where harvestable

surplus is at a maximum (estimated MSY escapement). The fit of the curve was measured using R^2 and the mean squared error of the regression.

Residuals in the regression-based, return per spawner rates for brood years 1976 through 1989 were calculated, arrayed by year, and examined for trends. Residuals in the spawner-recruit curve were compared to their respective escapement levels.

A second analysis of residuals was conducted wherein residuals in the spawner-recruit relationship were compared to the proportion of annual commercial fishing effort expended during the first half of the sockeye salmon run. McPherson and Clark (1995) found that sockeye salmon spawning in Mountain Lake in 1988 tended to pass the Situk River weir early and they comprised about 50% of the Situk River escapement from June 7th through July 3rd, decreasing to 31% of the Situk River escapement from July 4th through July 21st, and further decreased to 28% of the escapement from July 22nd through August 21st. We reasoned that differential commercial fishing efforts (and thus differential exploitation rates), applied to the first versus the second half of the annual Situk River sockeye salmon runs might explain a portion of the variability in return per spawner rates estimated for brood years 1976 through 1989.

Annual fishing effort by statistical week was calculated for the years 1976-1989 by multiplying the number of hours that the Situk River commercial set gill net fishery was open by the number of commercial fishing permittees that made at least one delivery to a processor during that statistical week (Figure 5). Because Riffe (1987) documented that statistical week 27 typically represents the 50% point in the migration of Situk River sockeye salmon, the fishing effort through week 27 was summed and compared to the total annual fishing effort to estimate the proportion of the total annual fishing effort that brood years 1976 through 1989 were exposed to during the first half of their spawning migration. These annual proportions of fishing effort were arrayed by year and compared to residuals in the regression based return per spawner rates for brood years 1976 through 1989.

Variability and bias associated with the estimated MSY escapement level was estimated using a bootstrap technique, similar to that used by McPherson (1990). The Ricker recruitment curve was fit to the original data used in the analysis and a set of predicted recruits was calculated for each spawning escapement in the data set. Residuals were calculated as the difference in the natural log of the observed recruits per spawner and the predicted log of recruits per spawner. The residuals of the data set were randomly selected with replacement. Thus each bootstrap iteration contained the original escapements, but with different recruits associated with these escapements, depending upon which residual was randomly chosen for each paired observation. These computer-generated spawner and recruit data were then used to estimate new values for the parameters a and P_m and the corresponding MSY escapement estimates. This procedure was repeated 4,001 times and the resulting MSY escapement estimates were ordered from the smallest to the largest. The 200th and 3,800th of these ordered estimates provided a 90% confidence interval and the 2,001st ordered estimate represented the median MSY escapement estimate.

The regression-based estimate of MSY escapement level was used as the basis for our recommendation concerning the biological escapement goal. The points on the spawner-recruit curve where sustainable harvest was estimated to result in 90% of the maximum yield were calculated. This range (escapements estimated to provide ± 90% of MSY) was used as the basis for our recommended management range for the biological escapement goal.

RESULTS AND DISCUSSION

Estimated sockeye salmon harvests from the Situk River commercial, sport, and subsistence/personal use fisheries ranged from a low of 9,093 fish in 1984 to a high of 125,175 fish in 1991 during the 19-year period of 1976-1994 (Table 1). The majority of the harvested sockeye salmon have been age-4, age-5, and age-6 fish, although a few age-2, age-3, and age-7 sockeye salmon have also been harvested (Tables 2 and 3). Estimated escapements of sockeye salmon in the Situk River during the 1976-1994 period ranged from a low of 46,701 fish in 1988 to a high of 216,631 fish in 1977 (Table 4). The majority of the sockeye salmon in these escapements have been age-4, age-5, and age-6 fish (Tables 4 and 5). Total annual runs of sockeye salmon to the Situk River were estimated to have ranged from a low of 67,281 fish in 1984 to a high of 302,430 fish in 1977 during the 1976-1994 period (Table 6).

The 1976-1989 brood year escapements of Situk River sockeye salmon were estimated to have produced adult returning recruitments that ranged from a low of 76,255 recruits from the 1979 escapement of 128,879 fish to a high of 249,416 recruits from the 1986 escapement of 71,543 fish (Table 7). Estimated number of recruits per spawner from the 1976-1989 brood year escapements were estimated to have ranged from a low of 0.404 recruits per spawner for the 1977 escapement of 216,631 fish to a high of 3.486 recruits per spawner for the 1986 escapement of 71,543 fish (Table 7).

The estimated escapements and resulting recruitments for the 1976-1989 brood years of Situk River sockeye salmon were fitted to a Ricker recruitment curve (Figure 6). The regressions R^2 value was 0.756 and the mean squared error was 0.1145. The regressions intercept (a) was estimated to be 1.556 and the regressions slope (a/P_m) was estimated to be -0.000012595. The carrying capacity (P_m) of the Situk River for sockeye salmon (replacement point on the Ricker curve) was estimated to be 123,562 fish. Maximum recruitment of sockeye salmon from the Situk River was estimated to occur with an escapement of 79,397 fish. The optimum escapement or MSY escapement level for the Situk River was estimated to be 48,535 sockeye salmon.

The Situk River escapements estimated to produce 90% or more of maximum sustained yield ranged from about 30,000 to 70,000 sockeye salmon (plus or minus about 40% of the MSY escapement level). Only 4 of the 14 brood year escapements during the 1976-1989 period have been in the range of escapements predicted to provide 90% or more of maximum sustained yield (Figure 6). The other 10 brood year escapements exceeded this range and diminished harvestable yield likely resulted from these higher levels of escapement. The four largest escapements in the data base all produced recruitments below replacement, indicating a significant degree of density dependent mortality.

Examination of residuals in the regression-modeled return-per-spawner rates indicates that recruitments have been variable with most of the variability being associated with brood year escapements in the 60,000 to 80,000 fish range (Figure 7). The correlation between brood year 1976-1989 escapements and residuals in the modeled recruit per spawner curve was not significant ($r = 0.132$; Figure 7). These residuals were, however, significantly correlated with the annual proportion of fishing effort expended in statistical weeks 24-27 ($r = 0.591$; Figure 8). Annual fishing efforts expended during the early portions of the Situk River sockeye salmon runs were typically 40% or less of the totals (Tables 8-11 and Figure 8). In general, the smaller the annual proportion of fishing effort expended during weeks 24-27, the larger the brood year recruitment residual; or in other words, recruitments larger than expected for a given escapement level are associated with annual fishing regimes wherein lesser than typical proportional fishing efforts occur during the early part of the run. Deletion of the 1984 data set, when legal fishing time was confined to weeks 25-27, and recalculation of the correlation coefficient resulted in an even stronger relationship ($r = 0.781$; Figure 8).

The median bootstrap estimate of MSY escapement was 48,318, only 217 fish different (0.45% less) than the regression based estimate of MSY escapement indicating that the regression based estimate is not substantially biased when only recruitment residuals are considered. The 90% confidence bounds of MSY escapement level obtained from bootstrapping range from 43,153 to 56,481 fish (-11% to +16% of the bootstrap median). This range is substantially smaller than the range of escapements predicted to provide for 90% or more of maximum sustained yield (plus or minus about 40% of the MSY escapement level).

We believe the Alaska Department of Fish and Game should adopt 50,000 sockeye salmon migrating past the Situk River weir as the biological escapement goal for sockeye salmon returning to the Situk River. This value is reasonably close to our estimate of the MSY escapement level and if achieved should produce a sustainable harvest of about 75,500 sockeye salmon per year. Exploitation rate with MSY escapement and MSY harvests would be about 61%, a rate similar to other sockeye salmon stocks managed for MSY (McPherson 1990). We believe the Alaska Department of Fish and Game should use a management range of 30,000 to 70,000 sockeye salmon migrating past the Situk River weir. This range of escapements is predicted to provide 90% of more of maximum sustained harvest or about 68,000 sockeye salmon or more annually in the combined commercial, sport, and subsistence/personal use fisheries of the Situk River.

The data base used for developing the recommended biological escapement goal and associated management range is well suited for spawner-recruit analysis. Total escapement has been accurately counted with a weir structure for the past 20 years. The range of escapements is over four-fold, from a low of 46,701 spawners in 1988 to a high of 216,631 spawners in 1977. Age-specific estimates of returning fish in both catches and escapements were estimated from annual sampling in almost all strata used in the analysis. Precision of these estimates is high (about 2,000 fish were sampled annually from the escapements and the set gill net fishery harvests in most years between 1982 and 1994). Estimated recruitments from the four largest escapements in the

data base were below replacement, indicating a good deal of density dependent mortality and that the Ricker model was an appropriate choice.

RECOMMENDATIONS

We believe that preserving long-term stock assessment programs should continue to be one of the highest priorities for the Alaska Department of Fish and Game. These types of programs provide information on the basic biology of the resource which is often poorly understood due to the lack of long-term programs. These programs also provide a continuing time series of data that can be used to understand the causes of abundance fluctuations, allow for comparisons of year-to-year abundance and overall status of the resource, and help improve in-season management. Because of the two to seven year life span of sockeye salmon, many years of data are necessary to monitor the spawning abundance and subsequent returns of a few cohorts, and omission of a single year of data can add uncertainty to an analysis.

We recommend that annual monitoring of sockeye salmon escapements in the Situk River by a weir located downstream near the mouth continue. Age, sex, and size composition sampling of the Situk River escapement of sockeye salmon should also continue, with target sample sizes of approximately 600 fish annually. We recommend that annual commercial, sport, and subsistence fishery harvests in the Situk River continue to be monitored to document catch levels. We recommend that the age, sex, and size composition of sockeye salmon harvested in the commercial set gill net fishery continue to be sampled with target sample sizes of 600 fish per year.

The current escapement goal for Situk River sockeye salmon is 40,000 to 55,000 fish through the weir. We recommend that the current escapement goal be formally changed by the Alaska Department of Fish and Game to 50,000 spawners per year (as measured by the Situk River weir) to approximately conform to our current estimate of the MSY escapement level. We recommend that the Alaska Department of Fish and Game adopt a fishery management range of 30,000 to 70,000 sockeye salmon per year (as measured by the Situk River weir).

Finally, we recommend that this escapement goal be reexamined in five years. The returns from the 1990 through 1995 escapements which ranged from about 45,000 (1995) to 75,000 (1991 and 1992) will be reasonably complete at that time. Analysis of the spawner-recruit relationship will be enhanced with additional completed brood years and an improved estimate of the MSY escapement level may result. Further, it is recommended that a more extensive statistical analysis be conducted on the data at that time. The analysis should consider such factors as measurement error in harvest estimates, time series effects (e.g. density effects between brood years), correlation of return per spawner rates with differential fishing effort applied to various segments of the annual escapements, and environmental effects.

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Table 1. Estimates of the annual sockeye salmon harvests in various Situk River fisheries and in the Yakutat Bay and Manby Shore commercial fisheries, 1976-1994.[1]

	Harvest Estimates of Sockeye Salmon in Numbers of Fish					
Year	Situk Commercial	Situk Sport	Situk Subsistence	Situk Total	Yakutat Bay Commercial	Manby Shore Commercial
1976	60,678	466	1,346	62,490	9,977	0
1977	83,956	497	1,346	85,799	14,150	9,785
1978	31,363	578	1,346	33,287	5,399	3,149
1979	46,384	145	1,346	47,875	3,635	6,232
1980	32,473	818	1,346	34,637	9,454	10,620
1981	29,058	292	1,346	30,696	14,400	13,463
1982	29,756	419	1,346	31,521	24,851	18,657
1983	17,817	274	1,346	19,437	17,893	7,819
1984	7,401	346	1,346	9,093	9,213	6,093
1985	18,620	61	597	19,278	11,665	5,677
1986	7,617	306	1,113	9,036	21,956	5,013
1987	63,595	1,105	1,179	65,879	25,230	8,109
1988	52,108	582	1,363	54,053	14,210	9,153
1989	99,945	1,689	2,477	104,111	24,524	30,370
1990	90,735	1,403	2,346	94,484	41,854	20,735
1991	120,123	2,134	2,918	125,175	28,581	8,413
1992	105,473	1,709	4,472	111,654	31,706	4,526
1993	104,049	6,727	3,990	114,766	19,176	3,634
1994	56,007	3,548	3,573	63,128	14,524	8,720
Averages	55,640	1,257	2,403	58,758	18,021	9,483

[1] Commercial harvest estimates were obtained from IFDB. Sport harvest estimates for 1977-1994 were taken from Mills (1977-1994); 1976 was not estimated and the average value for the 5-year period of 1977-1981 was used as a proxy estimate; 1994 estimate was from Mike Mills (personal communication). Subsistence harvest estimates for the years 1985-1994 were provided by Gordon Woods (personal communication); subsistence harvests not estimated for the years 1976-1984, the average value for the 5-year period of 1985-1989 was used as a proxy estimate for these years. Averages listed above are for the years 1976-1994 except sport (1977-1994) and subsistence (1985-1994).

Table 2. Sockeye salmon catches from the Situk commercial, sport, and subsistence fisheries and age composition estimates for the annual commercial catches, 1976-1994.[1]

Year	Situk River Sockeye Salmon Catches	Estimated Age Composition					
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1976	62,490	0.0%	1.5%	25.7%	54.8%	17.6%	0.4%
1977	85,799	0.0%	1.5%	25.7%	54.8%	17.6%	0.4%
1978	33,287	**0.0%**	1.5%	25.7%	54.8%	17.6%	0.4%
1979	47,875	**0.0%**	**1.5%**	25.7%	54.8%	17.6%	0.4%
1980	34,637	**0.0%**	**1.5%**	**25.7%**	54.8%	17.6%	0.4%
1981	30,696	**0.0%**	**1.5%**	**25.7%**	**54.8%**	17.6%	0.4%
1982	31,521	0.0%	1.2%	14.5%	51.8%	31.9%	0.6%
1983	19,437	0.0%	0.8%	13.0%	76.7%	9.4%	0.1%
1984	9,093	0.0%	0.3%	32.4%	56.6%	10.7%	0.0%
1985	19,278	0.0%	2.6%	27.3%	57.7%	12.2%	0.2%
1986	9,036	0.0%	1.3%	25.3%	51.0%	22.2%	0.2%
1987	65,879	0.0%	0.3%	13.5%	59.8%	26.2%	0.2%
1988	54,053	0.0%	1.1%	29.6%	43.1%	26.1%	0.1%
1989	104,111	0.0%	5.2%	37.5%	37.9%	16.5%	2.9%
1990	94,484	0.5%	1.0%	43.7%	45.2%	9.4%	0.2%
1991	125,175	0.0%	0.5%	25.7%	70.6%	3.2%	0.0%
1992	111,654	0.0%	1.8%	18.4%	66.2%	13.5%	0.1%
1993	114,766	0.0%	2.5%	34.7%	43.1%	19.4%	0.3%
1994	63,128	0.0%	0.6%	17.9%	53.1%	27.8%	0.6%
Averages	58,758	0.0%	1.5%	25.7%	54.8%	17.6%	0.4%

[1] Annual catches are based on estimates as described in Table 1. Age composition estimates for the years 1982-1988 were taken from Rowse (1990). Age composition estimates for the years 1989-1994 were provided by Benjamin Van Alen and Mark Olsen (personal communication). Age composition of the annual catches for the years 1976 through 1981 were not monitored; average age composition for the years 1982-1994 was used as proxy estimates. Data cells highlighted and underlined above are those cells (strata) used in the spawner-recruit relationship that were based upon average age data rather than upon than measured age composition.

Table 3. Estimated age-specific sockeye salmon catches from the Situk commercial, sport, and subsistence fisheries, 1976-1994.

Year	Situk River Sockeye Salmon Catches	Estimated Age-Specific Catches					
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1976	62,490	0	937	16,060	34,245	10,998	250
1977	85,799	0	1,287	22,050	47,018	15,101	343
1978	33,287	**0**	499	8,555	18,241	5,859	133
1979	47,875	**0**	**718**	12,304	26,236	8,426	192
1980	34,637	**0**	**520**	**8,902**	18,981	6,096	139
1981	30,696	**0**	**460**	**7,889**	**16,821**	5,402	123
1982	31,521	0	378	4,571	16,328	10,055	189
1983	19,437	0	155	2,527	14,908	1,827	19
1984	9,093	0	27	2,946	5,147	973	0
1985	19,278	0	501	5,263	11,123	2,352	39
1986	9,036	0	117	2,286	4,608	2,006	18
1987	65,879	0	198	8,894	39,396	17,260	132
1988	54,053	0	595	16,000	23,297	14,108	54
1989	104,111	0	5,414	39,042	39,458	17,178	3,019
1990	94,484	472	945	41,290	42,707	8,881	189
1991	125,175	0	626	32,170	88,374	4,006	0
1992	111,654	0	2,010	20,544	73,915	15,073	112
1993	114,766	0	2,869	39,824	49,464	22,265	344
1994	63,128	0	379	11,300	33,521	17,550	379
Averages	58,758	25	981	15,917	31,778	9,759	299

Data cells highlighted and underlined are those cells (strata) used in the spawner-recruit relationship that were based upon average age data rather than upon measured age composition.

Table 4. Sockeye salmon escapements in the Situk River and age composition estimates for the annual escapements, 1976-1994.[1]

Year	Situk River Sockeye Salmon Escapement	Estimated Age Composition					
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1976	116,989	0.0%	0.7%	23.1%	59.3%	16.7%	0.3%
1977	216,631	0.0%	0.7%	23.1%	59.3%	16.7%	0.3%
1978	146,884	**0.0%**	0.7%	23.1%	59.3%	16.7%	0.3%
1979	128,879	**0.0%**	**0.7%**	23.1%	59.3%	16.7%	0.3%
1980	79,058	**0.0%**	**0.7%**	**23.1%**	59.3%	16.7%	0.3%
1981	61,772	**0.0%**	**0.7%**	**23.1%**	**59.3%**	16.7%	0.3%
1982	75,501	0.0%	0.0%	12.1%	55.3%	32.4%	0.2%
1983	63,645	0.1%	2.2%	21.1%	70.2%	6.5%	0.0%
1984	58,188	0.0%	0.2%	32.2%	54.3%	13.0%	0.3%
1985	107,586	0.0%	0.1%	28.4%	51.3%	19.4%	0.8%
1986	71,543	0.0%	0.0%	16.2%	68.2%	15.6%	0.0%
1987	72,720	0.0%	0.0%	5.3%	78.6%	16.0%	0.1%
1988	46,701	0.0%	1.7%	21.1%	43.2%	33.0%	1.0%
1989	84,383	0.0%	3.2%	49.2%	34.8%	12.3%	0.5%
1990	70,000	0.0%	0.4%	37.1%	53.7%	8.8%	0.0%
1991	74,000	0.0%	0.1%	19.0%	78.0%	2.8%	0.1%
1992	76,773	0.0%	0.2%	11.9%	71.9%	16.0%	0.0%
1993	61,792	0.0%	0.9%	25.0%	54.8%	18.9%	0.4%
1994	72,472	0.0%	0.4%	21.1%	56.4%	21.9%	0.2%
Averages	87,928	0.0%	0.7%	23.1%	59.3%	16.7%	0.2%

[1] Annual escapements for the years 1976-1987 were taken from IFDB. Annual escapements for the years 1988-1994 were provided by Gordon Woods (personal communication). Age composition estimates for the years 1982-1988 were taken from Rowse (1990). Age composition estimates for the years 1989-1994 were provided by Benjamin Van Alen and Mark Olsen (personal communication). Age composition of the annual escapements for the years 1976 through 1981 were not monitored; average age composition for the years 1982-1994 was used as proxy estimates. Data cells highlighted and underlined above are those cells (strata) used in the spawner-recruit relationship that were based upon average age data rather than upon measured age composition. In 1990 the weir washed out on July 29th; the count of sockeye salmon was 61,375 as of that date. Based on timing considerations, it is estimated that the 1990 escapement totaled approximately 70,000 sockeye salmon. In 1991 the weir washed out on July 28th; the count of sockeye salmon was 67,737 as of that date. Based on timing considerations, it is estimated that the 1991 escapement totaled approximately 74,000 sockeye salmon.

Table 5. Estimated age-specific sockeye salmon escapements in the Situk River, 1976-1994.

Year	Situk River Sockeye Salmon Escapement	Estimated Age-Specific Escapements					
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1976	116,989	0	819	27,024	69,374	19,537	234
1977	216,631	0	1,516	50,042	128,462	36,177	433
1978	146,884	**0**	1,028	33,930	87,102	24,530	294
1979	128,879	**0**	**902**	29,771	76,425	21,523	258
1980	79,058	**0**	**553**	**18,262**	46,881	13,203	158
1981	61,772	**0**	**432**	**14,269**	**36,631**	10,316	124
1982	75,501	0	0	9,136	41,752	24,462	151
1983	63,645	64	1,400	13,365	44,679	4,137	0
1984	58,188	0	116	18,737	31,596	7,564	175
1985	107,586	0	108	30,554	55,192	20,872	861
1986	71,543	0	0	11,590	48,792	11,161	0
1987	72,720	0	0	3,854	57,158	11,635	73
1988	46,701	0	794	9,854	20,175	15,411	467
1989	84,383	0	2,700	41,516	29,365	10,379	422
1990	70,000	0	280	25,970	37,590	6,180	0
1991	74,000	0	74	14,060	57,720	2,072	68
1992	76,773	0	154	9,136	55,200	12,284	0
1993	61,792	0	556	15,448	33,862	11,679	247
1994	72,472	0	290	15,292	40,874	15,871	145
Averages	87,928	3	617	20,622	52,570	14,683	217

Data cells highlighted and underlined are those cells (strata) used in the spawner-recruit relationship that were based upon average age data rather than upon measured age composition.

Table 6. Estimated age-specific total annual runs of sockeye salmon to the Situk River, 1976-1994.[1]

Year	Situk River Sockeye Salmon Total Return	Estimated Age-Specific Total Returns					
		Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1976	179,479	0	1,756	43,084	103,619	30,535	484
1977	302,430	0	2,803	72,092	175,480	51,278	776
1978	180,171	**0**	1,527	42,485	105,343	30,388	427
1979	176,754	**0**	**1,620**	42,075	102,661	29,949	449
1980	113,695	**0**	**1,073**	**27,164**	65,862	19,299	297
1981	92,468	**0**	**893**	**22,158**	**53,452**	15,718	246
1982	107,022	0	378	13,706	58,080	34,518	340
1983	83,082	64	1,556	15,892	59,587	5,964	19
1984	67,281	0	144	21,683	36,743	8,537	175
1985	126,864	0	609	35,817	66,315	23,224	899
1986	80,579	0	117	13,876	53,401	13,167	18
1987	138,599	0	198	12,748	96,554	28,895	204
1988	100,754	0	1,389	25,854	43,472	29,519	521
1989	188,494	0	8,114	80,558	68,823	27,557	3,441
1990	164,484	472	1,225	67,260	80,297	15,041	189
1991	199,175	0	700	46,230	146,094	6,078	74
1992	188,427	0	2,163	29,680	129,115	27,357	112
1993	176,558	0	3,425	55,272	83,326	33,943	591
1994	135,600	0	669	26,592	74,395	33,421	524
Averages	146,686	28	1,598	36,538	84,348	24,442	515

[1] Estimates developed by adding age-specific estimates of the catch (Table 3) to age-specific estimates of the escapement (Table 5). Data cells highlighted and underlined are those cells (strata) used in the spawner-recruit relationship that were based upon average age data rather than upon measured age composition.

Table 7. Estimated adult recruitments and return per spawner calculations for sockeye salmon escapements in the Situk River, 1976-1989.[1]

Brood Year	Estimated Escapement	Estimated Recruitment	Return per Spawner
1976	116,989	116,774	0.998
1977	216,631	87,450	0.404
1978	146,884	83,623	0.569
1979	128,879	76,255	0.592
1980	79,058	102,925	1.302
1981	61,772	118,842	1.924
1982	75,501	143,999	1.907
1983	63,645	84,083	1.321
1984	58,188	109,990	1.890
1985	107,586	168,433	1.566
1986	71,543	249,416	3.486
1987	72,720	211,037	2.902
1988	46,701	148,117	3.172
1989	84,383	158,885	1.881

[1] Estimated adult recruitment from brood year *i* calculated by adding age-specific total returns from escapement *i* as provided in Table 6 for age-2 through age-7 fish as follows: $i+2 + i+3 + i+4 + i+5 + i+6 + i+7$. Brood year 1988 recruitment includes an average age-7 adjustment (Age 2-6 sum/[1-0.0035]) for the age-7 fish returning in 1995. Brood year 1989 recruitment includes an age-6 and an age-7 adjustment for the age-6 fish returning in 1995 and the age-7 fish returning in 1996 (Age 2-5 sum/[1-{0.1657+0.0035}]).

Table 8. Hours of legal fishing time by statistical week in the Situk River commercial set gill net fishery, 1976-1989.[1]

	Legal Hours of Fishing Time Per Statistical Week									
Year	24	25	26	27	28	29	30	31	32	33
1976	0	0	60	60	60	60	60	60	72	72
1977	0	0	84	60	84	84	84	84	84	72
1978	0	60	60	36	60	84	84	72	72	72
1979	0	36	36	60	60	36	60	60	72	72
1980	0	60	60	36	36	36	36	60	72	72
1981	0	60	60	60	60	60	60	60	96	96
1982	0	0	36	36	36	36	60	60	72	72
1983	0	0	60	36	24	36	36	36	72	72
1984	0	36	36	12	0	0	0	0	0	0
1985	0	36	36	0	36	60	60	108	72	72
1986	0	0	0	0	24	36	24	0	0	0
1987	0	0	24	48	108	108	132	132	120	120
1988	0	0	36	96	108	132	60	36	72	72
1989	0	108	108	132	162	168	168	114	132	72

[1] Data Source: Review of Emergency Orders and Annual Management Reports.

Table 9. Number of commercial permittees making at least one delivery during each statistical week in the Situk River commercial set gill net fishery, 1976-1989.[1]

	Number of Permits Fished by Statistical Week									
Year	24	25	26	27	28	29	30	31	32	33
1976	0	0	64	69	73	69	79	61	57	41
1977	0	0	67	74	69	78	67	64	34	29
1978	0	84	82	76	89	88	79	66	17	24
1979	1	70	74	76	66	72	75	58	42	32
1980	0	56	59	53	60	51	44	26	33	31
1981	0	59	63	54	54	55	43	30	23	24
1982	0	0	40	39	43	47	42	38	42	28
1983	0	0	30	35	29	43	31	25	27	23
1984	0	27	30	25	0	0	0	0	12	32
1985	0	24	26	0	37	46	37	24	14	14
1986	0	0	0	0	30	28	29	0	0	0
1987	0	0	14	61	61	48	60	47	24	16
1988	0	0	42	77	66	87	67	46	32	31
1989	0	78	76	94	84	60	65	38	33	31

[1] Data Source: IFDB computer run.

Table 10. Fishing effort by statistical week in the Situk River commercial set gill net fishery expressed in fishing permit hours, 1976-1989.[1]

	Number of Fishing Permit Hours by Statistical Week									
Year	24	25	26	27	28	29	30	31	32	33
1976	0	0	3,840	4,140	4,380	4,140	4,740	3,660	4,104	2,952
1977	0	0	5,628	4,440	5,796	6,552	5,628	5,376	2,856	2,088
1978	0	5,040	4,920	2,736	5,340	7,392	6,636	4,752	1,224	1,728
1979	0	2,520	2,664	4,560	3,960	2,592	4,500	3,480	3,024	2,304
1980	0	3,360	3,540	1,908	2,160	1,836	1,584	1,560	2,376	2,232
1981	0	3,540	3,780	3,240	3,240	3,300	2,580	1,800	2,208	2,304
1982	0	0	1,440	1,404	1,548	1,692	2,520	2,280	3,024	2,016
1983	0	0	1,800	1,260	696	1,548	1,116	900	1,944	1,656
1984	0	972	1,080	300	0	0	0	0	0	0
1985	0	864	936	0	1,332	2,760	2,220	2,592	1,008	1,008
1986	0	0	0	0	720	1,008	696	0	0	0
1987	0	0	336	2,928	6,588	5,184	7,920	6,204	2,880	1,920
1988	0	0	1,512	7,392	7,128	11,484	4,020	1,656	2,304	2,232
1989	0	8,424	8,208	12,408	13,608	10,080	10,920	4,332	4,356	2,232

[1] Estimates based on data provided in Table 8 multiplied by data provided in Table 9.

Table 11. Estimated proportion of the total fishing effort expended during statistical weeks 24-27 in the Situk River commercial set gill net fishery and return per spawner residuals, 1976-1989.[1]

Year	Total Fishing Effort During Weeks 24-27 Early	Total Fishing Effort During Weeks 28-33 Late	Total Fishing Effort During Weeks 24-33 Total	Annual Early Proportion	Return Per Spawner Residuals
1976	7,980	23,976	31,956	0.2497	-0.08311
1977	10,068	28,296	38,364	0.2624	+0.09452
1978	12,696	27,072	39,768	0.3193	-0.17336
1979	9,744	19,860	29,604	0.3291	-0.33954
1980	8,808	11,748	20,556	0.4285	-0.43964
1981	10,560	15,432	25,992	0.4063	-0.24014
1982	2,844	13,080	15,924	0.1786	+0.08612
1983	3,060	7,860	10,920	0.2802	-0.79255
1984	2,352	0	2,352	1.0000	-0.38660
1985	1,800	10,920	12,720	0.1415	+0.30400
1986	0	2,424	2,424	0.0000	+1.45923
1987	3,264	30,696	33,960	0.0961	+0.99931
1988	8,904	28,824	37,728	0.2360	+0.55632
1989	29,040	45,528	74,568	0.3894	+0.25301

[1] Fishing effort data based on information provided in Table 10. Residuals in the return-per-spawner rates calculated by subtracting the regression-based estimates of return-per-spawner from actual return-per-spawner rates estimated with the brood table of Situk River sockeye salmon total returns.

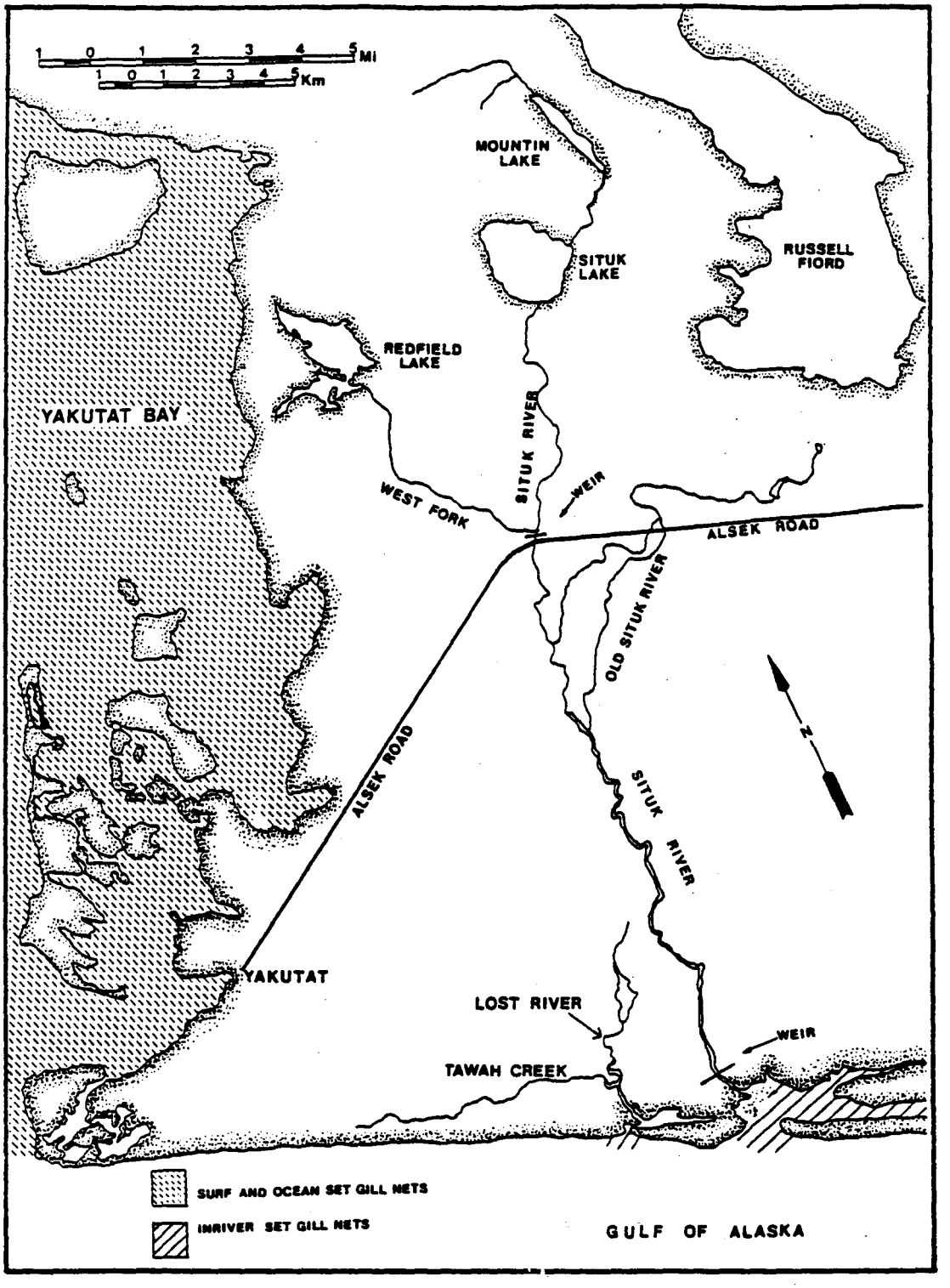

Figure 1. Map of Situk River area.

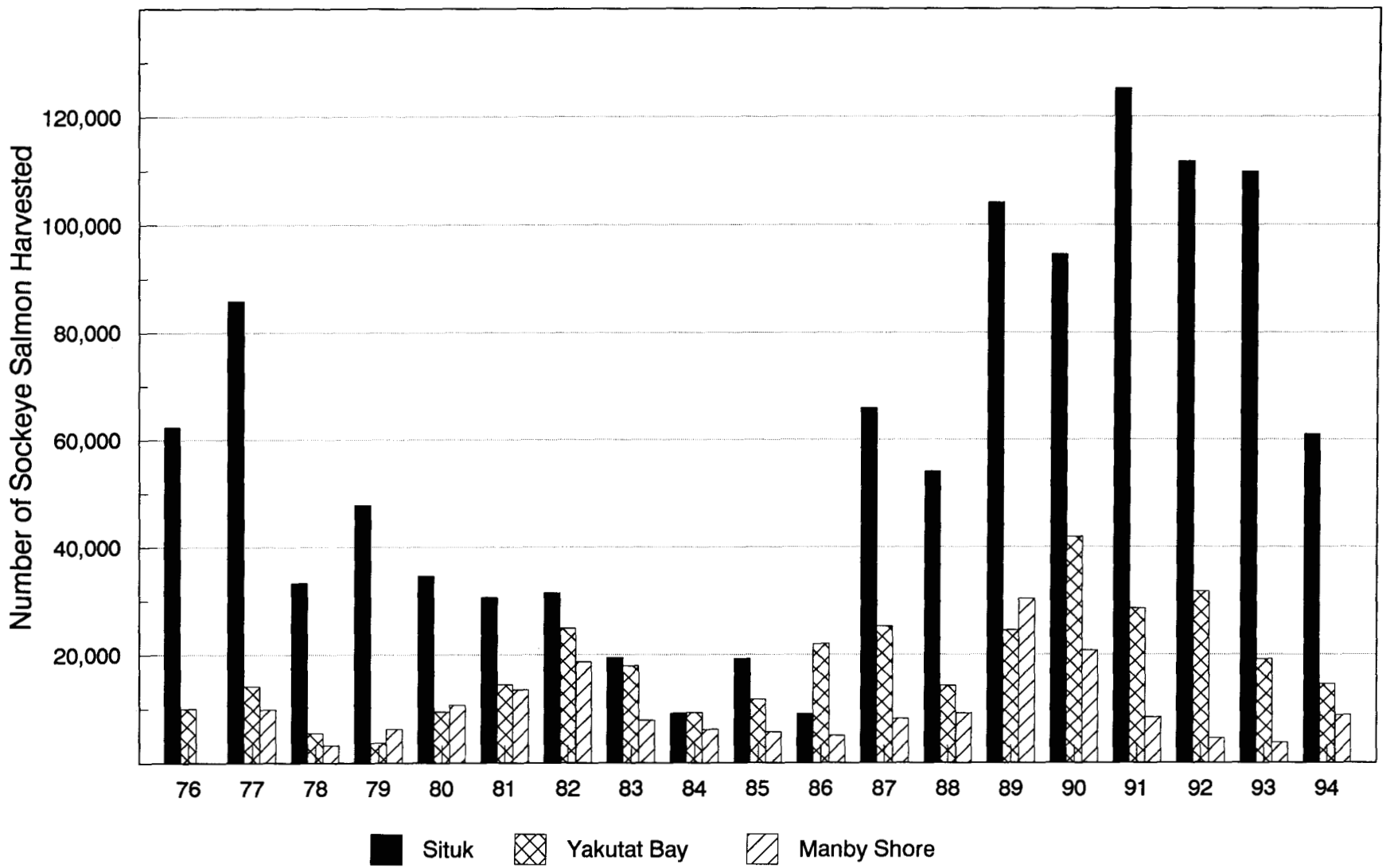

Figure 2. Sockeye salmon harvests in three fishing sub-districts of the Yakutat area, 1976-1994.

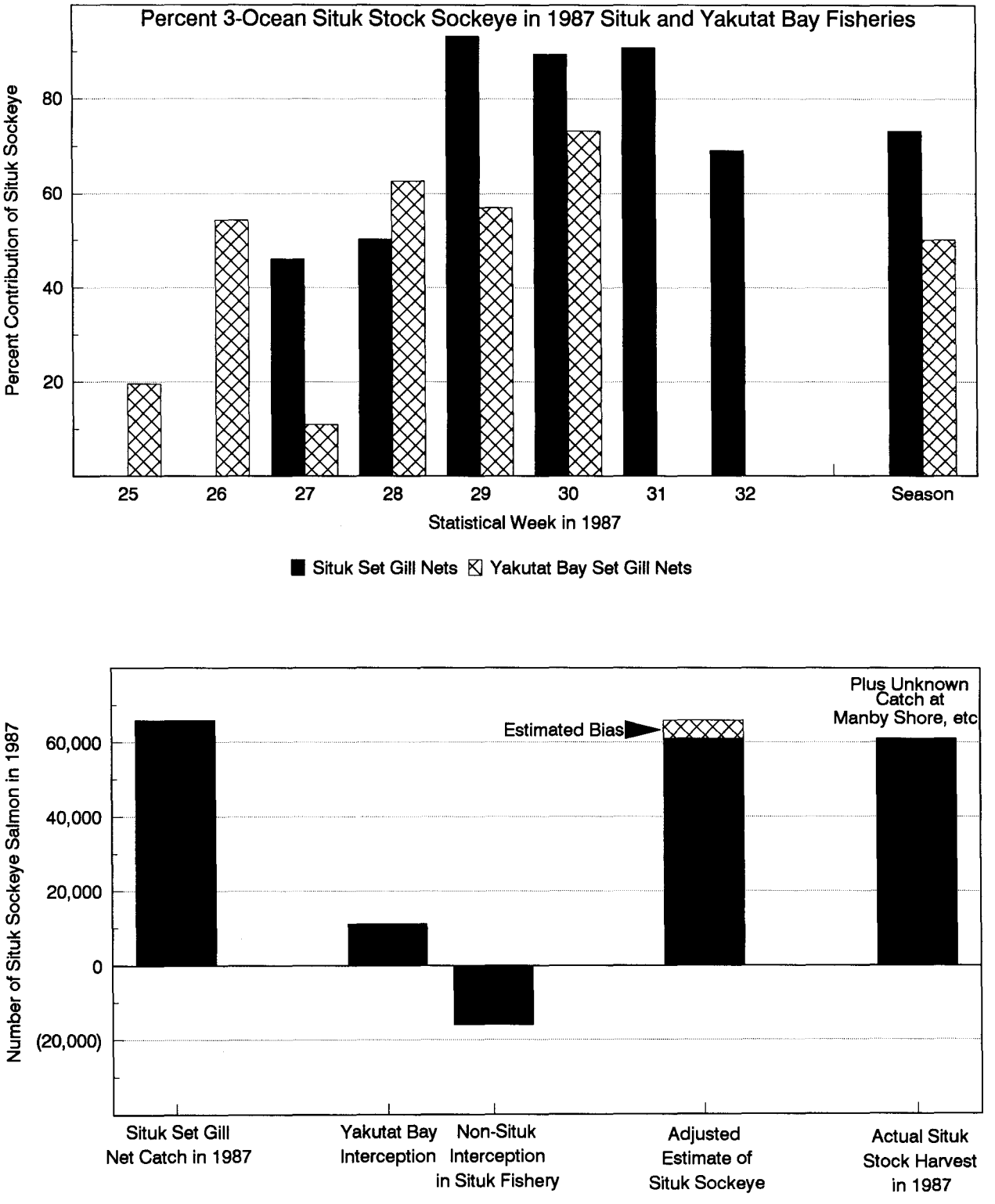

Figure 3. Contribution of 3-ocean Situk stock sockeye salmon to the Situk and Yakutat Bay set gill net fisheries in 1987 (upper) and the potential effects of interceptions on the harvest estimate used in 1987 (lower).

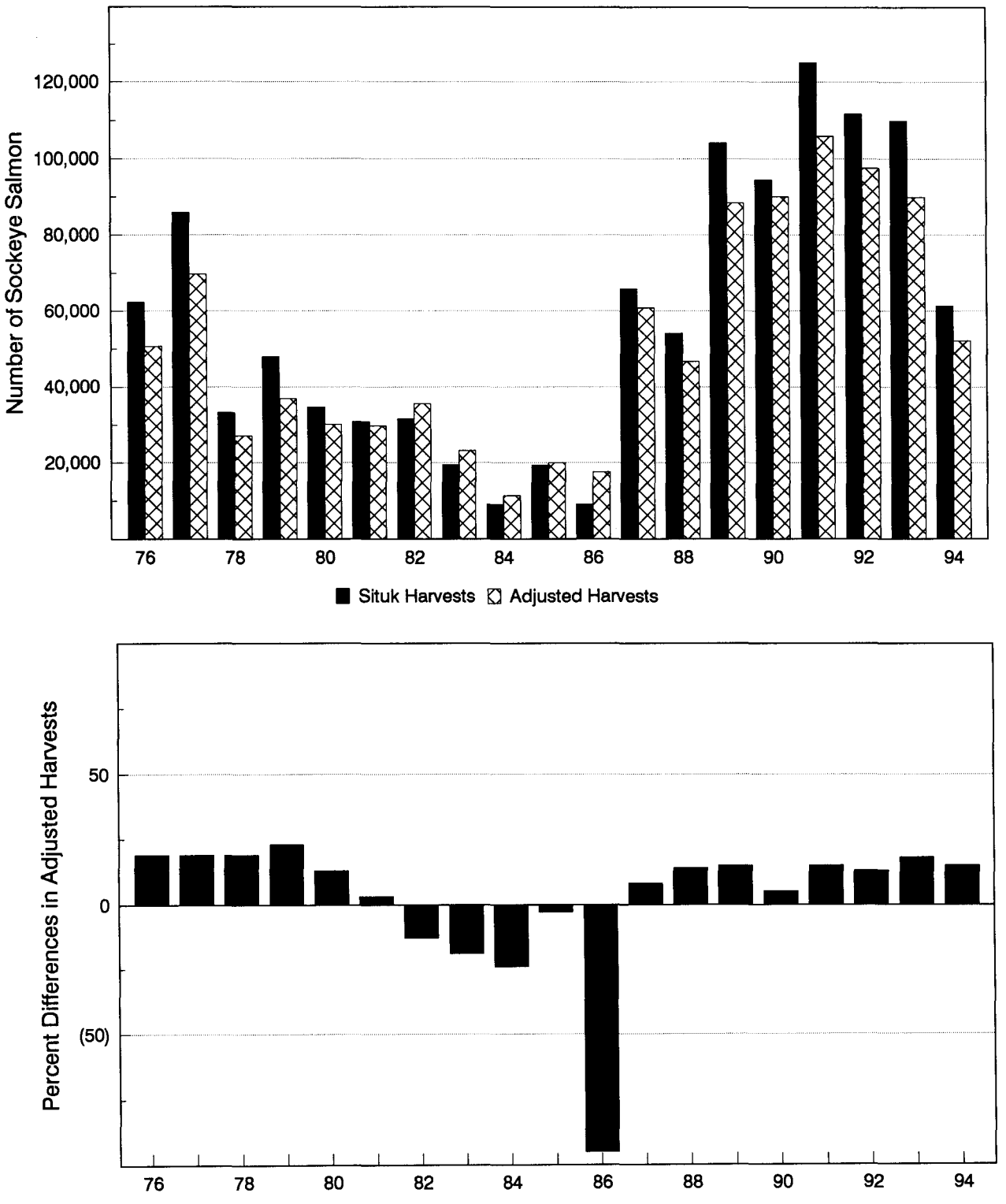

Figure 4. Comparison of harvests of sockeye salmon in the Situk sub-district with Situk stock harvests adjusted as per interception rates documented in 1987 (upper) and percent differences in these annual harvest estimates (lower), 1976-1994.

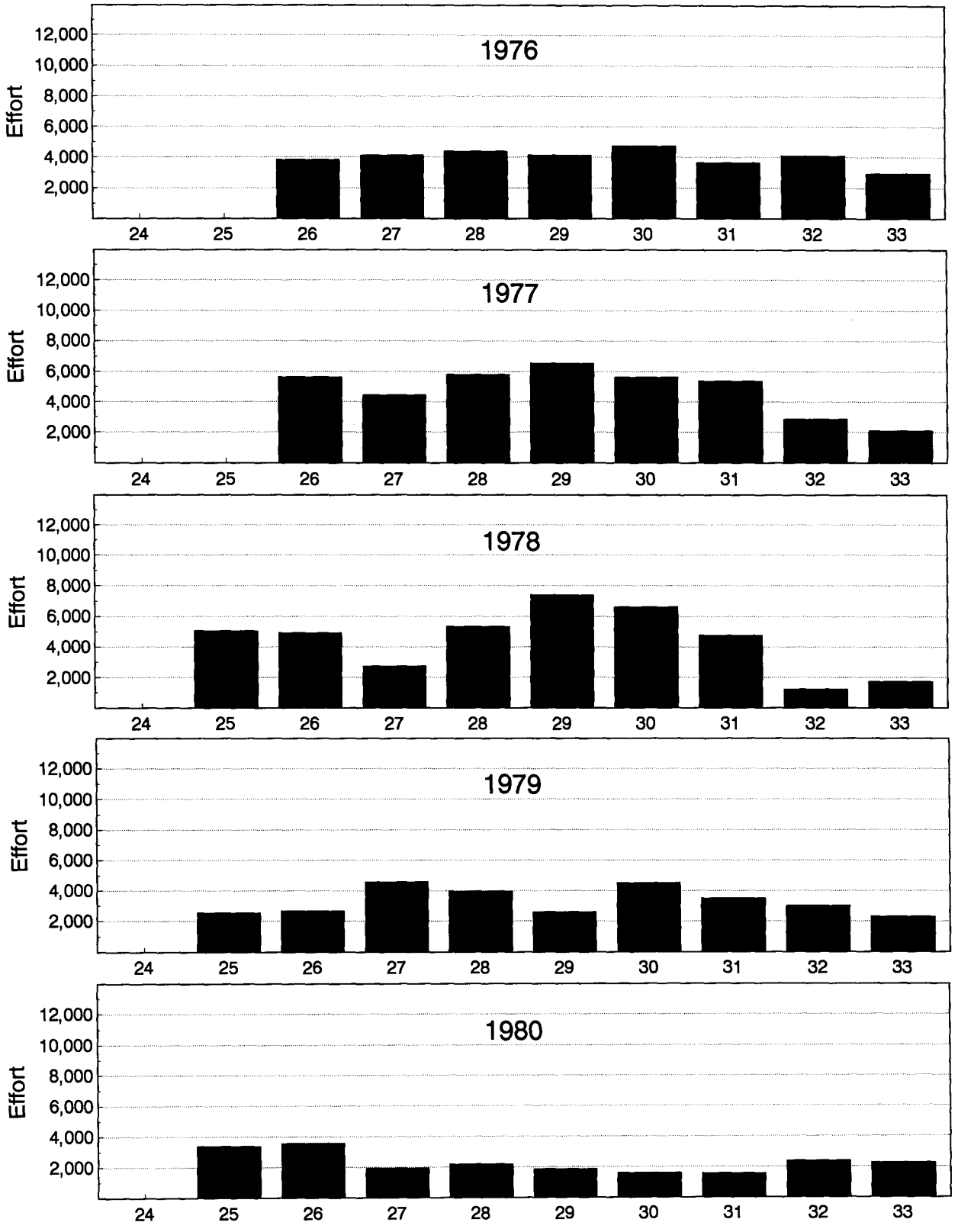

Figure 5. Fishing effort (hours open x permits fished) expended in the Situk commercial set gill net fishery by statistical week, 1976-1989 (page 1 of 3).

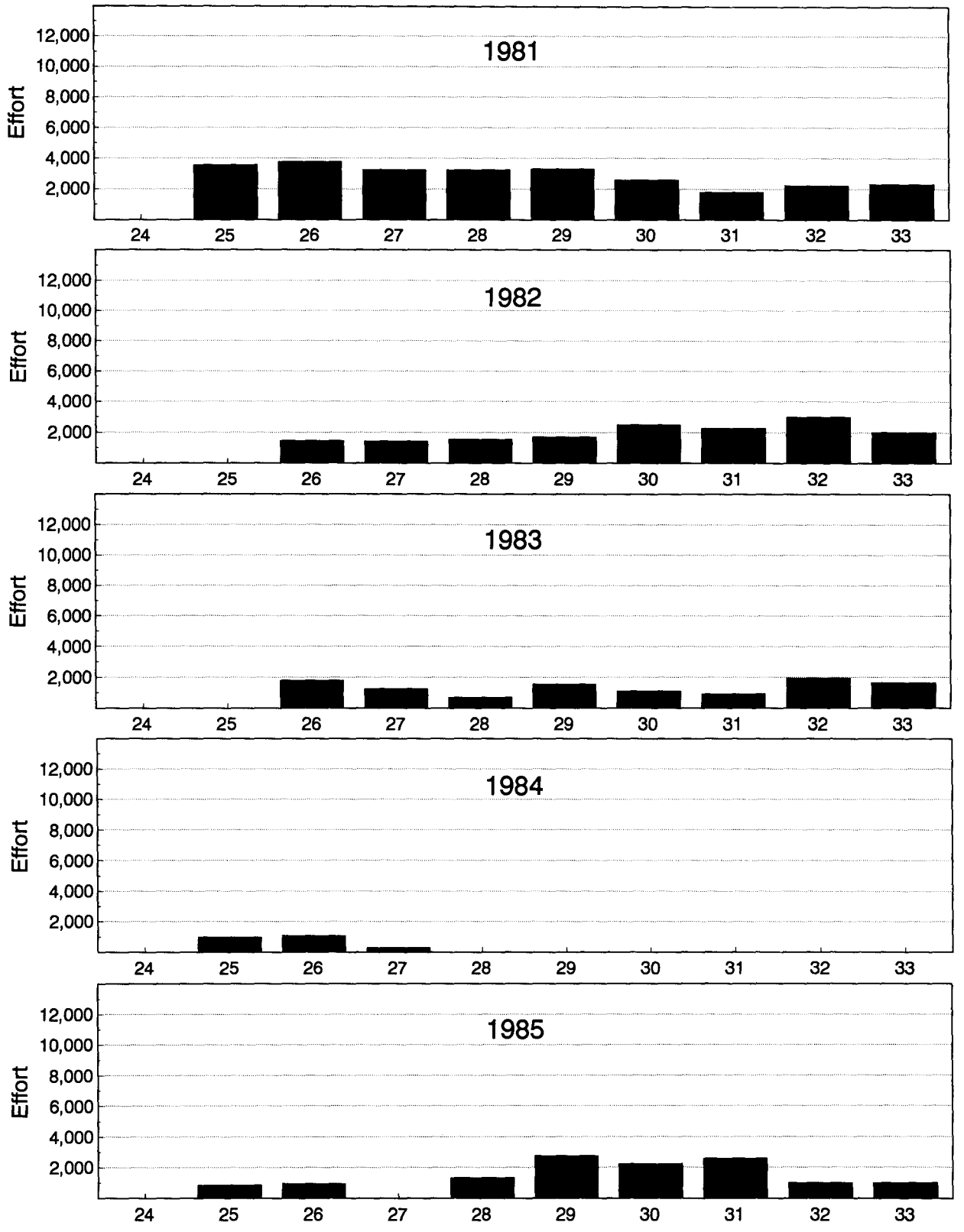

Figure 5. Fishing effort (hours open x permits fished) expended in the Situk commercial set gill net fishery by statistical week, 1976-1989 (page 2 of 3).

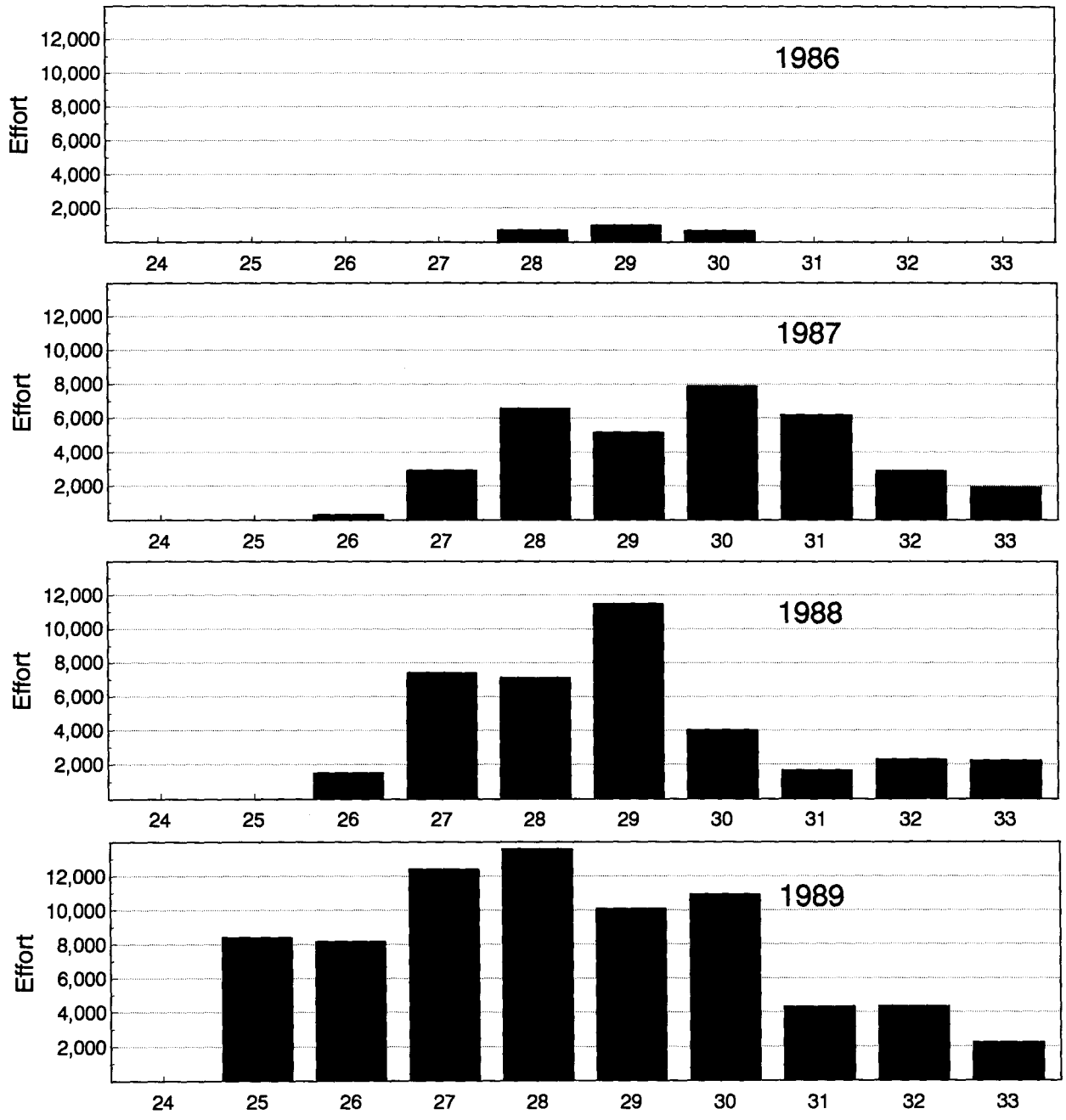

Figure 5. Fishing effort (hours open x permits fished) expended in the Situk commercial set gill net fishery by statistical week, 1976-1989 (page 3 of 3).

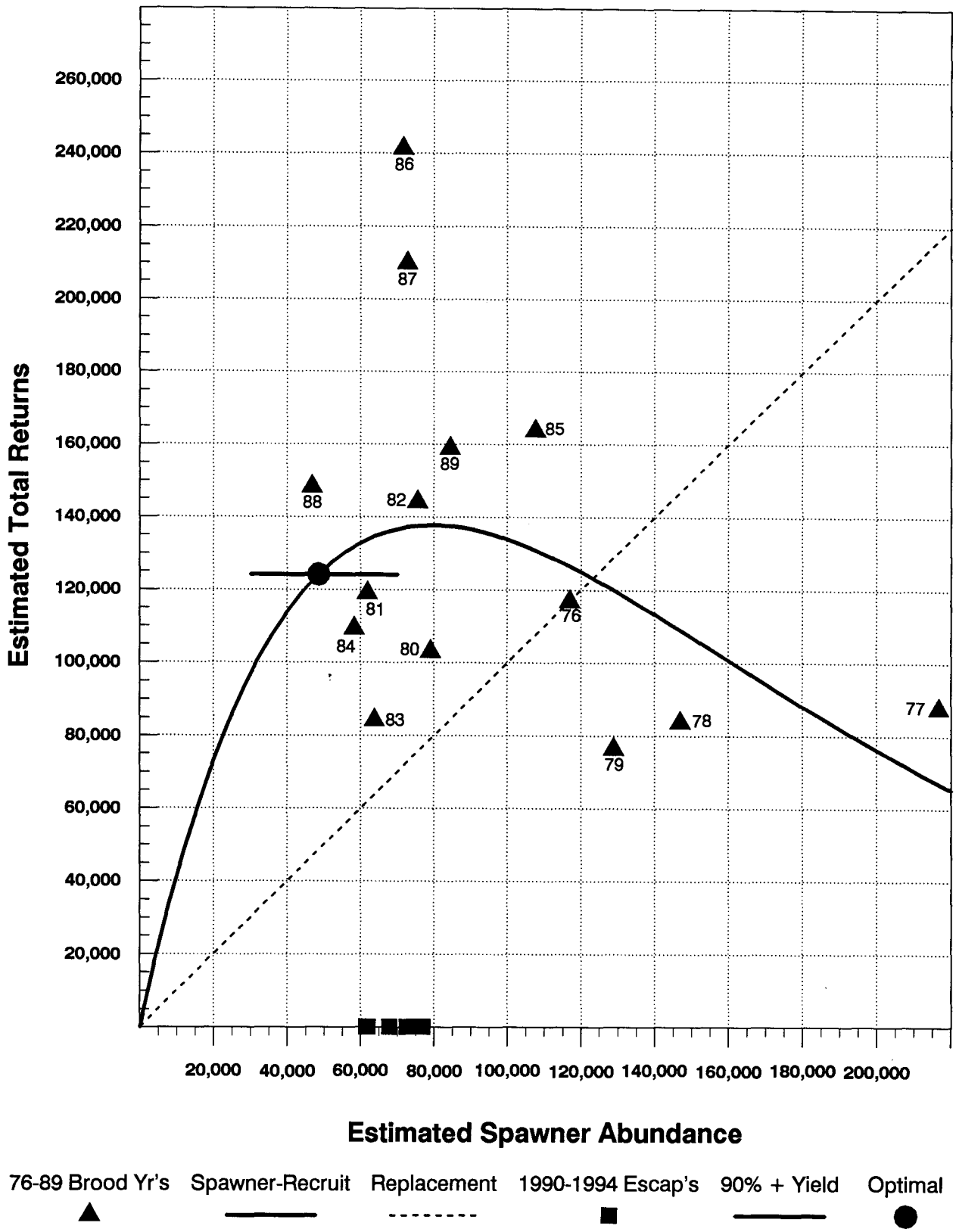

Figure 6. Spawner-recruit relationship for sockeye salmon returning to the Situk River.

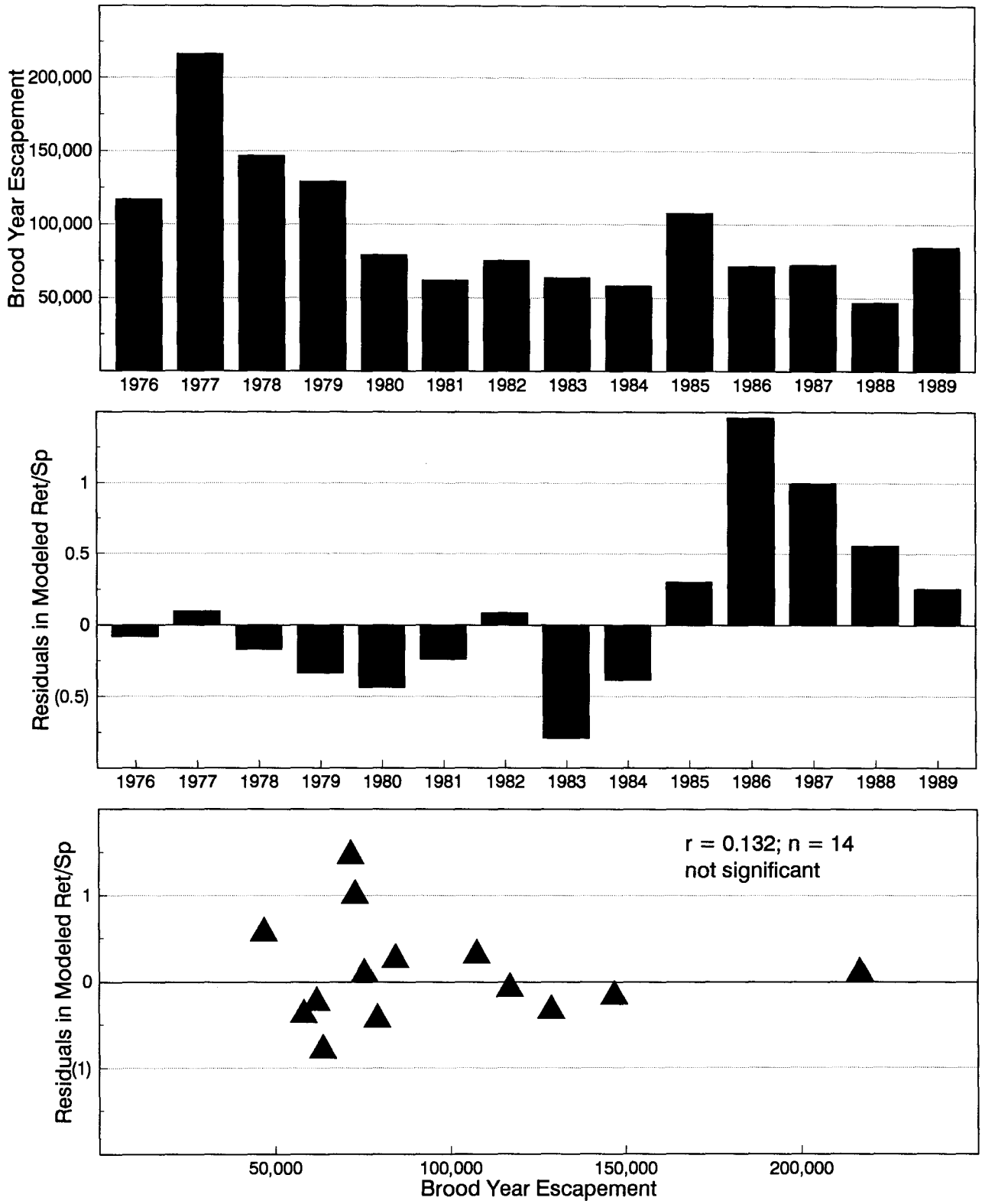

Figure 7. Brood year escapements used to develop return per spawner curve (upper); the residuals in the modeled recruit per spawner curve (middle); and the relationship between escapements and residuals (lower).

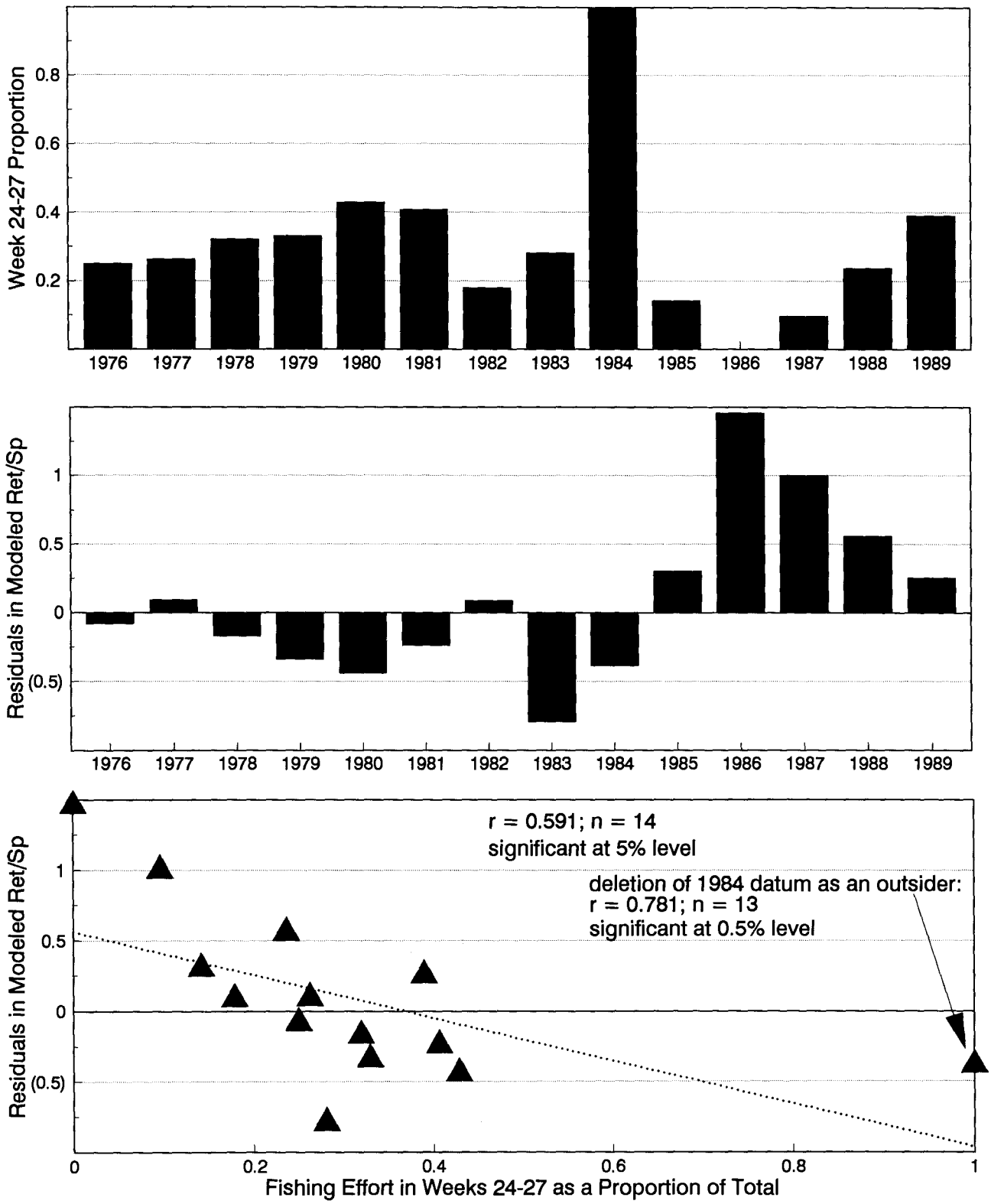

Figure 8. The proportion of annual fishing effort expended in statistical weeks 24-27 (upper); the residuals in the modeled recruit per spawner curve (middle); and the relationship between the two variables (lower).