**STATE/FEDERAL NATURAL RESOURCE DAMAGE ASSESSMENT**
**DRAFT PRELIMINARY STATUS REPORT**

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| Project Title: | Sockeye Salmon Overescapement |
| Study ID Number: | Fish/Shellfish Study No. - 27 |
| Lead Agency: | State of Alaska, ADF&G;<br>Commercial Fish Division<br>FRED Division |
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## EXECUTIVE SUMMARY

This status report describes preliminary conclusions drawn from studies conducted on the effect of overescapement on the production of sockeye salmon from major sockeye salmon rearing lakes impacted by the Exxon Valdez oil spill. Large escapements may result in the over abundance of juvenile salmon rearing in lakes. Exceeding the rearing capacity, prey resources are altered by changes in species, size composition, and biomass (Koenings and Burkett 1987; Kyle et al. 1988; Koenings and Kyle 1991). In some sockeye salmon systems, escapements of two to three times normal levels create major changes in the nursery lakes which affect the number, size, and age structure of sockeye salmon smolts. These alterations in the nursery level may be sustained, adversely affecting productivity past the initial affected year.

We report on the results of the 1989 overescapement event caused by the presence of oil on the fishing grounds for three sockeye salmon systems (Kenai/Skilak in Cook Inlet; Red and Akalura on Kodiak Island). Upper Station Lake (Kodiak) and Tustumena Lake (Cook Inlet) did not receive large escapements in 1989 and are reported as controls(Figures 1 and 2).

Preliminary data are available on the 1991 smolt production, including size, age structure, and abundance. Most striking are the major decreases in smolt abundance from Red Lake and the Kenai River systems. If the abundance estimates are accurate, projected returns from this year class smolt production would fail to meet current escapement goals established for this system. Decreases in weight of smolt and a shift in age classes to older fish is consistent with density of rearing fry limiting production in these systems. The Akalura system on Kodiak Island did not show a decrease in smolt production but did demonstrate an age shift to predominantly two year old smolt, indicative of density effects on the population.

Zooplankton size of copepoda used as prey by pelagic rearing sockeye salmon have not shown consistent changes in either abundance or average size. Other taxa more susceptible to cropping effects of high densities of rearing fry have not been examined for changes in abundance or average size.

Because the potential of complete closure of commercial fisheries on these stocks and the potential of failing to reach escapement goals may have multiple generation impacts, verification of the smolt enumeration methods used in red lake is desirable. In addition, detailed examination of potential impacts that may continue on the rearing potential of red lake and the Kenai River system lakes is desirable.

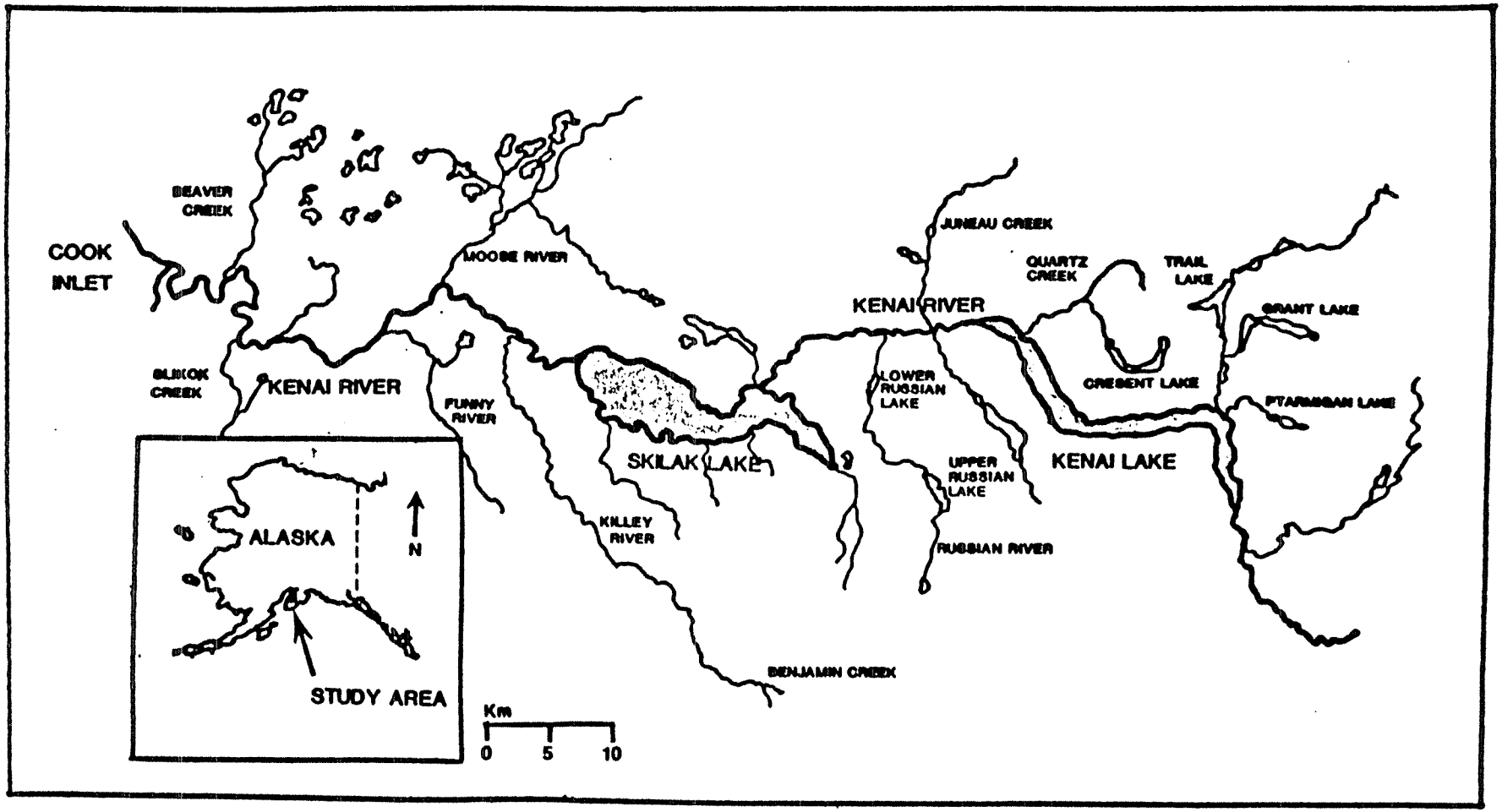



Figure 1. Location of Skilak and Kenai Lakes within the Kenai River drainage in Upper Cook Inlet.

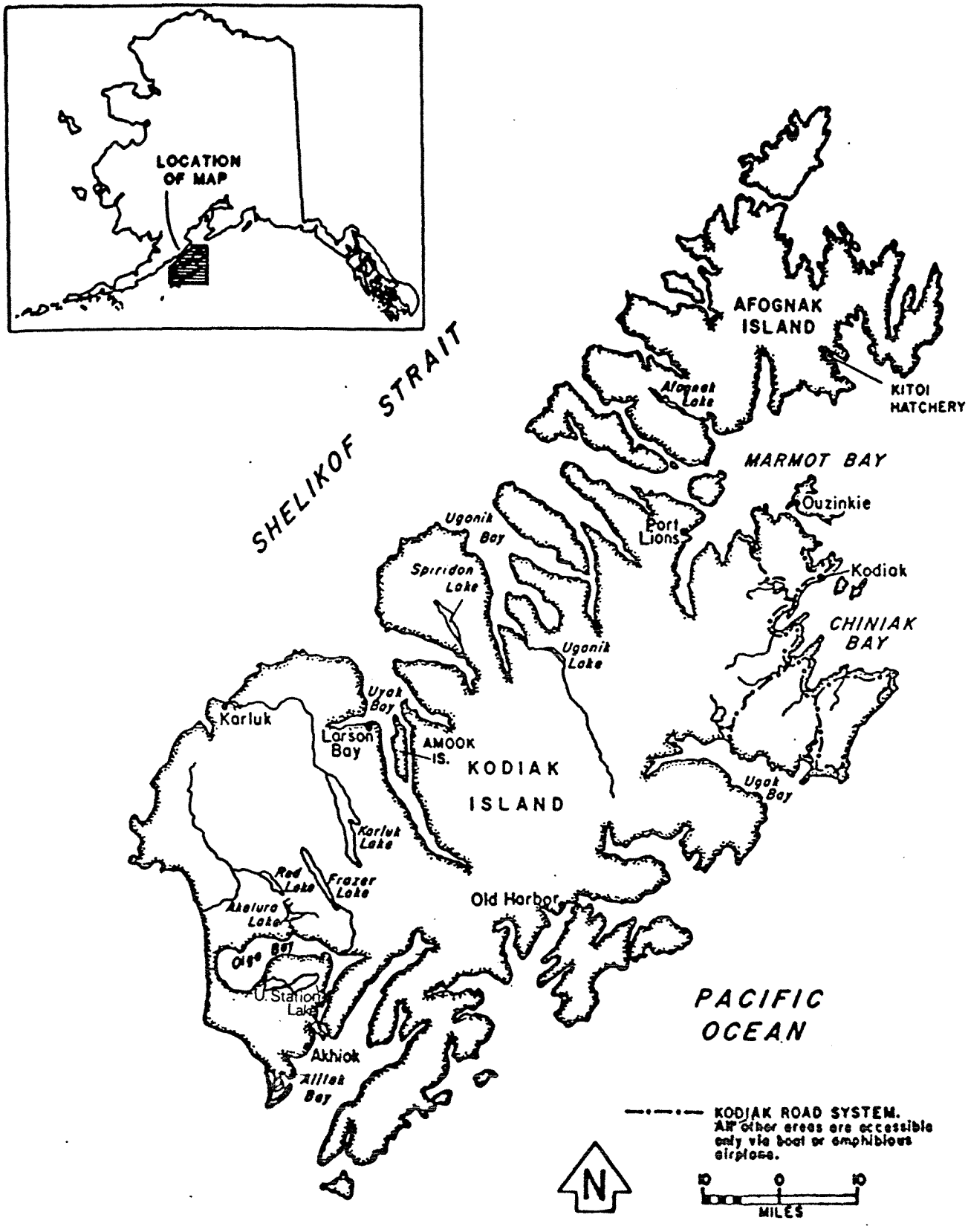



Figure 2. Location of Red, Akalura, and Upper Station Lakes on the southern end of Kodiak Island.

## OBJECTIVES

The following objectives are established as objectives of this study required to assess the impacts of overescapement on the production of sockeye salmon.

1. Estimate the number, age, and size of sockeye salmon juveniles rearing in selected freshwater systems.

2. Estimate the number, age, and size of sockeye salmon smolts migrating from selected freshwater systems.

3. Determine effects of overly large escapements on the rearing capacity of selected nursery lakes through:

   a. analysis of age and growth of juveniles and smolts; and

   b. examination of nursery area nutrient budgets and plankton populations.

4. Determine the feasibility of using otolith microstructure to evaluate density dependent growth.

5. Identify potential alternative methods and strategies for restoration of lost use, populations, or habitat where injury is identified.

# INTRODUCTION

The first two years of study (1990-1991) were designed to characterize the population parameters of sockeye salmon smolts resulting from escapements prior to and during 1989 when oil on the fishing grounds curtailed fishing. Smolt body sizes, ages, and numbers should reflect the density-dependent effects of escapements consistent with established goals, and thus help to establish pre-impact conditions. The limnological assessment, however, determined rearing conditions during the initial impact of potentially large numbers of rearing fish and the effects of large nutrient additions to the systems in the form of carcasses. High densities of planktivorous fish can exert top-down control over lower trophic levels, measurable ecosystem wide changes within the affected lakes are expected to occur. For example, major forage items within the zooplankton community will be eliminated, and prey item body-sizes and biomass will be reduced i.e. preferred food items will be exchanged for forms resistent to predation.

Use of the rearing habitat will be curtailed, and the losses may extend over several generations of fish before the lake nursery recovers. Not only will lower sockeye smolt and adult yields result, but the high/low cycle of populations may deepen to the extent of adult returns being below replacement levels. Such oscillations may impact other populations such as brown bears on the Kodiak National Wildlife Refuge i.e. escapement goals include the adult fish necessary for bear food.

In addition to understanding the magnitude of losses, the measurements of nutrients and the zooplankton community can provide needed information to support potential rehabilitation programs to restore the lost productivity.

## STUDY METHODOLOGY

### Adult sockeye salmon escapement and harvest

Numbers of adult sockeye salmon that entered selected spawning systems outside Prince William Sound prior to and during 1989, 1990, and in 1991 have been estimated at weir stations or by sonar. Estimates of adult sockeye escapement and harvest will continue at each of the study sites. Adult scales are collected for age analysis from the fishery and from fish collection devices near the sites where escapements are being enumerated.

### Rearing juvenile assessment

For each of the five lake systems identified above, the response (abundance, growth, and freshwater age) of rearing juveniles from the 1989 escapement was studied through hydroacoustic surveys conducted during the fall (September-October) of 1990. Freshwater growth and age of sockeye salmon rearing juveniles from all study systems either were or will be determined from scale and otolith measurements made either by direct visual analysis of scales or on a recently purchased Biosonics Inc. Optical Pattern Recognition system.

### Sockeye smolt enumeration

The total number of sockeye smolt (with 95% confidence intervals) migrating from each of the lake systems in 1990 was determined with a mark-recapture study using inclined plane traps. Size and ages of sockeye smolts were determined, and will be compared to brood-year smolts from the 1989 escapements migrating in 1991. Subsamples of smolts were stored frozen and sent to the University of Alaska in Fairbanks to determine the relative levels of marine versus terrestrial nitrogen. Otoliths were also obtained from a separate subsample of smolts and retained in Soldotna for growth rate analysis and freshwater pattern determinations.

### Limnological studies

Limnological studies were conducted at about three week intervals on each lake during the May through October period at two to three stations per lake (Koenings et al. 1987). Water chemistries (nutrients), chlorophyll a, and zooplankton samples were collected and sent to the State of Alaska's Limnology Laboratory located in Soldotna for analysis (Koenings et al. 1987). In cases where seasonal data is available, limnological parameters taken during residence of the juveniles from the 1989 escapements will be compared to parameters within these systems during prior years. Also, parameter values will be collected in the 1991 rearing season to assess changes in subsequent rearing years.

## STUDY RESULTS

Preliminary results from the studies have been completed with the expected dominant year class of sockeye salmon whose parents escaped into the river systems during 1989. The numbers of smolts which migrated out of the system in the spring of 1990 are compared with those which outmigrated in 1991 (Table 1). The 1990 smolts would have had minimal impact from the 1989 escapements while the 1991 smolts would primarily be from the 1989 parent escapement. These data suggest major decreases in smolt production from 1990 to 1991 in the red lake and Kenai river systems, but not in Akalura, Upper Station, and Tustumena (Kasilof River) Lake systems. Because significant numbers of juveniles may have overwintered an additional year, measurement of most of the impact of the 1989 escapement on smolt populations will not be completed until after the 1992 outmigration. With the Skilak and Kenai Lakes system, the appears unlikely as the fall 1991 juveniles from the lakes did not have appreciable numbers of 1989 brood year juveniles appearing in the trawl samples from the lakes (less than 5%). Actual fry abundance estimates for the 1991 season have not been estimated to date and age composition data for the Kodiak Island systems are not yet available. The combined effect of escapement with changes in smolt production is illustrated on Figure 3 for the Kenai and Kasilof systems.

The average length of smolts compared among the lake systems and between years 1990 and 1991 are illustrated on Figure 4. The average length of age one smolts from red lake was significantly reduced in 1991 for the smolts outmigrating from red lake.

The age class composition of smolt shifted significantly to older age class smolt in Akalura, with few outmigrants of the 1989 year class (age 1) (Table 1 and Figure 5). The red lake smolts showed a major increase in the proportion of age 3 smolt (1987 brood year). This would be consistent with very poor production of smolt from the 1988 and 1989 brood years. Kenai and Kasilof systems did not show significant changes in age class composition with respect to recent changes in abundance. However, the Kasilof river smolt demonstrated an increase to older age smolt in earlier years. Because of consistent high escapements into the Kenai River, the age composition shift or decreases in length of smolt produced from Kenai river lakes may have occurred prior to the limited time series illustrated. Age 2 smolt outmigrating from the river systems in the spring of 1992 will also have been produced from the 1989 over-escapement event.

The zooplankton communities in these lakes demonstrate minor decreases in density in these systems (Figure 6), but no significant trends. Average length of key taxa utilized by rearing sockeye did not demonstrate a significant decrease in average length (Figure 7). The trend in zooplankton density and abundance does not suggest major affects of cropping either within the summer growing season or between years. Density dependency limitations on

fry trends may occur in early spring, and may not have major effects on the pelagic rearing zooplankton communities. Examination of otoliths collected from outmigrating smolts may provide some insight into the time period where decreased growth occurs and insight into what factors adversely affect survival.

Water quality parameters were examined for red lake to determine if nutrient additions from the carcasses from large escapements from 1989. An increase in total phosphorous apparently occurred in the spring during the first sampling period but rapidly returned to normal levels by the subsequent sampling period.

## STATUS OF INJURY ASSESSMENT

The results of these investigations highlight some of the significant findings. Although preliminary, the results are generally consistent with high escapements creating an overtaxing of the rearing areas in Red Lake on Kodiak Island and Skilak and Kenai Lakes on the Kenai river system. Akalura demonstrated a major shift in age class composition with minimal numbers of 1989 smolt being produced. Injurious affects of high density may result in weak production of 1992 smolt, since the 1991 outmigrating smolt were dominated by 1988 brood year smolt. Smolt sizes have decreased or remained constant with a shift to older age classes. Extreme declines in abundance may have occurred if estimations of smolt outmigrating from the systems are accurate. Potentially, larger numbers of smolt may be produced from the 1989 brood year that will outmigrate from these systems in the spring of 1992.

If the abundance of smolt being produced by red lake and the Kenai River lake systems are accurately reflected in the estimates provided, major decreases in commercial production of sockeye salmon can be forecast. To insure accuracy in this prediction, investigations need to be continued during the upcoming season to determine if recovery occurs as densities in these systems are reduced because of decreased escapements in 1990 and 1991. Because smolt production methods used on red river indicate a high degree of avoidance of the traps. Verification of the enumeration technique should be completed during the spring of 1992 by using weir counts to provide an alternative method of estimating trap efficiency.

On the Kenai River, continued monitoring of smolt production is required to determine if a response to decreased escapements in 1990 and 1991 result in improved survival of over-wintering fry in Skilak and in Kenai lakes. In addition, ongoing studies of zooplankton and the examination of otolith growth patterns in surviving smolt compared with rearing fall fry should provide additional information as to the effects of density on survival. An additional years data to compare smolt outmigration enumeration techniques on the Kenai river will also be of assistance in determining if the observed poor over-wintering survival of

juvenile sockeye salmon is not an artifact of inconsistent estimating techniques of smolt abundance. Smolt samples from the Russian River system would be desirable to confirm aging of smolt collected from the Kenai river. Because decrease survivorship in Kenai and Skilak lakes is not reflected in the zooplankton trends observed, late winter and early spring tow netting in the lakes may help elucidate when the population of rearing fry is encountering stress related to density.

Table 1. Summary of escapement and smolt production data from study area lakes on Kodiak Island and the Kenai Peninsula. Years refer to escapement year with smolt numbers indicated being produced from the listed escapement values.

Kenai River Smolt Production

| Year | Adult Esc | Smolt Production Age-0.0 | Age-1.0 | Age-2.0 | Age-3.0 |
|---|---|---|---|---|---|
| 1986 | 501,157 | | | 71,626 | 11,488 |
| 1987 | 1,596,870 | | 23,803,713 | 6,054,266 | 0 |
| 1988 | 1,021,500 | 0 | 5,422,416 | 418,169 | |
| 1989 | 1,599,959 | 0 | 2,590,239 | | |
| 1990 | 659,520 | 0 | | | |
| 1991 | 645,421 | | | | |

Kasilof River Smolt Production

| Year | Adult Esc | Smolt Production Age-0.0 | Age-1.0 | Age-2.0 | Age-3.0 |
|---|---|---|---|---|---|
| 1986 | 275,963 | 0 | 2,056,000 | 3,009,000 | 0 |
| 1987 | 249,246 | 0 | 3,109,000 | 3,521,000 | 0 |
| 1988 | 204,000 | 0 | 3,961,000 | 2,335,300 | |
| 1989 | 158,206 | 0 | 2,400,200 | | |
| 1990 | 144,136 | 0 | | | |
| 1991 | 237,956 | | | | |

Red River Smolt Production

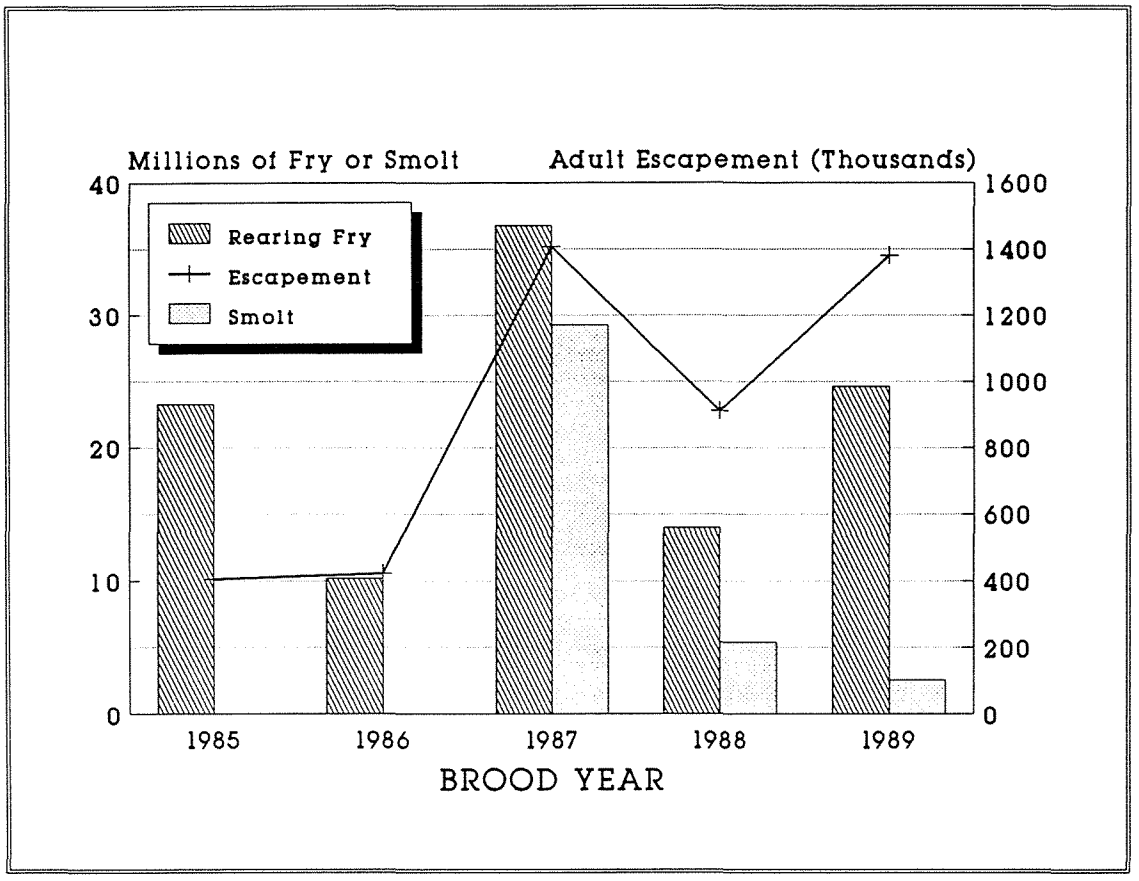
| Year | Adult Esc | Smolt Production Age-0.0 | Age-1.0 | Age-2.0 | Age-3.0 |
|---|---|---|---|---|---|
| 1986 | 381,135 | | | | 7,116 |
| 1987 | 261,913 | | | 512,351 | 45,990 |
| 1988 | 291,774 | | 192,131 | 99,645 | |
| 1989 | 768,101 | 0 | 109,865 | | |
| 1990 | 371,282 | 0 | | | |
| 1991 | 374,859 | | | | |

Akalura Smolt Production

| Year | Adult Esc | Smolt Production Age-0.0 | Age-1.0 | Age-2.0 | Age-3.0 |
|---|---|---|---|---|---|
| 1986 | 9,800 | | | | 0 |
| 1987 | 6,116 | | | 248,284 | 3,900 |
| 1988 | 38,618 | | 238,548 | 374,400 | |
| 1989 | 116,029 | 0 | 11,700 | | |
| 1990 | 47,181 | 0 | | | |
| 1991 | 44,189 | | | | |

Upper Station Smolt Production

| Year | Adult Esc | Smolt Production Age-0.0 | Age-1.0 | Age-2.0 | Age-3.0 |
|---|---|---|---|---|---|
| 1986 | 466,385 | | | | 137,600 |
| 1987 | 232,195 | | | 3,439,989 | 46,667 |
| 1988 | 306,560 | | 1,031,997 | 700,000 | |
| 1989 | 286,288 | 2,270,393 | 466,667 | | |
| 1990 | 254,446 | 1,120,000 | | | |
| 1991 | 292,886 | | | | |



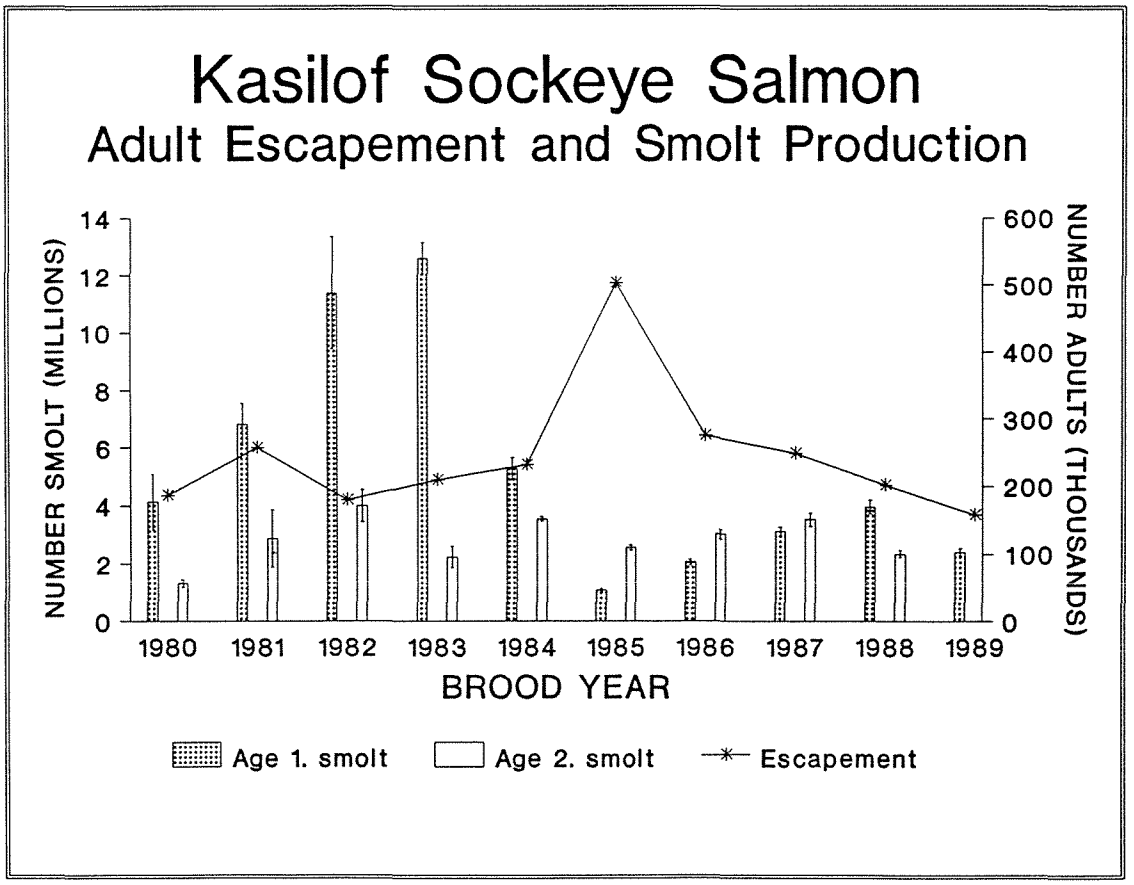




Figure 3. Escapement versus smolt production on the Kenai and Kasilof rivers for recent years.

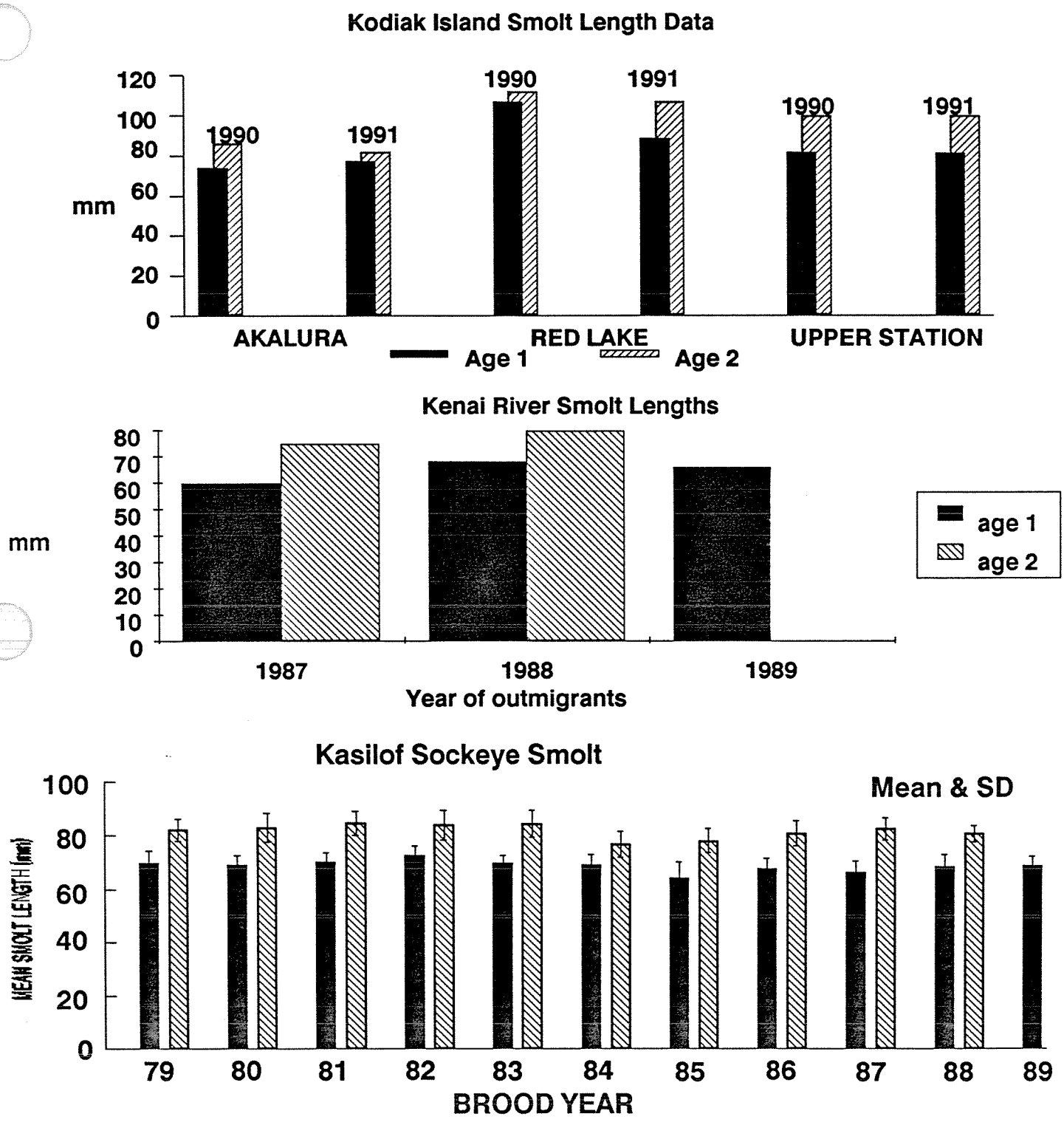



Figure 4. Average lengths of smolt produced from Kenai Peninsula and Kodiak Island lake systems during recent years.

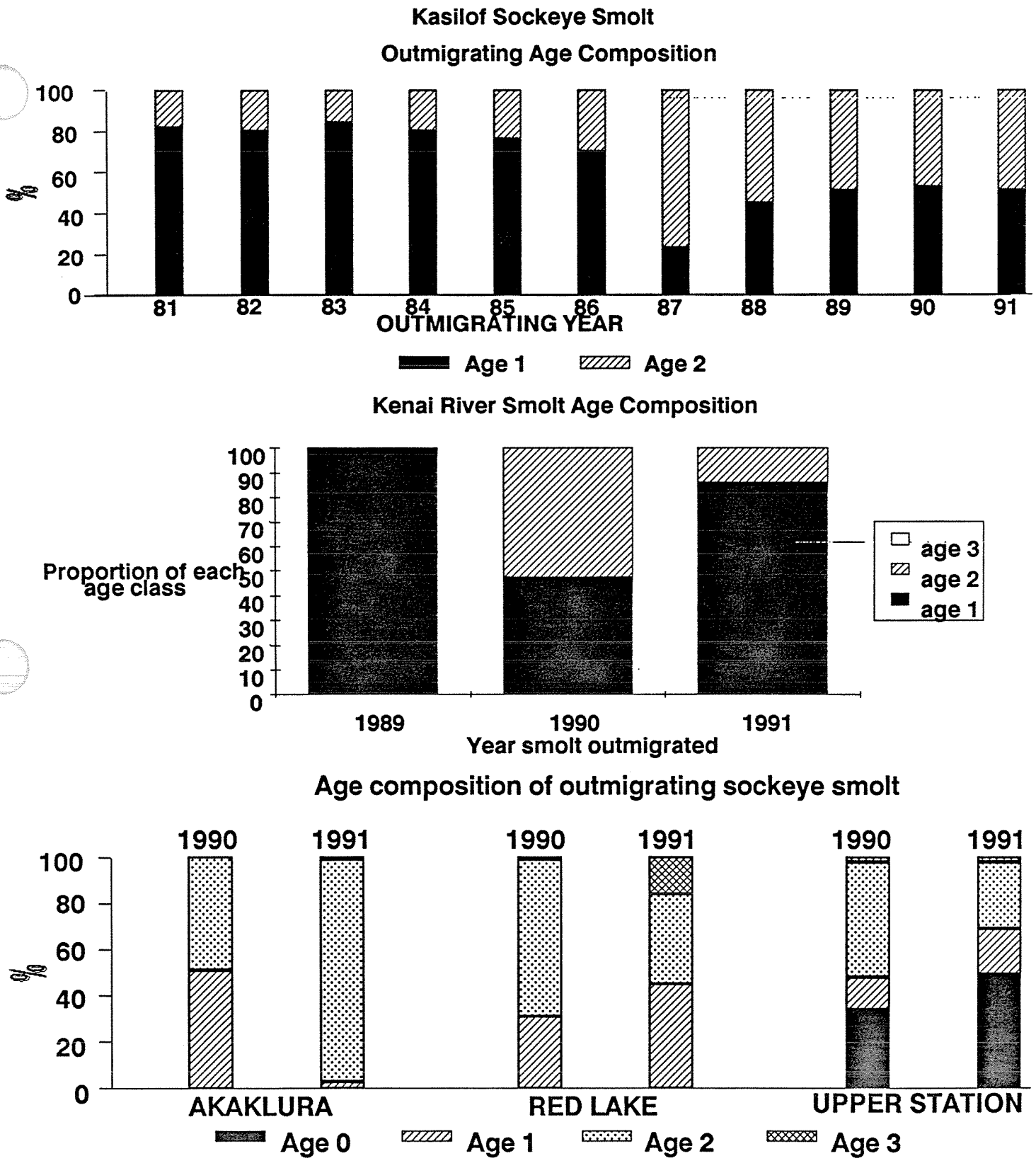



Figure5. Age composition of smolt produced from the Kenai Peninsula and Kodiak Island lake systems during recent years.

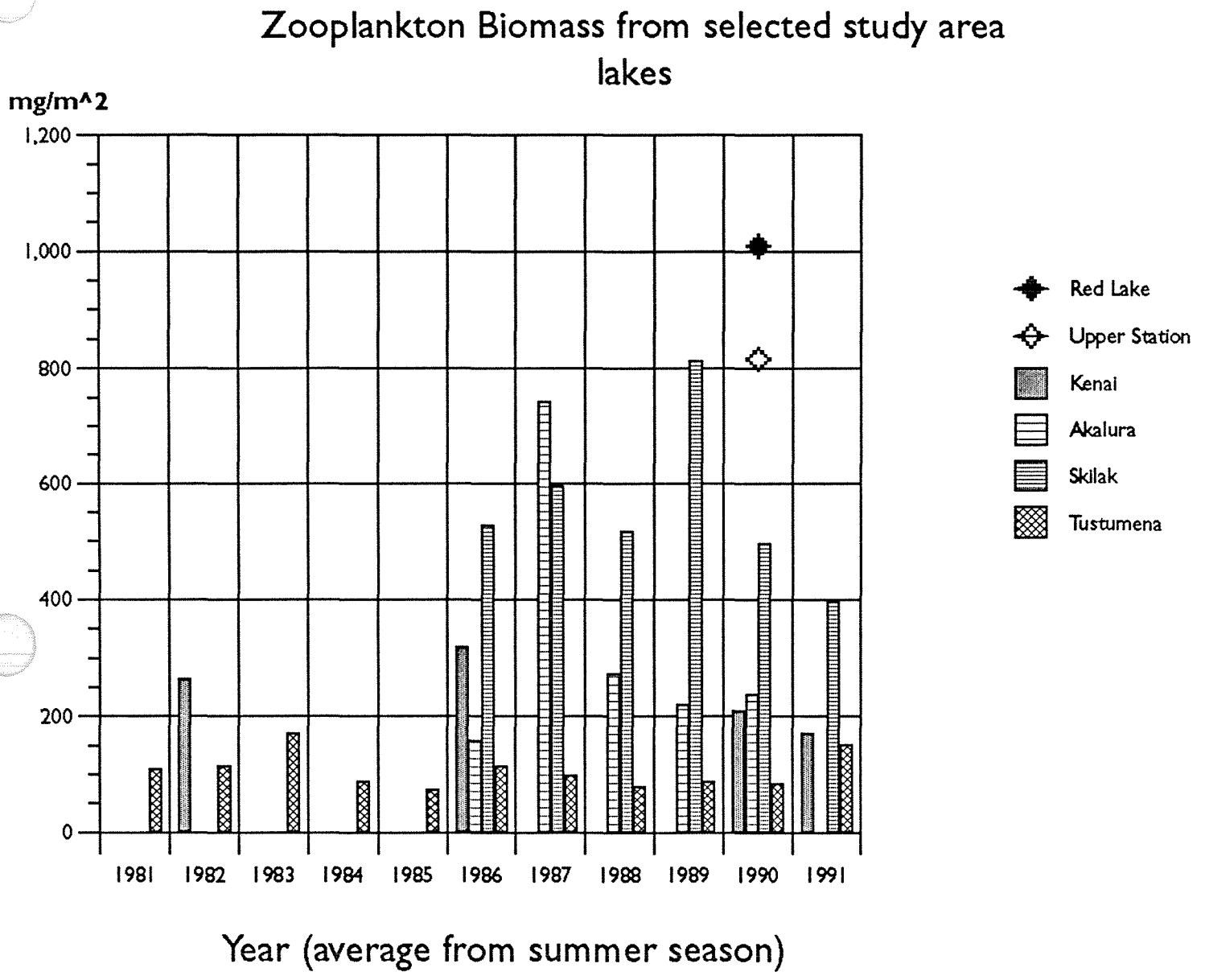



Figure 6. Interannual variations in average zooplankton biomass from Kenai, Skilak, and Tustumena Lakes on the Kenai Peninsula and from Akalura, Red, and Upper Stations Lakes on Kodiak Island. Zero values reflect missing data.

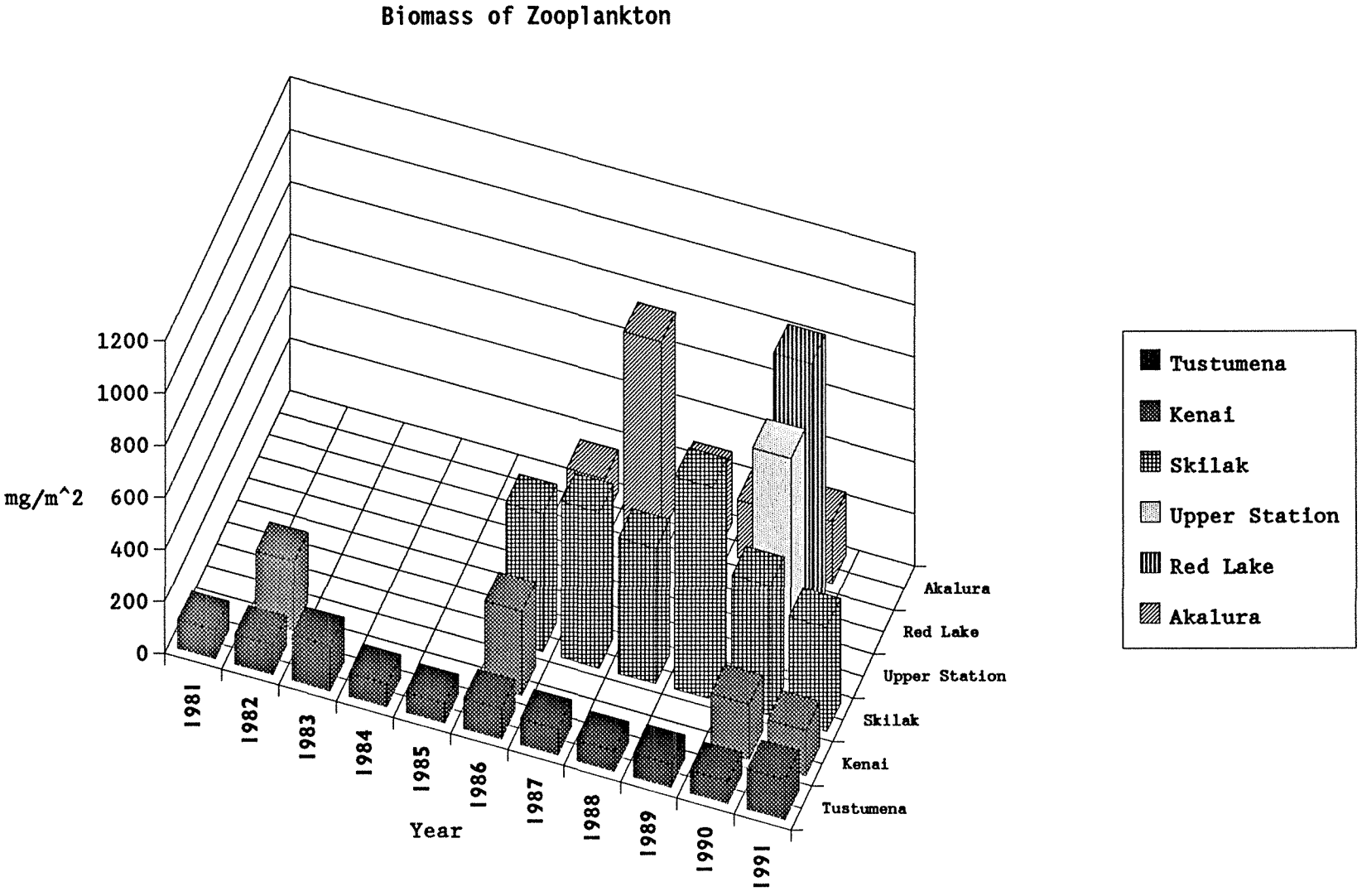



Figure 6. Interannual variations in average zooplankton biomass abundance from Kenai, Skilak, and Tustumena Lakes on the Kenai Peninsula and from Akalura, Red, and Upper Stations Lakes on Kodiak Island. Zero values reflect missing data.

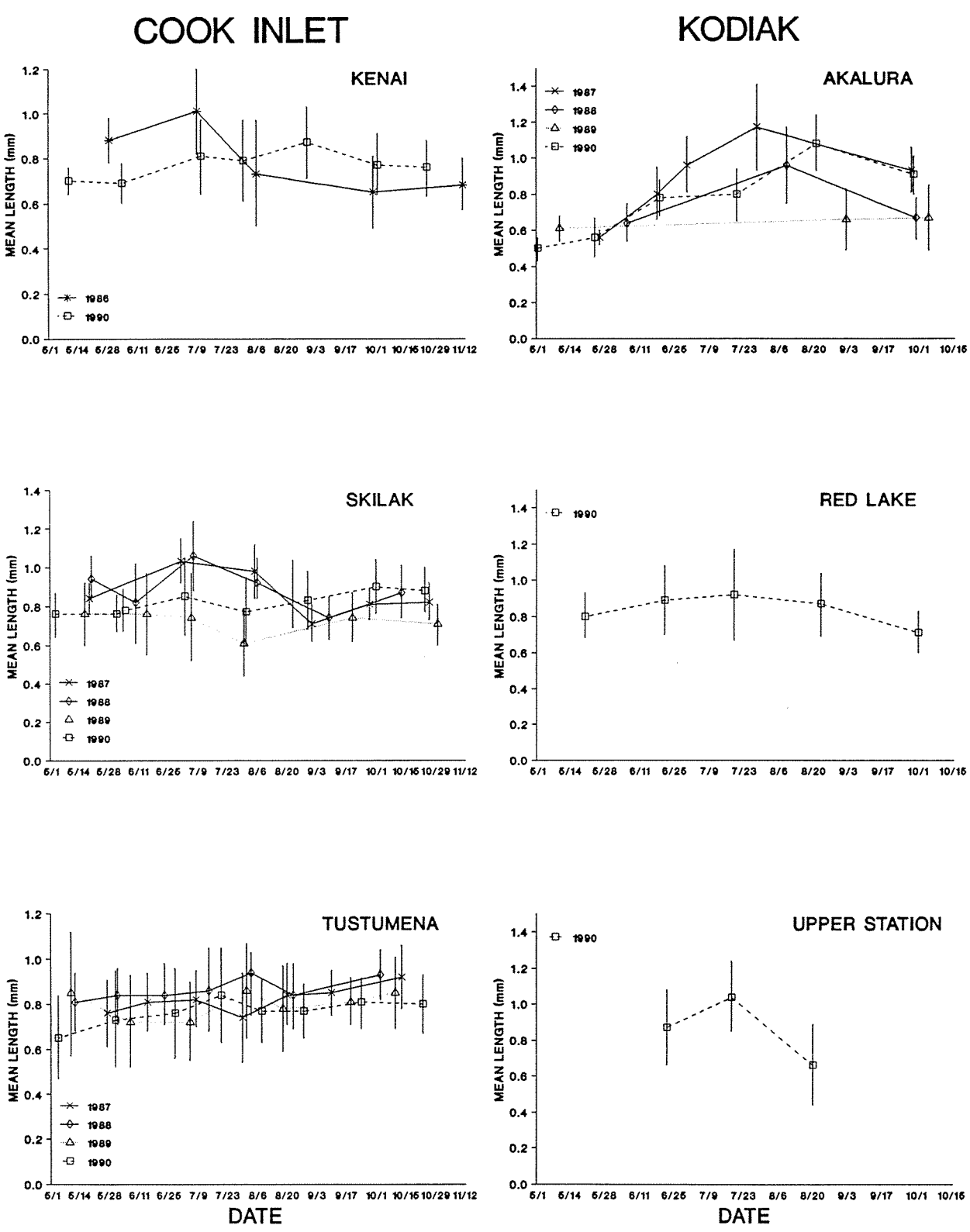



Figure 7. Interannual and intra annual variations in average zooplankton average lengths of copepods from the Kenai, Skilak, and Tustumena Lakes on the Kenai Peninsula and from Akalura, Red, and Upper Station Lakes on Kodiak Island.