Frazer Lake Fish Pass Sockeye Salmon Smolt and Adult Research, 1997 and 1998

by

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ABSTRACT

Smolt emigration estimates in 1997 (3,069,352) were lower than the previous five year average (1992-1996; 6,221,189). The total emigration estimate for 1998 was not possible due to high water conditions preventing safe operation of the smolt trap during a large portion of the season. Despite lower emigration numbers in 1997, overall smolt productivity (1997 and 1998) appears healthy with similar age compositions (> 50% age 2.) and average lengths and weights to previous years. Size (length and weight) of age 2. smolt were larger (15mm longer and 3.5 g heavier) in 1998 than previous years.

Similarly average lengths and dominant age class of returning adult sockeye salmon were comparable in 1997 and 1998 to the previous ten years. In general age 2.2 adult sockeye are the dominant age class, although age 1.2 sockeye were dominant in 1990 and 1993. Percentage of males to females remains close to a 50/50 ratio.

Commercial harvest (i.e., surplus production) of the Frazer Lake sockeye stock has remained high through the late 1990s.

INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* were first introduced into Frazer Lake with egg plants in 1951 (Blackett 1979). The donor source for the 1951 - 1954 plants came from Karluk Lake (early run) and in 1969 eggs were planted that had been taken from Becharof Lake (late run). The primary donor for other introductions (1955 - 1978 except 1969) came from the Red Lake stock taken from the June-July portion of the run, which typically spawned in tributary streams (Blackett 1979).

Sockeye introductions at Frazer Lake totaled 29,894 transplanted adults, 10,936,000 eggs, and 2,975,000 fry (Blackett 1979). From 1956 - 1961 returning adults were back-packed over the falls and in 1962 a fish pass was built to allow fish to circumvent the falls. The design of the original fish pass was modified in 1970 because early returns were avoiding the entrance. In 1979 a second fish pass was added to facilitate greater fish movement with the onset of higher production levels (Blackett 1987).

During the early years of the run (1950 - 1970s) the escapement goal for building the run was set at 175,000 fish (Brennan 1998). Research on available spawning and rearing capacity during the late 1970s indicated that a higher escapement (400,000) would provide larger returns (Blackett 1979). The Alaska Department of Fish and Game (ADF&G) did not adopt this higher escapement goal because it was uncertain whether identified spawning habitat would actually be utilized (Manthey et al. 1978). However, due to the research and a large escapement in 1980 that confirmed utilization of available spawning areas, the escapement goal was raised to 350,000 - 400,000 fish in 1981. Unfortunately, Frazer Lake returns off large escapements (e.g., 1980, 1981 and 1982) were poor and subsequent research (e.g., Kyle et al. 1988) indicated overescapement effects; for example, reduced size and changes in age composition of emigrating smolt. Thus escapement goals were reduced to 200,000 - 275,000 in 1986 and reduced again to 140,000 - 200,000 in 1988 (Malloy and Prokopowich 1992). To help alleviate overescapement impacts, the department implemented a fertilization program from 1988 through 1992 (mixture of nitrogen and phosphorous) to stimulate primary and secondary production and enhance smolt survival of lake rearing sockeye fry.

There are two weirs on Dog Salmon Creek; one near salt water (known as the Dog Salmon weir) and one at the Frazer Lake fish pass facility. The Dog Salmon weir is used to help ADF&G management make more timely decisions with respect to escapement because of the migration time (average 4 days) between freshwater entry and the Frazer Lake fish pass. Escapement counts are also used in management decisions (i.e., achievement of escapement goals) at the Frazer Lake fish pass because of mortality incurred between the Dog Salmon weir and Frazer fish pass as well as monitoring the quality of escaped fish; for example, percent net-marked or jacks.

The Frazer Lake sockeye run is harvested commercially in June and early July by set gill net and purse seine fishermen mainly at the south end of Kodiak Island in the Alitak Bay District (ABD; Figure 1). The run is managed using 1) catch trends from the ABD commercial test fishery (traditionally June 9); 2) escapement counts through the weir on Dog Salmon Creek located 0.5 km above lower Olga Bay; 3) catch per unit of effort data provided by the Moser-Olga test fishery located in Chip Cove adjacent to Olga Narrows; and 4) the ADF&G pre-season forecast.

Management of the ABD is complicated by the commingling of the Upper Station Lakes early sockeye run with the normally stronger Frazer Lake run (Barrett 1988).

This report addresses the 1998 field work conducted at the Frazer Lake fish pass. Specifically smolt data, adult age weights and lengths (AWL), and escapement surveys are reported. This report also includes a brief review of the 1997 field season and historic data.

Description of Study Area

Frazer Lake has a surface area of 16.1 km^2 and is located on the south end of Kodiak Island (Figure 2). The lake is approximately 14.2 km long, 1.6 km wide, with a mean depth of 33.2 m and a maximum depth of 58.9 m. The principal inlet stream, where the majority of stream spawning occurs, is Pinnell Creek, which enters at the west end of the lake (Barrett 1988). The outlet stream, Dog Salmon Creek, is located at the east end of the lake and flows southeast 12.9 km where it enters Olga Bay. A natural, 9 m high fish barrier falls is located approximately 1 km below the outlet of Frazer Lake on the Dog Salmon Creek. This barrier falls prevented salmon colonization of the lake until artificial introduction began in the 1950s (Russell 1972), and is the site of the Frazer Lake fish pass.

METHODS

Smolt Trapping

An inclined plane trap as described by Todd (1994) was operated from 1 May through 30 June in 1997 and 30 April through 2 June in 1998. During both years the trap was located approximately 1.2 km downstream of the lake outlet, upstream of the falls and 76 m upstream of the diversion weir (ADF&G 1998). The location of the smolt trap has moved from its original position below the falls (e.g., Barrett et al. 1993), however, the current position has been used since 1994 (Swanton et al. 1995). Previously, two traps were operated below the falls (Barrett et al. 1993). The 1997 and 1998 trap site was approximately 14 m and 11 m from the east and west banks respectively. Leads approximately 4 m in length were attached to the trap at an angle of about 30° toward both the east and west banks, spanning approximately 20% of the stream width. In 1998 the trap was pulled on 2 June due to high water preventing safe operation.

The smolt trap was checked during the evening approximately every half-hour for catch and proper operation (i.e., water level into the trap). During daylight hours the trap was monitored less frequently. During each check the total catch was enumerated by species and released; an exception was when a portion of the catch was held for sampling. Species identification was made by visual examination of external characteristics (McConnell and Snyder 1972; Trautman 1973). Smolt enumeration was completed using visual counts except when catch rates exceeded the crew's ability to hand tally (typically >10,000 smolt), in which case smolt were counted using a catch weight method. For the catch-weight method, the catch was transferred by dip net to a small wetted mesh basket attached to a weight scale suspended over the stream by an A-frame support; each dip net load was individually weighed, with fish immediately released

downstream of the trap. Approximately every tenth dip net load was sampled to determine species count by weight. All catch weights were recorded to the nearest 0.1 kg. All catch data were recorded by sampling day. A sampling day extended from noon to noon and was identified by the calendar day of the noon to midnight period. Trap efficiency was determined weekly depending upon smolt availability, using a single trap mark-recapture technique as described in ADF&G (1998).

Smolt Emigration Estimation

Total smolt emigration was estimated using procedures outlined by Carlson et al. (1998) with the following definitions:

h: stratum or period index (release event paired with a recovery period).
j: age index.
L: number of strata ($h = 1, 2, \ldots, L$).
M_h: number of marked releases in stratum h.
M: total number of marked releases ($= \Sigma M_h$).
m_h: number of marked recoveries in h.
u_h: number of unmarked smolt captured in h.
U_h: total population size of smolt in h, excluding marked releases and minus observed mortality.
U: total population size of smolt, excluding marked releases ($= \Sigma U_h$).
A_{jh}: number of age j smolt sampled in h.
A_h: number of smolt sampled in h.
θ_{jh}: proportion of age j smolt in h.
U_{jh}: total population size of age j smolt in h, excluding marked releases.
U_j: total population size of age j smolt, excluding marked releases ($=\Sigma U_{jh}$).

The approximately unbiased estimator of the total population within each stratum (U_h) is given as

$$\hat{U}_h = \frac{u_h(M_h + 1)}{m_h + 1}. \tag{1}$$

with variance

$$v\left(\hat{U}_h\right) = \frac{(M_h + 1)(u_h + m_h + 1)(M_h - m_h)u_h}{(m_h + 1)^2(m_h + 2)}. \tag{2}$$

The estimate of U is therefore

$$\hat{U} = \sum_{h=1}^{L} \hat{U}_h, \tag{3}$$

with variance estimate

$$v\left(\hat{U}\right) = \sum_{h=1}^{L} v\left(\hat{U}_h\right). \tag{4}$$

To estimate the number of emigrating smolt by age class during each stratum h, the proportion of each age is first estimated as

$$\hat{\theta}_{jh} = \frac{A_{jh}}{A_h}, \tag{5}$$

with estimated variance

$$v\left(\hat{\theta}_{jh}\right) = \frac{\hat{\theta}_{jh}\left(1-\hat{\theta}_{jh}\right)}{A_h}. \tag{6}$$

Within each stratum, the total population size by age class is estimated as

$$\hat{U}_{jh} = \hat{U}_h \hat{\theta}_{jh}, \tag{7}$$

with estimated variance ignoring the covariance term

$$v\left(\hat{U}_{jh}\right) = \hat{U}_h{}^2 v\left(\hat{\theta}_{jh}\right) + v\left(\hat{U}_h\right)\hat{\theta}_{jh}{}^2. \tag{8}$$

Finally, the total population size of each age class among all strata is estimated as

$$\hat{U}_j = \sum_{h=1}^{L} \hat{U}_{jh}, \tag{9}$$

with estimated variance

$$v\left(\hat{U}_j\right) = \sum_{h=1}^{L} v\left(\hat{U}_{jh}\right). \tag{10}$$

Daily counts and cumulative counts are recorded daily and reported back to the office via SSB radio along with weekly dye test results (i.e., release and recapture numbers). Estimates of total emigration are calculated post season.

Smolt Size, Age, and Condition Factor

When daily numbers allowed, 70 sockeye smolt were sampled for age, length, and weight. To prevent bias all fish in the live-box were stirred immediately before being removed for sampling. Each sampled fish was anesthetized with MS-222 and a scale smear from the preferred area (INPFC 1963) was removed and mounted on a standard microscope slide for aging. Smolt length (tip of snout to fork of tail) was recorded to the nearest 1 mm and weight was recorded to the nearest 0.1 g. After sampling all smolt were revived and released downstream of the trap site (below the falls). Aging of scales was conducted back at the office using a 42X lens microfiche reader. All ages were recorded in European notation (Koo 1962).

Condition factor for each smolt sampled was estimated using:

$$\hat{K} = \frac{W}{L^3} 10^5;$$

where

$\hat{K}$: smolt condition factor.
W: weight in grams.
L: length (tip-of-snout to fork-of-tail) in millimeters.

During periods of high water (post 2 June 1998), when the inclined plane trap was inoperable, a concrete smolt trap located at the south end of the lower diversion weir was used to collect smolt for age and size data.

Fish Ladder Operation and Adult Escapement Enumeration

In 1997, the adult weir associated with the fish pass was installed on 12 June and kept fish tight through 5 August; in 1998, the adult weir was installed on 14 June and kept fish tight through 15 August. A description of the fish pass facility is presented in Blackett (1987). Adult salmon ascending the fish pass were counted at the top exit pool. Observers used hand-held tally counters to record the species counts and wore polarized glasses for improved visibility.

Sockeye salmon escapement was sampled for age, length, and sex at a rate of 240 fish per statistical week. In general 80 samples were collected every other day, in an attempt to spread sampling out over the entire week. Stream foot-surveys were conducted weekly from 15 July through 21 August on Linda and Midway Creeks. Streams were surveyed to the upper limits of spawner distribution and live and dead sockeye recorded. Stream mouth counts were recorded separately from actual stream counts.

Adult Sockeye Harvest Estimation

Although Frazer Lake sockeye were likely caught in several harvest areas, the majority of the run is presumed to be harvested within Cape Alitak and Moser-Olga Bay Sections of the ABD. Fisheries within the ABD result in mixed stock catches (e.g., Frazer and early-run Upper Station). Catches from individual sections were apportioned by system to reconstruct the major sockeye systems within the ABD. Catches were determined from fishtickets and samples from each section were taken each statistical week. Samples were aged inseason and measured post season for catch apportionment and run reconstruction. Apportionment to the correct system was based upon run reconstructions that utilized scale pattern analysis or system specific age-markers (i.e., 0-checks from late-run Upper Station).

Adult Sockeye Run Reconstructions

Frazer Lake sockeye run timing generally coincides with the early-run Upper Station. The following assumptions were made for 1997 and 1998 run reconstructions:

1) post-July 15 catches in either Cape Alitak or Moser Olga areas did not contribute to the Frazer run;

2) post-July 7 catches did not contribute to the Upper Station early run;

3) Upper Station escapements pre-July 16 are attributed to the Upper Station early run;

4) Pre-July 15, 5% of the catch in the Moser-Olga sections and 20% of the catch in the Cape Alitak sections are from stocks other than Frazer Lake and Upper Station early runs.

These assumptions are based upon system run-timing curves as well as historic tagging data (Manthey 1984).

Age composition of the catch by day was assigned by using the age composition from the catch samples. Samples taken from a particular day were assumed to represent the age composition of the catch of a particular day. Age composition of the catch from days not sampled were estimated by daily interpolation from age compositions between sampled days. Catch-at-age by day was then estimated by multiplying the daily catch by the daily age composition.

Dominant age classes common to both Frazer Lake and early-run Upper Station were selected for performing scale pattern analysis (SPA). For 1997 ages 2.2 and 2.3 were used to differentiate contributions of Upper Station and Frazer run stocks to ABD catches. In 1998, the only common dominant age class was age 2.2; these made up 55% of Frazer and 36% of early-run Upper Station. Other dominant age classes were not common in 1998; for example, age 1.2 sockeye made up 34% of early-run Upper Station, but only made up 4% of the Frazer Lake escapement. Knowns for the SPA in both 1997 and 1998 were based upon scale samples collected from escapements at the Upper Station and Dog Salmon weirs.

Catch-at-age by day was then apportioned to Frazer and Upper Station using stock composition estimates by day and age. Stock composition of selected ages (2.2 and 2.3 in 1997 and 2.2 in 1998) were estimated using a linear discriminant function (i.e., SPA; proc discrim; SAS 1987) for days which catch samples were available. Stock composition for days not sampled was estimated using daily linear interpolation between days. The stock composition of other age classes in 1998 was estimated using the following (Stratton et al. 1992):

$$\hat{S}_{ij} = \frac{\hat{S}_{i(2.2,2.3)} \dfrac{\hat{T}_{ij}}{\hat{T}_{i(2.2,2.3)}}}{\displaystyle\sum_{i=1}^{N} \left(\hat{S}_{i(2.2,2.3)} \dfrac{\hat{T}_{ij}}{\hat{T}_{i(2.2,2.3)}} \right)};$$

$$\hat{C}_{i(2.2,2.3)} = \frac{\hat{C}_{i(2.2)} + \hat{C}_{i(2.3)}}{\hat{C}_{(2.2)} + \hat{C}_{(2.3)}};$$

$$\hat{T}_{i(2.2,2.3)} = \frac{\hat{E}_{i(2.2)} + \hat{E}_{i(2.3)}}{\hat{E}_{i}};$$

Where:

S_{ij}:	estimated number of stock i at age j.
$S_{i(2.2, 2.3)}$:	number of age 2.2 and 2.3 sockeye salmon of stock i (catch + escapement).
$C_{i(2.2,2.3)}$:	estimated proportion of age 2.2 and 2.3 sockeye in ABD catch.
C_{ij}:	estimated number of stock i at age j sockeye salmon in the catch.
$C_{i(2.2)}$	estimated ABD catch (via SPA) of age 2.2 sockeye salmon of stock i.
$C_{(2.2)}$	number of age 2.2 sockeye salmon in ABD catch.
T_{ij}:	estimated proportion of age j sockeye in stock i escapement.

E_{ij}: estimated number of stock i at age j sockeye salmon in the escapement.

In 1998 the same formula was used; however, only the proportion of age 2.2 fish was used to apportion the other age classes.

Genetic Sampling and Spawner Habitat Selection

A graduate thesis project through University of Alaska School of Fisheries, funded by the Kodiak Regional Aquaculture Association, was initiated in 1996 at Frazer Lake utilizing microsatellite DNA, allozyme allele frequency and mark-recapture data to determine if spawning habitat selection is correlated with time of return and to determine the extent to which Frazer Lake run timing is consistent with that of the donor stocks. Experimental design consisted of weekly genetic samples at the fish pass (concurrent with age, length, and sex information already being gathered) and sampling major spawning areas in the Frazer drainage (Lake outlet, shoreline site near Midway Creek, shoreline site of Caida Creek, and Pinnell, Midway, Stumble, and Summit Creeks) at peak escapement. This genetic research will provide a baseline for further study of changes in genetic variability, run timing, and spawning habitat utilization within the Frazer Lake drainage.

RESULTS

Smolt Emigration Estimates and Timing at Age

An estimated 3,069,352 sockeye salmon smolt emigrated from Frazer Lake during 1997. The age 2. smolt (1994 brood year) were dominant in 1997 contributing 71.6% to the total emigration. Similarly, age 2. smolt were dominant in 1998 (1995 brood year), making up 65.5% of the emigration. Age composition of both years is consistent with the historic age composition (Table 1). Emigration of smolt appeared later in 1998 than in 1997 and as compared to the 1990-1996 emigration timing average (Figure 3).

A large number of smolt were not observed in 1998 until 30 May, in contrast to previous years when a large portion of the smolt (up to half the emigrating year class) was usually observed by this same date. Despite the later timing in 1998, large numbers were observed. For example, on 26 May over 35,000 smolt were counted and on 31 May over 40,000 smolt were observed. This is in contrast to 1997 when the highest daily count was just over 29,000 smolt. Unfortunately, the smolt trap was inoperable after 2 June in 1998 due to the high water. As a result total emigration estimates were not possible as it is uncertain whether the high numbers observed at the end of May would have continued resulting in an average or even larger emigration class or whether numbers would have dropped off.

In 1997 and 1998 age 1. smolt began emigrating later, while age 3. smolt were more prominent at the beginning in relation to the entire emigrating population. In 1997, average lengths of age 1., age 2., and age 3. smolt were 87.1, 93.4, and 106.1 mm respectively. In 1998, average lengths of age 1., age 2., and age 3. smolt were 97.5, 109.6, and 114.4 mm respectively. While length

and weight of age 1. fish have been annually consistent, age 2. smolt in 1998 were 15 mm longer and 3.5 grams heavier than previous years (Figure 4).

Adult Sockeye Escapement at Age and Timing

In 1997, adult sockeye salmon were counted through the Frazer Lake fish pass from 13 June until the fish pass was closed on 5 August. A total of 205,264 adult sockeye salmon and 454 chinook salmon were counted through the fish pass. Based on scale samples collected at the fish pass, the predominant age class contributing to the run was age 2.2 making up an estimated 56% of the total escapement (114,944; Table 3). In 1998, adult sockeye were counted through the Frazer Lake fish pass from 14 June until the fish pass was closed on 15 August. A total of 233,755 sockeye salmon and 147 chinook salmon were counted through the fish pass in 1998. The predominant age class contributing to the run in 1998 was again age 2.2, making up an estimated 55% of the total escapement (Table 3).

Adult sockeye salmon movement patterns were anomalous in 1998 taking several days longer than previous years to migrate from the Dog Salmon weir to the Frazer Lake fish pass; presumably due to the high water. In previous years, migration time from the Dog Salmon weir took approximately four days (Brennan 1998). During 1998, the high water prevented normal operation of the Dog Salmon weir and initial counts (through 22 June) were estimated by the onsite crew leader. The Frazer Lake fish pass was operable during this high water period so it was possible to count actual fish numbers into the lake. However, the numbers of fish passed were less than expected given normal migration time from the Dog Salmon weir. The Dog Salmon weir counts were considered representative of the amount of fish entering the stream; however, they were held with some reservation due to the discrepancy of the known number going through the fish pass. Postseason comparison confirmed that estimates made at the Dog Salmon weir were fairly close to actual numbers (although slightly underestimated). The result of the altered fish movement through Dog Salmon Creek was substantially fewer fish earlier in the season (as compared to previous years) and then a large number of fish passing into the lake during a short period of time (Figure 5 and 6).

In 1997 the fish pass was closed 5 August due to fish numbers exceeding the upper escapement goal. In retrospect, the biologists felt that exceeding the goal would have been less harmful than cutting off the later portion of the run. Currently, research is being conducted to examine if escapement through the fish ladder corresponds with spawning within specific areas of Frazer Lake. One hypothesis is that the early portion of the run is responsible for tributary spawning while the latter part of the run is more responsible for shoal spawning. Another concern in 1997 was the large unescaped portion of fish congregated at the bottom of the fish pass, which caused some alarm from the public.

In 1998, escapements neared the upper escapement goal by 25 July. Due to the concerns from the previous experience in 1997, the fish pass remained opened until 15 August, when the numbers of escaping adult sockeye slowed.

Proportions of gillnet marked and jack sockeye observed in the escapement were similar in 1998 to that observed in 1997 and in general were proportional to the daily escapement (i.e., larger numbers of net-marked and jack sockeye on days with large escapements; Figures 7 and 8).

During 1997, the sampling strategy at the Frazer Lake fish pass was changed from previous years in order to attempt to address a perceived bias towards sampling jacks. This effort appears to have been successful comparing the number of jacks counted through the fish pass and the number of sampled jacks (age .1 fish). Overall, there were approximately 43 thousand net marked sockeye (18%) and 23 thousand jacks (10%) of the total 234 thousand escapement observed in 1998. It is not possible to derive the total affected escapement since a net marked jack is counted as both a jack and a net marked fish.

Adult Sockeye Escapement Sex and Length

Percent age and sex contribution to 1997 and 1998 escapements were similar. Both years were composed primarily of age .2 sockeye, with smaller contributions from age .3 and age .1 fish. In comparison to previous years it appears that age contributions have remained relatively consistent since 1990; however, in 1996 there was a higher percentage of age .1 returning adults. While the pattern (i.e., timing within escapement as reflected by sampling) of percent contribution by sex has changed since 1990, the overall contribution of male and females to the escapement has been relatively equal and has remained consistent (Figures 9-12). The 1998 escaped average length of males was 451.3 mm and females averaged 502.8 mm, with a combined average length of 478.4 mm (Table 2). This average length is slightly smaller than the average length observed in 1997, however it is similar to the average lengths observed since 1986 (Table 3).

Nineteen different spawning locations were surveyed in 1998 (Table 4). Historic and current data suggests that the majority of sockeye spawning occurs in Pinnell Creek as well as lake shoal areas (Table 5).

Harvest Contribution, Total Run, and Exploitation Rate

The largest discrepancy between catch and escapement age compositions is the percentage of 1-ocean fish in the escapement relative to the catch. The most noticeable example is in 1997 where 15% of the escapement through Dog Salmon was age 2.1 adult sockeye whereas age 2.1 fish made up less than one percent of ABD catch (Table 6). This difference is presumably due to selective fishing pressure (e.g., Swanton and Sagalkin 1997).

Since 1988, when the escapement goals were set at approximately 200 thousand fish, on average over 60% of the run has been harvested. This is dramatically higher than the early 1980s which had some escapements in excess of 300 thousand fish and harvests were on average 20% of the run (Figure 13, Table 7). While some of this success is due to the successful management of the Alitak Bay District, large scale climatic influences might be confounding these patterns (e.g., Welch et al. 1998).

Thesis Progress

A total of 3,450 adult sockeye salmon were tagged at the Frazer Lake fish pass during the 1996, 1997 and 1998 seasons. Approximately 600 tagged salmon were subsequently observed on the

spawning grounds. Analysis of migratory timing using Darroch's method (Quinn and Deriso 1999) indicated an insufficient number of tag recoveries for adequate discriminatory ability. Preliminary calculations of mean of migratory time density have been more promising and may yield significant variation in run timing between spawning locations within Frazer Lake.

All of the tissue samples necessary for the allozyme portion of the study have been collected. During the 1996 and 1997 runs, tissue samples were collected from the escapement at the fish pass and from five of the major spawning locations within Frazer Lake.

Tissue samples (eye, heart, liver, and skeletal muscle) from 50 fish each of the four spawning locations sampled in 1996 were screened for variation in allele frequency at protein coding allozyme loci. The samples were processed using horizontal starch gel electrophoresis and the gels were stained for enzyme activity at 82 protein coding loci. Allelic frequencies were determined by direct count, and photographs were taken of gels with allelic variation.

Homogeneity of allele frequency between populations was tested using log-likelihood ratio analysis (G-test, Sokal and Rohlf 1995), and the null hypothesis of homogeneity between spawning locations was rejected for probability values less than 0.05. Statistically significant variation was detected at two loci, however the differences between spawning locations were small, and do not provide adequate discriminatory power to perform a mixed stock analysis on the samples collected from the daily escapement at the fish pass. At this time, no further analysis of the allozyme data are planned, however, they may augment conclusions about the nature of the Frazer Lake population reached through the tagging and microsatellite DNA studies.

During the 1996 and 1997 runs, sufficient tissue samples were collected from the fish pass and from the spawning grounds to fulfill the requirements of the microsatellite DNA portion of the project. To date, DNA has been extracted from approximately 30% of the samples collected and is available for analysis. The remaining samples are stored at –80°C at the JCSFOS. Analysis is pending acquisition of automated DNA sequencing equipment by JCSFOS.

SUMMARY AND CONCLUSIONS

Sockeye salmon productivity at Frazer Lake remains stable as measured by the consistency of smolt emigration numbers, age composition, and average lengths. Average length of age 2. smolt did increase slightly in 1998, which is consistent with a higher level of secondary productivity observed in 1997 (S. Schrof, Alaska Department of Fish and Game, Kodiak, personal communication). The 1997 smolt emigration population was smaller than previous years (since 1991) and estimates for 1998 were not calculated because high water prevented trap operation during a large portion of the emigration.

Adult escapement goals for both 1997 and 1998 were met and average length and age composition of returning adults was similar to historical trends. Due to the increased production at Frazer Lake and improved marine survival, harvests in the late 80s and 90s have been considerably higher than historical catches.

The 1998 Frazer Lake forecast (Hart et al. 1998) was for a total a run of 530 thousand and a harvest of 399 thousand and a sockeye salmon. The actual 1998 run and harvest was 606 and 361 thousand respectively. The 1999 Frazer Lake forecast is for a total run of 522 thousand with a harvest of 382 thousand sockeye. Frazer Lake is expected to perform well into the near future. Smolt productivity, as measured by recent emigration abundance and as reflected by average lengths and weights, has remained constant.

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Table 1. Estimated number of sockeye salmon smolt outmigrating from Frazer Lake by year and age class, 1991-1998.

Smolt Outmigration	Number and Relative Percent of Smolt by Age Class				Total Population		95% CI	
Year	1.	2.	3.	4.	Estimate	SE	Lower	Upper
1991	1,940,906	2,870,690	6,905	0	4,818,501	1,077,978	2,705,664	6,931,337
	40.3%	59.6%	0.1%	0.0%				
1992	82,415	4,978,109	305,253	0	5,365,777	624,657	4,141,448	6,590,106
	1.5%	92.8%	5.7%	0.0%				
1993	22,221	4,046,434	3,364,676	966	7,434,298	1,397,839	4,694,534	10,174,062
	0.3%	54.4%	45.3%	0.0%				
1994	673,765	4,450,246	537,478	0	5,661,489	344,992	4,985,306	6,337,672
	11.9%	78.6%	9.5%	0.0%				
1995	53,410	8,684,874	85,492	0	8,823,777	551,775	7,742,298	9,905,256
	0.6%	98.4%	1.0%	0.0%				
1996	57,487	3,480,272	282,845	0	3,820,604	268,297	3,294,742	4,346,466
	1.5%	91.1%	7.4%	0.0%				
1997	244,298	2,196,609	628,446	0	3,069,352	295,134	2,490,891	3,647,814
	8.0%	71.6%	20.5%	0.0%				
1998	emigration estimates unavailable due to high water conditions							
	33.6%	65.5%	1.0%	0.0%				

Table 2. Mean length, weight, and condition factor of Frazer Lake sockeye salmon smolt samples by age and week, 1997 and 1998.

			Length			Weight			Condition		
Age	Stat Week	Dates	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
1997											
1	19	(5/03-5/09)	7	79.4	3.64	7	3.9	0.52	17	0.8	0.04
1	20	(5/10-5/16)	4	89.5	4.11	4	5.4	0.29	84	0.8	0.01
1	21	(5/17-5/23)	16	86.9	0.80	16	4.8	0.12	19	0.7	0.01
1	22	(5/24-5/30)	20	87.1	0.54	20	5.0	0.10	41	0.8	0.01
1	23	(5/31-6/06)	54	87.1	0.43	54	5.0	0.07	7	0.8	0.00
1	24	(6/07-6/13)	105	87.4	0.25	105	5.2	0.05	214	0.8	0.00
1	25	(6/14-6/20)	143	89.7	0.22	143	5.5	0.04	59	0.8	0.00
1	26	(6/21-6/27)	195	90.0	0.20	195	5.9	0.04	177	0.8	0.00
	36	(8/30-9/05)	55	70.4	1.14	55	4.3	0.20	55	1.2	0.01
Totals			618	87.1	0.27	618	5.4	0.03	618	0.8	0.01
	18	(4/26-5/02)	1	105.0	-	1	9.4	-	1	0.8	-
2	19	(5/03-5/09)	68	100.6	0.75	68	8.1	0.18	68	0.8	0.01
2	20	(5/10-5/16)	112	102.1	0.53	112	8.4	0.13	112	0.8	0.00
2	21	(5/17-5/23)	207	101.2	0.41	207	8.1	0.10	207	0.8	0.00
2	22	(5/24-5/30)	273	94.9	0.45	273	6.6	0.10	273	0.8	0.00
2	23	(5/31-6/06)	273	88.1	0.21	273	5.2	0.04	273	0.8	0.00
2	24	(6/07-6/13)	225	88.0	0.18	225	5.3	0.04	225	0.8	0.00
2	25	(6/14-6/20)	182	90.2	0.19	182	5.7	0.04	182	0.8	0.00
2	26	(6/21-6/27)	44	89.4	0.47	44	5.6	0.10	44	0.8	0.01
	36		10	90.8	2.52	10	8.8	0.62	10	1.2	0.02
Totals			1395	93.4	0.20	1395	6.4	0.05	1395	0.8	0.00
3	18	(4/26-5/02)	2	103.5	0.50	2	9.1	0.15	2	0.8	0.00
3	19	(5/03-5/09)	241	106.4	0.28	241	9.6	0.08	241	0.8	0.00
3	20	(5/10-5/16)	210	106.7	0.31	210	9.6	0.09	210	0.8	0.00
3	21	(5/17-5/23)	109	107.1	0.34	109	9.6	0.10	109	0.8	0.00
3	22	(5/24-5/30)	49	104.7	1.29	49	9.0	0.46	49	0.8	0.01
3	23	(5/31-6/06)	13	108.2	4.30	13	11.1	1.75	13	0.8	0.02
3	24	(6/07-6/13)	7	91.0	1.18	7	6.1	0.21	7	0.8	0.01
3	25	(6/14-6/20)	7	89.9	0.91	7	5.5	0.22	7	0.8	0.02
Totals			638	106.1	0.23	638	9.5	0.07	638	0.8	0.00

-Continued-

Table 2. Page 2 of 2

Age	Stat Week	Dates	Length			Weight			Condition		
			Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
4	19	(5/03-5/09)	5	106.4	0.40	5	9.4	0.17	5	0.8	0.01
4	20	(5/10-5/16)	4	120.3	5.45	4	15.1	2.02	4	0.9	0.02
Totals			9	112.6	3.30	9	11.9	1.30	9	0.8	0.02
1998											
1	19	(5/03-5/09)	17	95.5	0.93	17	6.5	0.15	17	0.75	0.018
1	20	(5/10-5/16)	84	94.5	0.37	84	6.5	0.08	84	0.76	0.004
1	21	(5/17-5/23)	19	95.8	0.51	19	6.8	0.15	19	0.77	0.008
1	22	(5/24-5/30)	41	95.4	0.68	41	7.2	0.14	41	0.83	0.010
1	23	(5/31-6/06)	7	97.6	0.81	7	7.8	0.27	7	0.84	0.015
1	24	(6/07-6/13)	214	96.0	0.30	214	8.1	0.06	214	0.91	0.006
1	25	(6/14-6/20)	59	99.1	0.36	59	8.6	0.12	59	0.89	0.012
1	26	(6/21-6/27)	177	101.2	0.22	177	9.1	0.06	177	0.88	0.003
Totals			618	97.5	0.18	618	8.1	0.05	618	0.86	0.003
2	19	(5/03-5/09)	27	107.3	1.16	27	9.3	0.34	27	0.74	0.008
2	20	(5/10-5/16)	182	109.2	0.38	182	9.8	0.11	182	0.75	0.003
2	21	(5/17-5/23)	351	111.3	0.21	351	10.6	0.06	351	0.77	0.002
2	22	(5/24-5/30)	302	109.1	0.22	302	10.5	0.07	302	0.81	0.004
2	23	(5/31-6/06)	69	112.9	0.80	69	11.6	0.33	69	0.80	0.005
2	24	(6/07-6/13)	236	107.8	0.37	236	10.5	0.09	236	0.84	0.004
2	25	(6/14-6/20)	20	107.4	1.47	20	10.3	0.33	20	0.83	0.017
2	26	(6/21-6/27)	18	103.1	0.64	18	9.3	0.18	18	0.85	0.014
Totals			1205	109.6	0.15	1205	10.4	0.04	1205	0.79	0.002
3	20	(5/10-5/16)	4	118.0	2.55	4	12.2	0.71	4	0.74	0.007
3	21	(5/17-5/23)	7	115.4	1.04	7	11.9	0.43	7	0.77	0.021
3	22	(5/24-5/30)	1	116.0	-	1	12.7	-	1	0.81	-
3	24	(6/07-6/13)	5	111.2	2.18	5	11.2	0.69	5	0.81	0.021
3	25	(6/14-6/20)	1	108.0	-	1	10.8	-	1	0.86	-
Totals			18	114.4	1.10	18	11.8	0.30	18	0.78	0.012

Table 3. Mean length and dominant age class of adult sockeye salmon sampled at the Frazer Lake fish pass, 1986-1998.

Year	Escapement	Mean Length			Dominant Age		% Males
		Males	Females	Combined	Class	%	
1986	126,529	546.4	537.9	541.1	2.3	74	37.2
1987	40,544	475.6	549.6	509.0	1.3	48	54.8
1988	246,704	479.2	505.0	491.0	2.2	80	54.4
1989	360,373	535.0	528.4	531.6	2.3	58	48.8
1990	226,707	473.0	480.0	477.5	1.2	78	34.7
1991	190,358	494.4	509.2	501.4	2.2	73	52.7
1992	185,825	466.1	510.5	486.1	2.2	40	55.5
1993	178,391	479.0	503.0	490.0	1.2	46	51.7
1994	206,071	485.0	501.2	493.4	2.2	54	48.0
1995	196,323	473.5	517.3	493.4	2.2	38	54.5
1996	198,695	435.1	537.9	465.4	2.1	40	70.5
1997	205,264	481.4	527.2	504.3	2.2	54	50.0
1998	233,755	451.3	502.8	478.4	2.2	55	47.5

Table 4. Sockeye salmon spawning survey data of Frazer Lake tributaries and shoal areas, 1998.

Location	Date	Live	Dead	Mouth	Comments
PINNELL	10-Jul	0	0	0	
	17-Jul	0	0	500	POOR VIS.
	19-Jul	200	0	500	
	25-Jul	400	0	1,500	
	30-Jul			1,500	NO RIVER SURVEY
	5-Aug	1,500	350	1,000	
	11-Aug	3,000	500	1,000	
MIDWAY	7-Jul	0	0	0	
	16-Jul	193	0	200	
	23-Jul	239	0	500	
	30-Jul	61	13	600	
	6-Aug	15	24	400	
	11-Aug			2,000	NO RIVER SURVEY
	12-Aug	3	25	2,000	
LINDA	16-Jul	5	0	750	
	23-Jul	843	5	1,000	
	30-Jul	80	35	1,300	
	6-Aug	260	61	1,000	
	11-Aug			1,500	NO RIVER SURVEY
	12-Aug	0	0	1,500	
VALERIAN	7-Jul	0	0	0	
	16-Jul	0	0	0	
	23-Jul	0	0	750	
	30-Jul	150	2	3,000	
	6-Aug				POOR VIS.
	10-Aug				POOR VIS.
	12-Aug	1,000	21	50	
SUMMIT	7-Jul	0	0	0	
	16-Jul	0	0	10	
	23-Jul	0	0	300	
	30-Jul	65	2	1,500	
	6-Aug	124	9	800	
	12-Aug			600	NO RIVER SURVEY
CAIDA	10-Jul	0	0	0	
	17-Jul	0	0	5	
	23-Jul	0	0	200	
	5-Aug	0	0	300	
	11-Aug	0	0	200	
STUMBLE	10-Jul	0	0	0	
	17-Jul				POOR VIS.
	19-Jul	0	0	350	
	25-Jul	130	0	1,500	

-Continued-

Table 4. (page 2 of 3)

Location	Date	Live	Dead	Mouth	Comments
STUMBLE (Cont.)	30-Jul			750	NO RIVER SURVEY
	5-Aug	300	25	600	
	11-Aug	250	42	500	
JAEGER	10-Jul	0	0	0	ALL FISH OBSERVED HERE
	17-Jul	0	0	40	WERE SPAWNING ON THE
	25-Jul	0	0	50	SHOAL 50-100 METERS SE
	5-Aug	0	0	600	OF THE RIVER MOUTH.
	11-Aug	0	0	400	
COURTS	10-Jul	0	0	0	
	17-Jul				POOR VIS.
	19-Jul	0	0	100	
	25-Jul	12	0	50	
	5-Aug	5	0	50	
	11-Aug	0	0	200	
PIDDLE	6-Jul	0	0	0	
	19-Jul	0	0	175	
	25-Jul	0	0	5	
	6-Aug	0	0	0	
	11-Aug	0	0	0	
FRAZER	6-Jul	0	0	0	
(NOT OUTLET)	19-Jul	0	0	125	
	25-Jul	0	0	100	
	5-Aug	15	0	30	100 ON SHOAL SE OF MOUTH
	11-Aug	0	0	0	400 ON SHOAL SE OF MOUTH
HOLLOW FOX	6-Jul	0	0	0	
	23-Jul	0	0	200	
	30-Jul	32	1	300	
	6-Aug	25	4	300	
	11-Aug	0	0	200	
WHITE CROWN	6-Jul	0	0	0	
	23-Jul	0	0	0	
	30-Jul	0	0	0	
	6-Aug	0	0	0	
	11-Aug	0	0	0	
OUTLET	6-Jul	0			
	17-Jul				POOR VIS
	19-Jul	75			ALL FISH OBSERVED HERE ARE
	23-Jul	300			SHOAL SPAWNERS IN THE
	30-Jul	700			RUNNING LINE/BOAT SHED
	6-Aug	400			AREA.
	12-Aug	450			

-Continued-

Table 4. (page 3 of 3)

Location	Date	Live	Dead	Mouth	Comments
CAIDA SHOAL	16-Jul	100			
	23-Jul	30			
	5-Aug	350			
	11-Aug	350			
STUMBLE SHOAL	17-Jul	500			
	25-Jul	350			
	30-Jul	500			
	5-Aug	600			
	11-Aug	500			
COURTS SHOAL	17-Jul				POOR VIS.
	19-Jul	250			
	25-Jul	250			
	5-Aug	600			
	11-Aug	400			
STUMP SHOAL	16-Jul	300			THIS IS THE SHOAL SE OF
	23-Jul	500			MIDWAY CK. 1/2 WAY BETWEEN
	30-Jul	500			MIDWAY AND THE OUTLET.
	6-Aug	600			THERE IS A LARGE ROOT WAD/
	11-Aug	500			STUMP ON THE BEACH ALONG
					WITH OTHER ASST. WOODY DEBRIS.
MIDWAY SHOAL	16-Jul	1,000			
	23-Jul	1,500			
	30-Jul	1,000			
	6-Aug	1,000			
	11-Aug	1,500			

Table 5. Peak escapement counts of sockeye salmon utilizing major spawning locations within the Frazer Lake drainage, 1980-1998.

Spawning Location	1980-1989 peak	1990-1998 peak
Pinnell Creek	248,500 [a]	5,600
Caida Creek	128	700
Courts Creek	1,182	700
Frazer Creek	214	500
Hollow Fox Creek	75	500
White Crown Creek	127	700
Jaeger Lagoon	121	600
Linda Creek	1,333	2,151
Midway Creek	1,160	2,000
Piddle Creek	273	300
Valerian Creek	1,189	3,000
Summit Creek	172	1,500
Stumble Creek	1,175	3,500
Frazer Lake outlet	1,500	550
Frazer Lake shoals	156,000 [a]	10,950

Note: All counts are from ground surveys except where indicated, and include both live and dead salmon.

[a] Aerial survey.

Table 6. Run reconstructions for the Frazer Lake sockeye salmon run, 1997 and 1998. [a]

	Age Class											
	1.1	0.3	1.2	2.1	1.3	2.2	3.1	2.3	3.2	2.4	3.3	Total
1997												
Frazer Catch Cape Alitak												
Numbers	207	0	2,214	609	6,065	16,246	67	12,882	190	61	961	39,504
Percent	1	0	6	2	15	41	0	33	0	0	2	
Frazer Catch Moser-Olga Bay												
Numbers	0	0	4,103	93	13,170	44,384	0	32,164	291	160	3,020	97,386
Percent	0	0	4	0	14	46	0	33	0	0	3	
Frazer Catch Dog Salmon Flats												
Numbers	0	45	648	0	380	6,351	0	3,444	0	0	335	11,203
Percent	0	0	6	0	3	57	0	31	0	0	3	
Frazer Catch Cape Alitak, Moser-Olga Bay, and Dog Salmon Flats												
Numbers	207	45	6,966	702	19,616	66,981	67	48,490	481	221	4,316	148,092
Percent	0	0	5	0	13	45	0	33	0	0	3	
Dog Salmon Escapement												
Numbers	1,849	0	5,711	41,057	7,856	144,979	4,599	56,871	149	234	5,024	268,328
Percent	1	0	2	15	3	54	2	21	0	0	2	
Total 1997 Frazer Lake Run												
Numbers	2,056	45	12,677	41,759	27,471	211,959	4,666	105,361	630	455	9,340	416,420
Percent	0	0	3	10	7	51	1	25	0	0	2	

-Continued-

Table 6. (Page 2 of 2)

	Age Class								
	1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	Total
1998									
Frazer Catch Cape Alitak									
Numbers	0	5,473	64	24,642	68,073	0	54,765	7,938	160,955
Percent	0	3	0	15	42	0	34	5	
Frazer Catch Moser Olga Bay									
Numbers	0	8,260	144	22,989	78,165	0	82,120	8,317	199,995
Percent	0	4	0	11	39	0	41	4	
Frazer Catch Cape Alitak and Moser Olga Bay									
Numbers	0	13,733	208	47,632	146,238	0	136,885	16,255	360,950
Percent	0	4	0	13	41	0	38	5	
Dog Salmon Escapement									
Numbers	10,108	9,302	17,483	8,547	144,982	4,834	48,265	1,889	245,410
Percent	4	4	7	3	59	2	20	1	
Total 1998 Frazer Lake Run									
Numbers	10,108	23,035	17,690	56,179	291,220	4,834	185,150	18,144	606,360
Percent	2	4	3	9	48	1	31	3	

[a] Totals may not be exact due to rounding.

Table 7. Catch, escapement and total run of Frazer Lake sockeye salmon, 1971-1998.

Year	Run[a]	Frazer Lake Escapement	Dog Salmon Escapement	Catch[b]	Comment
1971	65,915	55,366		10,549	Directed fisheries on Frazer stocks
1972	69,180	66,419		2,761	did not occur until 1978;
1973	57,465	56,255		1,210	however, Kyle et al. (1988) estimated
1974	85,374	82,609		2,765	contributions (incidental catch) of
1975	67,499	64,199		3,300	Frazer sockeye salmon to ABD fisheries
1976	128,091	119,321		8,770	
1977	140,914	139,548		1,366	
1978	172,317	141,981		30,336	
1979	153,547	126,742		26,805	
1980	460,708	405,535		55,173	over escapement
1981	487,926	377,716		110,210	over escapement
1982	506,655	430,423		76,232	over escapement
1983	196,323	158,340	166,655	29,668	
1984	67,377	53,524	48,844	18,533	
1985	637,871	485,835	506,336	131,535	over escapement
1986	178,205	126,529	136,553	41,652	
1987	57,582	40,544	48,956	8,626	
1988	458,461	246,704	248,055	210,406	
1989	1,070,871	360,373	362,007	708,864	over escapement
1990	979,833	226,707	254,540	725,293	
1991	1,268,145	190,358	288,013	980,132	
1992	418,773	185,825	206,406	212,367	
1993	751,405	178,391	198,412	552,993	
1994	650,045	206,071	240,913	409,132	
1995	952,377	196,323	222,170	730,207	
1996	700,913	198,695	208,638	492,275	
1997	416,419	205,264	268,328	148,091	
1998	606,343	233,755	245,393	360,950	

[a] Run calculated as the sum of escapment and catch. Prior to 1983 Frazer fish pass counts are used to calculate escpament, post 1982 Dog Salmon weir counts are used.

[b] Frazer sockeye are caught in mixed stock fisheries. Catch is allocated to Frazer based upon run-reconstructions that utilize scale pattern analysis.

Figure 1. Map of the Alitak Bay District showing seine vs. gillnet fishing areas.

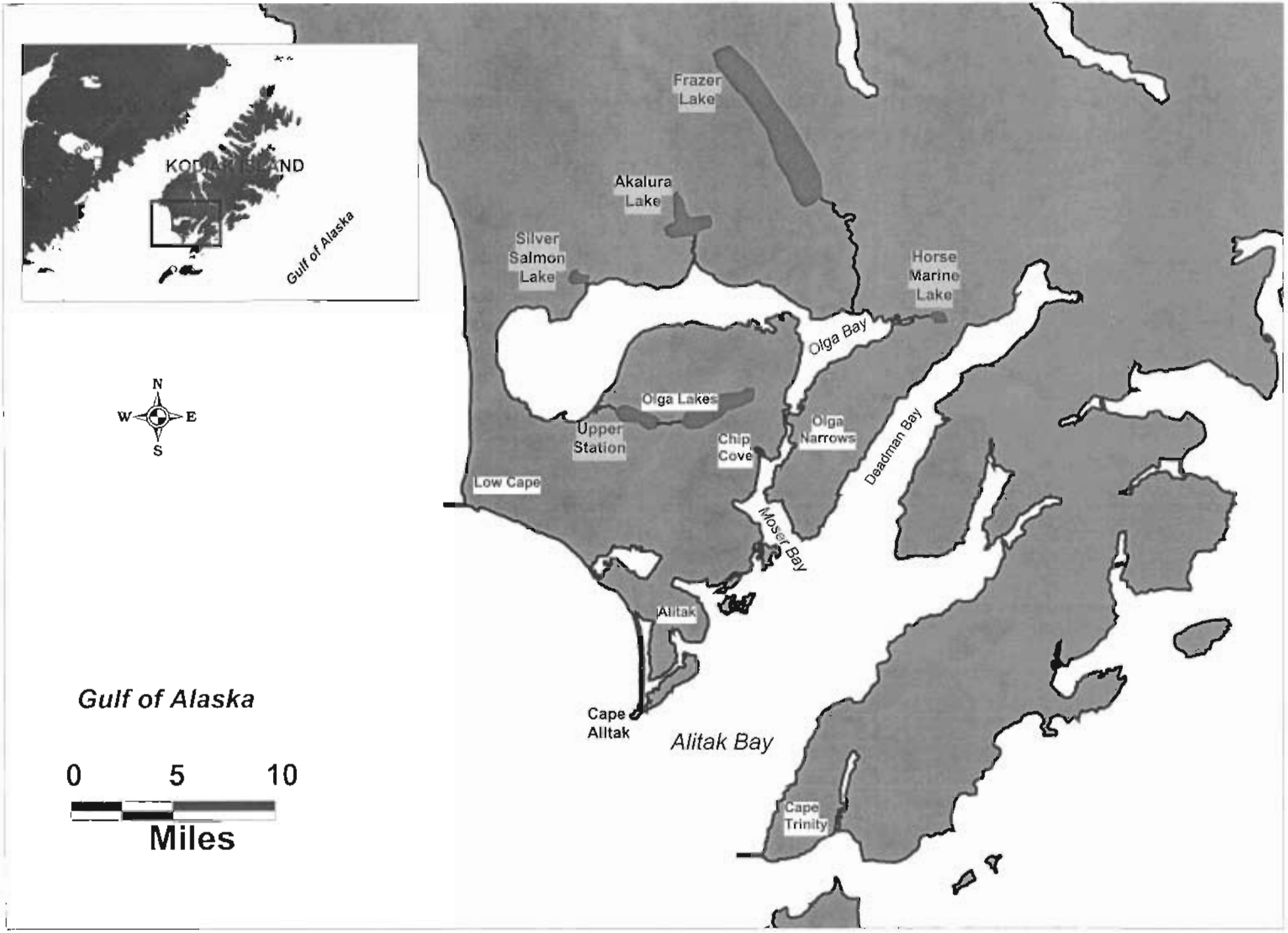


Figure 2. Map of the Alitak Bay commercial fishing district and sockeye salmon producing systems.

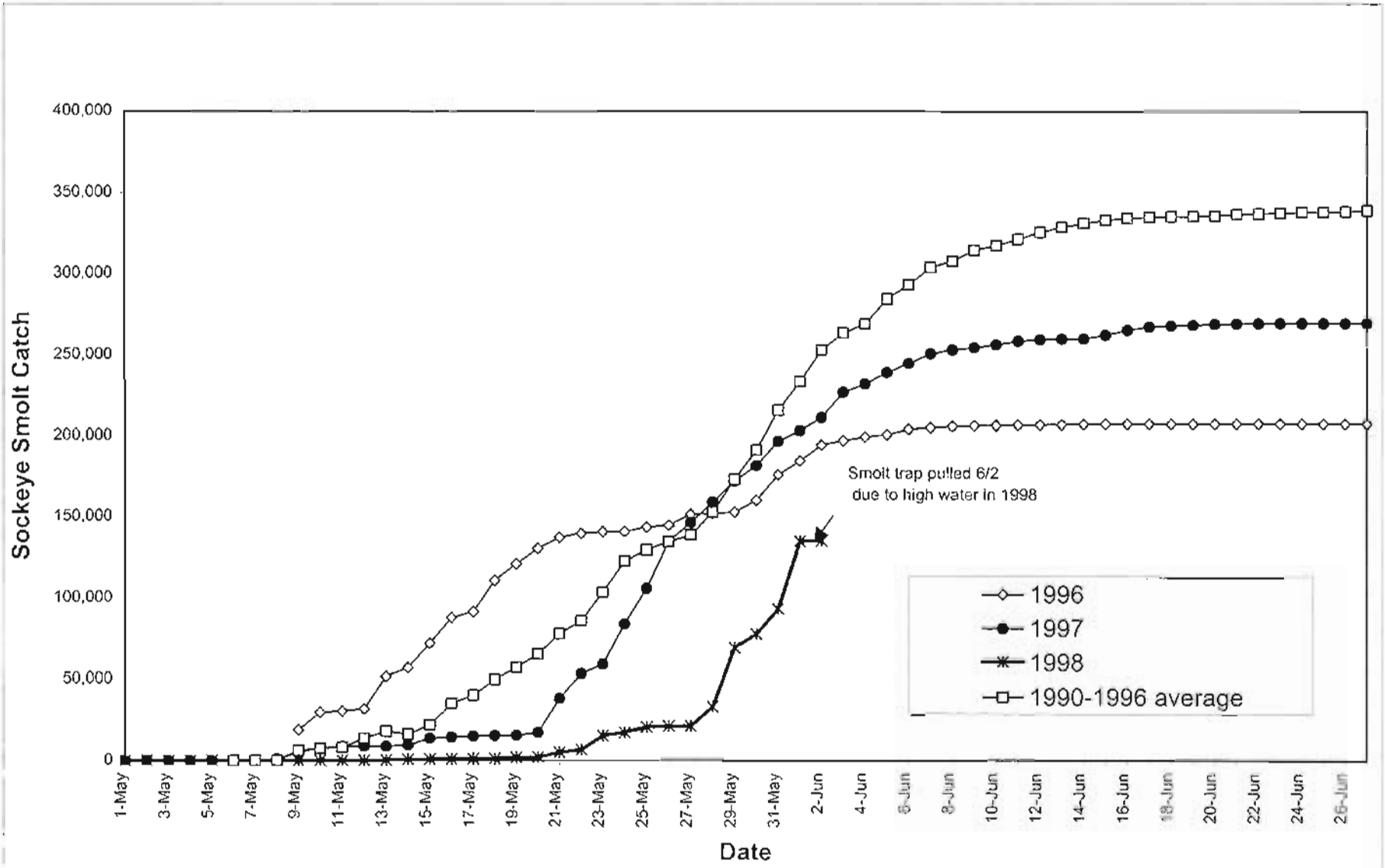


Figure 3. Cumulative smolt trap counts for sockeye salmon at Frazer Lake for 1996 - 1998 and the average counts for 1991 - 1996.

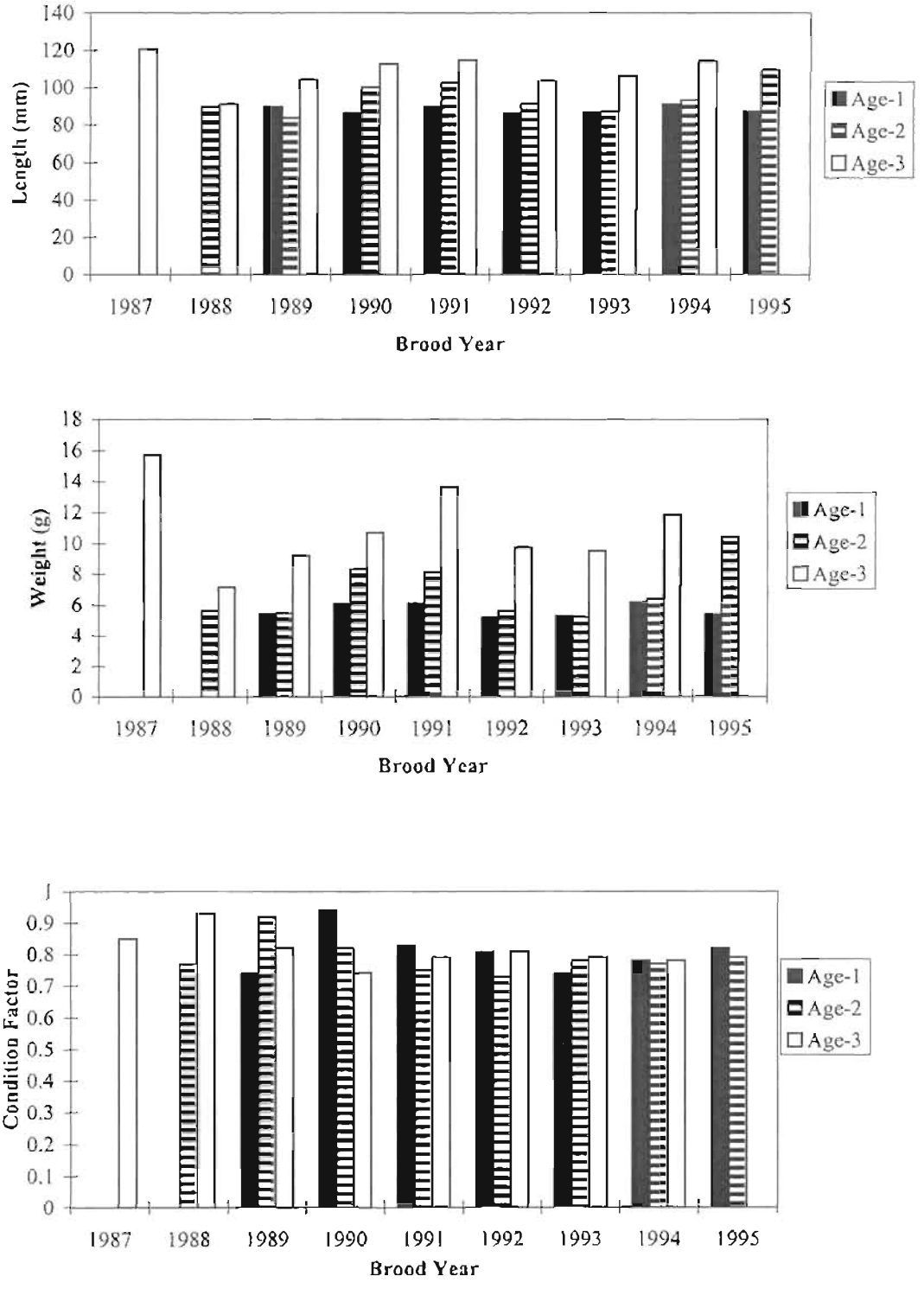


Figure 4. Frazer Lake sockeye salmon smolt length, weight, and condition factor by age and brood year, 1987-1995.

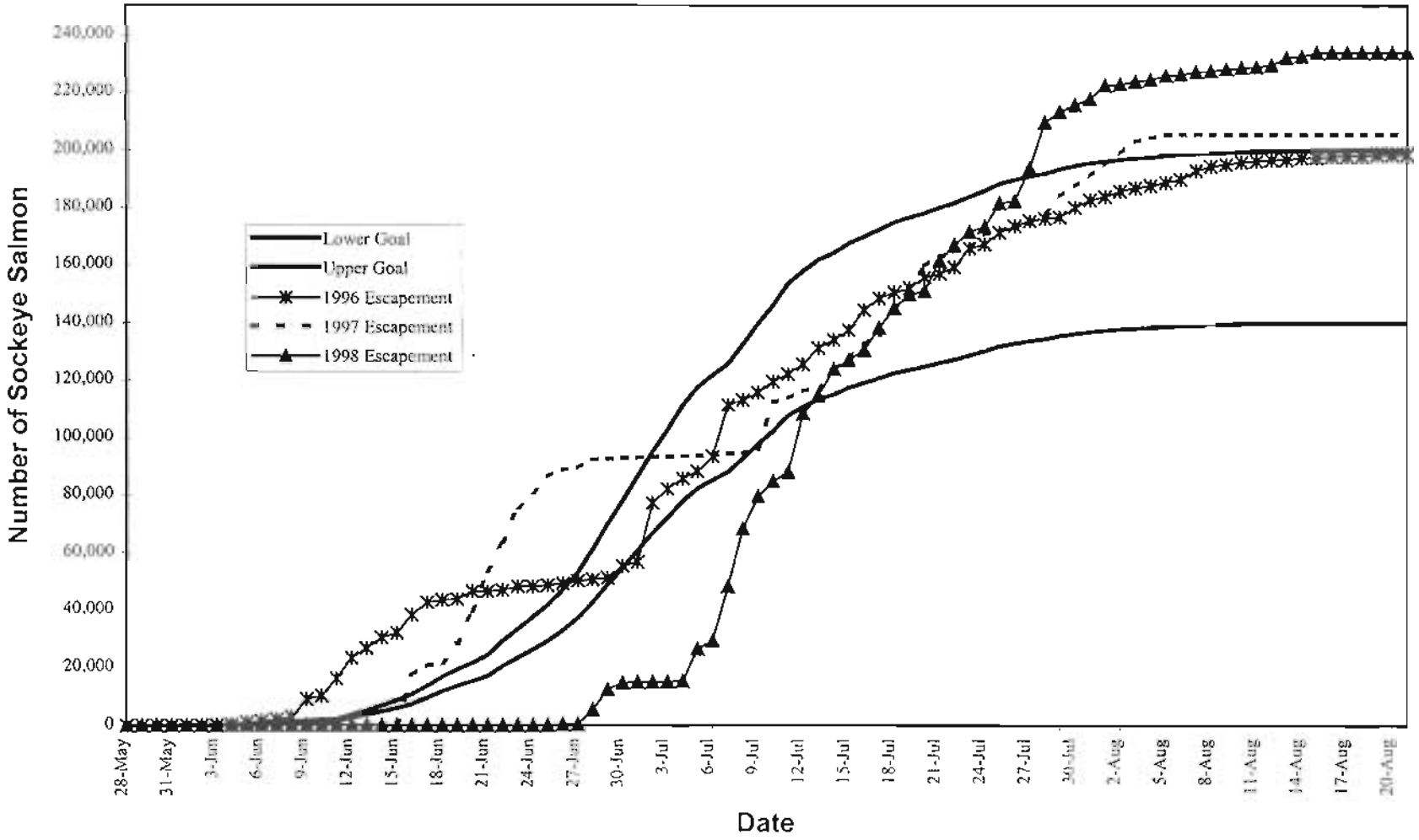
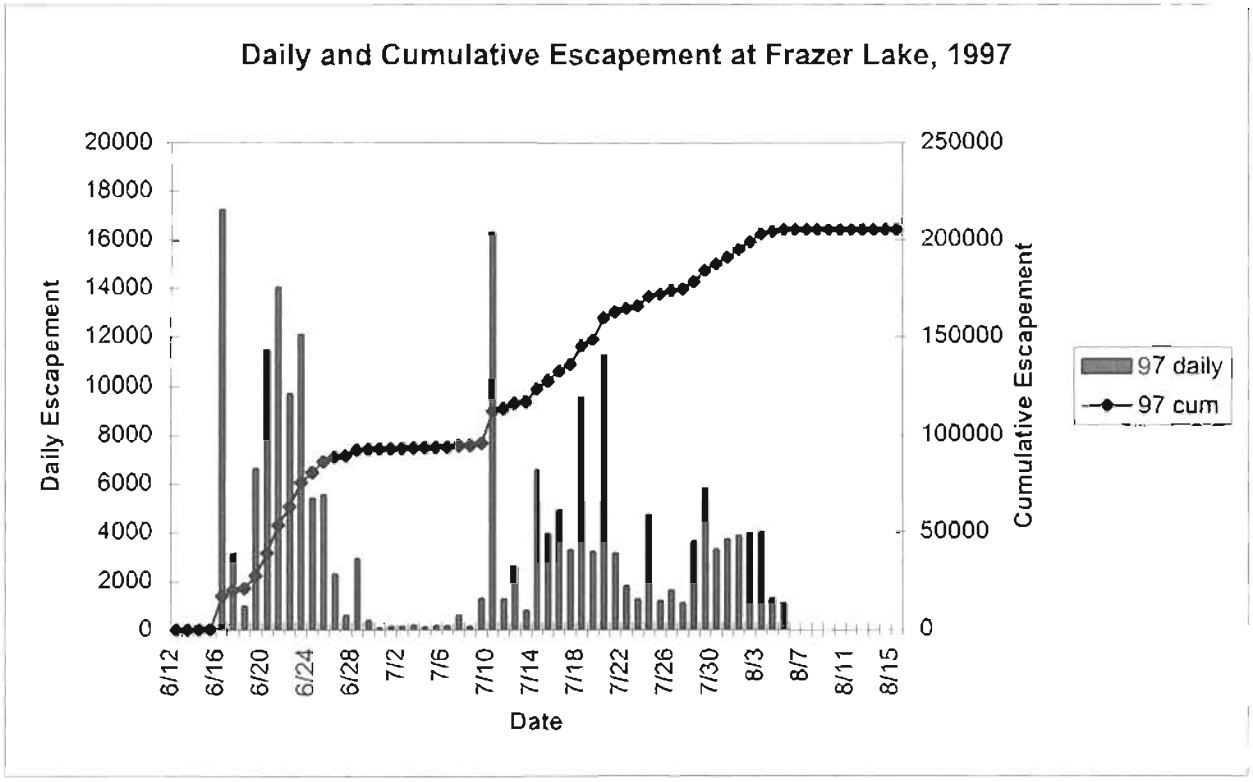


Figure 5. Frazer Lake daily escapement of adult sockeye salmon through the Frazer Lake fish pass 1996-1998 in relation to the lower and upper escapement goal bounds.



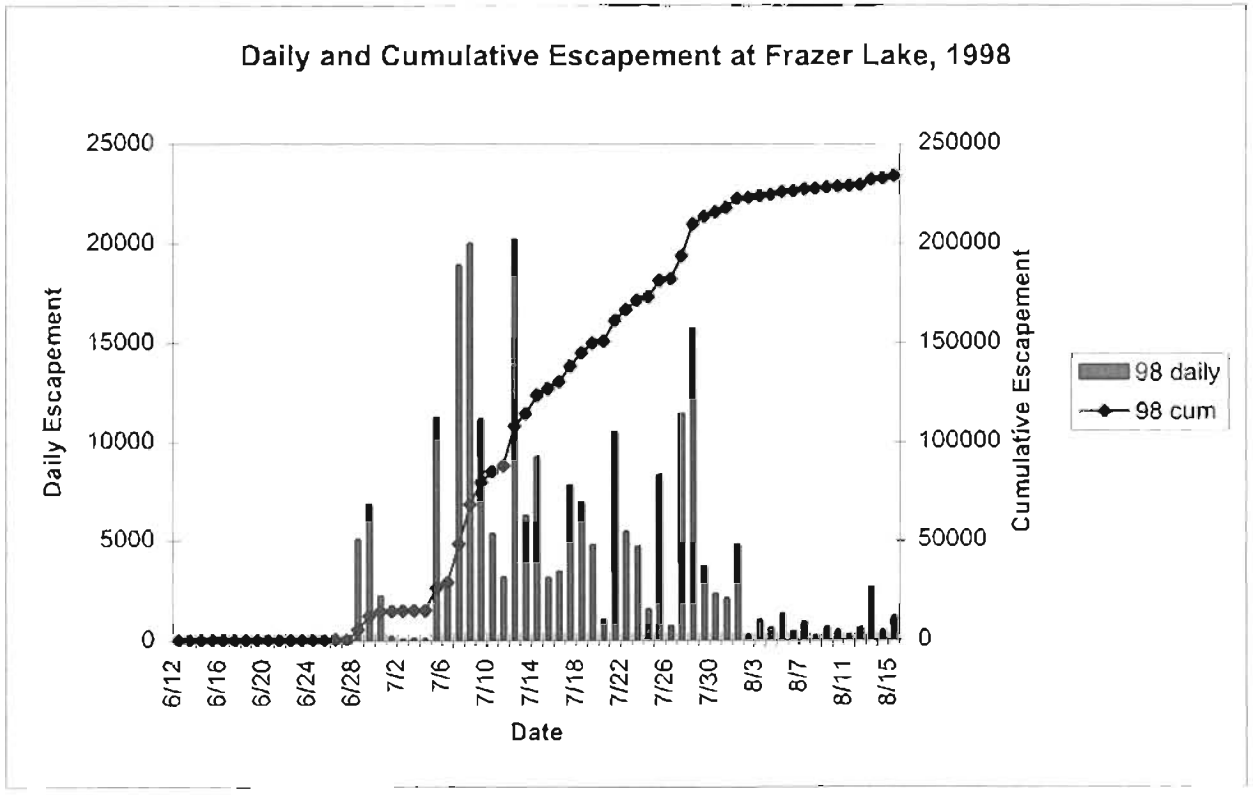


Figure 6. Daily and cumulative escapement of adult sockeye salmon through the Frazer Lake fish pass 1997 and 1998.

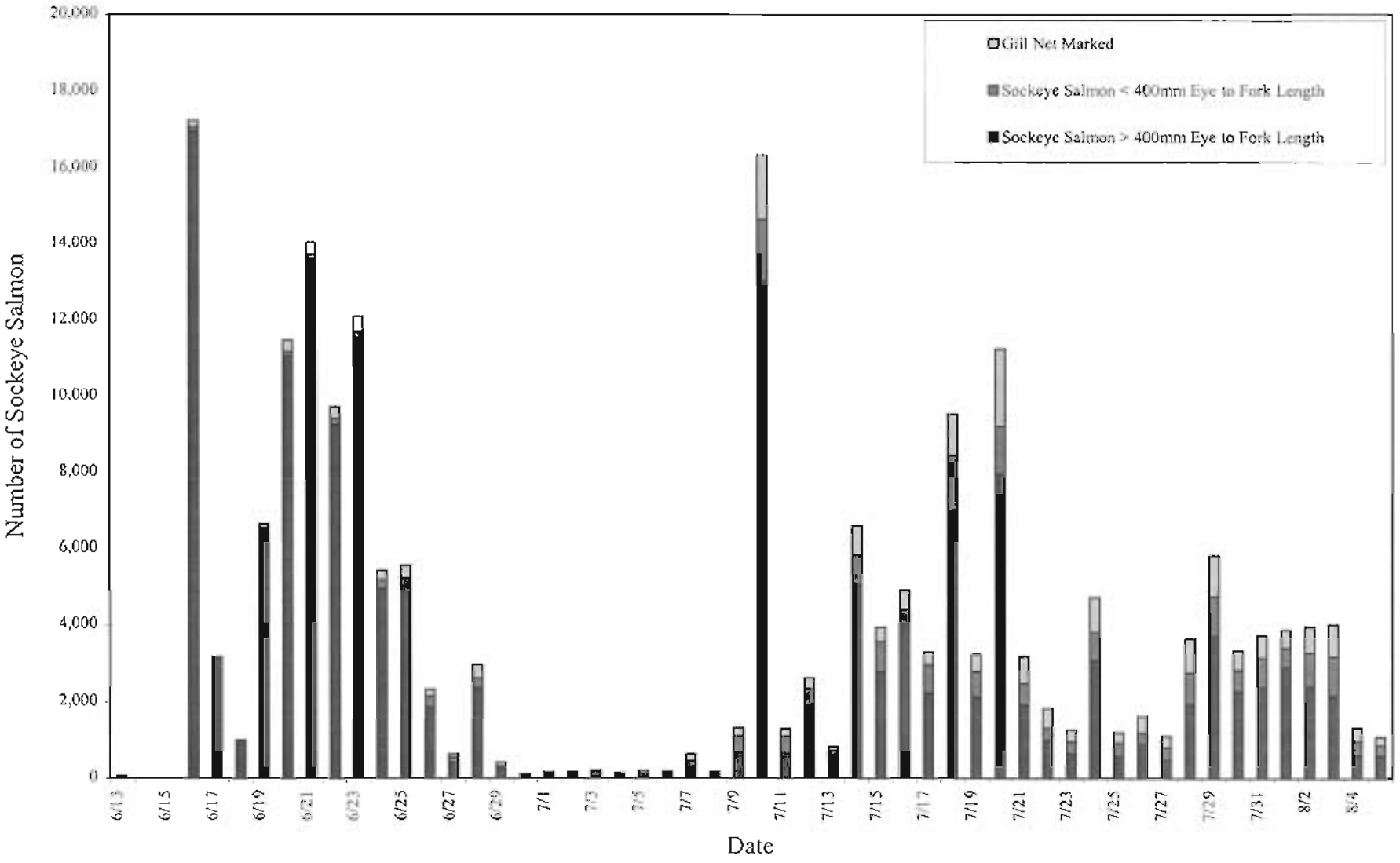


Figure 7. Daily Frazer Lake adult sockeye salmon escapement, including jack and net-marked components, 1997.

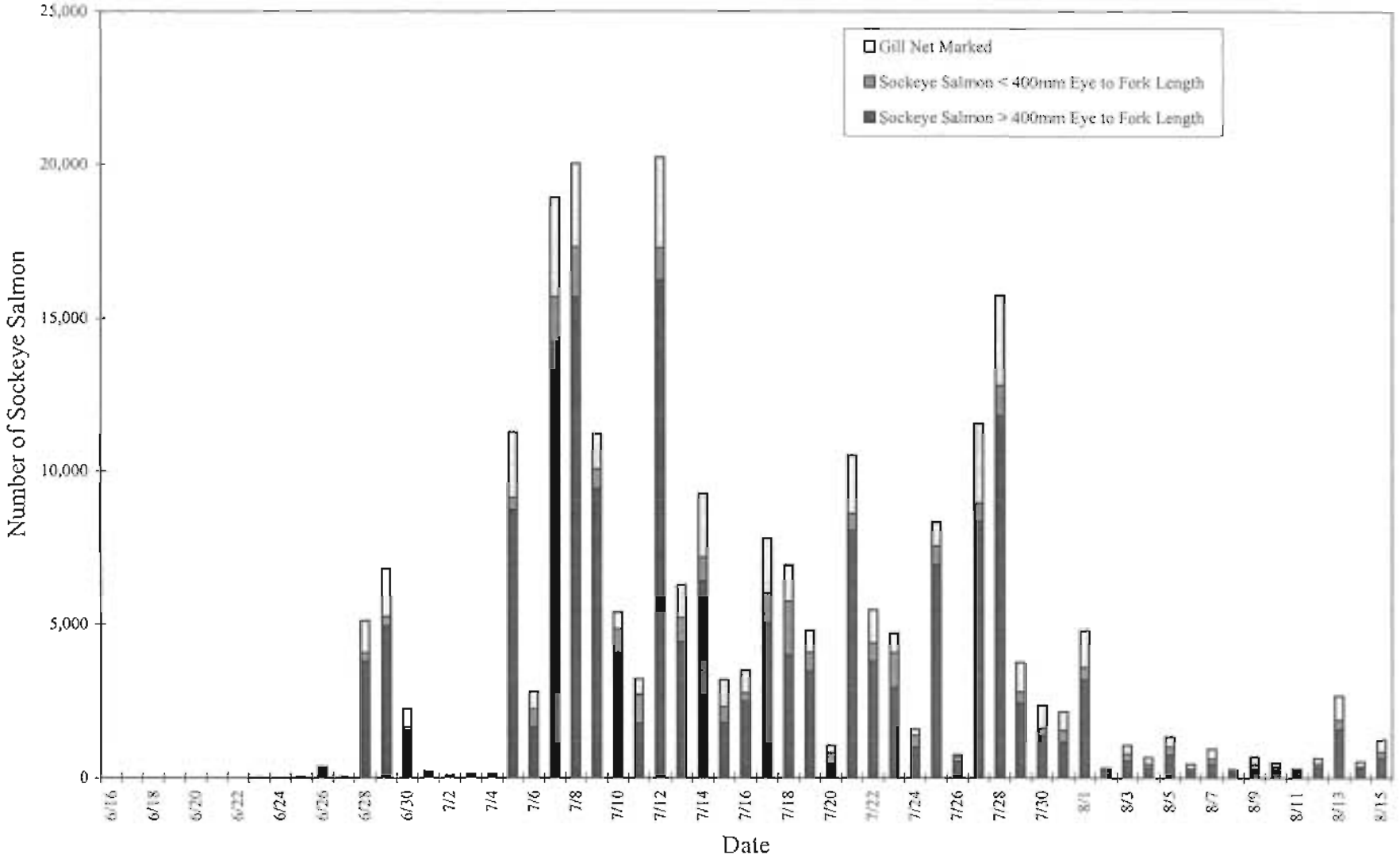


Figure 8 . Daily Frazer Lake adult sockeye salmon escapement, including jack and net-marked components, 1998.

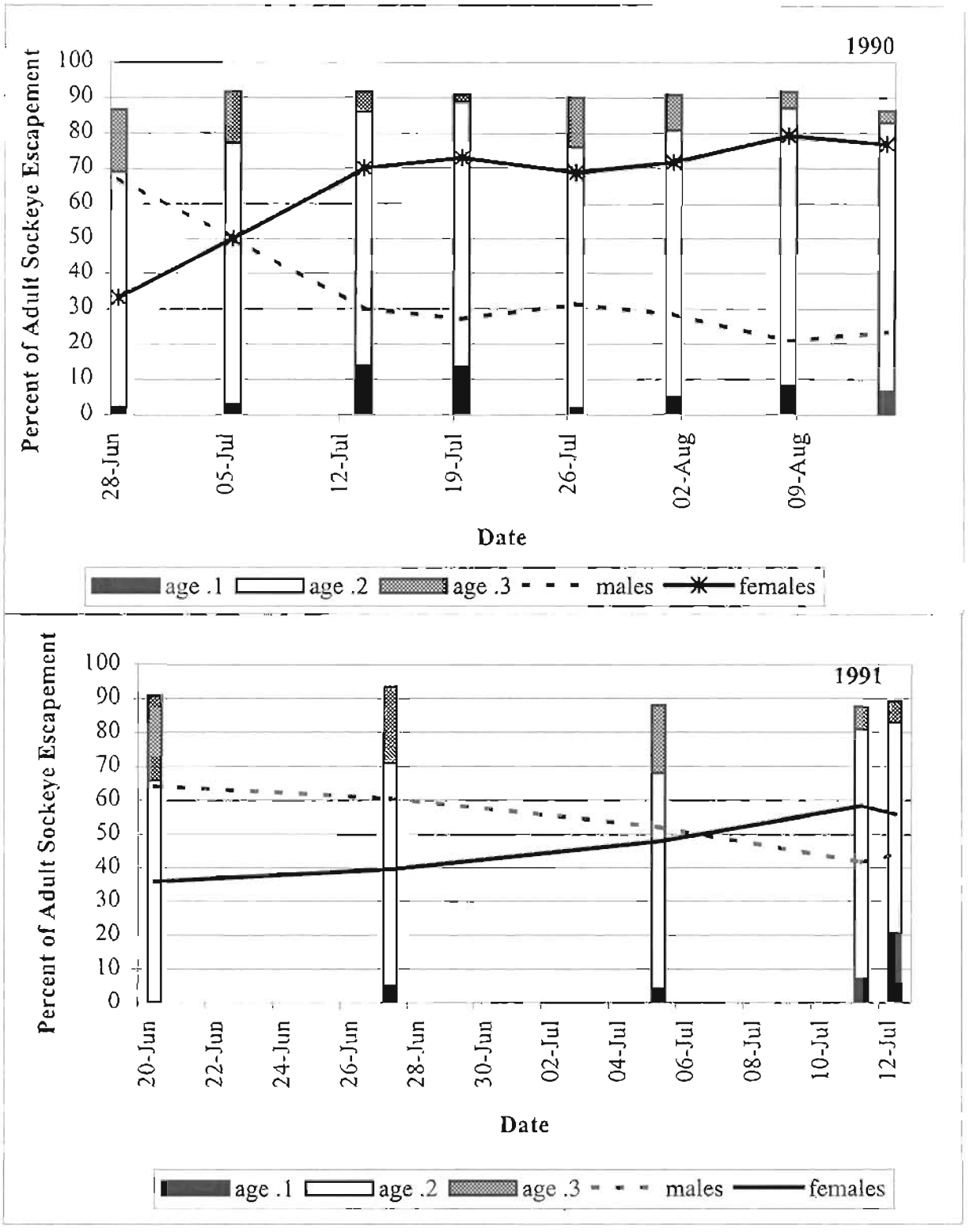


Figure 9. Percent adult sockeye salmon escapement by age and sex from Frazer Lake fish pass, 1990 and 1991.

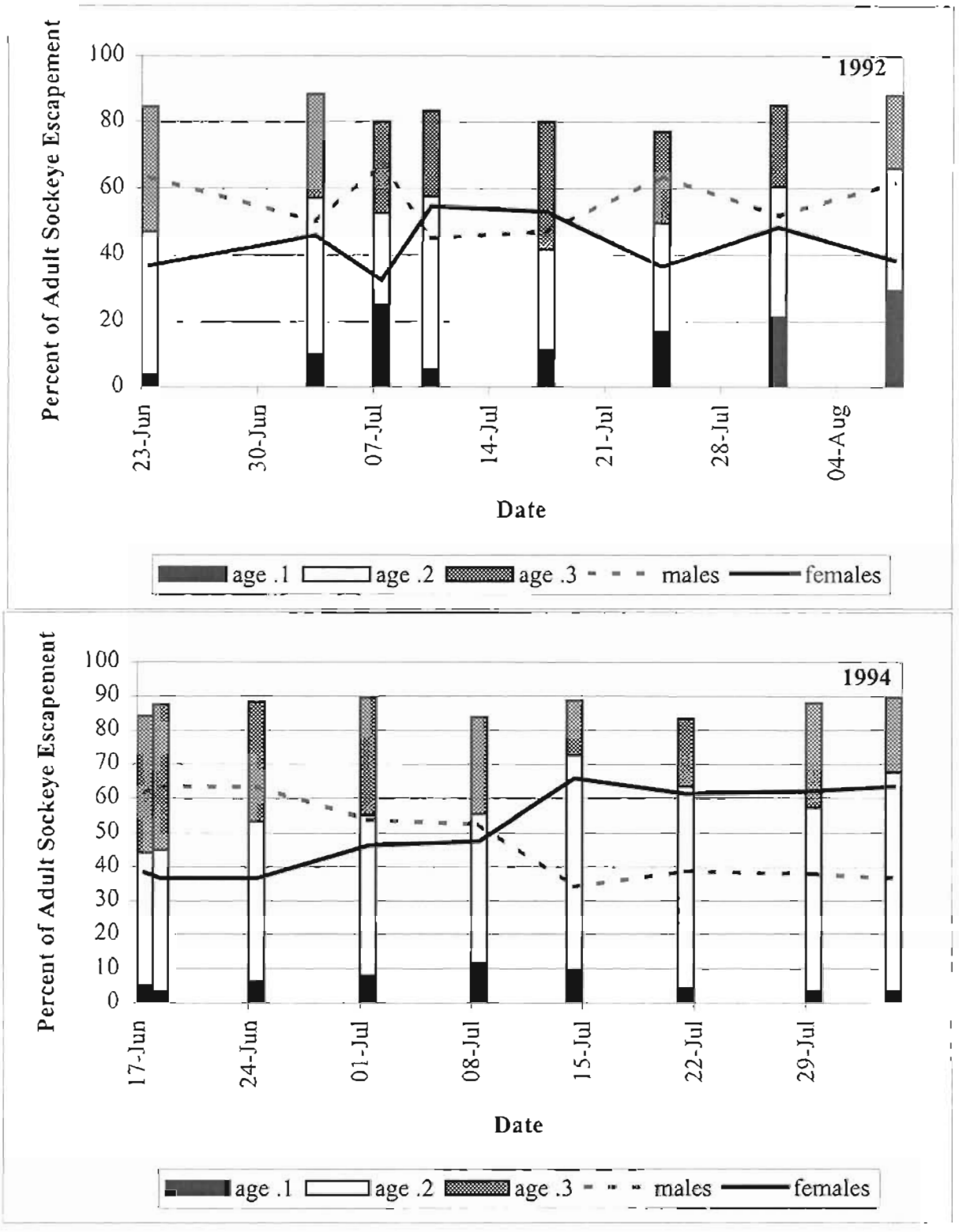


Figure 10. Percent adult sockeye salmon escapement by age and sex from Frazer Lake fish pass, 1992 and 1994.

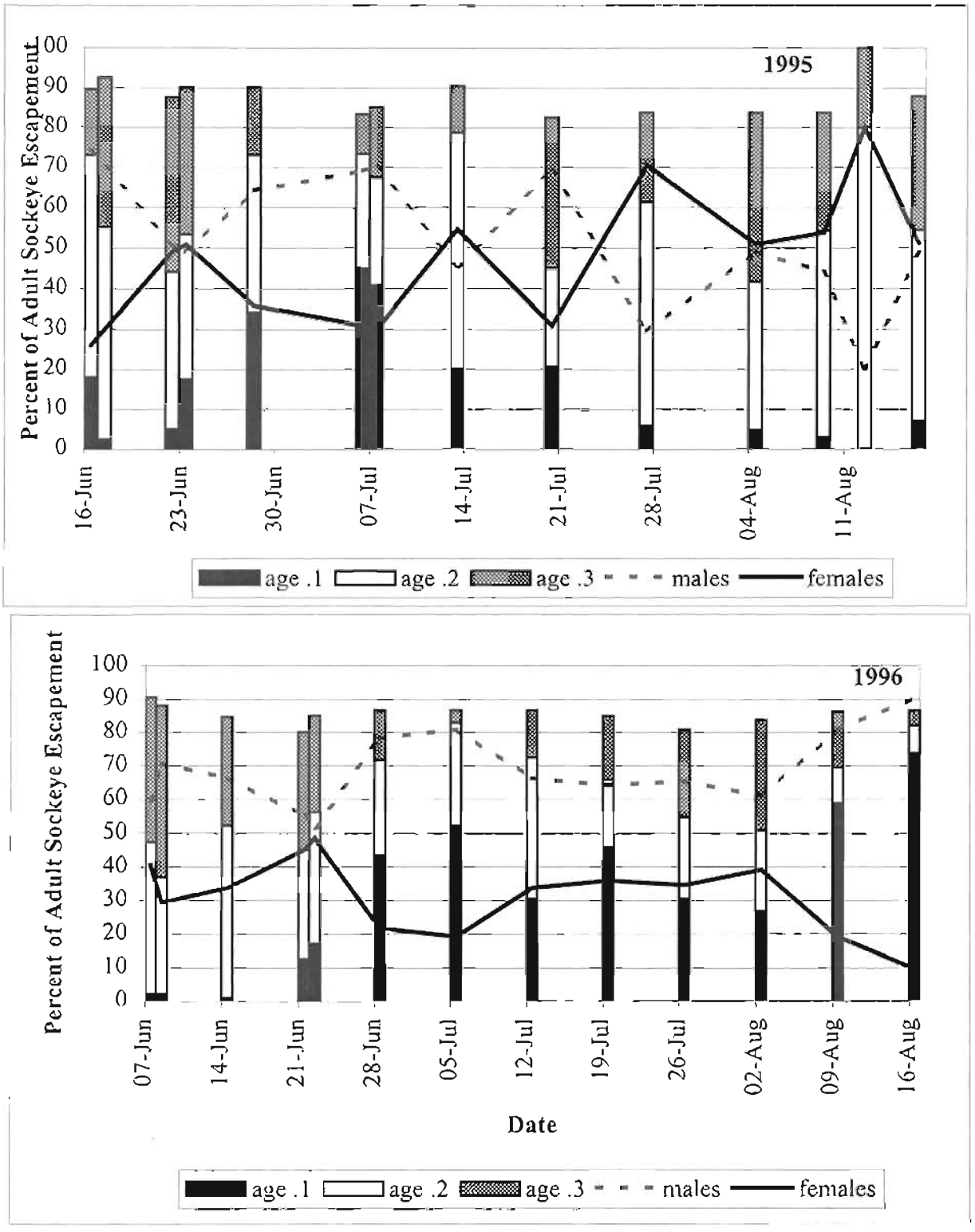


Figure 11. Percent adult sockeye salmon escapement by age and sex from Frazer Lake fish pass, 1995 and 1996.

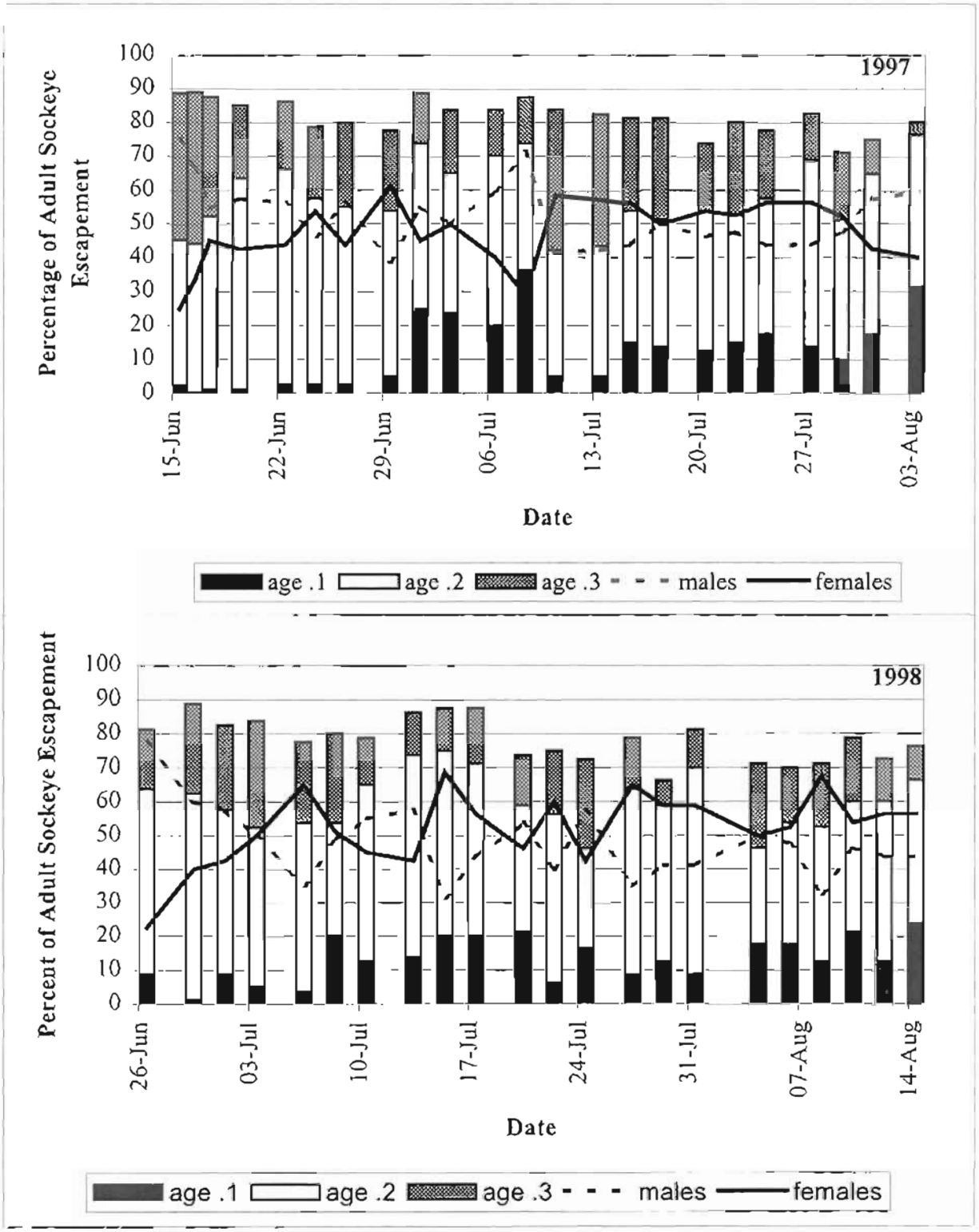


Figure 12. Percent adult sockeye salmon escapement by age and sex from Frazer Lake fish pass, 1997 and 1998.

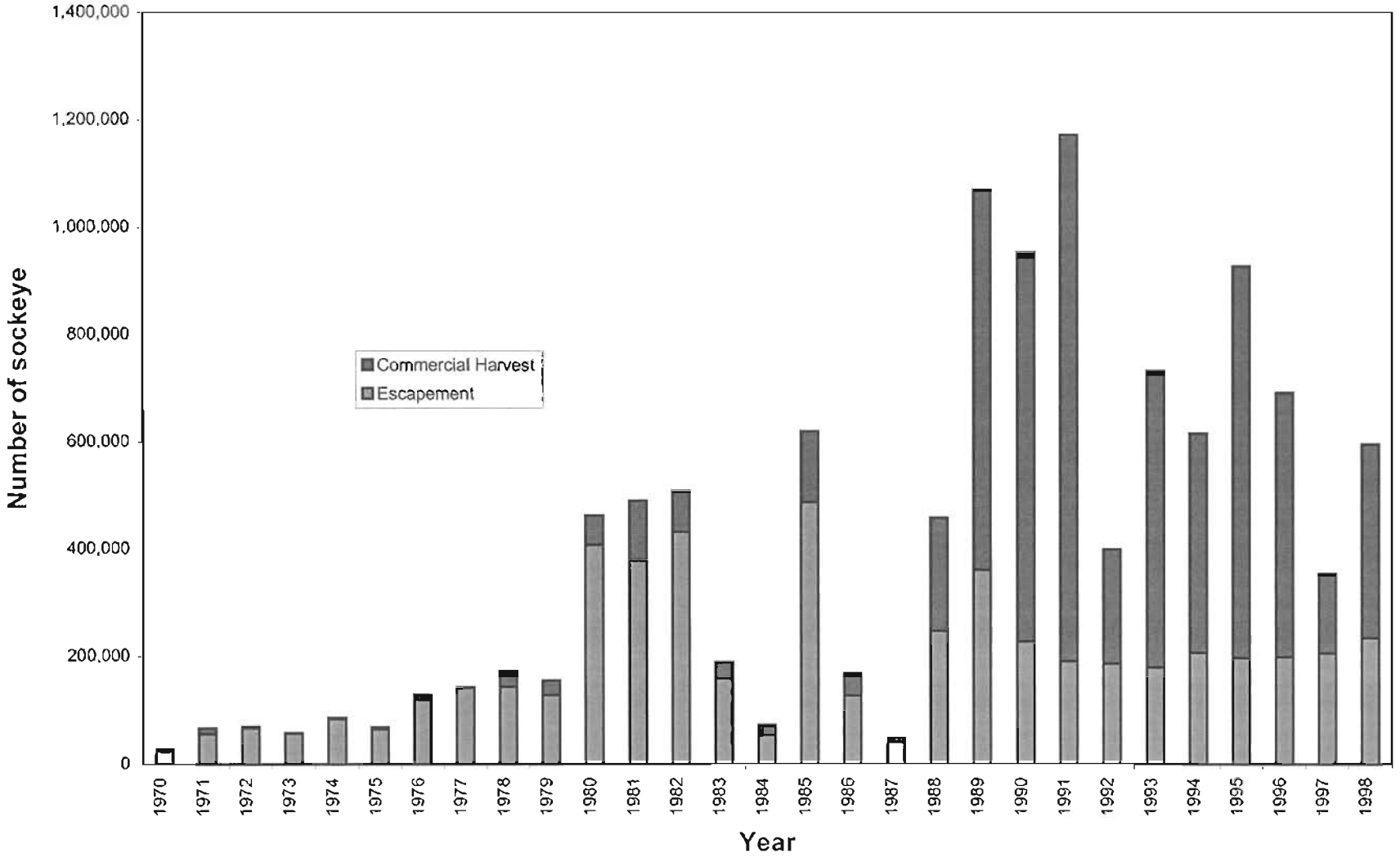


Figure 13. Frazer Lake sockeye salmon return in escapement and commercial harvest components, 1970-1998.