KENAI RIVER SOCKEYE SALMON SMOLT STUDIES, 1990-91

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ABSTRACT

The estimated number of sockeye salmon, *Oncorhynchus nerka*, smolt migrating seaward from the Kenai River between 16 May and 25 June 1990 was 10,844,005 fish. The seaward migration was 46.7% age-1.0 and 53.2% age-2.0 fish. Migration occurred primarily between 20 May and 9 June. In 1991 the estimated smolt seaward migration was 2,999,995, consisting of 86.1% age-1.0 fish and 13.9% age-2.0 fish. The migration was relatively steady from 23 May through 4 July. Environmental parameters measured at the site did not appear to influence timing of the migration in either year of the project.

KEY WORDS: Sockeye salmon smolt, *Oncorhynchus nerka*, biological sampling, migratory timing, bismark brown dye, mark-recapture, population estimation

INTRODUCTION

The Kenai River (Figure 1) typically contributes greater than 50% to the annual Upper Cook Inlet (UCI) commercial harvest of sockeye salmon, *Oncorhynchus nerka*. Forecasting the return of this stock is important to the successful management of the fishery. Forecasting was historically based on a combination of adult escapement, average age specific maturity schedules, and average numbers of returns per spawner representing the classic escapement-return approach. The current forecasting method applies Box Jenkins ARIMA modeling procedures with historic catch information (Tarbox 1991). Neither method relies on direct measurement of annual reproductive success as measured by egg, fry, or smolt abundance.

The Kenai River smolt project was designed to estimate the number and age composition of sockeye salmon smolt migrating out of the drainage. This project will contribute to the evaluation and understanding of sockeye salmon production in the Kenai River drainage when coalesced with estimates from adult sockeye salmon enumeration (King and Tarbox 1991), juvenile sockeye salmon enumeration in Kenai and Skilak lakes (Tarbox and King 1991), and adult salmon counting weirs at Hidden Lake (CIAA 1991) and Russian River (Carlon et al. 1991) tributaries. Comparable studies are ongoing in the Kasilof River drainage, the second largest producer of sockeye salmon in UCI (Kyle et al. 1992).

The objectives of the Kenai River smolt project were to:

1. Estimate the number of sockeye salmon smolt migrating seaward from 15 May through 30 June.
2. Estimate the age composition, mean weight, and mean length of sockeye salmon smolt.
3. Assess daily and seasonal migration timing of sockeye salmon smolt.

METHODS

Fishing Methods

Four stationary floating inclined plane traps were placed in the Kenai River approximately 31 km upriver from the mouth (Figure 1). The traps were anchored from the south bank with steel cable, and held at the appropriate distance from shore with tubular aluminum booms. Traps were positioned 9, 15, 21, and 24 m from shore and designated traps 1, 2, 3, and 4, respectively (Figure 2).

The Kenai River is approximately 110 m wide during the study period at the trap location. Water depth generally does not exceed 2.5 m during the study period and the thalweg occurs approximately 21 m from the south bank. From that point there is a gradual ascent of the bottom to the north bank. Traps were placed adjacent to the south bank in the area of highest surface water velocities and greatest flow volume. In contrast, the river on the north bank is shallow and slow moving out to approximately 40 m from shore. Placement of traps from this point out was impractical because of anchoring considerations and constant boat traffic.

In 1990, each trap was 2.1 m long, 1.4 m wide, and tapered in height from 1.4 m at the mouth to 0.1 m at the outlet or downstream end. Traps were designed after those used by the Fisheries Rehabilitation Enhancement and Development (FRED) Division as described by Kyle (1983). Traps were supported on metal frames which rested on pontoon floats. The outermost trap (trap 4) was new in 1990 and was constructed of aluminum plate with 13 mm diameter holes and netting with 13 mm square mesh. The remaining traps had 8 mm diameter holes in the bottom plate and 6 mm square mesh netting on the sides and top. The change in hole and mesh size was made to increase control of water flow at the outlet end and facilitate cleaning. The outlet end emptied into a 1.5 x 1.1 x 0.6 m live box which contained one vertical baffle. Both the mouth and outlet ends of the trap could be adjusted vertically to control fishing depth and the amount of water which entered the live box. Prior to the 1991 season all traps were rebuilt, with the opening modified to 1.5 m wide and 1.05 m high at the upstream end and standardizing to a 13 mm hole diameter and netting mesh size. In both years the traps were typically fished at approximately 1.0 m below the surface. All traps were fished continuously, and generally emptied for the first time at approximately 2200 to 2300 h each day. These fish represented the catch which had accumulated since the end of the previous shift (approximately 0500 h). Traps were then monitored continuously and emptied at least twice more prior to the end of the shift at 0500 h.

Catches which appeared to be less than 300 fish were counted by species. Prior to weighing in 1990, large fish (coho salmon *O. kisutch*, *salmo* spp, and non-salmonids in excess of 150 mm) were removed from the catch. In 1991, large numbers of pink salmon *O. gorbuscha* fry were expected as seen in 1989. In that year, the percent sockeye salmon smolt dropped as low as 3% (King et al. 1990) resulting in unreasonably large sample sizes for estimating the trap catch. An alternative method of mechanical sorting was used in 1991 to remove non-sockeye salmon smolt. The catch was passed through a series of 2 mesh sizes (0.64 mm and 1.91 mm) selected to remove large (~>120 mm) and small (~<40 mm) fish. These mesh sizes were selected because no sockeye salmon smolt less than 40 mm long were captured in 1989, and we suspected that nearly all sockeye salmon smolt which exceeded 120 mm reared in Hidden Lake and were estimated as they left that system (Kyle et al. 1990, CIAA 1991).

Estimating Smolt Abundance

Estimating the seaward migration of sockeye salmon smolt requires: (1) an estimate of the number of fish caught; (2) the species composition of the catch; and, (3) the capture efficiency of the traps for sockeye salmon smolt.

Estimating Trap Catches

Subsample Size for Estimating Trap Catches. We assumed that the magnitude of the catch on some days would prohibit counting every fish, and that the number of sockeye salmon smolt could be estimated from subsamples. Therefore on those days, trap catches were weighed, and the total number of sockeye salmon smolt captured ($\hat{C}$) was estimated as:

$$\hat{C} = W\frac{p}{w}$$

where:

W = Total weight of catch in trap (all species)
w = Estimated mean weight of fish in subsample
p = Proportion of subsample (n) which is sockeye smolt (n_s).

We assumed that $\hat{C}$ was a function of two independent random variables (p,1/w) and estimated its variance ($V(\hat{C})$) as:

$$V(\hat{C}) = W^2 [p^2 V(\frac{1}{w}) + \frac{V(p)}{w^2} - V(\frac{1}{w})\, V(p)]\,.$$

We then used the delta method to approximate a variance for 1/w as:

$$V(\frac{1}{w}) = \frac{S_w^2}{w^4 n}$$

where the mean weight (w) and its variance (S_w^2) were obtained from a sample of n fish which were counted and weighed. The number of sockeye salmon smolt in this sample (n_s) was assumed to follow a binomial (n,π) distribution. Therefore, the proportion of sockeye salmon in the sample (p) and its variance $V(p)$ was estimated by:

$$p = \frac{n_s}{n}$$

and:

$$V(p) = \frac{p(1-p)}{n}\,.$$

The variance of $\hat{C}$, $V(\hat{C})$, then became:

$$V(\hat{C}) = W^2\left[\frac{p^2S_w^2}{w^4n} + \frac{p(1-p)}{w^2n} - \frac{S_w^2p(1-p)}{w^4n^2}\right].$$

A sample size for estimating trap catches was sought which would minimize $V(\hat{C})$ and allow its omission from our population variance. Lacking an initial estimate of w or S_w^2, we used the mean (w_s) and standard deviation (S_{ws}^2) of sockeye salmon smolt weights (1.931 g, 0.204) in 1989 (King et al. 1990). These were combined with a mean pink salmon fry weight (w_p = 0.35 g) from catches that were greater than 95% pink salmon fry in 1989, and assuming a 25% coefficient of variation (CV) to estimate its standard deviation ($S_{wp}^2=0.25^2w_p^2$). An average fish weight was estimated as:

$$w = pw_s + (1-p)w_p$$

and its variance, based on 1,000 fish (n) was estimated as:

$$S_w^2 = \frac{[(n_s-1)S_{ws}^2 + n_sw_s^2 + (n_p-1)S_{wp}^2 + n_pw_p^2 - nw^2]}{(n-1)}$$

where the number of sockeye salmon smolt (n_s) and pink salmon fry (n_p) varied as:

$$n_p = pn$$

and:

$$n_s = (1-p)n$$

for p = 0.1, 0.2, ..., 1.0.

The variance of w, S_w^2, was found to vary with the proportion of sockeye salmon (Figure 3). Ultimately we were interested in estimating sample sizes which would keep the relative error (R) under 10% at various levels of p. R was defined as:

$$R = \frac{1.96\sqrt{V(\hat{C})}}{\hat{C}}.$$

Sample size was found to be sensitive to the proportion of sockeye salmon smolt (Figure 4 and Appendix A). In 1990 we assumed that during periods of high catches the proportion of sockeye salmon smolt would exceed 70%. Therefore a sample size of 300 fish per trap per clearing would keep the relative error below 10%. Trap catches which appeared to have substantially more than 300 fish were weighed and subsampled.

Estimating Trap Efficiency

Trap efficiency was estimated at different times during the season to assess the influence of changes in water condition and fish behavior. Sockeye salmon smolt were captured each 3-5 days and dyed in a 5 g Bismark Brown dye to 190 l water solution (approximately 1:36,000) for twenty minutes. Dyeing was generally done in the morning, using the previous night's catch. These fish were then transported approximately 2 km upstream of the traps and released near the south bank. Any dyed smolt recovered dead in the traps immediately after release were not included in the analysis. This procedure was modified in 1991 so that all dyed fish were held for approximately 12 hours prior to release. After release, the dead fish remaining in the live box were counted and the percent mortality calculated. All fish captured during the following 48 hours were examined for evidence of dye.

The number of fish dyed (M_i) for each dye marking event (3 to 5 d period) was set to obtain an estimate of abundance (N_i) with a relative error of ± 25% for trap efficiencies (r_i/M_i) equal to or greater than 2%. Sample size (M_i) for a given trap efficiency varied only slightly with number of fish caught ($\hat{C}_i$), but increased dramatically with decreasing trap efficiency. A sample size objective of 2,800 sockeye smolt for 2% trap efficiency was chosen. This trap efficiency was double that seen in 1989, however in choosing this level we recognized the logistic limitations of handling the number of fish required for lower efficiencies. We also assumed (as seen in 1989) that dye marking events would be pooled when trap efficiencies of adjacent time strata were not significantly different (χ^2-test with α=0.05 critical level). A minimum level of pooling, two adjacent strata, would meet the sample size of 5,700 needed for 1% trap efficiencies.

This estimator, like other mark-recapture estimates of population size, is biased at low sample size (Seber 1982). The number of marked fish needed to be large enough to ensure that at least 10 dyed fish were recaptured during each strata to keep the level of bias below 10%. Fewer recaptures would result in a large positive bias which increases rapidly as recaptures decrease below 10 (Figure 5).

The following analyses assumed: (1) all dyed sockeye salmon smolt released upstream are either caught or pass the traps within 48 hours and no dyed fish from one time period are caught in another; (2) there was no difference in marked and unmarked sockeye salmon smolt regarding probability of capture among traps; (3) a fish is either caught or not caught independently of the fate of other fish; and (4) trap efficiency (for all traps combined) is independent of trap location within a period and time across periods. The first assumption was evaluated by recording the date and time of all recaptures of dyed fish and only undertaking another dyeing event after 48 hours without a recapture from the previous period. Differences in behavior between dyed and undyed fish was assessed by testing whether the number of dyed and undyed fish varied among traps using a Chi square test (χ^2-test with α=0.05 critical level). Samples from adjacent time periods or dye events were pooled only when their trap efficiencies were not significantly different based on a Chi square test (χ^2-test with α=0.05 critical level).

In addition to the regularly scheduled releases of dyed fish, two releases of inanimate objects (one floating and one sinking) were done to gauge the relative volume of water sampled by the traps and travel time of passive objects. Radishes were chosen for the first release because they were biodegradable and easily seen. Only radishes which floated were selected. The second release was of dead dyed fish to simulate their probability of capture.

Estimating Sockeye Salmon Smolt Abundance

Sockeye smolt abundance ($\hat{N}_i$) was estimated as:

$$\hat{N}_i = \hat{C}_i \frac{M_i}{r_i} [1 + \frac{M_i - r_i}{M_i r_i}]$$

where:

- $\hat{N}_i$ = number of unmarked sockeye smolt migrating past traps in period i
- $\hat{C}_i$ = number of sockeye smolt caught in traps in period i
- M_i = number of sockeye smolt dyed and released upstream in period i
- r_i = number of dyed fish recaptured in traps in period i

using LaPlace's ratio estimate (Cochran 1978) described by Rawson (1984).

The Variance of $\hat{N}_i$ was estimated as:

$$V(\hat{N}_i) = \hat{C}_i(\hat{C}_i + r_i) M_i \frac{(M_i - r_i)}{r_i^3}$$

and the (1-α) confidence interval as:

$$\hat{N}_i \pm z_\alpha \sqrt{V(\hat{N})}$$

where z_α is the 1-α/2 percentage point of standard normal distribution.

The total estimate of out-migrating smolt ($\hat{N}$), and its variance ($V(\hat{N})$) were calculated as follows:

$$\hat{N} = \sum_{i=1}^{k} \hat{N}_i$$

and:

$$V(\hat{N}) = \sum_{i=1}^{k} V(\hat{N}_i)$$

where:

$\hat{N}$ = total number of fish migrating past traps
k = number of periods

and the 1-α confidence interval as:

$$\hat{N} \pm z_\alpha \sqrt{V(\hat{N})}\ .$$

Run Timing

Migration timing was estimated following the procedures of Mundy (1979). The mean date (D) of the migration was:

$$D = \sum_{i=1}^{n} d_i q_i$$

where q_i is the proportion of the smolt migration passing on day i (d_i). The variance of the mean day ($V(D)$) becomes:

$$V(D) = \sum_{i=1}^{n} (d_i - D_i)^2 q_i\ .$$

Age, Weight, and Length Sampling

Sockeye salmon smolt were also sampled for age, weight, and length (AWL) information. In order to obtain an abundance estimate by age class, sampling was stratified into 5 day periods. Samples were randomly selected from the catch of all traps combined. A daily sample size of 85 fish, 425 fish per 5 d period, was selected to satisfy a binomial simultaneous 90% confidence interval of ± 0.05 (Thompson 1987). A scale smear was taken from the preferred area (INPFC 1963) of each fish and placed on a standard laboratory slide for later age determination. Each fish was weighed to the nearest 0.05 g and measured (fork length) to the nearest mm.

Climatological/Hydrological Sampling

Environmental parameters except velocity were measured daily. Velocity measurements were taken at 0.3 m changes in depth. Water depth was recorded in meters, temperature in °C, turbidity as the maximum depth (m) a sechi disc was visible, and velocity (m/sec) by a Marsh-McBirney flow meter. Water depth, temperature, and turbidity were taken at least once daily. Water velocity was measured at the surface, bottom and midpoint of the water column at each trap location.

RESULTS

1990

Operation of the traps began 15 May and ended 25 June 1990. Traps were fished continuously prior to 12 June when high water and debris load forced a reduction in fishing time to 2000 h through 600 h. Based on catches to date, this time period was chosen because it represented 95% of the daily sockeye smolt catch.

An estimated 141,202 fish were captured in the four traps (Table 1). Traps 3 and 4 accounted for 78.4% of the total, with the highest catches recorded in trap 3 (45.0%). The lowest catches were recorded in traps 1 (7.5%) and 2 (14.1%). Trap catches for the season were predominantly sockeye salmon smolt, ranging from 82.1% in trap 1 to 93.7% in trap 3 for a total of 129,867 fish (Table 1). The remainder of the fish captured in the traps were predominantly chinook salmon (*O. tshawytscha*) smolt. In general, the numbers of sockeye and chinook salmon smolt increased with distance from shore and the numbers of fry of these same species decreased.

Approximately 74% of the catch was estimated from subsamples (Tables 2-5). Catches were of sufficient magnitude to require subsampling from 20 May through 9 June. During that 21 day period, catches were estimated for 8 days in trap 1 to 18 days in traps 3 and 4. The percent sockeye averaged 94% for those days ranging from 81% to 100%.

A total of 11,202 sockeye salmon smolt were dyed and released on 4 dates (Table 6). One hundred thirty of the 45,385 smolt examined for the mark were dyed. Trap efficiency ranged from 0.75% for period 1 (15-23 May) to 1.52% for period 2 (24-28 May). When trap catches for all four traps were combined and then compared by time period, a chi-square test indicated that the recovery of dyed fish (trap efficiency) was not independent of the release date (χ^2=10.61, 3 df, p=0.014). When period 1 was removed from the test, there was no difference (χ^2=4.76, 2 df, p=0.093) in trap efficiency for the remaining periods. When only traps 1-3 were tested, there was no difference (χ^2=7.62, 3 df, p=0.055) in trap efficiency between all four periods.

The ratio of dyed to undyed sockeye salmon smolt in each trap was the same for periods 1 and 4. In period 2 the ratio was higher in trap 1 (χ^2=78.8, 2 df, p=0.049), and in period 3 the ratio was lower in trap 3 (χ^2=13.26, 3 df, p=0.004). There was insufficient evidence to suggest that trap efficiency was independent of location for traps 2, 3, and 4 for period 1 (χ^2=1.38, 2 df, p=0.50) and traps 1, 2, and 4 for period 3 (χ^2=2.48, 2 df, p=0.29).

The estimated number of sockeye salmon smolt migrating seaward was 10,844,005 from 15 May through 25 June, with a 95% confidence interval (CI) of 8,442,035 to 13,245,974 fish (Table 7). This estimate was based on catches from all four traps using the observed trap efficiency for period 1 and a trap efficiency for periods 2, 3, and 4 combined. A second estimate was made using the same number of traps and offshore placement as in 1989 (King et al. 1990). Only the catch from traps 1-3 and the resulting trap efficiency when all periods were pooled (0.81%) was used. Seaward migration was estimated at 10,747,794 (95% CI of 8,531,068 to 12,964,521).

Ninety-seven percent of the sockeye salmon seaward migration occurred between 20 May and 9 June (Table 7). The mean and median day of migration was 31 May. There were 4 distinct peaks in the migration (Figure 6). The peak in daily passage occurred on 26 May. Less than 0.1% of the migration occurred in the first three or last four days of operation.

A total of 3,417 sockeye salmon smolt were sampled for age, length, and weight data (Table 8). When the estimated migration was weighted by period using age data, age-1.0 made up 46.7% and age-2.0 made up 53.2% of the migration. The age composition changed by period, with age-2.0 smolt leaving the drainage earliest (Figure 7). The change in age composition over time was significant (χ^2=355.9, 3 df, p<0.001).

The mean length of all age-1.0 fish sampled was 67.6 mm, ranging from 61.2 to 69.6 mm by period (Table 8). Age-2.0 fish averaged 74.4 mm, ranging by period from 73.7 to 75.1 mm. There was considerable overlap in length frequency distribution of the two age classes (Figure 8). The mean weight of age-1.0 fish varied by period from 1.86 to 3.11 g, resulting in a overall mean of 2.78 g. Age-2.0 smolt average weight was 3.39 g (range: 3.19 to 3.67 g).

The water level on the Kenai River was low in the beginning of the season and increased daily with the exception of a drop on 1 June. Water clarity did not vary linearly through the season but cycled between periods of clear and turbid water conditions. There was no apparent temperature trend through time except for a warming event between 6-19 June. Water clarity, temperature, and discharge measured at the smolt site did not appear to correlate with smolt migration timing (Figure 9).

Inanimate objects were placed in the river on two occasions, 26 May and 24 June. In the first test, radishes were evenly distributed across the river in the area of dyed smolt releases. Thirty-six of the 900 (4.0%) radishes placed in the river were recovered from the traps. Most of the radishes were carried by the current between the release and capture site within one hour. Later in the season 852 dead dyed sockeye salmon smolt were placed in the river at the location where live dyed fish had previously been released. These fish appeared to sink immediately to the bottom of a small eddy. Four (0.5%) were recovered from the traps within 2-5 hours.

1991

In 1991, the traps began fishing 16 May. In response to low catches and a possible change in migratory timing the project was extended through July 10. Traps 3 and 4 were left in the river until 11 July and one trap (Trap 4) through 12 July.

A total of 33,620 fish (excluding pink salmon fry) were counted in the traps from 16 May through 10 July 1991 (Table 9). All sockeye, coho, and chinook salmon were counted (Tables 10-13). Only those pink salmon fry remaining after the catch was sieved through screens were counted and represent an unknown proportion of the total pink catch. The percent of the total catch in each trap increased with distance from shore ranging from 8.0% in trap 1 to 39.1% in trap 3. Sockeye, chinook, and coho salmon smolt catches increased with distance from shore while fry of these species were more likely to be caught near the bank (Table 9).

In 1991, only one dye event was conducted due to insufficient numbers of fish in the trap catches. A total of 2,271 sockeye salmon smolt were dyed on 26 June. Forty two of the marked fish died in transport, and an additional 306 or 14% died in the holding box over the next 12 hours. Nineteen of the remaining 1923 dyed smolt were recovered. Seventeen of the recoveries occurred within 5 hours of release, and the remaining 2 dyed fish were captured within 12 hours. The ratio of dyed to undyed smolt was the same for all four traps (χ^2=3.65, 3 df, p=0.3). The resultant estimated trap efficiency was 0.00988 (Table 14).

The estimated number of sockeye salmon smolt migrating seaward was 2,999,995 from 16 May through 10 July. The 95% confidence interval was 1,702,269 to 4,297,931 fish (Table 15), a 43% relative error. The overall migration was relatively steady with 1-3% of the total occurring nearly every day from 23 May through 4 July. Nightly migrations which exceeded 5% of the total occurred from 20 through 22 June and on 26 June, making this period the peak of the seaward migration (Figure 10). The mean day of the migration was 14 June and the median day (50% passage) was 19 June. Less than 0.2% of the estimated migration occurred on the first seven or last 11 d of operations. Approximately 157,000 sockeye smolt (5%) passed the traps after the project normally ends 30 June. Over 85% of those smolt migrated in the first four days of July.

A total of 3,740 sockeye salmon smolt were sampled for age, length, and weight data (Table 16). Six age composition periods were established based on statistical testing of the similarity of temporally adjacent 425 fish samples. When the estimated migration was weighted using age by period data, age-1.0 fish made up 86.1% and age-2.0 fish made up 13.9% of the migration. The age composition changed by period, with the age-2.0 smolt leaving the drainage earliest (Figure 11). The change in age composition over time was significant (χ^2=1913, 5 df, p<0.001).

The mean length of age-1.0 fish was 65.6 mm and age-2.0 fish was 79.7 mm (Table 16). Mean weights of age-1.0 and -2.0 fish were 2.68 g and 4.20 g. Age-1.0 fish were larger in the first period, exceeding the mean length and weight of the remaining periods by at least 6.7 mm and 0.57 g.

The water level increased steadily from 17 May through 21 June, dropped on 22 June and increased to a stable level by 25 June. Turbidity was low early in the season but within the range of values observed in 1990. Water clarity, temperature and discharge measured at the smolt site did not appear to correlate with the smolt migration timing (Figure 12).

DISCUSSION

1990

A number of assumptions were made in the development of this project regarding minimum sample sizes, species composition of the trap catches, and the efficiency of each trap for capture of dyed fish. These assumptions were examined in 1990 relative to their effects on the estimate and variance calculations.

An important assumption underlying this population estimate is that marked and unmarked fish behaved similarly. A violation of this assumption would be apparent if we obtained very different marked to unmarked ratios among traps. We tested this assumption with a Chi-square analysis comparing dyed to undyed smolt sampled from each trap, testing each period separately. Only trap 3 period 3 was significantly different from the others. This was curious as trap 3 was not the outermost trap and the farthest offshore trap (trap 4) was not statistically different from traps 1 and 2. The sensitivity of the abundance estimate to trap 3 catches was examined by omitting trap data from the analysis. Little change in the estimate was observed (10,747,794); consequently, we had no evidence to suggest that marked and unmarked fish behaved differently.

The number of fish dyed each period was based on the assumption that trap efficiency would equal 2%, or be consistent over time if less than 2%. Sample sizes would need to be greater than 5,700 to ensure a relative error of less than 25% for efficiencies equal to or less than 1%. Violation of this assumption resulted in wider confidence intervals on the estimate. In the first estimate for period 1, we dyed 2,793 fish and estimated a trap efficiency of 0.75% resulting in relative error bounds of 41% around the estimated seaward migration during that period.

The release and capture of inanimate objects provided an indication of potential trap avoidance and provided natural bounds for trap efficiencies. Recovery of the floating inanimate objects was approximately four times that for marked fish, and was proportional to the cross section of the river surface covered by the traps. The discrepancy between efficiency measurements could be attributed to trap avoidance; however, the bell-shaped distribution (NSC) of length frequencies for sockeye salmon smolt as well as the presence of larger coho and chinook salmon smolt (Figure 13) indicated that avoidance was probably not solely a function of size. Similar trap efficiencies at varying surface velocities in both 1989 and 1990 weaken the conclusion of avoidance based on fish size alone.

The difference in capture rates between live and dead dyed fish caused concern regarding the observed trap efficiency for live fish. The percent of dyed dead fish recaptured equalled 0.5%, which was approximately one-half of the average trap efficiency for dyed live fish. A case could be made that some recoveries each period were actually dead fish and therefore the trap efficiency did not reflect that of active live fish. We had no measure of the marked fish mortality after release, so no assessment of this potential source of error was possible in 1990. We did however eliminate dead dyed fish found in the traps immediately after release from the trap efficiency calculations.

Several estimates were generated from the 1990 data. Since we assumed that sockeye salmon smolt distribution in the river was patchy as they schooled to travel downstream at night, our first estimate was based on the maximum number of traps. We also decided that the efficiency of trap 3 in period 3 was in question and omitted it from one estimate. Lastly, we included an estimate of seaward migration based on the catches from traps 1 through 3 only, comparable to the 3 traps fished in 1989. All estimates were very close (10,747,794 to 10,844,005) indicating that the estimate was not overly sensitive to choice of traps or period stratification.

Age composition sampling revealed a difference in migration timing between age classes with age-2.0 fish generally exiting the system first. This phenomenon is widely observed in mixed age class smolt migrations (Kyle et al. 1990, Bue et al. 1988). There was evidence of either noticeable growth or the appearance of different substocks in the size information collected from age-1.0 smolt after 3 June. The average length of age-1.0 fish changed from 61.2 mm in the previous period to 69.6 mm. This same change in size was not evident in age-2.0 sockeye salmon smolt.

1991

After experiencing the high by-catch of pink salmon fry in 1989, we decided in 1991 to mechanically sort large and small fish from the catches and use the remaining fish to estimate the seaward migration of sockeye salmon smolt. Sorting of fish was intended to reduce the coefficient of variation of the mean size of fish in samples used to estimate trap catches which were weighed and not counted. As it turned out, catches were small enough in 1991 that sockeye salmon smolt were completely enumerated, and therefore the sorting procedure was not necessary. We did however continue sorting to evaluate it's potential for use in the future. It was successful since few sockeye salmon smolt were found in the excluded fish, and sorted catches were greater than 87% sockeye salmon smolt.

Since there was only one dye test in 1991, there was no opportunity to determine if trap efficiency changed over time. Holding of dyed fish appeared to improve the mark/recapture process and resulted in added confidence in the recapture data. The 14% mortality during holding seemed reasonable when we looked at the trap efficiency in 1991 relative to previous years. The trap efficiency of 0.0098 in 1991 was comparable to values (0.0079-0.0141) seen in 1989-90 after a 14% decrease was calculated. The mortality observed in 1991 may have been high due to handling stress associated with trying to obtain an adequate sample size.

If trap efficiency was significantly lower early in the 1991 season, as seen in period 1, 1990, it would effect the estimate of age-2.0 smolt more than age-1.0. We would have underestimated the run magnitude and documented a later run timing for the age-2.0 component because we would have underestimated early run strength in relation to later migrating smolt. Yet the estimated mean date of passage was 29 May for age-2.0 smolt in both 1990 and 1991 (Table 17, Appendix B) with similar variances (37.8 and 44.5). In contrast, the mean date for age-1.0 in 1991 was 17 June, at least 12 days later than in 1989 (5 June) or 1990 (1 June). The age-1.0 migration was also very protracted with a variance (82.8) over twice that previously seen.

The final estimate of 2,999,995 sockeye salmon smolt was considerably less than expected from fall fry estimates and average winter survival. October 1990 lake surveys resulted in estimates of 24,619,000 age-0.0 and 768,000 age-1.0 fry in Kenai and Skilak Lakes (Tarbox and King 1991). This estimate did not include production from Hidden or Russian Lakes. An average winter survival of 75% should have produced approximately 18,000,000 age-1.0 and 600,000 age-2.0 smolt from the two major lakes. Most of the Russian River production leaves the system as age-2.0 smolt, while Hidden Lake fish are primarily age-1.0. Neither of these substocks were part of the fall fry estimates.

There are several potential explanations for the less than expected 1991 smolt seaward migration estimate. The estimate may be real and reflect high mortality, perhaps due to rearing limitations. It could also simply be a function of fry remaining in the lake as a result of some undefined environmental factors. We also do not discount the possibility of juvenile or smolt population measurement error given the evolving experimental nature of the techniques.

If the estimates prove even reasonably accurate, the data suggests that sockeye salmon smolt production from the 1987-89 parent years varied considerably despite the record escapements achieved in each year (Table 18). The 1987 parent year escapement of 1.6 million resulted in 29.6 million smolt. Most of these fish (23.8 million) left the drainage at age-1.0. The remaining 5.8 million held over in the lake and migrated the same spring as the 5.1 million age-1.0 smolt which resulted from the 1988 adult return. The 1988 adult escapement of 1.0 million also produced 0.4 million age-2.0 smolt for a total smolt production of 5.5 million. The 1989 parent year adult escapement produced 2.6 million age-1.0 smolt. The age-2.0 component of the 1989 brood year will leave the system as smolt in 1992, however preliminary indications are that the numbers will not account for the difference in expected production from the 1.6 million adults in the parent year escapement (age-1.0 fry comprised approximately 2.9% of the Kenai Lake and 4% of the Skilak Lake fall 1991 tow net catches).

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Table 1. Estimated numbers of juvenile fish caught with inclined plane traps in the Kenai River, 1990.

Estimated Trap Catch

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Fry	Pink Fry	Other	Total
1	8,708	481	861	300	87	23	148	10,608
2	18,132	180	1,168	239	69	17	134	19,939
3	59,528	631	2,776	232	106	100	184	63,557
4	43,499	43	3,114	68	58	44	272	47,098
Total	129,867	1,335	7,919	839	320	184	738	141,202

Percent of Individual Trap Catch

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Fry	Pink Fry	Other	Total
1	82.1	4.5	8.1	2.8	0.8	0.2	1.4	100.0
2	90.9	0.9	5.9	1.2	0.3	0.1	0.7	100.0
3	93.7	1.0	4.4	0.4	0.2	0.2	0.3	100.0
4	92.4	0.1	6.6	0.1	0.1	0.1	0.6	100.0

Percent of Total Catch

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Fry	Pink Fry	Other	Total
1	6.2	0.34	0.61	0.21	0.06	0.02	0.10	7.5
2	12.8	0.13	0.83	0.17	0.05	0.01	0.09	14.1
3	42.2	0.45	1.97	0.16	0.08	0.07	0.13	45.0
4	30.8	0.03	2.21	0.05	0.04	0.03	0.19	33.4

Table 2. Numbers of fish captured by trap 1 in the Kenai River, May 15 through June 25, 1990.

		Numbers of Fish in Trap Subsample												
	Live Fish Weight	Sockey		Chinook					Number of Fish	Number of Fish	Total Number of	Sockeye Smolt	Number of Sockeye	Total Number of
Date	(Kg)	Smolt	Fry	Smolt	Fry	Coho[a] Fry	Pink Fry	Other	Counted	Estimated	Fish	Proportion	Estimated	Sockeye
15-May	0.04	2	0	0	7	0	0	2	11		11	0.182		2
16-May	0.04	3	1	2	34	0	4	1	45		45	0.067		3
17-May	0.14	2	3	6	61	1	1	8	82		82	0.024		2
18-May	0.20	37	6	10	34	4	0	0	91		91	0.407		37
19-May	0.14	15	0	26	4	1	0	5	51		51	0.294		15
20-May	1.08	311	0	5	12	3	0	0	331		331	0.940		311
21-May	3.12	711	1	4	7	5	0	5	733	335	1,068	0.970	325	1,036
22-May	1.30	375	0	27	17	5	0	5	429	87	516	0.874	76	451
23-May	0.30	48	0	11	7	4	0	1	71		71	0.676		48
24-May	0.22	41	0	15	14	10	2	1	83		83	0.494		41
25-May	0.84	296	0	8	0	1	4	6	315		315	0.940		296
26-May	1.68	548	4	13	13	1	0	6	585		585	0.937		548
27-May	1.66	673	13	8	12	0	4	9	719	160	879	0.936	150	823
28-May	0.60	176	3	12	6	2	0	4	203		203	0.867		176
29-May	0.72	177	0	11	9	0	2	5	204		204	0.868		177
30-May	1.58	522	16	28	9	4	0	7	586		586	0.891		522
31-May	1.96	323	32	15	3	2	0	2	377	271	648	0.857	232	555
01-Jun	1.26	308	52	31	4	4	0	8	407		407	0.757		308
02-Jun	0.86	189	50	29	2	2	1	10	283		283	0.668		189
03-Jun	1.02	294	9	17	4	4	4	5	337		337	0.872		294
04-Jun	1.70	377	21	16	4	0	0	6	424	158	582	0.889	141	518
05-Jun	2.08	325	18	10	4	5	0	5	367	326	693	0.886	289	614
06-Jun	2.02	317	13	7	3	6	0	3	349	229	578	0.908	208	525
07-Jun	1.76	332	42	10	0	0	0	1	385	152	537	0.862	131	463
08-Jun	0.88	228	38	8	2	0	0	1	277		277	0.823		228
09-Jun	0.98	261	38	2	1	0	0	0	302		302	0.864		261
10-Jun	0.56	91	33	31	1	1	0	6	163		163	0.558		91
11-Jun	0.92	49	5	34	1	2	0	2	93		93	0.527		49
12-Jun	0.08	7	2	8	0	0	0	0	17		17	0.412		7
13-Jun	0.26	9	0	28	1	0	0	2	40		40	0.225		9
14-Jun	0.72	11	1	91	1	0	0	0	104		104	0.106		11
15-Jun	0.34	13	2	35	0	0	0	2	52		52	0.250		13
16-Jun	0.52	23	0	59	1	1	0	0	84		84	0.274		23
17-Jun	1.04	20	0	122	1	1	0	1	145		145	0.138		20
18-Jun	0.20	4	0	21	0	1	0	6	32		32	0.125		4
19-Jun	0.12	6	0	12	1	1	0	1	21		21	0.286		6
20-Jun	0.08	9	0	4	1	2	0	2	18		18	0.500		9
21-Jun	0.10	11	1	7	0	0	0	1	20		20	0.550		11
22-Jun	0.18	9	2	15	0	0	0	0	26		26	0.346		9
23-Jun	0.02	0	0	1	0	0	0	1	2		2	0.000		0
24-Jun	0.16	1	0	15	0	1	0	2	19		19	0.053		1
25-Jun	0.02	4	0	4	1	0	0	0	9		9	0.444		4
Total	33.50	7,158	406	818	282	74	22	132	8,892	1,717	10,609	0.821	1,550	8,708

[a] Coho salmon smolt were removed before trap catches were counted or weighed.

Table 3. Numbers of fish captured by trap 2 in the Kenai River, May 15 through June 25, 1990.

		Numbers of Fish in Trap Subsample[a]												
		Sockeye		Chinook										
Date	Live Fish Weight (Kg)	Smolt	Fry	Smolt	Fry	Coho[b] Fry	Pink Fry	Other	Number of Fish Counted	Number of Fish Estimated	Total Number of Fish	Sockeye Smolt Proportion	Number of Sockeye Estimated	Total Number of Sockeye
15-May	0.04	1	0	3	13	0	2	0	19		19	0.053		1
16-May	0.04	2	0	2	14	0	2	1	21		21	0.095		2
17-May	0.06	9	1	2	30	3	0	5	50		50	0.180		9
18-May	0.38	77	8	13	39	1	4	2	144		144	0.535		77
19-May	0.54	80	0	48	6	1	0	6	141		141	0.567		80
20-May	1.64	521	0	2	1	0	0	0	524		524	0.994		521
21-May	4.82	859	1	8	5	5	0	6	884	683	1,567	0.972	663	1,522
22-May	1.88	497	3	28	9	6	0	9	552	177	729	0.900	160	657
23-May	0.44	130	0	10	6	5	4	3	158		158	0.823		130
24-May	0.26	54	0	7	4	6	0	3	74		74	0.730		54
25-May	1.22	384	0	0	2	1	0	3	390		390	0.985		384
26-May	8.02	794	4	2	7	0	0	2	809	1,686	2,495	0.981	1,655	2,449
27-May	5.00	570	0	4	1	0	0	4	579	1,223	1,802	0.984	1,204	1,774
28-May	1.30	384	1	13	7	0	3	1	409		409	0.939		384
29-May	2.34	472	3	15	8	0	1	10	509		509	0.927		472
30-May	5.24	465	0	25	3	0	0	0	493	2,198	2,691	0.943	2,073	2,538
31-May	4.54	353	8	12	3	2	0	1	379	1,037	1,416	0.931	966	1,319
01-Jun	1.70	197	7	28	5	3	0	2	242	351	593	0.814	286	483
02-Jun	1.94	352	7	47	2	4	1	4	417	95	512	0.844	80	432
03-Jun	3.06	353	5	5	2	2	0	1	368	574	942	0.959	550	903
04-Jun	3.10	368	1	8	1	1	0	2	381	530	911	0.966	511	879
05-Jun	2.82	338	4	14	0	0	0	2	358	410	768	0.944	387	725
06-Jun	2.40	308	7	14	2	0	0	1	332	297	629	0.928	276	584
07-Jun	2.14	448	14	10	4	0	0	2	478	155	633	0.937	146	594
08-Jun	1.32	353	9	13	1	0	0	1	377		377	0.936		353
09-Jun	2.81	361	2	16	0	0	0	2	381	333	714	0.948	315	676
10-Jun	0.62	31	9	58	2	2	0	2	104		104	0.298		31
11-Jun	0.42	10	13	39	0	0	0	2	64		64	0.156		10
12-Jun	0.22	15	0	19	0	0	0	0	34		34	0.441		15
13-Jun	0.54	10	1	61	0	1	0	5	78		78	0.128		10
14-Jun	0.60	2	0	83	0	0	0	1	86		86	0.023		2
15-Jun	0.58	10	2	63	1	0	0	1	77		77	0.130		10
16-Jun	0.32	6	0	35	1	0	0	1	43		43	0.140		6
17-Jun	0.82	12	0	94	0	1	0	1	108		108	0.111		12
18-Jun	0.26	1	0	28	0	1	0	2	32		32	0.031		1
19-Jun	0.18	2	0	20	0	0	0	1	23		23	0.087		2
20-Jun	0.08	9	0	5	0	1	0	1	16		16	0.563		9
21-Jun	0.06	6	0	3	0	0	0	1	10		10	0.600		6
22-Jun	0.10	4	0	9	2	0	0	1	16		16	0.250		4
23-Jun	0.14	6	0	16	0	0	0	1	23		23	0.261		6
24-Jun	0.22	4	0	13	0	1	0	2	20		20	0.200		4
25-Jun	0.06	1	0	7	1	1	0	2	12		12	0.083		1
Total	64.27	8,859	110	902	182	48	17	97	10,215	9,750	19,965	0.908	9,273	18,132

^^ua^^0u Subsamples taken within two hours of the end of the day (2400 h) were included in the next day totals.
^^ub^^0u Coho salmon smolt were removed before trap catches were counted or weighed.

Table 4. Numbers of fish captured by trap 3 in the Kenai River, May 15 through June 25, 1990.

Date	Live Fish Weight (Kg)	Numbers of Fish in Trap Subsample[a]: Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho[b] Fry	Pink Fry	Other	Number of Fish Counted	Number of Fish Estimated	Total Number of Fish	Sockeye Smolt Proportion	Number of Sockeye Estimated	Total Number of Sockeye
15-May	0.02	2	0	2	7	0	1	2	14		14	0.143		2
16-May	0.06	0	0	5	14	0	0	3	22		22	0.000		0
17-May	0.12	8	1	3	15	1	6	5	39		39	0.205		8
18-May	0.56	111	4	11	10	5	5	3	149		149	0.745		111
19-May	0.62	102	0	26	1	2	0	7	138		138	0.739		102
20-May	5.48	616	0	0	2	1	0	0	619	214	833	0.995	213	829
21-May	5.58	852	0	7	2	0	0	0	861	601	1,462	0.990	595	1,447
22-May	2.72	810	2	53	10	1	0	16	892	267	1,159	0.908	242	1,052
23-May	0.8	165	0	23	13	8	0	2	211		211	0.782		165
24-May	0.48	100	0	17	5	23	1	3	149		149	0.671		100
25-May	1.8	590	0	7	1	0	0	1	599		599	0.985		590
26-May	31.28	451	1	6	2	2	4	1	467	8,592	9,059	0.966	8,297	8,748
27-May	11.48	658	0	7	2	0	0	2	669	3,055	3,724	0.984	3,005	3,663
28-May	2.91	504	0	16	1	1	0	3	525	218	743	0.960	209	713
29-May	2.64	320	0	6	5	0	0	5	336	97	433	0.952	92	412
30-May	9.72	694	1	20	0	1	0	1	717	3,120	3,837	0.968	3,020	3,714
31-May	11.74	464	0	5	0	0	0	1	470	4,291	4,761	0.987	4,236	4,700
01-Jun	4.08	443	7	19	3	1	0	5	478	497	975	0.927	460	903
02-Jun	4.18	326	5	22	2	0	0	1	356	676	1,032	0.916	619	945
03-Jun	13.56	420	0	6	0	0	1	0	427	3,534	3,961	0.984	3,476	3,896
04-Jun	21.5	459	0	5	0	0	0	2	466	5,176	5,642	0.985	5,098	5,557
05-Jun	28.4	413	1	11	2	0	0	0	427	7,568	7,995	0.967	7,320	7,733
06-Jun	18.5	454	2	11	2	0	0	1	470	4,302	4,772	0.966	4,155	4,609
07-Jun	13.74	328	1	3	0	0	0	0	332	3,275	3,607	0.988	3,235	3,563
08-Jun	6.76	296	9	7	0	0	0	0	312	1,867	2,179	0.949	1,771	2,067
09-Jun	11.22	340	1	6	1	1	0	0	349	2,741	3,090	0.974	2,670	3,010
10-Jun	1.2	159	9	79	3	0	0	4	254		254	0.626		159
11-Jun	1.34	94	3	121	2	0	0	1	221		221	0.425		94
12-Jun	0.84	123	0	40	0	0	0	2	165		165	0.745		123
13-Jun	0.96	34	1	94	0	0	0	5	134		134	0.254		34
14-Jun	1.68	14	0	175	1	0	0	8	198		198	0.071		14
15-Jun	1.66	54	0	166	1	2	0	5	228		228	0.237		54
16-Jun	1	40	0	93	0	3	0	1	137		137	0.292		40
17-Jun	2.36	46	0	245	0	2	0	4	297		297	0.155		46
18-Jun	0.54	10	0	55	1	1	0	4	71		71	0.141		10
19-Jun	0.38	14	0	36	0	0	0	1	51		51	0.275		14
20-Jun	0.46	66	0	15	1	0	0	1	83		83	0.795		66
21-Jun	0.64	100	0	27	0	0	0	1	128		128	0.781		100
22-Jun	1.04	56	0	49	0	0	0	0	105		105	0.533		56
23-Jun	0.28	21	0	23	0	0	0	1	45		45	0.467		21
24-Jun	0.9	8	0	83	1	0	0	1	93		93	0.086		8
25-Jun	0.48	49	0	25	0	0	0	1	75		75	0.653		49
Total	225.71	10,814	48	1,630	110	55	18	104	12,779	50,088	62,867	0.947	48,714	59,528

[a] Subsamples taken within two hours of the end of the day (2400 h) were included in the next day totals.
[b] Coho salmon smolt were removed before trap catches were counted or weighed.

Table 5. Numbers of fish captured by trap 4 in the Kenai River, May 15 through 25 June, 1990.

Date	Live Fish Weight (Kg)	Numbers of Fish in Trap Subsample[a]: Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho[b] Fry	Pink Fry	Other	Number of Fish Counted	Number of Fish Estimated	Total Number of Fish	Sockeye Smolt Proportion	Number of Sockeye Estimated	Total Number of Sockeye
15-May	0.04	3	0	4	6	0	1	0	14		14	0.214		3
16-May	0.32	0	0	6	2	0	0	10	18		18	0.000		0
17-May	0.22	15	0	9	12	0	10	11	57		57	0.263		15
18-May	0.98	151	0	28	11	2	4	11	207		207	0.729		151
19-May	2.44	310	0	53	4	3	1	20	391		391	0.793		310
20-May	2.48	1,292	0	6	4	0	0	0	1,302	208	1,510	0.992	206	1,498
21-May	3.64	539	1	20	3	1	0	3	567	227	794	0.951	215	754
22-May	1.58	423	0	37	1	1	2	14	478	122	600	0.885	108	531
23-May	0.82	71	0	31	1	9	0	7	119		119	0.597		71
24-May	0.46	87	0	16	1	2	0	2	108		108	0.806		87
25-May	1.16	375	0	5	1	0	0	3	384		384	0.977		375
26-May	17.00	713	1	6	0	0	1	5	726	4,025	4,751	0.982	3,953	4,666
27-May	5.92	598	0	9	1	0	0	1	609	1,220	1,829	0.982	1,198	1,796
28-May	2.68	442	0	9	1	1	0	5	458	194	652	0.965	187	629
29-May	3.88	327	0	16	0	0	0	4	347	378	725	0.942	357	684
30-May	7.78	560	1	20	0	1	0	0	582	2,333	2,915	0.962	2,244	2,804
31-May	8.69	398	1	3	0	0	0	0	402	2,935	3,337	0.990	2,906	3,304
01-Jun	6.28	395	4	27	0	5	3	6	440	1,354	1,794	0.898	1,216	1,611
02-Jun	4.98	318	1	26	0	0	2	2	349	771	1,120	0.911	703	1,021
03-Jun	11.10	487	0	8	0	0	0	2	497	2,508	3,005	0.980	2,457	2,944
04-Jun	14.66	400	0	10	0	0	0	3	413	2,920	3,333	0.969	2,828	3,228
05-Jun	17.50	337	0	18	1	2	0	0	358	5,028	5,386	0.941	4,733	5,070
06-Jun	13.10	335	0	17	0	0	0	1	353	3,033	3,386	0.949	2,879	3,214
07-Jun	13.34	456	1	7	1	0	0	0	465	3,326	3,791	0.981	3,262	3,718
08-Jun	6.08	314	0	10	0	0	0	0	324	1,515	1,839	0.969	1,468	1,782
09-Jun	9.90	359	0	8	0	0	0	0	367	2,075	2,442	0.978	2,029	2,388
10-Jun	1.36	148	2	91	0	0	0	8	249		249	0.594		148
11-Jun	1.62	108	0	122	0	0	0	9	239		239	0.452		108
12-Jun	1.24	103	0	62	1	0	0	8	174		174	0.592		103
13-Jun	1.00	40	0	89	1	0	0	8	138		138	0.290		40
14-Jun	2.38	24	0	247	2	0	0	8	281		281	0.085		24
15-Jun	1.88	54	1	178	0	0	0	1	234		234	0.231		54
16-Jun	1.24	96	0	102	0	0	0	5	203		203	0.473		96
17-Jun	2.56	45	0	272	0	0	0	4	321		321	0.140		45
18-Jun	0.60	2	0	67	0	0	0	2	71		71	0.028		2
19-Jun	0.44	14	0	46	1	0	0	1	62		62	0.226		14
20-Jun	0.56	102	0	15	0	0	0	2	119		119	0.857		102
21-Jun	0.60	51	0	35	0	1	0	3	90		90	0.567		51
22-Jun	0.52	39	0	36	0	0	0	4	79		79	0.494		39
23-Jun	0.22	10	0	24	0	0	0	0	34		34	0.294		10
24-Jun	0.76	7	0	75	0	0	0	3	85		85	0.082		7
25-Jun	0.20	2	0	19	0	0	0	0	21		21	0.095		2
Total	174.21	10,550	13	1,889	55	28	24	176	12,735	34,171	46,906	0.927	32,949	43,499

[a] Subsamples taken within two hours of the end of the day (2400 h) were included in the next day totals.
[b] Coho salmon smolt were removed before trap catches were counted or weighed.

Table 6. Trap efficiencies by period and trap for the Kenai River sockeye salmon smolt project in 1990.

Trap	Time Period[a]	Fish Dyed[b]	Dyed Fish Recaptured	Total Examined	Trap Efficiency[c]	Marked Unmarked[d]
1	1	2,793	5	975	0.18%	0.51%
2	1	2,793	4	1,361	0.14%	0.29%
3	1	2,793	7	1,377	0.25%	0.51%
4	1	2,793	5	630	0.18%	0.79%
Subtotal	1	2,793	21	4,343	0.75%	0.48%
1	2	2,769	9	1,007	0.33%	0.89%
2	2	2,769	11	2,336	0.40%	0.47%
3	2	2,769	13	4,423	0.47%	0.29%
4	2	2,769	9	2,646	0.33%	0.34%
Subtotal	2	2,769	42	10,412	1.52%	0.40%
1	3	2,801	5	802	0.18%	0.62%
2	3	2,801	10	1,830	0.36%	0.55%
3	3	2,801	7	5,797	0.25%	0.12%
4	3	2,801	19	5,665	0.68%	0.34%
Subtotal	3	2,801	41	14,094	1.46%	0.29%
1	4	2,839	3	1,009	0.11%	0.30%
2	4	2,839	4	1,190	0.14%	0.34%
3	4	2,839	12	8,286	0.42%	0.14%
4	4	2,839	7	6,051	0.25%	0.12%
Subtotal	4	2,839	26	16,536	0.92%	0.16%
Total		11,202	130	45,385	1.16%	0.29%

[a] Time periods were: (1) May 15-23; (2) May 24-28; (3) May 29-June 2; (4) June 3-25.

[b] Dye dates: (1) May 21; (2) May 26; (3) May 31; (4) June 5.

[c] Trap efficiency = Number dyed / Number of dyed fish recaptured.

[d] Marked/Unmarked = Number recaptured/(Total examined- number recaptured).

Table 7. Estimated daily sockeye salmon smolt outmigration from the Kenai River, 15 May through 25 June, 1990. Population estimates were based on the observed trap efficiency for period 1 and a pooled trap efficiency for periods 2,3, and 4.

Date	Estimated Trap Catch of Sockeye	Estimate of Sockeye Smolt Migration[a]				
		Daily	Cumulative	Age-1.0	Age-2.0	Age-3.0
15-May	8	1,114	1,114	355	759	0
16-May	5	696	1,811	222	474	0
17-May	34	4,736	6,546	1,511	3,225	0
18-May	376	52,371	58,918	16,706	35,665	0
19-May	507	70,618	129,536	22,527	48,091	0
20-May	3,159	439,977	569,513	140,353	299,625	0
21-May	4,760	662,945	1,232,459	211,480	451,466	0
22-May	2,690	374,705	1,607,164	119,531	255,174	0
23-May	414	57,664	1,664,828	18,395	39,269	0
24-May	282	21,952	1,686,781	5,005	16,837	110
25-May	1,645	128,056	1,814,836	29,197	98,219	640
26-May	16,411	1,277,512	3,092,348	291,273	979,851	6,388
27-May	8,057	627,188	3,719,536	142,999	481,053	3,136
28-May	1,903	148,114	3,867,649	33,770	113,603	741
29-May	1,745	135,823	4,003,472	61,175	74,295	353
30-May	9,578	745,610	4,749,083	335,823	407,849	1,939
31-May	9,878	768,959	5,518,042	346,339	420,621	1,999
01-Jun	3,305	257,260	5,775,302	115,870	140,721	669
02-Jun	2,587	201,379	5,976,680	90,701	110,154	524
03-Jun	8,037	625,674	6,602,354	396,677	228,997	0
04-Jun	10,182	792,628	7,394,982	502,526	290,102	0
05-Jun	14,143	1,100,936	8,495,918	697,993	402,942	0
06-Jun	8,931	695,262	9,191,180	440,796	254,466	0
07-Jun	8,337	649,023	9,840,203	411,481	237,543	0
08-Jun	4,430	344,872	10,185,075	218,649	126,223	0
09-Jun	6,336	493,197	10,678,272	312,687	180,510	0
10-Jun	429	33,396	10,711,668	21,173	12,223	0
11-Jun	261	20,318	10,731,985	12,881	7,436	0
12-Jun	248	19,306	10,751,291	12,240	7,066	0
13-Jun	93	7,240	10,758,530	4,590	2,650	0
14-Jun	51	3,970	10,762,501	2,517	1,453	0
15-Jun	131	10,198	10,772,698	6,465	3,732	0
16-Jun	165	12,844	10,785,543	8,143	4,701	0
17-Jun	123	9,575	10,795,118	6,071	3,504	0
18-Jun	17	1,323	10,796,441	839	484	0
19-Jun	36	2,802	10,799,244	1,777	1,026	0
20-Jun	186	14,479	10,813,723	9,180	5,299	0
21-Jun	168	13,078	10,826,801	8,291	4,787	0
22-Jun	108	8,407	10,835,208	5,330	3,077	0
23-Jun	37	2,880	10,838,088	1,826	1,054	0
24-Jun	20	1,557	10,839,645	987	570	0
25-Jun	56	4,359	10,844,005	2,764	1,596	0
Total	129,868	10,844,005		5,069,115	5,758,392	16,498

[a] Total estimated migration: 10,844,005; Variance (9.553E+10); Lower CI (8,442,035); Upper CI (13,245,974).

Table 8. Morphological information collected from sockeye salmon smolt captured in the Kenai River, 1990.

Period Dates n No. Smolt		1 5/15-23 756 1,664,828	2 5/24-28 423 2,202,821	3 5/29-6/2 423 2,109,031	4 6/3-25 1,815 4,867,324	Total 5/15-6/25 3,417 10,844,004
Age-1.0	number	241	97	191	1,150	1,679
	%	31.9	22.9	45.2	63.4	
Length	mean=	64.8	63.4	61.2	69.6	67.6
	range=					47-138
	Var=	30.1	24.7	25.3	53.5	54.6
	SD=	5.5	5.0	5.0	7.3	7.4
Weight	mean=	2.23	2.03	1.86	3.11	2.78
	range=					0.8-23.8
	Var=	0.34	0.27	0.28	2.17	1.83
	SD=	0.59	0.52	0.53	1.47	1.35
Age-2.0	number	515	326	232	665	1,738
	%	68.1	77.1	54.8	36.6	
Length	mean=	73.7	74.2	73.9	75.1	74.4
	range=					60-123
	Var=	21.0	35.3	42.7	28.2	29.7
	SD=	4.6	5.9	6.5	5.3	5.4
Weight	mean=	3.19	3.21	3.24	3.67	3.39
	range=					1.2-13.4
	Var=	0.55	0.68	1.12	0.71	0.76
	SD=	0.74	0.82	1.06	0.84	0.87

Table 9. Numbers of juvenile fish caught with inclined plane traps in the Kenai River, 1991. Pink salmon were not included because daily catches were periodically subsampled for this species.

Estimated Trap Catch[a]

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Other	Total
1	1,758	62	451	131	93	27	177	2,699
2	3,291	30	918	97	224	31	161	4,752
3	10,540	23	1,526	62	775	10	200	13,136
4	10,239	17	1,697	57	832	9	182	13,033
Total	25,828	132	4,592	347	1,924	77	720	33,620

Percent of Individual Trap Catch

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Other	Total
1	65.1	2.3	16.7	4.9	3.4	1.0	6.6	100.0
2	69.3	0.6	19.3	2.0	4.7	0.7	3.4	100.0
3	80.2	0.2	11.6	0.5	5.9	0.1	1.5	100.0
4	78.6	0.1	13.0	0.4	6.4	0.1	1.4	100.0

Percent of Total Catch

Trap No.	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Other	Total
1	5.2	0.2	1.3	0.4	0.3	0.1	0.5	8.0
2	9.8	0.1	2.7	0.3	0.7	0.1	0.5	14.1
3	31.4	0.1	4.5	0.2	2.3	0.0	0.6	39.1
4	30.5	0.1	5.0	0.2	2.5	0.0	0.5	38.8

[a] Does not include 2,271 sockeye smolt caught 26 June which were not counted by trap to minimize handling mortality prior to dyeing.

Table 10. Numbers of fish captured by trap 1 in the Kenai River, 16 May through 10 July, 1991.

Date	Sockeye		Chinook		Coho			
	Smolt	Fry	Smolt	Fry	Smolt	Fry	Other	Total
16-May	0	0	0	1	0	0	1	2
17-May	0	3	2	5	0	0	3	13
18-May	0	1	0	4	0	0	2	7
19-May	0	1	0	4	1	0	5	11
20-May	1	3	2	4	0	0	0	10
21-May	0	4	2	4	1	0	8	19
22-May	2	2	0	3	1	0	3	11
23-May	23	1	1	5	0	0	6	36
24-May	20	3	1	8	1	0	6	39
25-May	25	0	1	5	4	0	4	39
26-May	19	8	0	9	0	2	9	47
27-May	13	0	8	5	1	7	6	40
28-May	17	0	5	9	0	0	6	37
29-May	42	1	2	0	3	0	5	53
30-May	73	1	10	2	1	1	3	91
31-May	76	1	3	0	3	0	3	86
01-Jun	34	0	2	4	2	0	1	43
02-Jun	51	1	0	4	2	0	3	61
03-Jun	39	0	1	1	5	0	3	49
04-Jun	51	0	1	1	1	0	1	55
05-Jun	31	0	0	1	1	0	1	34
06-Jun	28	5	0	1	2	1	2	39
07-Jun	30	3	1	1	1	0	8	44
08-Jun	43	0	0	2	2	0	3	50
09-Jun	24	2	0	1	4	0	4	35
10-Jun	47	4	2	1	0	0	2	56
11-Jun	47	0	1	0	0	0	3	51
12-Jun	60	0	1	1	2	0	4	68
13-Jun	94	0	2	0	2	0	5	103
14-Jun	71	5	0	1	1	0	3	81
15-Jun	59	0	4	5	6	0	2	76
16-Jun	19	0	8	1	1	0	2	31
17-Jun	20	0	9	2	1	0	2	34
18-Jun	0	0	0	0	0	0	0	0
19-Jun	42	1	9	3	6	5	3	69
20-Jun	75	0	1	0	3	1	0	80
21-Jun	127	0	8	0	8	2	1	146
22-Jun	145	2	16	1	3	1	2	170
23-Jun	56	4	36	1	0	1	5	103
24-Jun	51	0	24	1	1	1	4	82
25-Jun	3	0	24	0	3	4	3	37
26-Jun	7	0	21	0	0	0	0	28
27-Jun	39	0	18	2	4	1	3	67
28-Jun	25	0	60	1	3	0	5	94
29-Jun	19	0	15	2	0	0	3	39
30-Jun	12	0	3	6	2	0	3	26
01-Jul	31	3	34	5	4	0	7	84
02-Jul	2	0	1	0	2	0	3	8
03-Jul	13	0	7	0	1	0	2	23
04-Jul	37	0	28	2	2	0	9	78
05-Jul	1	0	0	0	0	0	0	1
06-Jul	5	3	32	0	0	0	3	43
07-Jul	1	0	19	6	0	0	1	27
08-Jul	1	0	11	1	0	0	0	13
09-Jul	7	0	14	5	0	0	1	27
10-Jul	0	0	1	0	2	0	0	3
Total[a]	1,758	62	451	131	93	27	177	2,699

[a] Total does not include fish caught on June 26 which were not counted by trap to minimize handling mortality prior to dyeing.

Table 11. Numbers of fish captured by trap 2 in the Kenai River, 16 May through 11 July, 1991.

	Sockey		Chinook		Coho			
Date	Smolt	Fry	Smolt	Fry	Smolt	Fry	Other	Total
16-May	1	3	0	4	0	2	1	11
17-May	1	1	0	0	0	0	2	4
18-May	0	1	0	4	0	0	3	8
19-May	0	1	0	2	0	0	3	6
20-May	0	1	0	3	0	0	5	9
21-May	2	1	2	2	0	1	4	12
22-May	1	2	0	7	0	0	3	13
23-May	42	3	0	7	1	0	1	54
24-May	35	0	0	8	1	0	5	49
25-May	19	0	2	7	0	0	3	31
26-May	82	0	2	3	0	0	4	91
27-May	20	0	2	9	1	3	2	37
28-May	18	0	0	3	1	0	7	29
29-May	42	0	0	3	1	0	3	49
30-May	66	0	2	0	0	0	3	71
31-May	84	5	1	0	2	0	5	97
01-Jun	41	0	1	5	8	1	0	56
02-Jun	117	1	0	0	3	0	2	123
03-Jun	83	0	0	2	1	0	2	88
04-Jun	60	0	2	1	3	0	3	69
05-Jun	37	0	2	0	3	0	1	43
06-Jun	29	2	1	1	3	1	4	41
07-Jun	73	0	3	1	5	0	3	85
08-Jun	79	0	0	0	6	0	1	86
09-Jun	57	0	1	0	4	0	2	64
10-Jun	87	0	2	1	4	0	0	94
11-Jun	50	0	4	0	4	0	0	58
12-Jun	100	0	3	0	7	0	0	110
13-Jun	189	1	1	0	6	0	2	199
14-Jun	112	0	1	0	7	0	2	122
15-Jun	100	0	5	1	13	4	3	126
16-Jun	52	0	8	1	4	0	7	72
17-Jun	30	0	16	0	3	0	8	57
18-Jun	2	0	0	0	0	0	1	3
19-Jun	86	1	26	5	19	11	6	154
20-Jun	227	0	9	0	16	3	2	257
21-Jun	295	1	27	2	33	0	9	367
22-Jun	346	1	40	0	4	1	6	398
23-Jun	156	2	113	0	9	0	3	283
24-Jun	91	0	173	0	6	3	2	275
25-Jun	19	0	70	0	7	0	2	98
26-Jun	17	0	9	0	2	0	2	30
27-Jun	25	1	9	0	4	0	3	42
28-Jun	24	0	43	0	6	0	1	74
29-Jun	27	0	15	0	6	1	3	52
30-Jun	24	0	7	0	1	0	2	34
01-Jul	83	1	58	3	3	0	6	154
02-Jul	3	0	6	0	3	0	2	14
03-Jul	27	0	11	2	1	0	3	44
04-Jul	106	1	83	2	6	0	7	205
05-Jul	1	0	1	0	0	0	0	2
06-Jul	7	0	61	0	0	0	2	70
07-Jul	7	0	26	4	0	0	1	38
08-Jul	3	0	8	1	0	0	2	14
09-Jul	4	0	11	0	3	0	0	18
10-Jul	2	0	26	2	4	0	1	35
Total[a]	3,291	30	893	96	224	31	160	4,725

[a] Total does not include fish caught on June 26 which were not counted by trap to minimize handling mortality prior to dyeing.

Table 12. Numbers of fish captured by trap 3 in the Kenai River, 16 May through 15 July, 1991.

	Sockey		Chinook		Coho			
Date	Smolt	Fry	Smolt	Fry	Smolt	Fry	Other	Total
16-May	1	4	1	4	1	4	7	22
17-May	0	1	1	3	0	0	5	10
18-May	0	0	1	5	0	0	2	8
19-May	1	1	2	2	0	0	4	10
20-May	4	1	4	4	0	0	3	16
21-May	11	1	0	2	0	0	2	16
22-May	27	2	0	3	1	0	3	36
23-May	356	4	0	1	0	0	5	366
24-May	197	0	1	2	1	1	7	209
25-May	166	0	3	2	2	0	5	178
26-May	349	0	3	0	1	0	4	357
27-May	168	1	4	2	0	1	6	182
28-May	59	0	2	0	3	0	10	74
29-May	205	0	2	1	5	0	5	218
30-May	220	0	3	0	5	0	2	230
31-May	211	1	0	1	10	0	1	224
01-Jun	127	0	0	0	36	0	3	166
02-Jun	424	0	0	0	16	0	1	441
03-Jun	206	0	6	0	12	0	2	226
04-Jun	181	1	3	1	26	0	5	217
05-Jun	226	0	0	1	20	0	3	250
06-Jun	93	0	1	0	23	0	1	118
07-Jun	267	0	0	0	16	0	2	285
08-Jun	234	0	0	0	31	0	2	267
09-Jun	205	0	4	0	20	0	1	230
10-Jun	311	0	4	0	5	0	1	321
11-Jun	173	1	2	1	15	0	1	193
12-Jun	308	0	2	0	8	0	2	320
13-Jun	524	1	5	0	22	0	3	555
14-Jun	403	0	3	0	44	0	7	457
15-Jun	277	0	8	1	25	1	4	316
16-Jun	69	0	7	1	12	0	3	92
17-Jun	72	0	15	0	18	0	10	115
18-Jun	11	0	1	0	5	0	2	19
19-Jun	255	0	64	0	75	1	8	403
20-Jun	1,158	0	25	0	23	0	2	1,208
21-Jun	771	0	78	0	80	1	9	939
22-Jun	863	0	90	2	20	1	3	979
23-Jun	417	1	197	1	33	0	9	658
24-Jun	171	0	253	2	29	0	6	461
25-Jun	52	0	62	0	20	0	3	137
26-Jun	108	1	15	0	11	0	0	135
27-Jun	58	1	29	0	15	0	3	106
28-Jun	60	0	73	2	11	0	6	152
29-Jun	51	0	26	0	14	0	1	92
30-Jun	31	0	15	3	15	0	5	69
01-Jul	159	1	137	0	15	0	6	318
02-Jul	9	0	6	0	3	0	5	23
03-Jul	80	0	41	2	5	0	0	128
04-Jul	143	0	67	3	5	0	3	221
05-Jul	5	0	0	0	5	0	2	12
06-Jul	14	0	89	0	2	0	3	108
07-Jul	12	0	48	2	2	0	0	64
08-Jul	16	0	35	2	1	0	0	54
09-Jul	17	0	28	0	1	0	1	47
10-Jul	4	0	60	6	7	0	1	78
Total[a]	10,540	23	1,526	62	775	10	200	13,136

[a] Total does not include fish caught on June 26 which were not counted by trap to minimize handling mortality prior to dyeing.

Table 13. Numbers of fish captured by trap 4 in the Kenai River, 16 May through 10 July, 1991.

	Sockey		Chinook		Coho			
Date	Smolt	Fry	Smolt	Fry	Smolt	Fry	Other	Total
16-May	2	1	2	3	0	0	2	10
17-May	3	3	0	4	0	0	2	12
18-May	1	0	2	3	0	0	8	14
19-May	0	2	0	2	0	0	7	11
20-May	3	2	4	1	0	0	2	12
21-May	0	2	0	2	0	0	3	7
22-May	6	1	0	1	0	0	1	9
23-May	259	0	0	5	0	2	4	270
24-May	137	0	2	1	0	0	8	148
25-May	109	0	1	5	3	0	8	126
26-May	172	0	2	2	0	0	5	181
27-May	105	0	2	1	4	2	11	125
28-May	57	0	2	3	5	0	5	72
29-May	125	0	1	0	6	0	5	137
30-May	143	0	2	1	3	0	3	152
31-May	123	1	4	0	10	0	5	143
01-Jun	82	0	3	0	12	0	3	100
02-Jun	312	0	1	0	30	0	4	347
03-Jun	131	0	2	0	12	0	3	148
04-Jun	122	3	4	1	25	0	3	158
05-Jun	146	0	2	0	14	0	1	163
06-Jun	112	0	0	0	19	0	0	131
07-Jun	209	0	3	0	9	0	0	221
08-Jun	277	0	2	0	22	0	0	301
09-Jun	206	0	2	0	21	0	2	231
10-Jun	254	0	0	0	10	0	2	266
11-Jun	255	0	2	2	23	0	1	283
12-Jun	357	0	4	1	20	0	3	385
13-Jun	489	0	7	2	33	0	2	533
14-Jun	348	0	4	0	40	1	3	396
15-Jun	218	0	15	0	19	1	3	256
16-Jun	139	0	14	0	18	0	4	175
17-Jun	60	0	2	0	35	0	13	110
18-Jun	11	0	1	0	1	0	0	13
19-Jun	275	0	83	2	36	1	4	401
20-Jun	792	0	20	1	37	1	2	853
21-Jun	778	0	65	2	67	1	7	920
22-Jun	1,092	1	83	0	20	0	3	1,199
23-Jun	294	0	184	0	28	0	6	512
24-Jun	94	0	198	1	20	0	3	316
25-Jun	303	0	86	0	45	0	2	436
26-Jun	495	0	25	0	16	0	0	536
27-Jun	141	0	46	0	34	0	1	222
28-Jun	211	0	141	0	21	0	4	377
29-Jun	116	0	57	0	37	0	5	215
30-Jun	55	0	36	1	12	0	4	108
01-Jul	244	0	163	1	25	0	5	438
02-Jul	5	1	1	0	2	0	2	11
03-Jul	119	0	55	1	10	0	0	185
04-Jul	208	0	149	0	23	0	4	384
05-Jul	3	0	1	0	0	0		4
06-Jul	6	0	76	2	0	0	2	86
07-Jul	10	0	56	5	2	0	2	75
08-Jul	20	0	71	1	1	0		93
09-Jul	5	0	9	0	1	0	0	15
10-Jul	0	0	0	0	1	0		1
Total[a]	10,239	17	1,697	57	832	9	182	13,033

[a] Total does not include fish caught on June 26 which were not counted by trap to minimize handling mortality prior to dyeing.

Table 14. Trap efficiency for the Kenai River sockeye salmon smolt project in 1991.

Trap	Fish Dyed[a]	Dyed Fish Recapture	Total Examined	Trap Efficiency[b]	Marked/ Unmarked[c]
1	1,923	5	100	0.26%	5.00%
2	1,923	4	100	0.21%	4.00%
3	1,923	7	1,000	0.36%	0.70%
4	1,923	5	800	0.26%	0.63%
Total	1,923	19	2,000	0.99%	0.95%

[a] Fish were dyed on 26-June.
[b] Trap efficiency = Number dyed / Number of dyed fish recaptured.
[c] Marked/Unmarked = Number recaptured/(Total examined- number recaptured).

Table 15. Estimated daily sockeye salmon smolt migration from the Kenai River, 16 May through 10 July, 1991.

Date	Sockeye Catch in Traps	Estimate of Sockeye Smolt Migration				
		Daily	Cumulative	Age-1.0	Age-2.0	Age-3.0
16-May	4	426	426	48	377	1
17-May	4	426	852	48	377	1
18-May	1	106	958	12	94	0
19-May	1	106	1,065	12	94	0
20-May	8	852	1,917	96	754	2
21-May	13	1,384	3,301	156	1,225	3
22-May	36	3,833	7,134	433	3,391	9
23-May	680	72,410	79,544	8,178	64,061	170
24-May	389	41,423	120,967	4,678	36,647	97
25-May	319	33,969	154,935	3,836	30,052	80
26-May	622	66,234	221,169	7,480	58,597	156
27-May	306	32,584	253,753	3,680	28,828	77
28-May	151	16,079	269,832	10,991	5,089	0
29-May	414	44,085	313,917	30,133	13,952	0
30-May	502	53,455	367,372	36,538	16,917	0
31-May	494	52,603	419,976	35,956	16,647	0
01-Jun	284	30,242	450,218	20,671	9,571	0
02-Jun	904	96,262	546,480	65,798	30,464	0
03-Jun	459	48,877	595,356	33,409	15,468	0
04-Jun	414	44,085	639,441	30,133	13,952	0
05-Jun	440	46,853	686,294	32,026	14,828	0
06-Jun	262	27,899	714,193	19,070	8,829	0
07-Jun	579	61,655	775,848	57,012	4,642	0
08-Jun	633	67,405	843,253	62,330	5,075	0
09-Jun	492	52,391	895,643	48,446	3,945	0
10-Jun	699	74,433	970,076	68,828	5,604	0
11-Jun	525	55,905	1,025,981	51,695	4,209	0
12-Jun	825	87,850	1,113,831	84,749	3,101	0
13-Jun	1,296	138,004	1,251,835	133,134	4,871	0
14-Jun	934	99,457	1,351,292	95,947	3,510	0
15-Jun	654	69,641	1,420,933	67,183	2,458	0
16-Jun	279	29,709	1,450,642	28,661	1,049	0
17-Jun	182	19,380	1,470,022	18,696	684	0
18-Jun	24	2,556	1,472,578	2,520	36	0
19-Jun	658	70,067	1,542,645	69,078	989	0
20-Jun	2,252	239,804	1,782,448	236,418	3,385	0
21-Jun	1,971	209,881	1,992,330	206,918	2,963	0
22-Jun	2,446	260,462	2,252,792	260,243	219	0
23-Jun	923	98,285	2,351,077	98,203	83	0
24-Jun	407	43,339	2,394,416	43,303	36	0
25-Jun	377	40,145	2,434,561	40,111	34	0
26-Jun	2,972	316,473	2,751,034	316,207	266	0
27-Jun	263	28,005	2,779,039	27,982	24	0
28-Jun	320	34,075	2,813,115	34,046	29	0
29-Jun	213	22,681	2,835,796	22,662	19	0
30-Jun	122	12,991	2,848,787	12,980	11	0
01-Jul	517	55,053	2,903,840	55,006	46	0
02-Jul	19	2,023	2,905,863	2,022	2	0
03-Jul	239	25,450	2,931,313	25,428	21	0
04-Jul	494	52,603	2,983,916	52,559	44	0
05-Jul	10	1,065	2,984,981	1,064	1	0
06-Jul	32	3,408	2,988,388	3,405	3	0
07-Jul	30	3,195	2,991,583	3,192	3	0
08-Jul	40	4,259	2,995,842	4,256	4	0
09-Jul	33	3,514	2,999,356	3,511	3	0
10-Jul	6	639	2,999,995	638	1	0
Total[a,b]	8,173	2,999,995		2,581,817	417,581	597

[a] Total fish counted is greated than the sum of individual trap catches because the catch on June 26 was not counted by trap.

[b] Total migration: 2,999,995; Variance (1.903E+10); Lower CI (1,702,269); Upper CI (4,297,931).

Table 16. Morphological information collected from sockeye salmon smolt captured in the Kenai River, 1991.

Dates n No. smolt		5/16-27 425 253,753	5/28-6/6 850 460,440	6/7-11 425 311,788	6/12-17 425 444,041	6/18-21 425 522,308	6/22-7/15 1,190 1,007,665	Total 3,740 2,999,995
Age-1.0	n	48	581	393	410	419	1,189	3,040
	%	11.3	68.4	92.5	96.5	98.6	99.9	
Length	Mean	72.8	65.7	64.3	65.3	65	66.1	65.6
	Range							49-110
	Var.	90.7	42.9	16.4	15.6	20.9	14.6	23.6
	SD	9.5	6.6	4.1	4.0	4.6	3.8	4.9
Weight	Mean	3.43	2.41	2.37	2.63	2.80	2.86	2.68
	Range							1.2-5.9
	Var.	2.11	0.66	0.22	0.31	0.40	0.31	0.45
	SD	1.45	0.81	0.46	0.56	0.63	0.56	0.67
Age-2.0	n	376	268	32	15	0	0	700
	%	88.5	31.5	7.5	3.5	0.0	0.0	
Length	Mean	80.6	79.2	77.6	76.2			79.7
	Range							68-110
	Var.	30.5	36.7	24.1	18.6			32.3
	SD	5.5	6.1	4.9	4.3			5.7
Weight	Mean	4.26	4.14	4.09	4.03			4.20
	Range							2.4-10.7
	Var.	1.15	1.16	0.83	0.27			
	SD	1.07	1.07	0.91	0.52			1.04

Table 17. Timing of the sockeye salmon smolt migration River, 1989 through 1991.

Year	Age	Mean Date	Variance
1989[a]	1.0	05 June	40.4
	Total	05 June	40.4
1990	1.0	01 June	34.9
	2.0	29 May	37.8
	Total	31 May	39.7
1991	1.0	17 June	82.8
	2.0	29 May	44.5
	Total	14 June	120.4

[a] The 1989 seaward migration was 99.3% age-1.0.

Table 18. Sockeye salmon adult escapement and smolt production in the Kenai River, 1987 through 1990.

Brood Year	Total Spawning Escapement	Number of Smolt Produced			
		Age-1.0	Age-2.0	Total	Smolt per Spawner
1987	1,408,000	23,800,000	5,800,000	29,600,000	21.0
1988	910,000	5,100,000	400,000	5,500,000	6.0
1989	1,379,000	2,600,000		2,600,000	1.9
1990	548,000				

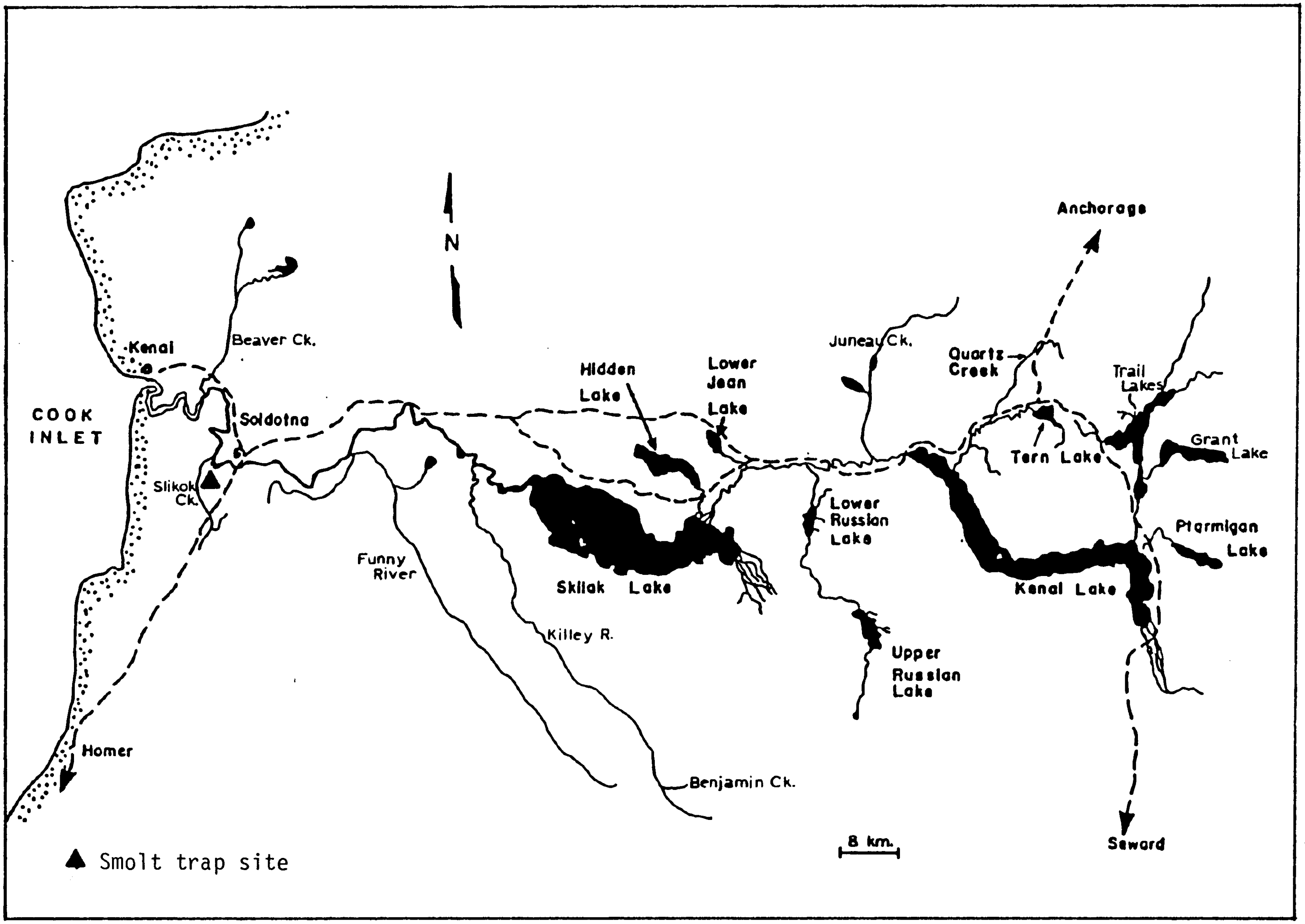

Figure 1. Kenai River drainage and major sockeye salmon rearing lakes.

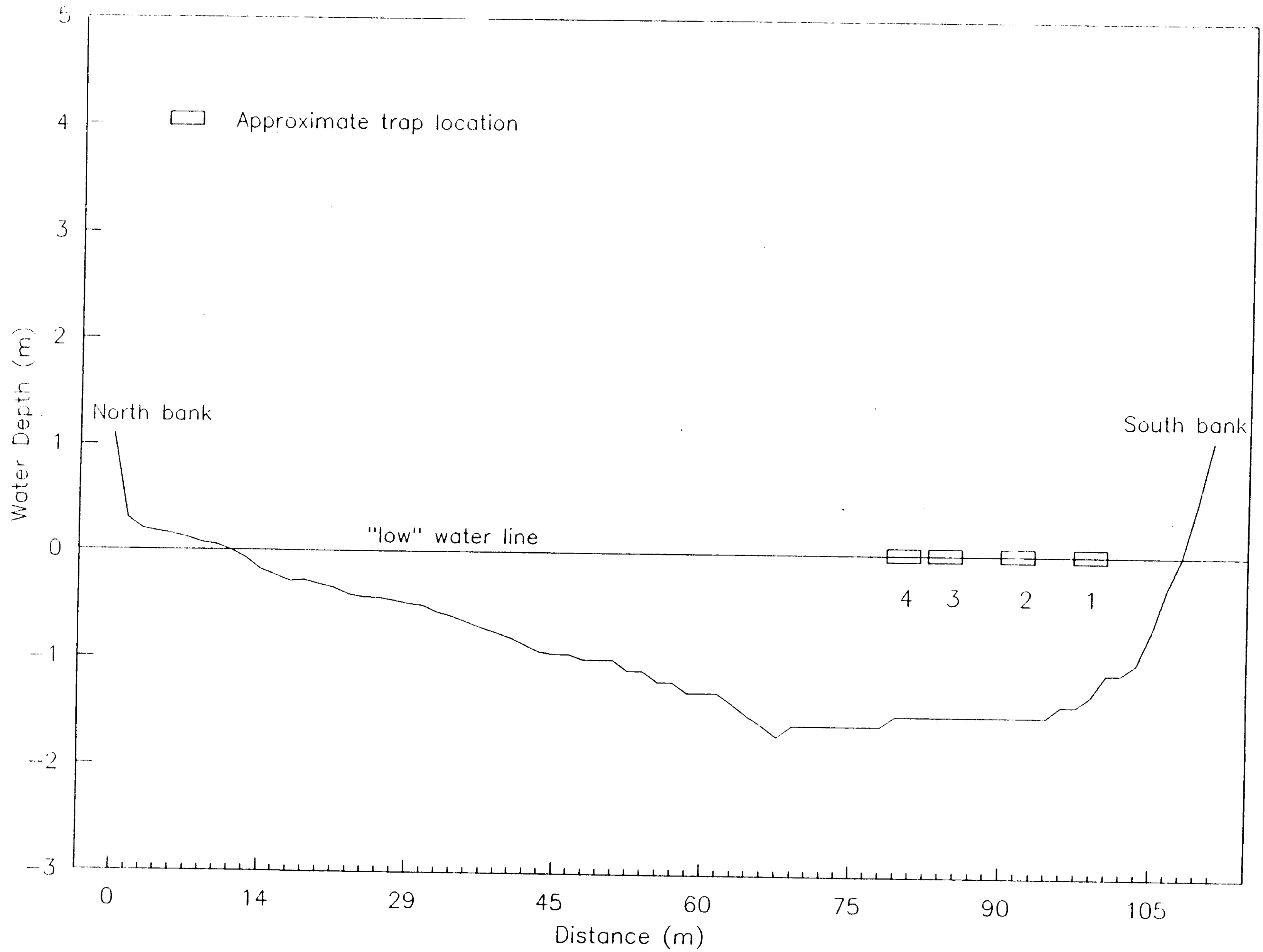

Figure 2. Trap placement relative to shore and river bottom at the Kenai River sockeye salmon smolt enumeration site in 1990 and 1991.

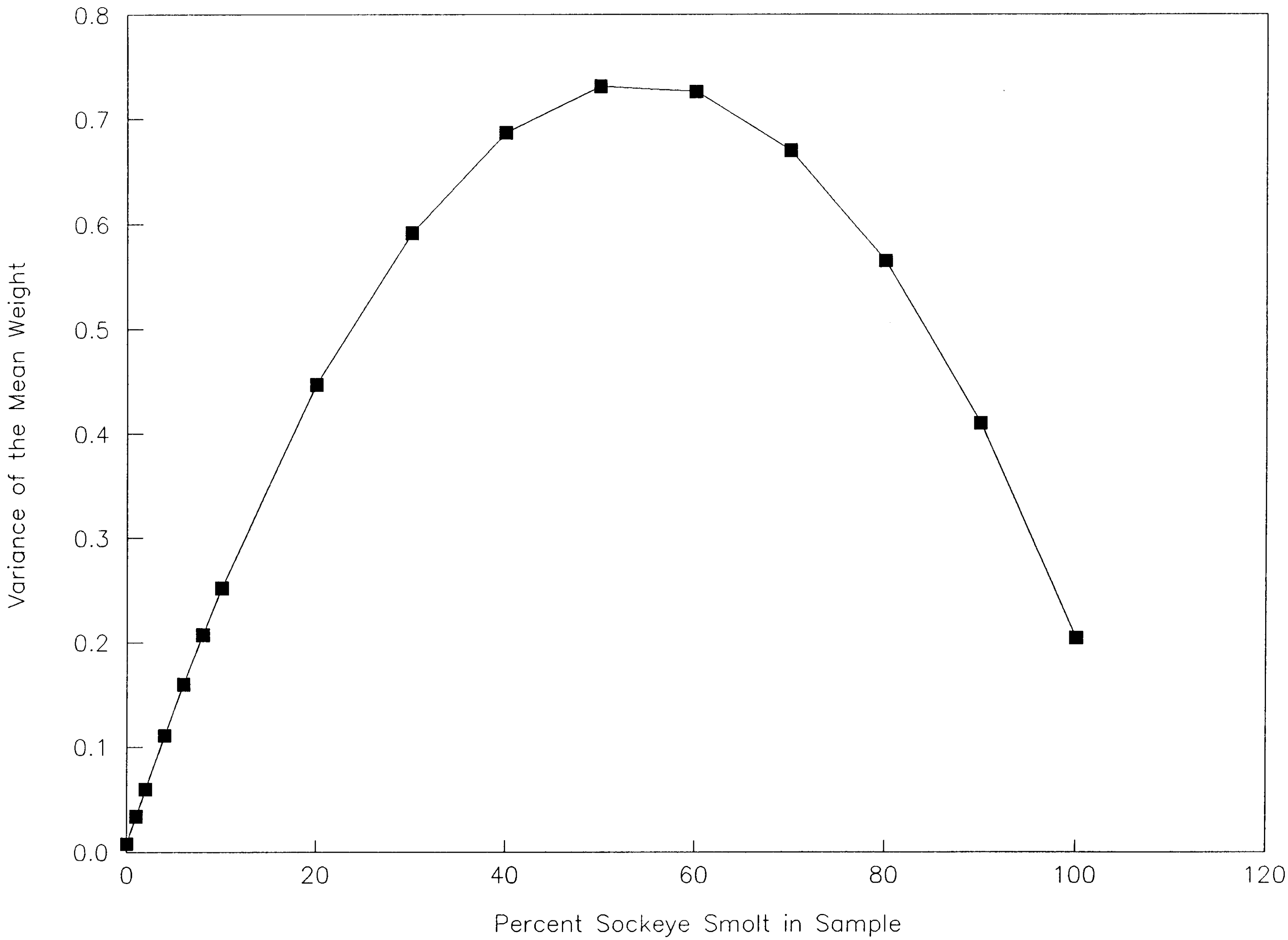

Figure 3. An estimated relationship between the variance of the mean weight of fish and percent sockeye smolt in smolt traps in the Kenai River.

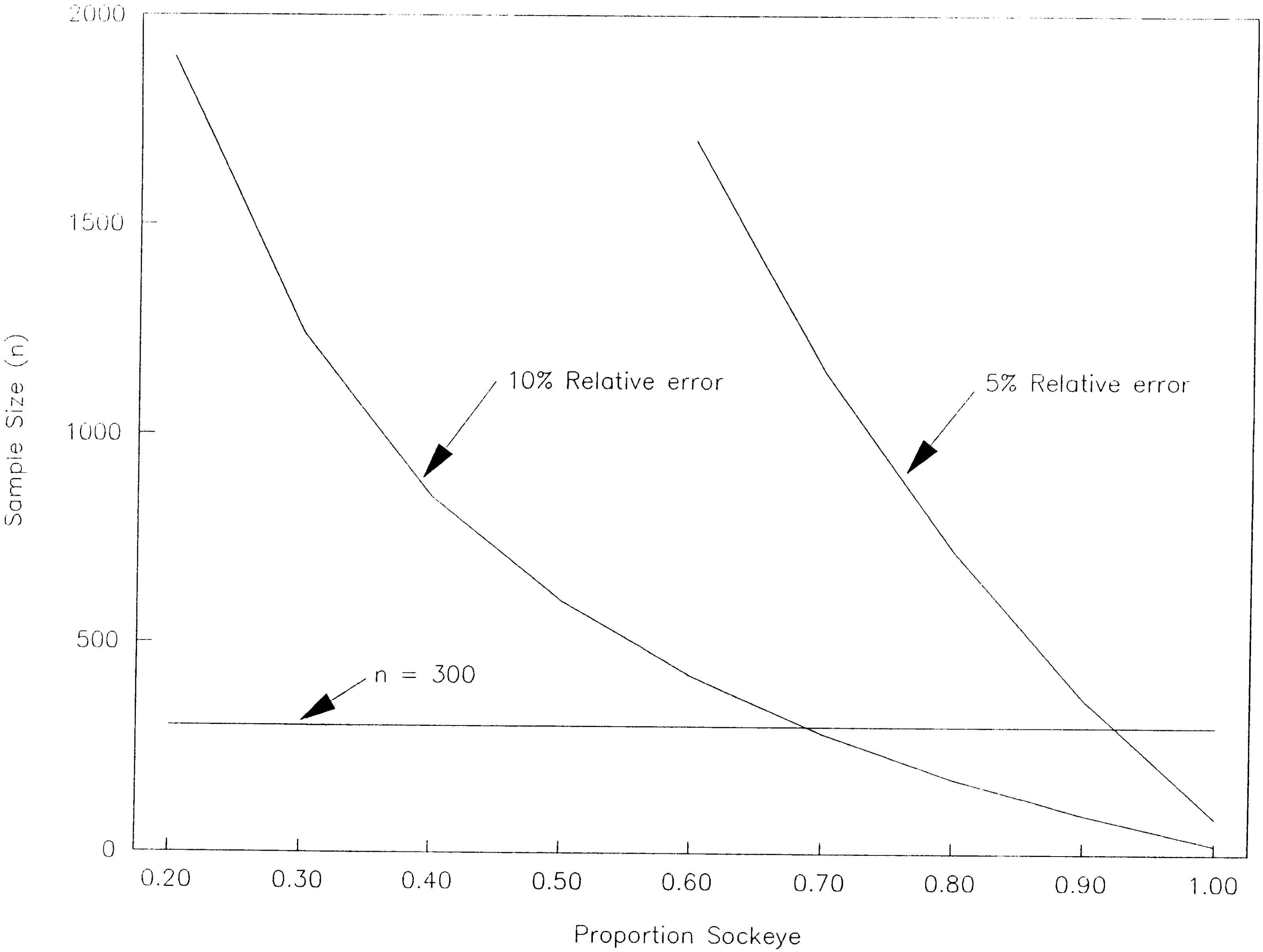

Figure 4. Number of fish (n) of all species needed in a subsample to estimate total trap catch of Kenai River sockeye smolt with a 5% or 10% relative error.

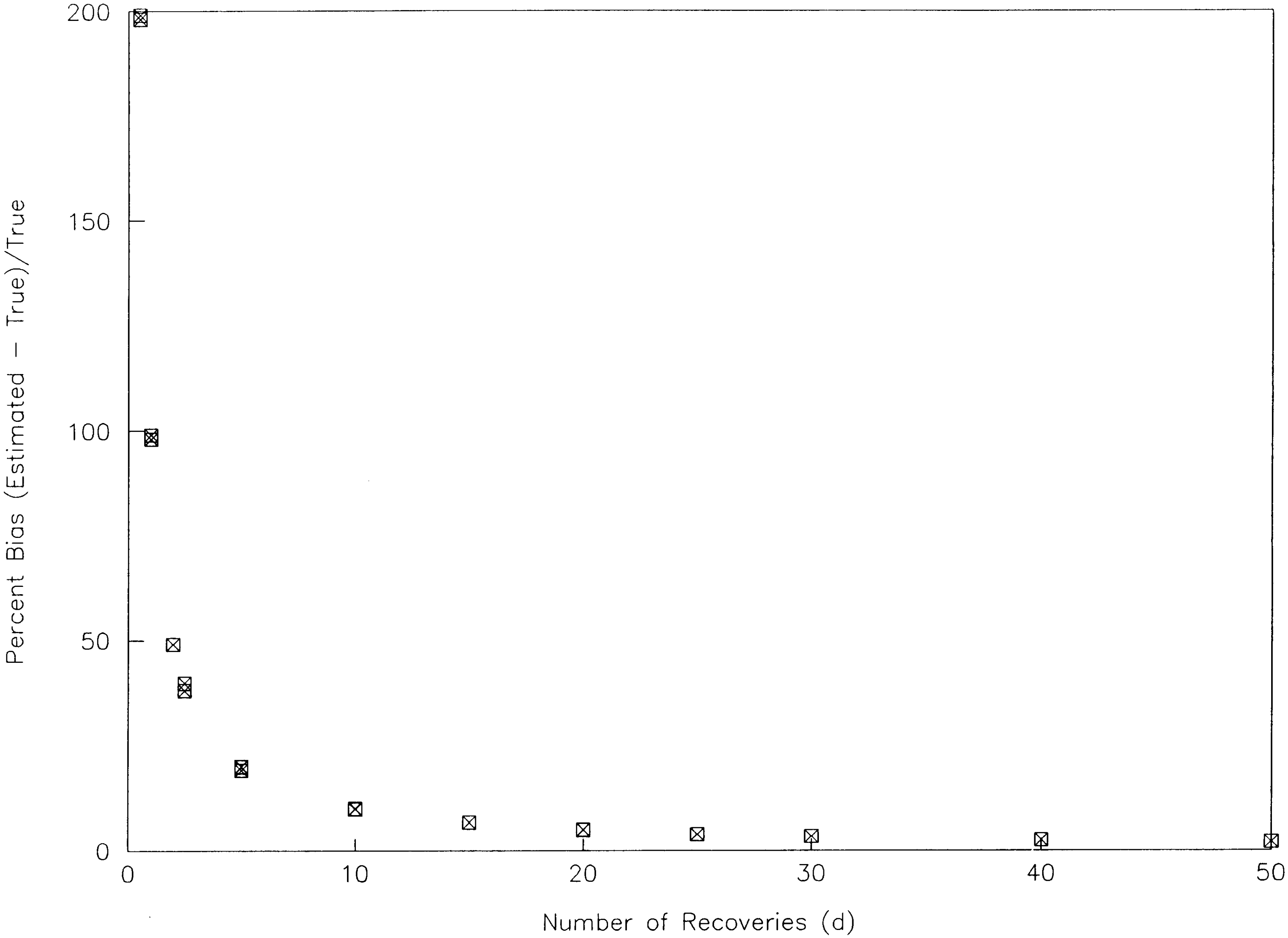

Figure 5. The potential bias in the estimate of population size as a function of the number of recoveries in a mark-recapture estimate.

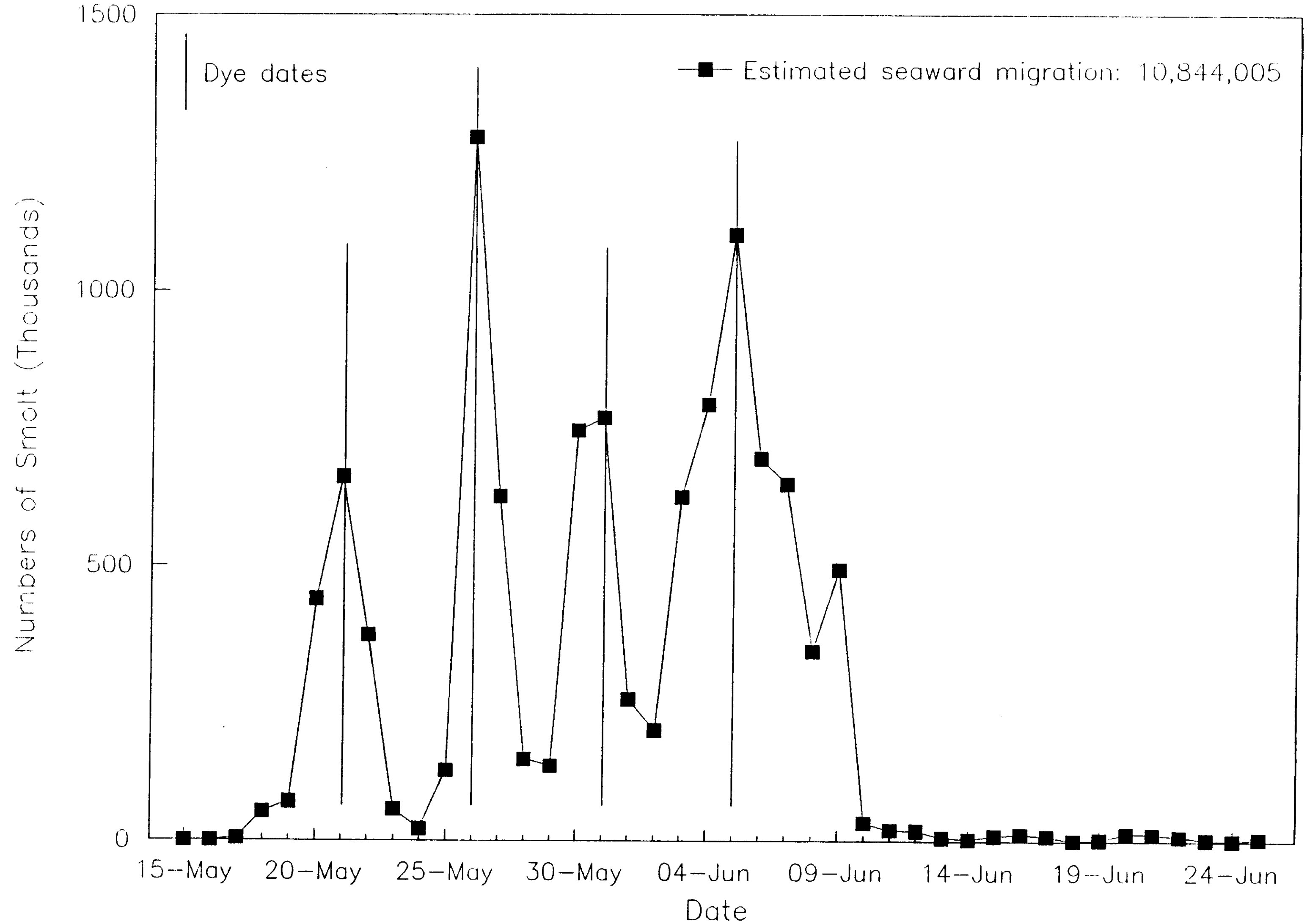

Figure 6. Daily Kenai River sockeye salmon smolt seaward migration, 1990.

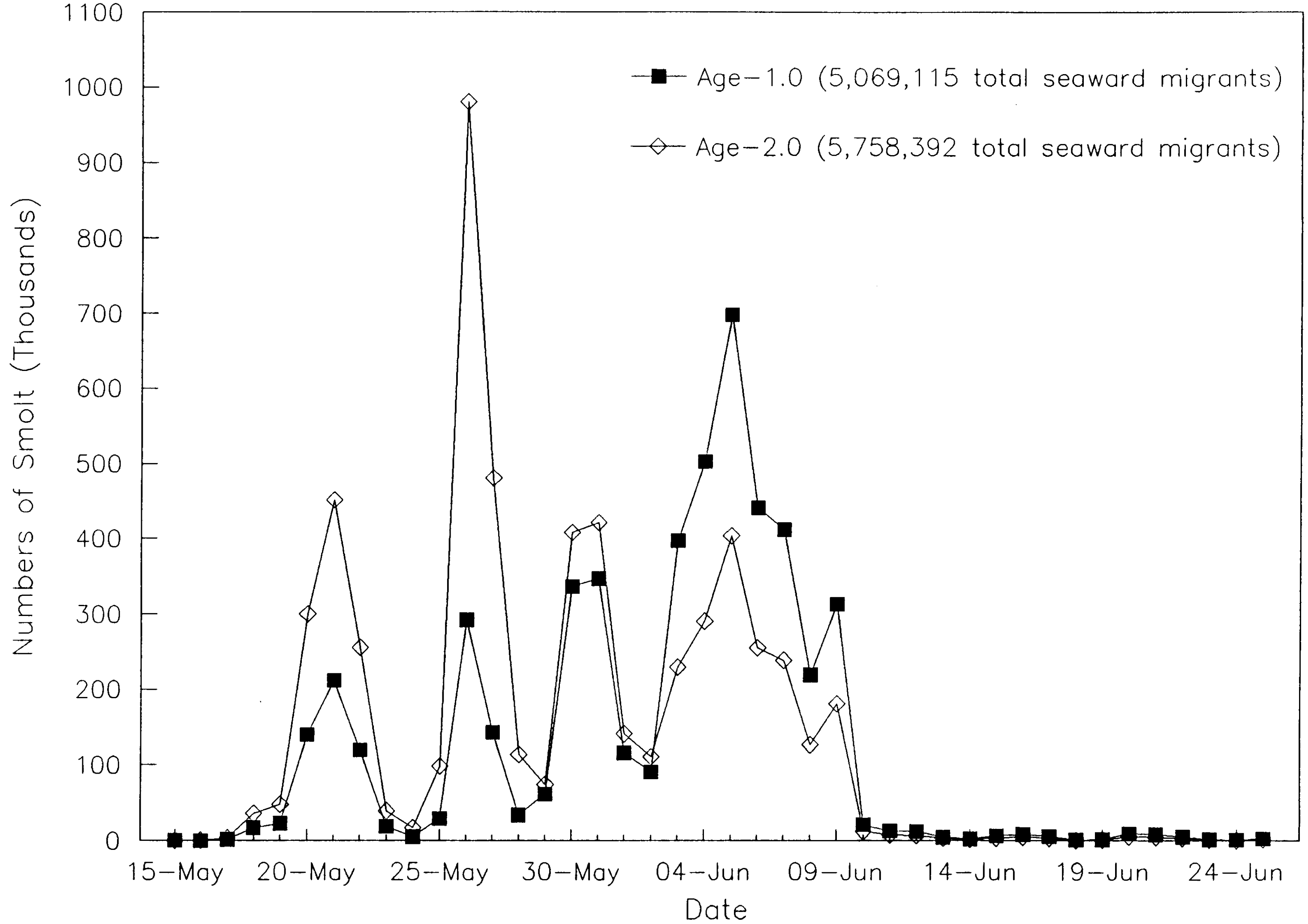

Figure 7. Daily Kenai River sockeye salmon smolt seaward migration by age class, 1990.

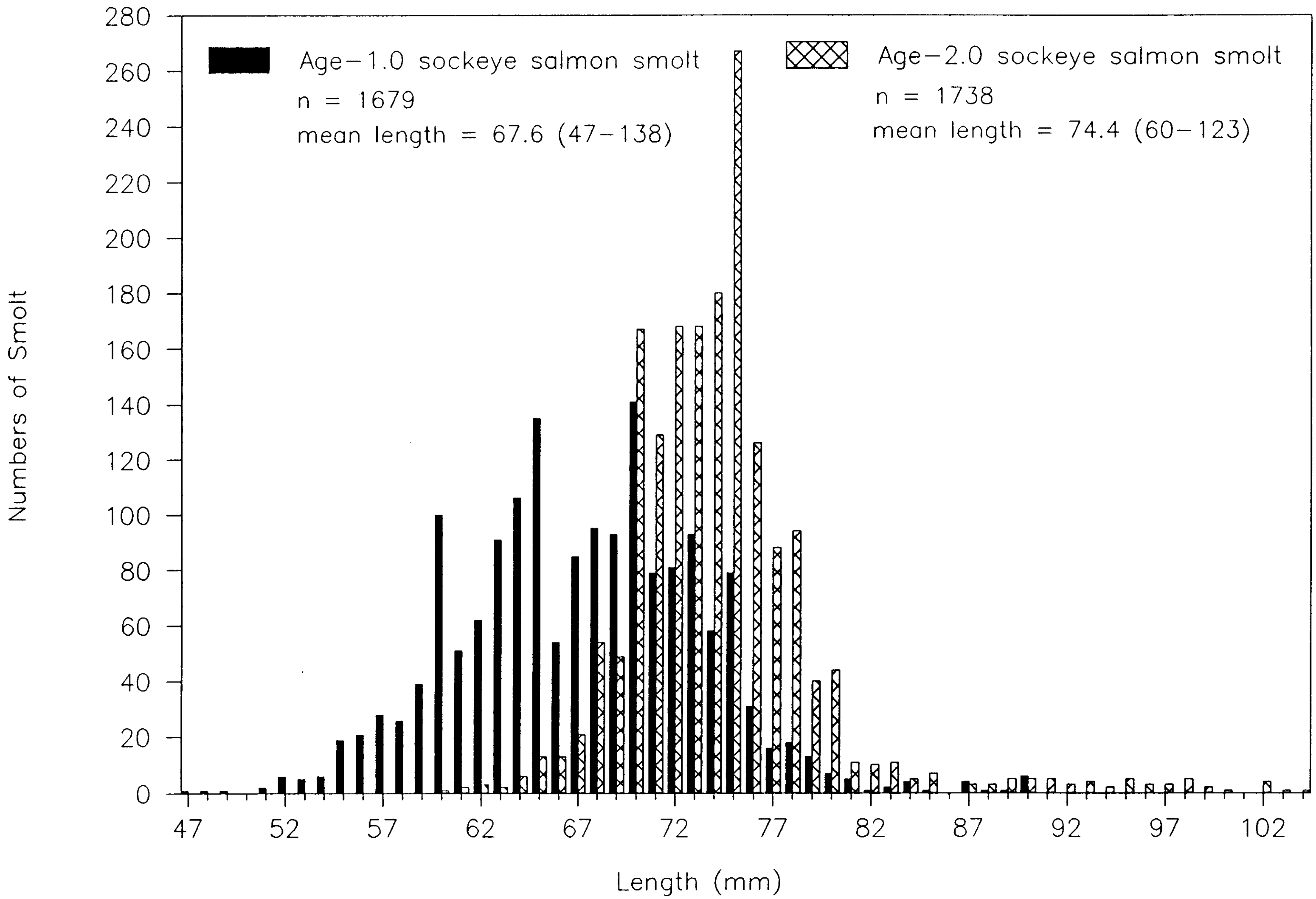

Figure 8. Length frequency distribution of age-1.0 and -2.0 sockeye salmon smolt captured in the Kenai River, 1990.

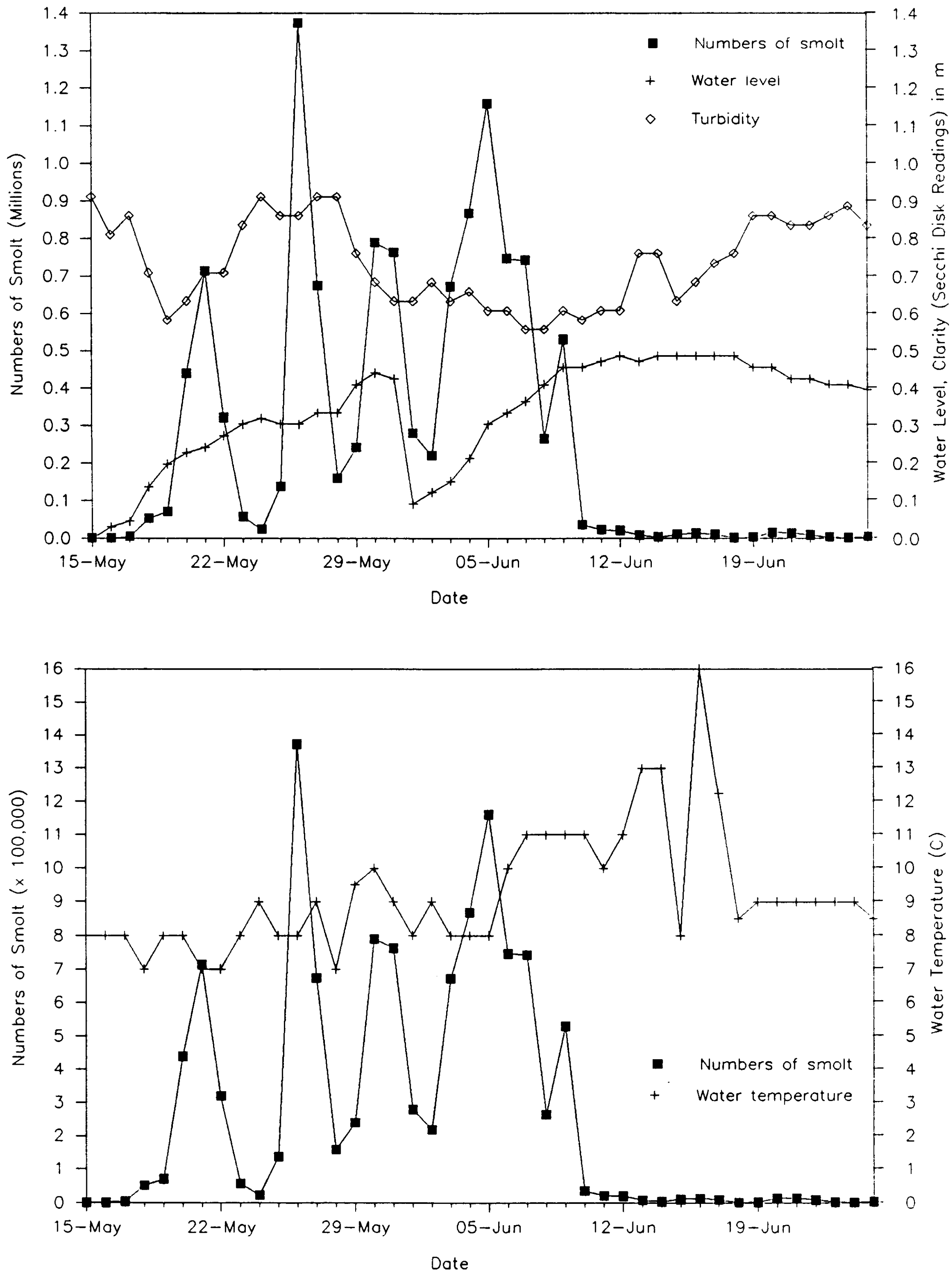

Figure 9. Daily sockeye salmon smolt migration and physical characteristics of the Kenai River, 1990.

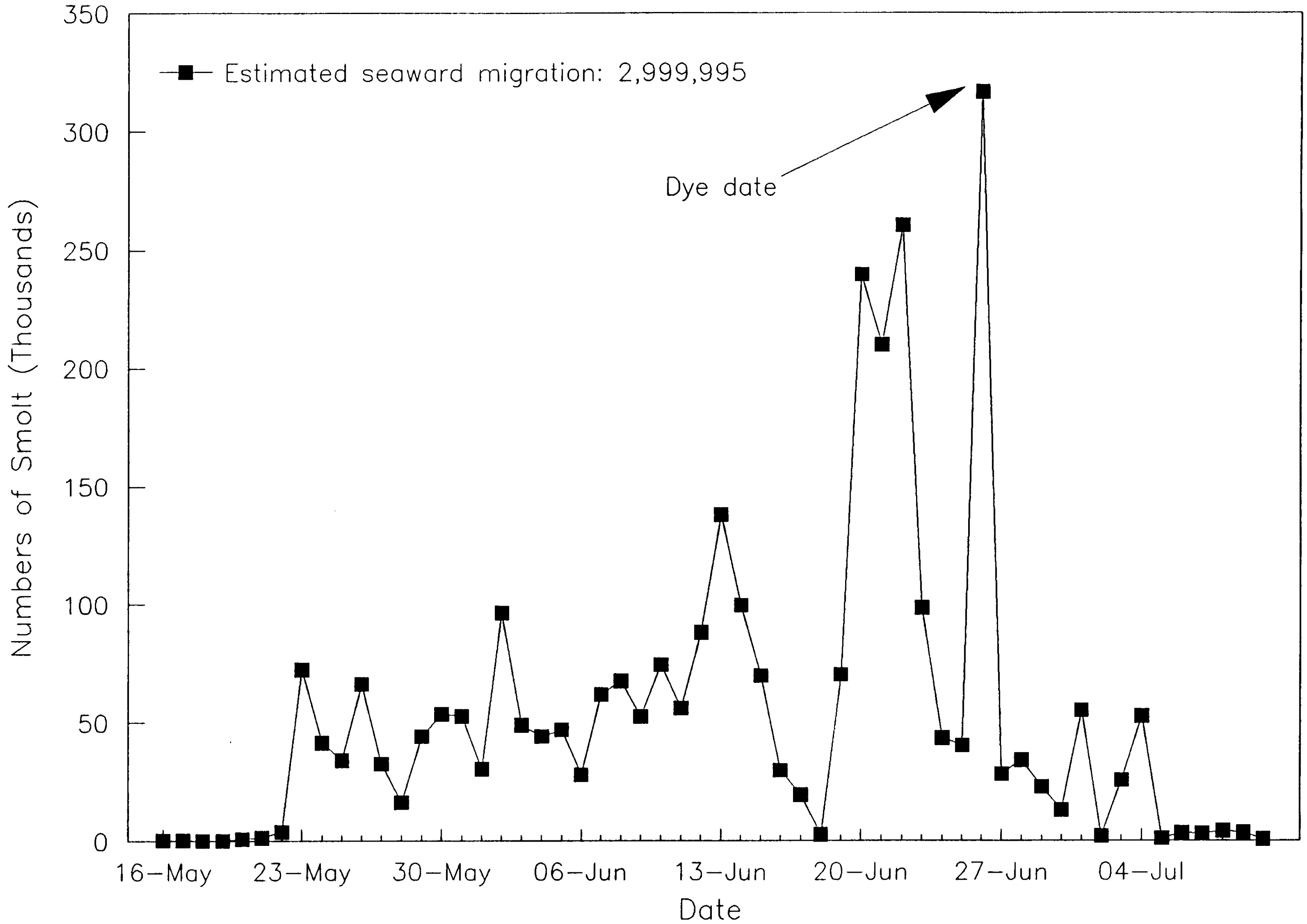

Figure 10. Daily Kenai River sockeye salmon smolt seaward migration, 1991.

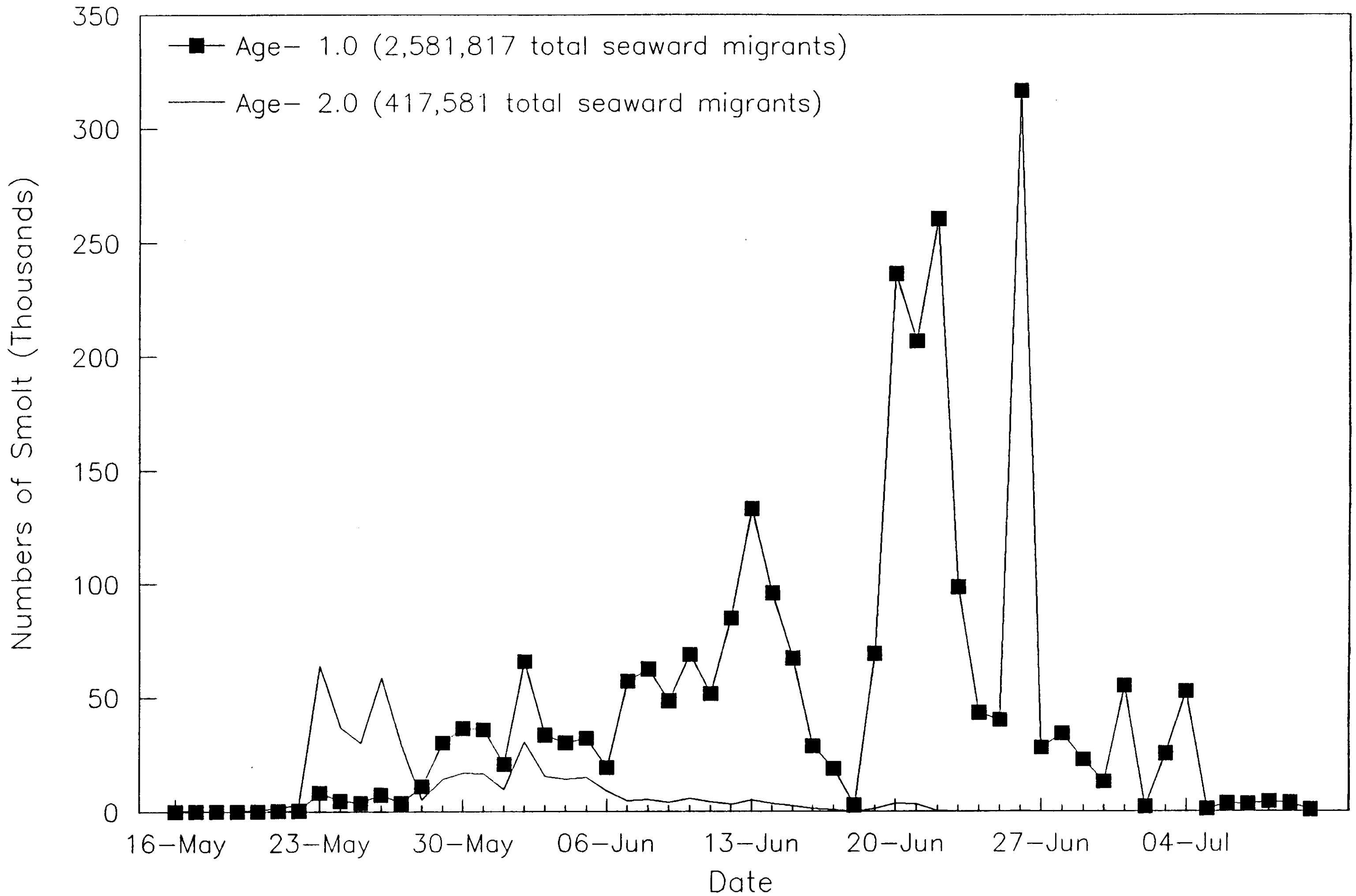

Figure 11. Daily Kenai River sockeye salmon smolt seaward migration by age class, 1991.

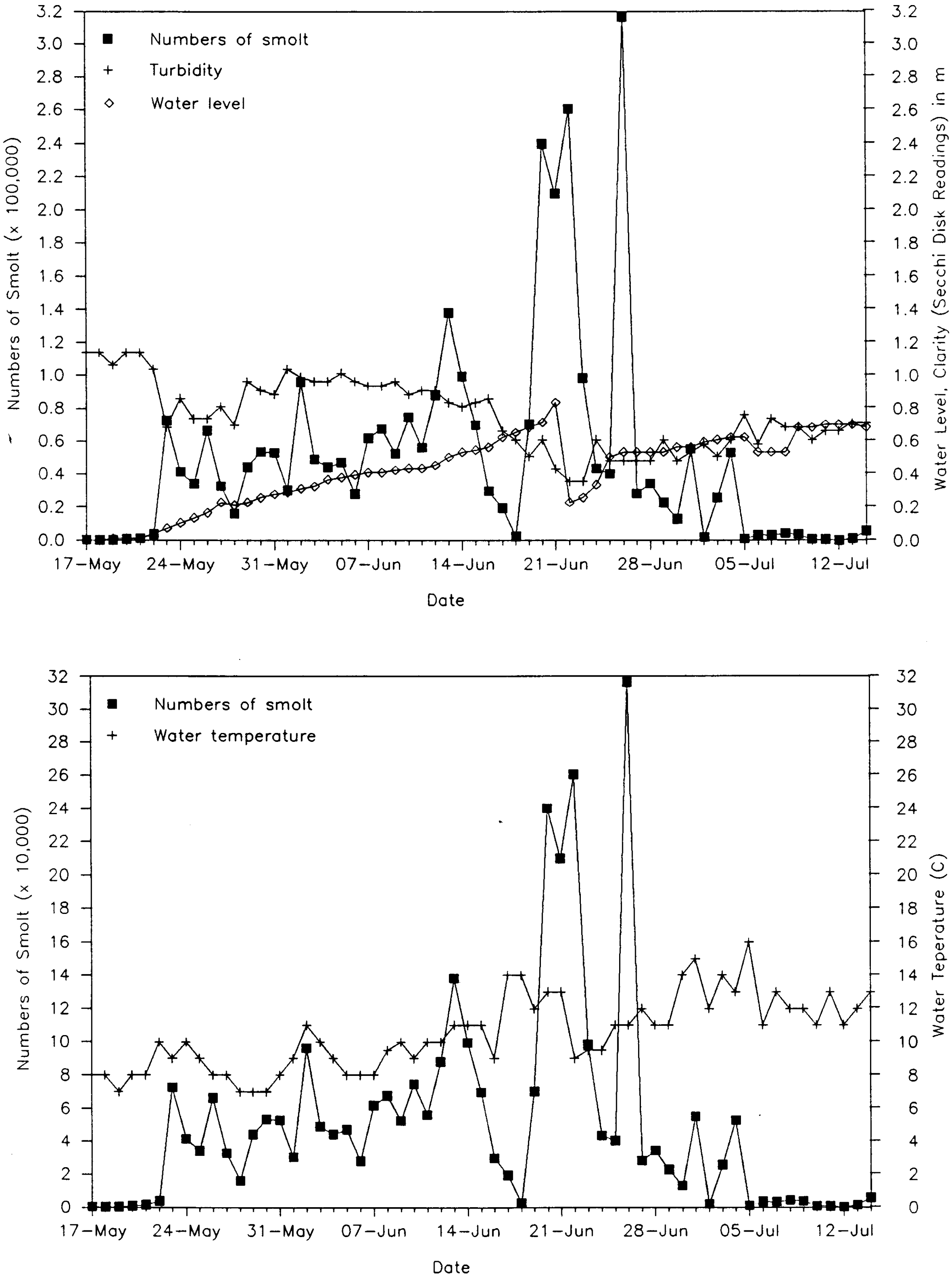

Figure 12. Daily sockeye salmon smolt migration and physical characteristics of the Kenai River, 1991.

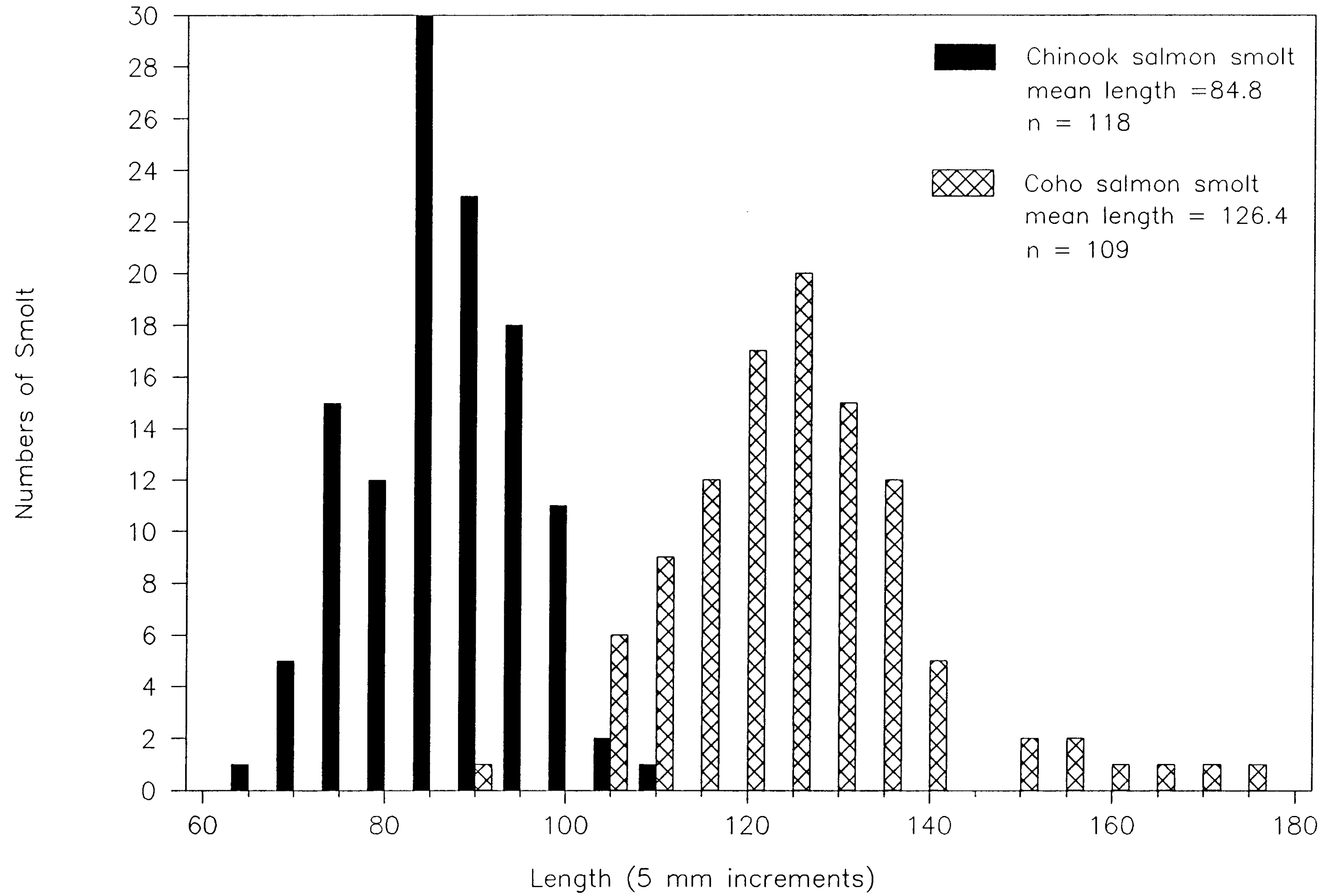

Figure 13. Length frequency distribution of chinook and coho salmon smolt captured in the Kenai River, 1991.

Appendix A.1. Sample sizes needed to estimate sockeye salmon smolt catches for various levels of relative error and proportion of sockeye salmon smolt in the catch.

Proportion Sockeye (p)	Relative Error 1%	5%
0.10	3,800	
0.20	1,900	
0.30	1,240	
0.40	850	
0.50	600	
0.60	420	1,700
0.70	285	1,150
0.80	178	720
0.90	93	365
1.00	21	85

Appendix B.1. Estimated migratory timing of Kenai River sockeye salmon smolt in 1989.

Date	Proportions	
	Daily	Cumulative
16-May	0.002	0.002
17-May	0.001	0.003
18-May	0.001	0.004
19-May	0.001	0.006
20-May	0.003	0.008
21-May	0.002	0.010
22-May	0.004	0.015
23-May	0.010	0.024
24-May	0.007	0.031
25-May	0.006	0.038
26-May	0.005	0.042
27-May	0.017	0.059
28-May	0.013	0.072
29-May	0.010	0.082
30-May	0.014	0.096
31-May	0.039	0.134
01-Jun	0.051	0.185
02-Jun	0.017	0.202
03-Jun	0.027	0.229
04-Jun	0.063	0.292
05-Jun	0.109	0.401
06-Jun	0.307	0.708
07-Jun	0.101	0.809
08-Jun	0.022	0.831
09-Jun	0.020	0.851
10-Jun	0.014	0.865
11-Jun	0.006	0.871
12-Jun	0.010	0.881
13-Jun	0.006	0.888
14-Jun	0.019	0.907
15-Jun	0.005	0.911
16-Jun	0.014	0.925
17-Jun	0.008	0.934
18-Jun	0.004	0.937
19-Jun	0.006	0.943
20-Jun	0.006	0.949
21-Jun	0.006	0.956
22-Jun	0.004	0.960
23-Jun	0.018	0.977

- Continued -

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	Proportions	
Date	Daily	Cumulative
24-Jun	0.011	0.989
25-Jun	0.004	0.993
26-Jun	0.004	0.997
27-Jun	0.003	1.000
Mean Date	05-Jun	
Variance	40.4	