KENAI RIVER SOCKEYE SALMON SMOLT STUDIES, 1994

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ABSTRACT

Inclined plane traps were placed in the Kenai River in 1994 to capture seaward migrating sockeye salmon *Oncorhynchus nerka* smolt. A total of 111,647 sockeye salmon smolt were captured. Assumptions required for making an estimate of the total number of seaward migrants were not met. Analysis of adult returns revealed that previous smolt population estimates were low. Approximately 95.7% of the sockeye smolt captured were age-1., and the remainder were age-2. (3.6%). Sockeye salmon smolt length frequency data and marked coho salmon smolt recapture data revealed decreased trap efficiency with increased smolt size.

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

INTRODUCTION

The Kenai River (Figure 1) smolt project has provided an estimate of the number and age composition of sockeye salmon *Oncorhynchus nerka* migrating out of the drainage since 1989 (King et al. 1990, 1991, 1994, 1995). This information has been used to evaluate sockeye salmon production in the Kenai River drainage in conjunction with mainstem estimates of spawners (Davis and King 1995), juvenile rearing in Kenai and Skilak lakes (Tarbox and Brannian 1995), and adult weir counts in Hidden Creek (Fandrei 1993) and Russian River (Marsh 1995a, 1995b) tributaries (Figure 2). Comparable production studies are being done in the Kasilof River drainage, the second largest producer of sockeye salmon in UCI (Kyle 1992, Kyle and Todd 1995).

Commercial fishing closures in UCI due to the 1989 Exxon Valdez oil spill resulted in an extremely large spawning escapement into the Kenai River. Several projects were designed to evaluate the effects of large spawning escapements on resulting progeny and lake rearing habitat. The Kenai River smolt project was a component of Natural Resource Damage Assessment Project No. 27, *"Sockeye Salmon Overescapement"*, from 1990 to 1992 (Schmidt and Tarbox 1991, 1992) and Kenai River Restoration Studies in 1993 and 1994 (Schmidt et al. 1995).

Objectives of the 1994 Kenai River smolt project were to:

1. Estimate the number of sockeye salmon smolt during the peak migration period of 15 May through 30 June;
2. Determine the age composition, mean weight, and mean length of sockeye salmon smolt;
3. Describe daily and seasonal migration timing of sockeye salmon smolt; and
4. Determine the number of sockeye salmon smolt migrating adjacent to the right bank.

METHODS

Fishing Methods

Trap design (Todd 1994) and placement at the km 31 site were identical to that of 1993 (Figure 3; King et al. 1995). Traps on the left side of the river were placed in the area of highest surface water velocities and greatest flow volume, since we thought most smolt would travel downriver through this area (Hoar 1954, Foerster 1968, Bue et al. 1988). The two traps on the right side of the river were as far toward the middle of the river as was practical and still allow boat travel through the area. Of the approximately 100 m river width, 25% of the middle was not monitored. In addition to the six traps fished at km 31 in 1994, two traps were placed in the river adjacent to the right bank at km 38. The two km 38 traps were anchored and held 6 m and 12 m offshore using cables and booms.

The river was 105 m wide with a maximum water depth of 2.5 m at the km 31 trap location. The thalweg occurred 25-30 m from the left bank and both current velocity and water depth generally decreased as one moved toward the right bank. Discharge typically increases during May and June, and ranges from 3,000 to 13,000 cubic feet per second.

Estimating Smolt Abundance

All km 31 traps were fished continuously throughout the study. Traps were monitored throughout the day and emptied at least twice between 0001 h and 0500 h. Traps were checked only sporadically through the remainder of the day, and generally emptied once more between 2200 and 2300 h. All captured juvenile salmonids were counted and recorded by species and stage of development.

Estimating Trap Efficiency

Sockeye salmon smolt were marked and released each day until a minimum sample size of 2,800 healthy dyed smolt was reached. No new releases of marked smolt were made during the next 48 hours to allow those released to pass the counting site. This provided trap efficiency data for 3 to 7 d time strata.

The Kenai River km 38 site was established as a marking site only. By dyeing 2,800 sockeye salmon smolt at this site, we hoped to eliminate dyeing at the km 31 site and allow the km 31 crew to focus on examining sockeye smolt for dye. We also suspected that we were subjecting sockeye smolt to additional stress at the km 31 site by first examining them for dye and then using the same fish for dyeing.

At the km 38 site, sockeye salmon smolt were dyed in a solution of 5 g Bismark Brown in 190 l of water (approximately 1:36,000) for twenty minutes. Fish were dyed in the morning, using the previous night's catch. As sockeye salmon smolt were removed from the trap, they were counted and immediately placed into a live tank mounted on the floats of the trap. Fresh water from the river was constantly circulated through the tank by a battery operated pump. Once an adequate sample size was reached, smolt were dyed, held in the live tank for at least 12 hours, and released at approximately 2200-2300 h. Dead and visibly weakened smolt were removed prior to release, and the number subsequently used to determine percent mortality from handling and dyeing. We assumed that since marked smolt were released in mid-stream at the onset of the nightly smolt migration, there would be adequate mixing of dyed smolt and other migrating sockeye salmon smolt prior to arrival at the km 31 traps. All smolt captured in the km 31 traps in the next 48 hours were examined for evidence of dye.

The number of smolt dyed and released (M_i) each marking period was set at 2,800 to obtain an estimate of abundance (N_i) with a relative error of +/- 25% for trap efficiencies equal to or greater than 2%. Trap efficiency was defined as the number of recaptures (r_i) divided by the number of smolt dyed and released. Required M_i for a given trap efficiency varied only slightly with number of smolt caught (C_i), but increased dramatically as trap efficiency decreased. A 2% trap efficiency was twice that seen in previous years, but sample sizes necessary for lower efficiencies would require handling more smolt than we thought we could capture and process. We also assumed that dye marking events could be pooled since trap efficiencies of adjacent time strata were not significantly different in 1989 and 1990 (Chi-square test with P=0.05 critical value). Pooling just two adjacent strata would result in a sample size of 5,600 smolt, which would provide estimates with the desired relative error for trap efficiencies as low as 1%. We tested to see if the numbers of dyed fish released and recaptured was independent of time stratum using all strata, followed by a stepwise comparison of succeeding strata (Chi-square; P=0.05 critical value).

Our estimator, like other mark-recapture estimates of population size, was biased when low numbers of dyed sockeye salmon smolt were recaptured (Seber 1982). To keep the level of bias below 10%, enough smolt had to be marked to ensure that at least 10 dyed smolt were recaptured within each time stratum. Fewer recaptures would result in a positive bias which would increase rapidly as recaptures fell below 10 smolt (King et al. 1994).

Analyses assumed: (1) all released dyed sockeye salmon smolt moved past the trap site within 48 hours so dyed smolt from one time period would not be caught in another; (2) the probability of capture among traps at km 31 was the same for marked and unmarked smolt; and, (3) the probability of capture for each individual smolt was independent of that of other smolt. We were able to test assumption 2 by comparing (Chi-square; P=0.05 critical value) the ratio of unmarked to marked fish by trap and time stratum.

Estimating Sockeye Salmon Smolt Abundance

Sockeye salmon smolt abundance (N_i) can be estimated from trap data using LaPlace's ratio estimate (Cochran 1978) as adapted by Rawson (1984):

$$\hat{N}_i = \hat{C}_i \frac{M_i}{r_i}\left[1 + \frac{M_i - r_i}{M_i r_i}\right] \quad , \tag{1}$$

where:

N_i = number of undyed sockeye salmon smolt migrating past traps in period i
C_i = number of sockeye salmon smolt caught in traps in period i
M_i = number of sockeye salmon smolt dyed and released upstream in period i
r_i = number of dyed sockeye salmon smolt recaptured in traps in period i.

The variance of N_i was estimated as:

$$V(\hat{N}_i) = \hat{C}_i(\hat{C}_i + r_i)\, M_i \frac{(M_i - r_i)}{r_i^3} \quad , \tag{2}$$

and the (1-α) confidence interval as:

$$\hat{N}_i \pm z_\alpha \sqrt{V(\hat{N})} \quad , \qquad (3)$$

where z_α = the (1-α)/2 percentage point of the standard normal distribution.

Run Timing

Migration timing was based on the proportion of the total catch made each day. We assumed that most smolt migrating from the Kenai River system passed the trap sites during the operational period. Therefore, the mean date of the migration was when 50% of the total catch had occurred at the km 31 trap site.

Age, Weight, and Length Sampling

Sockeye salmon smolt captured in km 31 traps were sampled for age, weight, and length (AWL) information. A scale smear from the preferred area (INPFC 1963) of each smolt was placed on a standard laboratory slide for age determination. Each smolt was also weighed to the nearest 0.1 g and measured (fork length) to the nearest mm. In order to obtain an abundance estimate by age, 5d time strata were defined. Within each day of each stratum, samples were collected from the catch of all traps combined. A daily sample size (n) of 60 fish (300 fish per 5 d period) was selected. This sample size provides a binomial (two age classes) simultaneous 90% confidence interval of +/- 0.05 when the proportion of the major age class in the population is at least 0.75.

AWL data were also collected from sockeye salmon smolt migrating from Moose River, Hidden Creek, and Russian River. We compared age composition, mean length, and length frequencies of smolt from these tributaries to values from samples collected at the km 31 site to determine whether these substocks were represented in the km 31 trap catches. Age-specific mean lengths were compared among smolt samples from the various locations using one-way analysis of variance (ANOVA) to determine whether differences could be detected. All tests results were evaluated at the nominal $P \leq 0.05$ level of significance.

We also examined length data from adipose fin clipped coho salmon (*Oncorhynchus kisutch*) smolt captured in the km 31 traps to provide another measure of trap efficiency. These marked coho salmon smolt were captured in the Moose River and marked by inserting a coded wire tag into the snout and removing the adipose fin (J. Carlon, ADF&G Sport Fish Div., Soldotna, pers. comm.). Nearly all coho salmon smolt passing the Moose River weir were tagged except a random sample preserved daily for collection of AWL data. We assumed that the length frequency distribution of the AWL sample (n= 1,288) accurately represented the distribution for marked migrants. Based on this assumption, we apportioned the total Moose River coho salmon smolt migration and the total km 31 catch of marked coho salmon smolt into 5 and 10 mm length intervals. We then calculated a trap efficiency for each length stratum and tested for differences in the numbers of marked fish recaptured by length.

Climatological and Hydrological Sampling

Water velocity (m/sec) measurements were taken at the surface in front of each km 31 trap whenever river depth rose or fell 0.3 m. Water depth (m), temperature (°C), and clarity (maximum secchi disc depth) were measured daily. Kenai River daily discharge was calculated from stage height data gathered at river km 34 by the Alaska River Forecast Center (L. Rundquist, National Weather Service, NOAA, Anchorage, pers. comm.).

RESULTS

A total of 141,222 fish were captured in traps 1-6 from 12 May until 30 July 1994 at the km 31 site (Table 1 and Appendix A). Seventy-nine percent (111,647) of the fish caught were sockeye salmon smolt. Captures of sockeye salmon fry exceeded those recorded in previous years (Table 2). The historical trend of increased numbers of smolt and decreased numbers of fry with distance from shore continued for sockeye and coho juveniles. Nearshore distribution of sockeye salmon fry was also observed by Clark and Smith (1972). Total sockeye salmon smolt captures were the third highest since the inception of the project in 1989. Highest individual trap catch of sockeye salmon was in trap 3. Traps 1 and 2 captured 41% of the left bank sockeye smolt total.

A total of 28,582 sockeye salmon smolt were dyed of which 27,126 were released. Survival per time strata during the holding period between dyeing and release ranged from 0.870 to 0.986 and averaged 0.949 (Table 3). Two hundred and ten of the dyed sockeye salmon smolt were recaptured, resulting in a total trap efficiency of 0.008. This compares with total trap efficiencies for the years 1989 through 1993 of 0.003 to 0.021 (Table 4).

An examination of trap efficiencies for all dye events (all traps pooled) revealed a chi-square p-value for nine strata of 0.098, a non-significant statistic (Tables 5 and 6). When progressive sets of strata (1-2, 1-3, 1-4, etc) were tested, we found that the p-value dropped dramatically when dye event number 4 (4-5 June) was added and was lowest (p=0.098) after including dye event number 6 (8 June). We therefore chose the first stratum to be dye events 1-3 (22 May - 3 June). We then tested progressive sets of dye events beginning with number 4 (4-5 June). A second stratum of dye events 4-9 (4 - 24 June) resulted from a chi-square test with p=0.314.

We also tested the homogeneity of marked to unmarked sockeye smolt ratios of the trap catches. We found that there was a significant (p<0.001) difference in the ratio's when all traps were tested using the data for all dye events. There was also a significant difference among traps on the left bank (traps 1-4; p<0.000) and between traps on the right bank (traps 5 and 6; p=0.034).

When trap catches were pooled into the two dye event strata defined above, different results emerged. Although a significant difference (p =0.004 and 0.000) still existed among the 6 traps within each time stratum, right bank traps were not significantly different for either stratum

(p=0.439 and 0.220). In contrast, left bank traps were significantly different (p=0.025 and p=.005) for both strata. The left inshore traps (1 and 2) were not significantly different for either strata (p=0.506 and 0.272) and tests of the offshore trap catches (3 and 4) had p-values of 0.041 for the first stratum and 0.21 for the second.

We calculated several population estimates using two dye event strata and various combinations of traps. Since tests of homogeneity resulted in nonsignificant statistics when traps 5 and 6, and traps 1 and 2 were grouped, the catches from these traps were used for two estimates. A third estimate used catches from the remaining pair of traps (3 and 4). Two additional estimates were made using catches from traps 1 through 4 and traps 1 through 6. All of the estimates were generated for purposes of evaluating the violation of assumptions on precision of this and previous years estimates of seaward migrants. Estimates of sockeye smolt generated with marked fish recapture data from different combinations of traps and two time strata varied from 8.5 million (traps 1 and 2) to 36.4 million (traps 5 and 6; Table 7).

Sockeye salmon smolt catches were relatively evenly distributed for a period of 31 days beginning 21 May. Less than 1% of the catch occurred within the first 8 and last 4 days of counting. In addition, only 23 sockeye smolt were caught in trap 3 from 5 through 11 May. Eighty percent of the total catch of age-2 sockeye smolt occurred in 18 days (Table 8), with the midpoint on 30 May. A similar proportion of the age-1. component passed the counting site in 25 days with a midpoint on 10 June. The general trend since 1989 has been for age-2 smolt to leave the system earlier and over a shorter time span than the age-1. smolt.

An estimated 95.7% of the sockeye salmon smolt sampled at the km 31 site were age-1. (Table 9). There was a significant ($p<0.001$, 16 df) change in the proportion of age-2. smolt in all strata. The general trend, similar to previous years, was a decrease in the proportion of age-2. smolt through time.

Mean length and weight of sockeye salmon smolt by age were comparable to those measured in 1989-1991 (Table 10; Figures 4 and 5). The mean length of age-1. sockeye salmon smolt from the km 31 (mainstem) traps and from samples collected in Hidden Creek and Russian River (Table 11) were, 64 mm, 129 mm, and 85 mm respectively. The mean length of the km 31 age-1. smolt was significantly less than each of the substocks ($P<0.001$). Mean length of age-2. sockeye smolt from the km 31 traps and from samples collected in the Moose and Russian River were 80 mm, 128 mm, and 97 mm. The mean length of km 31 age-2. smolt was also significantly less than each of the substocks ($p<0.001$). In general, age-1 Hidden Creek and Russian River, and age-2. Moose Creek sockeye salmon smolt appeared to be missing from the km 31 trap catches (Figures 6 and 7), and there was some overlap in the length frequency distribution of km 31 and Russian River age-2. smolt.

The average length of Moose River coho salmon smolt captured in km 31 traps was 120 mm in contrast to the average of 134 mm for the total Moose River migration (Figure 8; Jay Carlon, ADF&G Sport Fish Div, Soldotna, pers comm). These mean lengths were significantly different (ANOVA; $p<0.001$). Additional analysis of length frequency data for Moose River marked coho salmon smolt captured at km 31 indicated that trap efficiency decreased with increased length

(Figure 9). Significant differences (*p*=0.05) in trap efficiency were detected at 10 mm intervals in length frequency from 96mm to 125 mm. Trap efficiency was half or less of the next smallest 10 mm length increment. Coho salmon smolt 126 to 145 mm long were captured at the same rate of 0.0007, and only 8 of approximately 32,000 (0.0002) tagged coho smolt larger than 145 mm were recaptured. Recombination of data after chi-square analysis resulted in 4 trap efficiency estimates which predicted the outmigration of coho salmon smolt size 96 to 145mm (Figure 10).

Seasonal trends in hydrological parameters were similar to previous years. Water level increased daily, while temperature generally increased at the km 31 site throughout the study (Table 12). Daily discharge was low relative to previous years (Figure 11). Water clarity appeared to be a function of discharge (r^2 = 0.48). There was no measurable relationship (p<0.001) between numbers of fish caught daily and water clarity or temperature (Figure 12), nor was there a relationship between daily water clarity measurements and trap efficiency (p< 0.001).

The 1995 Kenai River adult sockeye salmon return provided an additional opportunity to evaluate the accuracy of smolt estimates based on adult returns of all age classes (Table 13). Returns of 6 year old fish from the 1989 brood year resulted in smolt to adult survival estimates of 85.8% for the age-1. component and 335.6% for the age-2. component. The 1990 brood year survival of smolt to adult was 287.7% for the age-1. component and 347.2% for the as yet incomplete (age-2.3 adults return in 1996) age-2. component. Finally, the 1991 brood year estimate of age-1.0 smolt has produced, without the age-1.3 component, a return of 484,000 age-1.2 fish, resulting in a preliminary smolt to adult survival of 60.7%

DISCUSSION

There are numerous factors which affect the accuracy of smolt population estimates in general, and those generated by mark and recapture methods. All methods assume that the population is measured during the timing of the seaward migration, and that the entire population is subject to the gear of choice. For the mark-recapture method used in this study to be successful, we assumed that the probability of capture among traps at km 31 had to be the same for marked and unmarked smolt and the probability of capture for each individual smolt had to be independent of that of other smolt. We reasoned that if these general (all methods) and specific assumptions were met, other factors commonly thought to affect population estimates (Seber 1982) would not be significant. We have subsequently found evidence that the assumptions may not have been met. Our smolt to adult survival data not only revealed impossible (greater than 100%) survival estimates for many brood years, it also revealed that age-2. survival rates were consistently higher than those of the age-1. component. Similar results can be inferred for the Kasilof River where the 1980 through 1993 brood years produced an average age-1. smolt proportion of 82% using the same capture method, but an average of 69% age-1. adults returning to Cook Inlet from those brood years. We discovered that factors affecting trap efficiency, largely unanticipated at project inception, were critical to the failure of the project. Among the latter were marked fish sample sizes, effects of the marking process, behavioral responses of the fish to the capture gear, and an inability to obtain a marked sample which was representative of the population.

With regard to the timing of the seaward migration, the initiation and duration of this project accounted for the majority of sockeye smolts migrating out of the Kenai River. Each year the first days of the project resulted in no or very low sockeye smolt catches. There was some evidence of low level migration at the end of counting activities, and we presume that some low level migration could occur throughout the summer. The majority of the Kenai River smolt migration does not however differ in timing from that of other drainages at similar latitudes (Hartman et al. 1967, Todd and Kyle 1995). The general trend of age-2. smolt leaving the drainage earlier and over a shorter time span than the age-1. smolt was also reported for a variety of lakes in Alaska by Hartman et al. (1967) and Todd and Kyle (1995).

We are less certain about the availability of the gear to all segments of the population. Sockeye salmon smolt are known to seek out the highest velocity areas of the river during migration (Hoar 1954, King et al. 1994, 1995). Our data showed that Traps 3 and 4 on the left side of the river were generally in the path of highest surface water velocities, with highest measurements frequently recorded in front of trap 3. The two traps on the right side of the river (5 and 6) were as far toward the middle of the river as was practical, however 25% of the middle of the river was unmonitored. During 1993 and 1994, when 6 traps were fished, surface velocities in the unmonitored portion of the river were equal to or greater than that measured at traps 4 and 5 during the period when most smolt were captured. Further, the velocity measurements in front of traps 2 through 5 (approximately half of the cross sectional distance of the river) did not differ by more than 15% on any date. As a result, sockeye smolt seeking the highest velocities were not necessarily directed to the traps.

The large proportion of the total 1994 sockeye salmon smolt catch in trap 3 was also observed in 1990 and 1993. In the other years of the study, traps 3 and 4 had approximately equal seasonal catch totals. Both 1990 and 1993 also had greater total discharge rates for May than other study years, and highest surface velocities were recorded in front of trap 3.

In contrast, 1994 discharge was relatively low, and highest velocity measurements were recorded in front of the offshore traps (3 and 4) only after 10 June. Catches of sockeye salmon smolt in 1994 were also more evenly distributed among the inshore traps (1 and 2). The proportion of each days catch found in traps 1 and 2 were highest prior to 4 June and during the period when surface velocities were also higher in front of trap 2 than traps 3 and 4. After early June when total discharge had increased to the point where highest velocities were encountered in front of traps 3 and 4, trap catches were also higher proportionally in the offshore traps.

While discharge level and resultant velocity profile appeared to have a bearing on trap catch, we could not assess their influence on trap catches because the annual data were contradictory in this regard. In addition, of the two years that we measured the highest discharges (1992-93) we also had the largest error in estimating smolt. We were also unable to answer the question of whether trap catches in any year were affected by water velocity in the middle of the river.

Although discharge rates and surface velocities influenced the proportion of the total sockeye salmon smolt catch by trap, there was no obvious relationship between these or other individual hydrological parameter changes and daily migration rates or trap efficiency. Temperature, has been related to the onset of smolt migration (Power 1985, Burgner 1962, Hartman et al. 1967), however in this study temperature effects were confounded by the addition of significant water between the lake of origin of most smolt and the counting site. Water clarity was correlated to discharge changes, but could not independently explain the daily smolt migration pattern, nor was it related to trap efficiency.

The failure to capture larger sockeye smolt migrating from the system in 1992 and 1993, coupled with the smolt to adult survival data collected in recent years, led us to seriously question the validity of our assumption that the entire population was subject to capture by the gear. We first began to see evidence that larger smolt had a different probability of capture in our traps than smaller smolt in 1992 (King et al. 1994). Prior to that, age-2. sockeye smolt lengths from trap samples appeared to be normally distributed (King et al. 1991) suggesting that size selectivity did not occur. We assumed that length frequency distributions would be truncated at larger values or be skewed toward smaller sizes if larger smolt were better able to evade capture. Length frequency data for Russian River, Moose River, and Hidden Creek sockeye smolt, first collected in 1992, suggested that Hidden Creek (age-1.) and Moose River (age-2.) sockeye smolt were not represented in mainstem trap catches. These length frequency distributions had little overlap with that measured for mainstem trap smolt samples, and the corresponding mean lengths were significantly different. In contrast, there was sufficient overlap between the mainstem and Russian River length frequency distributions to infer that Russian River smolt were at least partially represented in mainstem catches. These results were duplicated in 1994. The efficiency at which the mainstem traps were able to capture Russian River smolt is not known, but our data indicated that even if the highest of our five 1994 population estimates was used for mainstem age-2. smolt, the number was still substantially less than the age-2. component migrating from the Russian River.

Our data indicated that km 31 sockeye salmon smolt trap efficiency started to decline dramatically for smolt with a length range of 90-115 mm. Burgner (1962) also found that fyke nets in the Wood River failed to catch sockeye smolt larger than 105 mm in currents averaging 3 m/s, and mean lengths of the samples captured with the fyke nets was biased low relative to other techniques used to sample the smolt migration. The nets were however able to capture fish which averaged 85-90 mm. An inclined plane trap in the Kasilof River caught age-1. sockeye smolt with an average length of 64 mm and age-2 smolt which averaged 83 mm long in 1994 (Todd and Kyle 1995).

A comparison of length frequency distributions for coho salmon captured in Moose River and the mainstem Kenai River also provided evidence of size selectivity in trap catches. Carlon and Hasbrouck (1993) found a significant ($p<0.001$) difference in mean length between coho tagged in the Moose River and those recovered in the traps, and stated that traps could not be used to estimate the number of coho salmon migrating from that drainage. We found that trap efficiency could be estimated for coho salmon smolt of various size ranges, and that smolt from 100-114 mm were caught at a rate of slightly less than 2%. Since we were unable to capture Moose River and Hidden Creek sockeye salmon smolt which had similar lengths to the coho salmon smolt captured at km 31, it appeared that trap efficiency differed among species as well as within species. Similar results were reported by Thedinga et al. (1993) for screw traps used on the Situk River in Southeastern Alaska. It is not, however, clear why we were successful at capturing larger coho smolt than sockeye smolt in the km 31 traps. Our 1.2% trap efficiency for 96-105 mm coho salmon smolt exceeded that for sockeye with mean length 64 mm (age-1.) and 80 mm (age-2.). We know that trap avoidance was not totally a function of swimming ability since we are able to catch much larger sockeye smolt (90-135 mm) in comparable currents in the Russian River tributary using a trap with the same basic design (King and Westerman, *in press*).

While not central to this study, the captures of sockeye fry may also be indicative of differential catchability by size. Sockeye fry numbers increased nearly every year of the study, and made up over 10% of the total catch in 1993 and 1994. Historic returns to the river of age-0. adults have exceeded 1% of the total by brood year in only one year of our 33 year database (1962- 1990 brood years, David Waltemeyer, ADF&G, Soldotna, pers comm). We did not see evidence of significant numbers of 1992 brood year age-0. adults returning in 1995. Minor age-0. fry migrations with less than expected age-0. adult returns were also common in the Wood River Lakes system (Burgner 1962) and Lower Babine River (Clark and Smith 1972). While our results may be indicative of differential trap efficiency based on fish size, we were unable to separate this variable from potential differential survival of these cohorts in the marine environment.

Dye events were conducted more frequently in 1994 than in previous years, which allowed us to measure trap efficiency every 2-7 days during the migration. We thought that this increase would alleviate previous concerns about adequacy of sample sizes. With the exception of the last dye event, more than 10 dyed smolt were recaptured per dye event, reducing the chance of bias known to occur in mark-recapture estimates with small numbers of recaptures (Seber 1982). The minimum number of dyed smolt needed each period was based on the assumption that trap efficiency would either equal 2%, or be consistent over time if less than 2%. Sample sizes greater than 7,500 were needed to ensure a relative error of less than 25% for trap efficiencies equal to the 1994 total of 0.8%. Since we found that trap efficiency was independent of dye event date, we could have combined the results of all dye events. However, after examining changes in p values in chi-square stepwise comparisons of dye events, we decided that the relatively large change after the addition of dye event 4 warranted starting a new stratum at that point. Resulting dye sample sizes were still adequate for our prescribed error levels.

An important assumption underlying the population estimation procedure is that marked and unmarked smolt behave similarly. A violation of this assumption would be apparent if we obtained significantly different marked to unmarked ratios among traps. In previous years, we had mixed results in this regard, and it's impact on the estimate was considered negligible. However, in 1994 we observed poor mixing of marked and unmarked smolt, resulting in differences in this ratio between inshore and offshore traps on the left bank, and between banks. With the detection of such differences among traps we would violate assumption 2 (see methods) if we pooled catches for a population estimate. In similar mark recapture studies, Thedinga et.al (1994) and Dempson and Stansbury (1991) found significant differences in trap efficiency through time and poor mixing between marked and unmarked fish.

In the interest of examining the range of possible 1994 estimates that result from the violation of the mixing assumption, we made population estimates using pooled catches from several combinations of traps and two dye event strata. We were unable to say which if any of these estimates was better, or whether an average of all the estimates was better than the estimate from pooling the traps. Since the estimates ranged from 8 to 36 million, we elected not to publish a population estimate for forecasting or estimating freshwater or marine survival. We did however, use an average of the estimates for illustration purposes in comparing lengths of smolt substocks.

Finally, our examination of the data and literature revealed other factors that could have potentially affected the success of our estimates. Visibility (Robinson and Barraclough 1978), rheotactic response and schooling behavior (Hoar 1951, 1954, Hartman et al. 1967) all are potential influences on trap avoidance. Other researchers have focused on the detection of and responses to various environmental stimuli by fish. Carlson (1994) summarized much of the historical information on hydrodynamic flow detection and hearing in fish. While salmonids are not particularly good 'hearers', they are able to detect extremely small (measured in angstroms) changes in pressure. Carlson suggested that the ability to measure extremely low level pressure changes provides the avoidance mechanisms through which fish keep from colliding with instream obstacles. This implies that efficiency of movement in downstream migration is best achieved by moving along a stimulus field gradient that prevents collisions but minimizes radical course changes. Hartman et al. (1967) documented a switch in rheotactic response by sockeye smolt immediately upon entering the wings of a fyke net, suggesting a reaction to the pressure wave present in front of the net. Fletcher (1994) demonstrated that golden shiner *Notemigonus crysoleucas* motion paths coincided with flux lines of water motion. He interpreted this behavior as fish responding to velocity gradients as opposed to responding directly to solid surfaces that induced gradients. Urick (1967) concluded that the hearing of most fish overlaps the frequencies at which most ambient and man-made noises occur. In the case of smolt traps, any or all of these factors may influence trap avoidance.

While the basic physiological mechanism for detection of pressure waves is probably the same for all salmonids species (Carlson, 1994), object avoidance behavior can be different. The difference in rheotactic response changes the rate at which the physiological reaction takes place (Denton and Gray, 1988); ie positive rheotaxis (coho smolt) provides a different response from negative rheotaxis (sockeye salmon) to the same change in pressure. Schooling behavior (sockeye smolt) could result in a more immediate response than loose aggregates (coho smolt) where fish are apt to act more like individuals. Even the way in which each species reacts to stimuli (lateral movement in sockeye and diving reaction in coho), or the reaction of hatchery and wild stocks of the same species (Knudsen et al. 1992) can influence capture success. While we have no supporting evidence, we also suspect that there is a difference in species response time or degree of response based on habituation to background noise level in the juvenile rearing environment. That is, Kenai coho juveniles live in an acoustically very noisy environment and must sort these noises for reaction purposes. This may result in a 'noise threshold' below which no response is elicited. Sockeye juveniles rear in a relatively noise free environment, and are suddenly thrust into a very noisy environment for a brief time period during their migration to salt water. The lack of time to habituate may result in constant reaction to various noise sources which leads to a different stimulus gradient. Schwartz (1985) speculated that the relative insensitivity of Atlantic salmon to ambient noise might be an adaptation to it's acoustic environment.

As is often the case, project assumptions take time to evaluate and understand. In the case of this project our assumption that hydrological and behavioral variables would not be significant were made and viewed in the context of marked to unmarked smolt catchability. We did not initially consider the implications of small changes in body size of substocks or year classes resulting in significant changes in the ability to capture fish. We showed that the overall timing of the project was adequate, and that sample sizes of marked fish could be achieved for recovery levels less than 1%. However future studies of this type would benefit from: 1) placing more effort in the highest velocity areas of the river, or selecting sites where velocity profiles indicate the presence of a 'narrow', clearly defined velocity chute; 2) determining more revealing ways of examining the effects on trap efficiency of water clarity, and velocity, and water deceleration gradients caused by the traps; 3) obtaining fish for marking using an independent method that is not size selective and 4) developing methods to assess potential bias of capture methods with respect to fish size.

LITERATURE CITED

Bue, B.G., D.L. Bill, W.A. Bucher, S.M. Fried, H.J.Yuen, and R.E. Minard. 1988. Bristol Bay sockeye salmon studies for 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 88-15, Juneau.

Burgner, R.L. 1962. Studies of red salmon smolts from the Wood River Lakes, Alaska. In: Koo, T.S.Y., ed., Studies of Alaska Red Salmon. Univ. of Washington Press, Seattle.

Carlon, J. and J.J. Hasbrouck. 1993. Marking juvenile coho salmon in the Kenai River with coded, microwire tags. Alaska Department of Fish and Game Division of Sport Fisheries Fishery Data Series No. 93-52, Anchorage.

Carlson, T.J. 1994. Use of sound for fish protection at power production facilities: A historical perspective of the state of the art. Phase I Final Report on the Evaluation of the use of sound to modify the Behavior of fish. Prepared for: U.S. Department of Energy, Bonneville Power Administration.

Cochran, W.G. 1978. LaPlace's ratio estimator. *In* Contributions to survey sampling and applied statistics, *edited by* H.A. David, Academic Press, New York, pp. 3-10.

Clark, W.C. and H.D. Smith. 1972. Observations on the migration of sockeye salmon fry (*Oncorhynchus nerka*) in the lower Babine River. Journal of the Fisheries Research Board of Canada 29.

Davis, R.Z. and B.E. King. 1995. Upper Cook Inlet salmon escapement studies, 1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report 2A95-44. Anchorage.

Dempson, J.B. and D.E. Stansbury. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population.

Denton, E.J. and John A.B. Gray. 1988. Mechanical factors in the excitation of the lateral lines of fishes. *In* Atema, J., R.R. Fay, A.N. Popper, and W.N. Tavolga. Sensory Biology of Aquatic Animals. Springer-Verlagf, New York.

Fandrei, G. 1993. Hidden Lake sockeye salmon enhancement progress report 1993. Cook Inlet Aquaculture Association, Soldotna.

Fletcher, R.I. 1994. Flows and fish behavior: Large double-entry screening systems. Transactions of the American Fisheries Society 123.

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka.* Fisheries Board of Canada Bulletin 162. Ottawa.

Hartman, W.L., W.R. Heard, and B. Drucker. 1967. Migratory behavior of sockeye salmon fry and smolts. J. Fish. Res. Bd. Can. 24(10).

Hoar, W.S. 1954. The behavior of juvenile pacific salmon, with particular reference to the sockeye (*Oncorhynchus nerka*). Journal of the Fisheries Research Board of Canada 11(1).

Hoar, W.S. 1951. The behaviour of chum, pink and coho salmon in relation to their seaward migration. Journal Fisheries Research Board of Canada (8).

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Seattle, Washington.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1990. Kenai River sockeye salmon smolt studies, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2S90-5, Anchorage.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1991. Kenai River sockeye salmon smolt studies, 1990-91. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report No. 2S91-8, Anchorage.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1994. Kenai River sockeye salmon smolt studies, 1992. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report No. 2A93-28, Anchorage.

King, B.E., L.K. Brannian, and K.E. Tarbox. 1995. Kenai River sockeye salmon smolt studies, 1993. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report No. 2a94-41, Anchorage.

King, B.E. L.K. Brannian and D.L. Westerman. *In press*. Russian River drainage sockeye salmon juvenile and smolt studies, 1994 and 1995. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report, Anchorage.

Knudsen, F.R., P.S. Enger and O. Sand. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, *Salmo salar* L. Journal of Fish Biology 40:523-534.

Kyle, G.B. 1992. Summary of sockeye salmon *(Oncorhynchus nerka)* investigations in Tustumena Lake, 1981-1991. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development Division Report No. 122, Juneau.

Kyle, G.B. and G.B. Todd. 1995. Tustumena Lake project Report: Sockeye salmon investigations 1994. Alaska Department of Fish and Game Division of Commercial Fisheries Regional Information Report 5J95-12, Juneau.

Marsh, L. 1995a. Catch and effort statistics for the sockeye salmon sport fishery during the early run to the Russian River with estimates of escapement, 1994. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 95-11, Anchorage.

Marsh, L. 1995b. Catch and effort statistics for the sockeye salmon sport fishery during the late run to the Russian River with estimates of escapement, 1994. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 95-10, Anchorage.

Power, G. 1985. Estimating and understanding smolt output from Atlantic salmon rivers. In: 1985 Northeast Atlantic Salmon Workshop, New Brunswick.

Rawson, K. 1984. An estimate of the size of a migratory population of juvenile salmon using an index of trap efficiency obtained by dye marking. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development Report 28, Juneau.

Robinson, D.G. and W.E. Barraclough. 1978. Population estimates of sockeye salmon (*Oncorhynchus nerka*) in a fertilized oligotrophic lake. J. Fish. Res. Board Can. 35:851-860.

Schmidt, D. and K.E. Tarbox. 1991. Sockeye salmon overescapement. Fish/Shellfish Study No. 27. State/Federal Natural Resource Damage Assessment Draft Preliminary Status Report, Soldotna.

Schmidt, D. and K.E. Tarbox. 1992. Sockeye salmon overescapement. Fish/Shellfish Study No. 27. State/Federal Natural Resource Damage Assessment Draft Preliminary Status Report, Soldotna. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 5J95-15, Anchorage.

Schmidt, D., K.E. Tarbox, G.B. Kyle and S.R. Carlson. 1995. Sockeye salmon overescapement: 1993 annual report on the Kenai River and Kodiak investigations. *Exxon Valdez* Oil Spill Restoration Project 930002.

Schwartz, A.L. 1985. The behavior of fishes in their acoustic environment. 1985. Environmental Biology of Fishes 13(1): 3-15.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Second edition. Macmillan Publishing Co., New York.

Tarbox, K.E. and L.K. Brannian. 1995. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1993-1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Regional Information Report 2A95-31. Anchorage.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North Pacific Journal of Fisheries Management 14 (4).

Todd, G.L. 1994. A lightweight inclined-plane trap for sampling salmon smolts in rivers. Alaska Fishery Research Bulletin (2): 179-186.

Todd, G.L. and G.B. Kyle. 1995. Tustumena Lake project report: sockeye salmon investigations 1994. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development. Regional Information Report 5J96-02. Anchorage.

Urick, R.J. 1983. Principles of Underwater Sound. McGraw-Hill Book Co. New York.

Table 1. Numbers of fish captured by smolt traps at the Kenai River km 31 site, May 12 through June 30, 1994.

Date[a]	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	32	71	29	101	0	5	0	17	255
13-May	115	140	19	97	1	5	0	4	381
14-May	22	109	13	59	0	8	0	8	219
15-May	18	26	35	108	0	0	0	5	192
16-May	26	203	16	59	1	2	0	8	315
17-May	33	192	17	72	1	1	0	4	320
18-May	86	84	55	35	0	6	0	7	273
19-May	45	493	77	261	2	2	0	16	896
20-May	752	420	97	118	1	6	0	14	1,408
21-May	3,521	226	130	169	3	28	1	16	4,094
22-May	3,147	216	93	121	1	10	0	21	3,609
23-May	1,951	204	79	109	2	2	3	17	2,367
24-May	3,279	114	97	48	3	9	0	9	3,559
25-May	3,024	93	37	51	1	10	0	13	3,229
26-May	2,975	191	56	86	4	12	0	14	3,338
27-May	1,848	62	71	70	4	8	0	20	2,083
28-May	727	85	55	70	2	2	0	18	959
29-May	775	130	50	92	6	5	0	23	1,081
30-May	2,050	164	27	92	14	2	5	14	2,368
31-May	3,228	278	38	104	20	1	0	27	3,696
01-Jun	3,127	643	23	99	18	1	3	23	3,937
02-Jun	1,848	600	38	73	59	1	0	24	2,643
03-Jun	4,223	687	29	74	14	0	0	8	5,035
04-Jun	4,593	681	42	109	8	5	0	32	5,470
05-Jun	2,701	645	40	113	35	8	0	34	3,576
06-Jun	1,011	636	36	87	21	5	0	35	1,831
07-Jun	6,642	448	74	142	44	5	0	40	7,395
08-Jun	6,192	704	91	65	40	7	0	36	7,135
09-Jun	3,603	383	92	58	51	3	0	46	4,236
10-Jun	2,662	499	35	35	27	2	6	38	3,304
11-Jun	4,544	969	50	31	23	2	0	39	5,658
12-Jun	1,688	1,249	85	130	43	6	0	24	3,225
13-Jun	2,007	531	100	57	49	9	0	19	2,772
14-Jun	5,578	376	47	33	35	2	0	21	6,092
15-Jun	5,978	331	78	25	57	2	0	30	6,501
16-Jun	8,366	608	293	36	73	4	0	37	9,417
17-Jun	6,891	895	668	64	72	27	1	20	8,638
18-Jun	4,195	774	491	44	53	17	1	8	5,583
19-Jun	1,624	156	93	8	32	9	0	15	1,937
20-Jun	2,104	110	137	14	220	16	0	14	2,615
21-Jun	453	53	492	40	13	13	0	48	1,112
22-Jun	292	29	839	36	14	14	0	14	1,238
23-Jun	869	40	476	66	587	16	1	10	2,065
24-Jun	99	36	600	34	6	4	0	22	801
25-Jun	70	15	206	27	8	1	0	10	337
26-Jun	1,685	7	274	44	16	0	0	14	2,040
27-Jun	442	4	92	8	9	0	0	28	583
28-Jun	44	3	255	16	23	2	0	34	377
29-Jun	170	6	243	23	10	4	0	29	485
30-Jun	292	5	198	24	5	3	0	15	542
Total	111,647	15,624	7,308	3,537	1,731	312	21	1,042	141,222

[a] Traps generally fished 12 May through 30 June, exceptions are noted for individual trap results.

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Table 2. Numbers of juvenile fish caught with inclined plane traps in the Kenai River, 1990-1994.

Trap No.	Numbers of Fish: Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
1990									
1	8,708	481	861	300	[a]	87	23	148	10,608
2	18,132	180	1,168	239	[a]	69	17	134	19,939
3	59,528	631	2,776	232	[a]	106	100	184	63,557
4	43,499	43	3,114	68	[a]	58	44	272	47,098
Total	129,867	1,335	7,919	839		320	184	738	141,202
1991									
1	1,758	62	451	131	93	27	[a]	177	2,699
2	3,291	30	918	97	224	31	[a]	161	4,752
3	10,540	23	1,526	62	775	10	[a]	200	13,136
4	10,239	17	1,697	57	832	9	[a]	182	13,033
Total	25,828	132	4,592	347	1,924	77		720	33,620
1992									
1	47	1,594	500	944	141	117	23	183	3,549
2	189	306	598	274	338	44	23	159	1,931
3	1,205	223	1,198	229	1,021	46	32	179	4,133
4	1,725	82	1,544	136	1,968	45	17	269	5,786
Total	3,166	2,205	3,840	1,583	3,468	252	95	790	15,399
1993									
1	74	2,039	340	797	48	278	4,179	151	7,906
2	329	1,558	903	598	252	328	17,062	230	21,260
3	2,146	1,215	1,460	532	723	374	44,815	203	51,468
4	651	585	1,007	396	669	330	20,734	223	24,595
5	322	2,612	681	863	188	780	1,739	169	7,185
6	348	2,650	397	1,304	102	767	1,267	168	6,835
Total	3,870	10,659	4,788	4,490	1,982	2,857	89,796	1,144	119,249
1994									
1	11,702	5,777	1,329	1,188	264	99	8	205	20,572
2	18,147	2,040	1,922	542	296	73	2	216	23,238
3	27,058	1,322	1,611	198	353	31	2	189	30,764
4	16,003	585	1,411	138	473	17	4	195	18,826
5	22,673	2,171	618	571	239	57	2	118	26,449
6	16,064	3,729	417	900	106	35	3	119	21,373
Total	111,647	15,624	7,308	3,537	1,731	312	21	1,042	141,222

[a]No Counts conducted

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Table 3. Dyed Kenai River sockeye salmon smolt releases and recaptures by date, 1994.

Date		Number of Fish Dyed	Numbers of Dyed Fish Released	Capture to Release Survival[a]	Number of Dyed Fish Recovered	Trap Efficiency[b]
21-May		3,155	3,085	0.978		
22-May					27	
23-May					1	
Total	21-23 May	3,155	3,085	0.978	28	0.009
25-May		3,138	3,095	0.986		
26-May					30	
Total	25-26 May	3,138	3,095	0.986	30	0.010
28-May		572	554	0.969		
29-May		386	378	0.979	4	
30-May		1,615	1,601	0.991	2	
31-May		778	678	0.871	25	
01-Jun		594	564	0.949	5	
02-Jun					3	
Total	28 May-2 Jun	3,945	3,775	0.957	39	0.010
03-Jun		3,284	3,126	0.952		
04-Jun					17	
Total	3-4 Jun	3,284	3,126	0.952	17	0.005
05-Jun		1,668	1,598	0.958	4	
06-Jun		642	615	0.958	6	
Total	5-6 Jun	2,310	2,213	0.958	10	0.047
07-Jun		3,087	2,998	0.971	7	
08-Jun					15	
Total	7-8 Jun	3,087	2,998	0.971	22	0.007
09-Jun		1,240	1,173	0.946		
10-Jun		862	782	0.907	9	
11-Jun		1,111	1,033	0.930	11	
12-Jun		202	165	0.817	4	
Total	9-12 Jun	3,415	3,153	0.923	24	0.008
14-Jun		1,398	1,344	0.961		
15-Jun		2,244	2,070	0.922	10	
16-Jun					19	
17-Jun					1	
Total	14-17 Jun	3,642	3,414	0.937	30	0.004
18-Jun		1,298	1,159	0.893		
19-Jun		404	356	0.881	6	
20-Jun		411	350	0.852	1	
21-Jun		193	159	0.824	2	
22-Jun		130	106	0.815		
23-Jun		146	120	0.822	1	
24-Jun		24	17	0.708		
Total	18-24 Jun	2,606	2,267	0.870	10	0.004
Total	21 May-24 Jun	28,582	27,126	0.949	210	0.008

[a]Number of dyed fish released/Number of dyed fish.

[b]Number of dyed fish recovered/Numbers of dyed fish released.

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Table 4. Results of sockeye salmon smolt dye tests conducted on the Kenai River, 1989-1994.

Date	Number of Fish Dyed and Released	Number of Dyed Fish Recovered	Trap Efficiency
1989 total	12,599	86	0.007
1990 period 1	2,793	21	0.008
1990 period 2-4	8,409	109	0.013
1991 total	1,923	19	0.010
1992 total	926	19	0.021
1993 total	1,934	6	0.003
1994 total	27,126	210	0.008

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Table 5. Numbers of sockeye smolt by date and trap examined for marks, km 31 Kenai River, 1994.

Strata Dates	Total Dyed Sockeye Smolt Released	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6	All Traps	Traps 1 & 2	Traps 3 & 4	Traps 5 & 6	Traps 1- 4
		Number of dyed Sockeye Smolt recovered										
22-23 May	3,085	15	9	3	0	1	0	28				
26-27 May	3,095	5	12	2	3	3	5	30				
29 May-3 June	3,775	4	12	8	10	0	5	39				
22 May-3 June	9,955	24	33	13	13	4	10	97	57	26	14	83
4-5 June	3,126	3	5	6	3	0	4	21				
6-7 June	2,213	1	6	2	1	1	2	13				
8 June	2,998	5	5	2	2	1	0	15				
10-12 June	3,153	3	3	10	2	3	3	24				
15-17 June	3,414	2	7	12	6	3	0	30				
19-24 June	2,267	2	1	4	2	1	0	10				
4-24 June	17,171	16	27	36	16	9	9	113	43	52	18	95
Total	27,126	40	60	49	29	13	19	210				178

Total Sockeye Smolt examined for dyed fish

Dates	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6	All Traps	Traps 1 & 2	Traps 3 & 4	Traps 5 & 6	Traps 1- 4
22-23 May	1,884	1,018	489	303	736	668	5,098				
26-27 May	1,258	1,418	583	445	468	651	4,823				
29 May-3 June	1,676	3,105	4,653	1,870	1,297	2,650	15,251				
22 May-3 June	4,818	5,541	5,725	2,618	2,501	3,969	25,172	10,359	8,343	6,470	18,702
4-5 June	598	1,397	1,665	1,811	693	1,130	7,294				
6-7 June	327	1,054	1,867	2,002	1,199	1,204	7,653				
8-Jun	797	1,605	3,000	1,332	1,560	1,501	9,795				
10-12 June	798	1,773	3,827	2,269	5,210	2,602	16,479				
15-17 June	822	1,874	5,122	2,583	7,700	3,134	21,235				
19-24 June	440	1,317	2,327	1,519	1,229	364	7,196				
4-24 June	3,782	9,020	17,808	11,516	17,591	9,935	69,652	12,802	29,324	27,526	42,126
Total	8,600	14,561	23,533	14,134	20,092	13,904	94,824				60,828

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Table 6. Results of Chi-square analysis of marked to unmarked ratios by trap and time strata, km 31 Kenai River, 1994.

Comparison of Trap Efficiencies through Time

Strata Start Date	Strata End Date	Dye Event	Calculated Chi-square Value	P Value
22-23 May	26-27 May	1-2	0.062	0.803
22-23 May	29 May-3 June	1-3	0.273	0.884
22-23 May	4-5 June	1-4	2.691	0.442
22-23 May	6-7 June	1-5	5.006	0.116
22-23 May	8 June	1-6	9.328	0.098
22-23 May	10-12 June	1-7	9.437	0.152
22-23 May	15-17 June	1-8	9.569	0.216
22-23 May	19-24 June	1-9	13.467	0.098
4-5 June	6-7 June	4-5	0.144	0.705
4-5 June	8 June	4-6	0.761	0.684
4-5 June	10-12 June	4-7	1.780	0.619
4-5 June	15-17 June	4-8	3.876	0.424
4-5 June	19-24 June	4-9	5.927	0.314

Comparison of Marked to Unmarked Sockeye Smolt Among Traps

Strata Start Date	Strata End Date	Dye Event	Trap Numbers	Bank	Calculated Chi-square Value	P Value
22-23 May	19-24 June	all	all		73.878	0.000
22-23 May	19-24 June	all	1-4	left	25.176	0.000
22-23 May	19-24 June	all	5-6	right	4.514	0.034
22-23 May	29 May-3 June	1-3	all		17.569	0.004
22-23 May	29 May-3 June	1-3	1-4	left	9.386	0.025
22-23 May	29 May-3 June	1-3	5-6	right	0.599	0.439
4-5 June	19-24 June	4-9	all		44.852	0.000
4-5 June	19-24 June	4-9	1-4	left	12.942	0.005
4-5 June	19-24 June	4-9	5-6	right	1.508	0.220
22-23 May	29 May-3 June	1-3	1-2	left-inshore	0.442	0.506
22-23 May	29 May-3 June	1-3	3-4	left-offshore	4.169	0.041
4-5 June	19-24 June	4-9	1-2	left-inshore	1.21	0.272
4-5 June	19-24 June	4-9	3-4	left-offshore	1.574	0.210

x2rslts.xls

Table 7. Estimates of sockeye salmon smolt seaward migration from the Kenai River, 1994.

Trap Number	Total Migration[a]	Variance	Lower Confidence Interval	Upper Confidence Interval
1-2	8,480,667	5.776E+10	8,009,631	8,951,703
3-4	15,120,527	2.152E+11	14,211,237	16,029,818
5-6	36,440,042	3.918E+12	32,560,381	40,319,703
1-4	11,661,931	5.93E+10	11,184,763	12,139,100
all	15,286,138	8.911E+10	14,701,058	15,871,218

[a]Two time strata, 12 May through 3 June and 4 through 30 June.

dayestal.xls

Table 8. Cumulative proportion by day of sockeye salmon smolt seaward migration, 1989-1994.

	Age-1.						Age-2.					
Date	1989	1990	1991	1992	1993	1994	1989	1990	1991	1992	1993	1994
12-May						0.000						0.001
13-May						0.001						0.006
14-May						0.001						0.007
15-May		0.000				0.001		0.000				0.008
16-May	0.002	0.000	0.000	0.000		0.001	0.002	0.000	0.001	0.000		0.010
17-May	0.003	0.000	0.000	0.000	0.000	0.001	0.003	0.001	0.002	0.000	0.002	0.013
18-May	0.004	0.004	0.000	0.000	0.001	0.002	0.004	0.007	0.002	0.000	0.012	0.015
19-May	0.006	0.008	0.000	0.000	0.002	0.002	0.006	0.015	0.002	0.000	0.017	0.044
20-May*	0.008	0.036	0.000	0.000	0.003	0.006	0.008	0.067	0.004	0.000	0.024	0.180
21-May	0.010	0.078	0.000	0.000	0.004	0.026	0.010	0.146	0.007	0.000	0.031	0.218
22-May	0.015	0.101	0.000	0.000	0.004	0.047	0.015	0.190	0.015	0.000	0.031	0.242
23-May	0.024	0.105	0.003	0.000	0.005	0.060	0.024	0.197	0.169	0.000	0.045	0.283
24-May	0.031	0.106	0.005	0.000	0.009	0.082	0.031	0.200	0.256	0.000	0.078	0.320
25-May	0.038	0.112	0.007	0.001	0.012	0.102	0.038	0.217	0.328	0.001	0.104	0.356
26-May	0.042	0.169	0.010	0.001	0.022	0.122	0.042	0.387	0.469	0.001	0.193	0.402
27-May	0.059	0.197	0.011	0.001	0.043	0.133	0.059	0.471	0.538	0.001	0.368	0.419
28-May	0.072	0.204	0.015	0.001	0.056	0.137	0.072	0.490	0.550	0.002	0.461	0.439
29-May	0.082	0.216	0.027	0.002	0.059	0.142	0.082	0.503	0.583	0.002	0.505	0.489
30-May	0.096	0.282	0.041	0.002	0.063	0.155	0.096	0.574	0.624	0.003	0.547	0.568
31-May	0.134	0.350	0.055	0.004	0.080	0.174	0.134	0.647	0.664	0.004	0.694	0.615
01-Jun	0.185	0.373	0.063	0.004	0.210	0.195	0.185	0.672	0.687	0.004	0.741	0.643
02-Jun	0.202	0.391	0.089	0.007	0.298	0.207	0.202	0.691	0.759	0.007	0.774	0.706
03-Jun	0.229	0.469	0.102	0.009	0.347	0.234	0.229	0.730	0.797	0.010	0.792	0.807
04-Jun	0.292	0.569	0.113	0.026	0.512	0.279	0.292	0.781	0.830	0.028	0.852	0.867
05-Jun	0.401	0.706	0.126	0.036	0.542	0.305	0.401	0.851	0.865	0.039	0.864	0.874
06-Jun	0.708	0.793	0.133	0.079	0.586	0.316	0.708	0.895	0.887	0.086	0.880	0.918
07-Jun	0.809	0.874	0.155	0.099	0.717	0.383	0.809	0.936	0.898	0.108	0.928	0.959
08-Jun	0.831	0.918	0.179	0.107	0.779	0.446	0.831	0.958	0.910	0.117	0.951	0.982
09-Jun	0.851	0.979	0.198	0.135	0.802	0.482	0.851	0.989	0.919	0.147	0.960	1.000
10-Jun	0.865	0.983	0.225	0.155	0.809	0.509	0.865	0.992	0.933	0.169	0.962	
11-Jun	0.871	0.986	0.245	0.206	0.814	0.556	0.871	0.993	0.943	0.234	0.964	
12-Jun	0.881	0.988	0.277	0.272	0.820	0.574	0.881	0.994	0.950	0.366	0.966	
13-Jun	0.888	0.989	0.329	0.332	0.820	0.595	0.888	0.995	0.962	0.467	0.966	
14-Jun	0.907	0.990	0.366	0.352	0.822	0.653	0.907	0.995	0.970	0.502	0.967	
15-Jun	0.911	0.991	0.392	0.578	0.823	0.715	0.911	0.995	0.976	0.883	0.967	
16-Jun	0.925	0.993	0.403	0.657	0.824	0.801	0.925	0.996	0.979	0.905	0.967	
17-Jun	0.934	0.994	0.411	0.735	0.825	0.872	0.934	0.997	0.980	0.927	0.967	
18-Jun	0.937	0.994	0.412	0.773	0.827	0.916	0.937	0.997	0.980	0.937	0.967	
19-Jun	0.943	0.994	0.438	0.818	0.831	0.932	0.943	0.997	0.983	0.950	0.967	
20-Jun	0.949	0.996	0.530	0.892	0.831	0.954	0.949	0.998	0.991	0.970	0.967	
21-Jun	0.956	0.998	0.610	0.905	0.835	0.959	0.956	0.999	0.998	0.974	0.967	
22-Jun	0.960	0.999	0.711	0.907	0.843	0.962	0.960	0.999	0.998	0.974	0.967	
23-Jun	0.977	0.999	0.749	0.918	0.849	0.971	0.977	1.000	0.999	0.977	0.967	
24-Jun	0.989	0.999	0.766	0.922	0.861	0.972	0.989		0.999	0.978	0.970	
25-Jun	0.993	1.000	0.781	0.924	0.875	0.973	0.993		0.999	0.979	0.974	
26-Jun	0.997		0.904	0.925	0.907	0.990	0.997		0.999	0.979	0.983	
27-Jun	1.000		0.914	0.930	0.918	0.995	1.000		1.000	0.981	0.986	
28-Jun			0.928	0.961	0.929	0.995				0.989	0.989	
29-Jun			0.936	0.976	0.941	0.997				0.993	0.991	
30-Jun			0.941	1.000	0.953	1.000				1.000	0.993	
01-Jul			0.964		0.971						0.995	
02-Jul			0.973		0.999						1.000	
03-Jul			0.994		0.999							
04-Jul			0.994		1.000							
05-Jul			0.996									
06-Jul			0.997									
07-Jul			0.998									
08-Jul			1.000									
09-Jul												
mid date	6-Jun	4-Jun	20-Jun	15-Jun	4-Jun	10-Jun	6-Jun	29-May	27-May	14-Jun	29-May	30-May
# days 10%-90% of run	15	17	24	14	26	25	15	18	17	10	14	18

*Shaded area denotes date on which 0.1 increment reached.

cum%hist.xls

Table 9. Summary of Kenai River sockeye salmon smolt age composition, 1989-1994. Data collected at river km 31.

Sample Period	Percent of Seaward Migration Age- 0	Age-1	Age-2	Age-3	Sample Size
5/15-5/23/90	0.0	31.9	68.1	0.0	756
5/24-5/28/90	0.0	22.8	76.7	0.5	427
5/29-6/2/90	0.0	45.0	54.7	0.3	424
6/3-6/25/90	0.0	63.4	36.6	0.0	1,815
5/16-5/27/91	0.0	11.3	88.5	0.2	425
5/28-6/6/91	0.0	68.4	31.6	0.0	850
6/7-6/11/91	0.0	92.5	7.5	0.0	425
6/12-6/17/91	0.0	96.5	3.5	0.0	425
6/18-6/21/91	0.0	98.6	1.4	0.0	425
6/22-7/15/91	0.0	99.9	0.1	0.0	1,190
5/17-5/31/92	0.0	16.1	83.9	0.0	348
6/11-6/15/92	0.0	11.0	89.0	0.0	319
6/16-6/30/92	0.0	43.0	57.0	0.0	314
5/17-5/31/93	0.0	77.4	22.6	0.0	262
6/1-6/15/93	0.0	98.8	1.2	0.0	163
6/16-6/23/93	46.3	53.7	0.0	0.0	162
6/24-6/28/93	28.7	70.6	0.6	0.0	310
6/29-7/6/93	36.8	62.8	0.3	0.0	304
5/17-5/21/94	1.9	80.8	17.3	0.0	323
5/22-5/26/94	0.3	94.2	5.5	0.0	310
5/27-5/31/94	3.0	86.0	11.0	0.0	300
6/01-6/05/94	0.0	93.3	6.7	0.0	300
6/06-6/10/94	0.7	97.3	2.0	0.0	300
6/11-6/15/94	0.0	100.0	0.0	0.0	300
6/16-6/20/94	1.0	99.0	0.0	0.0	300
6/21-6/25/94	0.3	99.7	0.0	0.0	297
6/26-6/30/94	0.0	100.0	0.0	0.0	275
Season Summary					
1989	0.0	99.7	0.3	0.0	3,557
1990	0.0	46.7	53.1	0.2	3,422
1991	0.0	86.1	13.9	0.0	3,740
1992	0.0	17.3	82.7	0.0	981
1993	8.5	88.5	3.0	0.0	1,200
1994	0.7	95.7	3.6	0.0	2,705

agehist.xls

Table 10. Summary of sockeye salmon smolt mean length and weight by age class and time strata, 1989-1994. Data collected at river km 31.

Year	Time Period	Length N	Length Mean	Length Min.	Length Max.	Length Var.	Length Stand. Dev.	Weight N	Weight Mean	Weight Min.	Weight Max.	Weight Var.	Weight Stand. Dev.
					Age-1.								
89	5/16-20	413	60	46	80	19	4	413	1.9	0.8	4.3	0.18	0.42
	5/21-25	338	61	60	72	22	5	338	2.1	1.2	3.3	0.13	0.38
	5/26-30	421	60	53	77	17	4	421	1.9	1.2	3.8	0.15	0.39
	5/31-04	424	59	49	70	13	4	424	1.8	1.0	3.4	0.13	0.36
	6/06-09	423	59	46	73	15	4	424	1.8	0.8	3.7	0.15	0.39
	6/10-14	425	58	49	74	14	4	425	1.8	1.1	3.5	0.12	0.35
	6/15-19	429	58	46	75	17	4	429	1.8	0.2	4.0	0.20	0.45
	6/20-27	679	60	19	85	19	4	679	2.1	1.0	5.4	0.26	0.51
90	5/15-23	241	65	48	82	30	5	241	2.2	1.0	4.2	0.34	0.59
	5/24-28	97	63	52	78	25	5	97	2.0	1.0	3.8	0.27	0.52
	5/29-6/02	191	61	47	90	25	5	191	1.9	0.8	5.3	0.28	0.53
	6/03-25	1,150	70	52	138	53	7	1,150	3.1	1.0	23.8	2.17	1.47
91	5/23-27	48	73	52	110	92	10	48	3.4	1.8	10.4	2.15	1.47
	5/28-6/01	292	65	52	89	41	6	292	2.3	1.1	5.5	0.55	0.74
	6/02-06	289	67	55	100	44	7	289	2.5	1.3	7.4	0.75	0.86
	6/07-11	393	64	50	79	16	4	393	2.4	1.2	4.8	0.22	0.46
	6/13-17	410	65	49	84	16	4	410	2.7	1.2	5.9	0.31	0.56
	6/18-21	419	65	50	79	21	5	419	2.8	1.3	5.6	0.40	0.63
	6/22-25	340	66	50	84	19	4	340	2.9	1.3	5.6	0.34	0.58
	6/26-30	424	65	50	75	11	3	424	2.7	1.2	4.3	0.21	0.46
	7/01-05	425	67	54	80	13	4	425	3.1	1.5	5.9	0.31	0.55
92	6/05-10	56	74	60	90	54	7	28	3.9	2.5	6.3	1.21	1.10
	6/11-15	35	78	66	95	35	6	17	5.1	3.2	10.7	3.03	1.74
	6/16-29	135	78	58	130	86	9	97	4.7	1.9	22.0	5.33	2.31
93	5/17-31	203	76	59	124	81	9	145	4.4	2.0	19.7	3.5	1.9
	6/01-15	161	76	60	93	46	7	161	4.1	1.8	7.1	1.4	1.2
	6/16-23	87	79	65	91	38	6	87	4.5	2.2	7.4	1.2	1.1
	6/24-28	219	80	62	90	18	4	219	4.9	2.3	8.2	0.7	0.8
	6/29-7/06	191	79	65	90	17	4	191	5.0	2.9	6.6	0.4	0.7
94	5/17-21	261	63	45	81	36	6	104	2.2	0.7	3.5	0.3	0.5
	5/22-26	292	61	50	75	15	4	144	1.9	1.1	3.0	0.1	0.3
	5/27-31	258	61	48	77	23	5	79	2.1	0.8	5.1	0.4	0.6
	6/01-05	280	64	53	96	21	5	96	2.3	1.5	7.3	0.4	0.6
	6/06-10	292	64	50	76	17	4	93	2.3	1.4	3.4	0.2	0.4
	6/11-15	300	65	55	76	12	3	100	2.6	1.8	3.2	0.1	0.4
	6/16-20	297	65	50	126	47	7	99	2.7	1.4	19.3	2.9	1.7
	6/21-25	296	66	52	76	12	3	99	2.7	1.6	4.1	0.2	0.5
	6/26-30	275	67	54	79	8	3	100	2.8	1.4	3.7	0.1	0.3
					Age-2.								
90	5/15-23	515	74	62	123	21	5	515	3.2	1.9	13.4	0.55	0.74
	5/24-28	326	74	61	115	35	6	326	3.2	1.8	8.8	0.68	0.82
	5/29-6/02	232	74	62	104	43	7	232	3.2	1.2	8.9	1.12	1.06
	6/03-25	665	75	60	102	28	5	665	3.7	1.8	7.8	0.71	0.84
91	5/23-27	376	80	71	108	29	5	376	4.2	2.8	10.7	1.07	1.03
	5/28-6/01	133	79	70	101	32	6	133	4.1	3.0	8.9	1.01	1.01
	6/02-06	136	79	68	110	41	6	136	4.2	2.5	10.1	1.30	1.14
	6/07-11	32	78	70	91	25	5	32	4.1	2.4	6.3	0.85	0.92
	6/13-17	15	76	68	86	20	4	15	4.0	3.3	5.2	0.29	0.54
92	6/05-10	292	97	71	117	62	8	151	7.7	3.3	11.2	2.73	1.65
	6/11-15	284	89	76	110	22	5	156	6.9	4.3	10.4	1.08	1.04
	6/16-29	179	89	69	111	20	4	134	6.5	3.2	12.0	1.16	1.08
93	5/17-31	59	99	86	115	47	7	33	8.5	6.1	14.0	3.60	1.90
94	5/17-21	56	81	67	90	20	4	24	4.4	2.7	5.6	0.5	0.7
	5/22-26	17	79	65	87	31	6	7	3.8	2.1	5.5	1.1	1.0
	5/27-31	33	78	67	84	14	4	17	4.0	2.7	5.1	0.3	0.6
	6/01-05	20	80	71	99	46	7						

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Table 11. Morphological information collected from Hidden Creek, Moose River and Russian River sockeye salmon smolt, 1994.

		HIDDEN CREEK	MOOSE RIVER	RUSSIAN RIVER
Age-1	N =	1,316	1	622
	Percent	92.0%	0.3%	20.9%
Length (mm)	N =	1,316		622
	Range =	93 - 153		67 - 122
	Mean =	129		85
	Var =	48		26
	Stdev =	7		5
Weight (gm)	N =	1,289		622
	Range =	4.8 - 35.9		2.5 -13.7
	Mean =	19.9		6.0
	Var =	21.4		1.0
	Stdev =	4.6		1.0
Age-2	N =	111	260	2,339
	Percent	7.8%	88.1%	78.5%
Length (mm)	N =	111	260	2,339
	Range =	127 - 207	105 - 168	71 - 125
	Mean =	178	128	97
	Var =	373	124	90
	Stdev =	19	11	10
Weight (gm)	N =	109	260	2,339
	Range =	15.9 - 90.0	11.5 - 48.2	2.9 - 16.9
	Mean =	46.4	21.2	8.0
	Var =	322.5	40.3	4.7
	Stdev =	18.0	6.3	2.2
Age-3	N =	4	34	20
	Percent	0.3%	11.5%	0.7%
Length (mm)	N =		34	20
	Range =		123 - 175	93 - 137
	Mean =		153	115
	Var =		289	205
	Stdev =		17	14
Weight (gm)	N =		34	20
	Range =		19.4 - 55.0	7.5 - 21.3
	Mean =		36.1	13.6
	Var =		125.9	22.1
	Stdev =		11.2	4.7

awlhl&mr.xls

Table 12. Hydrological parameters measured daily at the Kenai River km 31 site, 1994.

Date	Water Level (m)	Water Temp (C)	Turbidity Reading (cm)	Water Velocity (mps) Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	trap 6
14-May	0.05	6		0.79	0.85	0.88	0.85	0.82	0.58
15-May	0.06	6							
16-May	0.08	7							
17-May	0.09	7							
18-May	0.16	5	86						
19-May	0.16	5	84	0.70		0.58		0.58	
20-May	0.18	7	86						
21-May	0.18	7	84						
22-May	0.20	7	86						
23-May	0.23	7	91						
24-May	0.26	7	91						
25-May	0.27	4	89						
26-May	0.28	6	91	0.85	0.98	0.94	0.94	0.85	0.70
27-May									
28-May	0.32	7		0.79	1.04	0.91	1.04		
29-May	0.38	7							
30-May	0.32	7	89						
31-May	0.34	9	86						
1-Jun	0.34	8	86						
2-Jun	0.34	8	89						
3-Jun	0.34	9	97						
4-Jun	0.38	8	79						
5-Jun	0.40	9	91						
6-Jun	0.37	9	91						
7-Jun	0.38	9	86						
8-Jun	0.43	9	81						
9-Jun									
10-Jun	0.44	9	66	0.85	0.91	1.07	1.07	1.07	1.07
11-Jun	0.44	9	71						
12-Jun									
13-Jun	0.48	10	81						
14-Jun	0.48	11	79						
15-Jun	0.54	11	79						
16-Jun	0.55	10	69						
17-Jun									
18-Jun	0.58	10	61						
19-Jun	0.61	10	58						
20-Jun	0.64	11	58						
21-Jun	0.67	11	56						
22-Jun	0.76	10	56						
23-Jun									
24-Jun									
25-Jun	0.88	9	53						
26-Jun	0.88	9	71						
27-Jun	0.88	9	71						
28-Jun	0.88	10	71						
29-Jun	0.85	9	76	1.65	1.83	1.86	1.86	1.80	1.74
30-Jun	0.82	10	74						

enviro2.xls

Table 13. Relationship between smolt outmigration and adult return for Kenai River age-1.2, -1.3, -2.2 and -2.3 sockeye salmon. All smolt and adult numbers are in thousands of fish.

Brood Year	Age-1. Smolt[a]	Adult Return Age-1.2	Age-1.3	Smolt to Adult Survival	Age-2. Smolt	Adult Return Age-2.2	Age-2.3	Age-2. Smolt to Adult Survival
86		312	721		115	140	599	
87	24,416	565	7,196	31.8%	5,807	225	1,851	35.7%
88	5,249	91	1,246	25.5%	431	209	424	146.9%
89	2,776	249	2,134	85.8%	312	335	712	335.6%
90	253	154	574	287.7%	36	125		347.2%
91	797	484		60.7%				
Average				98.3%				216.4%

[a]Includes Hidden Lake (1987-1991) and Moose River (1990-1991) smolt not thought to be captured by the km 31 traps.

survival.xls

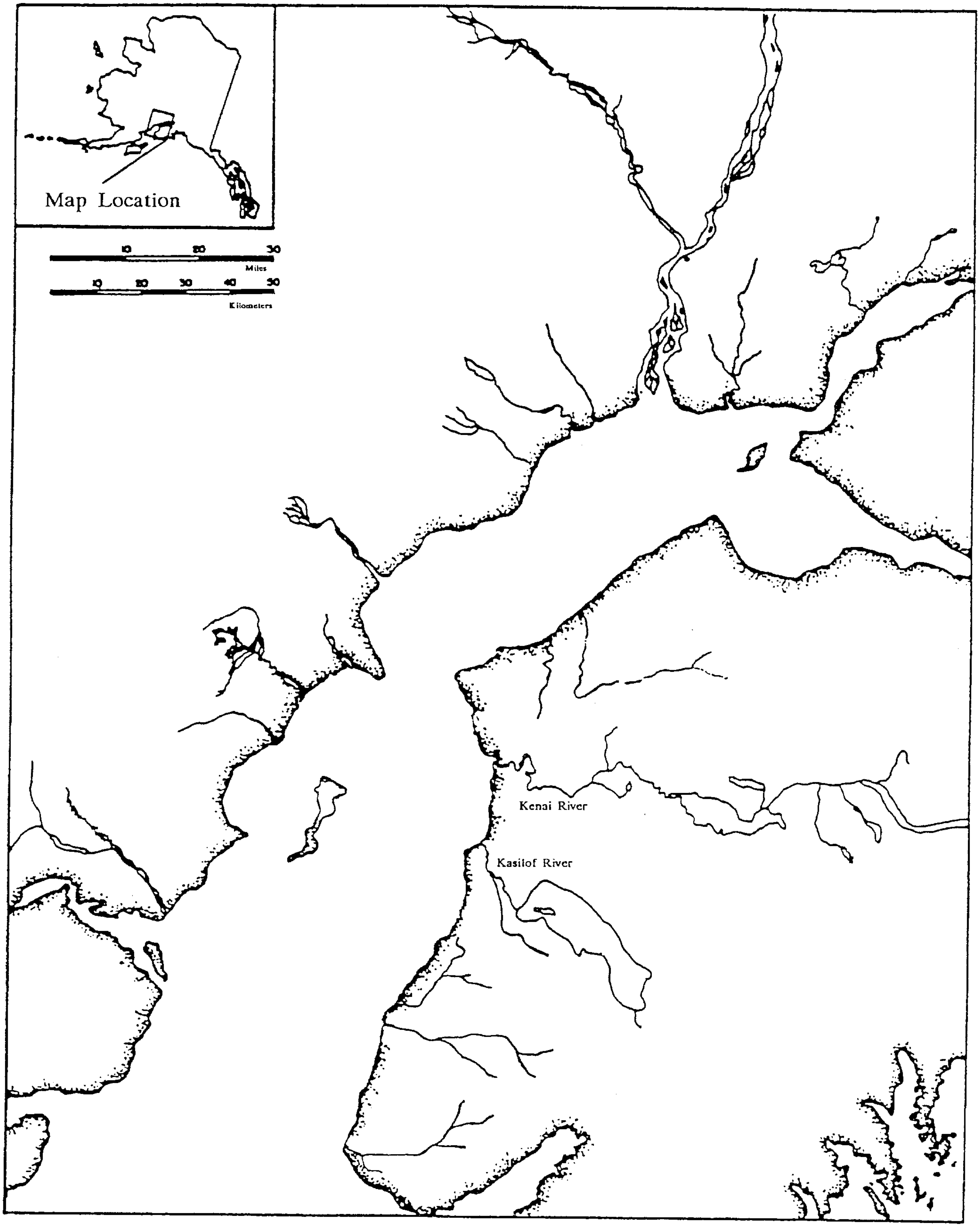


Figure 1. Map of upper Cook Inlet, Alaska, showing the location of the Kenai and Kasilof Rivers.

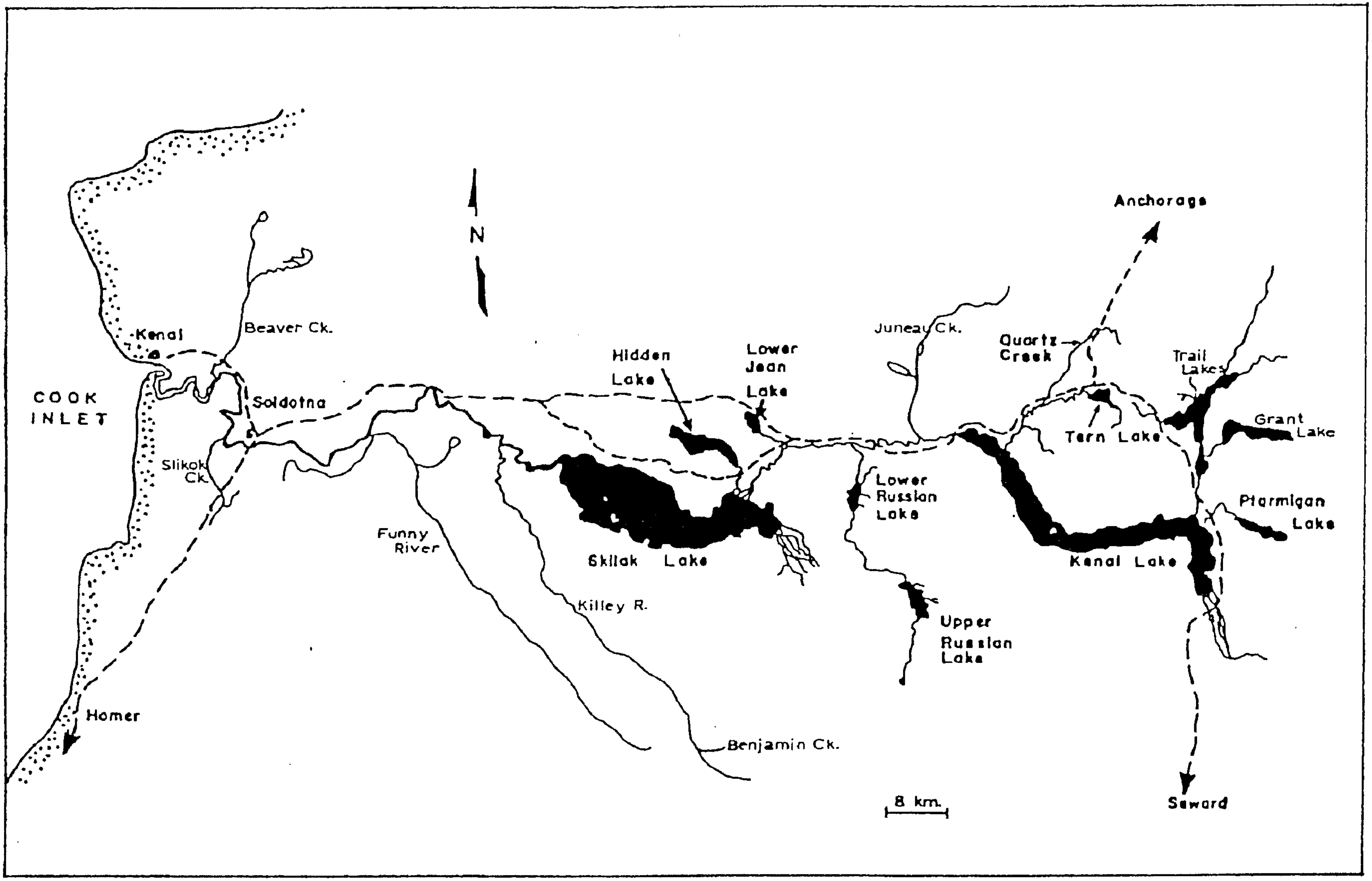


Figure 2. Kenai River drainage and major sockeye salmon rearing lakes.

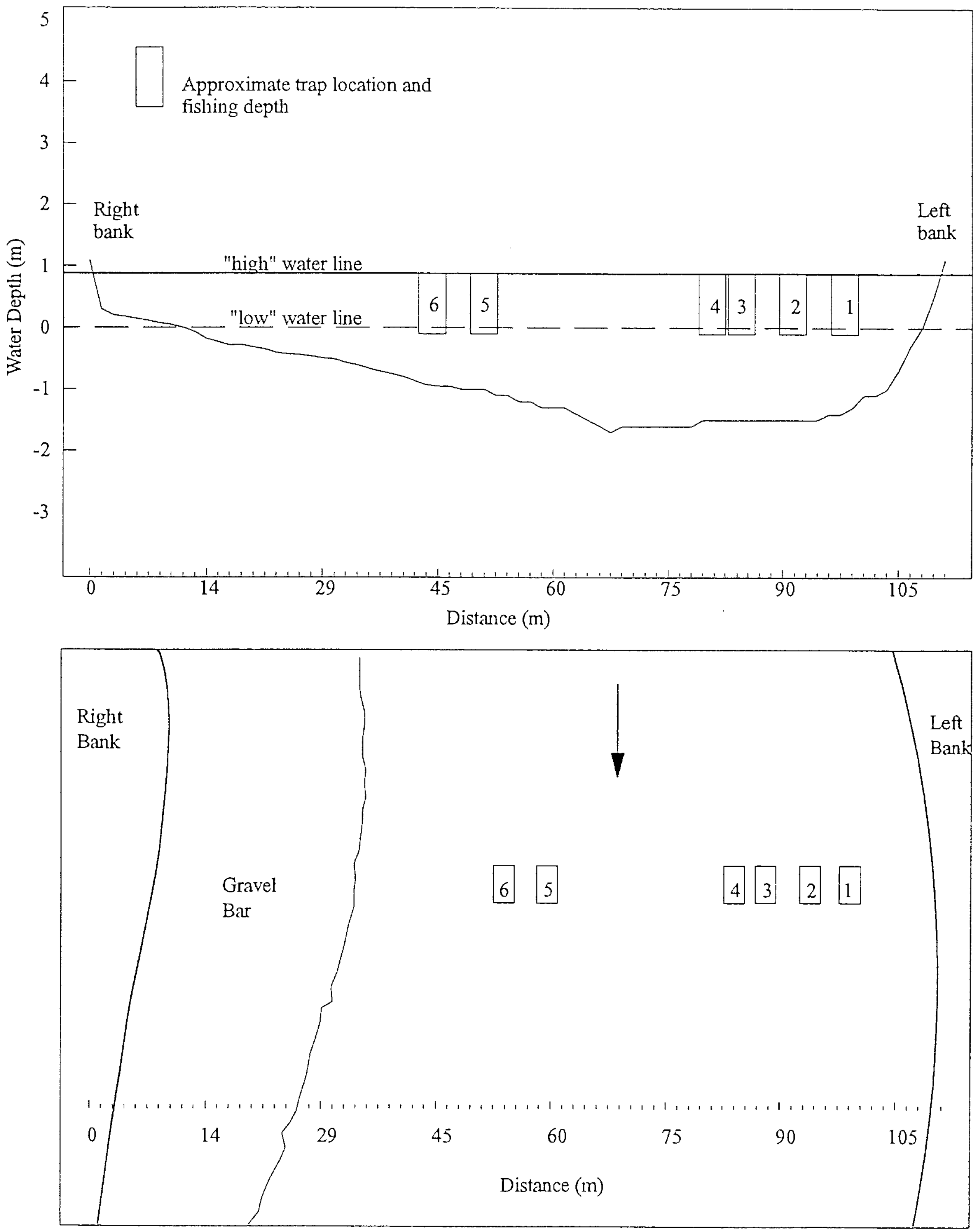
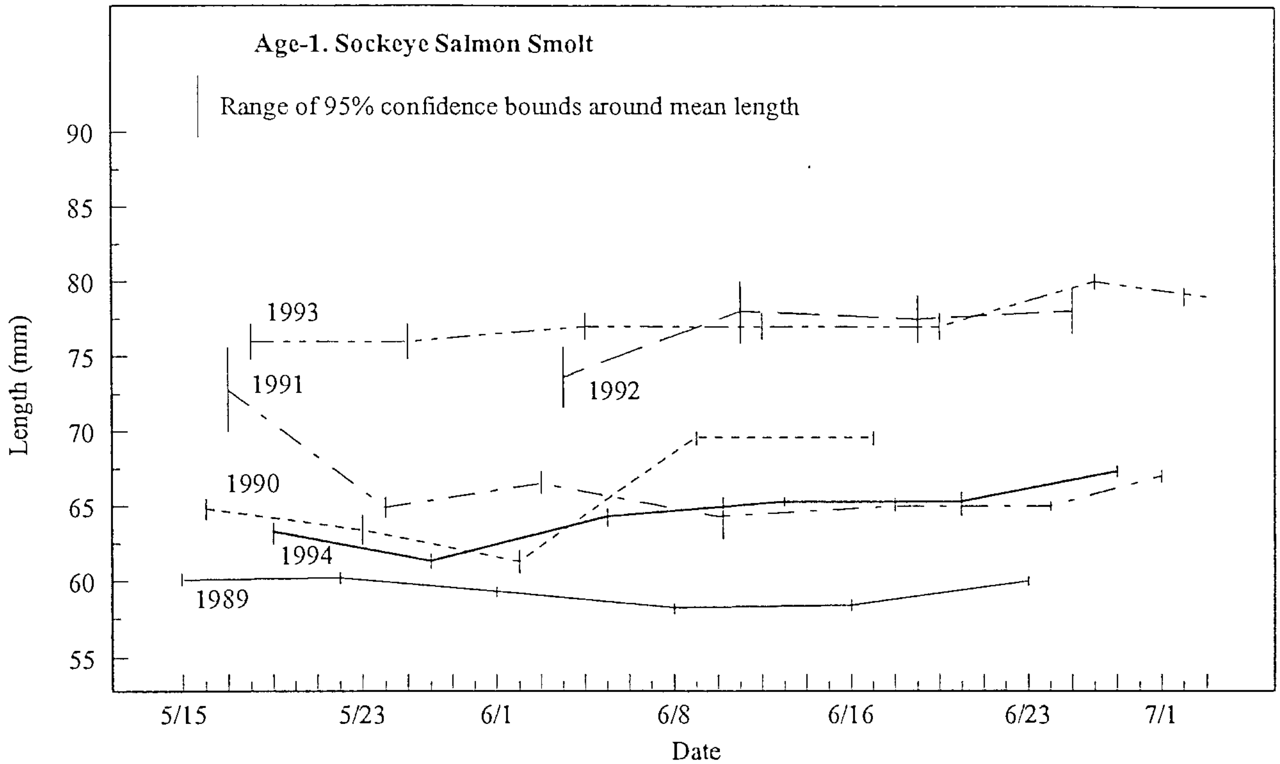


Figure 3. Cross section (top) and aerial view, Kenai River km 31 sockeye salmon smolt enumeration project site, 1994. traploc.pre



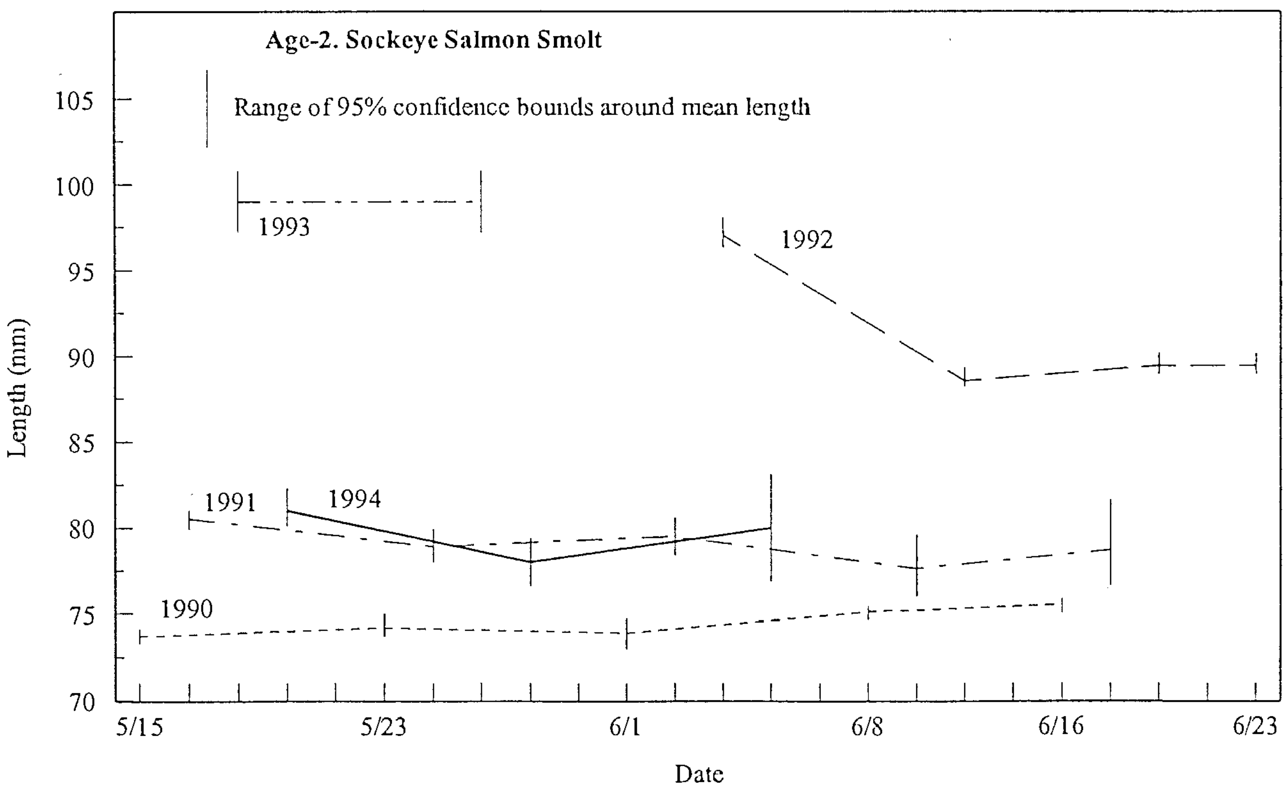
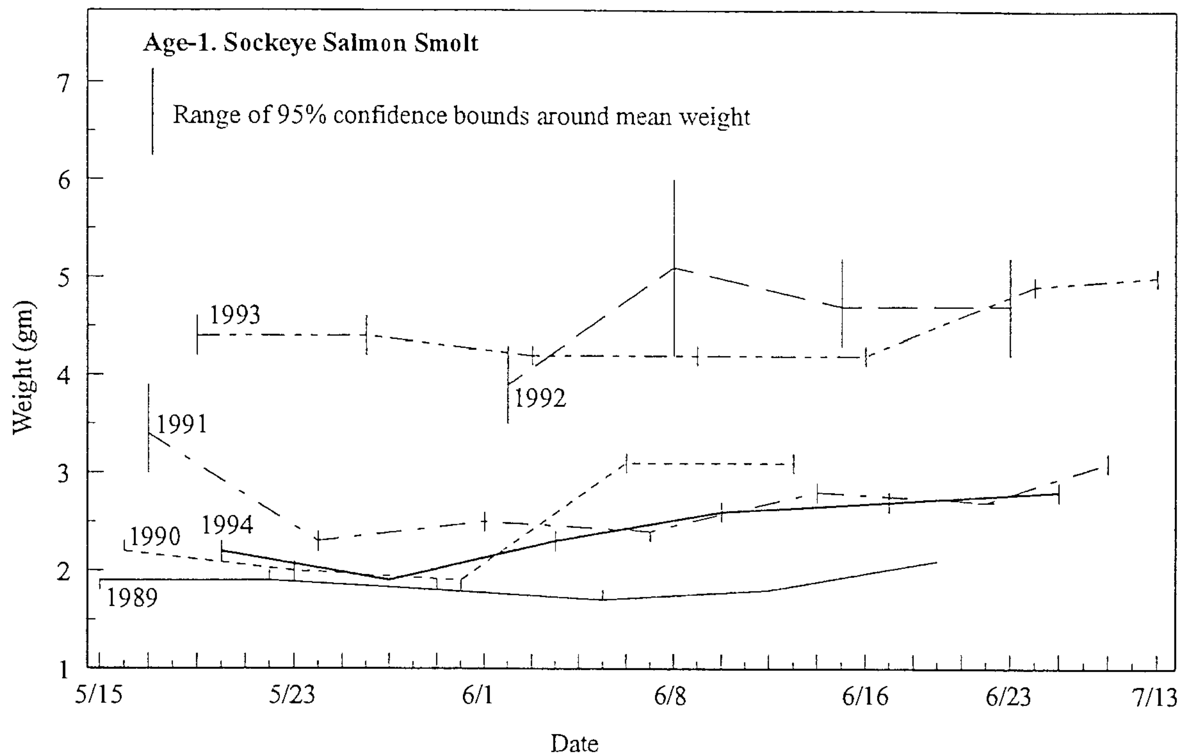


Figure 4. Mean lengths and 95% confidence bounds for age-1. (top) and age-2. sockeye salmon smolt sampled at the Kenai River km 31 site, 1989-1994.

lnghist.pre



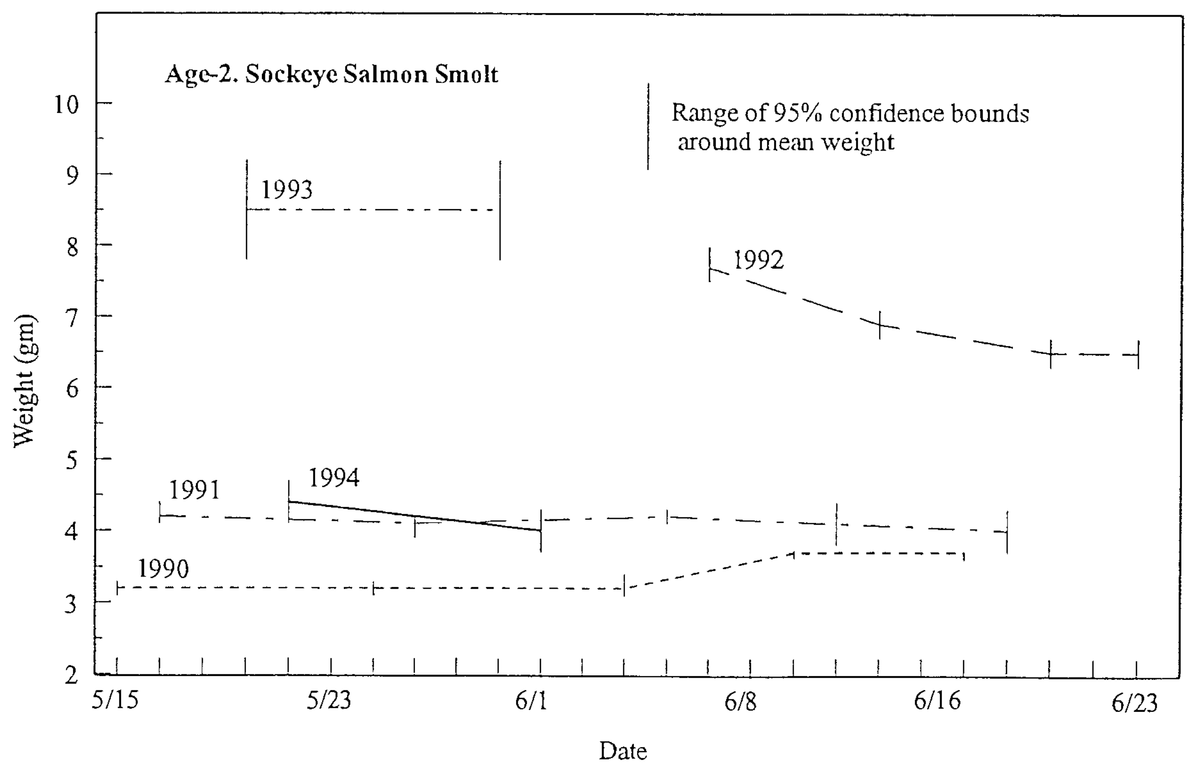
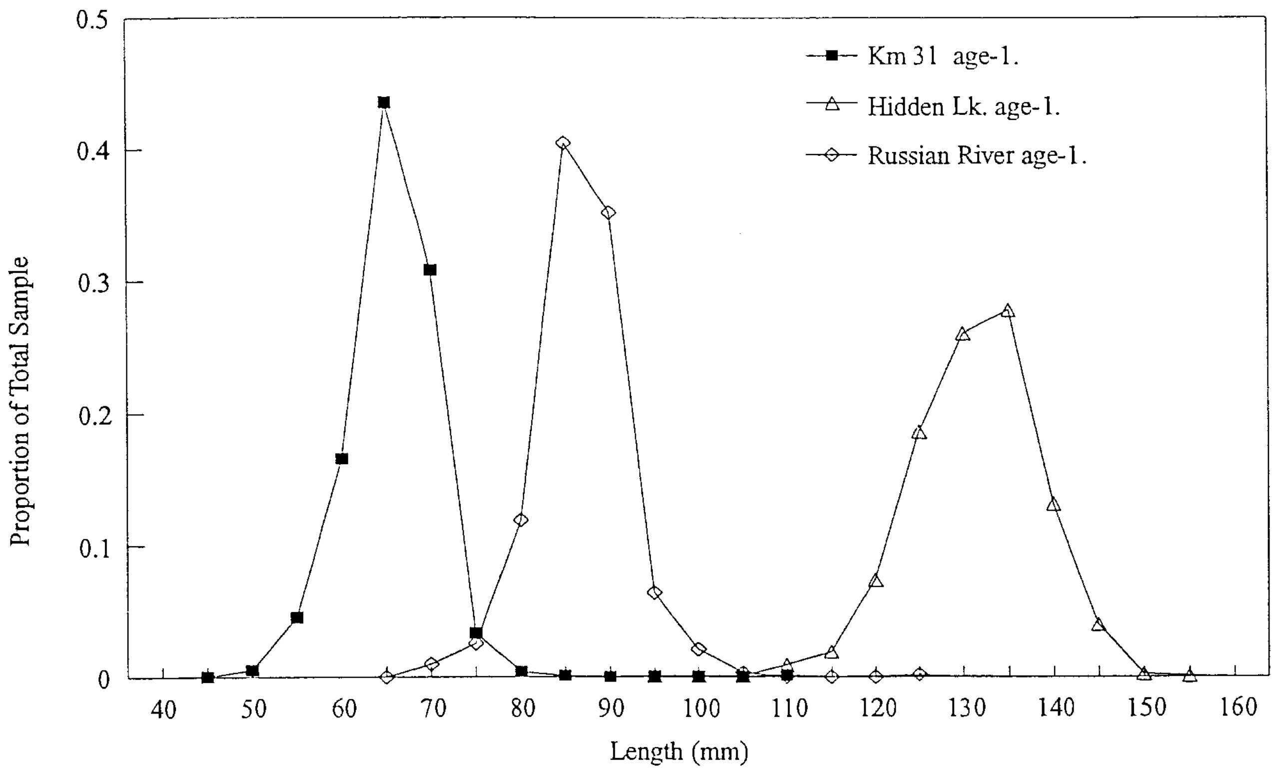


Figure 5. Mean weights and 95% confidence bounds for age-1. (top) and -2. sockeye salmon smolt sampled at the Kenai River km 31site, 1989-1994.



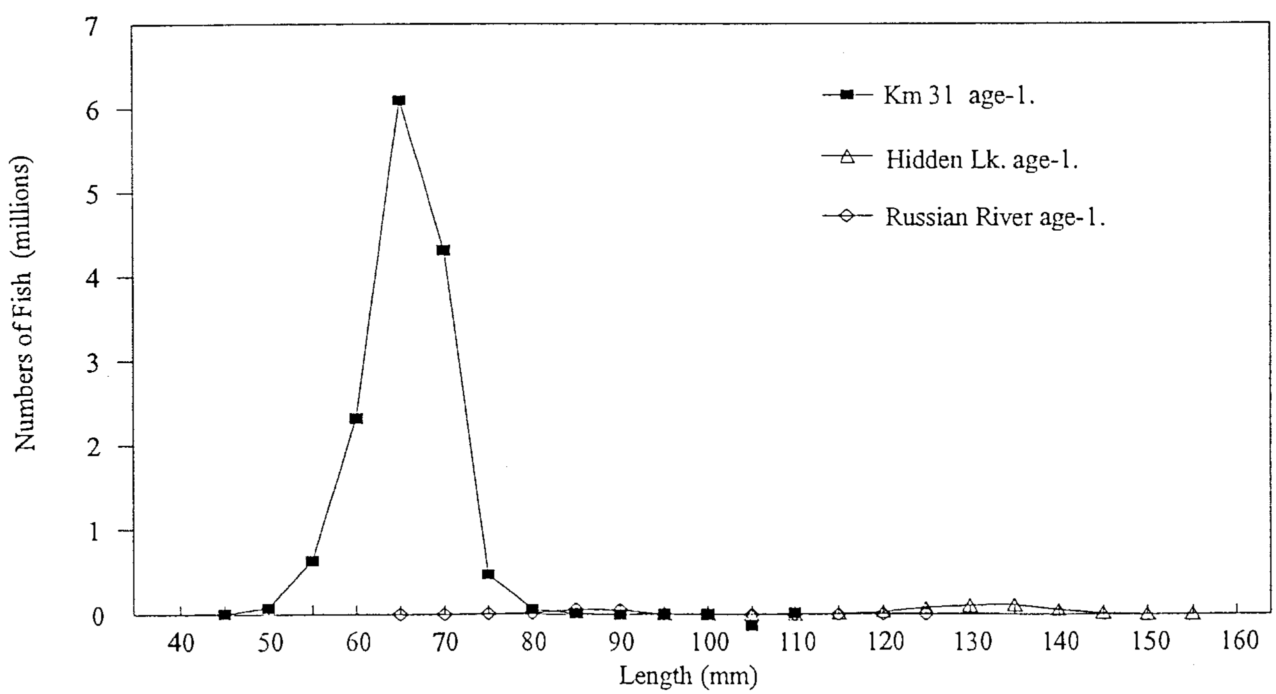


Figure 6. Length frequency distributions, unweighted (top) and weighted by migration estimate, for Kenai River drainage age-1. sockeye salmon smolt stocks, 1994.

lngfrq1.pre

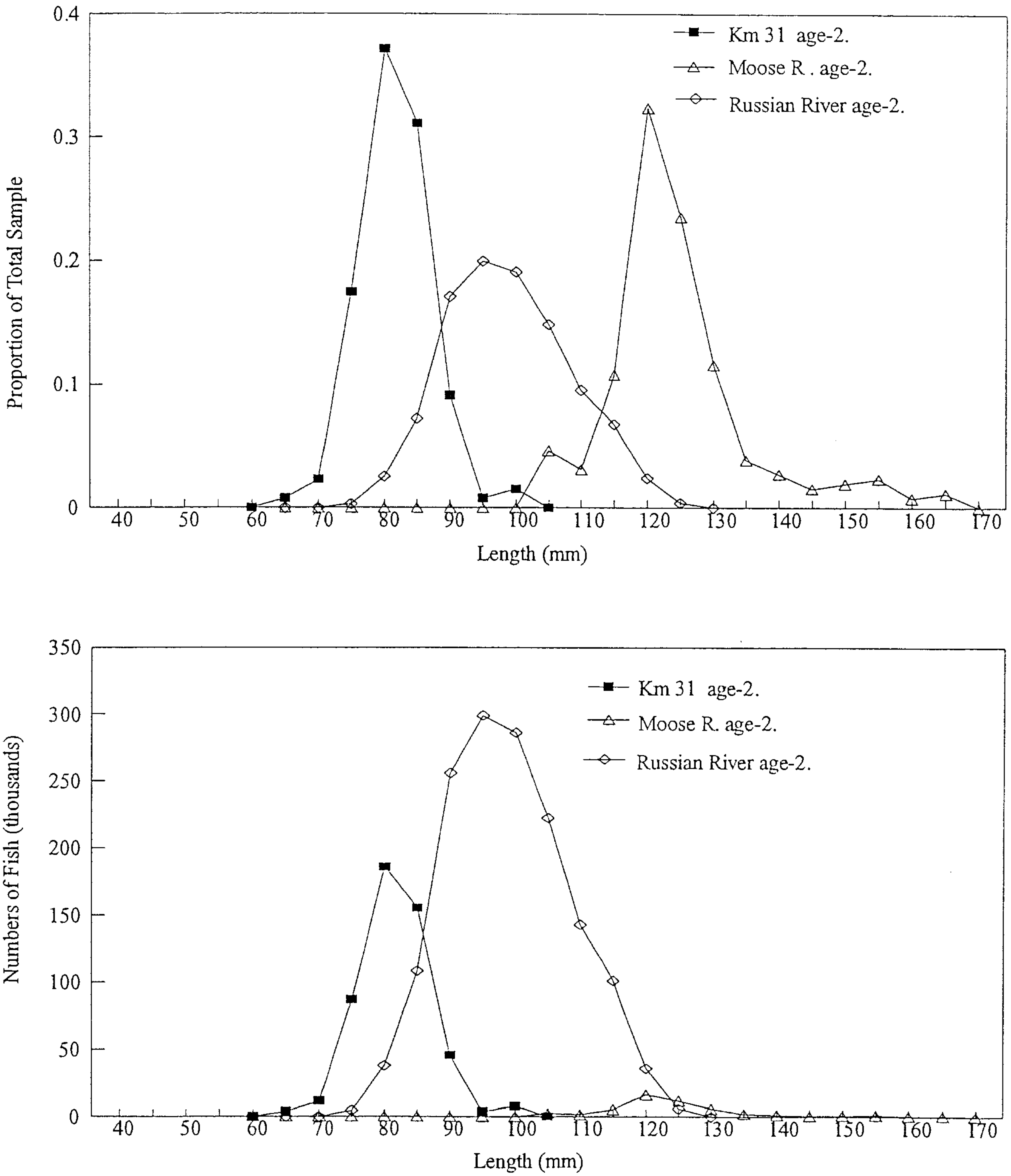


Figure 7. Length frequency distributions, unweighted (top) and weighted by migration estimate, for Kenai River drainage age-2. sockeye salmon smolt stocks, 1994.

lngfrq2.prc

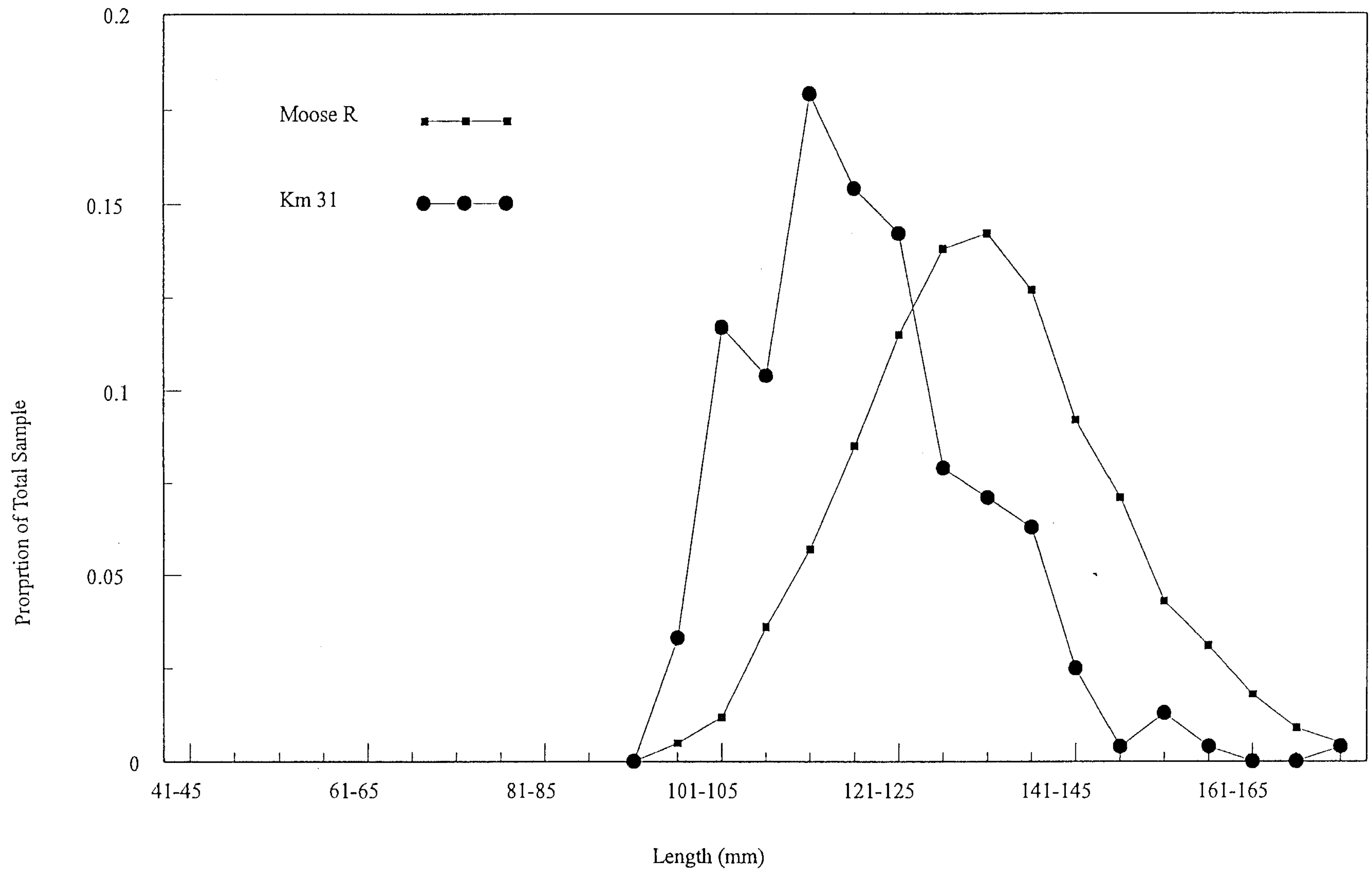


Figure 8. Length frequency distribution of coho salmon smolt caught in the Kenai River km 31 traps and the Moose River, 1994.

43lngfrq.pre

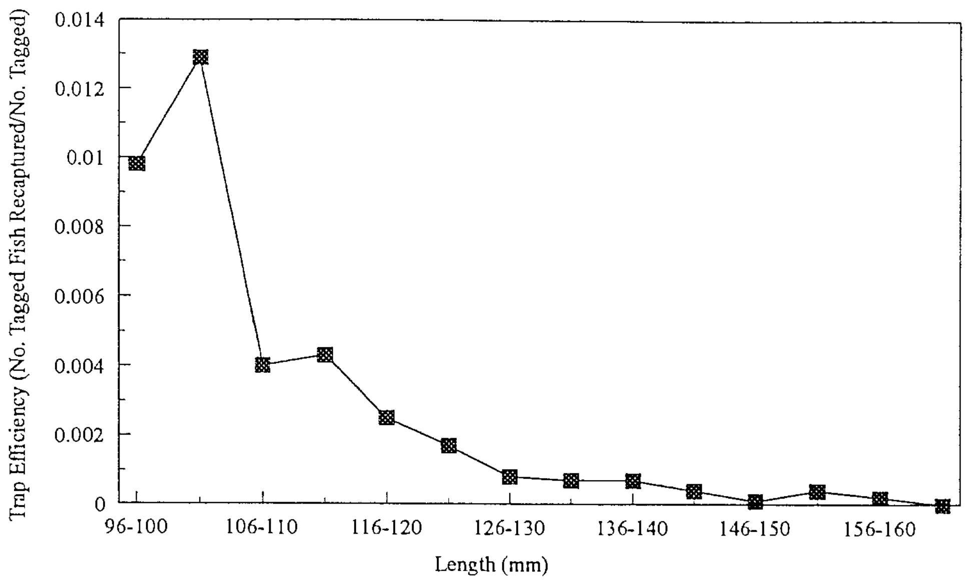


Figure 9. Capture efficiency (5 mm increments) of km 31 traps for different length coho salmon smolt, 1994.

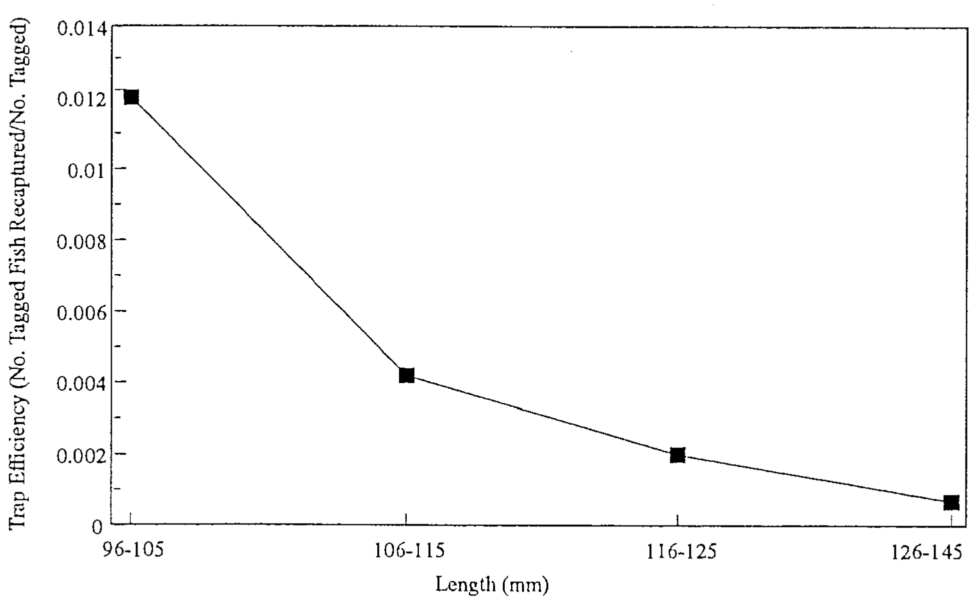


Figure 10. Capture efficiency (10 mm increments) of km 31 traps for different length coho salmon smolt, 1994.

4394eff2.pre

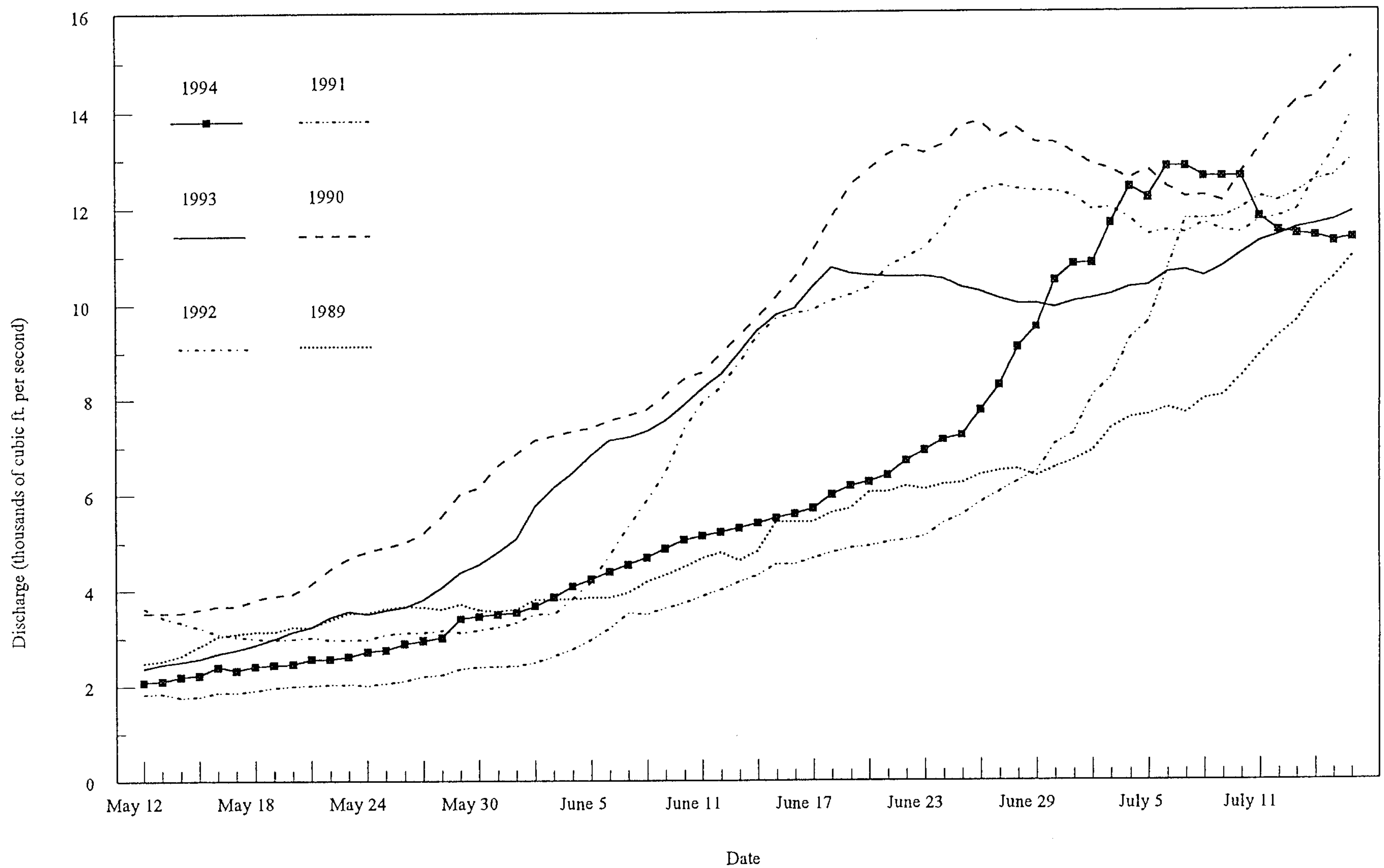


Figure 11. Daily discharge measured at km 34 of the Kenai River, 1989-1994.

discharg.pre

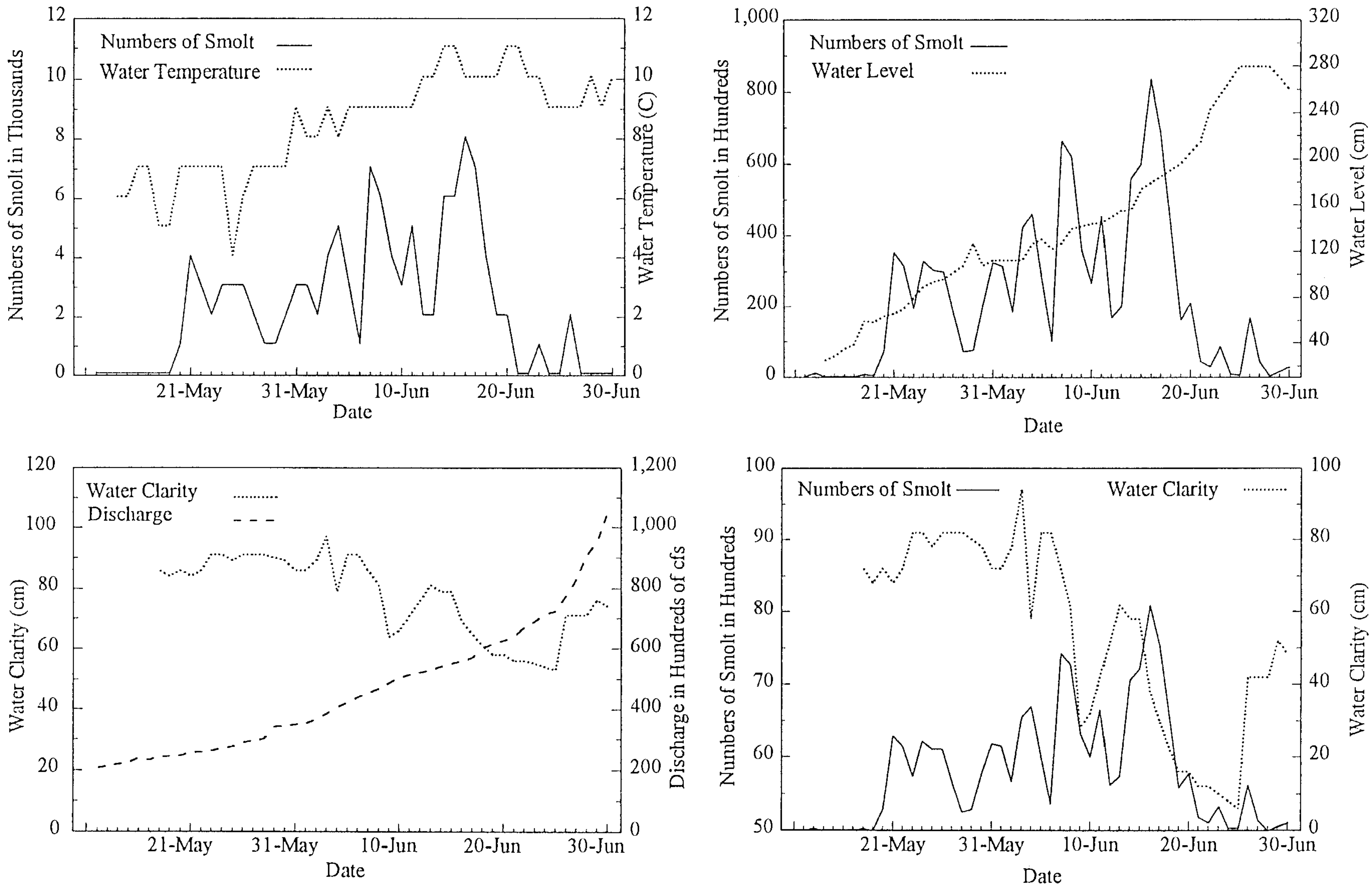


Figure 12. Comparison of Kenai River sockeye salmon smolt daily catches and hydrological parameters measured at km 31, 1994.

Enviro4.pre

Appendix A.1. Numbers of fish captured by trap 1 in the Kenai River, May 12 through June 27, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	8	52	10	48	0	2	0	0	120
13-May	31	62	2	62	0	4	0	0	161
14-May	2	28	0	5	0	0	0	1	36
15-May	11	10	19	29	0	0	0	1	70
16-May	9	106	10	38	0	0	0	2	165
17-May	7	144	0	39	0	0	0	1	191
18-May	39	71	23	17	0	4	0	1	155
19-May	15	182	27	140	1	1	0	2	368
20-May	168	143	43	70	1	1	0	4	430
21-May	957	78	54	45	1	18	0	3	1,156
22-May	1,215	85	41	33	0	5	0	7	1,386
23-May	669	95	34	34	0	1	3	5	841
24-May	967	51	26	10	0	9	0	5	1,068
25-May	465	50	9	19	0	1	0	1	545
26-May	674	27	13	20	2	2	0	5	743
27-May	584	22	10	21	1	3	0	5	646
28-May	185	43	8	32	0	1	0	6	275
29-May	121	37	7	13	0	2	0	3	183
30-May	177	53	9	24	0	2	5	3	273
31-May	404	105	15	26	0	0	0	2	552
01-Jun	448	220	3	40	2	1	0	5	719
02-Jun	234	242	9	23	1	0	0	4	513
03-Jun	292	281	7	14	1	0	0	5	600
04-Jun	267	225	8	34	0	1	0	5	540
05-Jun	331	206	7	20	1	3	0	4	572
06-Jun	92	175	6	22	1	2	0	5	303
07-Jun	235	141	11	35	2	1	0	4	429
08-Jun	456	276	13	18	2	1	0	4	770
09-Jun	341	131	12	28	2	0	0	6	520
10-Jun	173	152	7	10	0	0	0	8	350
11-Jun	212	252	7	12	1	0	0	10	494
12-Jun	241	345	14	45	2	0	0	9	656
13-Jun	49	211	3	7	0	1	0	5	276
14-Jun	123	88	3	3	0	0	0	2	219
15-Jun	198	65	3	1	1	0	0	5	273
16-Jun	383	162	19	5	2	0	0	5	576
17-Jun	241	585	100	40	9	7	0	2	984
18-Jun	216	324	95	9	1	0	0	1	646
19-Jun	41	83	18	6	1	5	0	5	159
20-Jun	104	47	14	6	83	4	0	4	262
21-Jun	29	37	88	13	1	5	0	29	202
22-Jun	41	26	168	11	1	6	0	5	258
23-Jun	115	25	91	25	139	4	0	1	400
24-Jun	3	19	159	9	2	2	0	4	198
25-Jun	9	9	48	11	1	0	0	2	80
26-Jun	98	3	47	15	2	0	0	2	167
27-Jun	22	3	9	1	0	0	0	7	42
Total	11,702	5,777	1,329	1,188	264	99	8	205	20,572

sptrp-1.xls

Appendix A.2. Numbers of fish captured by trap 2 in the Kenai River, May 12 through June 30, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	7	2	10	12	0	2	0	9	42
13-May	12	5	8	7	0	0	0	1	33
14-May	5	6	6	9	0	1	0	4	31
15-May	3	3	4	22	0	0	0	2	34
16-May	13	14	3	17	0	0	0	1	48
17-May	18	1	7	8	1	1	0	1	37
18-May	15	1	13	3	0	0	0	3	35
19-May	10	66	18	35	0	0	0	6	135
20-May	155	18	20	11	0	1	0	1	206
21-May	671	6	23	23	0	3	0	7	733
22-May	653	11	22	21	0	2	0	6	715
23-May	365	19	9	19	0	1	0	3	416
24-May	852	3	45	10	2	0	0	1	913
25-May	908	3	16	15	1	7	0	2	952
26-May	875	25	28	23	0	3	0	4	958
27-May	543	4	22	12	2	5	0	8	596
28-May	199	4	22	2	2	0	0	5	234
29-May	165	0	17	4	2	1	0	6	195
30-May	515	7	5	5	1	0	0	4	537
31-May	631	19	6	8	2	0	0	8	674
01-Jun	625	100	7	14	5	0	2	7	760
02-Jun	382	40	7	7	14	0	0	7	457
03-Jun	787	87	5	12	2	0	0	0	893
04-Jun	882	46	10	6	2	2	0	8	956
05-Jun	515	73	9	22	0	0	0	4	623
06-Jun	198	56	8	8	1	2	0	3	276
07-Jun	856	48	23	22	4	0	0	10	963
08-Jun	1,049	88	20	8	3	1	0	11	1,180
09-Jun	556	78	27	12	4	1	0	9	687
10-Jun	255	64	5	2	3	0	0	8	337
11-Jun	538	172	9	4	2	0	0	10	735
12-Jun	218	292	22	24	6	1	0	3	566
13-Jun	231	57	22	8	1	0	0	0	319
14-Jun	531	45	12	3	3	0	0	2	596
15-Jun	410	83	12	7	1	0	0	4	517
16-Jun	1,023	130	45	6	5	0	0	3	1,212
17-Jun	441	106	156	7	8	5	0	2	725
18-Jun	575	162	112	11	2	7	0	0	869
19-Jun	157	35	28	1	3	2	0	3	229
20-Jun	434	32	41	1	51	9	0	1	569
21-Jun	82	6	134	15	2	2	0	4	245
22-Jun	78	3	238	10	2	4	0	2	337
23-Jun	194	1	159	19	144	6	0	2	525
24-Jun	29	7	195	12	0	2	0	11	256
25-Jun	23	4	63	11	0	1	0	3	105
26-Jun	320	3	59	7	2	0	0	0	391
27-Jun	76	1	17	2	3	0	0	5	104
28-Jun	10	2	82	3	9	1	0	7	114
29-Jun	20	2	53	4	0	0	0	4	83
30-Jun	37	0	38	8	1	0	0	1	85
Total	18,147	2,040	1,922	542	296	73	2	216	23,238

sptrp-2.xls

Appendix A.3. Numbers of fish captured by trap 3 in the Kenai River, May 12through June 30, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	5	1	2	6	0	0	0	3	17
13-May	2	0	0	1	0	0	0	0	3
14-May	0	2	3	6	0	0	0	2	13
15-May	2	1	2	6	0	0	0	0	11
16-May	0	0	0	0	0	0	0	3	3
17-May	6	0	4	7	0	0	0	0	17
18-May	7	0	3	0	0	0	0	1	11
19-May	0	8	8	11	1	1	0	3	32
20-May	89	0	15	6	0	0	0	4	114
21-May	250	4	16	5	0	0	0	2	277
22-May	330	6	15	4	0	1	0	3	359
23-May	159	6	15	7	2	0	0	3	192
24-May	321	8	11	4	0	0	0	2	346
25-May	431	1	3	2	0	1	0	5	443
26-May	350	6	3	3	1	3	0	2	368
27-May	233	2	13	1	0	0	0	3	252
28-May	124	7	11	0	0	0	0	3	145
29-May	202	2	6	1	0	0	0	6	217
30-May	639	5	2	4	0	0	0	3	653
31-May	806	13	9	10	4	0	0	7	849
01-Jun	985	31	4	0	1	0	1	5	1,027
02-Jun	520	49	8	4	13	0	0	4	598
03-Jun	1,501	62	9	7	0	0	0	2	1,581
04-Jun	1,045	29	8	7	1	0	0	8	1,098
05-Jun	620	30	7	1	3	1	0	6	668
06-Jun	239	32	11	4	1	0	0	8	295
07-Jun	1,628	20	12	8	2	1	0	4	1,675
08-Jun	2,108	80	19	2	10	3	0	8	2,230
09-Jun	892	33	19	2	9	1	0	5	961
10-Jun	521	80	6	3	6	0	0	13	629
11-Jun	867	48	12	0	3	0	0	7	937
12-Jun	406	167	26	3	6	0	0	3	611
13-Jun	731	34	24	3	10	1	0	4	807
14-Jun	1,302	58	6	2	6	1	0	7	1,382
15-Jun	1,867	45	28	2	19	0	0	7	1,968
16-Jun	2,285	120	91	4	13	0	0	2	2,515
17-Jun	970	105	211	5	19	4	0	6	1,320
18-Jun	1,900	197	117	20	27	6	0	1	2,268
19-Jun	213	6	18	0	5	1	0	2	245
20-Jun	658	5	29	0	33	1	0	1	727
21-Jun	170	6	112	1	1	2	0	4	296
22-Jun	99	0	158	0	4	1	0	2	264
23-Jun	232	6	100	4	136	1	1	1	481
24-Jun	25	6	108	5	2	0	0	2	148
25-Jun	20	0	34	4	2	0	0	3	63
26-Jun	910	0	68	6	2	0	0	5	991
27-Jun	157	0	24	0	1	0	0	1	183
28-Jun	21	0	73	4	5	0	0	5	108
29-Jun	89	0	75	6	3	0	0	3	176
30-Jun	121	1	53	7	2	1	0	5	190
Total	27,058	1,322	1,611	198	353	31	2	189	30,764

sptrp-3.xls

Appendix A.4. Numbers of fish captured by trap 4 in the Kenai River, May 12 through June 30, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	3	1	5	12	0	0	0	2	23
13-May	8	0	6	2	0	0	0	2	18
14-May	1	0	0	1	0	4	0	1	7
15-May	1	0	8	2	0	0	0	1	12
16-May	0	0	3	0	1	0	0	0	4
17-May	1	1	0	0	0	0	0	2	4
18-May	0	0	2	0	0	0	0	1	3
19-May	4	4	13	6	0	0	0	5	32
20-May	70	0	10	2	0	0	0	4	86
21-May	197	2	11	9	0	0	0	0	219
22-May	196	5	6	4	0	0	0	5	216
23-May	107	2	12	3	0	0	0	4	128
24-May	331	0	1	0	1	0	0	1	334
25-May	37	0	3	0	0	0	0	2	42
26-May	247	2	7	7	0	1	0	2	266
27-May	198	1	13	6	1	0	0	3	222
28-May	68	2	9	2	0	0	0	2	83
29-May	122	4	9	3	3	1	0	6	148
30-May	321	8	5	3	10	0	0	2	349
31-May	358	9	3	5	8	0	0	6	389
01-Jun	427	16	4	1	6	0	0	2	456
02-Jun	242	22	5	2	27	1	0	9	308
03-Jun	400	19	5	4	8	0	0	1	437
04-Jun	1,321	24	8	5	2	0	0	8	1,368
05-Jun	490	11	8	1	20	0	0	7	537
06-Jun	157	27	7	4	12	0	0	11	218
07-Jun	1,845	14	15	1	19	1	0	11	1,906
08-Jun	899	18	24	0	11	0	0	8	960
09-Jun	433	9	16	1	17	0	0	15	491
10-Jun	315	38	6	2	6	0	4	6	377
11-Jun	679	51	8	2	4	1	0	2	747
12-Jun	118	71	10	5	12	0	0	6	222
13-Jun	380	37	27	0	12	1	0	3	460
14-Jun	777	44	10	3	11	0	0	4	849
15-Jun	796	27	17	1	19	0	0	3	863
16-Jun	1,433	56	65	6	26	1	0	9	1,596
17-Jun	354	23	91	0	22	2	0	1	493
18-Jun	848	12	104	0	11	0	0	4	979
19-Jun	162	3	21	0	14	0	0	0	200
20-Jun	539	8	41	2	35	2	0	3	630
21-Jun	116	1	100	2	7	0	0	6	232
22-Jun	37	0	186	2	3	1	0	4	233
23-Jun	271	5	70	8	114	0	0	5	473
24-Jun	35	2	112	3	2	0	0	2	156
25-Jun	16	2	41	0	5	0	0	1	65
26-Jun	343	0	64	3	7	0	0	1	418
27-Jun	118	0	23	1	2	0	0	4	148
28-Jun	10	0	70	2	8	0	0	4	94
29-Jun	51	3	65	6	5	0	0	3	133
30-Jun	121	1	62	4	2	1	0	1	192
Total	16,003	585	1,411	138	473	17	4	195	18,826

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Appendix A.5. Numbers of fish captured by trap 5 in the Kenai River, May 12 through June 30, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
12-May	9	15	2	23	0	1	0	0	50
13-May	25	23	2	9	0	1	0	0	60
14-May	4	13	3	5	0	3	0	0	28
15-May	0	2	1	5	0	0	0	0	8
16-May	3	8	0	0	0	1	0	2	14
17-May	1	28	5	9	0	0	0	0	43
18-May	8	1	8	3	0	2	0	0	22
19-May	9	0	3	0	0	0	0	0	12
20-May	209	4	7	0	0	1	0	0	221
21-May	1,039	27	19	30	0	0	1	1	1,117
22-May	484	29	7	15	1	1	0	0	537
23-May	252	33	2	18	0	0	0	1	306
24-May	393	2	9	7	0	0	0	0	411
25-May	360	4	4	5	0	1	0	3	377
26-May	380	22	3	13	0	1	0	1	420
27-May	88	7	3	8	0	0	0	0	106
28-May	73	12	2	20	0	0	0	2	109
29-May	83	37	4	34	0	1	0	0	159
30-May	120	17	4	23	2	0	0	0	166
31-May	262	47	0	15	2	1	0	2	329
01-Jun	266	97	4	19	2	0	0	2	390
02-Jun	201	65	6	9	2	0	0	0	283
03-Jun	365	111	2	20	3	0	0	0	501
04-Jun	389	143	4	33	1	1	0	3	574
05-Jun	304	132	6	39	10	3	0	6	500
06-Jun	138	127	3	23	5	1	0	4	301
07-Jun	1,061	74	8	32	10	2	0	7	1,194
08-Jun	876	112	10	9	8	1	0	3	1,019
09-Jun	684	56	10	10	15	1	0	4	780
10-Jun	971	90	7	9	12	2	1	3	1,095
11-Jun	1,480	253	7	9	11	1	0	0	1,761
12-Jun	465	166	7	20	16	4	0	1	679
13-Jun	371	90	18	15	23	3	0	5	525
14-Jun	1,923	83	10	7	10	1	0	3	2,037
15-Jun	1,845	54	10	8	14	2	0	6	1,939
16-Jun	2,402	83	42	7	24	2	0	12	2,572
17-Jun	3,453	36	74	5	8	7	0	4	3,587
18-Jun	376	42	36	3	6	2	0	1	466
19-Jun	805	15	1	1	7	1	0	2	832
20-Jun	292	6	6	4	13	0	0	1	322
21-Jun	41	2	32	8	1	2	0	3	89
22-Jun	35	0	60	11	3	2	0	0	111
23-Jun	37	0	30	3	24	2	0	1	97
24-Jun	7	2	26	5	0	0	0	3	43
25-Jun	1	0	8	1	0	0	0	0	10
26-Jun	11	0	14	9	2	0	0	4	40
27-Jun	51	0	12	1	3	0	0	7	74
28-Jun	3	0	17	2	0	1	0	6	29
29-Jun	9	1	33	4	1	2	0	7	57
30-Jun	9	0	27	3	0	0	0	8	47
Total	22,673	2,171	618	571	239	57	2	118	26,449

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Appendix A.6. Numbers of fish captured by trap 6 in the Kenai River, May 13 through June 30, 1994.

Date	Sockeye Smolt	Sockeye Fry	Chinook Smolt	Chinook Fry	Coho Smolt	Coho Fry	Pink Fry	Other	Total
13-May	37	50	1	16	1	0	0	3	108
14-May	10	60	1	33	0	0	0	1	105
15-May	1	10	1	44	0	0	0	0	56
16-May	1	75	0	4	0	1	0	1	82
17-May	0	18	1	9	0	0	0	0	28
18-May	17	11	6	12	0	0	0	0	46
19-May	7	233	8	69	0	0	0	1	318
20-May	61	255	2	29	0	3	0	0	350
21-May	407	109	7	57	2	7	0	1	590
22-May	269	80	2	44	0	1	0	3	399
23-May	399	49	7	28	0	0	0	0	483
24-May	415	50	5	17	0	0	0	1	488
25-May	823	35	2	10	0	0	0	0	870
26-May	449	109	2	20	1	2	0	0	583
27-May	202	26	10	22	0	0	0	0	260
28-May	78	17	3	14	0	1	0	1	114
29-May	82	50	7	37	1	0	0	0	177
30-May	278	74	2	33	1	0	0	2	390
31-May	767	85	5	40	4	0	0	2	903
01-Jun	376	179	1	25	2	0	0	2	585
02-Jun	269	182	3	28	2	0	0	2	486
03-Jun	878	127	1	17	0	0	0	0	1,023
04-Jun	689	214	4	24	2	1	0	0	934
05-Jun	441	193	3	30	1	1	0	0	669
06-Jun	187	219	1	26	1	0	0	7	441
07-Jun	1,017	151	5	44	7	0	0	4	1,228
08-Jun	804	130	5	28	6	1	0	4	978
09-Jun	697	76	8	5	4	0	0	2	792
10-Jun	427	75	4	9	0	0	1	7	523
11-Jun	768	193	7	4	2	0	0	0	974
12-Jun	240	208	6	33	1	1	0	10	499
13-Jun	245	102	6	24	3	3	0	2	385
14-Jun	922	58	6	15	5	0	0	2	1,008
15-Jun	862	57	8	6	3	0	0	3	939
16-Jun	840	57	31	8	3	1	0	5	945
17-Jun	1,432	40	36	7	6	2	1	6	1,530
18-Jun	280	37	27	1	6	2	1	5	359
19-Jun	246	14	7	0	2	0	0	1	270
20-Jun	77	12	6	1	5	0	0	3	104
21-Jun	15	1	26	1	1	2	0	4	50
22-Jun	2	0	29	2	1	0	0	2	36
23-Jun	20	3	26	7	30	3	0	1	90
24-Jun									0
25-Jun	1	0	12	0	0	0	0	0	13
26-Jun	3	1	22	4	1	0	0	1	32
27-Jun	18	0	7	3	0	0	0	2	30
28-Jun	0	1	13	5	1	0	0	4	24
29-Jun	1	0	17	3	1	2	0	12	36
30-Jun	4	3	18	2	0	1	0	12	40
Total	16,064	3,729	417	900	106	35	3	119	21,373

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