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SOCKEYE AND COHO SALMON ESCAPEMENT

STUDIES IN THE SUSITNA DRAINAGE 1998

by

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EXECUTIVE SUMMARY

This project was a cooperative venture between the Commercial Fisheries and Sport Fish Divisions of the Alaska Department of Fish and Game (ADF&G) to develop and improve estimation techniques of the escapement of sockeye *Oncorhynchus nerka* and coho *O. kisutch* salmon in the Susitna River drainage. Estimating sockeye and coho salmon escapements in the Susitna drainage depends on accurate sonar estimates in the Yentna River. Historically, side scanning sonar has been used to estimate sockeye and coho salmon escapements in the Susitna drainage. However, a pilot study conducted in 1997 indicated that the Yentna River sonar estimate of sockeye salmon may be biased low. Therefore, a sampling program was designed to determine if there was a difference in the number of stocked sockeye salmon at the Yentna River sonar site fish wheels (apportioned sonar counts) and weir counts at Chelatna Lake. However, the Chelatna Lake weir washed out during the peak of the run in 1998 so the stocked proportions could not be accurately determined and compared. Thermally marked otoliths from stocked sockeye salmon were recovered from 7.1% of the sampled fish at Chelatna Lake and 3.2% of the Yentna River samples; of which 64.5% and 35.4% were from the North and South Bank fish wheels, respectively. Also, the North Bank marked samples were predominantly age-0.3 (51.6%), while most South Bank marked samples were age-1.3 (41.2%), indicating fish were stratified by bank.

A mark-recapture (M-R) experiment was implemented to obtain a second sockeye salmon escapement estimate for comparison with the sonar-derived estimate. Fish wheels operated continuously to capture fish for marking, so tagging was assumed proportional to the catch. Fish were dual dart-tagged. Recovery weirs showed that sockeye salmon were partially bank oriented by destination at the fish wheels; the majority of North Bank recovered fish migrated to Chelatna Lake (82.5%), and South Bank fish migrated to Judd Lake (62.8% of recoveries). Recovery rates were significantly different ($P<0.05$), and arrival times were also different for tagged and untagged fish at the two lakes, so escapement estimates were not calculated in 1998 because M-R assumptions were not fulfilled.

Weirs were used to obtain a complete census of the adult salmon runs to select systems. The 1997 Chelatna Lake sockeye salmon escapement of 84,899 was the highest recorded escapement to date, with age-1.3 being the dominant returning age class (50.7%). The 1998 total escapement is unknown, although 27,284 sockeye salmon were enumerated through the weir prior to and after the weir washout. In 1998, the sampled run was 79.9% age-1.3; 15% greater than the 1990-1997 mean (64.1%). Total escapement was counted at Judd Lake in 1998, the first for this system. The sockeye salmon escapement of 34,416 accounted for 29% of the 1998 Yentna River sonar estimate of 119,623. The dominate age-class was age-1.3 which comprised 56.0% of the run. The sockeye salmon escapement to Larson Lake (in the Susitna drainage) totaled 63,514 in 1998. This was approximately two times greater than the (1984-1987, 1997) mean weir counts (32,497). Age-1.3 fish was the dominant age-class and comprised 49.0% of the run. Age-2.3 sockeye salmon comprised 24.0% of the 1998 run. This was three times greater than the historic (1984-1987, 1997) mean of 8.0%.

An M-R experiment was designed and conducted to test the selectivity of sockeye and coho salmon, quantify capture efficiency of the fish wheels, and to collect data about potential biases. A total of 44 tagged sockeye and 53 tagged coho salmon were recovered at the fish wheels (4.3% and 6.1% of marks, respectively). Chi-square (X^2) analysis of these recovery proportions showed no difference in recovery rates between the two species (P=0.081). Holdover time (from time released to time recaptured) was much lower for sockeye (2.7 days) than coho salmon (10.3 days).

Radiotelemetry was also used to examine the instream (nearshore/offshore) distribution of migrating coho salmon to evaluate availability to sonar counting, and to determine migration timing as well as the locations and relative importance of major spawning areas. Final destinations were determined for 170 (of 306) radiotagged coho salmon, with 99 (32.4%) in the Yentna River basin; 40 (12.9%) in the mainstem and 59 (19.3%) in tributary rivers. The proportion of radiotagged coho salmon males in the upper Yentna River basin was significantly higher (X^2=29.09, df=1, P<0.005) than females (86.9% males), compared to all tagged coho salmon (57.8% males). A total of 24 (27.6%) radiotagged coho salmon migrated through the ensonified areas at the Yentna River sonar sites (5 North Bank and 19 South Bank). Diel migration timing showed the majority of coho salmon migrating during the 1600-2000 hr time period (30.4%), followed by the 2000-0000 hr period (25.0%).

In conclusion, there was evidence that the stocked fish estimate from the Yentna sonar site was biased low, although the cause(s) was not determined. Also, marked fish were not found at the weirs in proportion to unmarked fish, and the timing for each was different indicating some type of bias. A possible cause were handling stress causing changes in migratory behavior, timing and/or survival. The same types of biases were found with sockeye and coho salmon tagged for the fish wheel selectivity study, and coho salmon tagged with radio transmitters. In future studies, decreasing the time that fish are held out of water during tagging, and not also sampling these fish, might increase survival and reduce delayed migration.

INTRODUCTION

Management of the mixed-stock fishery in Upper Cook Inlet, Alaska (Figure 1) relies on riverine sonar to estimate adult salmon escapements in three major watersheds: Kasilof, Kenai, and Yentna rivers (Ruesch and Fox 1997). The primary objective of the Yenta River sonar program is to estimate sockeye salmon *Oncorhynchus nerka* escapements. These data are used to index escapement trends in the whole Susitna River drainage. Data collected during the Susitna Hydrological (Su-Hydro) feasibility studies in the 1980s indicated that sockeye salmon escapement in the Yentna River represents a fairly constant proportion of the escapement in the Susitna River drainage (Pers. Comm., Ken Tarbox, ADF&G, oral report to the Alaska Board of Fisheries, February 1998).

In 1997 the Alaska State Legislature appropriated $1 million from the T/V *Exxon Valdez* oil spill (EVOS) criminal fines to fund Capital Improvement Projects (CIP) directed at sustained yield management of Pacific salmon spawning in the Northern District of Upper Cook Inlet. Some funds were expended for habitat protection, Forest Practices, and oil and gas leasing activities with the remaining for salmon stock assessment and other related research activities. To determine how these monies for salmon stock assessment could be best utilized, ADF&G assembled a steering committee with representatives from the divisions of Commercial and Sport Fisheries. After several meetings, the committee agreed that efforts would be focused on spawning escapement assessment and genetic stock identification. Spawning assessment work was to be primarily directed at sockeye and coho *O. kisutch* salmon in the Susitna River drainage, with some work also being done on smaller, currently unmonitored, Northern District systems. Genetic stock identification work was to be directed at sockeye salmon, since extensive information was already available from previous studies funded by the EVOS Trustee Council. Only projects conducted in the Susitna River drainage will be reported here.

The Susitna River watershed, which originates in the mountains of the Alaska Range about 145 km south of Fairbanks, comprises approximately 49,200 km^2. It flows southwesterly for about 400 km before entering Upper Cook Inlet west of Anchorage. The three largest tributaries of the Susitna drainage are the Yentna, Chulitna, and Talkeetna Rivers. Larson Lake, at the head of Larson Creek, is considered the largest producer of sockeye salmon in the Talkeetna drainage. The Yentna River drainage has at least 12 lakes known to support sockeye salmon, of which four, Chelatna, Shell, Hewitt, and Judd, are thought to have the majority of the production potential (Table 1). There is a long history of salmon assessment in the Susitna River watershed including mark-recovery (M-R) estimates of abundance, aerial and foot surveys, weir and tower counts, and sonar estimation (Fox 1998).

Namtvedlt et al. (1979) provided a summary of the first attempt to use M-R methods to estimate the abundance of sockeye, chum *O. keta*, and coho salmon in the Susitna River in 1977. Nine fish wheels were deployed (five for marking and four for tag recovery) in the lower Susitna River and a total of 4,875 sockeye and 1,056 coho salmon were tagged. From the tag recoveries (110 sockeye and 33 coho salmon) estimated escapements were 237,514 sockeye and 49,694 coho salmon in 1977. The coho salmon estimates were probably biased low in the late 1970s. Watsjold (1980) estimated the 1979 sport harvest along the road system at 17,000 and the escapement at 37,000, though coho salmon were still entering the river when the studies were terminated. Also, from earlier tagging and recovery data (1970s), stocks were partially segregated by left and right banks, and sonar studies of fish passage showed evidence that portions of the run migrate offshore and may have been unavailable to the mark and recovery fish wheels, which would lead to underestimation of abundance. Bingham (1986) demonstrated both temporal changes and spatial (east and west bank) differences in tag recapture proportions. These differences likely reflect migratory timing and channel selection of sub-stocks within the Susitna drainage. Tag recovery analyses from the Sunshine fish wheels indicated that sockeye and coho salmon had similar recapture rates (vulnerability) at the upstream fish wheels (Thompson and Barrett 1983, Thompson et al. 1986). These studies (over six years and several million dollars expenditures) failed to produce usable estimates to Susitna River salmon managers; sockeye salmon escapement too high (Cannon 1985), and coho salmon escapement too low (Watsjold 1980).

The Yentna River sonar program was developed to estimate the escapement of sockeye salmon using fish wheel apportioned sonar counts. Sonar counters and fish wheels are operated on both banks of the river to obtain bank specific estimates, which are summed to estimate the total escapement. Fish wheels have been used to estimate species composition in the ensonified area, which is used to apportion the sonar counts to fish species. In 1981 ADF&G began estimating sockeye salmon escapements in the Yentna River using *Bendix* side-scanning sonar (Davis and King 1997; Figure 1). The near-shore orientation of upriver migrating sockeye salmon insures that they are detected by the sonar and susceptible to fish wheel capture. Current sonar operations correspond temporally only to the run of sockeye salmon (i.e., first week of July to the second week of August). The coho salmon run is slightly later than the sockeye salmon run, extending from about mid July through August (Thompson et al. 1986). Barrett (1975) conducted escapement (tower) counts of salmon in the Talachulitna River in the early 1970s and noted that a significant portion of the coho salmon migration occurs after August 14. However, escapement estimates of coho salmon, the accuracy of which is affected by factors such as offshore distribution, are considered to be index counts only (Tarbox et al. 1983, Davis and King 1997). Bendock and Vaught (1994) radiotagged both coho and sockeye salmon in the Kenai River and found that coho salmon were not as bank oriented as sockeye salmon; 22 (58%) coho salmon were recorded in the bank sites and 16 (42%) migrated in the middle river corridor compared to 11 (85%) sockeye salmon in the bank sites and 2 (15%) in the middle corridor.

Larson Lake is the largest known producer of sockeye salmon in the upper Susitna drainage. Larson Lake weir escapement numbers available from the mid 1980s ranged from 16,753 to 37,874 (Marcuson and Schollenberger 1988). In 1994 an estimated 520,000 fry were estimated to be rearing in the lake (King and Walker 1997). In the first year of funding of this project a weir was operated at Larson Lake to enumerate the sockeye salmon escapement, and a M-R experiment was conducted to evaluate assumptions in M-R estimation using spawning ground recoveries (Carlson et al. 1998). A total of 40,282 sockeye salmon were counted in 1997 (Carlson et al. 1998).

Chelatna Lake is the largest lake in the lower Susitna drainage accessible to sockeye salmon returning to spawn, and is the largest producer of sockeye salmon in the Yentna River drainage (Table 1). Based on euphotic volume, Chelatna Lake has the highest estimated adult salmon production (Tarbox and Kyle 1989), and weir escapements from 1993 to 1997 have ranged from 20,104 to 84,899 (Fox 1998). Prior to 1993, escapement estimates were conducted by U. S. Fish and Wildlife Service (USF&WS), ADF&G and Cook Inlet Aquaculture Association (CIAA), by spawning ground and aerial surveys, and M-R studies (Marcuson 1989; Table 2). The estimated number of fall fry between 1993 and 1995 averaged 2.9 million (King and Walker 1997). Since 1990, CIAA has been stocking sockeye salmon in Chelatna Lake. Beginning in 1991 CIAA started marking all released fry with thermal (otolith banding) marks at the Trail Lakes Hatchery, and thermally marked fry continued to be released into Chelatna Lake through 1996. A total of 1.0 million marked sockeye salmon fry were released into Chelatna Lake in 1992, 1993, and 1996, 1.3 million were released in 1994 and 1.8 million in 1995 (Fandrei 1995 and 1996).

Judd Lake drains into the Skwentna River, which flows into the Yentna River and was thought by King and Walker (1997) to be the most productive in the Skwentna drainage. There have been very limited escapement surveys in the past at Judd Lake. In 1989 the estimated sockeye salmon escapement into the lake was 12,792 (CIAA extrapolated tower count). Fish were counted from a high bank above the creek as they migrated upstream over a canvas panel across the river bottom (Schollenberger 1989a). Fall fry hydroacoustic surveys conducted at Judd Lake in 1993 estimated 1.0 million fry, and 278 thousand in 1994 (King and Walker 1997).

Except for anecdotal information, little is known about the migration and spawning areas of coho salmon in the Yentna River basin. Thompson et al. (1986) reported that mid-river streams (e.g., Whiskers Creek) were favored spawning locations in the Susitna River. Bartlett (1996) compiled a summary of coho salmon programs that had been conducted in Northern Cook Inlet. This project component will attempt to determine migration timing and the location and relative importance of major spawning areas of coho salmon in the Yentna drainage. The study will be conducted using aerial radiotracking of fish fitted with radio transmitters during the instream distribution study. Radiotelemetry data is more qualitative than quantitative, and is useful for migratory behavior, stock separation, and location of spawning areas (Milligan et. al. 1986). The Yentna River, including all tributary rivers and creeks, is over 2,500 km in total length, with the majority of the rivers accessible to migrating coho salmon.

METHODS

Objectives

Primary objectives of the 1998 Susitna salmon assessment project were to: 1) assess bias in the sonar estimate of sockeye salmon escapement, and; 2) assess the susceptibility of coho salmon to fish wheel capture and sonar detection and investigate their migration to spawning areas. Mark-recovery (M-R) methods will be used to address objective 1. Objective 2 will be addressed with a combination of M-R methods and radiotelemetry. Specific objectives of the 1998 project are:

1. Test the hypothesis of no difference in the escapement of stocked sockeye salmon (hatchery fry releases at Chelatna Lake) between fish wheel apportioned sonar counts (Yentna River)

and sampling at Chelatna Lake weir; detect a difference within ± 1500 fish 80% of the time with a 5% probability of incorrectly rejecting the hypothesis of no difference;

2. Estimate the abundance of sockeye salmon escapement, independently of the sonar counters, to within ±10% of the true value with 95% probability (assuming the estimator is unbiased);
3. Count the escapement and estimate the age and sex composition (±5 percentage points of the true value with 95% probability) and average length (±5 mm of the true value with 95% probability) of sockeye salmon passing weirs located below the outlets of Chelatna, Judd, and Larson Lakes;
4. Test and quantify species selectivity and estimate the efficiency of capturing coho and sockeye salmon (±5 percentage points of the true value with 95% probability) in the Yentna River fish wheels;
5. Estimate the coho salmon proportion available to the ensonified areas on the north and south banks at Yentna River station; and,
6. Track coho salmon upstream to quantify major spawning areas or tributaries.

Yentna River Sonar Operations

In 1998 sonar operations were extended to late August, 2-3 weeks beyond the normal schedule to encompass the coho salmon run. Otherwise daily sonar operations were unchanged and conducted using standardized methods (Davis and King 1997). At the Yentna River site a transducer was deployed from each bank. The ensonified areas were 5.8 m to 7.3 m from the transducer on the north and south banks. Information used to estimate species composition of sonar counts were obtained from salmon captured in fish wheels. Fish wheels were operated up to 24 h per day and when operated for less than a full day, catches were expanded to represent 24 h for purposes of sockeye salmon estimation (Davis 2000).

Stocked Sockeye Salmon

Hatchery marked sockeye salmon returning to Chelatna Lake were sampled at the Chelatna Lake weir and Yentna River fish wheels for hatchery marks (from otolith samples), to compare proportions of marked to unmarked at both sites. The specific objectives were to: 1) estimate the proportion and number of stocked (otolith marked) sockeye salmon in the Chelatna lake escapement based on sampling at the weir; 2) estimate the number of stocked sockeye salmon bound for Chelatna Lake based on sampling and sonar counts at the Yentna River sonar site; and, 3) compare estimates from the two sites to evaluate potential bias at the Yentna sonar site. Specific causes of the bias were not identified but could have included: 1) sonar undercounting; 2) fish wheel selectivity; or, 3) inadequate sampling of the fish wheels. The study in 1997 was considered a pilot study and was repeated in 1998 with the goal of determining the bias and improving the precision. Thermally (otolith) marked sockeye salmon were to return in large numbers again in 1998. The majority of stocked fish are expected to return as ages-0.3 and 1.3.

A sampling program was designed to determine if there is a difference in the escapement of stocked sockeye salmon between fish wheel apportioned sonar counts at Yentna River sonar and sampling at Chelatna Lake, by comparing the number (proportion) of thermally marked adult sockeye salmon captured at the Chelatna Lake weir with those captured at the Yentna River fish wheels. Sockeye salmon otolith sampling was conducted in proportion to (1) the daily catch from both fish wheels on the Yentna River (every 14th fish sampled) and (2) the daily escapement at the Chelatna Lake weir (every 21st fish sampled). This sampling regime was self-weighting and should have ensured that a random sample of the fish wheel catch and weir escapement was obtained. If the run appeared stronger or weaker than estimated, the sampling rates would be adjusted in season. Otolith samples could be examined during the run to determine if expected hatchery proportions were accurate.

Sample sizes for otolith samples from the Yentna River and Chelatna Lake weir were based on estimates of returning sockeye salmon. The predicted escapement estimate of sockeye salmon to Chelatna Lake in 1998 was 30,000. In 1995 a sample of sockeye salmon smolt collected by CIAA estimated 25% of the escapement, or 7,500 fish would be of hatchery origin as indicated by thermally marked otoliths. An estimated escapement of 125,000 sockeye salmon (sonar estimate) would return to the Yentna River in 1998. Based on the 1997 results, about 6% of the escapement returning to Chelatna Lake would be otolith marked. Fish wheel efficiency relative to the sonar count has averaged 16%, for an expected fish wheel catch of 20,000 sockeye salmon in 1998. If target sample sizes of 1,400 fish at the two sites were met, a difference within ±1,500 fish should be detected 80% of the time with a 5% probability of incorrectly rejecting the no difference hypothesis. A difference of ±1,500 fish would be within 20% of the expected run of 7,500 stocked fish.

Every 14th sockeye salmon captured in the fish wheels was sacrificed for ALSO (age, length, sex, and otolith) sampling. These fish were placed into totes, labeled to match the fish wheel bank (north or south) and brought to a dock where sampling took place. Scales were removed from the preferred area (Koo 1955) and placed on labeled gummed cards. The gummed cards were later pressed onto acetate cards with a scale press, and read with a microfiche scale reader for age determination (Tobias et al. 1994). Otoliths (saggitae) were removed and stored in labeled vials filled with 95% ethanol, for analysis of hatchery induced marks. Each fish sampled was measured from mid-eye to tail fork (MEF) within ±5 mm, gender determined, and data recorded. Standard methods were used to estimate age composition, average length, and sex (ALS) composition (Davis and King 1997).

The proportion of stocked sockeye salmon passing the Chelatna Lake weir (P_w) was estimated as

$$\hat{P}_w = {}^{m_w}\!/_{n_w} \quad (1)$$

with variance estimate

$$v\left(\hat{P}_w\right) = \frac{\hat{P}_w\left(1-\hat{P}_w\right)}{n_w - 1}\left(\frac{N_w - n_w}{N_w}\right), (2)$$

where m_w is the number of otolith marked sockeye salmon sampled, n_w is the total number of fish sampled, and N_w is the weir count of sockeye salmon. The number of stocked sockeye salmon at the Chelatna Lake weir (H_w) was estimated as

$$\hat{H}_w = N_w \hat{P}_w, (3)$$

with variance estimate

$$v\left(\hat{H}_w\right) = N_w^2 v\left(\hat{P}_w\right). (4)$$

The proportion of stocked sockeye salmon in the Yentna River escapement (P_y) was estimated as

$$\hat{P}_y = {}^{m_y}\!/_{n_y} \quad (5)$$

with variance estimate

$$v\left(\hat{P}_y\right) = \frac{\hat{P}_y\left(1-\hat{P}_y\right)}{n_y - 1}\left(\frac{N_f - n_y}{N_f}\right), (6)$$

where m_y is the number of otolith marked sockeye sampled, n_y is the total number of fish sampled, and N_f is the fish wheel count of sockeye salmon. The proportion of sockeye salmon migrating past the Yentna sonar site each day i on bank j was estimated as

$$\hat{P}_{sij} = \frac{N_{fij}}{T_{fij}} \quad (7)$$

with variance estimate

$$v\left(\hat{P}_{sij}\right) = \frac{\hat{P}_{sij}\left(1-\hat{P}_{sij}\right)}{T_{fij} - 1}\left(\frac{T_{sij} - T_{fij}}{T_{sij}}\right), (8)$$

where T_f is the total fish wheel catch and T_s is the total sonar count. A stratified sampling technique was used to estimate the number of sockeye salmon migrating past the Yentna River sonar site (N_s):

$$\hat{N}_s = \sum_j \sum_i \hat{P}_{sij} T_{sij}, (9)$$

with variance estimate

$$v(\hat{N}_s) = \sum_j \sum_i T_{sij}^2 v(\hat{P}_{sij}).(10)$$

The number of otolith marked (stocked) sockeye salmon migrating past the Yentna River sonar site (H_y) was estimated as

$$\hat{H}_y = \hat{P}_y \hat{N}_s, (11)$$

with variance estimate

$$v(\hat{H}_y) = \hat{P}_y^2 v(\hat{N}_s) + \hat{N}_s^2 v(\hat{P}_y) - v(\hat{P}_y) v(\hat{N}_s).(12)$$

The abundance of stocked fish estimated at the two sites were compared by statistically evaluating the difference (D) between the two estimates:

$$\hat{D} = \hat{H}_w - \hat{H}_y, (13)$$

with variance estimate

$$v(\hat{D}) = v(\hat{H}_w) + v(\hat{H}_y).(14)$$

A 95% confidence interval of D was used to detect a significance difference between the two sites,

$$\hat{D} \pm 1.96\sqrt{v(\hat{D})}, (15)$$

which was used to detect and quantify bias at the sonar site (assuming the Chelatna Lake weir estimate is unbiased).

Sockeye Salmon M-R Estimate

Another method of assessing the accuracy of the sonar-derived abundance estimate of sockeye salmon was to obtain a second escapement estimate, independent of the sonar counters. An M-R experiment was planned, to compare to the sonar-derived estimate. A pilot experiment with dart tags (*Hallprint*® No. 2, plastic-tipped PD Series), which require minimal handling time to apply, suggested that they have a fairly minor affect on recapture compared to spaghetti tags; spaghetti tags were shown to be positively biased in the probability of recapture in a M-R study done at Larson Lake in 1997 (Carlson et al. 1998). In addition, tagging effects may be insignificant if recovery sampling is conducted prior to spawning, assuming that tag loss can be accounted for. This approach allowed for testing of important M-R assumptions.

Chapman's (1951) modification of the Peterson method was used to estimate the escapement of sockeye salmon in the Yentna River with the option of stratifying the estimate by area, time period, sex, and/or size-class (Darroch 1961, Seber 1982). The north (NB) and south bank (SB) fish wheels were operated continuously during the sockeye salmon migration, except for brief periods to allow for fish wheel adjustments. Every fourth sockeye salmon captured in each fish wheel was to be tagged; therefore tagging would be proportional to the catch. Each fish tagged was fitted with two identical numbered dart tags to test for tag retention. Age, length (MEF), and sex (ALS) data were collected and recorded for each tagged fish. Recovery sampling occurred at weirs located below Chelatna Lake (Lake Creek) and Judd Lake (Talachulitna Creek). All tagged fish observed at the weirs were diverted into holding areas so tags could be recovered. The target sample size (for tagging) was expected to be large enough to achieve a relative error (RE) of 10% with 95% probability ($\alpha = 0.05$) for estimating sockeye salmon abundance, based on the predicted weir escapements and fish wheel efficiency. The expected escapement at Judd Lake in 1998 was 10,000, based on prior partial weir/counting tower studies conducted by CIAA (Pers. Comm., Gary Fandrei, CIAA) and the anticipated sonar estimate in the Yentna River. Therefore, the total escapement expected through the two weirs was 40,000. The plan developed was to tag 5,000 fish, which would be 25% of the expected fish wheel catches. This sample size would exceed an escapement estimate with a RE ±10%.

We used Chapman's (1951) modification of the Peterson M-R method, as described by Seber (1982), to estimate sockeye salmon escapement in the Yentna River:

$$\hat{N} = \frac{(m_1+1)(n_2+1)}{(m_2+1)} - 1 \quad (16)$$

with variance estimate (Seber 1970)

$$v(\hat{N}) = \frac{(m_1+1)(n_2+1)(m_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}, \quad (17)$$

where $\hat{N}$ is the estimated abundance of adult sockeye salmon on the spawning grounds, m_1 is the number of sockeye salmon tagged at Yentna River fish wheels, n_2 is number of sockeye salmon inspected for tags at Chelatna and Judd Lake weirs, and m_2 is the number of fish with tags collected at the weirs.

The following assumptions are necessary for an unbiased M-R estimate of the escapement: 1) a. all sockeye salmon have an equal probability of being tagged at the fish wheels; b. all sockeye salmon have an equal probability of being inspected for tags; or, c. tagged fish mix completely with untagged fish between sampling events; 2) the population is closed, therefore the total escapement is constant; 3) all tags are reported on recovery at the weirs; 4) tags are not lost between release and recovery; and, 5) tagging does not affect the probability of a fish being caught.

The following techniques were used to assess assumption: 1) Continuous operation of the fish wheels and tagging proportional to the catch, to ensure the chances of equal probability sampling at the fish wheels (assumption 1a). If assumption 1a was met (which would preclude 1b and 1c), then the proportion of tagged fish passing the Chelatna and Judd Lake weirs should have been equal. This was analyzed using a chi-square test ($\alpha = 0.05$). If the hypothesis of equal tagged proportions were rejected, then a M-R design stratified by area (bank and weir) would be required (Darroch 1961; Seber 1982). A similar technique was also used to evaluate temporal consistency in tagged proportions (see Seber 1982). To assess selectivity of the fish wheels and recovery weirs, we compared sex composition and length (MEF) distributions between the two sampling events. Specifically, we compared: 1) fish wheel (tagged) samples and untagged fish sampled at the weirs; and, 2) unrecovered tagged fish and recaptured (tagged) fish. Chi-square tests were used to test the hypothesis of no difference in the proportion of males or females. Cumulative distributions (MEF) were compared using the Kolmogorov-Smirnov (K-S) two-sample test. Rejection of the hypotheses of no difference in sex composition and/or MEF distributions would indicate selectivity in one or both sampling events, and therefore would require estimates to be stratified. These test results were assessed in light of meaningful differences that may result in a serious bias in the abundance estimate (Appendix A-1).

Because of their life history, the population of sockeye salmon passing the Yentna River sonar site is closed to recruitment (assumption 2), and straying was assumed to be negligible. Field crews were instructed to carefully inspect all fish passing the weirs for the presence of dart tags (assumption 3).

Tag loss (assumption 4) should have been eliminated since we dual tagged 100% of all marked fish. However, we evaluated tag loss as described by Seber (1982). The probability of losing either a left- or right-side tag was estimated as

$$\hat{P}_L = \frac{m_C}{\left(m_C + 2m_{AB}\right)}, \quad (18)$$

where m_C is the number of dual tagged fish in the recovery sample with one dart tag, and m_{AB} is the number of dual tagged fish in the recovery sample with both tags present. The number of recaptured fish was then estimated as

$$\hat{m}_2 = \left(m_C + 2m_{AB}\right)^2 / 4m_{AB} \,. \quad (19)$$

To estimate N after accounting for tag loss, $\hat{m}_2$ was substituted for m_2 in the M-R equations. However, because we anticipated a very low probability of losing both tags, the adjustment to the escapement estimate was assumed to be negligible.

Tagging may cause increased mortality or modified fish behavior compared to unmarked fish (assumption 5). This assumption was difficult to evaluate. The following tagging methods were used to help reduce potential tagging effects. We used darts tags, which are small, light weight (<1 g), and required minimal handling of fish to apply, as compared to other currently available tagging methods. These tags could be attached very quickly, a barbed plastic-tipped head locks the tag in the flesh; tags were secured approximately two to three centimeters below the dorsal fin posterior terminus. Three-person tag crews were used to complete the tagging; the first crewmember netted the fish from the fish wheel live box and placed the fish in a measuring trough, the second person measured the fish (MEF), determined its sex, and affixed two tags prior to release, and the third person recorded data and reloaded the tagging needles with the proper tag colors and numbers. Stainless steel applicator needles were used to insert the tags. The needles were rinsed in a chlorine solution prior to each application. Typically, this required approximately 30 seconds or less to complete. When fish wheel capture rates increased, a fourth person was added to the tagging crews to help increase efficiency.

Sockeye Salmon Weirs

The objectives of the weirs operated at Chelatna, Judd and Larson Lakes in 1998 were to: 1) enumerate sockeye salmon escapements; 2) collect ALS data (and also otoliths at Chelatna); and, 3) recover tagged fish (Chelatna and Judd Lakes).

In 1998 the weir at Larson Lake was placed in the same location as previous years (Carlson et al. 1998). The design of the weir was similar to one described in Anderson and McDonald (1978), consisting of a top and bottom horizontal stringer; 3 x 3 in aluminum angle with 1 1/8 in diameter holes drilled on 2.5 in centers. Five-foot aluminum pickets (1 in diameter) were placed through the holes in the stringers. The weir spanned the entire creek (~11 m) and was supported every 3 m with tripod frames constructed of metal pipe (2 ½ in diameter x 4 ft) with two 5 ft wood, back support legs. A wood cross-member piece was attached to the back support legs for placement of sandbags and additional support. A holding/sampling area was constructed on the front of the weir where fish were diverted to conduct ALS sampling.

At the Larson Lake weir every 30^{th} sockeye salmon was to be sampled for ALS, based on an escapement of 30,000. Depending on the run strength in season, the sampling scheme would be adjusted up or down to meet certain statistical criteria.

In 1998 the Chelatna Lake weir was also placed in the same location as previous years. The weir design was similar to the Larson Lake weir, with the exception of a floating segment (resistance board weir) in the middle that allowed boat traffic to pass. The floating segment (5 m wide x 3 m deep) was constructed of plastic pipe (PVC) pickets anchored to the stream bottom and angled downstream (Tobin 1994). Boats (drift or jet) could pass upstream or downstream over the top of this section, while downstream fish remained underneath the overhang. Chutes were constructed on both ends of the weir, which allowed for sampling and recovery of tagged fish. The chutes were approximately 2 m x 6 m and were fabricated from aluminum perforated plate reinforced on all sides with aluminum channel. The width of Lake Creek at the weir site was greater than 50 m and is highly susceptible to fluctuations in depth and flows. A high level of maintenance and constant monitoring were required to keep the weir "fish tight". ALS (and otolith) data were to be collected from every 14^{th} sockeye salmon passing the Chelatna Lake weir, based on the expected escapement of 30,000. Also like the sampling program at Larson Lake, this sampling scheme could be altered in season.

Judd Lake enters Talachulitna Creek and drains into the Talachulitna River (Figure 1). A weir site was selected near the outlet of the lake which provided lower velocities and a good bottom substrate, although the site was substantially wider (approximately 40 m total width) than possible downstream sites. The weir construction and materials were similar to Larson Lake weir. A holding area (2 m x 3 m) was constructed on the front of the weir for ALS sampling and tag recovery. ALS data was to be collected from every 10th sockeye salmon passing the Judd Lake weir, based on an expected escapement of 10,000. Like the other weir sampling programs, this sampling schedule would be adjusted in season.

The weirs were operated to provide a complete census of sockeye salmon at each lake. ALS sampling was conducted in proportion to the daily count, essentially every k^{th} fish was collected. As indicated previously, the sample goal at Chelatna Lake was 1,400 sockeye salmon, which is equivalent to 4.7% of the expected 30,000 escapement, or every 21st fish. This sample was primarily intended to meet the 10% RE requirement for otolith sampling and was also used for ALS data. We estimated that approximately 1,000 sockeye salmon would be sampled at Judd Lake weir for ALS data, which is 10% of the expected escapement, or every 10th fish passing the weir. This was a higher number than required to meet the 5% RE requirement (Thompson 1992), but should have ensured an adequate sample size if the run was larger than expected. The expected escapement at Larson Lake in 1998 was 30,000, based on the historical ratio of Larson Lake to Yentna River escapements (Carlson et al. 1998). Similar to Judd Lake, we expected to sample approximately 1000 fish, which was 3.33% of the escapement, or every 30th fish passing the weir. If the runs into any of the three lakes appeared stronger or weaker than predicted, the sampling schedule was to be adjusted in-season.

All adult sockeye salmon passing the weirs were enumerated and ALS sampling was conducted in proportion to the count. This provided a simple random sample for estimating mean length (MEF) and sex and age composition of the population. Mean MEF and the variance were estimated as follows for males, females, and the sexes combined:

$$\overline{MEF} = \frac{\sum_{i=1}^{n} MEF_i}{n_k}, \text{ and} \quad (20)$$

$$v\left(\overline{MEF}\right) = \frac{\sum_{i=1}^{n}\left(MEF_i - \overline{MEF}\right)^2}{n_k\left(n_k - 1\right)}, \quad (21)$$

where n was the sample size of sockeye salmon collected at the weir and k indexed the group (male, female, or both). Sex and age-class proportions were estimated as follows:

$$\hat{P}_{jk} = \frac{n_{jk}}{n_j} \quad (22)$$

with variance estimate

$$v\left(\hat{P}_{jk}\right)=\frac{\hat{P}_{jk}\left(1-\hat{P}_{jk}\right)}{n_j-1}\left(\frac{N-n_j}{N}\right), (23)$$

where *j* indicated either age or sex composition, *k* indexed the gender or age-class being estimated, *n* was the sample size, and *N* was the number of the sockeye salmon counted through the weir.

Fish Wheel Selectivity

Fish caught in each fish wheel are assumed to represent the species composition of fish detected by the respective sonar counter. One critical aspect of evaluating the potential for enumerating coho salmon with sonar involved species selectivity and efficiency of capturing sockeye and coho salmon in the fish wheels. This component of the project entailed conducting a M-R experiment, designed to test the selectivity of sockeye and coho salmon and quantify capture efficiency of the fish wheels, and also to compute M-R escapement estimates on sockeye and coho salmon using these data. The species selectivity experiment was conducted primarily to collect data about potential biases (size, sex or species) in fish wheel captures (Appendix A-1).

The species selectivity experiment consisted of tagging a mixed sample of sockeye and coho salmon twice during the peak of the migration. For this study different colored tags were used than were used for the regular (M-R for independent escapement estimate) tagging study. For each experiment, a minimum of 400 fish of each species was to be tagged to assure that efficiency estimates were within ± 5 percentage points of the true value, with 90% probability (Thompson 1992). Fish were collected in the NB and SB fish wheels, sampled for ALS and dual dart tagged. The marked fish were then placed into totes filled with river water that was continuously aerated by bilge pumps with sprayer bars, and transported downriver approximately 3-4 km. The fish were released in sloughs on each side of the river corresponding to bank of capture, to facilitate recovery. The recapture rate (fish wheel efficiency) of each species was then compared to test the null hypothesis of consistency in the probability of capture. To assess diel variation and migration timing effects on capture efficiency, fish were marked and released at different times during a 24-hour period both tagging events. We also evaluated size selectivity of the fish wheels for each species.

A chi-square test ($\alpha = 0.05$) was used to test the consistency hypothesis. M-R assumptions discussed previously were also applied to the fish wheel tagging and recovery study. Fish wheel efficiency was estimated as

$$\hat{E}_j=\frac{m_{2j}}{m_{1j}} \quad (24)$$

with variance estimate

$$v\left(\hat{E}_j\right) = \frac{\hat{E}_j\left(1-\hat{E}_j\right)}{m_{1j}-1}, (25)$$

where m_{1j} was the number of species j fish tagged and released downstream and m_{2j} was the number of species j fish recaptured in the fish wheels. A chi-square test was used to evaluate temporal or distance effects on the capture efficiency of each species. Gender effects on capture efficiency were also assessed. Size selectivity was evaluated by comparing cumulative frequency distributions of non-recaptured and recaptured fish using the K-S test.

Coho Salmon Distribution

Radiotelemetry was used to examine the instream (nearshore/offshore) distribution of migrating coho salmon to determine availability to sonar counting. The results will be used to estimate the proportion of the run that migrates within the ensonified areas. This information, along with fish wheel apportioned sonar counts, will be used to estimate the escapement of coho salmon in the Yentna River. Ground based (stationary) monitoring sites were used to track tagged coho salmon movements and aerial telemetry surveys will attempt to determine migration timing and the location and relative importance of major spawning areas for coho salmon in the Yentna drainage.

Radiotelemetry Equipment

Advanced Telemetry Systems, Inc. (ATS) manufactured the radiotelemetry equipment. The radio transmitter tags (model 7 PN) operated in the frequency range of 150.000 MHz to 153.999 MHz, are approximately 20×40 mm in size (excluding the trailing antenna), weigh 13 grams (with mortality switch), and are powered by a 3-volt lithium battery with an expected operational life in excess of 90 days (Appendix C-1). Each tag was equipped with a mortality switch that becomes activated when the tag remained motionless for 4–5 hours. A total of 310 tags with 31 frequencies, each with 10 different digitized pulse codes, were ordered to tag 300 coho salmon. The 10 additional tags (highest frequency) were used for calibration and testing.

An ATS model R4000 receiver was interfaced with an ATS model DCC II D5041 data collection computer (data logger) at all stationary site locations. All frequencies were entered into each receivers (R4000 or R4100) memory prior to deployment. An ATS model R4100 receiver was used for aerial surveys, as the R4100 can decode (identify-ID) the tag pulse codes without interfacing to a DCC. The R4000 will operate approximately 3 weeks on an external power supply (12-volt deep discharge marine battery). A *United Solar Systems Corp.* solar panel (module US-32, maximum 32 watts and 16.5 volts) with a solar charge controller was connected to the external batteries at the up and down river sites so the sites would be "self contained". When interfaced to a receiver, the DCC controls the receiver's operation and draws power from the receiver. The DCC also has an internal battery backup for the data files, so if the receiver and external batteries lose power, data stored in the DCC is not lost.

The DCC records and stores received data: frequency, pulse code (including mortality codes: a 3 if received once, and a 6 if received twice in sequence), year, Julian date, time (hour and minutes), signal strength, period, and antenna (if multiple antennae and multiplexer are used). The DCC has the capability to monitor 400 fish within a 10-minute time span. There are two modes of operation, stationary and aerial, and certain settings are user programmable; scan (time receiver scans for frequency), timeout (if frequency is not present time before moving to next frequency), log (after scanning all frequencies time interval before receiver begins scanning again), and store (after storing frequency time interval before frequency is stored again). *PROCOM PLUS* software (supplied by ATS) was used to download the data from the DCC to a laptop computer.

Yagi antennae (4-element high frequency), manufactured by *Cushcraft Corporation*, were used at both the stationary monitoring sites, Big Bend (BB) upriver and River Mouth (RM) downriver, and on the aircraft for aerial surveys. At both the NB and SB Yentna River sonar sites coaxial cable was suspended in the river for antennae, the outer 15 cm of insulation was removed (McCleave et al. 1977, Solomon 1982).

Tagging and Sampling

Coho salmon collected for radio tagging were sampled in proportion to the daily fish wheel catch during the peak run period, from about mid July through the first week of August. The expected fish wheel catch during this period was 3,000 (based on catches over the past 5 years). Coho salmon captured in the fish wheels (approximately every 10th coho salmon) were sampled for ALS, as described in the sockeye M-R study, and tagged with a radio tag and numbered dart tag. Only healthy vibrant fish minimally impacted by capture were tagged, the remaining coho salmon were enumerated and released. All fish sampled and tagged were handled with rubberized gloves. Coho salmon were netted from the fish wheel live-box and placed into a tagging cradle modified from Larson (1995) in that a sliding meter stick was attached to the outside of the cradle for length measurements and the top side notches were deeper for tagging. The cradle was suspended in a large cooler filled with river water. The magnet was removed from the radio tag (turning the tag on) and needles were placed over the tag pins, then the tag was dipped in a Betadine solution prior to attachment on the salmon. After the coho salmon was sampled for ALS and the information recorded, the radio tag was placed on the fish; the needles were inserted through the flesh immediately posterior of the dorsal fin and approximately 2 cm down on one side of the body. The needles were removed and *Peterson* disk tags placed over the protruding pins and the ends of the pins were twisted with needle nose pliers until the radio tag was held firmly against the side of the fish (Winter et al. 1978). Finally a dart tag was inserted into the fish, on the side opposite the radio tag, and the fish transferred to the recovery/transport totes in the boat. The tagged and released times along with release location were also recorded for each fish. The radio tags were released in sequence by pulse code and frequency; the first (lowest) pulse code tags were all released (in order by increasing frequency), then the second pulse codes etc., until all tags were used, except at the very beginning when all pulse codes for the first (lowest) frequency were released.

A 20 foot welded aluminum skiff powered by an *Evinrude* 115 horsepower outboard motor was used to transport the tagged coho salmon, and species selectivity study fish. Two commercial fish totes were each outfitted with a *G-Lox* 12-volt 1,892 L/hr (500 gal) aerator pump and a 7,570 L/hr (2,000 gal) 12-volt bilge pump (to fill and empty the totes). After all the fish for the period were tagged, the fish were transported downriver in the totes to the release locations and released. The release locations were on opposite sides of the Yentna River, in calm water (back eddies), approximately half way between the fish wheel sites and the Yentna-Susitna River confluence.

Yentna River Sonar Ensonified Sites

On 18 July 1998 the radiotelemetry equipment was installed at both the NB and SB sonar sites, which is 9 km upriver from the confluence of the Yentna-Susitna Rivers. The number of tagged coho salmon available to sonar detection will be estimated by counting the number of tagged fish that migrate through the ensonified areas (a specified range offshore). These data and the total number of tagged fish that pass the upstream monitoring site will be used to estimate the proportion of coho salmon available to sonar detection. A receiver (R4000) and DCC were interfaced at each site, and programmed for a two second scan and four second record time (if frequency was received), before scanning for the next frequency. The receiver would scan all 30 programmed frequencies in the data log once every minute if no frequencies were found. On 26 July 1998 the scan and record rates were set to one and four seconds respectively, and remained at these settings for the remainder of the project. One 12-volt battery was installed at each site to power the receiver. A coaxial cable (for underwater antenna) was placed in the river at the same location as each sonar transducer and the outer end was oriented perpendicular to the bank. At the SB site the cable ran through a metal conduit (½ in x 10 ft) placed on the bank, which extended into the river, and was held in place by a sandbag and metal pipe pounded into the substrate. The cable, including the insulation stripped end, extended out of the pipe. The pipe, with attached cable, was moved up or down the bank horizontally depending upon the river level. At the NB site the cable was attached to the floating sonar shed, and the stripped end was secured underwater to the float platform.

Both NB and SB sites were operated continuously throughout the duration of the sonar operations, which were extended in 1998 for conducting the radiotelemetry and other studies. The NB site was removed on 21 August 1998 when the sonar was removed for the season. A 4-element Yagi antenna and multiplexer (required when using multiple antennae) were installed along with the existing underwater antenna at the SB site when equipment failed at the Big Bend (upriver) site, and operated from 11-21 August 1998. The scan rate was set at two seconds for each antenna, and therefore would take two minutes to scan all 30 frequencies. The receiver would scan a frequency for two seconds on antenna 1 (underwater) and then for two seconds on antenna 2 (aerial), before scanning for the next frequency. The SB 12-volt battery was connected to a solar panel when the sonar was removed (21 August), and the site remained in operation until 18 September 1998, when the telemetry equipment was removed for the season. The data collected by the DCCs at the sonar sites were downloaded to a laptop computer approximately every five days when the sonars were in operation. After checking that the recorded data downloaded and stored in the laptop computer, then the data were erased from the DCC memory.

A radio tag was attached to a foam buoy on the end of a 10 ft metal conduit and suspended in the river from a boat to test the range of the underwater antennae and ensure that the radio reception range was approximately equal to sonar ensonified areas. A person on shore monitored the receiver (receiver gain turned to maximum), noting when the frequency was received while the boat moved slowly inshore and back offshore, and up and down river from the antenna location. The conduit with attached tag was slowly lowered and raised in the water column during the testing at each area. This testing was done at both sonar sites (NB and SB) upon installation. On 24 August another radio tag was attached to a wood dowel (2.25 cm dia. x 23 cm long) on a metered line with lead weighs 20 cm below the dowel. This tag was suspended from an oar held out over the side of the boat at the SB site for testing/calibration. The lead weights were dragged along the river bottom periodically, so the tag was suspended in the water column at approximately the same depth as a tagged fish swimming along the river bottom.

The proportion of coho salmon available to sonar detection will be estimated as

$$\hat{P}_C = \frac{n_e}{n_c} \quad (26)$$

with variance estimate

$$v\left(\hat{P}_C\right) = \frac{\hat{P}_c\left(1-\hat{P}_c\right)}{n_c - 1}, \quad (27)$$

where n_e is the number of radio tagged fish counted by the receivers within the range of sonar detection and n_c is the number of tagged fish counted by the upstream receiver/logger. If the tagging operation is successful, n_c should be close to 300, although it is likely that some tagged fish will back out or die prior to moving upstream. The estimated proportion of coho salmon available to sonar (P_C) will be compared to the estimated fish wheel efficiency (E_C). An adjusted estimate of coho salmon escapement will also be computed:

$$\tilde{N}_C = \hat{N}_C \frac{n_c}{n_e}. \quad (28)$$

Several assumptions are involved in this approach. They include: (1) radiotagged fish are a random sample of the coho salmon population, (2) the population is closed, (3) all tags within defined detection ranges are recorded by the receiver/DCCs, (4) no tagged fish remain unaccounted for, (5) tagging does not affect the behavior of the fish, (6) fish wheels give an unbiased estimate of the composition of species counted acoustically, (7) sonar provides an unbiased estimate of the number of coho salmon that move through the ensonified area, and (8) the detection ranges of the radio receivers are equivalent to the ensonified areas.

River Mouth Site

The River Mouth (RM) or downriver site was installed on 17 July 1998 on the west bank of the Yentna River, approximately 500 m upriver from the confluence with the Susitna River, and 9 km below the Yentna River sonar site. This site was used to: (1) record tagged fish that move downstream (back-out) after release and are not available to the other receiving sites, (2) record tagged fish that move downstream after initially moving upstream and that were recorded at the upstream sites, and (3) record tagged fish that backed out but then returned upstream. Any fish detected at the downstream location, but not identified as moving back upstream at a later date, was censored from the data. The receiver (R4000 interfaced to the DCC) was connected to two batteries (in parallel) which were connected to a solar panel. The DCC was programmed to continually scan for all frequencies, with a two second scan and four second record time per frequency the total scan cycle was two minute (with two antennae). The store interval on the DCC was set at 15 minutes after the first week, so a fish remaining within the reception range would not be recorded every scan cycle (the fish would be recorded the first time received and then only once every 15 minutes afterwards until the fish moved out of reception). Two Yagi antennae were connected to a multiplexer and installed in a tree (height unknown), with one antenna oriented upriver and the other downriver to determine direction of movement. The radio equipment was stored in a cooler (strapped shut) for protection from the elements. On 26 July all the equipment was found in the river; a 5 by 6 m section of bank had caved into the river, along with the tree that the antennae were in. The site was reinstalled on 27 July with loaned equipment, until our equipment was repaired and returned. The antennae were installed 8-10 m up in a birch tree (*Betula spp.*). On 31 July and 4 August a bear damaged some coaxial cables and battery wires, all were replaced both times, and the equipment was placed in a commercial fish tote the second time and bleach was poured on the tote and around the site.

The site was relocated on 25 August approximately 100 m above the confluence with the Susitna River (with only one battery and the solar panel), to be accessible by float equipped aircraft. The antennae were installed up in a spruce tree (*Picea spp.*) approximately 15-20 m above the ground, again with one antenna oriented up the Yentna River and the second antenna oriented towards the Yentna-Susitna confluence to cover a portion of the Susitna River. These data were downloaded approximately every two days during the time the sonar site camp was in operation. After the sonar equipment was removed on 11 September 1998, the data were downloaded to a laptop computer approximately every week during the period that personnel were still stationed at the Yentna River camp, and also before leaving camp at the end of the field season.

Upon installation (17 July) the site reception range was tested with the radio tag (buoy on metal conduit) suspended over the side of the boat, both up and downriver from the site and across the river from bank to bank to check both antennae. The reception range was tested (again above and below and side to side) using the weighted line tag from an oar after the site was relocated on 25 August.

Big Bend Site

The Big Bend (BB) upriver site was installed on 17 July 1998 on the east river bank at the top of a high cut bank (approximately 25-50 m above the river). This site was located 24 km upriver from the Susitna River confluence and 16 km above the sonar site. The equipment set up and programmed settings were the same as at the RM site: R4000 receiver, DCC, two Yagi antennae with multiplexer, dual batteries, and solar panel with controller. On 8 August persons unknown had removed the cooler lid and tampered with the equipment, and the equipment was not operating and wet from the elements. Date of reinstallation is unknown. On 26 August the site was relocated (with only one battery) downriver (less than 1 km) but still remained on the high bank at the lower end of the Big Bend ridge, to be accessible to float aircraft. Upon initial installation the site reception range was also tested with the same tag and methods as were conducted at the RM site, and again on 26 August before and after relocation with both the conduit and weighted line tags. Data downloading was approximately weekly.

Aerial Surveys

The Yentna River, including all tributary rivers and creeks is over 2,500 km in total length, with the majority of the rivers accessible to migrating adult coho salmon. On aerial surveys, because of the river length and the time involved to pinpoint each fish to a specific locale, fish were only located to within a 5 km river section. The final destinations of radio tagged fish were assigned to the upper most locations where the fish were found, even if on subsequent surveys fish were found lower in the river system; unless the fish only moved a short distance upriver (usually within three weeks of tagging) and then dropped down and remained in lower locations for the duration of the aerial surveys. Data from the aerial surveys will be mapped to indicate major spawning areas of coho salmon. The proportion of tagged fish that migrate up the major tributaries and the average migration rate will also be calculated.

Aerial survey flights were conducted twice weekly, beginning on 20 July 1998, and continued through the week of 12 September, except during the weeks of 9 and 16 August when three flights were conducted. One flight was conducted weekly during 13 and 20 September, and three final flights on 7, 9 and 10 October were conducted to survey the whole Yentna River drainage including tributary rivers and creeks. Surveys were conducted at altitudes of 500-1,000 ft above ground level (AGL); 500 ft in areas where numerous tagged fish were received at the same time and at 1,000 ft in tributaries and areas where fish were widely dispersed. Flights were conducted using a *Piper* Super Cub PA-18-160 owned and operated by Clyde Dahle of Dahle Air Service Inc. Anchorage, Alaska. The aircraft was equipped with oversized (tundra) tires, and flights were conducted off a private airstrip located approximately 2 km above the sonar site/camp. Two flights the first week of September were conducted with the aircraft equipped on floats and originated from Lake Hood in Anchorage. Beginning the week of 6 September and throughout the remainder of the flights a *Cessna* 305-A (L-19 Bird Dog) equipped with floats was used, owned and operated by Jose DeCreeft of Northwind Aviation, Homer, Alaska. These flights originated from Longmere Lake in Soldotna.

On the first survey flight on 20 July, the receiver was not able to ID the tags using H style dipole antennae mounted on the aircraft. For all remaining flights two Yagi (4-element) antennae were used, each was mounted side looking with a 30 degree tilt down from horizontal on the aircraft wing lift strut (with strut mounting brackets manufactured by ATS) (Gilmer et al. 1981, Kenward 1987). An aircraft switch box inside the fuselage (connected to both antennae) allowed the observer to switch between left, right, or both antennae to better locate the direction of the radiotagged fish (Winter et al. 1978). When a tag frequency was received by the receiver (R4100), scanning was stopped and the tag(s) was ID-ed. If the receiver was not able to ID the tag then the antenna switchbox was used to determine which antenna had the strongest reception and the plane then proceeded in that direction until the tag was ID-ed. Upon ID-ing a tag, the

GPS coordinates, river/creek name and general location, and time were recorded on the aerial survey log. If on the next scan cycle the previously recorded frequency/pulse was received stronger then the new coordinates and time were recorded.

On 23 September and all survey flights in October the receiver was interfaced with a DCC, and the COMP/REC (computer/receiver) switch was held closed in the REC position with a rubber band. This allowed the receiver to operate without being controlled by the DCC. After ID-ing a tag with the receiver the REC switch on the receiver was set to the T/D (to DCC) position to verify the pulse code by the DCC, by pressing the ID button on the DCC. The DCC would place an M in front of the code (example M15) if the tag was transmitting in the mortality mode, where as the receiver would have a 3 or 6 at the end of the code for mortality mode (153 or 156 instead of 155).

Most aerial survey flights were conducted on the Yentna River and tributaries (Figure 2). Occasionally flights were conducted on other rivers to locate lost or unaccounted tags. The rivers and creeks on the west side of Cook Inlet from the West Forelands to past Palmer (up Knik Arm) were all partially surveyed at least once, and included (in order in a north heading up Cook Inlet); McArthur, Chakachatna, Middle, Nikolai, Old Tyonek, Chuitna, Beluga and tributaries, Olson, Theodore, Lewis, Ivan, Little Susitna (to ADF&G weir), Fish Creek (Big Lake), Cottonwood, Lucile, Wasilla, Knik, and Jim. The Susitna River was surveyed from the mouth (Cook Inlet) up to and including lower sections of the Talkeetna River; Chunilna (Clear), Disappointment, and Sheep. Other tributaries of the Susitna River that were partially surveyed included; Birch, Montana, Sheep, Kashwitna, Little Willow and Willow. Both the Deskha River (Kroto Cr.) and Alexander Creek were surveyed completely more than once. The lower Susitna River (from the Yentna-Susitna confluence downriver to Cook Inlet) and Kroto Slough were usually surveyed once a week with the Yentna River survey. On 27 August 1998 a survey was flown at low tide (2.9 ft) along the west side of Cook Inlet from the West Forelands to Fish Creek to locate fish (possible mortalities) on the exposed beaches.

Tributaries of the Yentna River that were surveyed include (in order upriver on the west side); Twentymile Slough, Skwentna (to confluence with Crystal) and tributaries; Eightmile, Shell, Talachulitna and tributaries (Thursday, Friday and Saturday), Contact, Canyon, Hayes, Trimble, Spring, and Happy up to and including Moose. Other west side Yentna tributaries above the Skwentna River to the upper forks included; Red, Johnson, Kichatna, Nakochna, and Fourth of July. East side Yentna River tributaries include (upriver from the confluence); Fish, Moose, Kahiltna, Peters Creek and tributaries (Cache, Treasure), Lake Creek and tributaries (Yenlow, Home, Camp, Sunflower), Fish Lakes, and finally Clearwater. Larger unnamed creeks, sloughs, and side channels were also surveyed, some only partially.

RESULTS

Stocked Sockeye Salmon

1997 Results

Otolith samples were read from 1,114 sockeye salmon collected at the Chelatna Lake weir in 1997, and a total of 67 were positive (6.01% thermally marked) (Table 3). A total of 814 otolith samples collected from the Yentna River fish wheels (95 NB and 770 SB) were read and 17 were positive (1.97% marked). The estimated abundance of otolith marked (stocked) fish were compared between projects using run timing lags of 4 to 7 days (Table 4). The effect of changing the assumed travel time was minor. The point estimates indicate that the Yentna River sonar site was only about 53% of the Chelatna Lake weir estimate. For each lag the 95% confidence interval of the abundance difference indicated that the sonar site was significantly lower than the Chelatna weir (the intervals do not overlap zero). However, as indicated by the width of the confidence intervals and relative error that ranged from 68% to 73%, the estimated differences exhibited fairly low reliability.

The dominate age class of marked fish from both sites was age-0.3, and the percent was similar between the two sites, 56.7% at Chelatna Lake and 52.9% at Yentna River (Table 5). There was a much higher percent of age-1.2 marked fish at the Yentna River (17.6%) than at Chelatna Lake (6.0%), while the percent age-1.3 marked fish was greater at Chelatna Lake (22.4%) than at Yentna River (11.8%).

1998 Results

Otolith samples were collected from 1,332 sockeye salmon at the Chelatna Lake weir in 1998. Of the 914 otoliths read (every 10th sample was pulled and not read), 65 (7.1%) were thermally marked (Table 3, Appendix A-2). Otolith samples were also collected from 1,801 sockeye salmon at the Yentna River fish wheels; 711 NB and 783 SB otolith samples were readable (284 were not read). Of the 1,494 Yentna River otoliths read, 48 (3.2%) marked otoliths were recovered (Appendix A-2), 31 (64.5%) from the NB and 17 (35.4%) from the SB fish wheels (Table 3). The age composition of marked fish at Chelatna Lake was predominantly age-0.3 (55.4%), although age-0.3 fish comprised only 7.3% of the total weir sample and 5.9% of the Yentna River fish wheel samples (Tables 5 and 6). Age-1.3 fish comprised 62.5% of the fish wheel samples and 82.6% of the weir samples but comprised only 23.1% of the marked recoveries at the weir. The NB fish wheel marked samples were predominantly age-0.3 (51.6%), age-1.3 comprised 25.8%, while SB marked samples consisted of more age-1.3 (41.2%) than age-0.3 (17.6%) (Table 5). Males comprised 55.8% and females 44.2% of the Chelatna Lake. ALSO samples, while males comprised 48.9% and females 51.1% of the fish wheels ALSO samples (Table 6).

The Chelatna weir was inoperable from July 25 through August 1, 1998 and therefore a total count of sockeye salmon into Chelatna Lake was not possible. Only 27,284 sockeye salmon were counted during the weir operation of which an estimated 1,937 had otolith marks. In contrast, 3,941 otolith marked fish were estimated to have passed the sonar counter. Without a total count we could not test for a difference in the escapement of stocked sockeye salmon between fish wheel apportioned sonar counts and sampling at the weir. Alternatively the same difference equation can be used to estimate total Chelatna escapement assuming equality and therefore setting equation 11 to zero. An estimated 55,000 sockeye salmon would have had to enter Chelatna Lake to account for the otolith proportions at the Yentna fish wheel, an average passage of 4,000 sockeye salmon per day during the period the weir was inoperable. At the extreme, 105,000 sockeye salmon would have had to enter Chelatna Lake to equal the percent undercounting at the sonar site (53%) estimated to have occurred in 1997. Fish passage would have had to average 11,000 sockeye salmon per day during the period the weir was inoperable.

Sockeye Salmon M-R Estimate

The Yentna River fish wheels operated 24 hours a day on both banks, from 7 July through 21 August, 1998. A total of 26,461 sockeye salmon were captured, 12,067 in the NB and 14,394 in the SB fish wheels. Catches included 17,057 pink *O. gorbuscha*, 1,102 chum, 1,712 coho and 54 chinook *O. tshawytscha* salmon (Appendix A-3). White tags were placed on a total of 2,918 (24.2%) sockeye salmon caught in the NB fish wheel and yellow tags placed on 3,426 (23.8%) sockeye salmon caught in the SB fish wheel. Very similar proportions of fish were tagged from each fish wheel through time (Appendix A-4).

All sockeye salmon enumerated through the weirs at Chelatna and Judd Lakes were observed for the presence of tags. A total of 627 tagged sockeye salmon were recovered, 5.3% of the tagged fish passed the Chelatna weir and 4.5% Judd weir (Table 7). No tags were observed or recovered at Chelatna Lake during the peak of the run (26 July to 1 August, 1998), as the weir was in-operable due to high water conditions. When detected, tagged fish were captured and tag colors and numbers were recorded. If a tagged fish escaped prior to capture, the tag color was recorded which identified the fish wheel bank from which it was tagged. From total recoveries of tagged fish, the majority (82.5%) of white tagged (NB) fish migrated to Chelatna Lake, while the majority (62.8%) of yellow (SB) tagged fish migrated to Judd Lake (Table 7). Tagged and untagged sockeye salmon may not have mixed well, as the marked proportion increased through time at both weirs (Figure 3).

Tag recoveries and escapement estimates were defined by fish wheel bank, tag color, and by sex of the tagged recoveries. Significantly different ($P<0.05$) recovery rates were observed at Chelatna and Judd Lakes (Table 8). When stratified into subgroups of tagged fish by bank and sex, only south bank tagged males were recovered in statistically equal proportions ($P> 0.05$) (Table 9). Lastly, there was a significantly different ($P<0.000$) recovery rate between bank of origin; 8% of the white NB tags and 11.5% of the yellow SB tags were recovered. To test the assumption that there was no tag loss, we dual tagged random numbers of sockeye salmon caught in each fish wheel. As fish passed through the weirs, tagged fish were observed for the number of tags present. There were 339 tagged sockeye salmon inspected for tag loss at Chelatna Lake with only 1 fish missing one tag. The tag retention rate was also good at Judd

Lake, only 1 tag was missing for 288 dual tag recoveries. The probability of losing either a left or right-side tag was calculated at 0.16% (Table 9).

We did not estimate population size based on tag recoveries in 1998. We were not confident that the assumptions underlying the estimator were fulfilled. We arrived at this decision after documenting the significant difference in tag recovery rates between bank of origin, the difference in time of arrival at the weirs between tagged and untagged fish, and the lack of recovery data during the peak of the run at Chelatna weir.

Sockeye Salmon Weirs

In 1997 the Chelatna Lake sockeye salmon escapement was 84,899, and was the highest recorded escapement to date, 3.4 times higher than the 1992-1996 (weir counts) mean of 24,331 (see Table 2, Figure 4, Appendix B-1). The midpoint of the run was 26 July 1997. Although age-class 1.3 was the dominant age class of returning fish in 1997 and comprised 50.7% of the run, it was also the lowest return percentage for age-1.3 fish recorded (Table 10). Age-1.2 fish comprised 31.7%, and age-0.3 fish comprised 15.9% of the 1997 sockeye salmon run.

The 1998 total Chelatna Lake sockeye salmon escapement is unknown as the weir washed out during the peak of the run. A total of 27,284 sockeye salmon were enumerated through the weir, prior to and after the washout. The run timing (both beginning and ending dates) was slightly later in 1998 than 1997 (Figure 4). A few coho, pink, and chinook salmon were also counted (Appendix B-2). A total of 1,122 ALS samples were collected and analyzed. The dominant age class of returning sockeye salmon to Chelatna Lake was age-1.3 (79.9%) (Tables 10 and 11), which was the second highest year since 1990 and 15% greater than the 1990-1997 mean of 64.1% (Table 10). The 0.3 age class, which is a significant component of the hatchery contribution to Chelatna Lake, comprised only 7.1% of the run. Three-ocean age fish comprised 88.1% of the return. Mean lengths (MEF) for age-1.3 fish were 578 mm for males, and 552 mm for females. Males comprised 54.5% and females 45.5% of the 1998 run (Table 11).

The Judd Lake sockeye salmon escapement was 34,416 in 1998 (Table 2, Figure 5, Appendix B-3), and accounted for 29% of the 1998 Yentna River sonar estimate of 119,623. The midpoint of the run was 6 August 1998. The peak escapement occurred on 2 August 1998, when 3,384 sockeye salmon passed through the weir. A total of 1,906 ALS samples were collected and 591 were analyzed. Age-class 1.3 was the dominant returning age class in 1998 and comprised 56.0%, while age-classes 2.2 and 2.3 comprised 19.1% and 18.6%, respectively (Table 11). Three-ocean age fish were also the dominant age class at Judd Lake and comprised 75.3% of the return. The mean lengths (MEF) of age-1.3 fish were 564 mm for males and 543 mm for females. Males comprised 40.8% and females 59.2% of the 1998 run.

The 1997 sockeye salmon escapement to Larson Lake was 40,282 (Figure 6) (Carlson et al. 1998). The midpoint of the run was 12 August 1997. Daily escapement counts are reported in Appendix B-4. The dominant age class was age-1.2 (53.5%), and age-1.3 fish comprised 27.3%

of the run (Table 10). Males comprised 44.3% and females 55.7% of the 1997 sockeye salmon run.

The 1998 sockeye salmon escapement to Larson Lake totaled 63,514 (Table 2, Figure 6, Appendix B-3), and was two times higher than the mean weir count of 32,497. The midpoint of the run was 1 August 1998. Very few pink, chum and coho salmon were counted through the weir (Appendix B-5). The Larson Lake escapement greatly exceeded pre-season predictions, so the sampling scheme was reduced approximately mid-way through the migration (beginning August 4). Samples collected prior to the reduction were systematically chosen (every nth sample) for analysis so the same proportions were analyzed throughout the run. A total of 1,800 samples were collected and 574 were analyzed. Age-class 1.3 was the dominant returning age class to Larson Lake and comprised 49.0% of the run, and was similar to the historic mean (50.8%) (Tables 10 and 11). Age-2.3 fish comprised 24.0% of the 1998 run, and was 3 times greater than the historic mean of 8.0%. Three-ocean age sockeye salmon comprised 73.2% of the return. The mean lengths (MEF) of age-1.3 fish were 571 mm males and 538 mm females. The 1998 run was comprised of 41.3% males and 58.7% females.

Age-class 1.3 was the dominant 1998 age class of all ALS sampled sockeye salmon at the fish wheels and weirs; Yentna River 62.7%, Chelatna Lake 79.9%, Judd Lake 56.0%, and Larson Lake 49.0% (Table 12). Sockeye salmon sampled for ALS by fish wheel bank at Yentna River showed a slight difference by bank. Mean lengths (MEF) for males age-1.3 were 564 mm on the NB and were 559 mm on the SB. The combined mean lengths were, males 562 mm and females 538 mm (Table 13). Age-1.2 sockeye salmon comprised 15.7% of the run and mean lengths were 485 mm males and females 486 mm. Males comprised 48.5% and females 51.5% of the 1998 run.

Fish Wheel Selectivity

A total of 1,032 sockeye salmon were ALS sampled and dual dart tagged for the species selectivity study, 569 (4.0%) of the SB total catch were blue tagged and 463 (3.8%) of the NB total catch were green tagged (Appendix A-4). A total of 876 coho salmon were also sampled and tagged, 655 (15.1%) of the SB total catch were blue tagged and 221 (12.9%) of the NB total catch were green tagged (Appendix A-5). All tagged fish were released in sloughs 3-4 km down river, along the same river bank as captured.

A total of 44 tagged sockeye salmon (4.3%) and 53 tagged coho salmon (6.1%) were recovered at the fish wheels. Chi-square analysis of these recovery proportions support the null hypothesis of no difference in recovery rates between the two species, P=0.081 (Appendix A-1). From the 44 recaptured sockeye salmon, 33 were tagged on the opposite bank (75.0% cross-over); 21 recaptures were NB tagged of which 16 were recaptured in the SB fish wheel, and 17 of the 23 SB tagged recaptures were in the NB (opposite) fish wheel (Table 15). Coho salmon crossed-over at less than half the rate as the sockeye salmon (35.8% cross-over, 19 out of 53 recaptures). A total of 9 NB coho salmon were recaptured, all in the SB fish wheel, and of the 44 SB tagged coho salmon recaptured 10 were in the NB fish wheel (Table 14). Chi-square analysis indicate that the cross-over rates between sockeye and coho salmon was significantly different

(P=0.00012). Holdover time (from time released to time recaptured) was much lower for sockeye than coho salmon (2.7 days vs. 10.3 days) (Appendix A-6).

In all recoveries pooled for both sockeye and coho salmon, these was no size selectivity (K-S test, sockeye P=0.297, coho salmon P=0.979), or bias associated with gender (chi-square, sockeye salmon P=0.674, coho salmon P=0.233) detected. When broken down into male and female groups, there were also no size biases detected for either sex of either species when recovered tagged fish were compared to unrecovered tagged fish (K-S test, P> 0.05) (Table 16, Appendix A-1).

Few tagged salmon were recovered in this study. Our inability to detect a difference between the recovery rate of coho and sockeye salmon does not necessarily mean that coho and sockeye are counted equally well at this site. Rather this result may be a function of small sample size and low power. In other words a difference may exist but we had no power to detect it. The resulting Chi-square test p-value might be considered significant laying between conventional levels of 0.1 and 0.05. Interestingly that priori we speculated that sockeye salmon would be recaptured at a greater rate than coho and not less. Another finding of the selectivity study was the difference in holdover time between sockeye and coho salmon. This compares with the handling reaction to radiotagging coho with the backing down-stream. We were also surprised by the cross-over rate between release and recapture.

Coho Salmon Distribution

Tagging and Sampling

During the period 17 July to 21 August 1998, a total of 306 coho salmon captured in the fish wheels (78 NB and 228 SB) were sampled for ALS and tagged with a radio and dart tag (nine returned radio tags were redeployed). During the peak week of 26 July to 1 August, 143 coho salmon (46.7%) were tagged and released (Table 16). The majority of the tagged coho salmon were held for less than one hour between tagging, transportation down river, and release. The longest time a tagged coho salmon was held before release was 1 hour 19 minutes, and the most coho salmon transported to the release location in one trip were 12.

The dominant age class of sampled coho salmon was age-2.1 (72.9%), and ages 1.1 and 3.1 comprised 20.2% and 7.0% of the sampled run, respectively. The mean lengths (MEF) of age-2.1 coho salmon were, males 583 mm and females 564 mm. The sex composition was dominated by males and comprised of 56.6% of the sampled fish (Table 17).

Radiotelemetry Equipment

The ATS equipment was reliable and operated at both the RM and BB sites for the duration of the project off the external 12-volt battery and solar panel with out having to recharge the receiver or external batteries. The data collected and stored by the DCC was easily downloaded and stored to a laptop computer with the PROCOM PLUS software. Initial setup with a receiver and programming the frequencies and setting variables into the DCC was straightforward. Although the user manuals are somewhat basic and lacking, especially the DCC manual about what certain output data means (Explanation of outputted data). The receiver (R4100) used on aerial surveys was able to pulse code the tags correctly most of the time, although it did not pulse the mortality codes (3 and 6) reliably. If several tags on the same frequency were received at the same time the receiver would only ID the strongest tags even when the aircraft was circling and the antenna switch box was used to try and isolate weaker signals. When the receiver was interfaced with a DCC, the DCC would ID tags in the mortality mode consistently.

The radio tags (model 7 PN) were quickly and easily attached to the fish, and the trailing antenna did not pose any deployment problems. We supplied ATS with the stainless steel attachment pins and they were installed on the radio tags by ATS prior to shipment. The operational life of the tags (battery life in excess of 90 days) seems more than adequate for this type of study. We do not believe that we "lost" any tags because of premature battery failure. On an aerial survey one tag was received and ID-ed from over 45 km distance, the tag was out of the water and the location offered clear line-of-sight to the aircraft. On other flights, several tags (also presumably located out of water) were received and ID-ed at distances greater than 25 km.

The Yagi antennae were not oriented correctly (antenna boom was placed with the elements in horizontal instead of vertical plane) at all stationary sites, and again when the sites were relocated. Consequently data at all the stationary sites was compromised; the equipment could not receive and therefore record all the radiotagged fish that migrated through the respective areas that should have been recorded. Some fish probably migrated along the river bottom and would have been out of effective reception range because of water depth even if the antennae were correctly installed. When receiver reception range tests were conducted at the RM and BB sites upon installation (with radiotag and buoy attached to metal conduit), the receiver/DCC was able to receive and correctly ID the tag all the way from the near to the far bank to the depth of the conduit (3 m), and both up and down river with each antennae for what we figured was an acceptable distance. When the reception range was tested again at the RM site with the weighted line tag, upon relocation on 25 August, neither antennae was able to receive the tag at any up or down river location or across the river. The tag was received (recorded) only once; when directly in front of the site approximately 5 m out from the bank, in less than 1 m water depth. When the tag was suspended in the river from the opposite bank the receiver would only recorded the tag to a depth of approximately 20 cm. We believe that when the tag was being tested that the conduit acted as an above water aerial even though the tag was on a foam buoy on the end of the conduit and no metal parts of the tag or trailing antenna were touching the conduit. Because the signal from the tag on the conduit was received in a large area around both the RM and BB sites, even though at limited depths (3 m maximum), we assumed everything was working properly and that most tagged coho salmon migrating past the sites would be recorded.

Sonar Ensonified Areas

Testing the range of the underwater antenna (coaxial cable with bare outer end) to approximately equal the sonar ensonified area with the radio tag attached to the metal conduit worked sufficiently at these sites. Later with both the conduit and weighted line tags the results were similar. With the receiver gain set to maximum, the receiver/DCC was able to receive and ID tags from shore out to a distance approximately equal to the ensonified range (Pers. Comm., sonar crew members) although it was not accurately measured, and the tag was also received from the river bottom to the surface. The lateral (perpendicular axis to antenna) distance was approximately 5 m at the outer reception range edge, again not accurately measured. The receiver was not able to receive the tag when the tag was moved less than one meter further out from the outer range edge.

The underwater antenna was exposed (approximately 2 m vertical height above the river level) when the equipment was removed for the season at the SB site, so September (suspect) data was excluded. Also excluded were coho salmon that the time tagged or released (if released at the fish wheel) was within two hours of the passage time as recorded by the DCC at the sites (because of the proximity of the fish wheels to the sonar sites the tags were recorded by the DCC when tagging occurred, primarily at the NB site), and fish recorded in either mortality mode (3 or 6).

A total of 24 radiotagged coho salmon with final destinations above the site, were recorded by the telemetry equipment as having migrated through the ensonified areas at the sonar sites (5 NB and 19 SB) in 1998 (Table 18). The majority of the coho salmon that passed through the ensonified areas were recorded by the DCC only once, 13 (54%) (Figure 7). The DCC records showed fish migrated slower on the NB and averaged 3.4 records per fish, while SB fish averaged 1.6 records. While the SB aerial antennae was in operation 12 fish were recorded, of which 5 were also recorded in the SB ensonified area at the same respective times (Table 19). The antenna was not placed very high above the river and did not have total coverage across the river; three coho salmon were recorded in the NB ensonified site, of which none were recorded on the SB aerial. With a final estimate of 84 radiotagged coho salmon with final destinations above the sonar site, 27.6% (24) were recorded migrating through the sonar ensonified ranges. This is 4.5 times higher than the fish wheel recaptures of the species tagged coho salmon (6.1%). Including deleted coho salmon (15) in the lower Yentna River (recorded through the sonar area by the DCCs but later backed down and remained below the site) the sonar counters would have counted 30.3% (30) of the run.

Coho salmon mean holdover times (lag time from handling affect), from time of release to time of first DCC record at the sonar sites (both sites) for radiotagged fish with final destinations above the sites was 15 days 2 hours (Table 20). Coho salmon that were dual dart tagged for fish wheel selectivity studies had a shorter mean holdover time than radiotagged fish in all categories (10 days 7 hours) except for NB released fish recorded at the SB site (10 days 5 hours).

The mean migration time from the RM to the sonar sites was determined from DCC records from both sites. If a fish was recorded at the sonar site, RM site records were checked to see if the fish had been recorded, and if so then the last record was used to calculate migration time (if less than 24 hours, longer times were deleted by assuming the fish were still milling and not actively migrating up-river). Although a small sample (*N*=5), the mean migration time was 11 hours 10 minutes for coho salmon to travel approximately 9 km upriver (Table 21).

The diel migration timing for coho salmon, from DCC records at the stationary sites for all fish, showed the majority of coho salmon migrating during the 1600-2000 hour time period (30.4%), followed by the 2000-0000 hour period (25.0%), and 0800-1200 period (16.1%) (Table 22). The lowest migration time periods were 1200-1600 hour (5.4%) and 0400-0800 hour (8.9%). The periods from highest to lowest migration were also the same for coho salmon with final destinations above the respective sites. The RM site data were not used in determining the migration timing as fish dropped down after release, and the records could not be used to determine if fish were migrating or milling without uncertainty.

River Mouth Site

As noted earlier the antennae at this location were improperly installed for maximum reception. Consequently only 131 individual fish were recorded, and some records were inaccurate or deleted (radiotagged sockeye salmon, time recorded same as tagging time, improper frequency). Although some of the 306 tagged coho salmon probably did not drop downriver after tagging and release (remained at or near the release location then migrated upriver), others might have been in deep water (areas were greater than 5 m deep at this location) when they migrated past the site and would have been out of effective reception range even if the antennae were correctly positioned. From the RM site records of radiotagged fish, 91 tagged coho salmon were later located (final destinations determined), and 34 were never located again (Table 23). The DCC records also showed immediate back-out for tagged fish after release, with a mean for all recorded fish of 6 hours (from release time to first record at site) (Table 24). The shortest time was for fish never located again (4.7 h, N=15) and the longest time was for fish released at the fish wheels (7.4 h), as would be expected. ANOVA indicate no significant difference (P=0.246) in mean backout times by destination. Most fish were recorded several times and on different days. One fish was recorded 51 times on one day and then at a later date 294 times almost consecutively over a 10 hour period for a total of 345 times, before the DCC settings were changed to a 15 minute store interval.

Big Bend Site

Antennae at the Big Bend site were also incorrectly installed for the duration of the project. A total of 11 radiotagged coho salmon (and 1 sockeye salmon) were recorded at the BB site, of which two coho were never located on aerial surveys, and four dropped back and remained down-river for a total of five coho salmon counted up-river (Table 23). The river was deep (greater than 5 m) for most of the distance both immediately up and down river along the bank adjacent to the site at the first location, and was still deep up river when the site was relocated on 26 August.

Aerial Surveys

A final total of 222 radiotagged coho salmon (of 306 released) were located on aerial surveys. Included are 52 fish that were only located once during aerial surveys, or located prior to 16 August and were not recorded later at any stationary site (Table 25). Also included are tags returned by sport and commercial fishermen as the final location or fate was known for these fish; seven were sport harvested, two sport released, six commercial harvested and six were moralities.

A final destination location was determined for 170 radiotagged coho salmon (55.6%), with 99 (32.4%) in the Yentna River basin, 40 were in the mainstem Yentna River and 59 were in tributary rivers and creeks (see Table 25). The Skwentna River system was the main tributary that the majority of tagged coho salmon migrated to (30 total), with 11 to the Talachulitna River and tributaries and 10 to the Hayes River area. The Kichatna River system had 18 total, with four each in Johnson and Red Creeks. The 84 tagged coho salmon in the upper Yentna River (BB and above) and tributaries are assumed to have spawned at these upper locations. The majorities of tagged coho salmon located in the lower Yentna and Susitna Rivers, and at confluences with Alexander and Deskha Rivers were assumed to have died prior to spawning. Most of the coho salmon at these locations migrated shortly after release and then remained in the same general vicinity throughout the duration of the aerial surveys. A few coho salmon migrated up the Alexander and Deskha Rivers and also into lower creeks of the Yentna River (Fish Creek and Kroto Slough) and probably spawned at these locations. A total of 14 known tagged coho salmon dropped back down into Cook Inlet, with the majority then migrating into west side Cook Inlet tributaries south of the Susitna River and north of the West Forelands.

The proportion of radiotagged coho salmon males in the upper Yentna River basin was significantly higher (X^2=29.09, df=1, P<0.005) than females, 86.9% (73) males, as compared to the sex composition of all tagged coho salmon at the fish wheels, 57.8% males (see Table 17). Males were also found in higher proportions in most other areas (groups), while the proportion of females was higher in the lost tags (unaccounted) group and was significant (X^2=9.41, df=1, P<0.005), (Figure 8, Appendix C-2).

DISCUSSION

Stocked Sockeye Salmon

Adult sockeye salmon otoliths (from marked fry plants into Chelatna Lake) were examined for the presence of thermal marks from fish sampled at both Yentna fish wheels and the Lake Creek weir, and provided a means of identifying the hatchery stock component. Simple extrapolation of the proportions of hatchery fish at each site would allow for a comparison of the sonar estimate of hatchery fish bound for Chelatna Lake to the extrapolated count at the weir. This method was used in 1997 and the results suggested that the sonar estimate may have been biased low, but the reliability of the difference in the estimates was also found to be statistically low (Carlson & Tarbox, 1997). The proportion of thermally marked sockeye salmon captured at the Lake Creek weir was slightly greater in 1998 (7%) than 1997 (6%). Similarly, the proportion of thermally marked fish sampled at the Yentna River fish wheel was also slightly greater in 1998 (3%) than 1997 (2%). We were unable to determine with any degree of confidence the number of stocked sockeye salmon that returned to Chelatna Lake in 1998, as a significant proportion of the escapement was unaccounted for when the weir was out of operation.

These results should be interpreted with some caution. Assuming that the Chelatna weir estimate is unbiased, there is fairly clear evidence that the estimate of hatchery fish from the Yentna sonar site is biased low, although the magnitude of the bias is not well defined. Also, there is no indication concerning the cause of the bias which could be or a combination of (1) sonar undercounting (one or both banks), (2) fish wheel selectivity against hatchery reared fish, (3) fish wheel selectivity against sockeye salmon, and (4) inadequate sampling of the fish wheels due to sonar counting inaccuracies (one or both banks). Fish wheel selectivity against sockeye salmon was tested in 1998 and the results indicate no detectable bias by species, size, or gender. It should also be noted that the Yentna river sonar estimates have been used for several years as an index of sockeye salmon abundance in the Susitna drainage. The results reported here do not suggest a lack of year-to-year consistency in the estimates nor do they imply that the sonar counts lack validity in stock-recruit assessment.

The average length of the predominant age classes of Chelatna Lake thermally marked sockeye salmon (both sexes) was about 18-21 mm longer than the average length of the same age classes of sockeye salmon sampled at the fish wheels. We assume the sampling technique was unbiased, and was the same at both the Yentna River fish wheels and Lake Creek weir.

Age-0.3 sockeye salmon were the highest proportion of thermally marked (stocked) fish recovered from the Yentna River fish wheels and the Chelatna Lake weir. Chelatna Lake is a highly productive lake in terms of plankton (Appendix C-3). When stocked, fry average about a quarter gram in weight, but many smolt the same summer and have grown to 2 to 5 grams (Fandrei 95). This explains why a large proportion of stocked sockeye salmon return as age-0.3 fish.

The majority of thermal marked recoveries came from the NB fish wheel (65%). This suggests that Chelatna Lake sockeye salmon are more north bank oriented when passing the fish wheel site, although the proportion of age-1.3 thermal marked fish was 2.3 times higher from the SB fish wheel, suggesting possible age-class stratification. Lake Creek enters the Yentna River on the north bank approximately 45-50 km above the fish wheel site. Results from the M-R study also strongly indicate the same north bank orientation for Chelatna Lake sockeye salmon and a south bank preference for Judd Lake (which drains into the Yentna River from the south) sockeye salmon.

Sockeye Salmon M-R Estimate

More than 6,300 sockeye salmon were tagged and released at the Yentna River fish wheels. We assumed all fish had an equal probability of being tagged. For the most part, tagging operations proceeded smoothly and we were able to keep up with fish wheel catches and met our tagging goals. Personnel at the weirs did not have a problem spotting tagged fish and identification of tag colors was easily accomplished. We encountered fewer tagged fish at the weirs than expected from our tagging ratio. We also observed an inconsistent marked/unmarked rate through time, which convinced us there were problems underlying this project component. Therefore, we were unable to effectively assess the accuracy of the Yentna River sonar escapement estimate. Why marked fish were not recovered in the same proportion at the weirs as were tagged at the fish wheels, and appeared to have different timing, is unclear. The most likely explanations are that a large number of tagged fish either died due to stress from fish wheel capture/tagging, or that tagging affected their normal migratory behavior, or possibly not all fish had the same probability of being tagged. Some of these scenarios are a function of handling. Carlson et al. (1998) also found that the proportion of tagged sockeye salmon recovered on their spawning grounds in Larson Lake was significantly less that the proportions that had been tagged at a weir located at the lake outlet. We felt that the M-R population estimate based on spawning grounds tag recovery was biased and not comparable. In addition, the Chelatna Lake weir was washed out for a week. Some tagged fish could have escaped into the lake unaccounted for, and given the difference in timing between marked and unmarked, even a greater number of unmarked fish entered un-counted.

If an unbiased M-R estimate is to be made, certain assumptions need to be met. Few assumptions were met in this study that would allow for an unstratified or stratified estimate to be made. Specifically, assumption 1 (equal probability of being tagged and inspected for tags, and complete mixing of tagged and untagged fish) was unsatisfied. The proportion of all tagged fish passing Judd and Chelatna Lakes were not equal (Table 8, $P < .05$). The second assumption that the population is closed cannot be satisfied in the case of a population of migrating salmon, as sport and subsistence fishing affects the second assumption, but Chapman's modification to Peterson's M-R method makes allowances for this assumption. The third assumption that all tagged fish were reported was also un-fulfilled; Chelatna weir washed out for a week and the timing difference in marked/unmarked negates fulfillment of this assumption. The fourth assumption that no tags were lost was also un-satisfied. Tag loss could not account for the low recovery rates of sockeye salmon at the weirs as dual tagging revealed less than one percent of recovered fish had lost a dart tag. Dart tagging proved to be a quick and effective method of marking fish. No corrections were required to the M-R population estimates to account for lost tags. The last assumption (5) may have been unsatisfied. It is believed that handling and tagging altered fish behavior and survival, making fish less susceptible to recapture. Results from the species selectivity study also imply that stress from handling may have caused fish to alter behavior (migratory) by the amount of crossover recoveries found at the fish wheels; 75% of the tagged sockeye salmon released down river of the fish wheel site crossed over to the opposite bank.

Recoveries of dart tagged fish (M-R study) at Judd Lake showed a definite south bank orientation in the Yentna River (63%), which corresponds to the bank that the Talachulitna River (Judd Lake) enters the Yentna River. Chelatna Lake marked recoveries were more north bank oriented in the Yentna River, (83%) which corresponds to the bank that Lake Creek (Chelatna Lake) enters.

Sockeye Salmon Weirs

The large weir count (over 60,000 sockeye salmon) at Larson Lake in 1998 demonstrates why this system is considered one of the largest producers of sockeye salmon in the Susitna River drainage. These weir counts provide important data as to whether or not Yentna River sonar estimates can be used as an indicator of discrete stock escapements. Prior to this year, only five years of data had been collected that would allow for a comparison of Yentna River sonar estimates to Larson Lake weir counts, and the relationship was strong, $r^2 = 0.65$. The large escapement count into Larson Lake in 1998 added a sixth data point, making the new relationship very weak, $r^2 = 0.24$. If the pre-1998 relationship between Yentna River sonar abundance estimates and Larson Lake weir counts were used to predict the 1998 escapement into Larson Lake, an estimate of 33,548 fish (53% of actual count) would have been expected. This could be another indication that the Yentna River sockeye salmon sonar estimate may be biased low, or it could be that Yentna River sonar estimates are not a good predictor of mainstem Susitna River stocks. However, one must exercise caution when using predictive models derived from only five or six data points.

The first total weir count at Judd Lake occurred in 1998. The sockeye salmon escapement was three times greater than the pre-season prediction, which was based upon the 1994 hydroacoustic estimate of 278,000 age-0 fry rearing in the lake (King and Walker 1997). Judd Lake accounted for nearly 29% of the Yentna River sonar derived escapement estimate of 119,623. It is probable that Judd and Chelatna Lakes produce over 50% of the sockeye salmon production within the Yentna River drainage as indicated by past sonar and weir counts. Weir counts should be conducted on this system in the future if funding allows, to assess if the 1998 escapement was normal for this system or a large escapement like the 1998 Larson Lake escapement, and to further address potential biases with the Yentna River sonar and discrete stock estimates.

Of the three weir sites operated during this study, Chelatna Lake required the greatest maintenance and challenge. The bottom substrate was comprised of sand and small aggregate which was easily washed away, and the depth at mid-stream approached 2 m under high water conditions. To facilitate boat traffic, the weir center has a floating section (resistance board weir) installed, which required constant monitoring to ensure proper operation. Also, Lake Creek is highly susceptible to flooding events; after multiple days of heavy rainfall the weir washed out for an entire week at the end of July. Unfortunately, the run had just started to build; over 6,000 salmon were counted prior to the weir wash out. By the time it was reinstalled, a significant segment of the migration had passed into the lake. Attempts were made to seine fish inriver while the weir was out to estimate the missed portion of the escapement by M-R using tag recoveries, but this was very difficult and abandoned. Further assessing biases in the Yentna River sonar abundance estimates would not be prudent without an accurate escapement count into Chelatna Lake.

The predominant age class of returning sockeye salmon to the Yentna and Susitna drainages has historically been age-1.3, as was also in 1998 from fish sampled at the Yentna fish wheels (62.7%), escapements at Judd (56%), Chelatna (79.9%), and Larson Lakes (49%). Average lengths for ALS sampled age-1.3 sockeye salmon, both sexes combined, differed by only 6 mm between Judd and Larson Lakes, and Yentna River fish wheels. Chelatna Lake age-1.3 sockeye salmon ALS samples were slightly larger (13-16 mm). Length data also indicate a significant size difference from otolith samples for age-1.3 sockeye salmon between Yentna River fish wheels and the Chelatna Lake weir (18 mm).

Fish Wheel Selectivity

One of the important objectives of the 1998 Yentna River studies was to complete an assessment of potential biases by size, gender, species, or riverbank in fish wheel captures. Daily sonar estimates are apportioned to gender and species as indicated by fish wheels captures. If the fish wheels are biased in their capture rates, the sonar estimates will also be biased. Therefore, we tagged both sockeye and coho salmon during the peak of the runs (two different times) and transported them down stream to be available for fish wheel recapture. Size by gender and species, as well as by bank of capture were carefully recorded for all tagged fish so that these same data could be statistically compared to recaptured fish.

The results of these studies show that fish wheel recaptures of marked fish revealed no bias in the proportions by species in size or gender, or by species. However, even though statistical analyses revealed no difference in recapture rates by species, we were surprised to find a higher proportion of coho (53 of 876) than sockeye recoveries (44 of 1,032). We recaptured proportionately 42% more marked coho salmon than we did sockeye salmon (6.1% coho to 4.3% sockeye salmon). Sockeye salmon are thought to be more bank oriented than coho salmon, and we expected to catch a higher proportion of marked sockeye salmon in the fish wheels than we did coho salmon.

Tag recoveries of marked fish during the species selectivity study also provided evidence that tagging may have affected the survival or modified fish behavior, as indicated by the amount of cross-over. All tagged fish (sockeye and coho salmon) were transported downstream and released in sloughs on the same side of the river as captured, to facilitate recovery. Although the sample size was small, our results showed that coho salmon cross-over less than sockeye salmon, which could be from the 'back-out/lag' factor. It is possible that sockeye salmon did not mix randomly after handling, by holding in sloughs only a few days before moving upstream, which would violate the assumption that marked individuals mix randomly with an unmarked population. By holding longer coho salmon may inadvertently be spreading out more, therefore more randomly mixing than sockeye salmon. Although both species suffered from the effects of handling as indicated by the lag times and cross-over rates.

Finally, M-R sockeye salmon escapement estimates in the Yentna River using species selectivity tag recoveries, applied to total fish wheel catches, also produced what we believe were exaggerated results. Thus, this study provides further evidence that tagging affected both sockeye and coho salmon fates. We are confident that all tagged fish passing through the weirs were observed satisfying only one assumption for making a population estimate.

If similar tagging studies are conducted in the future, fish handling/tagging methods need to be addressed. When fish remain out of water (even if only for 30 seconds) during handling, it has a pronounced affect on their survival, as was found during most of the components of these studies. Fish should be tagged fresh, not netted from crowded live boxes, as the amount of time that they remained in the boxes cannot be accurately determined, which might alter their behavior and therefore cause a difference in recapture probably (Cappiello and Bromaghin 1997). All sampling of fish should be conducted with the fish suspended in water, and if fish are to be tagged they should not be sampled (subjected to more undue stresses). Tag and release one fish then sample the next fish, and continue all the tagging and sampling alternately by this method. This will allow randomness tests to be conducted at the same time, and the tagged fish will be healthier so results will ultimately be better by recapturing or observing more tagged individuals. Coho salmon for the Yentna River radiotelemetry studies were placed in a tote of water during sampling and tagging, and we still had major handling affects as noted by the drop-out rates and delays (11 days) in continued upriver migration. Solomon and Storeton-West (1983) radiotagged sea trout (*Salmo trutta L.*) within 24 hours of migration into fresh water and found that fish released in calm water (sheltered lies) remained overnight before continued migration, and fish released where there was no calm water continued to migrate without delay. In the Little Susitna River, Alaska, less than 10 percent of radiotagged coho salmon continued upstream migration when tagged entering freshwater, as compared to more than 70 percent that continued upstream when tagged after adjusting to fresh water (Bentz 1985). Van Den Berghe and Gross (1986) found that body size was the most important variable in coho salmon breeding life-span, and on spawning grounds males lived longer than females. Also, coho salmon males survived the tagging/handling better than females in this study. Carlon (Pers. Comm., ADF&G) has observed the mortality to be approximately 50 percent less when coho salmon were not sampled when tagged (some other study parameters were also changed) for radiotelemetry studies in the Kenai River, Alaska, and has also found higher survival rates for males. If males were selected for tagging, although sometimes difficult to distinguish as sexual dimorphosis is not readily apparent early in the upriver migration when fish are still bright, a higher percentage might survive which will increase the amount of data gathered and the end results.

Radiotelemetry

The data collected during this first year radiotelemetry study of coho salmon in the Yentna River basin should provide useful information that will allow managers in the future to fine-tune project studies to gather the data needed to more accurately estimate the coho run strength, timing, and proportion accessible to the sonar counters. Except for improper antenna orientation at the stationary sites throughout the duration of this study, which compromised some of the data available and subsequently the results, the overall results were good and partially filled in the large gaps where information was missing and not available before for Yentna River coho salmon stocks. Although peak spawning times and exact locations of the spawning areas were not accurately determined (on aerial surveys) by this first year study, the proportion of coho salmon that migrated into the different tributaries gives a partial (limited first glance) picture of the importance of each tributary in this largely unknown system. Also because of the distances to be covered during aerial surveys accurate tracking of individual tagged coho was not done, this information would have allowed us to estimate swimming speeds and the timing when individual fish entered each tributary. More frequent aerial surveys would reduce the probability of losing tags (Milligan et. al. 1986),

To determine the timing when radiotagged fish enter tributary rivers, stationary receiver sites would need to be placed on the major tributaries. With a stationary site placed one-half kilometer above the confluence, and antennae pointed to the confluence and up the tributary, fish migrating up the main river and also up the tributary would be recorded. With coverage at the major tributary rivers aerial flights could be reduced to weekly or ten days to cover remaining areas. Possible tributary rivers would be the Kahiltna, Lake Creek, Talachulitna, and Kichatna. If a site was placed on the Talachulitna one would probably not be needed on the Skwentna River if adequate coverage was determined for recording fish migrating farther up the Skwentna. These sites could operate for the whole season unattended (with solar panels and 12-volt batteries), but after our problems with bears and unauthorized persons tampering with the equipment it would be best to check each site a minimum of every two weeks. Also the sites could possibly be setup at a lodge or residence where the owners would watch over the equipment. Site coverage needs to be thoroughly tested before operations begin, water depths (less than four meters for good coverage) and conductivity should be measured and recorded, and surrounding terrain examined to see if signal bounce from non-target areas would occur and compromise data. Areas of interest should be examined during low water conditions (early spring or late fall) and river bathometry recorded. The radiotags to be used for underwater testing should be mounted to a non-metallic surface, with no other metallic parts. Our second test tag (mounted to wood dowel and weighted line) worked very well in all depths and current velocities encountered, and has been used by Sport Fish Division for ongoing telemetry studies in the Kenai River with good results for testing coverage areas and depths.

Faurot and Palmer (1992) found coho salmon in every clear water tributary of the Fox River drainage, Kenai Peninsula, Alaska, and spawning was observed through November. Cousens et. al. (1982) noted that coho delayed spawning in highly turbid rivers until after freeze-up, when the turbidity and velocity decreased. If future telemetry studies are conducted on coho salmon, aerial surveys should continue through October and possibly until mid November. Some of our radiotags were only found on latter surveys and were located in the upper sections of the rivers. These fish may have been holding in deeper water on previous surveys; although very limited surveys, we found large areas in the Yentna River that were greater than 5 m deep at both the RM and BB sites. Tests of underwater radio signals conducted by Winter (et al. 1978), found a 50 percent loss of signal range at a depth of 4 m in Lake Bemidji (300 μS/cm conductivity), Minnesota, and suggested that underwater radio signal are attenuated exponentially with depth. Eiler (1990) evaluating low (30-31 MHz) and high (150-151 MHz) frequency transmitters in Mendenhall Lake (a glacial lake, 30 μS/cm conductivity) near Juneau, Alaska, found both frequency ranges were similar at 3 m depth; but high frequency ranges were greater in shallow water (1.5 m depth) but decreased substantially at a depth of 4.5 m and there was no reception for depths below 6.0 m.

The proportion of coho salmon that migrate past the sonar site and continue upriver, and those that backout into other rivers (Susitna, Alexander, and Deskha) may not be accurately determined at the current sonar site because of the proximity of the Yentna-Susitna confluence. This study did not accurately estimate this problem either, partially because of handling effects and the unknown mortality in the lower Susitna River, and at the confluences of Alexander and Deskha Rivers. If fish were captured further upriver for tagging (fish wheel placed near Big Bend) and then transported below the sonar counters for release, then the majority might be Yentna River stock and lower the back-out and mortality rates. This would still not determine the backout rate for coho salmon at the site, only for tagged coho salmon. Solomon (1982) found some Atlantic Salmon (*Salmo salar L.*) died within a week of radio tagging, and was likely caused by handling and physiological stress while adapting from salt to fresh water.

We believe the radiotagged coho salmon counted by the telemetry equipment as migrating through the ensonified areas was accurate. Although probably not all the coho salmon available were counted because of the one minute time scan cycle, and the majority of tagged fish averaged only one record during passage. If this portion of the study is repeated or continued, by splitting the underwater antennae into two (two underwater antennae cables connected into one

"Y" into a multiplexer) and placing a second double "Y" antennae inriver to the multiplexer, then the horizontal range should be large enough (depending on the distance between the upper and lower "Y"s) to count all tagged coho that migrate through the ensonified area several times. We also believe that radiotags, as opposed to sonictags, will perform very acceptable in this type of application, and based on lower costs per tags and receivers, longer battery life, plus the ability to locate tags by aircraft and ground sites that they are a better choice.

The Yentna River and tributaries are important sport fishing areas. There are many sport fishing lodges and guide services available to the public on the Yentna River. The Anchorage Daily News, in their Fishing Report section during the summer, lists Lake Creek and the Talachulitna River, along with other west side Cook Inlet and Susitna River tributaries, Alexander Creek, Deskha, Chuitna and Theodore Rivers. From information and tags returned to ADF&G, a total of seven radiotagged coho were sport harvested, two were sport caught and released, and six were caught in commercial fisheries, all in the Northern District with two off Kenai Peninsula beaches and the remaining four off west side beaches. This is not all of the harvested radiotagged coho salmon only reported ones. Vincent-Lang and Hepler (1988) conducted a creel survey at the mouth of Lake Creek during August and September 1988, and a total of 2,107 coho salmon were caught and 1,799 were harvested. As fishing pressure has continued to increase throughout the state, the harvest rates in the Yentna River basin would be expected to be higher now.

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Table 1. Summary of morphometric parameters for study lakes of the Susitna River drainage (Kyle et al. 1994).

Lake	Surface area (km^2)	Mean depth (m)	Maximum depth (m)	Volume ($m^3 \times 10^6$)
Chelatna	16.92	64.0	125.0	707.7
Shell	6.02	11.9	28.7	62.3
Red Shirt	5.15	5.3	15.2	25.6
Stephan	3.64	7.0	27.7	33.7
Hewitt	2.82	13.5	34.0	38.0
Larson	1.17	16.4	42.6	29.1
Byers	1.49	20.0	54.0	26.7
Judd	1.28	n a [a]	45.0 [b]	n a
Wiskey	1.10	3.0 [b]	6.0 [b]	n a

[a] Indicates not available.

[b] Estimated from 1993 field sampling.

Table 2. Sockeye salmon historical escapements into Chelatna, Judd, and Larson Lakes, and Yentna River sonar estimates.

	Chelatna Lake		Judd Lake		Larson Lake		Yentna River	
Year	Escapement	Method	Escapement	Method	Escapement	Method	Escapement	Method
1984			18,104	ADF&G survey	35,254	Weir, CIAA	149,375	sonar
1985					37,874	Weir, CIAA	107,124	sonar
1986					32,322	Weir, CIAA	92,076	sonar
1987					16,753	Weir, CIAA	66,054	sonar
1988							52,330	sonar
1989	3,725 [a]	M-R, CIAA	12,792	Tower, CIAA			96,269	sonar
1990	5,283 [b]	M-R, CIAA					140,290	sonar
1991	7,689 [c]	M-R, CIAA					109,632	sonar
1992	35,300	M-R, CIAA					66,083	sonar
1993	20,235 [d]	Weir, CIAA					141,694	sonar
1994	28,303	Weir, CIAA					128,032	sonar
1995	20,104	Weir, CIAA					121,220	sonar
1996	28,684	Weir, CIAA					90,781	sonar
1997	84,899	Weir, CIAA			40,282	Weir, ADF&G	157,822	sonar
1998	27,284 [e]	Weir, ADF&G	34,416	Weir, ADF&G	63,514	Weir, ADF&G	119,623	sonar

[a] M-R estimate, biased low because of small number of recoveries (Schollenberger 1989b).

[b] M-R estimate, biased low because of small number of recoveries (Schollenberger 1991).

[c] M-R estimate, biased low because of small number of recoveries, CIAA.

[d] First year of return of stocked fish.

[e] Incomplete count, the weir was washed out from 7/25-8/1/98.

Table 3. Summary of sockeye salmon checked for thermal (otolith) marks at Yentna River fish wheels and the Chelatna Lake weir, totals and percent hatchery, 1997 and 1998.

Location	Otoliths negative	Otoliths positive	Total	Percent hatchery
		1997		
Chelatna Lake	1,047	67	1,114	6.01%
NB fish wheel	93	2	95	2.11%
SB fish wheel	755	15	770	1.95%
Both fish wheels	848	17	865	1.97%
		1998		
Chelatna Lake	849	65	914	7.11%
NB fish wheel	680	31	711	4.36%
SB fish wheel	766	17	783	2.17%
Both fish wheels	1,446	48	1,494	3.21%

Table 4. Comparison of abundance estimates of otolith marked (hatchery origin) sockeye salmon from the Chelatna Lake weir and the Yentna River sonar site in 1997 (Carlson and Tarbox 1997).

Run timing		Estimated hatchery contribution			95% C.I.	
lag (days)	Site	bundanc	Variance	SE	Lower	Upper
4	Chelatna	5,106	361,264	601	3,928	6,284
	Yentna	2,744	386,340	622	1,526	3,962
	Difference	2,362	747,604	865	668	4,057
5	Chelatna	5,106	361,264	601	3,928	6,284
	Yentna	2,724	380,683	617	1,514	3,933
	Difference	2,382	741,947	861	694	4,071
6	Chelatna	5,106	361,264	601	3,928	6,284
	Yentna	2,694	372,445	610	1,498	3,890
	Difference	2,412	733,709	857	733	4,091
7	Chelatna	5,108	361,451	601	3,929	6,286
	Yentna	2,640	357,561	598	1,468	3,812
	Difference	2,468	719,012	848	806	4,130

Table 5. Age composition of thermally (otolith) marked sockeye salmon sampled at Chelatna Lake weir and Yentna River fish wheels, 1997 and 1998.

	Age class								Samples	Not	Totals
1997	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	not-aged	read-able [a]	used [b]
				Chelatna Lake							
No. marked otoliths	1	38		4	15				9	45	67
Percent of all marked	1.5%	56.7%		6.0%	22.4%				13.4%		
Total sample size	3	156		279	555				166		1,114
Percent marked by age		24.4%		1.4%	2.7%						6.01%
				Yentna River fish wheels							
No. marked otoliths		9		3	2				3	20	17
Percent of all marked		52.9%		17.6%	11.8%				17.6%		
Total sample size	8	79	1	243	328	1	35	54	135		865
Percent marked by age		11.4%		1.2%	0.6%						1.97%

	Age class								Samples	Not	Totals
1998	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	not-aged	read-able [a]	used [b]
				Chelatna Lake							
No. marked otoliths	2	36	0	5	15	0	1	0	6	20	65
Percent of all marked	3.1%	55.4%		7.7%	23.1%		1.5%		9.2%		
Total sample size	2	57	0	66	644	2	1	8	154		914
Percent marked by age	100.0%	63.2%		7.6%	2.3%	0.0%	100.0%	0.0%			7.11%
				NB fish wheel							
No. marked otoliths	2	16	1	2	8	0	0	0	2	8	31
Percent of all marked	6.5%	51.6%	3.2%	6.5%	25.8%				6.5%		
Total sample size	5	46	4	84	419	3	12	47	99		711
Percent marked by age	40.0%	34.8%	25.0%	2.4%	1.9%						4.36%
				SB fish wheel							
No. marked otoliths	1	3	0	5	7	0	0	0	1	15	17
Percent of all marked	5.9%	17.6%		29.4%	41.2%				5.9%		
Total sample size	5	29	1	119	376	1	36	85	146		783
Percent marked by age	20.0%	10.3%		4.2%	1.9%						2.17%
				Both fish wheels							
No. marked otoliths	3	19	1	7	15	0	0	0	3	23	48
Percent of all marked	6.3%	39.6%	2.1%	14.6%	31.3%				6.3%		
Total sample size	10	75	5	203	795	4	48	132	245		1,494
Percent marked by age	30.0%	25.3%	20.0%	3.4%	1.9%	0.0%	0.0%	0.0%			3.21%

[a] Not read-able - missing, broken on not able to positively read otoliths, not used in totals or calculations.

[b] Totals used - no. marked otoliths is sum of all posivive marked, sample size is sum of all age classes including age classes not listed and unreadable scales, but subtracts not read-able otoliths.

Table 6. Sockeye salmon age, length (mid-eye to tail fork, MEF mm), and sex composition (ALS) from sampled fish for thermal (otolith) marks at the Chelatna Lake weir and Yentna River fish wheels, 1998.

	Age class								
	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	Total
Sample period: 15 July-22 August, 1998 [a]				Chelatna Lake weir					
Males	35	1,399	0	805	12,802	35	35	105	15,216
Percent	0.1%	5.1%		3.0%	46.9%	0.1%	0.1%	0.4%	55.8%
Sample Size	1	40		23	366	1	1	3	435
Avg MEF	531	575		518	578	625	515	577	575
Std. Error		3		3	1			5	
Females	35	595	0	1,504	9,724	35	0	175	12,068
Percent	0.1%	2.2%		5.5%	35.6%	0.1%		0.6%	44.2%
Sample Size	1	17		43	278	1		5	345
Avg MEF	445	548		501	553	556		565	546
Std. Error		6		2	1			10	1
Both Sexes	70	1,994	0	2,309	22,526	70	35	280	27,284
Percent	0.3%	7.3%		8.5%	82.6%	0.3%	0.1%	1.0%	100.0%
Sample Size	2	57		66	644	2	1	8	780
Avg MEF	488	567		507	567	591	515	570	562
Std. Error		3		2	1			7	1
Sample period: 7 July-21 August, 1998				Yentna River fish wheels					
Males	658	3,386	376	8,746	36,207	94	2,633	6,395	58,495
Percent	0.6%	2.8%	0.3%	7.3%	30.3%	0.1%	2.2%	5.3%	48.9%
Sample Size	7	36	4	93	385	1	28	68	622
Avg MEF	459	560	315	485	561	620	485	556	543
Std. Error	19	5	6	4	1		7	4	1
Females	282	3,668	94	10,345	38,557	282	1,881	6,019	61,128
Percent	0.2%	3.1%	0.1%	8.6%	32.2%	0.2%	1.6%	5.0%	51.1%
Sample Size	3	39	1	110	410	3	20	64	650
Avg MEF	488	540	345	486	538	573	489	533	527
Std. Error	24	4		3	1	14	6	4	1
Both Sexes	940	7,054	470	19,091	74,764	376	4,514	12,414	119,623
Percent	0.8%	5.9%	0.4%	16.0%	62.5%	0.3%	3.8%	10.4%	100%
Sample Size	10	75	5	203	795	4	48	132	1,272
Avg MEF	468	549	321	486	549	585	487	545	535
Std. Error	15	3	6	2	1	14	5	3	1

[a] No samples were collected during the the peak of the run as the weir was inoperable, from 25 July-1 August.

Table 7. Tag recovery assessment, for mark-recapture (M-R) tagged sockeye salmon (top) and species selectivity tagged sockeye and coho salmon (bottom), at theYentna River fish wheels and weirs at Judd and Chelatna Lakes, 1998.

Tagging information			Weir recoveries					Fish wheel recaptures				
Release site	Tag color	Total tagged	Chelatna	Percent of total	Judd	Percent of total	Total	NB	Percent of total	SB	Percent of total	Total
			M-R estimate tags									
North	White	2,918	193	82.5%	41	17.5%	234					
	Percent of total tagged		6.6%		1.4%		8.0%					
South	Yellow	3,426	146	37.2%	247	62.8%	393					
	Percent of total tagged		4.3%		7.2%		11.5%					
Total M-R tags		6,344	339	54.1%	288	45.9%	627	0		0		0
	Percent of total tagged		5.3%		4.5%		9.9%					
			Sockeye salmon species selectivity tags									
North	Green	463	35	79.5%	9	20.5%	44	5	22.7%	17	77.3%	22
	Percent of total tagged		7.6%		1.9%		9.5%	1.1%		3.7%		4.8%
South	Blue	569	17	28.8%	42	71.2%	59	16	72.7%	6	27.3%	22
	Percent of total tagged		3.0%		7.4%		10.4%	2.8%		1.1%		3.9%
Total species tags		1,032	52	50.5%	51	49.5%	103	21	47.7%	23	52.3%	44
	Percent of total tagged		5.0%		4.9%		10.0%	2.0%		2.2%		4.3%
			Coho salmon species selectivity tags									
North	Green	221						0	0.0%	10	100.0%	10
	Percent of total tagged							0.0%		4.5%		4.5%
South	Blue	659						9	20.9%	34	79.1%	43
	Percent of total tagged							1.4%		5.2%		6.5%
Total species tags		880						9	17.0%	44	83.0%	53
	Percent of total tagged							1.0%		5.0%		6.0%

Table 8. Chi-Square statistical analyses comparing percent of tagged recoveries at Chelatna and Judd Lake weirs, by fish wheel (bank) tagged, sex, and all recoveries, for sockeye salmon, 1998.

Weir	Parameter	Number observed	Number recovered	Percent recovered	P value
Chelatna	All recoveries	27,284	339	1.24%	0.00000
Judd		34,416	288	0.84%	
Chelatna	South Bank - both sexes	27,284	146	0.54%	0.00464
Judd		34,416	247	0.72%	
Chelatna	North Bank - both sexes	27,284	193	0.71%	0.00000
Judd		34,416	41	0.12%	
Chelatna	South Bank - females	27,284	44	0.16%	0.00000
Judd		34,416	138	0.40%	
Chelatna	South Bank - males	27,284	102	0.37%	0.22731
Judd		34,416	109	0.32%	
Chelatna	North Bank - females	27,284	59	0.22%	0.00001
Judd		34,416	27	0.08%	
Chelatna	North Bank - males	27,284	134	0.49%	0.00000
Judd		34,416	14	0.04%	

Table 9. Dual dart tag loss assessment, and comparison by tag color from sockeye salmon recoveries at Chelatna and Judd Lake weirs, 1998.

	No. dual tag recoveries		No. with tags missing		Total	Percent tag
Tag Color	Chelatna	Judd	Chelatna	Judd	recoveries	retention
White	193	41	1	0	235	99.6%
Yellow	146	247	0	1	394	99.7%
Total (by lake)	339	288	1	1		
Total (all)	627		2		629	99.7%
m_2	340	289			629	
P_L			0.00147	0.00173	0.00159	

The probability of losing either a left or right side tag was estimated as:

$$\hat{P}_L = \frac{m_C}{(m_C + 2m_{AB})}$$

$P_L =$ 0.00159 (all tags - both weirs)
$P_L =$ 0.00147 (Chelatna Lake)
$P_L =$ 0.00173 (Judd Lake)

where m_C is the number of dual tagged fish in the recovery sample with one dart tag, and m_{AB} is the number of dual tagged fish in the recovery sample with both tags present.

The number of recaptured fish was then estimated as:

$$\hat{m}_2 = (m_C + 2m_{AB})^2 / 4m_{AB}$$

$m_2 =$ 629 (all tags)
$m_2 =$ 340 (Chelatna Lake)
$m_2 =$ 289 (Judd Lake)

Table 10. Historical age composition of sampled sockeye salmon escapements into Chelatna Lake 1990-1998 (top), and Larson Lake 1984-1987 and 1997-1998 (bottom).

			Chelatna Lake			
Year	0.3	1.2	1.3	2.2	2.3	Other
1990	3.2%	18.3%	74.2%	1.1%	0.0%	3.1%
1991	4.8%	23.2%	55.9%	1.3%	14.9%	0.0%
1992	1.9%	41.2%	53.5%	0.8%	1.5%	1.1%
1993 [a]	0.6%	32.9%	63.8%	0.4%	2.2%	0.0%
1994	4.1%	8.9%	82.2%	0.4%	3.0%	1.5%
1995	3.0%	26.9%	64.5%	0.9%	3.9%	0.7%
1996	5.1%	21.2%	67.9%	0.7%	2.6%	2.6%
1997	15.9%	31.7%	50.7%	0.4%	1.4%	0.0%
1998	7.1%	11.2%	79.9%	0.1%	1.1%	0.6%
1990-1997 Mean	4.8%	25.5%	64.1%	0.7%	3.7%	1.1%

[a] First year of return of stocked fish.

		Larson Lake		
Year	1.2	1.3	2.2	2.3
1984	77.3%	19.7%	1.4%	1.5%
1985	17.0%	50.0%	11.0%	22.0%
1986	23.0%	72.0%	3.0%	2.0%
1987	9.6%	84.9%	0.4%	4.8%
1997	53.5%	27.3%	9.3%	9.8%
1998	13.6%	49.0%	13.2%	24.0%
1984-1987, 1997 Mean	36.1%	50.8%	5.0%	8.0%

Table 11. Sockeye salmon age, length (mid-eye to tail fork, MEF mm), and sex composition (ALS) of sampled fish at weirs at Chelatna, Judd, and Larson Lakes, 1998.

	Age class							
Parameter	0.2	0.3	1.2	1.3	1.4	2.2	2.3	Total
				Chelatna Lake				
Males	1	53	47	502	1	1	6	611
%	0.1%	4.7%	4.2%	44.7%	0.1%	0.1%	0.5%	54.5%
Avg MEF	531	575	514	578	625	515	576	572
Females	2	27	79	395	2	0	6	511
%	0.2%	2.4%	7.0%	35.2%	0.2%		0.5%	45.5%
Avg MEF	469	545	496	552	564		561	543
Both Sexes	3	80	126	897	3	1	12	1122
%	0.3%	7.1%	11.2%	79.9%	0.3%	0.1%	1.1%	100%
Avg MEF	489	565	503	566	584	515	568	559
				Judd Lake				
Males	0	1	15	135	0	49	41	241
%		0.2%	2.5%	22.8%		8.3%	6.9%	40.8%
Avg MEF		565	485	564		479	559	541
Females	0	3	17	196	1	64	69	350
%		0.5%	2.9%	33.2%	0.2%	10.8%	11.7%	59.2%
Avg MEF		553	477	543	515	476	541	527
Both Sexes	0	4	32	331	1	113	110	591
%		0.7%	5.4%	56.0%	0.2%	19.1%	18.6%	100%
Avg MEF		556	480	552	515	478	548	533
				Larson Lake				
Males	0	0	20	130	0	27	60	237
%			13.6%	49.0%		13.2%	13.2%	41.3%
Avg MEF			523	571		516	566	559
Females	0	1	58	151	0	49	78	337
%		0.2%	10.1%	26.3%		8.5%	13.6%	58.7%
Avg MEF		560	499	538		496	538	525
Both Sexes	0	1	78	281	0	76	138	574
%		0.2%	13.6%	49.0%		13.2%	24.0%	100%
Avg MEF		560	505	553		503	550	539

Table 12. Sockeye salmon age comparisons between Yentna River fish wheel samples and escapement samples collected at Chelatna, Judd and Larson Lakes, 1998.

	Age class, number								
Location	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	Total
Yentna River	11	86	5	236	940	4	60	158	1,500
Chelatna Lake	3	80	0	126	897	3	1	12	1,122
Judd Lake	0	4	0	32	331	1	113	110	591
Larson Lake	0	1	0	78	281	0	76	138	574

	Age class, proportion								
Location	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	Total
Yentna River	0.7%	5.7%	0.3%	15.7%	62.7%	0.3%	4.0%	10.5%	100.0%
Chelatna Lake	0.3%	7.1%		11.2%	79.9%	0.3%	0.1%	1.1%	100.0%
Judd Lake		0.7%		5.4%	56.0%	0.2%	19.1%	18.6%	100.0%
Larson Lake		0.2%		13.6%	49.0%		13.2%	24.0%	100.0%

Table 13. Sockeye salmon age, length (mid-eye to tail fork, MEF mm), and sex composition (ALS) of sampled fish by bank at the Yentna River fish wheels, 1998.

	Age class								
Parameter	0.2	0.3	1.1	1.2	1.3	1.4	2.2	2.3	Total
				Yentna River North bank					
Males	6	25	3	49	239	1	10	28	361
%	0.8%	3.4%	0.4%	6.7%	32.7%	0.1%	1.4%	3.8%	49.5%
Avg MEF	452	568	313	490	564	620	488	563	548
Females	0	29	1	54	246	2	5	32	369
%		4.0%	0.1%	7.4%	33.7%	0.3%	0.7%	4.4%	50.5%
Avg MEF		537	345	483	539	564	489	538	529
Both Sexes	6	54	4	103	485	3	15	60	730
%	0.8%	7.4%	0.5%	14.1%	66.4%	0.4%	2.1%	8.2%	100.0%
Avg MEF	452	551	321	486	551	583	488	550	539
				Yentna River South bank					
Males	2	14	1	55	216	0	26	54	368
%	0.3%	1.8%	0.1%	7.1%	28.0%		3.4%	7.0%	47.7%
Avg MEF	460	547	321	481	559		480	556	540
Females	3	18	0	78	241	1	19	44	404
%	0.4%	2.3%		10.1%	31.2%	0.1%	2.5%	5.7%	52.3%
Avg MEF	488	539		488	538	591	486	531	525
Both Sexes	5	32	1	133	457	1	45	98	772
%	0.6%	4.1%	0.1%	17.2%	59.2%	0.1%	5.8%	12.7%	100.0%
Avg MEF	477	542	321	485	548	591	483	545	532
				Yentna River, both banks					
Males	8	39	4	104	453	1	36	82	727
%	0.5%	2.6%	0.3%	6.9%	30.2%	0.1%	2.4%	5.5%	48.5%
Avg MEF	454	561	315	485	562	620	482	558	544
Females	3	47	1	132	487	3	24	76	773
%	0.2%	3.1%	0.1%	8.8%	32.5%	0.2%	1.6%	5.1%	51.5%
Avg MEF	488	538	345	486	538	573	487	534	527
Both Sexes	11	86	5	236	940	4	60	158	1500
%	0.7%	5.7%	0.3%	15.7%	62.7%	0.3%	4.0%	10.5%	100.0%
Avg MEF	463	548	321	486	550	585	484	547	535

Table 14. Summary of Yentna River fish wheel species selectivity catches of tagged and recovered sockeye salmon (top) and coho salmon (bottom), and crossover rates, 1998.

		Sockeye salmon Number recovered and proportion, by release bank							
Recovery Bank	Sex	South		North		Both		Crossover rate	
North	Male	7	32%	3	14%	10	45%	S to N	77.3%
	Female	8	36%	2	9%	10	45%		
	Unknown	2	9%	0	0%	2	9%		
	Total	17	77%	5	23%	22			
South	Male	4	18%	10	45%	14	64%	N to S	72.7%
	Female	2	9%	5	23%	7	32%		
	Unknown	0	0%	1	5%	1	5%		
	Total	6	27%	16	73%	22			
Total recovery, both sexes		23	52%	21	48%	44			
Total recovery by bank to total tagged			2.2%		2.0%		4.3%	Total	75.0%
Total tagged and released		569	55%	463	45%	1,032			

		Coho salmon Number recovered and proportion, by release bank							
Recovery Bank	Sex	South		North		Both		Crossover rate	
North	Male	4	40%	0	0%	4	40%	S to N	100.0%
	Female	5	50%	0	0%	5	50%		
	Unknown	1	10%	0	0%	1	10%		
	Total	10	100%	0	0%	10			
South	Male	17	40%	5	12%	22	51%	N to S	20.9%
	Female	14	33%	4	9%	18	42%		
	Unknown	3	7%	0	0%	3	7%		
	Total	34	79%	9	21%	43			
Total recovery, both sexes		44	83%	9	17%	53			
Total recovery by bank to total tagged			5.0%		1.0%		6.1%	Total	35.8%
Total tagged and released		655	75%	221	25%	876			

Crossover rate for sockeye and coho salmon Chi-Square (P=0.00012)

Table 15. Summary of statistical analyses used to assess species, length (mid-eye to tail fork, MEF), and sex ratio biases in Yentna River fish wheel captures of sockeye and coho salmon, for species selectivity study, 1998.

		Sockeye					Coho				
					P value					P value	
			MEF		2-Sample			MEF		2-Sample	
Test parameter		*n*	(mm)	Chi-Sq.	t-test	K-S test	*n*	(mm)	Chi-Sq.	t-test	K-S test
All recoveries[a]	vs	44	545		0.089	0.297	53	572		0.738	0.979
All unrecovered		991	555				831	570			
Recovered females	vs	17	525		0.106	0.258	23	573		0.347	0.456
Unrecovered females		437	538				461	566			
				0.674[b]					0.233[b]		
Recovered males	vs	24	560		0.202	0.621	26	572		0.604	0.492
Unrecovered males		554	569				369	576			
All SB tagged	vs	569	549	0.000	0.000	0.000	659	572	0.010	0.042	0.086
All NB tagged		463	562				221	566			
NB tagged females	vs	173	540		0.198	0.375	138	563		0.229	0.617
SB tagged females		281	535				346	567			
SB tagged males	vs	288	562		0.000	0.000	313	577		0.202	0.0126
NB tagged males		290	575				83	570			
All SB unrecovered	vs				0.249	0.792	619	571		0.249	0.791
All SB recoveries							40	579			
All NB unrecovered	vs				0.052	0.054	212	567		0.052	0.054
All NB recoveries							9	542			
Gender selectivity											
Recovered females		17	41%				23	47%			
Unrecovered females		436	44%				831	55%			
Recovered males		24	59%				26	53%			
Unrecovered males		552	56%				831	45%			

[a] Includes 3 sockeye and 4 coho salmon of unknown sex.

[b] Test for difference in recovery between sexes

Table 16. Yentna River coho salmon radiotelemetry tagging summary, 1998.

Date tagged	Number tagged	Release trips	Release location(s)[a]	Trip time (minutes)[b]
17-Jul	3	1	N	35
18-Jul	4	1	N	35
19-Jul	11	1	N	72
20-Jul	13	2	N	44
21-Jul	7	1	N	47
22-Jul	9	1	N	75
23-Jul	12	1	S	79
24-Jul	8	1	N	52
25-Jul	10	1	N	62
28-Jul	28	0	FW	0
29-Jul	40	4	N	60
30-Jul	27	3	N	57
31-Jul	24	3	N	50
1-Aug	24	3	N	51
2-Aug	26	2	N-2, FW	47
3-Aug	12	2	N	40
7-Aug	12	1	N-1, FW	16
8-Aug	7	1	S	54
9-Aug	14	2	S	52
10-Aug	6	1	N	47
20-Aug	7	0	FW	0
21-Aug	2	0	FW	0
Total	306		Mean	44

[a] N=north side of river, S=south side of river, and FW=at fish wheel(s).

[b] Time the first fish was tagged to time all fish were released for that transport trip, if multiple trips is the longest trip time.

Table 17. Coho salmon age, length (mid eye to tail fork, MEF mm), and sex composition (ALS), from sampled and tagged fish for radiotelemetry studies at the Yentna River fish wheels, 1998.

	Age class				
	1.1	2.1	3.1	Total	NR & RG[a]
Males					
Sample size	33	101	13	147	30
Percent	22.4%	68.7%	8.8%	56.8%	57.8%
Avg MEF	564	583	607	581	584
Std. Error	32.23	31.58	26.09	33.12	28.29
Females					
Sample size	19	88	5	112	17
Percent	17.0%	78.6%	4.5%	43.2%	42.2%
Avg MEF	567	564	566	565	568
Std. Error	23.41	23.21	18.51	22.90	19.86
Both Sexes					
Sample size	52	189	18	259	47
Percent	20.1%	73.0%	6.9%		
Avg MEF	565	575	595	574	578
Std. Error	29.12	29.46	30.17	30.15	26.53

[a] NR=not readable scales, RG=regenerated scales, percent is Total plus NR & RG fish.

Table 18. Radiotagged coho salmon recorded passing through the Yentna River sonar ensonified areas by bank and SB aerial, number and means of DCC records, 1998.

	Final destination above sonar sites							
Number	NB Sonar		SB Sonar		Both Sonars		SB Aerial	
of records	No. fish	No. rec.	No. fish	No. rec.	No. fish	No. rec.	No. fish	No. rec.
1	2	2	11	11	13	13	6	6
2	0	0	6	12	6	12	3	6
3	0	0	1	3	1	3	1	3
4	1	4	1	4	2	8	1	4
5	1	5	0	0	1	5	0	0
6	1	6	0	0	1	6	0	0
7	0	0	0	0	0	0	1	7
Totals	5	17	19	30	24	47	12	26
Mean No.of records/fish		3.4		1.6		2.0		2.2

	All fish including fish never located and below sonar site							
Number	NB Sonar		SB Sonar		Both Sonars		SB Aerial	
of records	No. fish	No. rec.	No. fish	No. rec.	No. fish	No. rec.	No. fish	No. rec.
1	4	4	13	13	17	17	8	8
2	0	0	7	14	7	14	4	8
3	0	0	2	6	2	6	1	3
4	1	4	1	4	2	8	1	4
5	1	5	0	0	1	5	0	0
6	1	6	0	0	1	6	0	0
7	0	0	0	0	0	0	1	7
Totals	7	19	23	37	30	56	15	30
Mean No.of records/fish		2.7		1.6		1.9		2.0

Table 19. Radiotagged coho salmon recorded passing through the Yentna River sonar ensonified areas by bank and SB aerial, and crossover numbers and proportions, from DCC records, 1998.

	Above site			All fish		
Recovery site	NB	SB	SB Air	NB	SB	SB Air
NB tagged	2	3	2	2	5	3
SB tagged	4	15	10	4	19	12
Percent crossover	60.0%	21.1%	16.7%	71.4%	17.4%	20.0%

Table 20. Yentna River radiotagged coho salmon mean holdover times (tagging affect), from time released to first DCC record at the sonar sites, by site and release, and comparison to dual dart-tagged coho salmon for the species selecitivy study, 1998.

	NB Sonar			SB Sonar			Both Sonars			SB Aerial			Mean	
	N	days	hours	*N*	days	hours	*N*	days	hours	*N*	days	hours	days	hours
All fish	7	15	11.0	23	14	5.2	30	14	12.2	15	17	18.5	15	11.7
Above site	5	15	8.9	19	15	0.5	24	15	1.9	12	16	5.1	15	9.4
SB release	5	14	20.8	19	15	1.5	24	15	0.5	12	17	9.5	15	9.6
NB release	2	16	22.6	4	10	5.2	6	12	11.0	3	19	6.6	14	12.9
Mean		15	15.8		13	15.1		14	6.4		17	15.9		
Dart-tagged		10	2.0		10	9.0		10	7.0					

Table 21. Yentna River coho salmon radiotelemetry migration times from River Mouth site (last record on or before day) to first record at upriver (sonar DCCs) sites, excludes fish where time is greater than 24 hours, as these fish where assumed to be milling around, 1998.

Site	*N*	hours
NB sonar	1	15.0
SB sonar	4	10.2
SB aerial[a]	1	
	Mean	11.2

[a] SB aerial fish was also in, and used in SB Sonar.

Table 22. Yentna River coho salmon radiotelemetry diel migration timing from DCC records at the upriver stationary sites, 1998.

Site	Migration period (hours)						*N*
	00-04	04-08	08-12	12-16	16-20	20-00	
			First record, all fish				
NB sonar	0	0	3	2	1	1	7
SB sonar	5	3	3	0	5	7	23
SB aerial	2	2	2	0	5	4	15
Big Bend	1	0	1	1	6	2	11
Total	8	5	9	3	17	14	56
Percent	14.3%	8.9%	16.1%	5.4%	30.4%	25.0%	
			Fish with final destination above respective sites				
NB sonar	0	0	3	1	0	1	5
SB sonar	4	2	3	0	5	5	19
SB aerial	1	2	2	0	3	4	12
Big Bend	0	0	0	1	4	0	5
Total	5	4	8	2	12	10	41
Percent	12.2%	9.8%	19.5%	4.9%	29.3%	24.4%	
			Fish never located				
NB sonar					1		1
SB sonar		1				1	2
SB aerial					2		2
Big Bend					1	1	2
Total		1			4	2	7
Percent		14.3%			57.1%	28.6%	

Table 23. Yentna River coho salmon radiotelemetry, summary of DCC records by stationary site and final loction of tagged fish, 1998.

	Stationary Site				
Coho records	River Mout	Big Bend	NB sonar	SB sonar	SB aerial
Above site	40	5	5	19	12
At or below	51	4	1	2	1
Never located	34	2	1	2	2
Not released	3	2	0	0	0
Same day/time tagge	2	0	9	0	3
Sockeye	1	1	1	1	0
Total records	131	14	17	24	18
Located coho records	91	9	6	21	13

Table 24. Yentna River coho salmon radiotelemetry mean backout time (hours), from release to first DCC record at the River Mouth site, 1998. Anova analysis indicate no siginificant difference (P=0.246) in mean time by destination.

Final destination	*N*	hours	S.D.
Above	9	6.3	2.9
Below	23	5.5	3.8
Never located	15	4.7	3.8
Rel. @ fish wheel	20	7.4	4.9
All	67	6.0	4.1

Table 25. Yentna River coho salmon radiotelemetry, final destinations from returned tags and aerial survey data after 15 August, and before 16 August and single aerial locates, 1998.

River location or area name[a]	After 15 August	Before and single	Known fates[b]
Yentna River lower	15	6	
Yentna River upper	25	10	2SH
Yentna River Total	40	16	
Yentna River Tributaries			
Kahiltna River	3		
Peters Creek	3		
Lake Creek	5		1M
Skwentna River	9	4	
Hayes River area	10	3	
Talachulitna River	4		
Talach. Cr.	4		
other Crs.	3		
Kichatna River	10		
Johnson Cr.	4		
Red Cr.	4		
Yentna River drainage Total	99	23	
Susitna River lower	30	14	1M
Susitna River upper	10	5	
Susitna River Total	40	19	
Alexander River	8	3	3SH, 1SR
Deskha River	8	1	
Cook Inlet, SW tributaries	11	4	1SR, 3CH, 2M
Cook Inlet, E (Kenai)	2	1	2CH
Little Susitna River	1		
Unknown location	1	1	1CH
Totals	170	52	7SH, 2SR, 6CH, 6M
Lost-never located	84		

[a] River Location or area name

Yentna River lower: below Big Bend to confluence with Susitna R, Kroto slough and Fish Cr.

Yentna River upper: from Big Bend upriver past the upper forks below the glaciers, and includes confluences with tributary rivers.

Susitna River lower: from mouth at Cook Inlet to Susitna Station, including confluence with Alexander Cr.

Susitna River upper: upriver from Yentna confluence to Talkeetna River, including confluence with Deskha R.

Cook Inlet SW tributaries: includes all rivers and creeks from the West Forelands to the Susitna River, and West Side Cook Inlet beaches.

[b] Known fates from returned tags and information, SH=Sport Harvest, SR=Sport Released, CH=Commercial Harvest, and M=Mortality (dead fish).

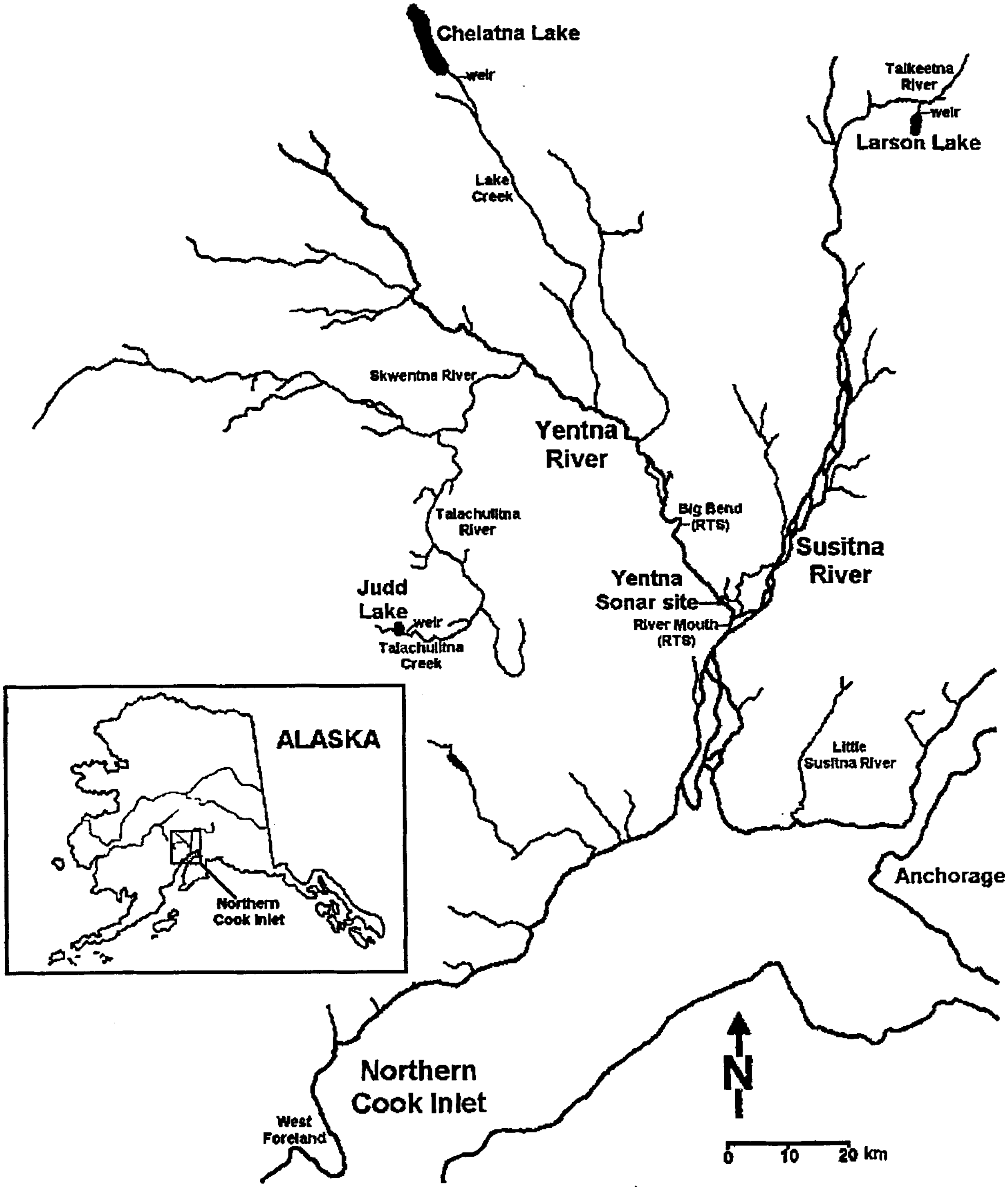


Figure 1. Map of Upper Cook Inlet, Alaska, Susitna and Yentna Rivers and Yentna sonar site, weir sites at Chelatna, Judd and Larson Lakes, and radiotelemetry stationary sites (RTS).

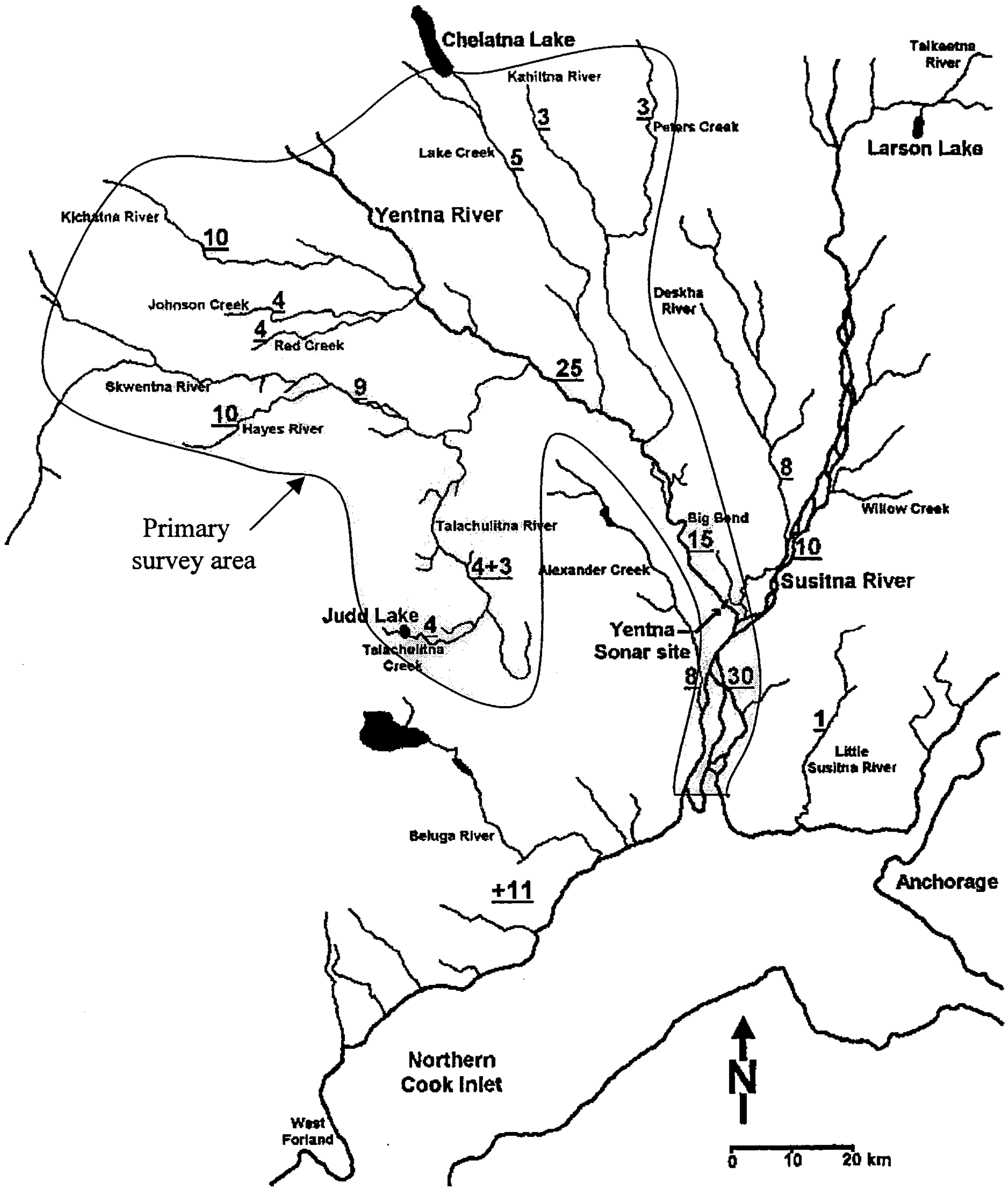
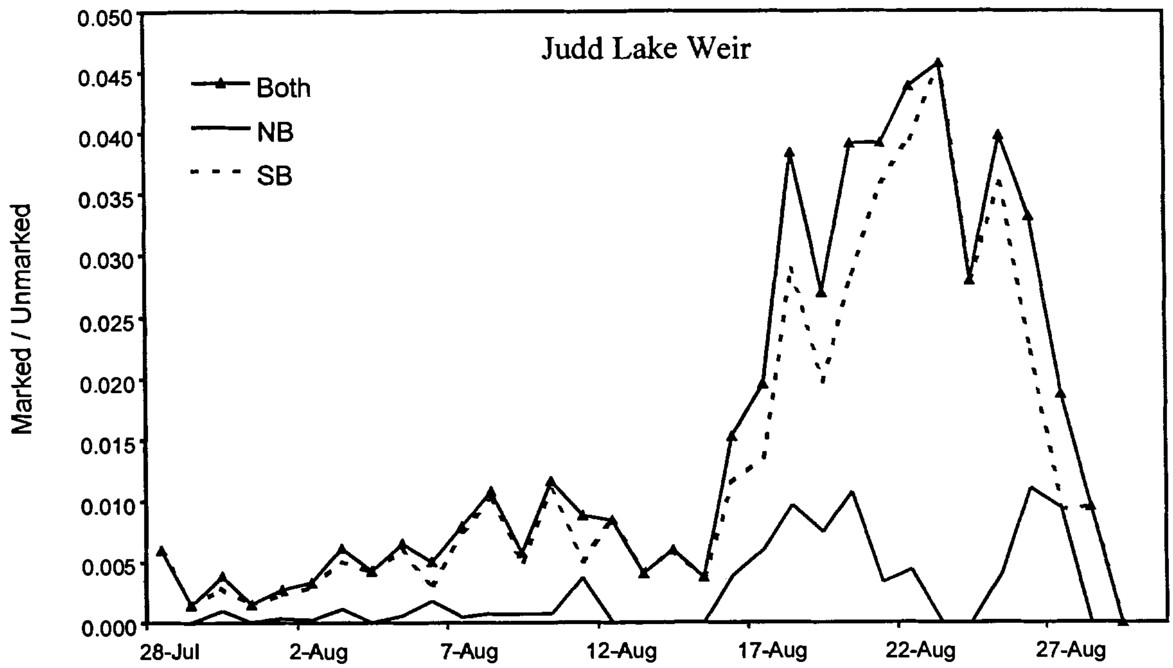


Figure 2. Map of aerial survey area showing main tributaries, and numbers of radiotagged coho salmon in each tributary (+ denotes coho in creeks and rivers not listed).



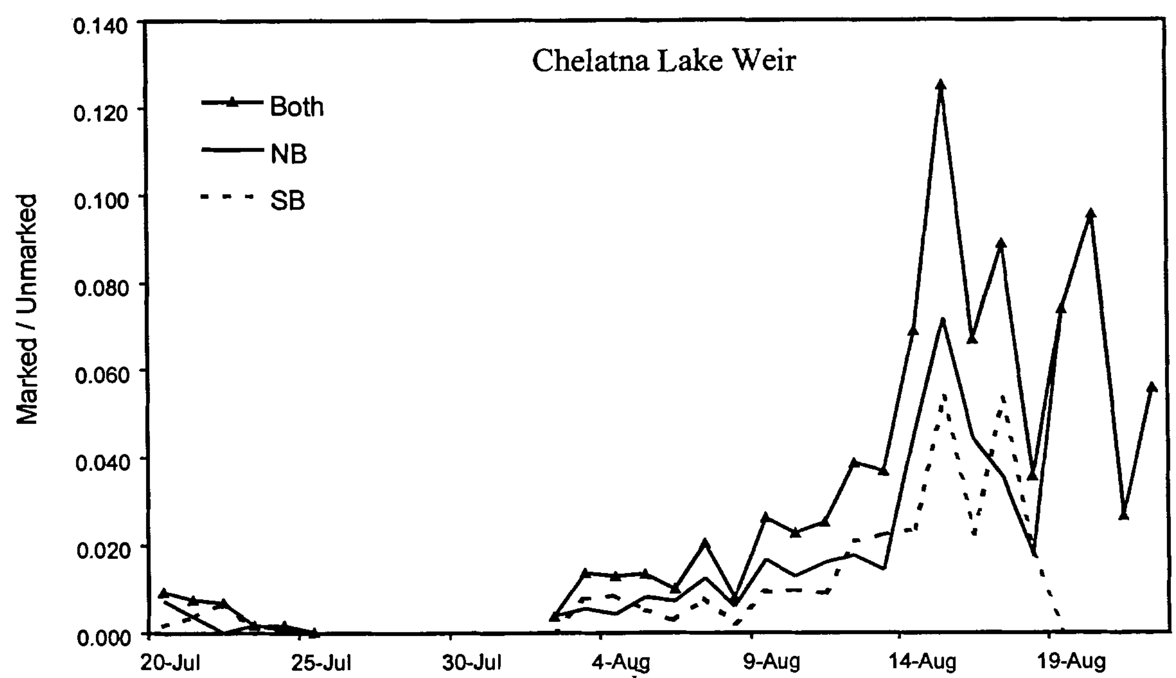


Figure 3. Tag recoveries at Judd (top) and Chelatna (bottom) lake weirs during project duration, 1998.

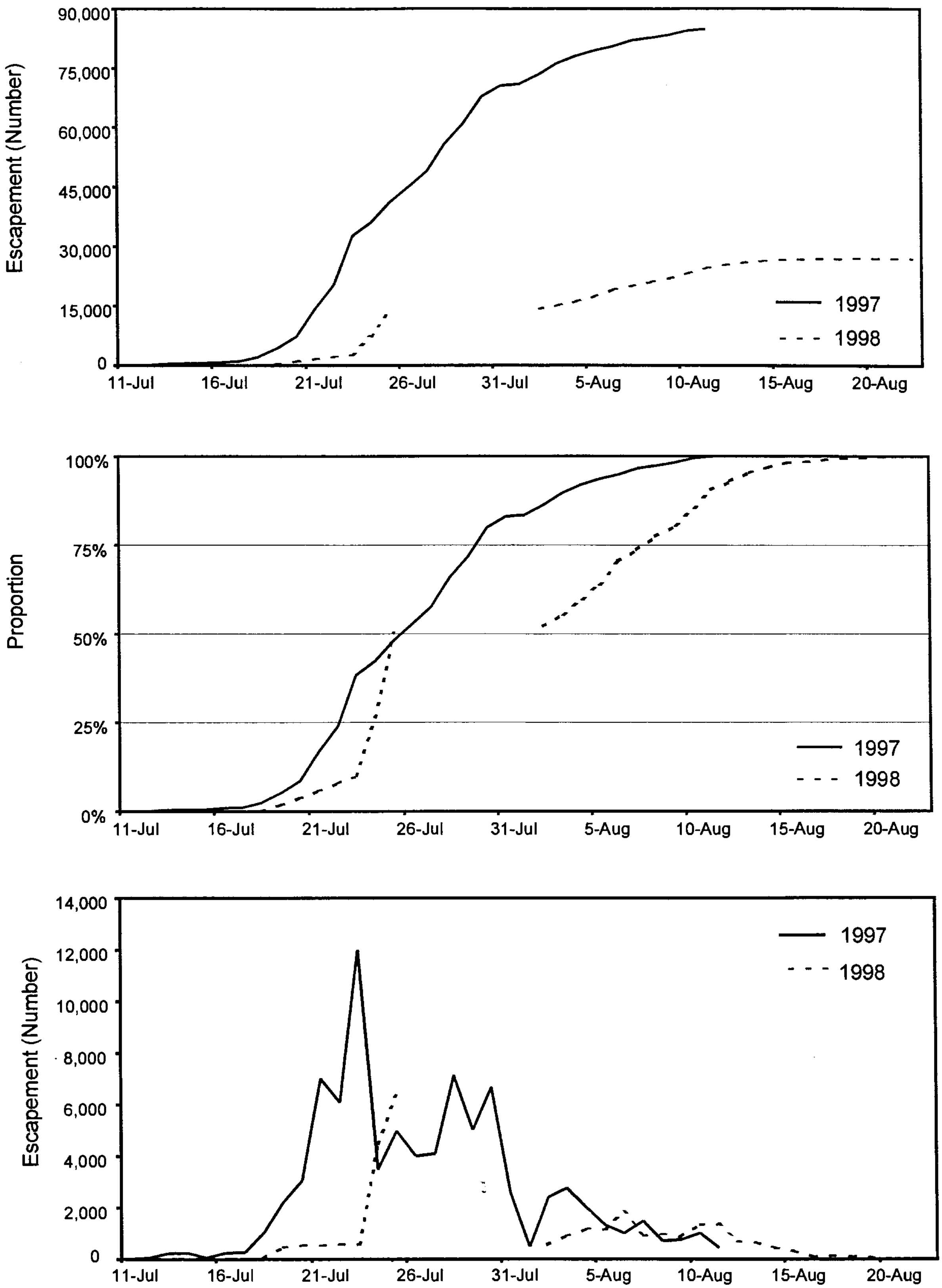


Figure 4. Sockeye salmon escapements at Chelatna Lake weir, cumulative (top), proportion (middle), and daily (bottom), for 1997 and 1998.

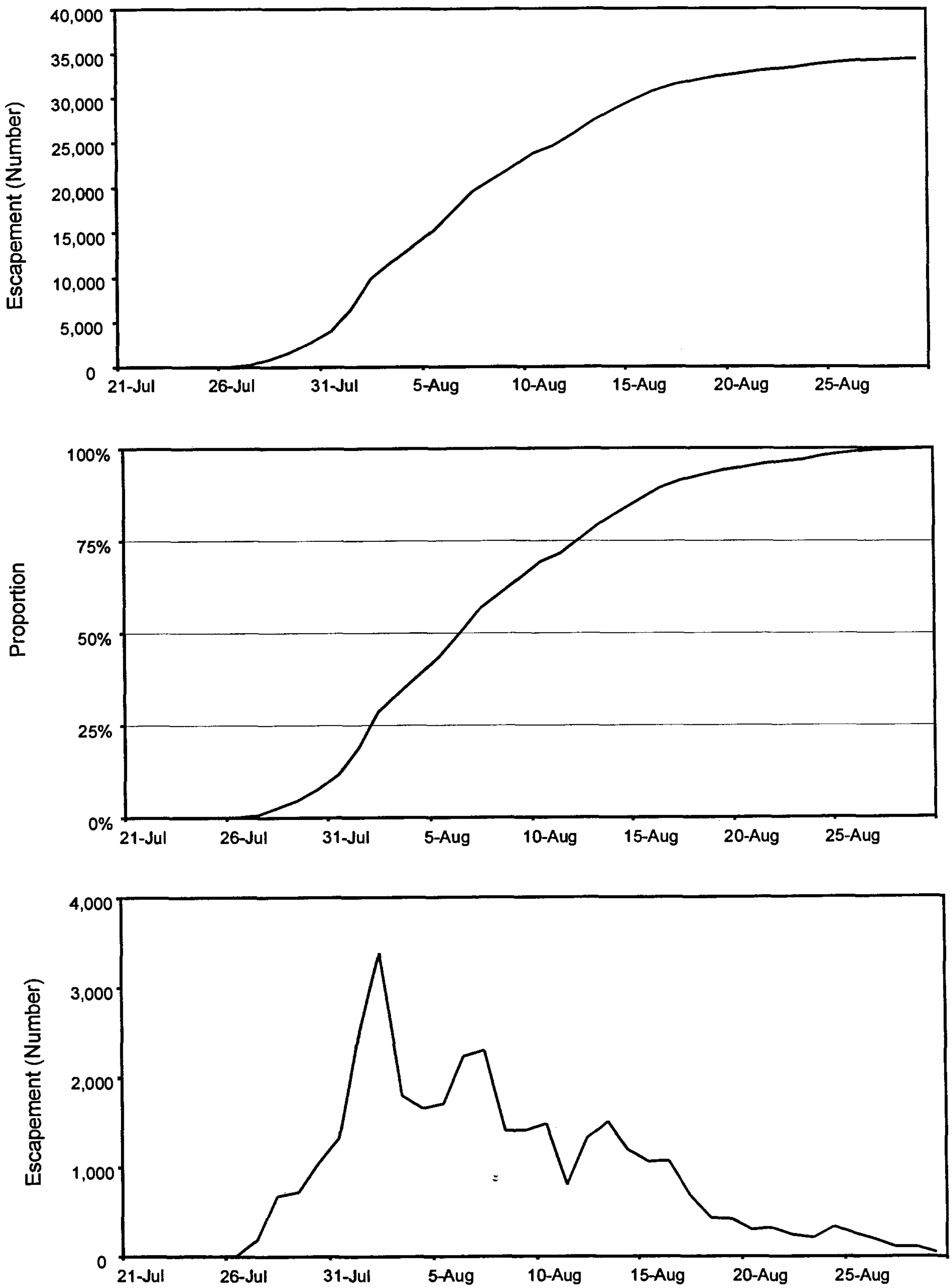


Figure 5. Sockeye salmon escapement at Judd Lake weir, cumulative (top), proportion (middle), and daily (bottom), 1998.

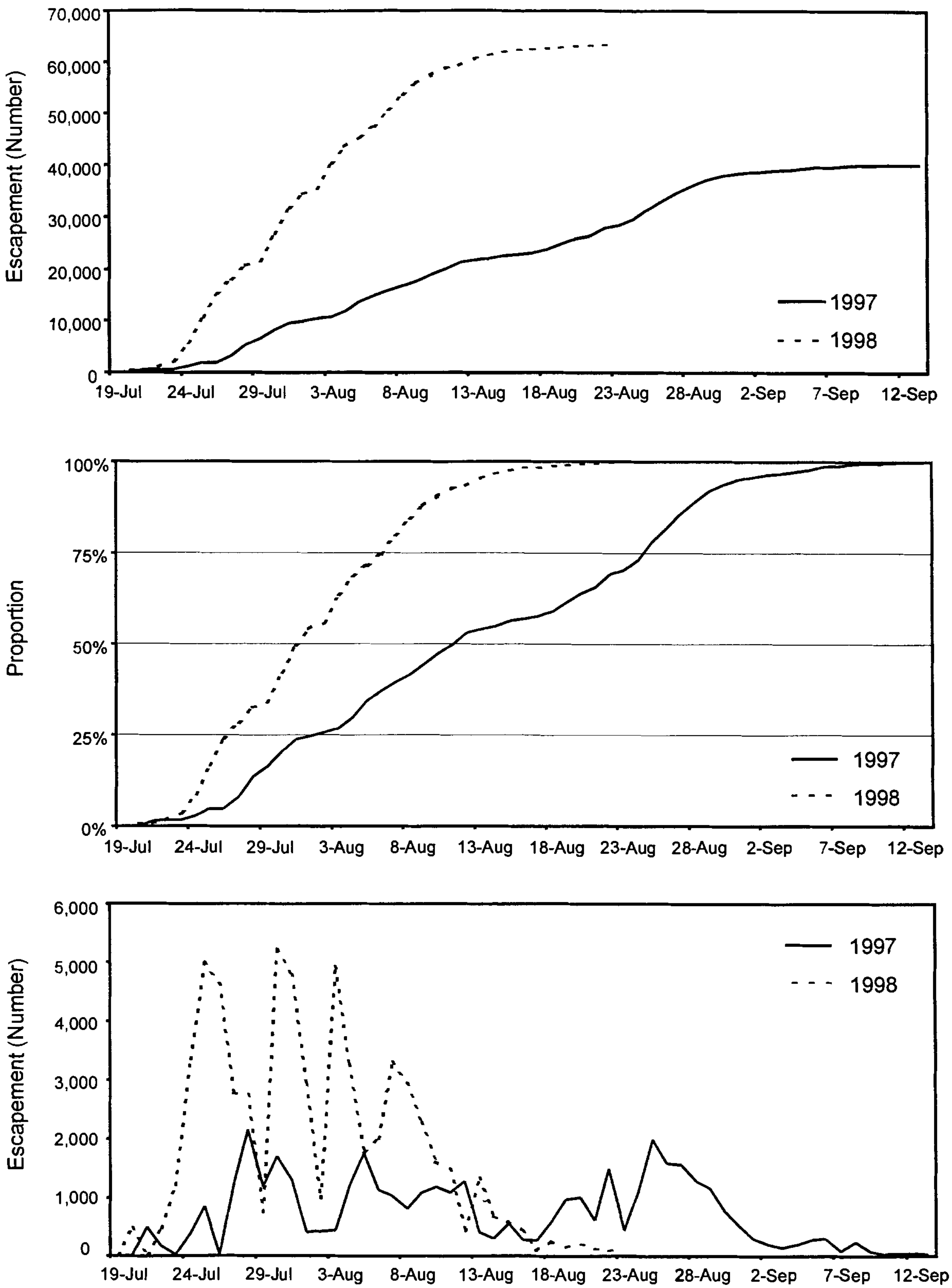


Figure 6. Sockeye salmon escapements at Larson Lake weir, cumulative (top), proportion (middle), and daily (bottom), for 1997 and 1998.

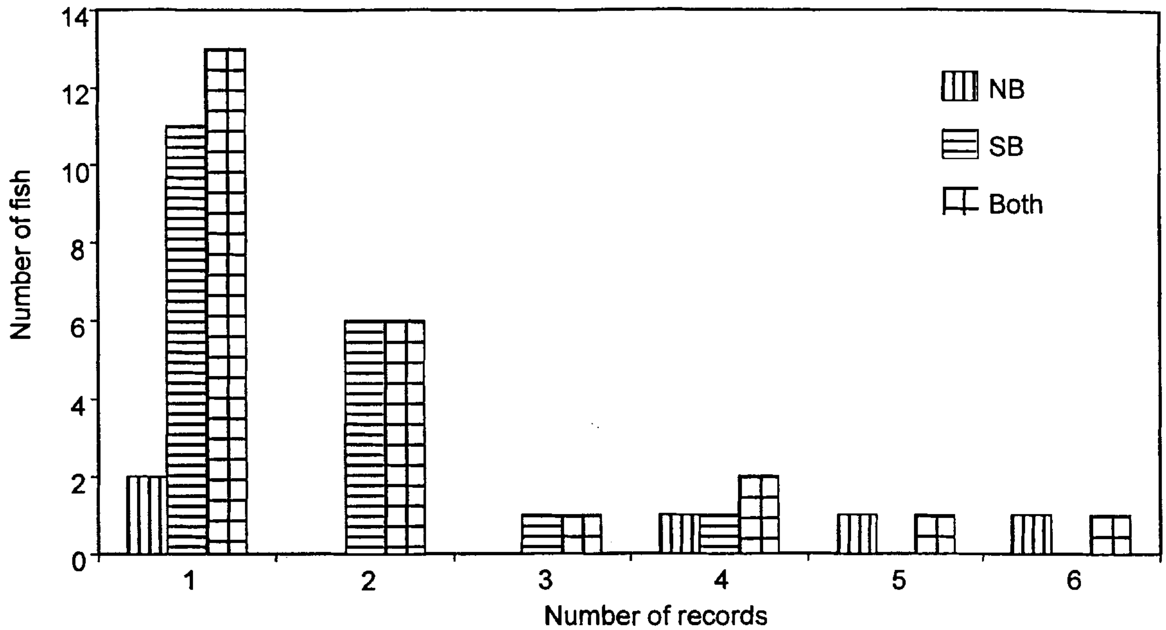


Figure 7. Yentna River coho salmon radiotelemetry, histogram of radiotagged fish migrating through the sonar ensonified areas, 1998.

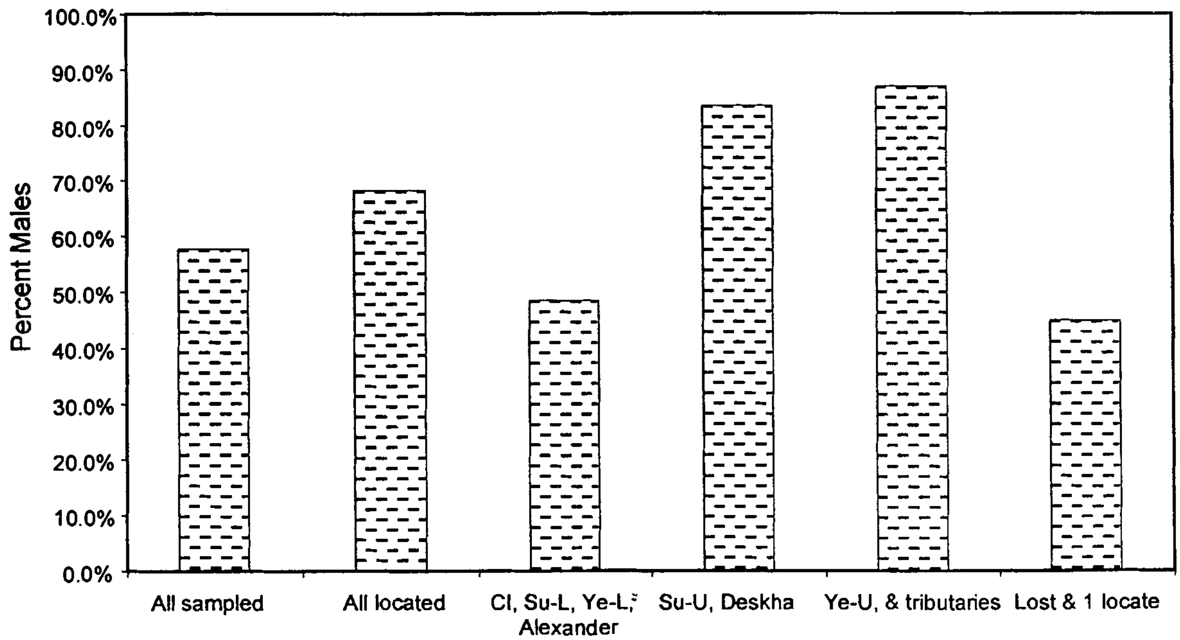


Figure 8. Yentna River coho salmon radiotelemetry, histogram of males by locations, 1998.

Appendix A-1. Summary of statistical analyses used to assess species, length, and sex ratio biases in fish wheel recaptues of tagged sockeye and coho salmon during species selectivity studies, 1998.

Test Parameter	Ho	Test	P Value Sockeye	P Value Coho
All unrecovered vs all recovered	no difference in species recovery ratios (both banks)	Chi-Square	0.081	
	no difference in species ratios of SB unrecovered to all recoveries of SB tagged	Chi-Square	0.043	
	no difference in species ratios of NB unrecovered to all recoveries of NB tagged	Chi-Square	0.782	
All unrecovered vs all recovered	no difference in recover to unrecover lengths	Two Sample t-Test	0.089	0.738
	no difference in recover to unrecover lengths	K-S Test	0.297	0.979
	no difference in recover to unrecover sex ratios	Chi-Square	0.674	0.233
All recovered female vs all unrecovered female	no difference in recover to unrecover lengths	Two Sample t-Test	0.106	0.347
	no difference in recover to unrecover lengths	K-S Test	0.258	0.456
All recovered male vs all unrecovered male	no difference in recover to unrecover lengths	Two Sample t-Test	0.202	0.604
	no difference in recover to unrecover lengths	K-S Test	0.621	0.492
All SB tagged vs all NB tagged	no difference in lengths of tagged fish (bank to bank)	Two Sample t-Test	0.000	0.042
	no difference in lengths of tagged fish (bank to bank)	K-S Test	0.000	0.086
“	no difference is sex ratios of tagged fish (bank to bank)	Chi-Square	0.000	0.010
All NB tagged female vs all SB tagged female	no difference in female lengths (bank to bank)	Two Sample t-Test	0.198	0.229
	no difference in female lengths (bank to bank)	K-S Test	0.375	0.617
All NB tagged male vs all SB tagged male	no difference in male lengths (bank to bank)	Two Sample t-Test	0.000	0.202
	no difference in male lengths (bank to bank)	K-S Test	0.000	0.126
All SB unrecovered to all recoveries of SB tagged	no difference in recover to unrecover lengths	Two Sample t-Test	0.249	0.006
	no difference in recover to unrecover lengths	K-S Test	0.792	0.033
All NB unrecovered to all recoveries of NB tagged	no difference in recover to unrecover lengths	Two Sample t-Test	0.052	0.695
	no difference in recover to unrecover lengths	K-S Test	0.054	0.299
SB unrecovered vs SB recover of SB tagged		Two Sample t-Test		0.259
		K-S Test		0.954
		Chi-Square		0.404
NB unrecovered vs NB recover of NB tagged	No NB recoveries			

Appendix A-2. Summary of sockeye salmon escapements, and numbers sampled and processed for thermal (otolith) marks, and results, by day at the Yentna River fish wheels and Chelatna Lake weir, 1998.

	Yentna River fish wheels						Chelatna Lake weir					
		No. samples		Marked		Unread-		No. samples		Marked		Unread-
Date	Daily esc.	Daily	Cum	No	Yes	able	aily esc.	Daily	Cum.	No	Yes	able
7-Jul	64	3	3	3								
8-Jul	52	4	7	4								
9-Jul	60	4	11	4								
10-Jul	204	15	26	14	1							
11-Jul	319	22	48	20		1						
12-Jul	306	21	69	21								
13-Jul	277	20	89	17	1	2						
14-Jul	222	16	105	15								
15-Jul	197	14	119	13		1	3					
16-Jul	248	19	138	13	1	2	0					
17-Jul	292	21	159	18			2					
18-Jul	430	31	190	24	1		21					
19-Jul	1,173	81	271	66	2		474	12	12	12		
20-Jul	1,220	89	360	70	2	2	545	37	49	34	3	
21-Jul	885	62	422	51	1		534	27	76	25	1	1
22-Jul	571	40	462	31	2		582	26	102	24		2
23-Jul	446	31	493	24	1	1	574	27	129	27		
24-Jul	637	45	538	38			4,481	80	209	74	1	5
25-Jul [a]	861	54	592	43		2	6,466	0	209			
26-Jul [a]	1,053	88	680	66	5	2		0	209			
27-Jul [a]	1,158	64	744	50	3			0	209			
28-Jul [a]	891	79	823	60	5	1		0	209			
29-Jul [a,b]	847	58	881	46	1	1	118	118	327			
30-Jul [a,b]	1,521	110	991	88	2	1	280	280	607			
31-Jul [a]	1,201	69	1,060	54	3	1		0	607			
1-Aug	1,239	93	1,153	73	2	2		0	607			
2-Aug	1,516	118	1,271	94	4		535	44	651	39	4	1
3-Aug	2,071	87	1,358	68	3	1	891	76	727	63	12	1
4-Aug	1,441	160	1,518	128	3	2	1,166	80	807	73	6	1
5-Aug	947	61	1,579	49	2		1,132	80	887	73	7	
6-Aug	754	63	1,642	48	3	1	1,811	80	967	74	5	1
7-Aug	507	37	1,679	31			903	40	1,007	36	3	1
8-Aug	418	30	1,709	26			990	40	1,047	34	6	
9-Aug	211	16	1,725	13			864	40	1,087	39		1
10-Aug	221	18	1,743	14			1,355	80	1,167	72	5	3
11-Aug	287	21	1,764	18			1,349	40	1,207	39	1	
12-Aug	264	19	1,783	16			702	40	1,247	36	4	
13-Aug	229	18	1,801	15			648	40	1,287	38	2	
14-Aug	226		1,801				451	40	1,327	35	2	3
15-Aug	170		1,801				315		1,327			
16-Aug	127		1,801				96		1,327			
17-Aug	137		1,801				123		1,327			
18-Aug	166		1,801				117		1,327			
19-Aug	123		1,801				73		1,327			
20-Aug	134		1,801				23	5	1,332	2	3	
21-Aug	138		1,801				39		1,332			
22-Aug			1,801				19		1,332			
Total	26,461	1,801		1,446	48	23	27,284	1.332		849	65	20
	Total read and percent			1,494	3.2%	1.5%				914	7.1%	2.1%

[a] The Chelatna Lake weir washed out on 25 July, and remained inoperable through 1 August.

[b] Sockeye salmon were seined in Lake Creek (Chelatna Lake outlet) but were not included in the otolith samples processed.

Appendix A-3. Yentna River daily (actual) and cumulative fish wheel catches, both banks, 1998.

Date	Sockeye		Pink		Chum		Coho		Chinook		Other[a]	
	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
7-Jul	64	64	4	4	0	0	0	0	8	8	0	0
8-Jul	52	116	1	5	0	0	0	0	5	13	0	0
9-Jul	60	176	3	8	3	3	0	0	5	18	3	3
10-Jul	204	380	6	14	9	12	3	3	1	19	9	12
11-Jul	319	699	7	21	4	16	3	6	0	19	7	19
12-Jul	306	1,005	7	28	6	22	25	31	6	25	2	21
13-Jul	277	1,282	26	54	12	34	16	47	4	29	10	31
14-Jul	222	1,504	33	87	19	53	33	80	1	30	6	37
15-Jul	197	1,701	81	168	27	80	44	124	6	36	9	46
16-Jul	248	1,949	149	317	53	133	68	192	1	37	1	47
17-Jul	292	2,241	144	461	41	174	64	256	4	41	0	47
18-Jul	430	2,671	288	749	38	212	128	384	4	45	3	50
19-Jul	1,173	3,844	837	1,586	54	266	159	543	7	52	12	62
20-Jul	1,220	5,064	1,035	2,621	50	316	164	707	5	57	17	79
21-Jul	885	5,949	797	3,418	28	344	137	844	6	63	14	93
22-Jul	571	6,520	944	4,362	34	378	169	1,013	3	66	9	102
23-Jul	446	6,966	1,117	5,479	43	421	202	1,215	6	72	1	103
24-Jul	637	7,603	1,948	7,427	80	501	278	1,493	3	75	2	105
25-Jul	861	8,464	2,839	10,266	118	619	276	1,769	1	76	4	109
26-Jul	1,053	9,517	3,307	13,573	88	707	161	1,930	3	79	2	111
27-Jul	1,158	10,675	5,047	18,620	89	796	205	2,135	0	79	4	115
28-Jul	891	11,566	3,090	21,710	66	862	249	2,384	4	83	8	123
29-Jul	847	12,413	2,808	24,518	63	925	269	2,653	0	83	18	141
30-Jul	1,521	13,934	2,254	26,772	90	1,015	475	3,128	0	83	16	157
31-Jul	1,201	15,135	1,945	28,717	85	1,100	400	3,528	0	83	12	169
1-Aug	1,239	16,374	1,514	30,231	86	1,186	341	3,869	2	85	13	182
2-Aug	1,516	17,890	1,431	31,662	166	1,352	349	4,218	0	85	11	193
3-Aug	2,071	19,961	1,846	33,508	166	1,518	277	4,495	1	86	6	199
4-Aug	1,441	21,402	1,133	34,641	83	1,601	91	4,586	0	86	2	201
5-Aug	947	22,349	785	35,426	99	1,700	115	4,701	2	88	4	205
6-Aug	754	23,103	550	35,976	104	1,804	85	4,786	0	88	1	206
7-Aug	507	23,610	546	36,522	119	1,923	90	4,876	2	90	4	210
8-Aug	418	24,028	511	37,033	112	2,035	182	5,058	3	93	10	220
9-Aug	211	24,239	321	37,354	117	2,152	196	5,254	2	95	10	230
10-Aug	221	24,460	295	37,649	105	2,257	156	5,410	0	95	35	265
11-Aug	287	24,747	174	37,823	63	2,320	195	5,605	0	95	17	282
12-Aug	264	25,011	118	37,941	53	2,373	77	5,682	1	96	17	299
13-Aug	229	25,240	122	38,063	73	2,446	82	5,764	2	98	20	319
14-Aug	226	25,466	73	38,136	78	2,524	98	5,862	1	99	22	341
15-Aug	170	25,636	59	38,195	48	2,572	53	5,915	0	99	16	357
16-Aug	127	25,763	38	38,233	51	2,623	41	5,956	0	99	6	363
17-Aug	137	25,900	16	38,249	30	2,653	22	5,978	1	100	8	371
18-Aug	166	26,066	17	38,266	33	2,686	23	6,001	2	102	7	378
19-Aug	123	26,189	19	38,285	24	2,710	11	6,012	0	102	5	383
20-Aug	134	26,323	21	38,306	28	2,738	10	6,022	1	103	2	385
21-Aug	138	26,461	9	38,315	31	2,769	16	6,038	1	104	2	387
	NB total	12,067		17,057		1,102		1,712		54		267
	SB total	14,394		21,258		1,667		4,326		50		120
	Total	26,461		38,315		2,769		6,038		104		387
	Proportion	35.7%		51.7%		3.7%		8.2%		0.1%		0.5%

[a] Other fish include mostly whitefish, but also Longnose sucker, burbot, Rainbow trout, Northern pike and Dolly varden.

Appendix A-4. Total number of sockeye salmon captured in the Yentna River fish wheels by day and bank, and numbers tagged by color and bank (different sampling studies), 1998.

	SB Fish wheel				NB Fish wheel				Both Fish wheels					
		No. tagged				No. tagged				Total tagged				
			Species				Species			M-R		Species select.		
	Number	M-R	selectivity		Number	M-R	selectivity		Total					
Date	captured	(Yellow)	(Blue)	Cum.	captured	(White)	(Green)	Cum.	captured	total	cum.	total	cum.	Cum.
7-Jul	26	7		26	38	10		38	64	17	17			64
8-Jul	28	7		54	24	4		62	52	11	28			116
9-Jul	40	8		94	20	4		82	60	12	40			176
10-Jul	90	21		184	114	28		196	204	49	89			380
11-Jul	187	45		371	132	31		328	319	76	165			699
12-Jul	212	51		583	94	22		422	306	73	238			1,005
13-Jul	174	42		757	103	23		525	277	65	303			1,282
14-Jul	119	27		876	103	24		628	222	51	354			1,504
15-Jul	99	24		975	98	21		726	197	45	399			1,701
16-Jul	159	39		1,134	89	20		815	248	59	458			1,949
17-Jul	181	43		1,315	111	27		926	292	70	528			2,241
18-Jul	267	66		1,582	163	39		1,089	430	105	633			2,671
19-Jul	604	146		2,186	569	140		1,658	1,173	286	919			3,844
20-Jul	628	155		2,814	592	146		2,250	1,220	301	1,220			5,064
21-Jul	536	131		3,350	349	86		2,599	885	217	1,437			5,949
22-Jul	404	99		3,754	167	41		2,766	571	140	1,577			6,520
23-Jul	300	74		4,054	146	36		2,912	446	110	1,687	0	0	6,966
24-Jul	391	96	119	4,445	246	57	65	3,158	637	153	1,840	184	184	7,603
25-Jul	457	116	145	4,902	404	107	173	3,562	861	223	2,063	318	502	8,464
26-Jul	566	142		5,468	487	124		4,049	1,053	266	2,329			9,517
27-Jul	597	149		6,065	561	139		4,610	1,158	288	2,617			10,675
28-Jul	506	125		6,571	385	98		4,995	891	223	2,840			11,566
29-Jul	408	99		6,979	439	109		5,434	847	208	3,048			12,413
30-Jul	610	154		7,589	911	226		6,345	1,521	380	3,428			13,934
31-Jul	481	121		8,070	720	182		7,065	1,201	303	3,731			15,135
1-Aug	511	119		8,581	728	158		7,793	1,239	277	4,008			16,374
2-Aug	747	217		9,328	769	216		8,562	1,516	433	4,441			17,890
3-Aug	1,205	302	170	10,533	866	217	112	9,428	2,071	519	4,960	282	784	19,961
4-Aug	726	180	135	11,259	715	178	113	10,143	1,441	358	5,318	248	1,032	21,402
5-Aug	530	132		11,789	417	106		10,560	947	238	5,556			22,349
6-Aug	500	127		12,289	254	63		10,814	754	190	5,746			23,103
7-Aug	360	88		12,649	147	36		10,961	507	124	5,870			23,610
8-Aug	277	69		12,926	141	33		11,102	418	102	5,972			24,028
9-Aug	121	32		13,047	90	23		11,192	211	55	6,027			24,239
10-Aug	93	26		13,140	128	37		11,320	221	63	6,090			24,460
11-Aug	169	42		13,309	118	32		11,438	287	74	6,164			24,747
12-Aug	162	40		13,471	102	26		11,540	264	66	6,230			25,011
13-Aug	136	34		13,607	93	23		11,633	229	57	6,287			25,240
14-Aug	121	31		13,728	105	26		11,738	226	57	6,344			25,466
15-Aug	96			13,824	74			11,812	170		6,344			25,636
16-Aug	80			13,904	47			11,859	127		6,344			25,763
17-Aug	97			14,001	40			11,899	137		6,344			25,900
18-Aug	95			14,096	71			11,970	166		6,344			26,066
19-Aug	92			14,188	31			12,001	123		6,344			26,189
20-Aug	96			14,284	38			12,039	134		6,344			26,323
21-Aug	110			14,394	28			12,067	138		6,344		1,032	26,461
Total by bank		3,426	569			2,918	463							
Proportion		23.8%	4.0%	54.4%		24.2%	3.8%	45.6%			24.0%		3.9%	

Appendix A-5 . Total number of coho salmon captured in the Yentna River fish wheels by day and bank, and numbers tagged by bank for the species selectivity study and radio tagged for the radiotelemetry studies, 1998.

	SB Fish wheel				NB Fish wheel				Both Fish wheels					
	Number	No. tagged			Number	No. tagged			Total	Selectivity		Radio		
Date	captured	select.	radio	Cum.	captured	select.	radio	Cum.	captured	total	cum.	total	cum.	Cum.
9-Jul	0			0	0			0	0					0
10-Jul	2			2	1			1	3					3
11-Jul	2			4	1			2	3					6
12-Jul	19			23	6			8	25					31
13-Jul	11			34	5			13	16					47
14-Jul	17			51	16			29	33					80
15-Jul	31			82	13			42	44					124
16-Jul	44			126	24			66	68			0	0	192
17-Jul	28		2	154	36		1	102	64			3	3	256
18-Jul	62		2	216	66		2	168	128			4	7	384
19-Jul	75		4	291	84		7	252	159			11	18	543
20-Jul	76		7	367	88		6	340	164			13	31	707
21-Jul	80		4	447	57		3	397	137			7	38	844
22-Jul	119		6	566	50		3	447	169			9	47	1,013
23-Jul	152		9	718	50		3	497	202	0	0	12	59	1,215
24-Jul	186	64	6	904	92	39	2	589	278	103	103	8	67	1,493
25-Jul	198	187	5	1,102	78	75	5	667	276	262	365	10	77	1,769
26-Jul	125	82		1,227	36	25		703	161	107	472	0	77	1,930
27-Jul	143			1,370	62			765	205			0	77	2,135
28-Jul	194		22	1,564	55		6	820	249			28	105	2,384
29-Jul	192		35	1,756	77		5	897	269			40	145	2,653
30-Jul	333		18	2,089	142		9	1,039	475			27	172	3,128
31-Jul	300		17	2,389	100		7	1,139	400			24	196	3,528
1-Aug	247		19	2,636	94		5	1,233	341			24	220	3,869
2-Aug	269		19	2,905	80		7	1,313	349			26	246	4,218
3-Aug	210	119	9	3,115	67	29	3	1,380	277	148	620	12	258	4,495
4-Aug	69	83		3,184	22	22		1,402	91	105	725	0	258	4,586
5-Aug	86	86		3,270	29	26		1,431	115	112	837	0	258	4,701
6-Aug	74	34		3,344	11	5		1,442	85	39	876	0	258	4,786
7-Aug	77		10	3,421	13		2	1,455	90		876	12	270	4,876
8-Aug	157		7	3,578	25			1,480	182		876	7	277	5,058
9-Aug	167		13	3,745	29		1	1,509	196		876	14	291	5,254
10-Aug	121		5	3,866	35		1	1,544	156		876	6	297	5,410
11-Aug	152			4,018	43			1,587	195		876	0	297	5,605
12-Aug	61			4,079	16			1,603	77		876	0	297	5,682
13-Aug	54			4,133	28			1,631	82		876	0	297	5,764
14-Aug	68			4,201	30			1,661	98		876	0	297	5,862
15-Aug	35			4,236	18			1,679	53		876	0	297	5,915
16-Aug	30			4,266	11			1,690	41		876	0	297	5,956
17-Aug	13			4,279	9			1,699	22		876	0	297	5,978
18-Aug	15			4,294	8			1,707	23		876	0	297	6,001
19-Aug	10			4,304	1			1,708	11		876	0	297	6,012
20-Aug	10		7	4,314	0			1,708	10		876	7	304	6,022
21-Aug	12		2	4,326	4			1,712	16		876	2	306	6,038
Total by bank		655	228			221	78							
Proportion		15.1%	5.3%	71.6%		12.9%	4.6%	28.4%			14.5%		5.1%	

Appendix A-6. Yentna River fish wheel recoveries of species selectivity tagged coho and sockeye salmon, by bank and date released and recovered, and lag days to recovery, 1998.

Coho Salmon

Release Date	Release Bank	Recovery Bank	Recovery Date	Lag (days)	Sex
24-Jul	NB	SB	8-Aug	15	M
24-Jul	SB	NB	25-Jul	1	F
24-Jul	SB	NB	25-Jul	1	F
24-Jul	SB	SB	27-Jul	3	M
24-Jul	SB	SB	6-Aug	13	M
24-Jul	SB	SB	6-Aug	13	M
24-Jul	SB	SB	15-Aug	22	M
25-Jul	NB	SB	26-Jul	1	M
25-Jul	NB	SB	28-Jul	3	M
25-Jul	NB	SB	8-Aug	14	M
25-Jul	NB	SB	12-Aug	18	F
25-Jul	SB	NB	3-Aug	9	M
25-Jul	SB	SB	26-Jul	1	F
25-Jul	SB	SB	31-Jul	6	F
25-Jul	SB	SB	1-Aug	7	F
25-Jul	SB	SB	1-Aug	7	M
25-Jul	SB	SB	5-Aug	11	F
25-Jul	SB	SB	9-Aug	15	F
25-Jul	SB	SB	10-Aug	16	F
25-Jul	SB	SB	10-Aug	16	F
25-Jul	SB	SB	10-Aug	16	F
25-Jul	SB	SB	11-Aug	17	M
26-Jul	SB	NB	27-Jul	1	M
26-Jul	SB	NB	14-Aug	19	M
26-Jul	SB	SB	14-Aug	19	M
26-Jul	SB	SB	17-Aug	22	M
3-Aug	NB	SB	12-Aug	9	F
3-Aug	SB	NB	12-Aug	9	F
3-Aug	SB	NB	14-Aug	11	F
3-Aug	SB	SB	10-Aug	7	F
3-Aug	SB	SB	13-Aug	10	F
3-Aug	SB	SB	16-Aug	13	M
3-Aug	SB	SB	16-Aug	13	F
4-Aug	NB	SB	11-Aug	7	F
4-Aug	NB	SB	15-Aug	11	M
4-Aug	NB	SB	17-Aug	13	F
4-Aug	SB	NB	15-Aug	11	M
4-Aug	SB	NB	15-Aug	11	F
4-Aug	SB	SB	9-Aug	5	F
4-Aug	SB	SB	11-Aug	7	M
4-Aug	SB	SB	11-Aug	7	M
4-Aug	SB	SB	15-Aug	11	M
5-Aug	SB	SB	10-Aug	5	M
5-Aug	SB	SB	11-Aug	6	M
5-Aug	SB	SB	14-Aug	9	F
5-Aug	SB	SB	16-Aug	11	M
5-Aug	SB	SB	16-Aug	11	M
5-Aug	SB	SB	17-Aug	12	M
5-Aug	SB	SB	17-Aug	12	F

Sockeye Salmon

Release Date	Release Bank	Recovery Bank	Recovery Date	Lag (days)	Sex
24-Jul	SB	NB	26-Jul	2	M
24-Jul	SB	NB	31-Jul	7	F
24-Jul	SB	NB	1-Aug	8	F
24-Jul	SB	NB	7-Aug	14	M
25-Jul	NB	NB	26-Jul	1	M
25-Jul	NB	NB	28-Jul	3	M
25-Jul	NB	NB	14-Aug	20	F
25-Jul	NB	SB	25-Jul	0	M
25-Jul	NB	SB	26-Jul	1	F
25-Jul	NB	SB	26-Jul	1	M
25-Jul	NB	SB	26-Jul	1	F
25-Jul	NB	SB	26-Jul	1	M
25-Jul	NB	SB	26-Jul	1	M
25-Jul	NB	SB	26-Jul	1	M
25-Jul	NB	SB	27-Jul	2	M
25-Jul	SB	NB	27-Jul	2	M
25-Jul	SB	NB	27-Jul	2	F
25-Jul	SB	NB	28-Jul	3	M
25-Jul	SB	SB	26-Jul	1	M
25-Jul	SB	SB	27-Jul	2	F
25-Jul	SB	SB	27-Jul	2	M
3-Aug	NB	NB	4-Aug	1	F
3-Aug	NB	SB	5-Aug	2	F
3-Aug	NB	SB	5-Aug	2	M
3-Aug	NB	SB	6-Aug	3	M
3-Aug	NB	SB	8-Aug	5	M
3-Aug	SB	NB	4-Aug	1	M
3-Aug	SB	NB	4-Aug	1	M
3-Aug	SB	NB	10-Aug	7	F
3-Aug	SB	SB	4-Aug	1	M
4-Aug	NB	NB	5-Aug	1	M
4-Aug	NB	SB	4-Aug	0	M
4-Aug	NB	SB	5-Aug	1	F
4-Aug	NB	SB	6-Aug	2	F
4-Aug	SB	NB	4-Aug	0	M
4-Aug	SB	NB	5-Aug	1	F
4-Aug	SB	NB	5-Aug	1	F
4-Aug	SB	NB	5-Aug	1	F
4-Aug	SB	NB	6-Aug	2	F
4-Aug	SB	SB	5-Aug	1	M
4-Aug	SB	SB	8-Aug	4	F

Average lag (days) between release and recovery.

Recovery bank	Coho Females	Coho Males	Coho Both	Sockeye Females	Sockeye Males	Sockeye Both
NB	6.6	10.0	8.1	5.0	2.8	3.9
SB	10.6	11.0	10.9	1.9	1.5	1.6
Both	9.7	10.9	10.3	3.7	2.0	2.7

Appendix B-1. Sockeye salmon daily and cumulative escapements into Chelatna Lake, 1997 and 1998

	1997		1998 [a]	
Date	Daily	Cum.	Daily	Cum.
12-Jul	52	52		
13-Jul	206	258		
14-Jul	242	500		
15-Jul	44	544	3	3
16-Jul	243	787	0	3
17-Jul	248	1,035	2	5
18-Jul	1,029	2,064	21	26
19-Jul	2,208	4,272	474	500
20-Jul	3,040	7,312	545	1,045
21-Jul	7,003	14,315	534	1,579
22-Jul	6,080	20,395	582	2,161
23-Jul	12,008	32,403	574	2,735
24-Jul	3,500	35,903	4,481	7,216
25-Jul	5,000	40,903	6,466	13,682
26-Jul	4,013	44,916		
27-Jul	4,096	49,012		
28-Jul	7,127	56,139		
29-Jul	5,032	61,171	118 [b]	
30-Jul	6,700	67,871	280 [b]	
31-Jul	2,600	70,471		
1-Aug	494	70,965		
2-Aug	2,402	73,367	535	14,217
3-Aug	2,759	76,126	891	15,108
4-Aug	2,034	78,160	1,166	16,274
5-Aug	1,330	79,490	1,132	17,406
6-Aug	1,012	80,502	1,811	19,217
7-Aug	1,482	81,984	903	20,120
8-Aug	701	82,685	990	21,110
9-Aug	760	83,445	864	21,974
10-Aug	1,004	84,449	1,355	23,329
11-Aug	450	84,899	1,349	24,678
12-Aug			702	25,380
13-Aug			648	26,028
14-Aug			451	26,479
15-Aug			315	26,794
16-Aug			96	26,890
17-Aug			123	27,013
18-Aug			117	27,130
19-Aug			73	27,203
20-Aug			23	27,226
21-Aug			39	27,265
22-Aug			19	27,284

[a] The weir washed out from 25 July to 1 August, 1998.

[b] These fish were seined in river, they are not included in the weir count.

Appendix B-2. Daily and cumulative salmon escapements into Chelatna Lake, 1998.

	Sockeye		Chinook		Coho		Pink	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
15-Jul	3	3	0	0	0	0	0	0
16-Jul	0	3	1	1	0	0	0	0
17-Jul	2	5	0	1	0	0	0	0
18-Jul	21	26	0	1	0	0	0	0
19-Jul	474	500	3	4	0	0	0	0
20-Jul	545	1,045	1	5	1	1	0	0
21-Jul	534	1,579	3	8	7	8	2	2
22-Jul	582	2,161	6	14	3	11	3	5
23-Jul	574	2,735	8	22	0	11	1	6
24-Jul	4,481	7,216	14	36	0	11	2	8
25-Jul	6,466	13,682	1	37	0	11	0	8
26-Jul [a]								
27-Jul [a]								
28-Jul [a]								
29-Jul [a]	118 [b]							
30-Jul [a]	280 [b]							
31-Jul [a]								
1-Aug [a]								
2-Aug	535	14,217	0	37	5	16	0	8
3-Aug	891	15,108	1	38	6	22	0	8
4-Aug	1,166	16,274	0	38	7	29	9	17
5-Aug	1,132	17,406	0	38	9	38	3	20
6-Aug	1,811	19,217	4	42	63	101	31	51
7-Aug	903	20,120	1	43	24	125	2	53
8-Aug	990	21,110	5	48	46	171	5	58
9-Aug	864	21,974	1	49	79	250	3	61
10-Aug	1,355	23,329	0	49	122	372	3	64
11-Aug	1,349	24,678	0	49	130	502	16	80
12-Aug	702	25,380	1	50	91	593	2	82
13-Aug	648	26,028	0	50	54	647	5	87
14-Aug	451	26,479	0	50	41	688	0	87
15-Aug	315	26,794	3	53	26	714	4	91
16-Aug	96	26,890	1	54	12	726	2	93
17-Aug	123	27,013	0	54	16	742	1	94
18-Aug	117	27,130	4	58	12	754	3	97
19-Aug	73	27,203	1	59	3	757	1	98
20-Aug	23	27,226	1	60	5	762	1	99
21-Aug	39	27,265	1	61	2	764	0	99
22-Aug	19	27,284	1	62	2	766	0	99

[a] The weir washed out from 25 July to 1 August.

[b] These fish were seined in river, they are not included in the weir count.

Appendix B-3. Daily and cumulative salmon escapements into Judd Lake, 1998.

	Sockeye		Chinook		Pink		Chum		Coho	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
18-Jul	0	0	6	6						
19-Jul	0	0	0	6						
20-Jul	0	0	1	7						
21-Jul	1	1	4	11						
22-Jul	0	1	-1	10						
23-Jul	0	1	6	16						
24-Jul	4	5	1	17						
25-Jul	2	7	1	18						
26-Jul	6	13	-1	17						
27-Jul	188	201	-2	15	0	0				
28-Jul	674	875	0	15	1	1				
29-Jul	722	1,597	0	15	0	1				
30-Jul	1,051	2,648	0	15	1	2				
31-Jul	1,325	3,973	0	15	0	2				
1-Aug	2,516	6,489	0	15	26	28				
2-Aug	3,384	9,873	0	15	86	114				
3-Aug	1,795	11,668	0	15	123	237				
4-Aug	1,656	13,324	0	15	264	501			0	0
5-Aug	1,708	15,032	0	15	208	709	0	0	1	1
6-Aug	2,231	17,263	2	17	415	1,124	1	1	2	3
7-Aug	2,295	19,558	0	17	731	1,855	1	2	4	7
8-Aug	1,401	20,959	0	17	525	2,380	1	3	0	7
9-Aug	1,413	22,372	0	17	822	3,202	0	3	7	14
10-Aug	1,483	23,855	0	17	710	3,912	2	5	2	16
11-Aug	801	24,656	0	17	284	4,196	1	6	2	18
12-Aug	1,325	25,981	0	17	745	4,941	1	7	4	22
13-Aug	1,502	27,483	0	17	836	5,777	-2	5	3	25
14-Aug	1,185	28,668	0	17	1,293	7,070	0	5	7	32
15-Aug	1,060	29,728	0	17	1,336	8,406	0	5	3	35
16-Aug	1,068	30,796	0	17	1,468	9,874	0	5	2	37
17-Aug	678	31,474	0	17	1,319	11,193	2	7	0	37
18-Aug	433	31,907	0	17	224	11,417	0	7	0	37
19-Aug	418	32,325	0	17	498	11,915	0	7	2	39
20-Aug	292	32,617	0	17	467	12,382	0	7	0	39
21-Aug	318	32,935	0	17	1,036	13,418	0	7	2	41
22-Aug	238	33,173	0	17	380	13,798	0	7	3	44
23-Aug	206	33,379	0	17	245	14,043	2	9	0	44
24-Aug	331	33,710	0	17	311	14,354	0	9	13	57
25-Aug	261	33,971	0	17	106	14,460	4	13	34	91
26-Aug	187	34,158	0	17	40	14,500	9	22	51	142
27-Aug	109	34,267	0	17	6	14,506	2	24	30	172
28-Aug	106	34,373	0	17	5	14,511	5	29	18	190
29-Aug	43	34,416	0	17	4	14,515	2	31	12	202

Appendix B-4. Sockeye salmon daily and cumulative escapements into Larson Lake, 1997 and 1998.

	1997		1998	
Date	Daily	Cum.	Daily	Cum.
19-Jul			0	0
20-Jul	0	0	486	486
21-Jul	495	495	11	497
22-Jul	168	663	473	970
23-Jul	24	687	1,210	2,180
24-Jul	395	1,082	3,350	5,530
25-Jul	849	1,931	4,988	10,518
26-Jul	23	1,954	4,639	15,157
27-Jul	1,258	3,212	2,788	17,945
28-Jul	2,159	5,371	2,751	20,696
29-Jul	1,182	6,553	751	21,447
30-Jul	1,697	8,250	5,213	26,660
31-Jul	1,311	9,561	4,788	31,448
1-Aug	398	9,959	2,928	34,376
2-Aug	426	10,385	996	35,372
3-Aug	443	10,828	4,923	40,295
4-Aug	1,176	12,004	3,258	43,553
5-Aug	1,759	13,763	1,779	45,332
6-Aug	1,135	14,898	2,009	47,341
7-Aug	1,027	15,925	3,301	50,642
8-Aug	812	16,737	2,939	53,581
9-Aug	1,081	17,818	2,268	55,849
10-Aug	1,190	19,008	1,608	57,457
11-Aug	1,083	20,091	1,480	58,937
12-Aug	1,279	21,370	424	59,361
13-Aug	401	21,771	1,335	60,696
14-Aug	300	22,071	682	61,378
15-Aug	559	22,630	597	61,975
16-Aug	277	22,907	442	62,417
17-Aug	264	23,171	95	62,512
18-Aug	597	23,768	257	62,769
19-Aug	964	24,732	159	62,928
20-Aug	999	25,731	216	63,144
21-Aug	612	26,343	130	63,274
22-Aug	1,504	27,847	95	63,369
23-Aug	453	28,300	145	63,514
24-Aug	1,111	29,411		
25-Aug	2,002	31,413		
26-Aug	1,591	33,004		
27-Aug	1,567	34,571		
28-Aug	1,291	35,862		
29-Aug	1,165	37,027		
30-Aug	759	37,786		
31-Aug	517	38,303		
1-Sep	304	38,607		
2-Sep	197	38,804		
3-Sep	140	38,944		
4-Sep	201	39,145		
5-Sep	282	39,427		
6-Sep	301	39,728		
7-Sep	88	39,816		
8-Sep	240	40,056		
9-Sep	74	40,130		
10-Sep	33	40,163		
11-Sep	48	40,211		
12-Sep	44	40,255		
13-Sep	27	40,282		

Appendix B-5. Daily and cumulative salmon escapements into Larson Lake, 1998.

	Sockeye		Pink		Chum		Coho	
Date	Daily	Cum.	Daily	Cum.	Daily	Cum.	Daily	Cum.
19-Jul	0	0						
20-Jul	486	486						
21-Jul	11	497						
22-Jul	473	970						
23-Jul	1,210	2,180						
24-Jul	3,350	5,530						
25-Jul	4,988	10,518						
26-Jul	4,639	15,157						
27-Jul	2,788	17,945						
28-Jul	2,751	20,696						
29-Jul	751	21,447						
30-Jul	5,213	26,660					0	0
31-Jul	4,788	31,448					1	1
1-Aug	2,928	34,376					0	1
2-Aug	996	35,372					0	1
3-Aug	4,923	40,295					0	1
4-Aug	3,258	43,553					0	1
5-Aug	1,779	45,332	0	0			0	1
6-Aug	2,009	47,341	1	1			1	2
7-Aug	3,301	50,642	9	10			0	2
8-Aug	2,939	53,581	4	14			0	2
9-Aug	2,268	55,849	11	25			0	2
10-Aug	1,608	57,457	4	29			0	2
11-Aug	1,480	58,937	5	34			2	4
12-Aug	424	59,361	0	34			0	4
13-Aug	1,335	60,696	4	38			1	5
14-Aug	682	61,378	3	41			1	6
15-Aug	597	61,975	1	42	0	0	0	6
16-Aug	442	62,417	19	61	12	12	2	8
17-Aug	95	62,512	2	63	0	12	1	9
18-Aug	257	62,769	5	68	0	12	2	11
19-Aug	159	62,928	2	70	0	12	1	12
20-Aug	216	63,144	5	75	2	14	0	12
21-Aug	130	63,274	4	79	1	15	1	13
22-Aug	95	63,369	2	81	4	19	0	13
23-Aug	145	63,514	0	81	0	19	1	14

Appendix C-1. Yentna River coho salmon radiotelemetry, radio tag frequencies and pulse codes, 1998.

Frequency	Pulse codes								
150.023	105	115	125	135	145	155	165	175	185	195
150.044	105	115	125	135	145	155	165	175	185	195
150.064	105	115	125	135	145	155	165	175	185	195
150.084	105	115	125	135	145	155	165	175	185	195
150.104	105	115	125	135	145	155	165	175	185	195
150.124	105	115	125	135	145	155	165	175	185	195
150.146	105	115	125	135	145	155	165	175	185	195
150.163	105	115	125	135	145	155	165	175	185	195
150.313	105	115	125	135	145	155	165	175	185	195
150.353	105	115	125	135	145	155	165	175	185	195
150.373	105	115	125	135	145	155	165	175	185	195
150.413	105	115	125	135	145	155	165	175	185	195
150.433	105	115	125	135	145	155	165	175	185	195
150.443	105	115	125	135	145	155	165	175	185	195
152.012	105	115	125	135	145	155	165	175	185	195
152.043	105	115	125	135	145	155	165	175	185	195
153.033	105	115	125	135	145	155	165	175	185	195
153.064	105	115	125	135	145	155	165	175	185	195
153.094	105	115	125	135	145	155	165	175	185	195
153.123	105	115	125	135	145	155	165	175	185	195
153.153	105	115	125	135	145	155	165	175	185	195
153.183	105	115	125	135	145	155	165	175	185	195
153.213	105	115	125	135	145	155	165	175	185	195
153.244	105	115	125	135	145	155	165	175	185	195
153.273	105	115	125	135	145	155	165	175	185	195
153.304	105	115	125	135	145	155	165	175	185	195
153.333	105	115	125	135	145	155	165	175	185	195
153.363	105	115	125	135	145	155	165	175	185	195
153.393	105	115	125	135	145	155	165	175	185	195
153.423	105	115	125	135	145	155	165	175	185	195
153.453 [a]	105	115	125	135	145	155	165	175	185	195

[a] Frequency 153.453 tags were used for calibration and testing, and were not released on coho salmon.

Appendix C-2. Yentna River coho salmon radiotelemetry, goodness of fit test using Chi square analysis of sex ratios by final destination, 1998.

Group	N	Observed[a] Male	Observed[a] Female	Expected Male	Expected Female	X^{2} [b]
Sampled population	306	177	129	177	129	3.84
		57.8%	42.2%			
All located fish	170	116	54	98	72	7.53
Cook Inlet, Susitna lower & Yentna lower & Alexander	58	28	30	34	24	2.18
Susitna upper & Deskha	18	15	3	10	8	4.80
Yentna upper & tributaries	84	73	11	49	35	29.09
Lost or 1 locate	136	61	75	79	57	9.41

[a] Observed sex is from all sampled fish, not just aged fish from ALS table.
[b] a=0.05, df=1.

Appendix C3. Ranking of seasonal mean macrozooplankton biomass for 30 lakes throughout Alaska. For 18 lakes an established population of sockeye salmon existed. The mean biomass for the 12 barren lakes listed is before stocking (Kyle 1996).

Rank	Lake	Mean escapement	Biomass (mg m^{-2})
1	Chenik	10000	2223
2	Hidden (Cook Inlet)	35000	2331
3	Chilkat	68400	1287
4	Karluk	650000	1041
5	Spiridon	Barren	1032
6	Eshamy	30000	972
7	Port Dick	Barren	866
	Chelatna [a]	**35000**	**832**
8	Crescent	Barren	701
9	Packers	20000	617
10	Skilak	800000	556
11	Hugh-Smith	175000	523
12	Hidden (Kodiak)	Barren	496
13	Pass	Barren	495
14	Bruin	Barren	443
15	Hazel	Barren	420
16	Waterfall	Barren	324
17	McDonald	98700	297
18	Ursus	Barren	207
19	Ester Pass	Barren	201
20	Sweetheart	Barren	186
21	Afognak	65000	185
22	redoubt	21100	159
23	Frazer	200000	155
24	Chilkoot	79600	145
25	Upper Malina	5000	123
26	Tustumena	235000	105
27	Coghill	10000	79
28	Kirschner	Barren	77
29	English Bay	5000	56
30	Portage	15000	30

[a] Chelatna Lake, escapement mean 1992-1998, Station-A zooplankton mean 1984-1996.