Fishery Data Series No. 94-14

Salmon Studies in Interior Alaska, 1993

by

Cal Skaugstad

August 1994

Alaska Department of Fish and Game Division of Sport Fish

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SALMON STUDIES IN INTERIOR ALASKA, 1993[1]

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

In 1993, abundances were estimated for chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Salcha River and Chena River near Fairbanks, Alaska. Estimates of abundance were also made for chum salmon *Oncorhynchus keta* at the same time; however, the time period that was sampled (1 July through 8 August) covered only a portion of the chum salmon population. Chinook and chum salmon were counted during 20 min periods each hour as they passed beneath the Richardson Highway bridge on the Salcha River and the Moose Creek Dam on the Chena River. Estimates of abundance for chinook and chum salmon in the Salcha River were 10,007 (SE = 360) and 5,809 (SE = 250), respectively. Estimates of abundance for chinook and chum salmon in the Chena River were 12,241 (SE = 387) and 5,400 (SE = 248), respectively. In early August, chinook salmon carcasses were collected from both rivers. Males comprised 72% of the carcass sample in the Salcha River and 83% in the Chena River. In both rivers, more than 80% of the males were age 1.3 or younger while 77% of the females were age 1.4 or older. Estimated potential egg production for the chinook salmon population in the Salcha River was 23 million eggs (SE = 2.1 million). Potential egg production was not estimated for the Chena River chinook salmon population because the sample was too small. The highest counts of chinook salmon during aerial surveys were 3,636 for the Salcha River and 2,943 for the Chena River populations. These aerial counts were about 36% and 24% of the respective abundance estimates.

Chinook salmon were captured and tagged near Manley on the Tanana River to estimate the migration time to the Salcha and Chena rivers. Four-hundred-thirteen chinook salmon were captured and 403 were tagged and released from 12-15 July. The tagged salmon were counted as they passed the counting sites on each river and as they were caught in the commercial and subsistence fisheries. Only two chinook salmon were sighted at the Salcha River (24-25 July), eight were sighted at the Chena River (20 July - 2 August), and 19 were captured in the commercial and subsistence fisheries (16-24 July). Mean migration times from Manley were 11.0 days (SE = 1.4) to the Salcha River and 11.6 days (SE = 3.5) to the Chena River counting sites.

Coho salmon in the Delta Clearwater River near Delta Junction were counted from a drifting river boat on six occasions during September and October, 1993. Counts of coho salmon ranged from 228 on 23 September (only a portion of the river was surveyed) to 10,875 on 21 October (the entire river was surveyed). Two-hundred-ninety-nine carcasses were collected on 8 November. The sex composition of the sample was 52% male and 48% female. Ages 1.1 and 2.1 comprised 63% and 37% of the sample, respectively.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, chum salmon, *Oncorhynchus keta*, coho salmon, *Oncorhynchus kisutch*, Salcha River, Chena River, age-sex-length composition, aerial survey, fecundity, egg production, abundance, migration timing, counting towers, carcass survey, escapement, Delta Clearwater River, egg retention.

CHINOOK AND CHUM SALMON STUDIES FOR THE SALCHA AND CHENA RIVER

Introduction

The Salcha and Chena rivers have some of the largest chinook salmon escapements in the Yukon River drainage. The Salcha River is a 250 km, clear stream flowing into the Tanana River about 60 km east of Fairbanks (Figure 1). The Chena River is a 240 km, clear stream that flows into the Tanana River 8 km west of Fairbanks (Figure 2). At the mouth of the Salcha River there is a popular sport fishery; annual harvests have approached 1,000 chinook salmon in some years (Mills 1979-1993; Table 1). A sport fishery takes place in the lower 72 km of the Chena River where up to 375 chinook have been harvested (Mills 1979-1993; Table 1). Before reaching their spawning grounds, the chinook salmon travel about 1,500 km from the ocean and pass through six different commercial fishing districts in the Yukon and Tanana rivers (Figure 3). Subsistence and personal use fishing also occur in each district.

In previous years, the abundance of the chinook salmon escapements into the Salcha and Chena rivers were estimated using mark-recapture experiments and monitored with aerial surveys. This information has been used to evaluate management of the commercial, subsistence, personal, and sport fisheries on these stocks of chinook salmon. However, these methods provide fishery managers with limited information that can be used during the fishing season. Aerial surveys and mark-recapture experiments occur after most of the escapement has passed through the various fisheries. These methods only inform fishery managers if the escapement objectives were met.

Minimum escapement guidelines for chinook salmon returning to the Salcha and Chena rivers are 2,500 and 1,700 spawners, respectively, counted during aerial surveys (established by the Department of Fish and Game). Using counts from aerial surveys and abundance estimates of escapement, the minimum escapement guidelines for aerial surveys were expanded into actual abundance. The minimum escapement guidelines for abundance of chinook salmon are 7,100 for the Salcha River and 6,300 for the Chena River.

In 1987 the Board of Fisheries recognized the need to regulate the harvest of chinook salmon caught by sport anglers in the Salcha and Chena rivers. In response, the board imposed a sport harvest guideline of 300 to 700 chinook salmon for the Salcha River and 300 to 600 chinook salmon for the Chena River. The harvest by anglers is monitored with creel surveys. By counting chinook salmon as they enter the spawning streams, the Division of Sport Fish can regulate the sport fisheries during the fishing season to insure that the sport harvest does not adversely impact the escapement.

Chum salmon returning to the Salcha and Chena rivers also are harvested in local sport fisheries. The migration timing of chum salmon is later than that for chinook salmon, but does overlap the chinook salmon migration. Because sport fisheries exist on these stocks, the abundance of the chum salmon escapements also were monitored to insure that the sport harvest did not adversely impact the escapement.

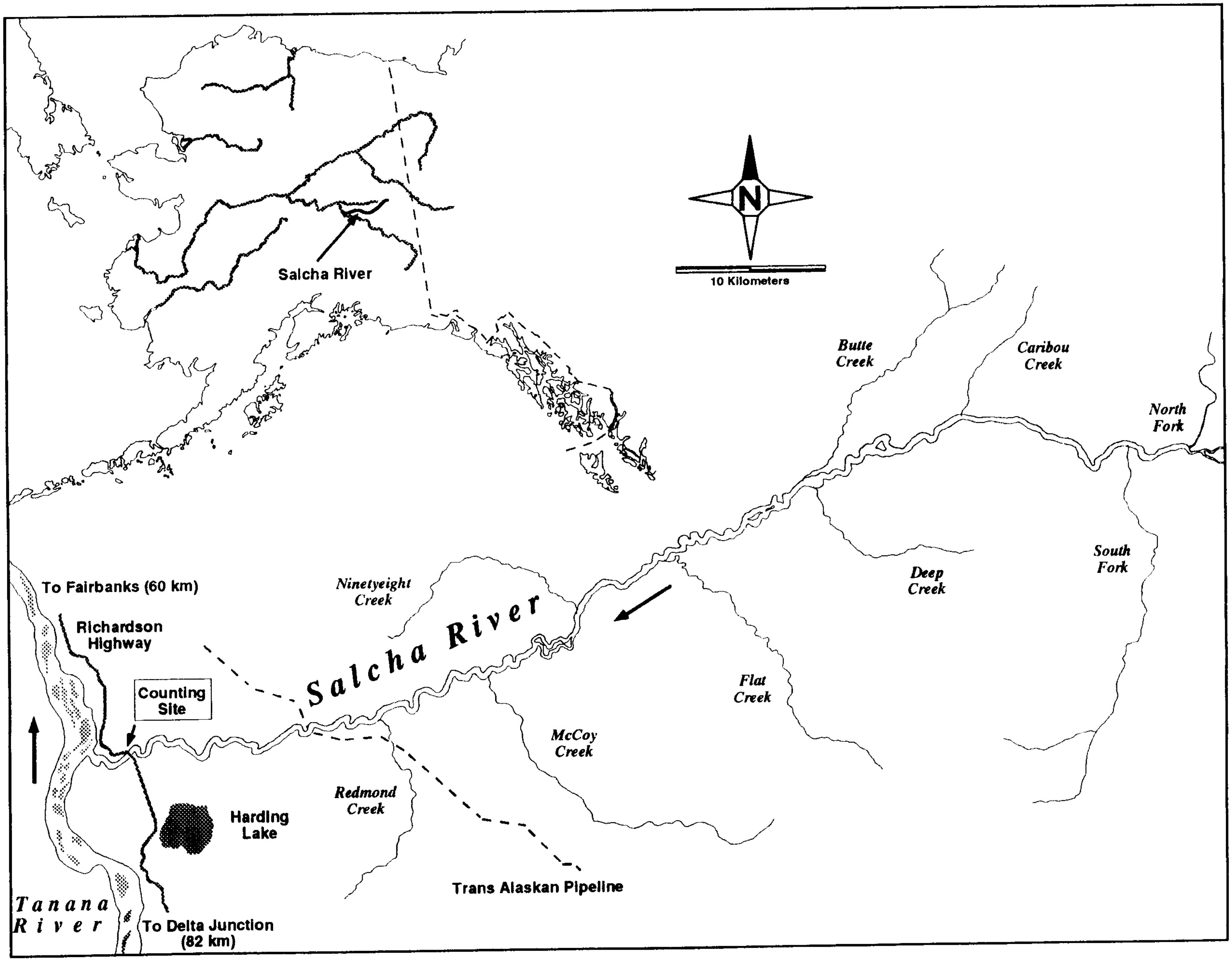


Figure 1. Salcha River study area.

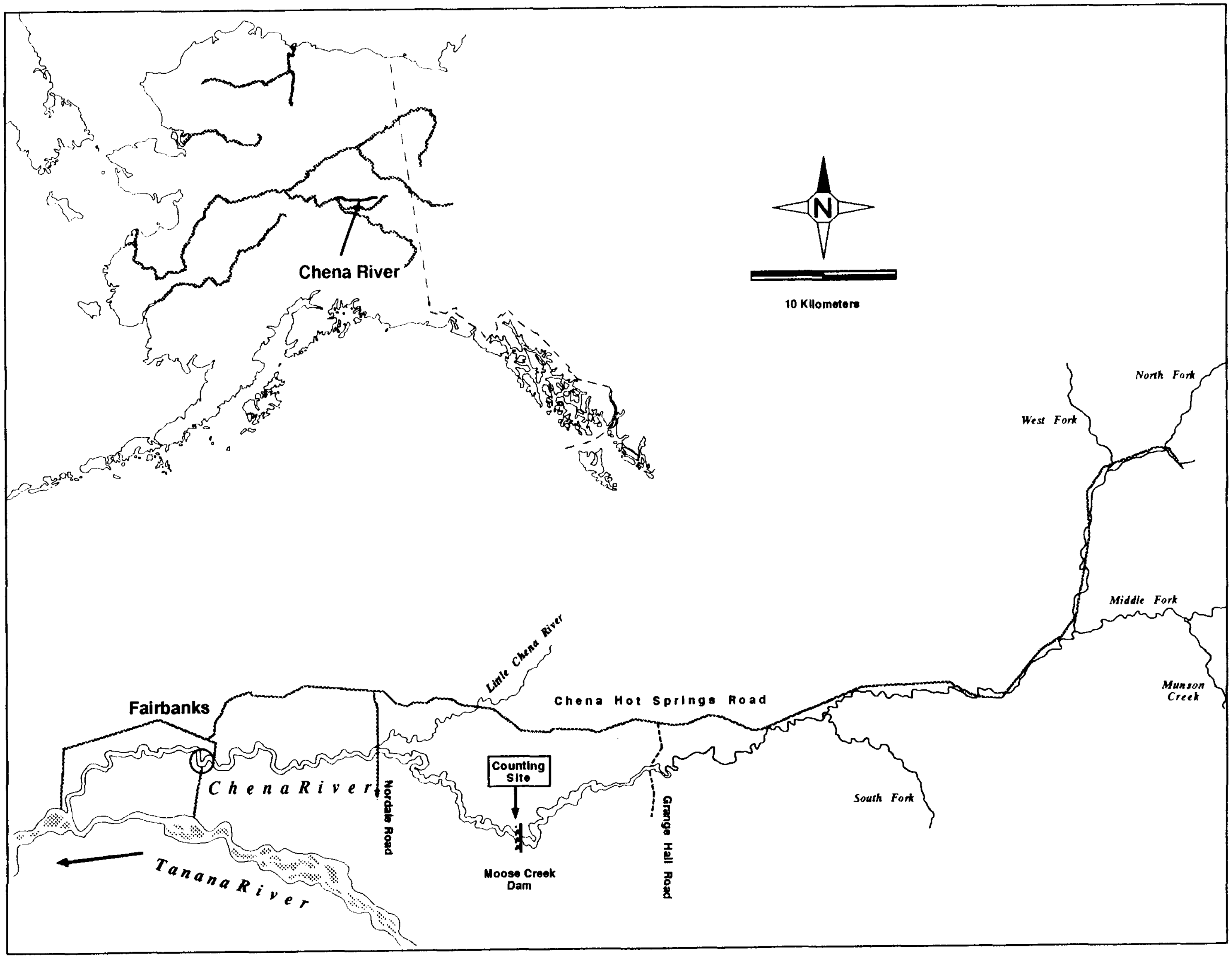


Figure 2. Chena River study area.

Table 1. Harvests of anadromous chinook salmon by sport, commercial, subsistence, and personal use fisheries, Tanana River drainage, 1978 - 1993.

	On Site Sport Harvest Estimates[a]		Statewide Survey Estimates of Sport Harvest[b]						Estimated Harvest by User Group		
Year	Chena River	Salcha River	Chena River	Salcha River	Chatanika River	Nenana River	Other Streams	All Waters	Commercial Harvests[c]	Subsistence and Personal Use Harvests[c]	Total Known Harvest
1978	none	none	23	105	35	none	0	163	635	1,231	2,029
1979	none	none	10	476	29	none	0	515	772	1,333	2,620
1980	none	none	0	904	37	none	0	941	1,947	1,826	4,714
1981	none	none	39	719	5	none	0	763	987	2,085	3,835
1982	none	none	31	817	136	none	0	984	981	2,443	4,408
1983	none	none	31	808	147	none	10	1,048	911	2,706	4,665
1984	none	none	0	260	78	none	0	338	867	3,599	4,804
1985	none	none	37	871	373	none	75	1,356	1,142	7,375	9,873
1986	none	526	212	525	0	none	44	781	950	3,701	5,432
1987	none	111	195	244	21	7	7	474	1,202	4,096	5,772
1988	567	19	73	236	345	36	54	744	786[d]	5,441[e]	7,090
1989	685	123	375	231	231	39	87	963	2,181[d]	3,046[e]	5,001
1990	24	200	64	291	37	0	0	439	2,989[d]	3,759[e]	7,140
1991	none	362	110	373	82	11	54	630	1,163[d]	2,687[e]	4,480
1992	none	4[g]	39[g]	47[g]	16[g]	0[g]	0[g]	118[g]	712[d]	2,438[efh]	3,150[f]
1993	none	54[i]	NA[j]	NA	NA	NA	NA	NA	1,113[d]	NA	NA

a Creel census estimates from Clark and Ridder (1987), Baker (1988, 1989), Merritt et al. (1990), and Hallberg and Bingham (1991 and 1993).

b Sport fishery harvest estimates from Mills (1979-1993).

c Commercial, subsistence, and personal use estimates (Schultz, Keith. 1991-1993. Personal Communication. Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701.

d Includes chinook salmon sold from ADFG test fisheries occurring near Nenana and Manley (24 fish in 1988, 440 fish in 1989, 833 fish in 1990, 91 fish in 1991, 32 fish in 1992, and none in 1993).

e The personal use designation was implemented in 1988 to account for non-rural fishermen participating in this fishery. Harvest by personal use fishermen was 395 fish in 1988 and 495 fish in 1989.

f Preliminary data and subject to change.

g The sport fishery was closed by emergency order in 1992.

h No chinook salmon were harvested in the personal use fishery in 1992.

i This is a minimal estimate because of problems wit h the survey method.

j NA means data not available at this time.

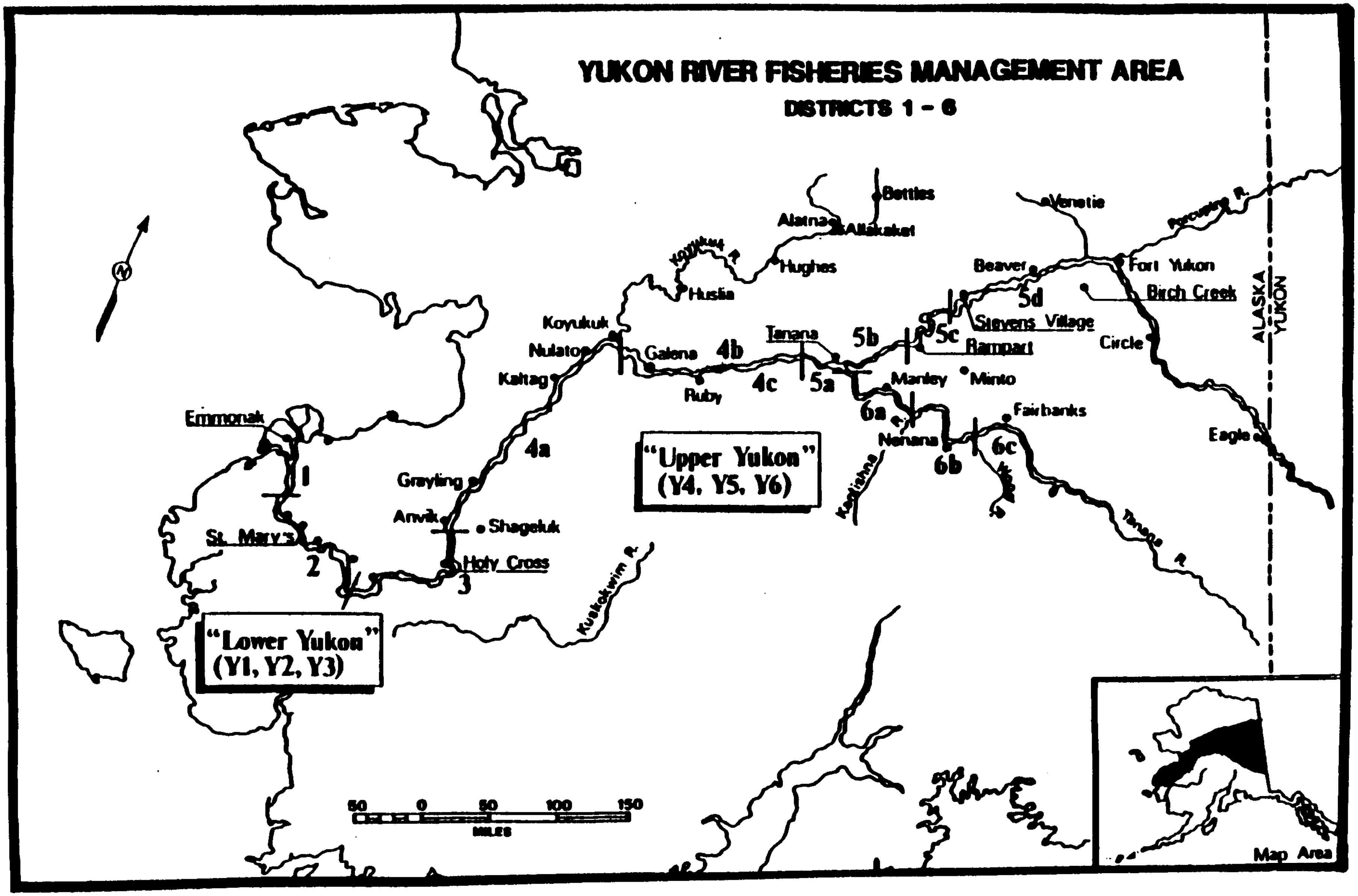


Figure 3. Fishing districts in the Yukon River drainage.

The objectives of the salmon escapement project for the Salcha River and Chena River in 1993 were to:

(1) estimate the escapements of chinook salmon in the Salcha and Chena rivers; and,

(2) estimate age, sex, and length compositions of the escapements of chinook salmon in the Salcha and Chena rivers.

In addition, there were three tasks:

(1a) generate absolute and relative cumulative frequency distributions using daily counts of chinook salmon past the counting sites;

(1b) generate absolute and relative cumulative frequency distributions using daily counts of marked chinook salmon past the counting sites;

(2) generate weekly estimates of the number of chinook salmon that pass the counting sites; and,

(3) count chum salmon in the Salcha and Chena rivers in conjunction with counting chinook salmon.

Methods

Counts:

Chinook and chum salmon returning to the Salcha and Chena rivers (Figures 1 and 2) were estimated by counting fish as they passed beneath counting sites (the Richardson Highway Bridge on the Salcha River and the Moose Creek Dam on the Chena River). The counting of salmon began on 1 July 1993 and ended on 8 August 1993. Light colored panels were placed beneath the Salcha River bridge and the Moose Creek Dam to make fish more visible as they crossed beneath the structures. The panels were made of painted hardware cloth and woven plastic fabric. Lights were suspended from the bridge and dam and were used during low ambient light. Because salmon often will avoid areas with unusual substrate or illuminated with artificial lighting, the panels were positioned to form a continuous band from bank to bank. Also, artificial lighting was continuous from bank to bank. Once the artificial lighting was turned on it was left on until the ambient light level was high enough to observe salmon with out the aid of artificial lighting. This was done in case salmon would not enter the illuminated area during a 20 min count, but would move upstream between counts if the lights were turned off.

A fishery biologist (crew leader) and three technicians were assigned to each river to conduct counts. Personnel were assigned 8 h shifts (actually 7.5 h) and counted salmon the first 20 min of every hour. This was a systematic sampling design. The counts were limited to 20 min to alleviate eye strain and fatigue associated with this type of work. There were 21 periods each week and three shifts each day. Each period was one 8 h shift. Shift I started at 0000 h (midnight) and ended at 0730 h; Shift II started at 0800 h and ended at 1530 h; Shift III started at 1600 h and ended at 2330 h. Technicians were assigned five periods each week and crew leaders were assigned two periods each week. There were four periods each week when no counts were made. These four periods were randomly assigned each week, but with the constraint that two or more periods without counts would not occur consecutively. Nor would periods without counts occur during the same shift on two consecutive days and each of the three shifts would receive at least one period without counts each week.

During the salmon counts, observers subjectively classified chinook salmon as small, ≤760 mm TL (total length as measured from the tip of the snout to the end of the caudal fin) or large, >760 mm TL. Size was estimated as the fish crossed the panels for which the width of the panel was known. The size of the fish was visually compared to the size of the panel and the observer then determined the size category of the fish. Most small chinook salmon were males, while most females were larger than 760 mm. These data provided a coarse estimate during the migration of the number of females in the population which in turn provided information on the population's potential egg deposition.

Abundance Estimator:

Estimates of abundance were stratified by day. Daily estimates of abundance were considered a two-stage direct expansion where the first stage was 8 h shifts within a day and the second stage was 20 min counting periods within a shift. The second stage was considered systematic sampling because the 20 min counting periods were not chosen randomly.

The number of salmon to pass by the tower per day was estimated:

$$\hat{N}_h = \overline{Y}_h D_h \tag{1}$$

$$\hat{V}\left[\hat{N}_h\right] = \left(1 - f_{1h}\right) D_h^2 \frac{s_{1h}^2}{d_h} + f_{1h}^{-1} \sum_{i=1}^{d_h} \left[M_{hi}^2 \left(1 - f_{2hi}\right) \frac{s_{2hi}^2}{m_{hi}} \right] \tag{2}$$

where:

$$\overline{Y}_h = \frac{\sum_{i=1}^{d_h} Y_{hi}}{d_h} \tag{3}$$

$$s_{1h}^2 = \frac{\sum_{i=1}^{d_h} \left(Y_{hi} - \overline{Y}_h\right)^2}{d_h - 1} \tag{4}$$

$$s_{2hi}^2 = \frac{\sum_{j=2}^{m_{hi}} \left(y_{hij} - y_{hij-1} \right)^2}{2\left(m_{hi-1}\right)} \tag{5}$$

$$f_{1h} = \frac{d_h}{D_h} \tag{6}$$

$$f_{2hi} = \frac{m_{hi}}{M_{hi}} \tag{7}$$

h = day;

i = 8 h shift;

j = 20 min counting period;

Y = number of chinook or chum salmon counted;

m = number of 20 min counting periods sampled;

M = total number of possible 20 min counting periods;

d = number of 8 h shifts sampled;

D = total number of possible 8 h shifts;

L = total number of possible days;

f_1 = fraction of 8 h shifts sampled;

f_2 = fraction of 20 min counting periods sampled;

s_2^2 = estimated variance of total across counting periods; and,

s_1^2 = estimated variance of total across shifts.

The total abundance was then estimated using:

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \tag{8}$$

$$\hat{V}\left(\hat{N}\right) = \sum_{h=1}^{L} \hat{V}\left(\hat{N}_h\right) \tag{9}$$

A Kolmogorov-Smirnov test statistic was used to compare the entry pattern of chinook salmon in the Salcha and Chena rivers. The data consisted of the estimated daily abundance.

Carcass Survey:

Chinook salmon carcasses were collected from a drifting river boat using long-handled spears. Carcasses were collected in the Salcha River 50 to 96 km from the mouth and in the Chena River 145 to 72 km from the mouth. All collected carcasses were examined to determine sex and measured from mid-eye to fork-of-tail (ME-FT). Three scales were removed from each fish and placed directly on gum cards for later age determination. Scales were removed from the left side approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956). Ages were determine from scale patterns as described by Mosher (1969). All female carcasses were cut open and the author made a subjective estimate of the proportion of eggs remaining in each carcass. Each carcass collected during the survey was cut along the left side to indicate that the carcass had been sampled.

Age-Sex-Length Compositions:

Mean lengths were estimated for combinations of age and sex using the sample mean and sample variance of the mean (Zar 1984 pp. 19 and 87). Proportions of female and male chinook salmon by ocean-age or 10 mm length category and the associated variances were estimated using:

$$\hat{p}_g = \frac{n_g}{n} \tag{10}$$

$$\hat{V}(\hat{p}_g) = \hat{p}_g \frac{(1-\hat{p}_g)}{n-1} \tag{11}$$

where:

$\hat{p}_g$ = estimated proportion of chinook salmon;

g = the group of interest (i.e. age, sex, length category);

n_g = number of chinook salmon of category g in the sample; and,

n = number of chinook salmon in the sample.

The abundance of female and male chinook salmon by age or length class was estimated:

$$\hat{N}_g = \hat{p}_g \hat{N} \tag{12}$$

where $\hat{N}$ = population abundance estimate.

The associated variance was estimated using Goodman's (1960) formula for the exact variance of a product of two independent estimates:

$$\hat{V}(\hat{N}_g) = \hat{N}^2\hat{V}(\hat{p}_g) + \hat{p}_g^2\hat{V}(\hat{N}) - \hat{V}(\hat{p}_g)\hat{V}(\hat{N}) \tag{13}$$

The Chi-squared test statistic from a contingency table was used to compare the sex ratios of chinook salmon between rivers and the Kolmogorov-Smirnov test statistic was used to compare the length compositions of just the female chinook salmon between rivers. The data were obtained from chinook salmon carcasses collected during surveys of the Salcha and Chena rivers.

The proportion of the population comprised of small (≤760 mm) and large (>760 mm) chinook salmon was estimated using abundance estimates from hourly counts of fish past the counting sites and data collected from the carcass surveys. Using abundance estimates, the proportions were estimated by:

$$\hat{p}_g = \frac{\hat{n}_g}{\hat{N}} \tag{14}$$

The associated variance was estimated using the Delta Method (explained by Seber 1982) and Goodman's formula (1960):

$$\hat{V}(\hat{p}_g) = n_g^2\left[\frac{\hat{V}(\hat{N})}{\hat{N}^4}\right] + \frac{\hat{V}(\hat{n})}{\hat{N}^2} - \hat{V}(\hat{n})\left(\frac{\hat{V}(\hat{N})}{\hat{N}^4}\right) \tag{15}$$

where:

$\hat{p}_g$ = estimated proportion of chinook salmon in the population;

g = size group of interest (i.e. small and large);

$\hat{n}_g$ = estimated abundance of chinook salmon of category g in the population; and,

$\hat{N}$ = estimated abundance of the chinook salmon population.

Using data from the carcass surveys, the proportions of small and large chinook salmon were estimated with Equations 10 and 11.

Potential Egg Production:

Fecundity of chinook salmon that returned to the Salcha River in 1993 was estimated using parameters from a linear regression model that described the relation between fecundity and length (Skaugstad and McCracken 1991). These parameters were estimated from a sample of 49 female chinook salmon collected from the Tanana River during 1989 and are designated with a subscript "o" in Equations 16 and 17. With these parameters the fecundity of chinook salmon was estimated for the smallest female in 10 mm length intervals:

$$\hat{F}_g = a_o + b_o L_g \tag{16}$$

$$\hat{V}(\hat{F}_g) = MSE_o\left\{1 + \frac{1}{n_o} + \frac{(L_g - \bar{L}_o)^2}{\sum L_{of}^2 - \left(\sum L_{of}\right)^2 / n_o}\right\} \tag{17}$$

where:

$\hat{F}_g$ = estimated fecundity of the smallest possible female in the 10 mm length interval g;

L_g = lower limit of the 10 mm length interval g;

$\bar{L}_o$ = mean length of the females from sample o (902 mm);

L_{of} = length of fish f in sample o;

n_o = size of sample o (49);

a_o = y-intercept of sample o (-7,937.5);

b_o = slope of sample o (19.97);

MSE_o = mean square error from the regression of F on L from sample o (2,656,900); and,

$\hat{V}(\hat{F}_g)$ = variance of $\hat{F}_g$.

Potential egg production of the population of chinook salmon that spawned was estimated by multiplying the estimated abundance of all females in a 10 mm length interval by the estimated fecundity of the smallest possible female in the length interval:

$$\hat{E} = \sum \hat{N}_g \hat{F}_g \tag{18}$$

$$\hat{V}(\hat{E}) = \sum \left[\hat{N}_g^2 \hat{V}(\hat{F}_g) + \hat{F}_g^2 \hat{V}(\hat{N}_g) - \hat{V}(\hat{N}_g) \hat{V}(\hat{F}_g) \right] \tag{19}$$

where:

$\hat{E}$ = potential egg production of the spawning chinook salmon population;

$V(\hat{E})$ = variance of $\hat{E}$;

$\hat{N}_g$ = estimated number of females within length interval g (Equation 12);

$\hat{V}(\hat{N}_g)$ = variance of $\hat{N}_g$ (Equation 13);

$\hat{F}_g$ = estimated fecundity for the smallest fish in length interval g (Equation 16); and,

$\hat{V}(\hat{F}_g)$ = variance of $\hat{F}_g$.(Equation 17).

Migration Time:

Chinook salmon were captured near Manley from 12 - 15 July 1993 using a fish wheel. The fish wheel was built and owned by Greg Taylor of Manley. Mr. Taylor operated the fish wheel under contract for the Alaska Department of Fish and Game.

The fish wheel's position from shore was adjusted so the rotating fish baskets came within about 15 cm from the river bottom. The clearance was checked daily with a marked spruce pole and the fish wheel's position relative to shore was adjusted to maintain the 15 cm clearance. The distance from shore to the near shore log raft varied from about 7 to 9 m. A clearance of about 15 cm was maintained so the fish wheel would not catch on the river bottom and stop rotating if the water level dropped a few centimeters while the fish wheel was unattended. Any greater clearance would allow fish to pass between the rotating basket and the river bottom. The clearance could also be adjusted by raising or lowering the fish wheel using a hand crank and pulley system. The rotation period of the fish wheel was about 22 s, but varied slightly with the water velocity. Water velocity was not measured at the fish wheel nor at any other location. Depths were not measured for a cross section of the river at the fish wheel site.

Captured fish were marked with colored surveyor's tape. Different colors (bright green, pink, and white) were used to indicate the time period when the fish were marked and released. The surveyor's tape was attached to the fish by passing it through the dorsal fin at the insertion line midway between the anterior and posterior ends of the fin. The tape was knotted next to the fish's body and the ends of the tape were left even with the posterior portion of the caudal fin. The adipose fin was removed from each fish to estimate the proportion of marks lost. All fish were measured to the nearest millimeter from mid-eye to fork-of-tail (ME-FT) and the sex determined. The average number of days to migrate from Manley to the counting sites on the Salcha and Chena rivers was calculated using formulas for the sample mean and sample variance of the mean (Zar 1984 pp. 19 and 87).

Relation of Aerial Counts to Abundance Estimates:

Personnel from the Fairbanks office of the Division of Commercial Fisheries of the Alaska Department of Fish and Game counted live and dead adult chinook salmon in the Salcha and Chena rivers during the salmon migration. Counts were made from low flying, fixed-wing aircraft. Barton (1987) described the methods used for these aerial surveys. The proportion of salmon counted by the aerial survey was calculated as:

$$\hat{p} = \frac{C}{\hat{N}} \qquad (20)$$

where:

- $\hat{p}$ = estimated proportion of chinook salmon counted by aerial survey;
- C = aerial survey count; and,
- $\hat{N}$ = estimated abundance of chinook salmon using data from counting sites (Equation 1).

Results

Water levels and turbidity in the Salcha River and Chena River were low during the project except for the final three days. Salmon counts stopped on 8 August due to poor visibility caused by high water levels and increased turbidity. For the carcass survey in the Salcha River during 3-5 August the water level and turbidity were low and visibility was good. The carcass survey in the Chena River was delayed until the following week (9-11 August) because there was a high water event which resulted in no visibility. After the water level dropped the carcasses were difficult to see because they were covered with silt and detritus.

Counts:

Chinook salmon were observed in both rivers on the first day of counting, 1 July. For the Salcha River, the highest daily estimates of abundance were on 12 and 19 July (Table 2; Figure 4). The highest daily abundance for the Chena River was on 13 August (Table 2; Figure 4). Few chinook salmon were observed during the final week, and by 1 August the estimated daily abundance was less than 50 fish in each river. Examination of the cumulative percent distributions for daily abundance indicated that the shapes of the distributions were similar for both rivers; but, migration timing past the counting sites was about 1-2 days earlier for Chena River chinook salmon (Figures 5 and 6). The difference was not significant ($P = 0.92$).

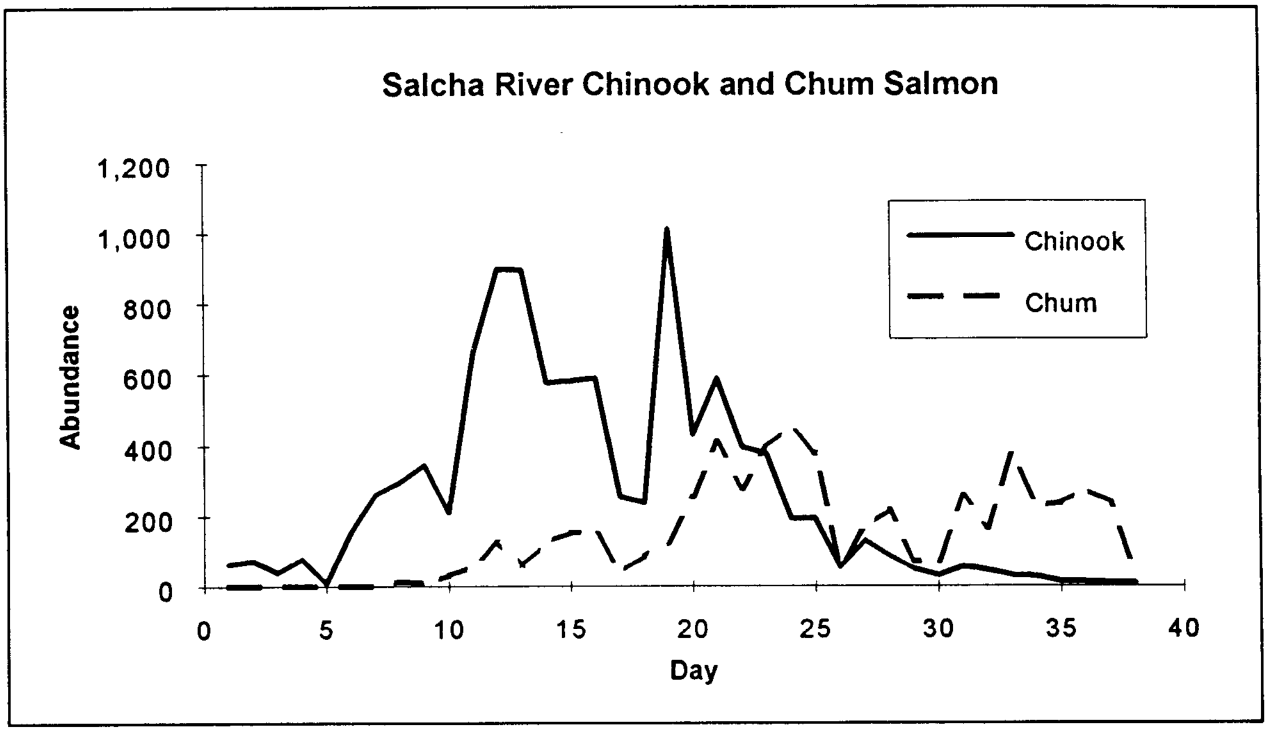
The migration timing (daily abundance) for small and large chinook salmon past the Salcha River counting site were different (Figure 5). Small chinook salmon migrated past the counting site in two spurts (11-13 July and 21-23 July) while daily abundance of large chinook salmon gradually increased then gradually decreased over time. For Chena River chinook salmon, the migration timing was similar for small and large chinook salmon; a gradual increase in daily abundance then a gradual decrease over time (Figure 6).

The highest average hourly counts for Salcha River chinook salmon migrating past the counting site occurred between 0000 h and 0800 h (Figure 7). The Chena River chinook salmon migration did not show such a pronounced difference in average hourly counts; however, counts generally were highest in the morning and lowest in the evening (Figure 7).

Chum salmon were first observed at the Salcha River counting site on 16 July and at the Chena River counting site on 14 July (Table 2; Figure 4). Daily counts of chum salmon increased after 20 July but did not reach a peak count. The daily counts decreased after 5 August as water levels and turbidity increased. Examination of the cumulative percent distributions for daily abundance indicated the timing of the migrations were virtually identical for both rivers (Figures 5 and 6). The pattern of the average hourly counts for

Table 2. Daily estimates of the number of chinook and chum salmon that passed the counting sites on the Salcha River and Chena River.

	Salcha River				Chena River			
	Chinook Salmon			Chum	Chinook Salmon			Chum
Date	Total	Large	Small	Salmon	Total	Large	Small	Salmon
Jul 1	63	63	0	0	81	81	0	0
2	36	9	27	0	78	63	15	0
3	41	41	0	0	194	180	14	0
4	78	78	0	0	77	72	5	0
5	27	27	0	0	405	401	5	0
6	158	149	9	0	224	175	49	9
7	264	246	18	0	432	333	99	9
8	300	282	18	15	243	174	69	6
9	342	311	32	9	297	239	59	0
10	212	203	9	32	612	536	77	9
11	663	399	264	57	828	588	240	105
12	900	558	342	126	1,013	761	252	72
13	896	635	261	68	1,157	936	221	158
14	636	567	69	126	900	729	171	84
15	582	579	3	153	867	696	171	90
16	576	576	0	162	882	765	117	149
17	257	257	0	41	248	216	32	90
18	240	234	6	87	651	495	156	111
19	1,013	986	27	126	338	225	113	113
20	432	432	0	257	792	513	279	90
21	588	483	105	411	492	369	123	255
22	396	306	90	279	339	264	75	426
23	378	270	108	396	312	213	99	462
24	195	195	0	453	145	87	58	261
25	194	189	5	378	95	59	36	178
26	50	50	0	54	95	59	36	320
27	131	131	0	167	131	95	36	270
28	87	72	15	198	75	57	18	315
29	50	50	0	72	57	33	24	153
30	32	32	0	68	51	36	15	180
31	57	57	0	288	14	9	5	144
Aug 1	45	45	0	167	27	23	5	194
2	38	38	0	404	32	32	0	185
3	27	27	0	230	18	18	0	108
4	14	14	0	239	9	5	5	230
5	15	15	0	309	18	18	0	351
6	0	0	0	222	9	6	3	240
7	0	0	0	153	9	9	0	36
8	0	0	0	68				



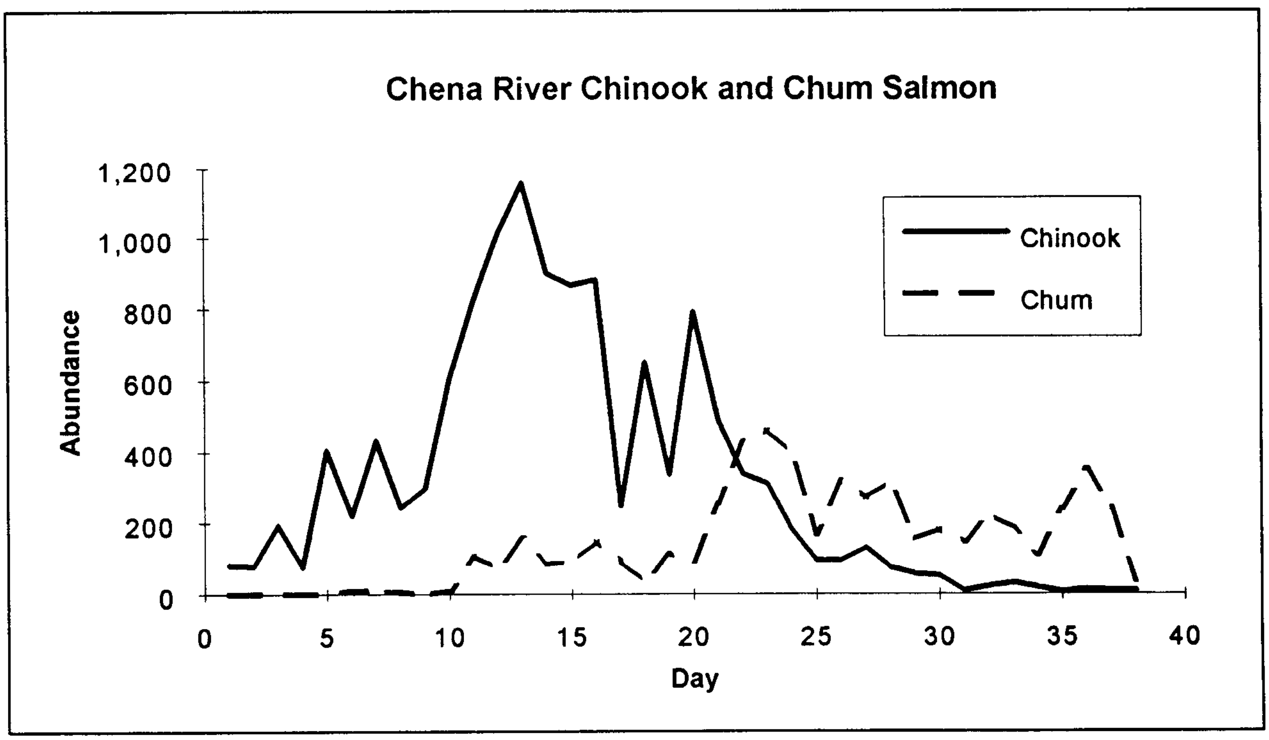
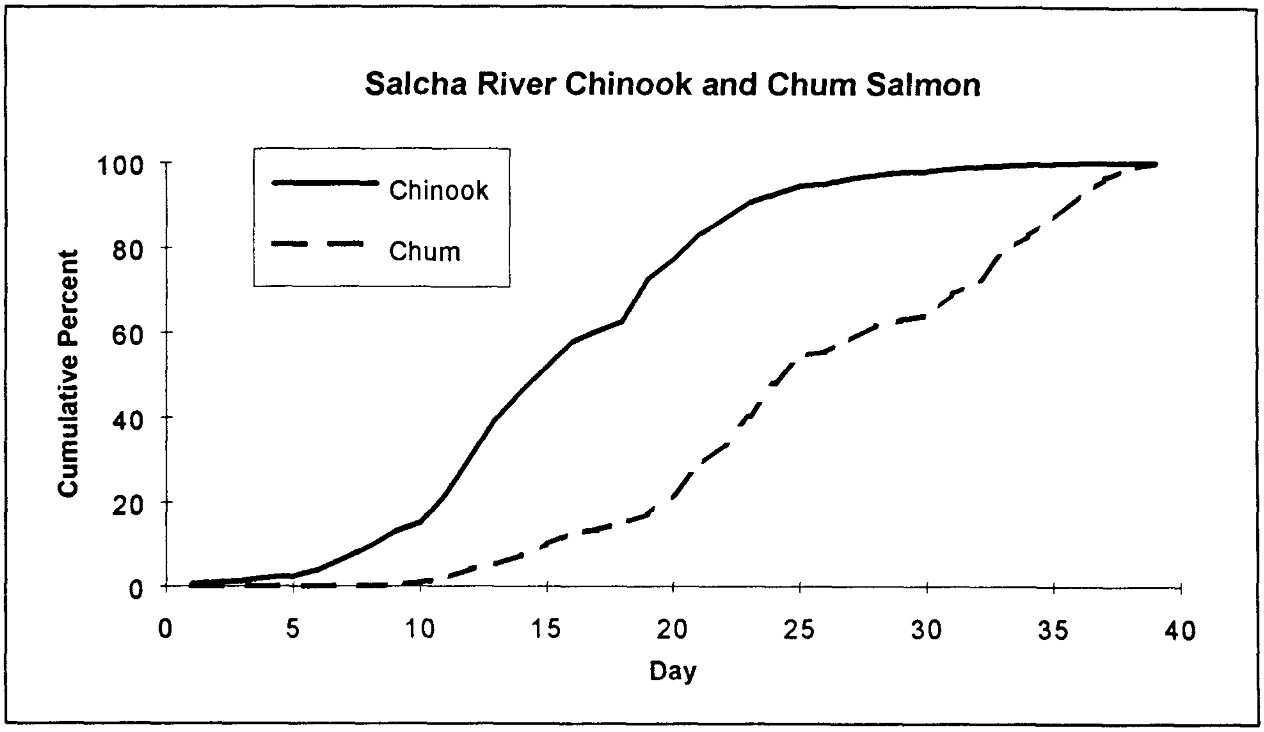


Figure 4. Daily estimates of abundance for adult chinook and chum salmon past the counting sites on the Salcha River and Chena River, 1993.



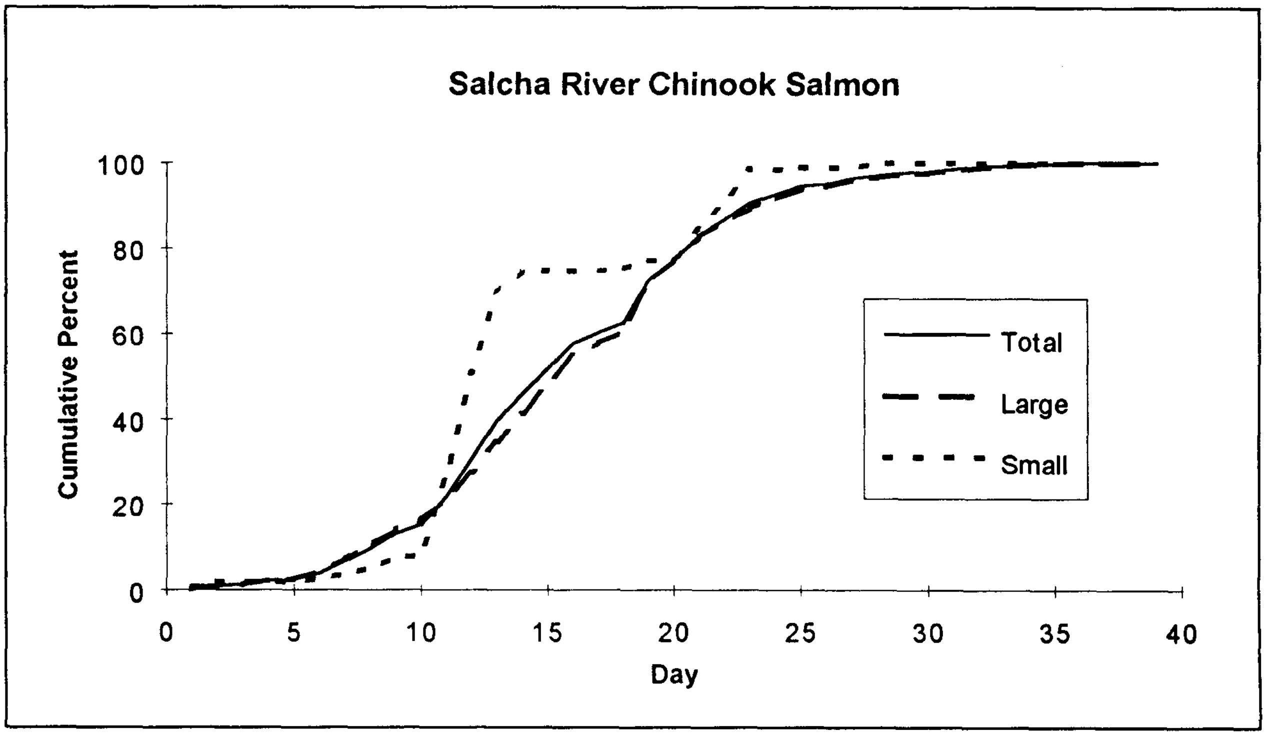


Figure 5. Cumulative relative frequency of daily estimates of abundance for chinook and chum salmon, Salcha River, 1993. Large fish were greater than 760 mm and small fish were equal to or less than 760 mm ME-FT.

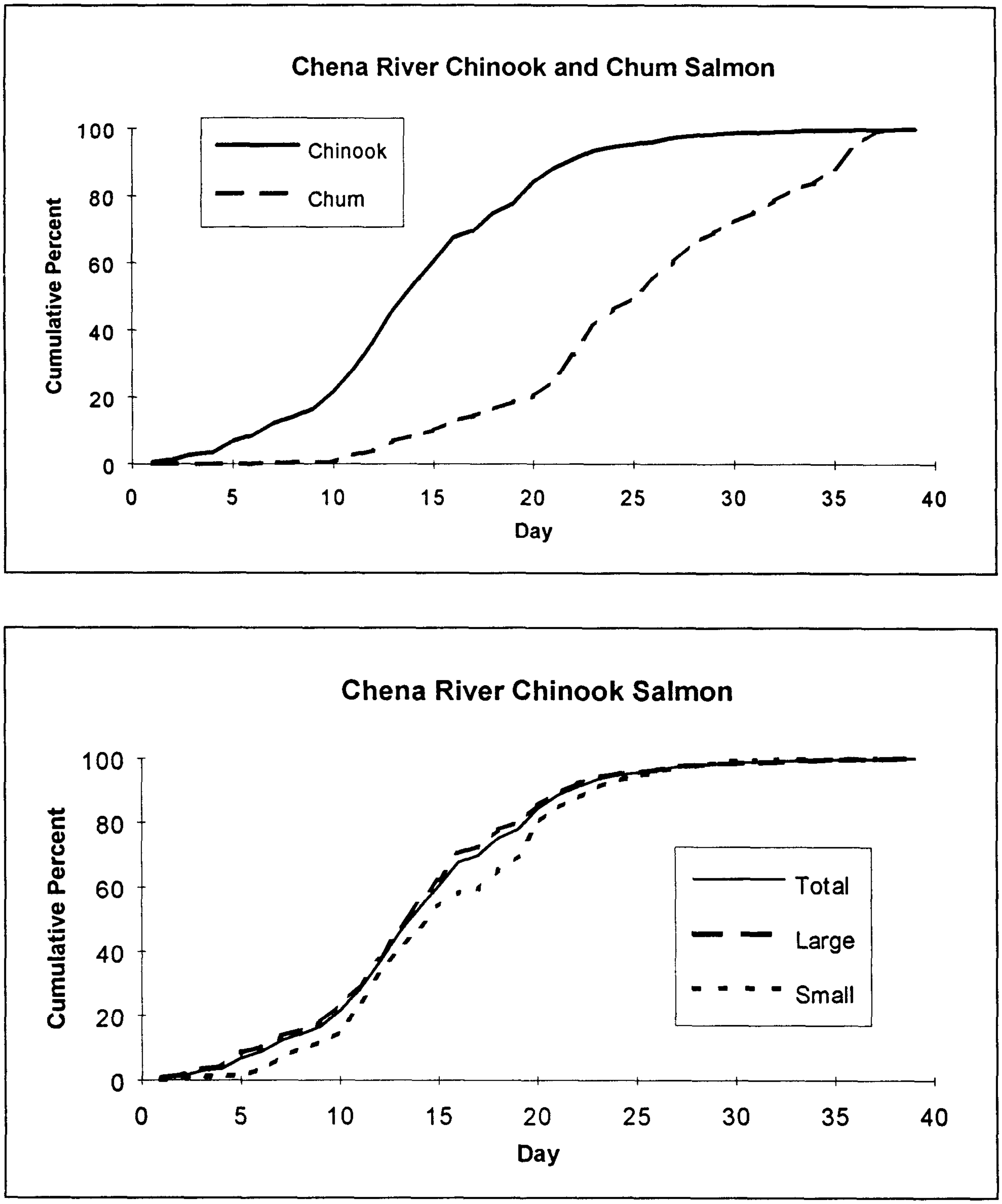
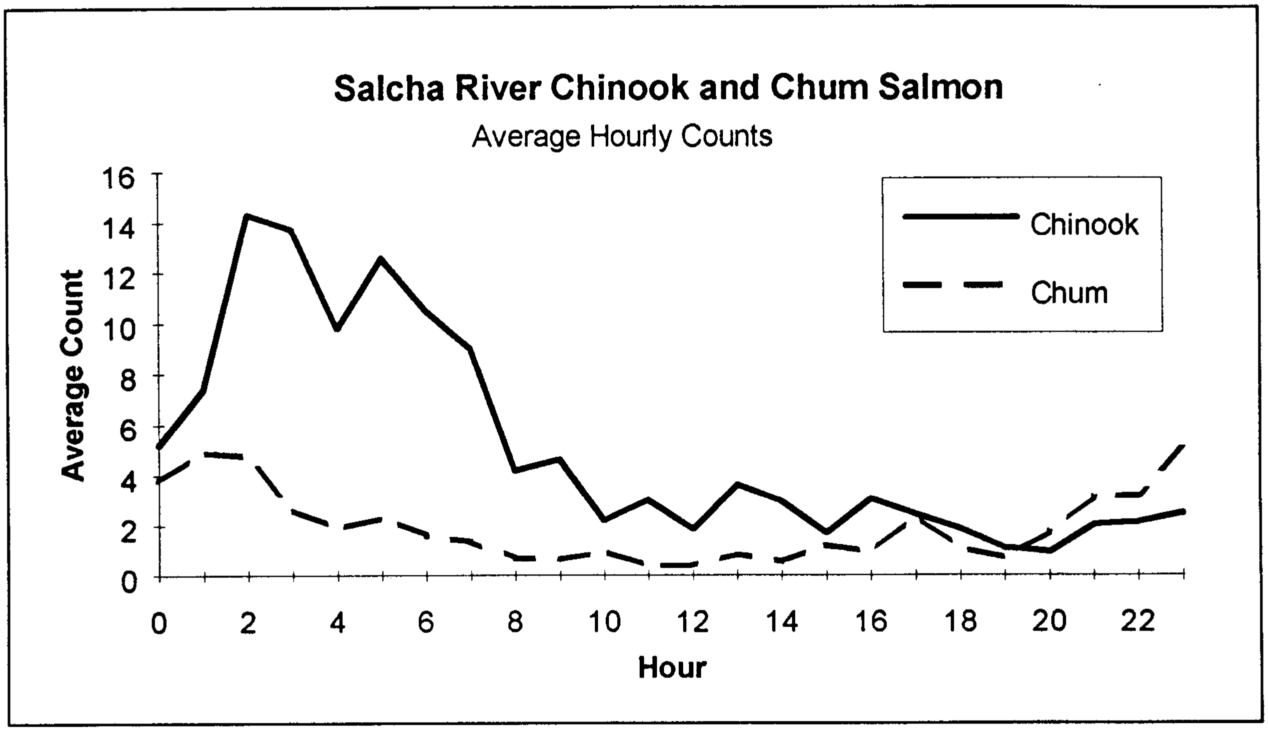


Figure 6. Cumulative relative frequency of daily estimates of abundance for chinook and chum salmon, Chena River, 1993. Large fish were greater than 760 mm and small fish were equal to or less than 760 mm ME-FT.



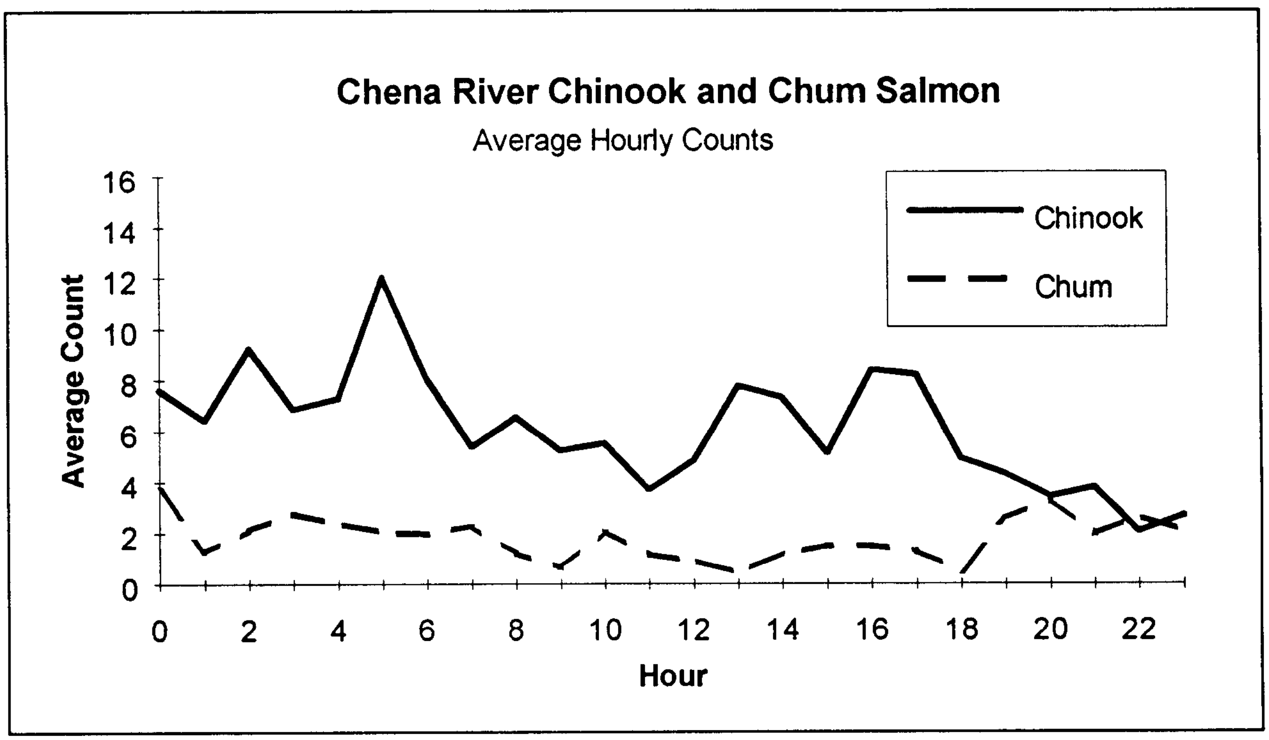


Figure 7. Average hourly counts of adult chinook and chum salmon past the counting sites during 24 h. periods on the Salcha River and Chena River, 1993.

chum salmon migrating past the counting sites was similar to those for chinook salmon in the same river (Figure 7).

Abundance Estimate:

The estimated abundance of chinook salmon moving past the counting site in the Salcha River was 10,007 (SE = 360; Table 3). The estimated abundances of small and large chinook salmon were 1,407 (SE = 110) and 8,600 (SE = 332; Table 3). The estimated abundance of chinook salmon in the Chena River was 12,241 (SE = 387; Table 3). The estimated abundances of small and large chinook salmon were 2,676 (SE = 114) and 9,565 (SE = 320; Table 3).

The estimated abundance of chum salmon in the Salcha River was 5,809 (SE = 250; Table 3) and in the Chena River was 5,400 (SE = 248; Table 3).

Carcass Surveys and Age-Sex-Length Compositions:

Salcha River. Six-hundred chinook salmon carcasses were collected from the Salcha River. Of these, 418 were male, 150 were female, and sex was not determined for 32 chinook salmon (Table 4). The sex composition (and abundance) was 74% male (7,246; SE = 335) and 26% female (2,761; SE = 233; Table 4).

Age was estimated for 328 males, 125 females, and 27 chinook salmon for which sex was undetermined. In the carcass sample males were either age 1.2 (27.8%) or 1.3 (32.9%) while most females were age 1.4 (20.3%; Table 5).

Lengths were obtained for 599 of the 600 carcasses. Lengths of males ranged from 420 to 1,000 mm (Table 6; Figures 8 and 9). Most males (71%) were less than 750 mm. Length of females ranged from 530 to 980 mm (Table 6; Figures 8 and 9). Most females (92%) were 750 mm or larger.

The proportions of small and large chinook salmon were 0.14 (SE = 0.012) and 0.86 (SE = 0.045) using estimates of abundance (Table 7). In contrast, the proportions of small and large chinook salmon were 0.60 (SE = 0.020) and 0.40 (SE = 0.020) using data from the carcass surveys (Table 7).

Of the 150 female carcasses collected, 140 were examined for egg retention. Ten carcasses were too decomposed to make a reliable estimate. One-hundred seven carcasses either contained no eggs or the quantity of eggs remaining in the carcasses was less than 10% of the estimated fecundity based on the length (ME-FT) of the carcasses. The quantity of eggs remaining in twelve carcasses ranged from 11 to 25%, nine carcasses ranged from 26 to 50%, six carcasses ranged from 51 to 75%, and six carcasses ranged from 76 to 100% (Table 8).

Chena River. Two-hundred forty-five chinook salmon carcasses were collected from the Chena River. Of these, 205 were male, 38 were female, and sex was not determined for two chinook salmon (Table 4). The sex composition (and abundance) was 84% male (10,212; SE = 464) and 16% female (2,029; SE = 340; Table 4).

Table 3. Estimates of abundance of adult chinook and chum salmon in the Salcha River and Chena River, 1993.

River	Species (size)	N	SE[N]	L95%CI	U95%CI	RP[a]
Salcha:	Chinook (≤760 mm)	1,407	110	1,191	1,623	15.3
	Chinook (>760 mm)	8,600	332	7,949	9,251	7.5
	Total	**10,007**	**360**	**9,302**	**10,712**	**7.0**
	Chum	5,809	250	5,318	6,300	8.4
Chena:	Chinook (≤760 mm)	2,676	114	2,453	2,900	8.4
	Chinook (>760 mm)	9,565	320	8,939	10,192	6.5
	Total	**12,241**	**387**	**11,483**	**13,001**	**6.2**
	Chum	5,400	248	4,913	5,887	9.0

[a] Relative precision.

Table 4. Numbers of male and female chinook salmon collected during carcass surveys and estimated sex compositions for the Salcha River and Chena River chinook salmon populations.

	Salcha River	Chena River	Total	Proportion	
				Salcha River	Chena River
Male	418	205	623	0.74	0.84
Female	150	38	188	0.26	0.16
Total:	568	243	811	1.00	1.00

Results of the above contingency table comparing the proportions of male and female chinook salmon carcass collected during surveys of the Salcha River and Chena River.

χ^2	df	P-value	Power (α=0.05)
11.1	1	0.0009	0.93

Table 5. Estimates of age composition of adult chinook salmon in the Salcha River, 1993.

		Brood Year and Age Group						
	Sampling Dates:	1990	1989	1988	1987	1986		
	3 Aug - 5 Aug 1993	1.1	1.2	1.3	1.4	2.3	1.5	Total
Female	Sample Size	0	1	28	92	0	4	125
	Percent of Sample	0.0	0.2	6.2	20.3	0.0	0.9	27.6
Male	Sample Size	4	126	149	48	1	0	328
	Percent of Sample	0.9	27.8	32.9	10.6	0.2	0.0	72.4
Total	Sample Size	4	127	177	140	1	4	453
	Percent of Sample	0.9	28.0	39.0	30.9	0.2	0.9	100.0
	Relative Error	0.4	2.1	2.3	2.2	0.2	0.4	

Table 6. Statistics by age and sex for chinook salmon carcasses collected from the Salcha and Chena rivers, 1993.

	Brood Year and Age[a] Group				
	1990	1989	1988	1987	1986
River - Sex:	1.1	1.2	1.3	1.4	1.5
Salcha River - Males:					
Count	4	126	150	48	
Minimum Length (mm)	420	430	460	440	
Maximum Length (mm)	590	800	920	980	
Mean	503	560	711	845	
Standard Error	35	6	6	14	
Upper 95% Confidence Limit	571	572	723	872	
Lower 95% Confidence Limit	434	547	700	817	
Salcha River - Females:					
Count		1	28	92	4
Minimum Length (mm)			670	750	840
Maximum Length (mm)			920	980	970
Mean		660	781	858	918
Standard Error			12	5	28
Upper 95% Confidence Limit			805	868	972
Lower 95% Confidence Limit			758	848	863
Chena River - Males:					
Count	1	55	69	29	1
Minimum Length (mm)		395	520	515	
Maximum Length (mm)		925	870	1010	
Mean	495	591	698	788	680
Standard Error		14	8	21	
Upper 95% Confidence Limit		619	714	829	
Lower 95% Confidence Limit		564	682	747	
Chena River - Females:					
Count			8	22	1
Minimum Length (mm)			695	750	
Maximum Length (mm)			1005	935	
Mean			834	846	945
Standard Error			37	10	
Upper 95% Confidence Limit			906	866	
Lower 95% Confidence Limit			762	826	

[a] Each age class is made up of fish that spent one or two years in the rivers as juveniles before migrating to the ocean (*i.e.* age 1.2 includes both age 1.2 and age 2.2).

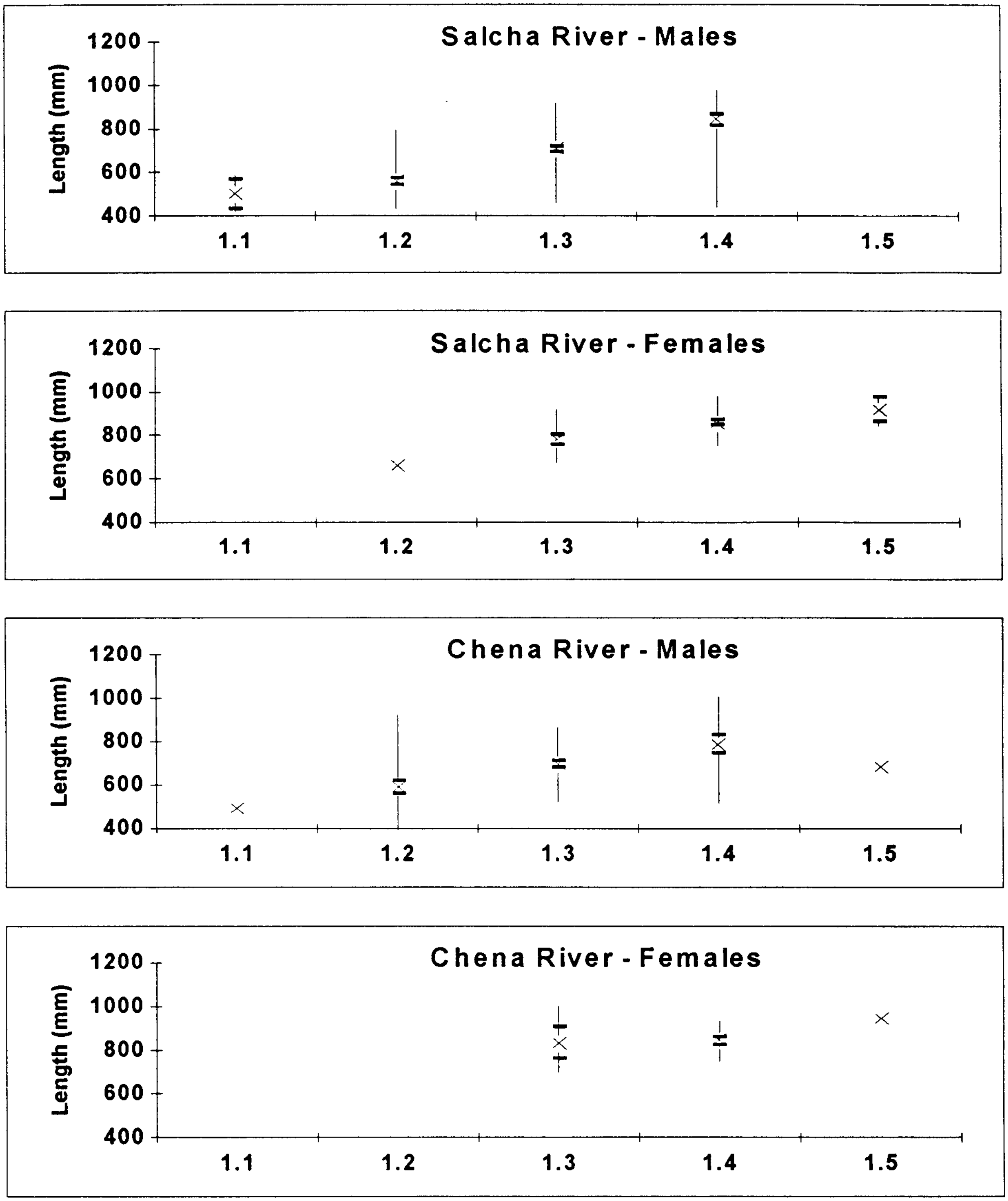


Figure 8. Length statistics by age and sex for chinook salmon carcasses collected from the Salcha River and Chena River, 1993. Vertical lines represent the range of lengths, X represents the means, and the horizontal lines are the upper and lower 95% confidence limits of the means.

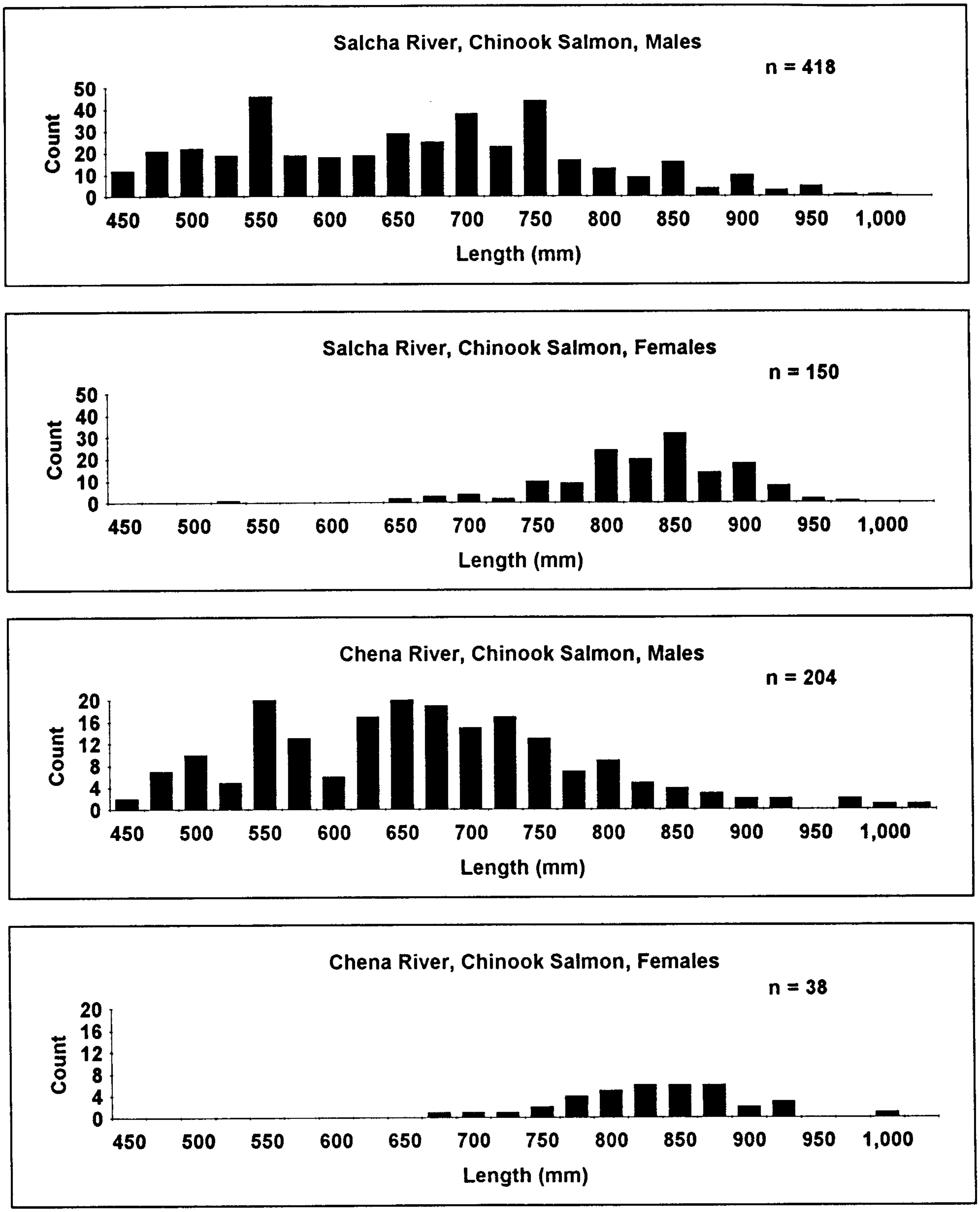


Figure 9. Length frequency of chinook salmon carcasses collected from the Salcha River and Chena River, 1993.

Table 7. Comparison of the estimated proportions of small (≤760 mm) and large (>760 mm) chinook salmon using abundance estimated by hourly counts of salmon passing counting sites and carcass surveys.

		Proportions Estimated from Abundance Estimates				Proportions Estimated from Carcass Survey		
River	Species (size)	$\hat{N}$[a]	SE[$\hat{N}$][b]	$\hat{p}$[c]	SE[$\hat{p}$][d]	Count[e]	$\hat{p}$[f]	SE[$\hat{p}$][g]
Salcha:	Chinook (≤760 mm)	1,407	110	0.14	0.012	359	0.60	0.020
	Chinook (>760 mm)	8,600	332	0.86	0.045	240	0.40	0.020
	Total	10,007	360			599		
Chena:	Chinook (≤760 mm)	2,676	114	0.22	0.012	170	0.70	0.030
	Chinook (>760 mm)	9,565	320	0.78	0.036	74	0.30	0.030
	Total	12,241	387			244		

[a] The abundance of chinook salmon was estimated from hourly counts of salmon passing counting sites.

[b] The standard error of the abundance estimate.

[c] The estimated proportion of the population comprised of small or large chinook salmon using estimates of abundance.

[d] The standard error of the estimated proportion using the estimated abundance.

[e] The number of small or large chinook salmon carcasses collected during the carcass survey.

[f] The estimated proportion of the population comprised of small or large chinook salmon using data from the carcass surveys.

[g] The standard error of the estimated proportions using data from the carcass surveys.

Table 8. Proportion of eggs remaining in chinook salmon carcasses in the Salcha River and Chena River, 1993.

River	0-10%	11-25%	26-50%	51-75%	76-100%
Salcha	107	12	9	6	6
Chena	9	2	1	0	0

Age was estimated for 156 males, 31 females, and 1 chinook salmon for which sex was undetermined. In the carcass sample males were either age 1.2 (29.4%) or 1.3 (36.9%) while most females were age 1.4 (11.8%; Table 9).

Lengths were obtained for 244 of the 245 carcasses. Length of males ranged from 395 to 1,025 mm (Table 6; Figures 8 and 9). Most males (76%) were less than 750 mm. Length of females ranged from 695 to 1,005 mm (Table 6; Figures 8 and 9). Most females (92%) were 750 mm or larger.

The proportions of small and large chinook salmon were 0.22 (SE = 0.012) and 0.78 (SE = 0.036) using estimates of abundance (Table 7). In contrast, using data from the carcass surveys the proportions of small and large chinook salmon were 0.70 (SE = 0.030) and 0.30 (SE = 0.030; Table 7).

Of the 38 female carcasses collected, 12 were examined for egg retention (Table 8). Twenty-six carcasses were too decomposed to make a reliable estimate. Nine carcasses either contained no eggs or the quantity of eggs remaining in the carcasses was less than 10% of the estimated fecundity based on the length (ME-FT) of the carcasses. The quantity of eggs remaining in two carcasses ranged from 11 to 25%, and one carcass ranged from 26 to 50%.

A high water event occurred in the Chena River before the carcass survey. During the survey the water level was normal, but most of the salmon carcasses were partially or completely covered by silt and detritus. The sex compositions were different for the samples of carcasses collected in the Salcha River and Chena River (P = 0.0009; Table 4). However, the length compositions of the samples of female carcasses were not different between the Salcha River and Chena River (P = 0.89; Figure 10).

Potential Egg Production:

For the Salcha River, the estimated egg production of the spawning population of chinook salmon was 23 million eggs (SE = 2.1 million) based on the length-fecundity relation (Table 10) or 25 million eggs (SE = 4.9 million) based on the age-fecundity relation (Skaugstad and McCracken 1991). Only female chinook salmon having length data were used to estimate egg production. As a result, the estimated abundance of females in the population was different from the abundance estimated with sex composition data. The fecundity of the Chena River chinook population was not estimated because too few female carcasses were collected to make a reliable estimate. Estimates of potential egg production for the chinook salmon populations in the Salcha and Chena rivers are summarized in Table 11.

Migration Time:

Four-hundred thirteen chinook salmon were captured at the fish wheel located on the Tanana River below Manley (Table 12). Of these 403 were marked and released. Few large fish were captured in the fish wheel and only 14 of the 413 chinook salmon were female (Figure 11). The first marked fish was observed at the Chena River counting site on 20 July and seven others were seen from 23 July through 2 August (Table 13). There were six green and two

Table 9. Estimates of age composition of adult chinook salmon in the Chena River, 1993.

		Brood Year and Age Group					
	Sampling Dates:	1990	1989	1988	1987	1986	
	9 Aug - 11 Aug 1993	1.1	1.2	1.3	1.4	1.5	Total
Female:	Sample Size	0	0	8	22	1	31
	Percent of Sample	0.0	0.0	4.3	11.8	0.5	16.6
Male:	Sample Size	1	55	69	30	1	156
	Percent of Sample	0.5	29.4	36.9	16.0	0.5	83.4
Total:	Sample Size	1	55	77	52	2	187
	Percent of Sample	0.5	29.4	41.2	27.8	1.1	100.0
	Relative Error	0.5	3.3	3.6	3.3	0.8	

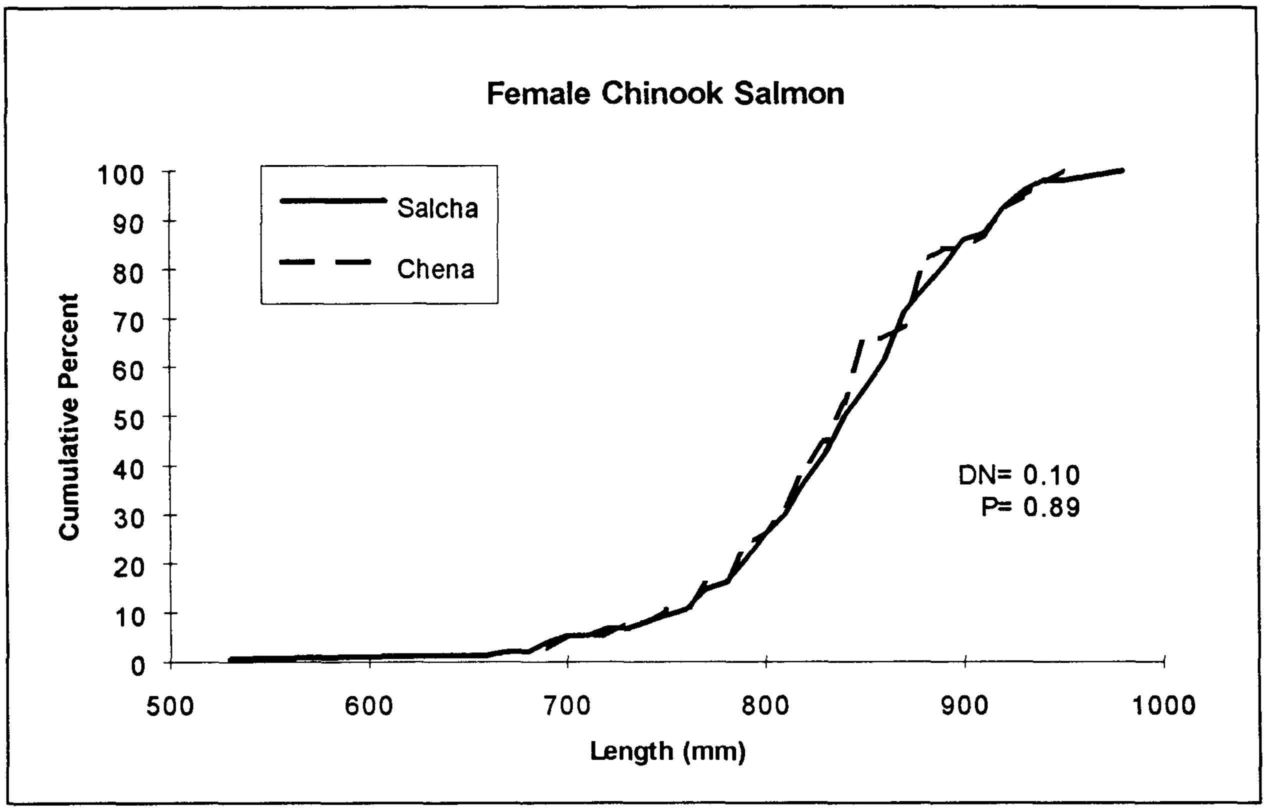


Figure 10. Cumulative length frequencies of female chinook salmon collected during carcass surveys in the Salcha River and Chena River, 1993.

Table 10. Estimated potential egg production of the chinook salmon population in the Salcha River, 1993.

Length (mm)	Sample Size n	Estimated Number of Fish $\hat{N}$	$SE(\hat{N})$	Estimated Number of Eggs $\hat{E}$	$SE(\hat{E})$
530	1	18	18	46,623	46,623
660	1	18	18	92,359	92,359
670	1	18	18	95,878	95,878
680	0	--[a]	--	--	--
690	3	53	31	308,742	193,645
700	2	35	25	212,864	156,657
710	0	--	--	--	--
720	2	35	25	226,937	166,116
730	0	--	--	--	--
740	2	35	25	241,010	175,642
750	2	35	25	248,046	180,426
760	2	35	25	255,083	185,222
770	6	106	43	786,357	359,776
780	2	35	25	269,155	194,851
790	7	123	47	966,672	412,132
800	8	141	50	1,132,913	456,703
810	6	106	43	870,794	389,878
820	10	176	56	1,486,505	545,335
830	8	141	50	1,217,350	482,225
840	12	211	61	1,868,243	633,894
850	8	141	50	1,273,641	499,649
860	9	159	53	1,464,510	546,231
870	15	264	68	2,493,623	767,590
880	7	123	47	1,188,318	486,391
890	7	123	47	1,212,946	494,938
900	8	141	50	1,414,369	544,412
910	2	35	25	360,629	258,225
920	8	141	50	1,470,660	562,730
930	5	88	39	936,754	438,238
940	3	53	31	572,607	338,031
950	0	--	--	--	--
960	1	18	18	197,905	197,905
970	1	18	18	201,424	201,424
980	1	18	18	204,942	204,942
Totals	150	2,643		23,317,860	2,136,205

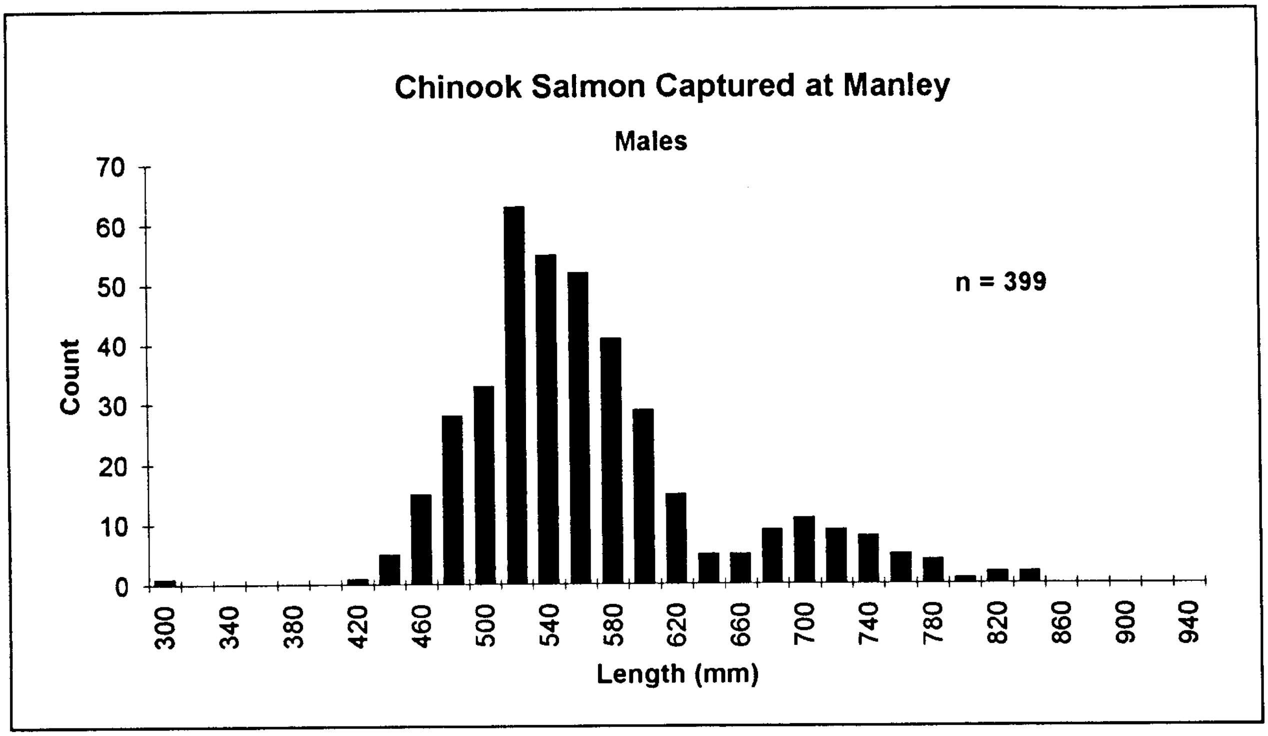
[a] Estimates of the number of chinook salmon and egg production could not be made because no carcasses were collected for these length categories.

Table 11. Estimated potential egg production of chinook salmon in the Salcha River and Chena River, 1986-1993.

River: Year	Estimated Abundance: Population	(SE)	Females	(SE)	Estimated Production (millions): Eggs	(SE)
Salcha:						
1987	4,771	504	2,481	349	25.9	3.2
1988	4,562	556	1,525	197	16.2	2.8
1989	3,294	630	1,704	484	16.6	1.8
1990	10,728	1,405	5,322	735	52.0	2.7
1991	5,608	644	2,522	197	23.0	1.7
1992	7,862	975	2,842	373	27.2	2.1
1993	10,007	360	2,761	233	23.0	2.1
Chena:						
1986	9,065	1,080	2,301	538	NA	NA
1987	6,404	557	3,501	416	NA	NA
1988	3,346	556	NA	NA	NA	NA
1989	2,666	249	1,039	145	9.8	0.8
1990	5,603	1,164	2,633	564	24.7	1.4
1991	3,025	282	954	99	8.5	0.6
1992	5,230	478	1,607	162	14.9	1.1
1993	12,241	387	3,233	249		

Table 12. Number of migrating chinook salmon captured and marked at Manley, 1993.

Date	Catch	Tape Color	Killed	Marked & Released
12 July	110	Green	0	110
13 July	95	Green	2	93
13 July	21	Pink	2	19
14 July	103	Pink	4	99
15 July	84	White	2	82
Total	413		10	403



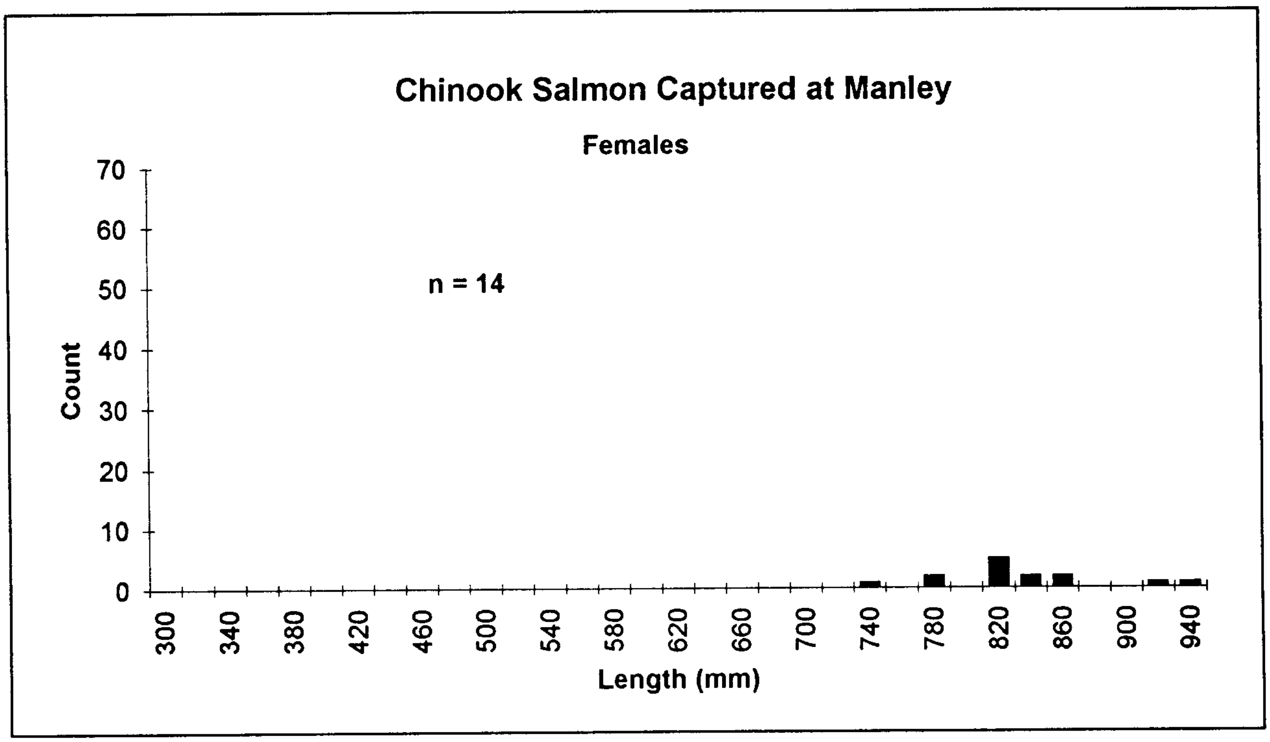


Figure 11. Length frequency of adult chinook salmon captured in a fish wheel on the Tanana River near Manley, 1993.

Table 13. Location, date, and number of marked chinook salmon captured in the commercial, subsistence, and personal use fisheries and numbers observed at the counting sites, 1993.

Count	Color	Date	Location
3	Green	16-17 July	Nenana
3	Green	19-20 July	Nenana
1	Pink	19-20 July	Nenana
2	White	19-20 July	Nenana
1	Pink	19-21 July	Nenana
1	White	19-21 July	Nenana
1	Green	20 July	Chena Pump Campground
1	White	20 July	Chena Pump Campground
1	Pink	20 July	Swan Neck Slough/Tolavana R.
1	White	20 July	Swan Neck Slough/Tolavana R.
1	Green	20 July	Chena R. Dam
2	Green	20-21 July	Chena Pump Campground
1	Pink	20-21 July	Chena Pump Campground
1	Green	23 July	Chena R. Dam
1	Pink	23 July	Chena R. Dam
1	Pink	23-24 July	Nenana
1	Pink	24 July	Salcha R. Bridge
1	Green	25 July	Salcha R. Bridge
3	Green	25 July	Chena R. Dam
1	Green	25 July	Chena R. Dam
1	Pink	2 August	Chena R. Dam
Total 29			

pink flags. Average travel time was about 11 days (SE = 3.5; Table 14). At the Salcha River counting site a pink flag was seen on 24 July and a green flag was seen on 25 July. Average travel time was about 11 days SE = 1.4; Table 14).

In addition to the marked chinook salmon that were observed passing the counting sites, 29 marked chinook salmon also were recovered in the commercial, subsistence, and personal use fisheries in the Tanana River and its tributaries (Table 13). No marked chinook salmon carcasses were found, nor were live marked chinook salmon observed during carcass surveys in August.

Relation of Aerial Counts to Abundance Estimates:

During aerial surveys on 25 July, 3,636 chinook salmon were counted in the Salcha River and 2,943 were counted in the Chena River (Table 15). These aerial counts were about 36% and 24% of the respective abundance estimates. Both surveys were rated "fair". Since 1986, the proportion of the population observed during aerial surveys ranged from 0.19 to 0.71 for the Salcha River (Skaugstad 1993) and 0.16 to 0.59 for the Chena River (Evenson 1993; Table 15 and Figure 12).

Discussion

In 1993 this project provided the Division of Sport Fish with current data to regulate the sport fishery during the sport fishing season. Using data from this project, the daily bag limit for chinook salmon in the Salcha and Chena rivers was increased from one to two fish when fishery managers realized that the escapement goals would be achieved. In previous years mark-recapture experiments did not provide timely data to regulate the sport fishery during the fishing season.

The abundance estimator provided estimates of abundance for the chinook salmon escapements in both rivers that were within the bounds specified by the objective. The variances associated with the estimates of abundance from counting migrating salmon was less than half the variances associated with estimates of abundance from previous mark-recapture experiments on Salcha River and Chena River chinook salmon populations (Burkholder 1991; Evenson 1991, 1992, 1993; Skaugstad 1988, 1989, 1990a, 1990b, 1992, 1993). If wider bounds are acceptable (25% instead of 10%) then fewer counts are needed. Wider bounds also would allow more missed counts due to poor visibility during high water events. In previous years, one or two high water events are usual during July but none occurred this year until August.

In 1993, the estimated abundances of chinook salmon in the Salcha River was the second highest recorded, and, in the Chena River was more than twice any estimate since 1987. The abundance estimates in 1993 probably were high because more chinook salmon returned to the Salcha River and Chena River and in 1993 a different method was used to estimate abundance. Observations of the numbers of live and dead chinook salmon during carcass surveys indicated that the population abundance in the Salcha River was probably larger than the population abundances in most other years. The high abundance estimate of

Table 14. Migration time of adult chinook salmon from Manley to the counting sites on the Salcha River and the Chena River, 1993.

River: Color	Date Released	Date Observed	Difference in Days
Chena			
Green	13-Jul-93	20-Jul-93	7
Green	13-Jul-93	23-Jul-93	10
Green	13-Jul-93	25-Jul-93	12
Green	13-Jul-93	25-Jul-93	12
Green	13-Jul-93	25-Jul-93	12
Green	13-Jul-93	25-Jul-93	12
Pink	14-Jul-93	23-Jul-93	9
Pink	14-Jul-93	2-Aug-93	19
		Mean	11.6
		SE	3.5
Salcha			
Pink	14-Jul-93	24-Jul-93	10
Green	13-Jul-93	25-Jul-93	12
		Mean	11.0
		SE	1.4

Table 15. Estimated abundance, highest counts during aerial surveys, aerial survey conditions, and proportion of the population observed during aerial surveys for chinook salmon escapement in the Salcha (1987-1993) and Chena (1986-1993) rivers.

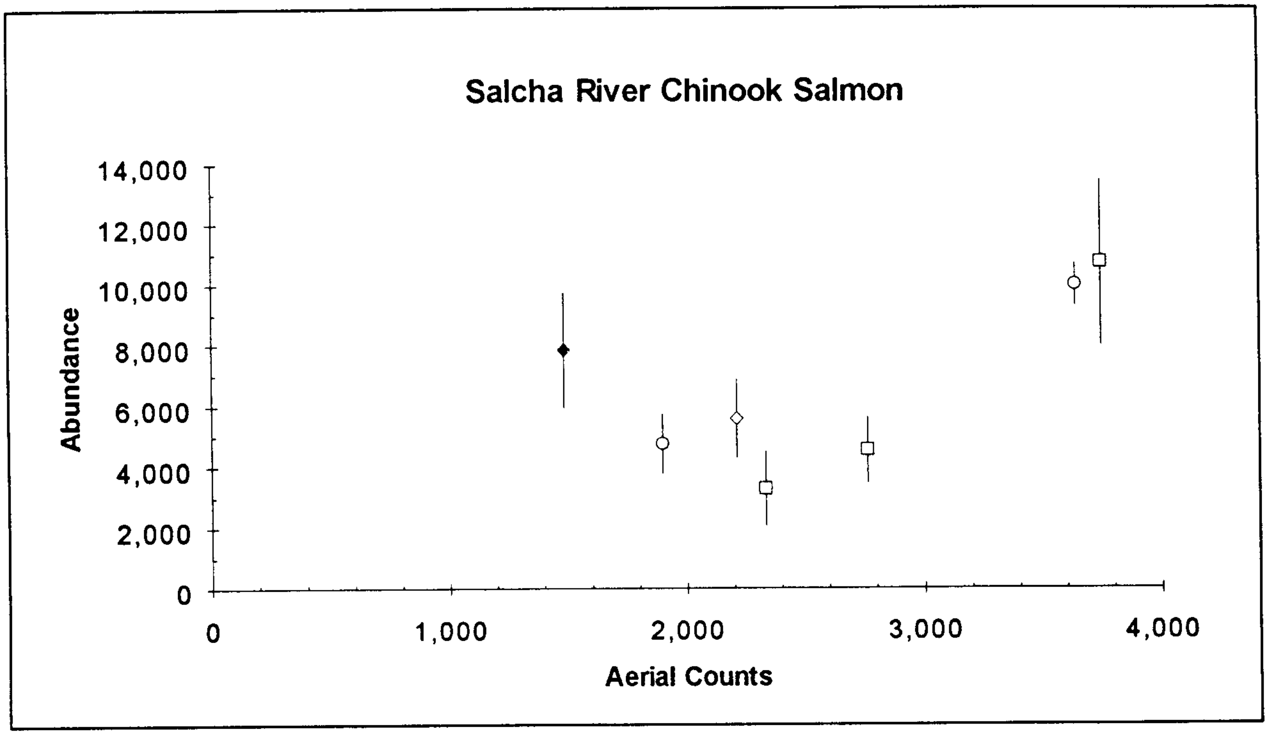
River Year	Estimated Abundance	SE	Aerial Survey Count	Aerial Survey Condition	Proportion of population Observed for Aerial Survey
Salcha:					
1987	4,771	504	1,898	Fair	0.40
1988	4,562	556	2,761	Good	0.61
1989	3,294	630	2,333	Good	0.71
1990	10,728	1,404	3,744	Good	0.35
1991	5,608	664	2,212	Poor	0.39[b]
1992	7,862	975	1,484	Fair-Poor[c]	0.19
1993	10,007	360	3,636	Fair	0.36
Chena:					
1986	9,065	1,080	2,031	Fair	0.22
1987	6,404	557	1,312	Fair	0.20
1988	3,346[d]	556	1,966	Fair-Poor[c]	0.59
1989	2,666	249	1,180	Fair-Good[c]	0.44
1990	5,603	1,164	1,436	Fair-Poor[c]	0.26
1991	3,025	282	1,276	Poor	0.42
1992	5,230	478	825	Fair-Poor[c]	0.16
1993	12,241	387	2,943	Fair	0.24

[a] During these surveys, conditions were judged on a scale of "poor, fair, good, excellent".

[b] Aerial survey was made a few days before spawning peaked.

[c] During these surveys, conditions were judged to vary by area on a scale of "poor, fair, and good".

[d] Original estimate was 3,045 (SE = 561) for a portion of the river. The estimate was expanded based on the distribution of spawners observed during an aerial survey.



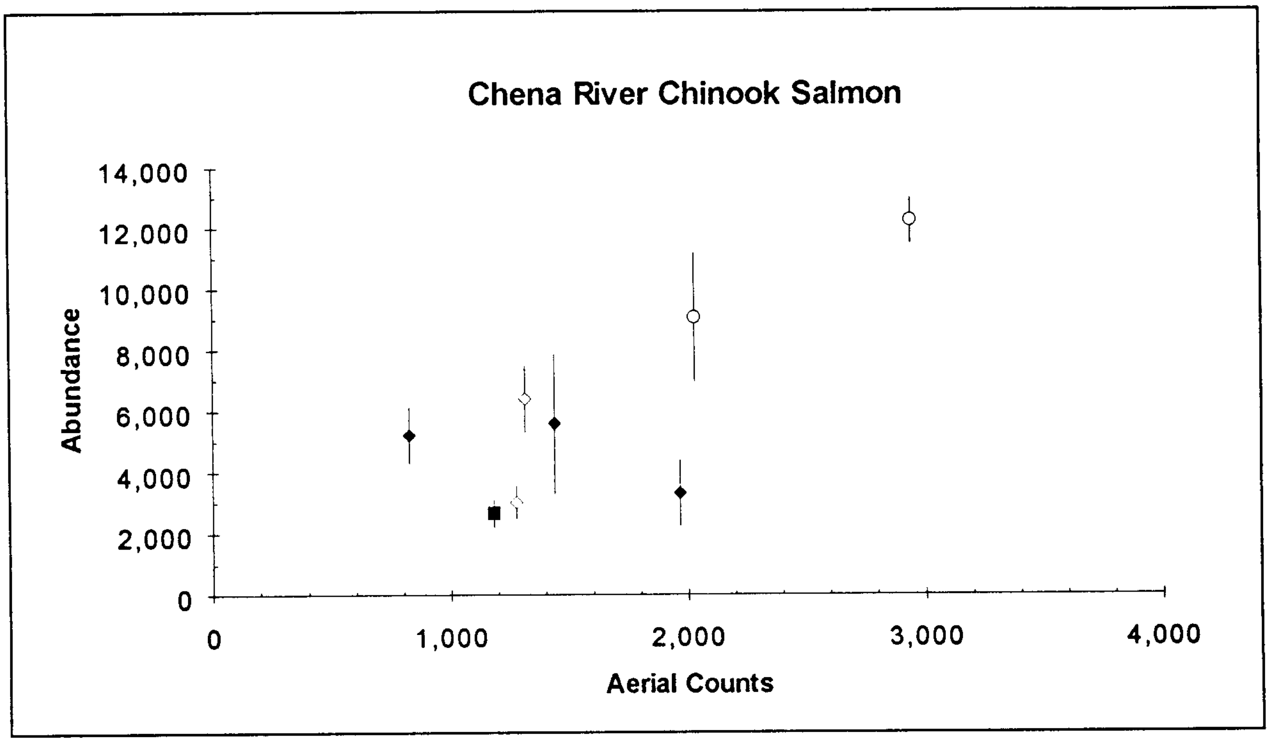


Figure 12. Counts from aerial surveys and estimated abundance of spawning chinook salmon in the Salcha River (1987-1993) and Chena River (1986-1993). Point estimates with survey conditions: good (□), fair (○), poor (✧), good-fair (■), and fair-poor (◆). Vertical lines are 95% confidence intervals.

chinook salmon in the Salcha River in 1993 agreed with the observations. However, in the Chena River observations of the numbers of live and dead chinook salmon during carcass surveys were less than numbers of fish observed in most other years. This was probably the result of the flood event prior to the carcass survey. An unknown portion of the carcasses may have been washed from the survey area during the flood event and the carcasses that remained in the survey area were covered with silt making them harder to detect.

The method used in 1993 to estimate abundances of chinook salmon in the Salcha River and Chena River may have contributed to larger estimates of abundance. In 1993, sampling occurred over the entire population for each river (fish were counted as they passed a fixed site from the beginning of the migration to its end). In contrast, the mark-recapture experiments used to estimate abundances prior to 1993 probably did not sample over all the population for a given year. The mark-recapture experiments only estimated the abundance of chinook salmon over a portion of the river where most of the fish spawned and when most, but not all the population was present. The portion of the Salcha River covered during the mark-recapture experiments included a majority of the spawning grounds used by the chinook salmon. However, the portion of the Chena River covered during the mark-recapture experiments may have covered a smaller portion of the spawning grounds because the upper river and large tributaries were not accessible by boat. Because a smaller portion of the population was sampled in the Chena River, the abundance estimate would be smaller compared to that for the Salcha River given equal sized populations. The estimates of abundance provide some support for this hypothesis. From 1988 to 1992 the estimates of abundance were higher for the Salcha River population than for the Chena River population. However, in 1987 and 1993, the opposite was true.

Mark-recapture experiments in the Salcha River and Chena River were conducted using electrofishing gear to capture fish in the first event and carcass surveys to collect fish in the second event. However, in 1986 and 1987 gill nets were used in the Chena River to capture chinook salmon in the first event. When gill nets were used the entire population was sampled over time as it passed a fixed site. This was similar to the method used in 1993 to count fish as the population migrated past a fixed site. Because the entire population was sampled, the abundance would be higher. The abundance estimate in 1987 was higher for the Chena River population. The abundance estimate was even higher for the Chena River population in 1986 (compared to 1987) but no estimate was made for the Salcha River population in 1986.

These data indicated that mark-recapture experiments probably under estimated abundance because not all of a population was available during either the first or second sampling events, or both. Abundance estimates were higher when the entire population was sampled over time (with gill nets or by counting) as it passed a fixed site.

One assumption made in 1993 was that the samples of carcasses collected in the Salcha River and Chena River represented their respective populations. Prior to 1993, this assumption was tested with data collected during the mark-recapture experiments. However, in 1993, this assumption could not be tested. Violation of this assumption would result in bias estimates for sex and length compositions and population egg production. Review of mark-recapture experiments on chinook salmon populations for the Salcha River (1987-1992) and Chena River (1989-1992) showed carcass sampling was biased by sex or length in four out of ten data sets.

The two methods used to estimate the proportions of small and large chinook salmon yielded opposite results. Small fish always comprised less of the population when proportions were estimated using the abundance estimates but when data from the carcass surveys were used the small fish comprised most of the populations. At least one of the methods was biased. The observers may not have been able to accurately distinguish between small and large chinook salmon or small chinook salmon were more likely to be recovered during the carcass surveys. Neither method provides a means to evaluate bias. As a result, fishery managers using these data should be aware that the two methods give opposite results and the extent of the bias is unknown.

In 1991 and 1992 a portion of the female carcasses were examined for egg retention to determine if electrofishing, handling during marking, or both resulted in increased egg retention (Skaugstad 1992 and 1993). Most of the mark-recapture experiments conducted prior to 1993 used pulsating direct current (PDC) to stun the chinook salmon for capture. The data collected prior to 1993 indicated that some marked and unmarked female carcasses contained eggs, but it was not determined if egg retention was natural or an effect of PDC. It was originally assumed that the unmarked fish had not been stunned by PDC. This assumption was incorrect. An unknown portion of the chinook salmon population was stunned but were not captured and marked. In 1993, the data sets collected during the carcass survey of the Salcha River showed that a portion of the female population died with retained eggs. The amount of retained eggs varied from completely full to completely empty. In fact, six of the female carcasses were full of eggs and looked as if the fish had died with out spawning. (Although the data set from the Chena River is similar it was not used because the sample size was small.) Manzer and Miki (1986) found egg retention in sockeye salmon *Oncorhynchus nerka* also varied from totally spawned to totally unspawned. These data imply that it is natural for a portion of the female population to die with retained eggs and the egg retention observed in previous years was probably not the result of PDC or handling.

The number of days elapsed between chinook salmon marked at Manley and observed at the counting towers cannot be considered as representative of the escaping population's passage rate for several reasons. First, fewer than the expected number of chinook salmon that were marked with surveyors' tape were observed at the counting sites. None were observed during carcass surveys in either the Salcha River or Chena River. However, a small number of marked fish were observed alive in the Chena River above the counting site by ADF&G crews working on other projects. This implies that more chinook salmon than expected were captured in the fisheries or more marked fish than expected may have returned to streams other than the Salcha River and Chena River. Second, escaping salmonids do not always travel at a constant rate between two points. Lough (1981) found from radio telemetry studies that steelhead did not always move directly into their spawning tributary, and the chinook salmon in this study may have behaved similarly. And third, travel rates in salmon are influenced by water level, so that high water contributes to variations in the mean date of migration (Merritt and Roberson 1986). No information on water levels was collected during this study. In future studies of migration, radio transmitters implanted in chinook salmon at Manley would provide information on rate of passage, proportions of fish captured in the various fisheries, proportions that returned to the Chena and Salcha rivers, and proportions that returned to streams other than the Salcha and Chena rivers. To obtain the migratory timing of the chinook salmon runs through the various fisheries between Manley and the Chena and Salcha rivers, additional information, such as water level, should be collected.

Estimates of chum salmon abundances for the Salcha River and Chena River populations were minimal estimates because only the first portion of the migration was sampled (counted). The decrease in daily counts of chum salmon after 5 August may be the result of poor visibility or fewer fish migrating past the counting sites. Fewer fish migrating past the counting sites may be due to a change in river conditions (high water level) or the migration rate (number of fish per day) had peaked and was declining. The portion and extent of the migration that was sampled was not known.

Counts made during aerial surveys and abundance estimates from 1986 through 1992 were evaluated to determine if aerial surveys could be used to predict the abundance of spawning chinook salmon in the Salcha River and Chena River (Skaugstad 1993; Evenson 1993). Evaluation of these data indicated that only aerial surveys rated as "good" along with the corresponding abundance estimates should be used to predict spawning abundance. If a relation exists between aerial counts and the abundance of spawning chinook salmon, the relation may be seen best when aerial survey conditions were good. The reason for using just good surveys is that aerial counts are samples with some (unknown) variance about each count and at a given abundance this error is probably smaller during years of good conditions than during years of fair or poor survey conditions. As a result, data collected in 1993 were not used to modify the predictions because the aerial surveys in 1993 were rated "fair" for both rivers.

COHO SALMON STUDY FOR DELTA CLEARWATER

Introduction

The Delta Clearwater River has the largest known coho salmon escapements in the Yukon River drainage (Table 16; Parker 1991). The river is a spring-fed tributary to the Tanana River, located near Delta Junction about 160 km southeast of Fairbanks (Figure 13). The main river is 32 km, with a 10 km north fork. The river supports an increasingly popular fall sport fishery. Annual harvests have exceeded 1,000 coho salmon from 1986 - 1991 (Mills 1979-1993; Table 16). Before reaching their spawning grounds, the coho

Table 16. Escapements of coho salmon into the Delta Clearwater River and Clearwater Lake Outlet, 1972-1993[a].

Year	Survey Date	Delta Clearwater River[b] Lower River[c]	Upper River[d]	Total	Sport Harvest[e]	Clearwater Lake Outlet[b]
1972	9 Nov			632		417[f]
1973	20 Oct			3,322		551
1974				3,954[f]		560[f]
1975	24 Oct			5,100		1,575
1976	22 Oct			1,920		1,500
1977	25 Oct	2,331	2,462	4,793	31	730
1978	26 Oct	2,470	2,328	4,798	126	570
1979	23 Oct	3,407	5,563	8,970	0	1,015
1980	28 Oct	2,206	1,740	3,946	25	1,545
1981	21 Oct	4,110	4,453	8,563[g]	45	459
1982	3 Nov	4,015	4,350	8,365[g]	21	
1983	25 Oct	3,849	4,170	8,019[g]	63	253[f]
1984	6 Nov	5,434	5,627	11,061	571	1368[f]
1985	13 Nov			6,842[f]	722	750[f]
1986	21 Oct	5,490	5,367	10,857	1,005	1,800
1987	27 Oct	11,700	10,600	22,300	1,068	4,225
1988	28 Oct	5,300	16,300	21,600	1,291	825
1989	25 Oct	5,400	7,200	12,600	1,049	1,600
1990	26 Oct	4,525	3,800	8,325	1,375	2,375
1991	23 Oct	11,525	12,375	23,900	1,721	3,150
1992	26 Oct	1,118	2,845	3,963	615	229
1993	21 Oct	3,425	7,450	10,875		550[h]

[a] Only peak surveys are presented, ratings of visibility were fair to good.
[b] Boat survey by Division of Sport Fish.
[c] Mile 8 to Mile 0.
[d] Mile 17.5 to Mile 0.
[e] Data were obtained from Mills (1979-1993).
[f] Survey by Division of Commercial Fisheries.
[g] Population estimate.
[h] Clearwater Lake Outlet was not surveyed on 21 October 1993. A survey was conducted on 29 October 1993.

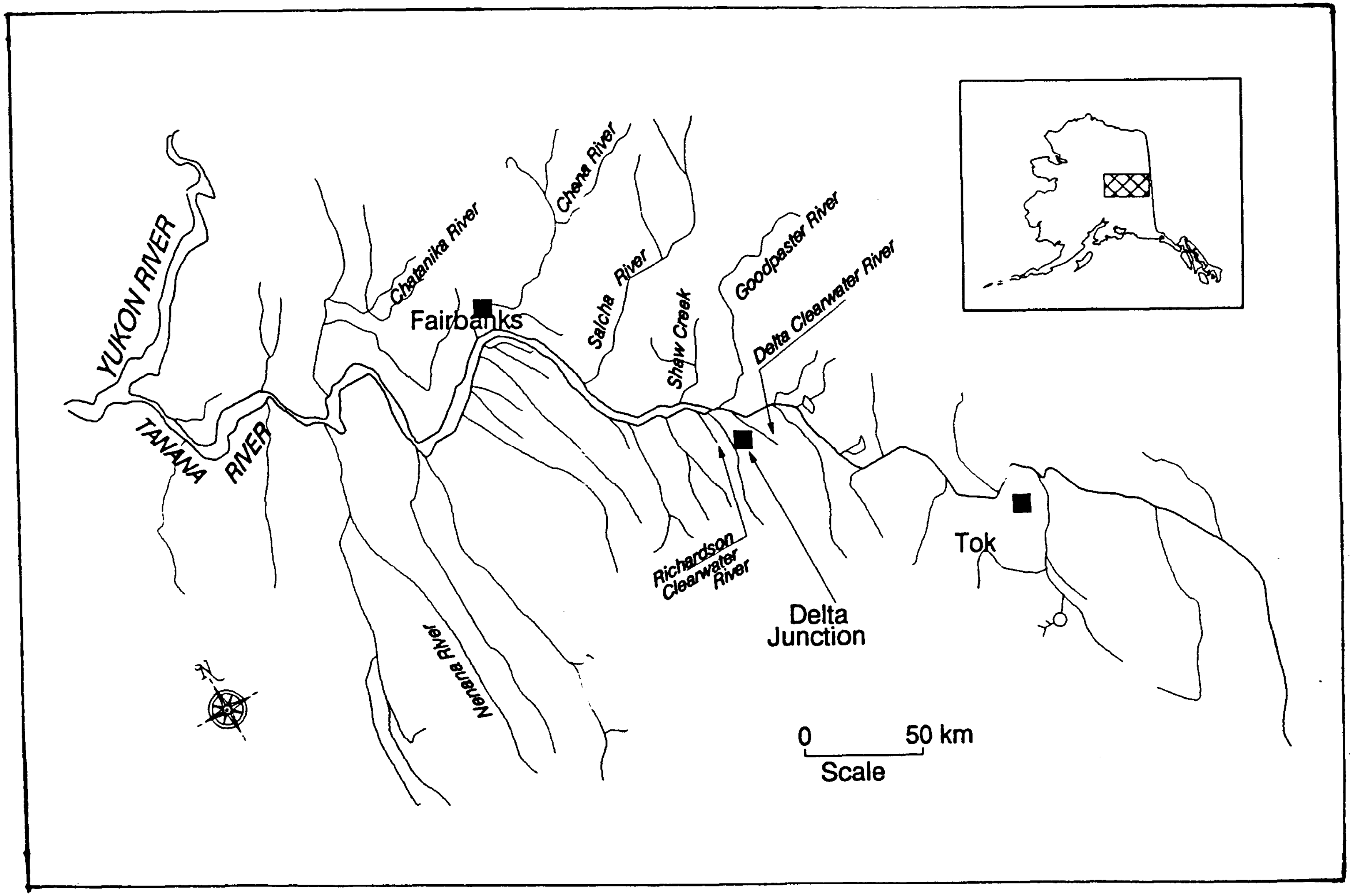


Figure 13. Tanana River drainage.

salmon travel about 1,693 km from the ocean and pass through six different commercial fishing districts in the Yukon and Tanana rivers (Figure 3). Subsistence and personal use fishing also occur in each district.

Escapements of coho salmon into the Delta Clearwater River have been monitored by counting fish from a drifting river boat. This information has been used to evaluate management of the commercial, subsistence, and personal use fisheries. The information is also used to regulate the harvest of coho salmon in the Delta Clearwater River sport fishery by opening and closing the season and changing the bag limit. The present bag limit is three coho salmon per day and three in possession. ADF&G has established a minimum escapement of 9,000 coho salmon to the Delta Clearwater River. When counts indicate that the escapement is low, the sport fishery is regulated by reducing the bag limit or closing the fishery. When the count exceeds the minimum escapement then the bag limit may be increased.

The objective of the coho salmon escapement project for the Delta Clearwater River in 1993 was to estimate age, sex, and length compositions of the escapement of coho salmon in the Delta Clearwater River. In addition, there was one task to count coho salmon in the Delta Clearwater River from a drifting riverboat.

<u>Methods</u>

Counts:

Adult coho salmon were counted from a drifting riverboat equipped with an observation platform. The person counting fish stood on the platform which was about 2 m above the water. The Delta Clearwater River was divided into 1.6 km (1 mi) sections and fish were counted by section (Figure 14). The sections were numbered from the mouth (Mile 0). Arctic grayling and chum salmon were also counted. Six counts were made about one week apart to determine the entry pattern (proportion of the population that entered the river during a time period) of the coho salmon.

Counts of coho salmon were made over either an index area (a portion of the river from Mile 14 to Mile 0) or over the majority of the spawning grounds (Mile 17.5 to Mile 0). Counts made over the index area on 9 October 1993 were expanded to estimate the total number of coho salmon from Mile 17.5 to Mile 0. The expansion was based on the proportion of coho salmon observed in the index area (Mile 14 to Mile 0) during a count over the majority of the spawning grounds (Mile 17.5 to Mile 0) on 14 October 1993:

$$ {}_{t-1}\hat{N}_{17.5} = \frac{{}_{t-1}N_{14}}{{}_{t}\hat{p}} \tag{21} $$

$$ Var({}_{t-1}\hat{N}_{17.5}) = \frac{{}_{t-1}N_{14}^{2}}{{}_{t}\hat{p}^{4}} Var({}_{t}\hat{p}) \tag{22} $$

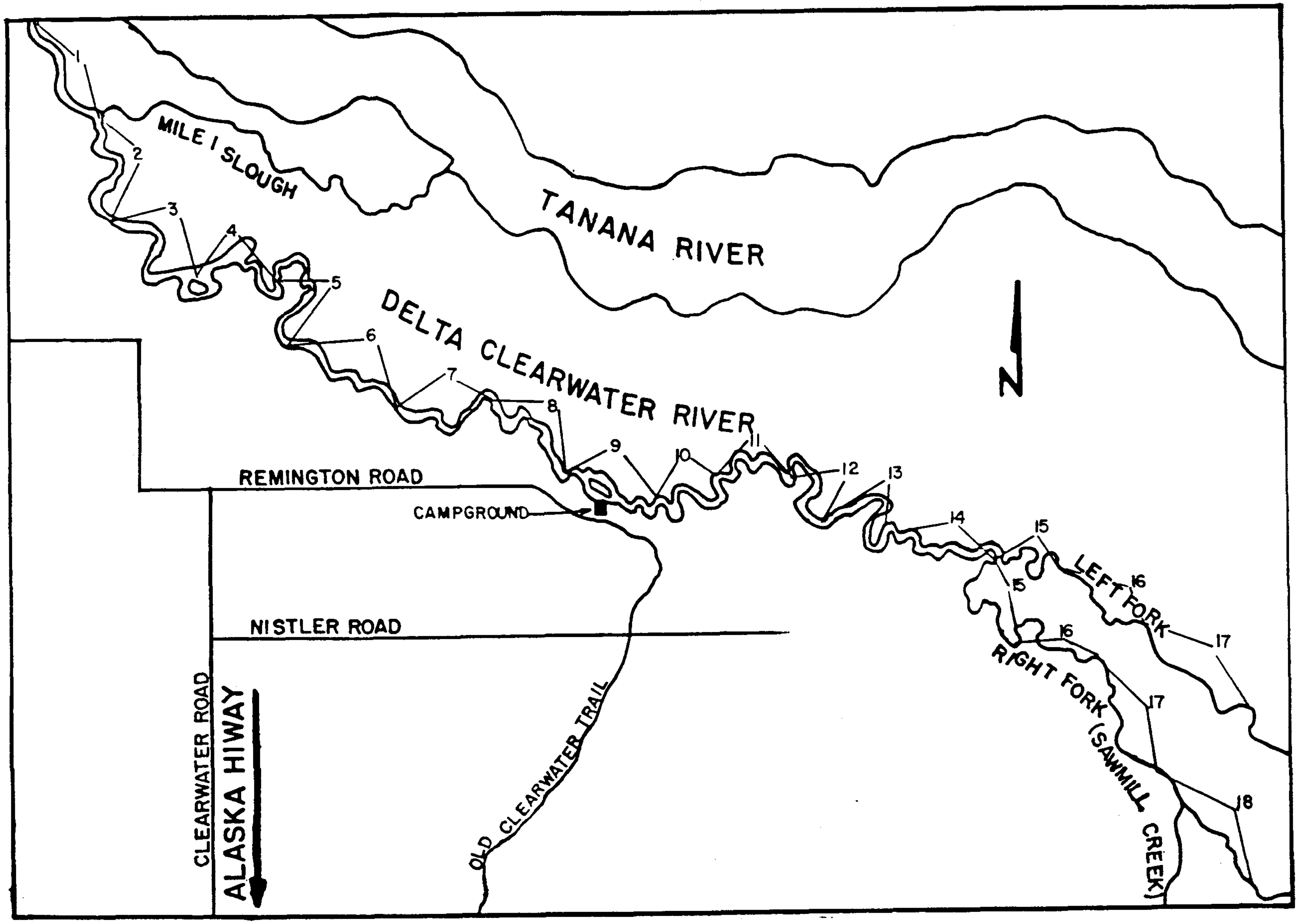


Figure 14. Delta Clearwater River study area.

$$_t\hat{p} = \frac{_tN_{14}}{_tN_{17.5}} \tag{23}$$

$$Var(_t\hat{p}) = \frac{_t\hat{p}(1-_t\hat{p})}{(_tN_{17.5}-1)} \tag{24}$$

where:

$_{t-1}N_{14}$ = count of coho salmon from Mile 14 to Mile 0 on 9 October 1993 (time *t-1*);

$_{t-1}\hat{N}_{17.5}$ = estimated number of coho salmon from Mile 17.5 to Mile 0 on 9 October 1993 (time *t-1*);

$_tN_{14}$ = count of coho salmon from Mile 14 to Mile 0 on 14 October 1993 (time *t*);

$_tN_{17.5}$ = count of coho salmon from Mile 17.5 to Mile 0 on 14 October 1993 (time *t*); and,

$_t\hat{p}$ = proportion of the total number ($_tN_{17.5}$) of coho salmon seen from Mile 14 to Mile 0 on 14 October 1993 (time *t*).

Carcass Survey:

Coho salmon carcasses were collected from Mile 15 to Mile 9 on 8 November 1993. In a drifting river boat one person collected carcasses with a long handled spear while two others measured length, determined sex, and collected scale samples. Length was measured from mid-eye to fork-of-tail (ME-FT) to the nearest 5 mm. Sex was determined from observation of body morphology or cutting into the body cavity to examine the gonads. Scales were removed from the left side approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956). After the carcasses were examined each carcass was slashed, so it would not be resampled, and was returned to the river.

Age-Sex-Length Compositions:

Ages were determined from scale patterns as described by Mosher (1969). Estimates of composition were determined using only carcasses for which there were data for age, sex, and length. The proportions of the population represented by combinations of age and sex were estimated using Equations 10 and 11. Mean lengths were estimated for combinations of age and sex using the sample mean and variance (Zar 1984, pp. 19 and 87).

Migration Past Nenana:

A fish wheel was operated at Nenana to monitor the migration of the coho salmon population past Nenana. Catches of coho salmon were recorded every

24 h. The fish wheel was located below Nenana about 6.5 km above Totchaket Slough and 3.2 km below Sawmill Island. The fish wheel was owned and operated by Percy Duyck from Nenana under contract for the Alaska Department of Fish and Game. Daily catches in the fish wheel were assumed to be in proportion to the number of coho salmon that passed the site. If this assumption was true then the daily catches would represent the daily relative abundance over time of the migration of the coho salmon population past the fish wheel.

Results

Counts:

Counts of coho salmon in the Delta Clearwater River were made on 23 and 27 September, and 9, 14, 21, and 29 October (Table 17). The number of coho salmon counted were 228, 239, 2,685, 7,900, 10,875, and 9,200, respectively. Visibility during the counts was rated either excellent or good. The counts on 23 and 27 September, and 9 and 29 October were made in the index area from Mile 14 to Mile 0. The counts on 14 and 21 October were made over the majority of the spawning grounds from Mile 17.5 to Mile 0. The count on 9 October from Mile 14 to Mile 0 was expanded to 3,550 (SE = 928) to estimate the number of coho salmon from Mile 17.5 to Mile 0.

Carcass Survey:

Two hundred ninety-nine coho salmon carcasses were collected and measured. The sex was determined and scale samples were collected from all carcasses.

Age-Sex-Length Compositions:

Sex and length were determined for all 299 coho salmon. Age was determined for only 275 coho salmon. There were 98 males age 1.1 and 45 males age 2.1 and 74 females age 1.1 and 58 females age 2.1 (Table 18). Mean lengths ranged from 533 to 553 mm by sex and age combinations (Table 18 and Figure 15). Males had a wider range in length than females by age but the mean lengths of females were larger than for males by age (Table 18 and Figure 16).

Migration Past Nenana:

Coho salmon were first caught on 26 August (Table 19 and Figure 17). Fewer than 10 coho salmon were caught daily through 10 September. The highest count was 372 fish on 22 September. By 5 October, when the project ended, a total of 2,553 coho salmon had been captured.

Discussion

In 1993, data collected during surveys of the Delta Clearwater River were used to open the sport fishery that had been closed because of conservation concerns. Sonar at Pilot Station indicated the number of coho salmon that entered the Yukon River on their way to their spawning grounds was less than 40,000 by the end of August, a third of what fishery managers expected. As a result, all fisheries for fall chum salmon and coho salmon were closed by an

Table 17. Counts of adult coho salmon in the Delta Clearwater River, 1993.

	Date					
River Mile	23 Sep	27 Sep	8 Oct	14 Oct	21 Oct	29 Oct
17.5-16	ND	ND	ND	425	925	675
16-15	ND	ND	ND	1,225	1,475	1,025
15-14	ND	ND	ND	875	1,625	1,350
14-13	25	47	435	1,025	1,150	900
13-12	14	17	250	525	700	425
12-11	8	0	125	450	525	500
11-10	28	32	375	600	700	525
10-9	31	31	100	225	275	275
9-8	19	4	50	75	75	75
8-7	35	27	100	225	300	375
7-6	6	12	25	50	75	75
6-5	0	3	150	225	200	200
5-4	6	19	175	400	575	550
4-3	20	14	325	575	550	500
3-2	6	16	100	75	100	750
2-1	15	10	300	675	1,300	700
1-0	15	7	175	250	325	300
Summary						
17.5-8	125	131	1,335	5,425	7,450	5,750
8-0	103	108	1,350	2,475	3,425	3,450
14-0	228	239	2,685	5,375	6,850	6,150
17.5-0	228	239	2,685	7,900	10,875	9,200
Visibility	Excellent	Excellent	Good	Good	Good	Good

Table 18. Statistics by age and sex for coho salmon carcasses collected from the Delta Clearwater River, 1993.

	Male		Female	
Age[a]	1.1	2.1	1.1	2.1
Brood Year	1990	1989	1990	1989
Count[b]	98	45	74	58
Minimum Length (mm)	430	430	460	480
Maximum Length (mm)	620	600	590	600
Mean Length (mm)	541	533	550	553
Standard Error	4	7	3	4
Upper 95% Confidence Limit[c]	549	546	556	560
Lower 95% Confidence Limit[c]	532	520	544	546

[a] The notation X.X represents the number of annuli formed during river residence and ocean residence (i.e. an age of 2.1 represents two annuli formed during river residence and one anuli formed during ocean residence). One annulus is formed each year.

[b] Coho salmon were not included when sex was not determined, length was not measured, or age was not determined due to missing or unreadable scales.

[c] The upper and lower 95% confidence limits were estimated for the mean length.

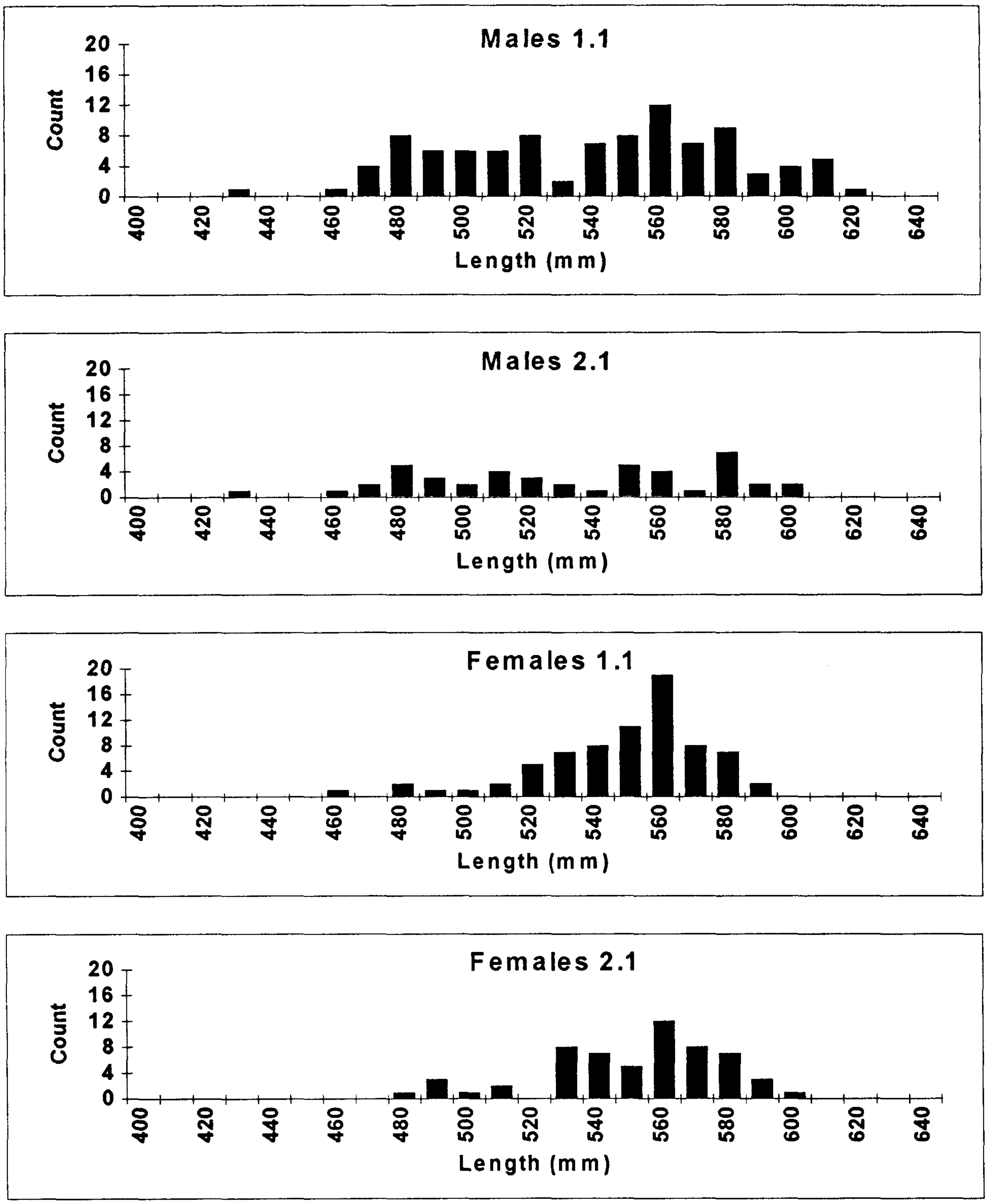


Figure 15. Length frequency of coho salmon carcasses collected from the Delta Clearwater River, 1993, by sex and age.

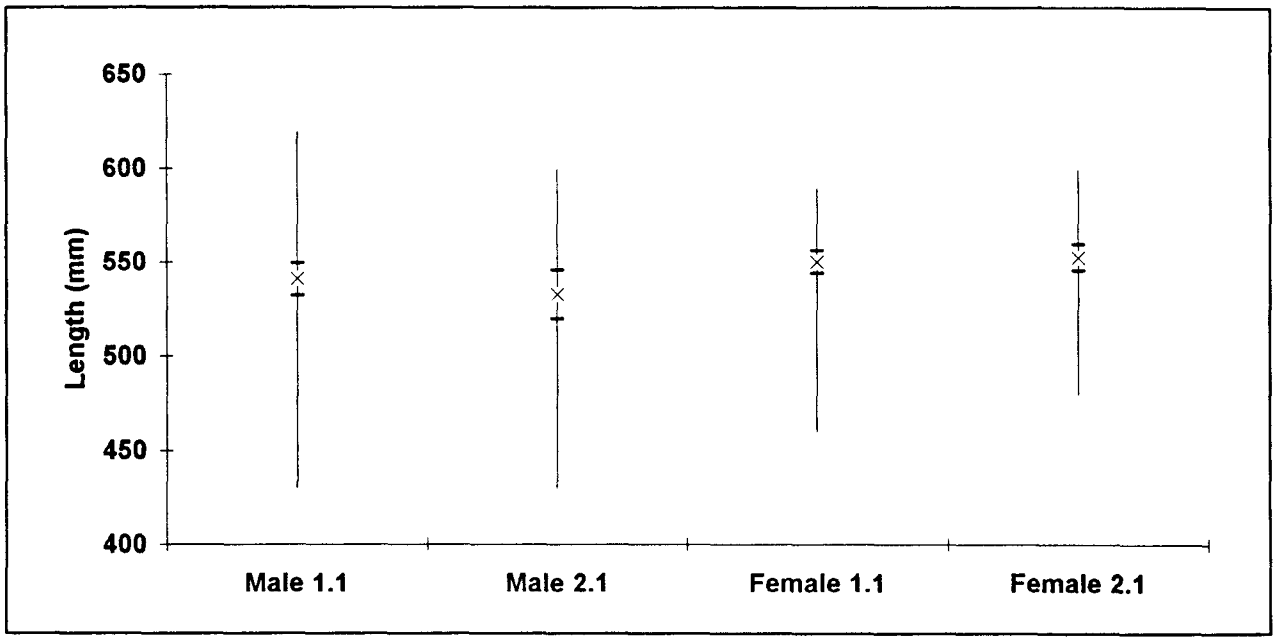


Figure 16. Length statistics by age and sex for coho salmon carcasses collected from the Delta Clearwater River, 1993. Vertical lines represent the range of lengths, X represents the means, and the horizontal lines are the upper and lower 95% confidence limits of the means.

Table 19. Daily catches of coho salmon at a fish wheel on the Tanana River near Nenana, 1993.

Date	Males	Females	Total
26-Aug	1	0	1
27-Aug	0	0	0
28-Aug	0	0	0
29-Aug	1	3	4
30-Aug	0	0	0
31-Aug	1	0	1
1-Sep	2	1	3
2-Sep	8	1	9
3-Sep	8	0	8
4-Sep	6	1	7
5-Sep	6	0	6
6-Sep	4	1	5
7-Sep	3	1	4
8-Sep	3	0	3
9-Sep	4	1	5
10-Sep	7	2	9
11-Sep	18	3	21
12-Sep	23	12	35
13-Sep	31	13	44
14-Sep	37	18	55
15-Sep	44	20	64
16-Sep	35	10	45
17-Sep	50	35	85
18-Sep	77	45	122
19-Sep	50	42	92
20-Sep	109	89	198
21-Sep	131	114	245
22-Sep	189	183	372
23-Sep	102	135	237
24-Sep	59	66	125
25-Sep	72	68	140
26-Sep	85	70	155
27-Sep	40	46	86
28-Sep	36	38	74
29-Sep	20	25	45
30-Sep	31	27	58
1-Oct	21	26	47
2-Oct	36	25	61
3-Oct	10	8	18
4-Oct	21	27	48
5-Oct	4	12	16
Total	**1,385**	**1,168**	**2,553**

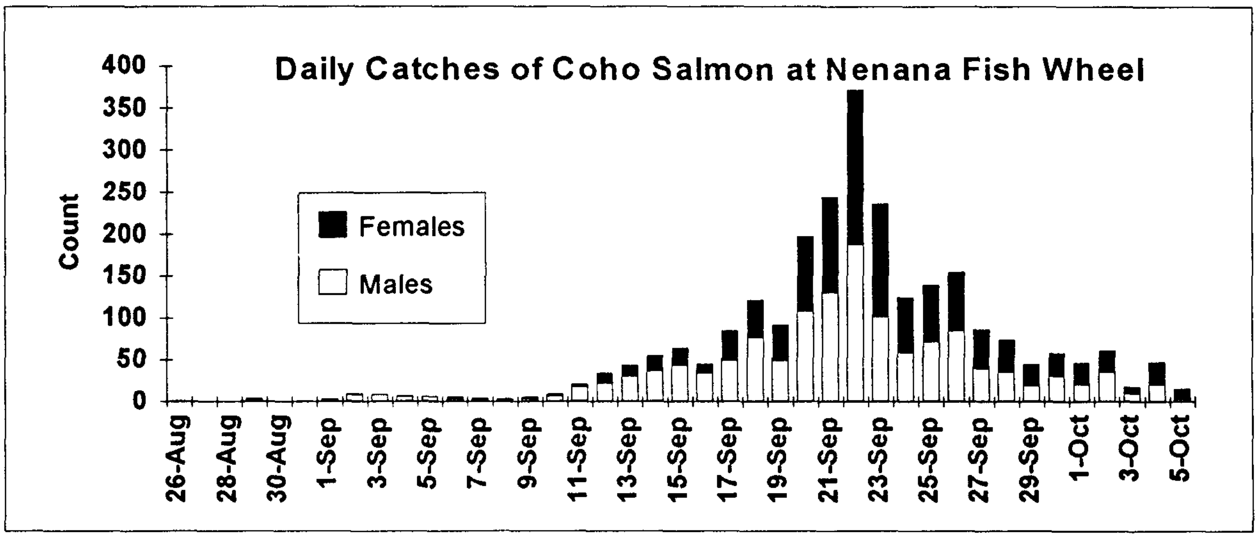


Figure 17. Daily catches of coho salmon at a fish wheel on the Tanana River near Nenana, 1993.

Emergency Order to conserve the populations. By 14 October, surveys on the Delta Clearwater River indicated that the escapement goal for coho salmon in the Delta Clearwater River would be met. The coho salmon fishery in the Delta Clearwater River was then opened by an Emergency Order on 15 October.

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Appendix A

Appendix A. Data files used to estimate parameters of chinook, chum, and coho salmon populations, 1993.

Data File	Description
U0020TA3.ARC	Hourly counts of adult chinook and chum salmon past the counting site on the Chena River, 1993
	Hourly counts of adult chinook and chum salmon past the counting site on the Salcha River, 1993.
SALMCNTS.WK1	Lotus 123 file of hourly counts of adult chinook and chum salmon past the counting sites on the Salcha River and Chena River, 1993.
CHEKG93E.AWL	Excel file of length, sex, age, and egg retention data for chinook salmon carcass collected from the Chena River, 1993.
CHENKG93.AWL	Data file of length, sex, and age data for chinook salmon carcass collected from the Chena River, 1993.
SALKG93E.AWL	Excel file of length, sex, age, and egg retention data for chinook salmon carcass collected from the Salcha River, 1993.
SALCKG93.AWL	Data file of length, sex, and age data for chinook salmon carcass collected from the Chena River, 1993.
SKAUG1.DTA	Data file of length and sex data for chinook salmon captured and marked at a fish wheel on the Tanana River near Manley, 1993.
DCRCOHO.DTA	Data file of length, sex, and age data for coho salmon carcasses collected from the Delta Clearwater River, 1993.

[a] Data files have been archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska, 99518-1599.