Fishery Data Series No. 93-23

Abundance, Egg Production, and Age-Sex-Length Composition of the Chinook Salmon Escapement in the Salcha River, 1992

by

Cal Skaugstad

August 1993

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 93-23

ABUNDANCE, EGG PRODUCTION, AND AGE-SEX-LENGTH COMPOSITION OF THE CHINOOK SALMON ESCAPEMENT IN THE SALCHA RIVER, 1992[1]

By

Cal Skaugstad

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

August 1993

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-8, Study S, Job No. 3-1(b).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 1992, the abundance of chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Salcha River near Fairbanks, Alaska, was estimated using a mark-recapture experiment. A riverboat equipped with electrofishing gear was used to capture 434 chinook salmon in late July and early August. Captured chinook salmon were marked with jaw tags, fin clipped, and released. In early August, 957 chinook salmon carcasses were collected of which 52 were marked. The estimate of chinook salmon abundance was 7,862 (SE = 975). The proportions of males and females were 0.64 and 0.36, respectively. Males spent 1 to 5 years in the ocean while most females spent 3 to 5 years. The estimate of potential egg production for the 1992 escapement was 27 million eggs (SE = 2.1 million). A count of chinook salmon during an aerial survey on 3 August was 1,484, about 19% of the abundance estimate from the mark-recapture experiment.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, Salcha River, age-sex-length composition, aerial survey, fecundity, egg production, tag loss.

INTRODUCTION

Management of stocks of Yukon River chinook salmon *Oncorhynchus tshawytscha* is complex and requires that accurate estimates of escapement be made in a number of major spawning streams. During a 1,540 km migration from the ocean to their spawning grounds in the Salcha River, chinook salmon pass through six different commercial fishing districts in the Yukon and Tanana rivers. Subsistence and personal use fishing also occur in each district. At the mouth of the Salcha River there is a popular sport fishery in which annual harvests have approached 1,000 chinook salmon in some years (Table 1).

To perpetuate the stocks of chinook salmon, fishery managers set harvest levels for the various fisheries such that a desired number of chinook salmon are allowed to reach their spawning grounds. Harvest levels for the current year are based on estimates of numbers of chinook salmon that enter the Yukon River along with results from prior years (numbers of chinook salmon that were harvested and numbers of chinook salmon that reached spawning grounds). An important factor when evaluating stock status of chinook salmon is the number of spawners that successfully reach their spawning grounds (escapement). When the number of spawners is less than desired, then the overall harvest level was probably too high. This information can be used in the future to better estimate harvest levels that allow optimal numbers of chinook salmon to reach spawning grounds.

The Salcha River is a 250 km long, clear stream flowing into the Tanana River about 60 km east of Fairbanks (Figure 1). From 1972 to 1990, the number of mature chinook salmon counted in the Salcha River during aerial surveys has ranged from 391 to 6,757 (Barton 1984, Skaugstad 1990a, Burkholder 1991). These counts imply that the Salcha River supports one of the largest populations of spawning chinook salmon in the entire Yukon River drainage. Aerial surveys, however, only give an index of abundance because only a portion of the entire spawning population is present during a single aerial survey. Also, other factors such as weather, water level, water clarity, and overhanging vegetation affect the surveyor's ability to count chinook salmon. Skaugstad (1988, 1989, 1990a) and Burkholder (1991) found that the number of chinook salmon counted during surveys of the Salcha River in 1987, 1988, 1989, and 1990 was about 40%, 61%, 71%, and 35% respectively, of the estimated abundance from mark-recapture experiments. Barton (1987a, 1987b), Skaugstad (1991b), and Evenson (1991, 1992) found that the number of mature chinook salmon counted during an aerial survey was less than 20%, 44%, 26%, and 42%, respectively, of the estimated abundance based on mark-recapture experiments in the Chena River (near Fairbanks). Barton (1987a, 1987b) found that less than 20% of the fish counted through a weir in Clear Creek (near Nenana) were observed during an aerial survey.

Mark-recapture experiments are more expensive to conduct than aerial surveys but they are able to provide estimates of abundance. By conducting aerial surveys and mark-recapture experiments at the same time, a relationship might be established to expand counts from an aerial survey into estimates of abundance.

Table 1. Harvests of anadromous chinook salmon by sport, commercial, subsistence, and personal use fisheries, Tanana River drainage, 1978 - 1992.

	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[eg]	7,090
1989	685	123	375	231	231	39	87	963	2,181[d]	3,046[eg]	5,001
1990	24	200	64	291	37	0	0	439	2,989[d]	3,759[eg]	7,140[g]
1991	none	362	110	373	82	11	54	630	1,163[dg]	2,687[eg]	4,480[g]
1992	none	4[h]	N.A.[f]	N.A.	N.A.	N.A.	N.A.	N.A.	712[dg]	N.A.	N.A.

[a] Creel census estimates from Clark and Ridder (1987), Baker (1988, 1989), Merritt et al. (1990), and Hallberg and Bingham (1991 and 1992).

[b] Sport fishery harvest estimates from Mills (1979-1992).

[c] Commercial, subsistence, and personal use estimates (Schultz, Keith. 1991. 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, and 91 fish in 1991).

[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] N.A. means data not available at this time.

[g] Preliminary data and subject to change.

[h] Data from Hallberg and Bingham 1992.

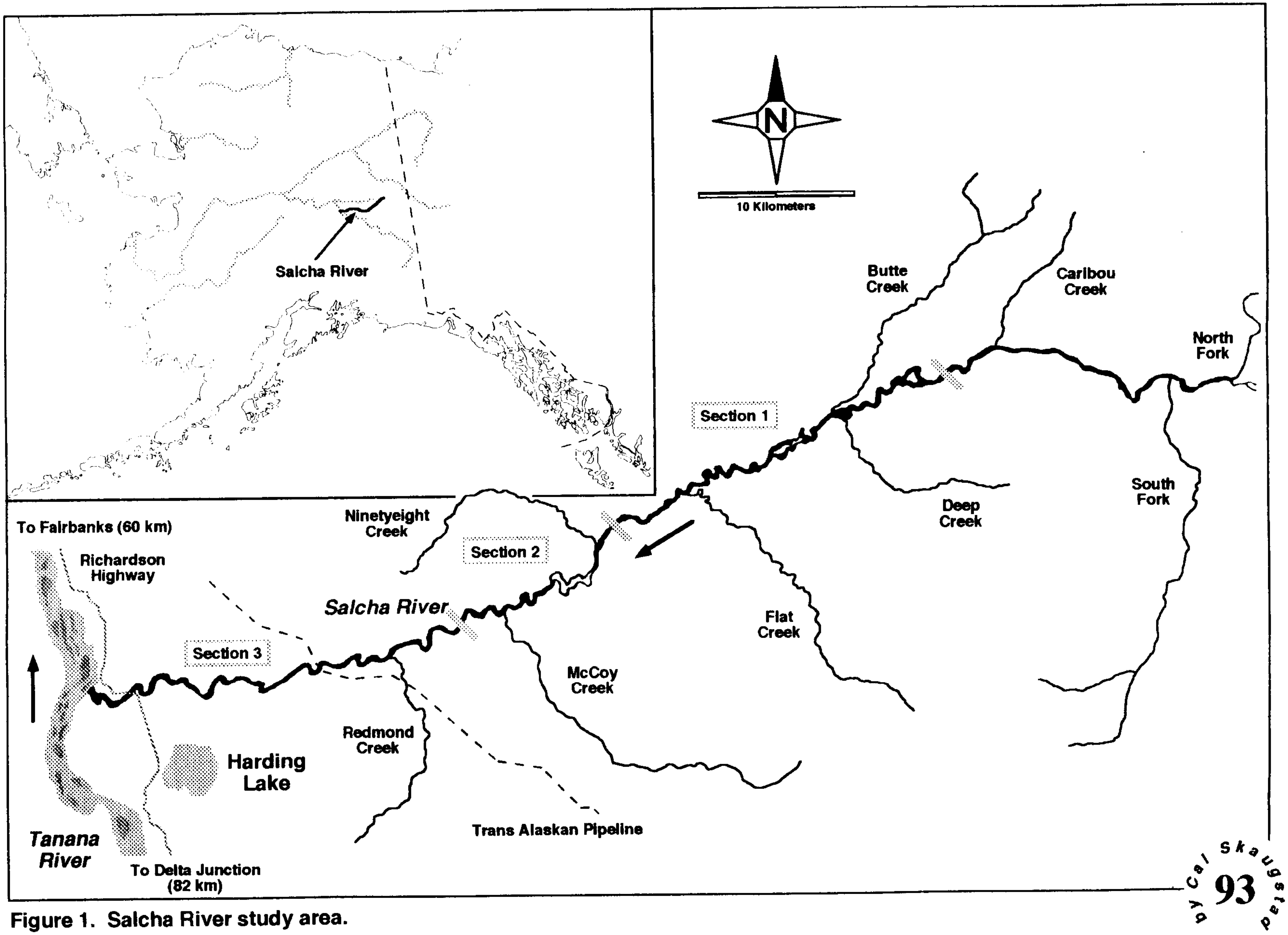

Figure 1. Salcha River study area.

The objectives of the chinook salmon project for the Salcha River in 1992 were to:

1. estimate the abundance of spawning chinook salmon in the Salcha River; and,

2. estimate the age-sex-length compositions of chinook salmon in the Salcha River.

In addition, the population abundance estimate was compared to counts of spawning salmon from aerial surveys; and, potential egg production of the escapement was estimated.

METHODS

The number of chinook salmon that reached their spawning grounds in the Salcha River were estimated using a Petersen mark-recapture experiment. This type of experiment required two events. During the first event, a sample of the population was captured, marked, and released back into the population. During the second event, after allowing time for the marked and unmarked fish to mix, another sample was collected and examined for marks. Terms used in mark-recapture experiments to describe "capture" of animals during the first and second events usually apply to live animals. This report uses "collect" to refer to the "capture" or collection of chinook salmon carcasses in the second event.

Event 1 - Capture and Marking

Adult chinook salmon were captured using a riverboat equipped with electrofishing gear (Clark 1985; Table 2). Chinook salmon were stunned using pulsating direct current electricity, dipped from the river with long handled dip nets, and placed in a holding tank. River water was continuously pumped through the holding tank. Since past aerial surveys of the Salcha River have shown that few chinook salmon spawn above Caribou Creek (Fred Andersen pers. comm[1]), only the lower 97 km of the Salcha River, between the confluences of the Salcha River with Caribou Creek and the Tanana River, were sampled. The sample area was divided arbitrarily into three sections (Figure 1). One pass was made through sections 1, 2, and 3 on 29, 30, and 31 July (Period 1), respectively. A second pass was made through sections 1, 2, and 3 on 3, 4, and 5 August (Period 2). Each pass through a section started at the upstream end. Any chinook salmon carcasses found during the first event also were collected.

All captured chinook salmon (including carcasses) were tagged, fin clipped, measured, and released. A uniquely numbered metal tag was attached to the

---

1 Andersen, Fred. 1987. Personal Communication. Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701.

Table 2. Description of equipment, control settings, and water conductivity while electrofishing the Salcha River in 1992.

Generator characteristics:	4 KW, 60 Hz, 120 V
VVP:	Coffelt (no model number) Manufactured around 1967.
Pulse duration:	2.5 milliseconds (ms).
Duty cycle:	50%
Frequency:	40 pulses per second (pps).
Voltage:	100 - 250 volts (peak).
Amperage:	2 - 4 amperes.
Cathode:	The boat served as the cathode.
Anode:	16 mm (5/8 in) diameter flexible wire rope.
Water conductivity:	90 - 110 microsiemens/cm^3.
Water temperature	9 - 11°C

lower jaw of each fish. A combination of adipose, pectoral, anal, and pelvic fin clips was used to identify the location and period of capture. Length was measured from mid-eye to fork-of-tail (ME-FK) to the nearest 5 mm. Sex was determined from observation of body morphology. The marking process was repeated about every 20 min or when the number of chinook salmon approached the capacity of the holding tank. By stopping at 20 min intervals fish were released near their capture location and the time that fish were in the holding tank was minimized to reduce stress.

Each captured female salmon was subjectively judged by the project leader as spawned out (none or very few eggs in the body cavity) or as a percentage spawned out.

Event 2 - Collection and Mark Recovery

Chinook salmon carcasses were collected from the same three river sections in which electrofishing was performed. One pass was made through sections 1, 2, and 3 on 10, 11, 12, and 13 August. Carcasses were collected with long handled spears from a drifting riverboat. Each carcass was measured to the nearest 5 mm and examined for a jaw tag and fin clip. Sex was determined from observation of body morphology or examination of the gonads. Three scales were removed from each of the first 793 carcasses for age analysis. Where possible, a preferred scale was taken from the left side of the body, at a point on a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin, two rows above the lateral line. If the preferred scale could not be obtained another scale was taken from as close to the preferred scale as possible (Welander 1940). If no scales were available in the preferred area on the left side of the fish, scales were collected from the preferred area on the right side of the fish.

All carcasses of female chinook salmon were cut open to determine if eggs were present. Each carcass was subjectively judged by the project leader as spawned out or as a percentage spawned out.

Test of Assumptions for Abundance Estimator

Data collected during the two-sample mark-recapture experiment were evaluated with a battery of statistical tests to choose an appropriate estimator for estimating abundance and methods for estimating age, sex, and length compositions (Bernard and Hansen 1992).

Sex Selectivity:

Sex selectivity was evaluated using a contingency table of numbers of marked fish recovered and not recovered during Event 2. The chi-square statistic was then used to test the null hypothesis of no significant difference between the rates of recovery by sex.

The probabilities of capture for males and females during Event 1 were evaluated using a contingency table of numbers of unmarked and marked carcasses recovered during Event 2. The chi-square statistic was then used to test the null hypothesis of no significant difference between the probabilities of capture for males and females.

Size Selectivity:

Three tests were used to evaluate gear bias by size (length of the fish). Length distributions were compared for: 1) chinook salmon captured in the first event and marked chinook salmon carcasses recovered in the second event; and 2) all chinook salmon captured in the first event and all chinook salmon carcasses collected in the second event. A Kolmogorov-Smirnov statistic was calculated for each comparison to test the null hypothesis of no difference between cumulative length frequency distributions. 3) Rates of recovery were compared using a contingency table of numbers of marked chinook salmon that were recovered and not recovered by size category (small: ≤630 mm, medium: >630 mm and ≤790 mm, and large: >790 mm) during the second event. The divisions between length categories were determined through examination of length frequency histograms of all carcasses collected in the second event. Divisions were made at the lowest frequency between modes. The chi-square statistic was used to test the null hypothesis of no difference between rates of recovery among length categories.

Timing:

Rates of recovery of chinook salmon marked during the first pass (early) and second pass (late) in Event 1 were used to evaluate timing bias. A contingency table was constructed using numbers of marked chinook salmon recovered and not recovered in Event 2 by time (early and late). The chi-square statistic was used to test the null hypothesis of no significant difference between rates of recovery of chinook salmon marked during the early pass and late pass in Event 1.

Location:

To evaluate rates of capture by river section, a contingency table was constructed using numbers of marked and unmarked chinook salmon carcasses collected by river section in Event 2. A chi-square statistic was used to test the null hypothesis of no difference between rates of capture by river section.

Mixing of marked fish between river sections was evaluated by examination of the capture history.

Abundance Estimator

Based on the results of these tests, abundance was estimated using an unstratified Petersen estimator (described by Chapman 1951, cited in Seber 1982).

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \qquad (1)$$

$$V(\hat{N}) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \qquad (2)$$

where:

$\hat{N}$ = estimated abundance of chinook salmon;
n_1 = number of chinook salmon marked in Event 1;
n_2 = number of chinook salmon carcasses collected in Event 2;
m_2 = number of chinook salmon carcasses with marks in Event 2; and,

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

Confidence limits were estimated using an approach described by Burnham et al. (1987) based on the assumption that the number of individuals in the population not captured is log-normally distributed. The confidence limits were calculated as:

$$M_{t+1} + \frac{f_0}{C} \quad , \quad M_{t+1} + f_0 * C \tag{3}$$

where M_{t+1} is the number of unique individuals captured and f_0 is the number of individuals not captured ($\hat{N}$ - M_{t+1}) and,

$$C = \exp(1.96(\log(1+ \frac{V(\hat{N})}{f_0^2}))^{½}) \tag{4}$$

Tag Loss

The proportion of tags lost during the study was estimated using:

$$\hat{p}_t = n_u/n_r \tag{5}$$

$$V(\hat{p}_t) = \hat{p}_t(1-\hat{p}_t)/(n_r-1) \tag{6}$$

where:

$\hat{p}_t$ = proportion of tags lost;
n_u = number of recovered fish without jaw tags;
n_r = total number of marked fish recovered; and,

$V(\hat{p}_t)$ = variance of $\hat{p}_t$.

Age, Sex, and Length Compositions

Proportions of females and males by ocean age or length interval were estimated using:

$$\hat{p}_z = n_z/n, \quad \text{and} \tag{7}$$

$$\hat{V}(\hat{p}_z) = \hat{p}_z(1-\hat{p}_z)/(n-1) \tag{8}$$

where:

$\hat{p}_z$ = estimated proportion (by sex, age, or length) of chinook salmon in category z;
n_z = number of chinook salmon in category z;
n = total number of chinook salmon in the sample; and,
$\hat{V}(\hat{p}_z)$ = variance of $\hat{p}_z$.

Abundance of females (or males) of ocean age a or length interval a in the population was estimated using:

$$\hat{N}_{sa} = (\hat{p}_a)(\hat{p}_s)(\hat{N}), \tag{9}$$

and the variance was estimated using (Goodman 1960):

$$\hat{V}(\hat{N}_{sa}) = \hat{N}^2\hat{p}_s^2\hat{V}(\hat{p}_a) + \hat{N}^2\hat{p}_a^2\hat{V}(\hat{p}_s) + \hat{p}_s^2\hat{p}_a^2\hat{V}(\hat{N}) - \hat{N}^2\hat{V}(\hat{p}_s)\hat{V}(\hat{p}_a) - \hat{p}_s^2\hat{V}(\hat{N})\hat{V}(\hat{p}_a)$$
$$-\hat{p}_a^2\hat{V}(\hat{N})\hat{V}(\hat{p}_s) + \hat{V}(\hat{N})\hat{V}(\hat{p}_s)\hat{V}(\hat{p}_a) \tag{10}$$

where:

$\hat{N}$ = the estimated abundance of spawning chinook salmon;
$\hat{V}(\hat{N})$ = the variance of abundance;
$\hat{p}_s$ = the estimated proportion of chinook salmon of sex s;
$\hat{V}(\hat{p}_s)$ = the variance of the estimated proportion of chinook salmon of sex s;
$\hat{p}_a$ = the estimated proportion of chinook salmon of age a; and,
$\hat{V}(\hat{p}_a)$ = the variance of the estimated proportion of chinook salmon of age a.

Estimates of mean length-at-age were generated with standard normal procedures. Simple averages and squared deviations from the mean were used to calculate means and variances of the means.

Potential Egg Production

Fecundity of chinook salmon of a given length was predicted using a regression model of fecundity against length (Skaugstad and McCracken 1991) developed from a sample of 49 female chinook salmon collected from the Tanana River during 1989. The variables and parameters from this study are designated with subscript "o" below. The model was used to estimate fecundity for the smallest possible female in each 10 mm length interval:

$$\hat{F}_l = a_o + b_o L_l \quad (11)$$

$$\hat{V}(F_l) = MSE_o \left\{ 1 + \frac{1}{n_o} + \frac{(L_j - \bar{L}_o)^2}{\sum L_{of}^2 - (\sum L_{of})^2/n_o} \right\} \quad (12)$$

where:

$\hat{F}_l$ = fecundity of the smallest possible fish in 10 mm length interval l;
$\underline{L}_l$ = lower limit of 10 mm length interval l;
L_o = mean length of fish 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,
$\hat{V}(F_l)$ = variance of $\hat{F}_l$.

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

$$\hat{E} = \sum \hat{N}_l \hat{F}_l \quad (13)$$

$$\hat{V}(E) = \sum \hat{N}_l^2 \hat{V}(F_l) + \hat{F}_l^2 \hat{V}(N_l) - \hat{V}(N_l)\hat{V}(F_l) \quad (14)$$

where:

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

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

$\hat{N}_l$ = the estimated number of females of length interval l (Equation 9);

$\hat{V}(N_l)$ = the variance of $\hat{N}_l$ (Equation 10);

$\hat{F}_l$ = the estimated fecundity for the smallest fish in length interval l (Equation 11); and,

$\hat{V}(F_l)$ = variance of $\hat{F}_l$ (Equation 12).

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 River on 20 July. Counts were made from low flying, fixed-wing aircraft. Barton (1987c) described the methods used for these aerial surveys.

A Monte Carlo simulation using aerial survey counts was used to predict spawning abundance. The simulation generated 500 data sets each containing three data points of survey counts (x) and abundance estimates (y). The survey count values were those recorded during the three "good" aerial survey conditions. If a relationship does exist between aerial counts and the abundance of spawning chinook salmon, this relationship may be seen best when aerial survey conditions were good. In addition, aerial counts are samples with some (unknown) variance about each count. At a given abundance this error is probably smaller during years of good conditions than during years of poor or fair survey conditions.

The abundance values were chosen randomly from a normal distribution having a mean of the estimated abundance and a variance of the estimated variance of abundance. For example, in each data set with an aerial count of 2,761 salmon, the abundance was chosen at random from a normal distribution with a mean of 4,562 and a variance of $(556)^2 = 309{,}136$. the proportion of salmon counted by the aerial survey was also calculated as:

$$p = \frac{\text{Aerial Survey Count}}{\text{Abundance}} . \qquad (15)$$

For each data set a linear regression was fit to the three data points and the slope estimate used to test the hypotheses

$$H_o: \beta = 0 \qquad H_a: \beta \neq 0.$$

Failure to reject the null hypothesis implies there was no significant linear relationship between aerial counts and abundance of spawning chinook. If the null hypothesis was rejected, it was concluded that a relationship existed between aerial counts under good survey conditions and the abundance of chinook.

RESULTS

In the first event, 434 chinook salmon (including five carcasses) were captured, marked, and released. During the second event, 957 chinook salmon carcasses were collected and examined for marks. Of these fish, 52 were marked. In the first event, one chinook salmon was not measured. In the second event, 32 chinook salmon were not measured because only portions of some carcasses were found. Sex was not determined for eight chinook salmon captured in the second event. Ages were determined for only 650 of the first 793 individuals. Capture histories of chinook salmon in the Salcha River from 1987 through 1992 are archived in Appendix A.

Of 58 females examined during the first run in Event 1: 32 were spawned out, two were at least 75% spawned out, five were at least 50% spawned out, three were at least 25% spawned out, and 16 had not spawned. Of 64 females examined during the second run in Event 1: 61 were spawned out and three were at least 75% spawned out.

Twenty of 343 carcasses were found that still contained eggs. Eight carcasses were at least 75% spawned out (one of these was marked), six carcasses were at least 50% spawned out, five were at least 25% spawned out, and one had not spawned.

Tests of Assumptions for Abundance Estimator

Sex Selectivity:

The recovery rates for males and females were 0.11 and 0.14, respectively, and were not significantly different ($P = 0.29$; Table 3). The marking rates for males and females were 0.049 and 0.064, respectively, and were not significantly different ($P = 0.34$; Table 4).

Size Selectivity:

Length distributions of live chinook salmon captured in Event 1 and marked chinook salmon carcasses collected in Event 2 were not different ($P = 0.23$; Figure 2). Length distributions of live chinook salmon captured in Event 1 and all chinook salmon carcasses recovered in Event 2 were different ($P = 0.013$; Figure 2). These tests indicated that there was no size selectivity during Event 2 but there was during Event 1. Therefore, only chinook salmon collected during Event 2 were used to estimate sex, age and length compositions. Rates of recovery of small (0.12), medium (0.085), and large fish (0.15) were not significantly different ($P = 0.26$; Table 5).

Timing:

Rates of recovery of marked chinook salmon relative to the marking period were 0.081 (early) and 0.17 (late; Table 6). Rates of recovery were significantly different ($P = 0.007$).

Location:

Rates of capture in Sections 1, 2, and 3 were 0.054, 0.066, and 0.015 (Table 7). Rates of capture were not significantly different ($P = 0.27$).

Examination of the capture history showed there was only partial mixing of marked fish between sections and movement from one section to another was downstream (Table 8).

Table 3. Number of marked male and female chinook salmon carcasses collected in Event 2.

	Male	Female	Total
Recovered	30	22	52
Not recovered	249	133	382
Total released	279	155	434
Recovery rate	0.11	0.14	0.12

Degrees of Freedom: 1
χ^2 : 1.12
P Value: 0.29
Power: 0.18 (for $\alpha = 0.05$)

Table 4. Number of marked and unmarked male and female chinook salmon collected in Event 2.

	Male	Female	Total
Marked	30	22	52
Unmarked	576	321	897
Total Carcasses	606	343	949
Marking rate	0.049	0.064	0.055

Degrees of Freedom: 1
χ^2 : 0.91
P Value: 0.34
Power: 0.16 (for $\alpha = 0.05$)

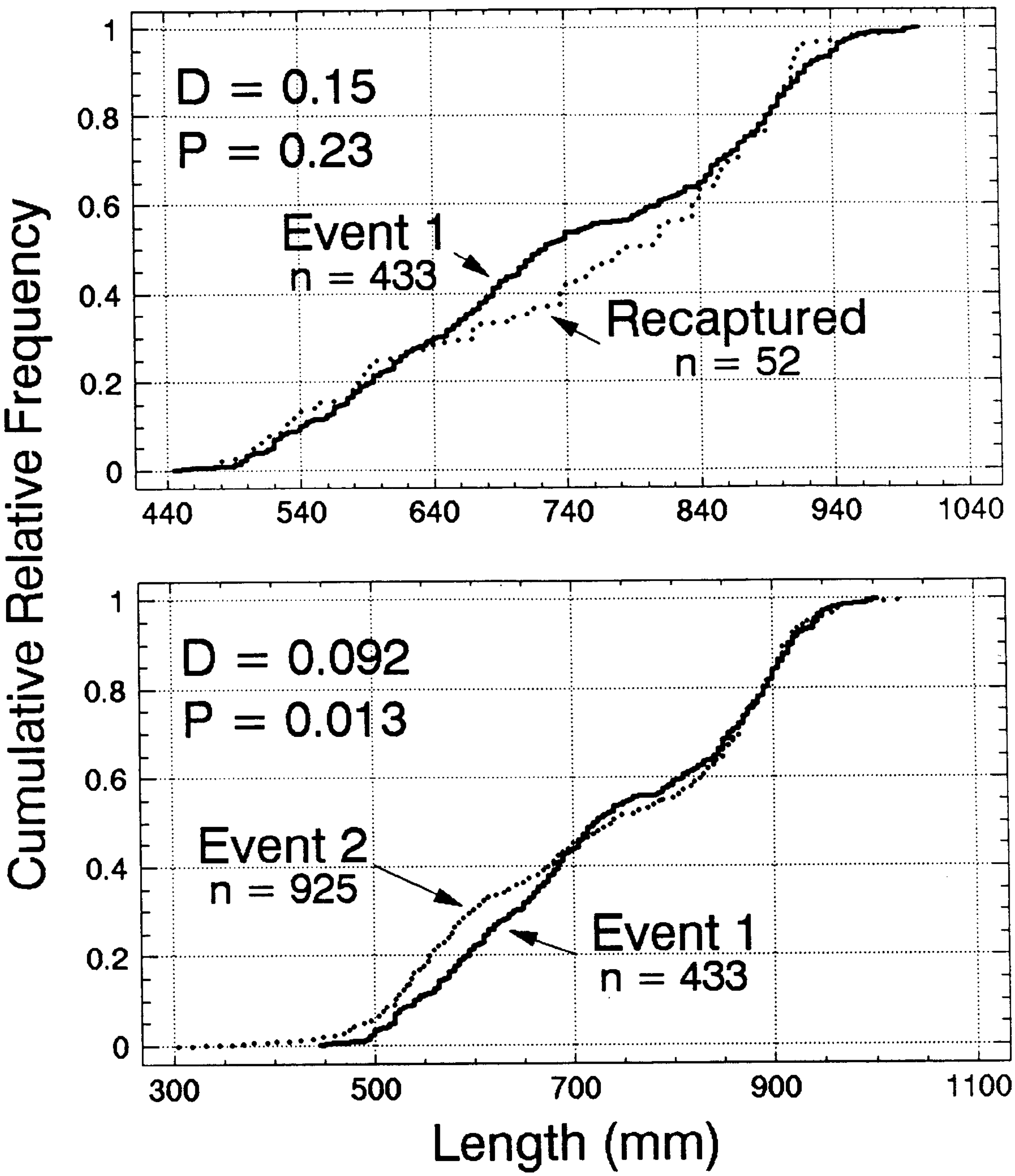

Figure 2. Cumulative relative frequency of chinook salmon captured in Event 1 and marked chinook salmon recovered in Event 2; and, cumulative relative frequency of chinook salmon captured in Event 1 and all chinook salmon carcasses collected in Event 2.

Table 5. Number of marked chinook salmon recaptured and not recaptured in Event 2 by length category.

	Length Class			
Capture Status	> 790	790 ≤ x > 630	≤ 630	Total
Recaptured	27	11	14	52
Not Recaptured	157	118	106	386
Total	184	129	120	433
Recapture rate:	0.15	0.085	0.12	0.12

Degrees of Freedom: 2
χ^2 : 2.73
P Value: 0.26
Power: 0.30 (for $\alpha = 0.05$)

Table 6. Number of chinook salmon carcasses recovered in Event 2 that were marked in period 1 (early) and period 2 (late) in Event 1.

	Period 1	Period 2	Total
Recovered	20	32	52
Not recovered	226	156	382
Total released	246	188	434
Recovery rate	0.081	0.17	0.12

Degrees of Freedom: 1
χ^2 : 7.17
P Value: 0.0074
Power: 0.81 (for $\alpha = 0.05$)

Table 7. Number of marked and unmarked chinook salmon carcasses collected in Event 2 by river section.

	River Section			
	1(Upper)	2(Middle)	3(Lower)	Total
Marked	36	15	1	52
Unmarked	629	211	65	905
Total collected	665	226	66	957
Capture rate	0.054	0.066	0.015	0.054

Degrees of Freedom: 2
χ^2 : 2.61
P Value: 0.27
Power: 0.28 (for $\alpha = 0.05$)

Table 8. Capture history of chinook salmon by river section.

River Section Where Marked Fish Were Released	River Section Where Marked Fish Were Recovered 1(Upper)	2(Middle)	3(Lower)	Total	Number Not Recovered	Total Marked
1(Upper)	35	14	0	49	287	336
2(Middle)	0	1	1	2	45	47
3(Lower)	0	0	1	1	50	51
Total	36	15	1	52	382	434
Unmarked Carcasses	629	211	65			
Total Carcasses	665	226	66	957		

Abundance Estimate

The estimated abundance of spawning chinook salmon in the Salcha River was 7,862 (SE = 975). The 95% confidence limits were 6,723 and 9,242.

Proportions of males and females captured in Event 2 were 0.64 (606/949) and 0.36 (343/949), respectively. Using these proportions, estimates of abundance for males was 5,020 (SE = 634) and for females was 2,842 (SE = 373).

Tag Loss

Of the 52 marked fish recovered during the second event, 47 had jaw tags and five were identified by fin clips because jaw tags were lost. The estimated proportion of jaw tags lost was 0.096 (SE = 0.041). Of the five carcasses without jaw tags, one carcasses was headless.

Age, Sex, and Length Compositions

Of the 957 chinook salmon carcasses collected during the second event, scale samples were obtained from 793 individuals. Of these 793 fish, ages could be determined for only 650 fish. Of these 650 fish, sex was not determined for one individual and length was not recorded for 22 individuals. These fish spent 1 to 5 years in the ocean and most individuals spent one year in freshwater (Table 9). The dominant age class for males was 1.2 (brood year 1988) and for females was 1.4 (brood year 1986). Using only males and females that were aged, the overall estimate of abundance was apportioned by age and sex (Table 9).

Lengths of males ranged from 305 to 1,030 mm and females ranged from 650 to 995 mm (Figures 3a, 3b, and Table 10). The distribution of lengths of females had a single mode at about 880 mm with much less dispersion compared to the males. The distribution of lengths of males had multiple modes at about 550, 690, and 890 mm. Males less than 660 mm spent 1 to 3 years in the ocean. The mean lengths of ocean age 4 and 5 males were larger than the same age females, but mean lengths of males younger than ocean age 4 were smaller than females of the same age (Table 10). In the carcass sample, about 83% of the males (492/592) and 4% of the females (12/332) were less than 780 mm.

Potential Egg Production

The estimated egg production of the spawning population was 27 million eggs (SE = 2.1 million) based on the length-fecundity relationship (Table 11) or 24 million eggs (SE = 4.7 million) based on the age-fecundity relationship (Skaugstad and McCracken 1990). Estimates of annual egg production since 1987 are summarized in Table 12.

Relation of Aerial Counts to Abundance Estimates

During the aerial survey on 3 August, 1,484 chinook salmon were counted, about 19% of the estimated abundance of 7,862 (Table 13). The survey was rated "fair to poor". Since 1987, the proportion of the population observed during aerial surveys ranged from 0.35 to 0.71 (Table 13).

Table 9. Estimates of proportions and abundance of female and male chinook salmon by age class.[a]

Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
Females:					
1.1	0				
1.2	1	0.002	0.002	12	12
1.3	72	0.111	0.012	876	145
2.2	0				
1.4	143	0.221	0.016	1,740	251
2.3	0				
1.5	3	0.005	0.003	37	21
2.4	1	0.002	0.002	12	12
Sub-totals	220	0.341	0.020	2,665	368
Males:					
1.1	8	0.012	0.004	97	36
1.2	233	0.356	0.019	2,799	377
1.3	145	0.224	0.016	1,765	254
2.2	3	0.005	0.003	37	21
1.4	36	0.056	0.009	438	89
2.3	2	0.003	0.002	24	17
1.5	2	0.003	0.002	24	17
2.4	0				
Sub-totals	429	0.659	0.027	5,197	678
Sexes combined:					
1.1	8	0.012	0.004	97	36
1.2	234	0.358	0.019	2,811	378
1.3	217	0.336	0.019	2,641	358
2.2	3	0.005	0.003	37	21
1.4	179	0.277	0.018	2,178	303
2.3	2	0.003	0.002	24	17
1.5	5	0.008	0.003	61	28
2.4	1	0.002	0.002	12	12
Total	649	1.000		7,862	975

[a] For this analysis, only chinook salmon were used that were captured in Event 2 (975) for which both age and length data were collected (649).

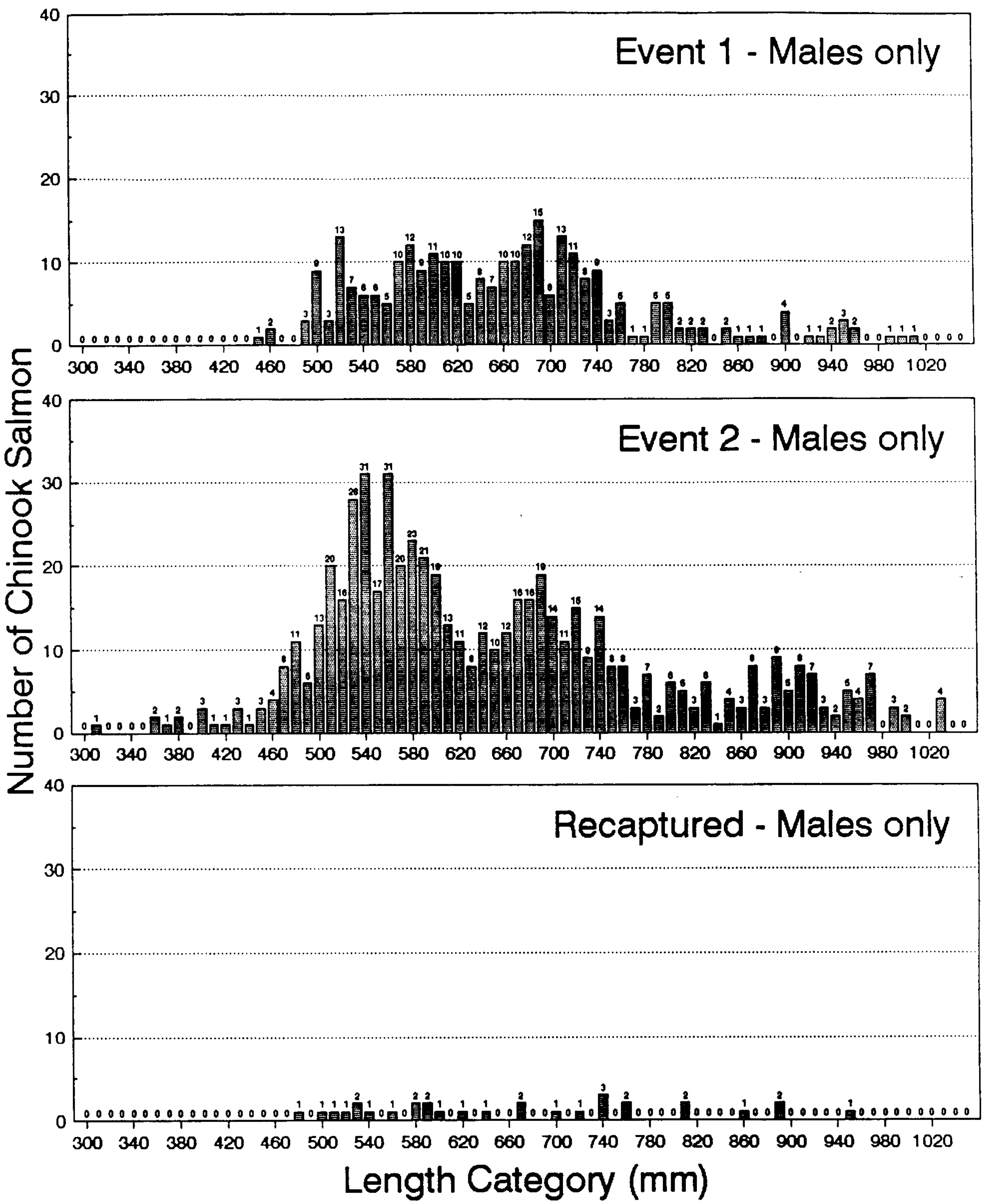

Figure 3a. Histogram of lengths of male chinook salmon captured during the mark-recapture experiment.

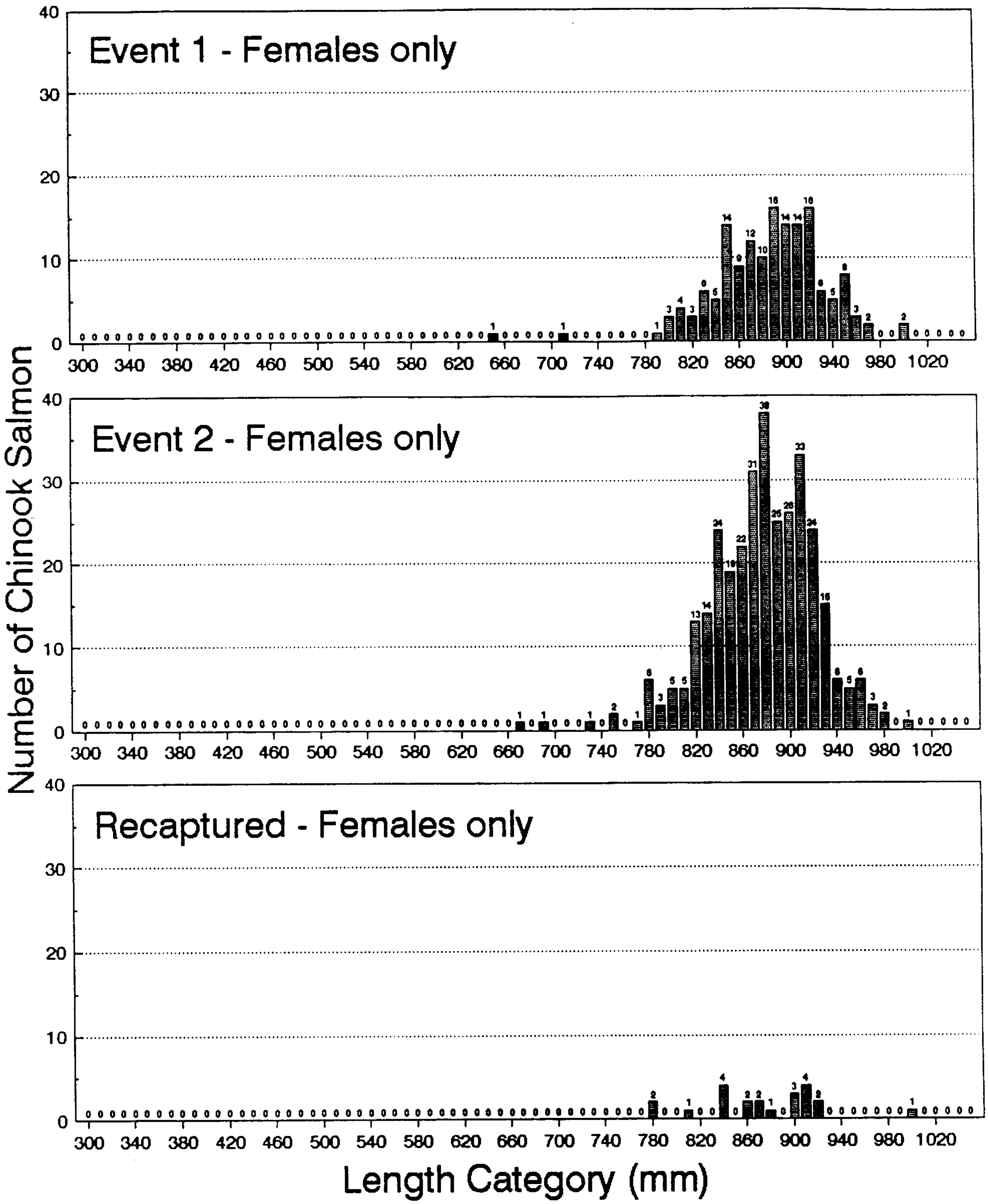

Figure 3b. Histogram of lengths of female chinook salmon captured during the mark-recapture experiment.

Table 10. Estimated length-at-age of chinook salmon.[a]

Ocean Age	Sample Size	Length (mm)		
		Mean	SE	Range
Females:				
1	0			
2	1	685		
3	70	844	5	725 - 910
4	140	887	3	775 - 980
5	3	938	31	890 - 995
Males:				
1	8	386	9	355 - 420
2	226	559	4	400 - 740
3	141	725	5	575 - 910
4	36	926	8	810 - 1,025
5	2	1,028	3	1,025 - 1,030
Females and Males:				
1	8	386	9	355 - 420
2	227	560	4	400 - 740
3	211	765	6	575 - 910
4	176	895	3	775 - 1,025
5	5	974	28	890 - 1,030

[a] For this analysis, only chinook salmon were used that were captured in Event 2 (975) for which age, sex, and length data were collected (627).

Table 11. Estimated potential egg production of chinook salmon from the Salcha River, 1992, based on relationship between length and fecundity[a].

Length (mm)	Number[b] of Fish	SE (fish)	Egg Production (eggs)	SE (eggs)
680	9	9	48,288	48,288
690	9	9	49,997	49,997
700	0	0	0	0
710	0	0	0	0
720	0	0	0	0
730	9	9	56,833	56,833
740	0	0	0	0
750	17	12	120,504	88,224
760	0	0	0	0
770	9	9	63,670	63,670
780	51	22	392,276	183,346
790	26	15	201,266	122,911
800	43	20	343,989	170,454
810	43	20	352,534	174,038
820	111	33	938,809	332,495
830	120	35	1,034,953	356,185
840	205	48	1,815,226	539,991
850	163	42	1,469,528	458,576
860	188	46	1,739,161	519,153
870	265	57	2,503,621	686,424
880	325	65	3,133,904	818,677
890	214	50	2,104,508	595,977
900	223	51	2,233,127	622,337
910	282	59	2,890,757	758,508
920	205	48	2,143,389	601,879
930	128	36	1,365,256	436,158
940	51	22	556,357	247,305
950	43	20	472,177	225,991
960	51	22	576,868	255,625
970	26	15	293,561	175,315
980	17	12	199,126	143,201
990	0	0	0	0
1,000	9	9	102,981	102,981
1,010	0	0	0	0
Total	2,842		27,202,666	2,094,741

[a] Relationship between length and fecundity estimated by Skaugstad and McCracken (1990).

[b] For this analysis only female chinook salmon were used that were captured in Event 2 (343) for which length data were collected (332).

Table 12. Potential egg production of chinook salmon in the Salcha River, 1987-1992.

Year	Estimated Abundance				Estimated Production (millions)	
	Population	(SE)	Females	(SE)	Eggs	(SE)
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

Table 13. Estimated abundance, highest counts during aerial survey, aerial survey conditions, and proportion of the population observed at highest count during aerial surveys for chinook salmon in the Salcha River, 1987-1992.

Year	Estimated Abundance	SE	Aerial Survey		Proportion of Population Observed For Aerial Survey
			Count	Condition[a]	
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	0.19

[a] During these surveys, conditions were judged on a scale of "poor, fair, good".
[b] Aerial survey was made a few days before spawning peaked.

Aerial counts increased as abundance increased during years of good survey conditions (Figure 4). During the three years when aerial survey conditions were poor or fair, 20-40% of the estimated abundance of chinook salmon was observed during the aerial survey irrespective of population size.

The simulation produced abundance values which on average mimicked the distribution of the abundance estimates during the three years of good aerial survey conditions (Tables 13 and 14). The means of the proportion of the population observed during the simulation were also near the estimated proportion observed during the surveys. As abundance increased, the aerial surveys counted on average a smaller proportion of the population and the range of the proportion of fish observed also became smaller. At the smallest aerial count the proportion of the population observed ranged from 0.45 to >1.0. In other words, during some simulation runs the aerial survey counted all the chinook salmon present in the population. At the highest aerial count the proportion observed only ranged from 0.25 to 0.57.

The linear relationship between counts and abundance was significant in only 23% of the 500 data sets. This likely occurred because with only 3 data points the power of the test was low.

Finally, examination of the data (Figure 4) indicated that aerial counts of 2,000-2,200 under good aerial survey conditions may indicate the population of spawning chinook salmon was extremely low.

DISCUSSION

Examination of data from the mark-recapture experiment indicated that marked chinook salmon only partially mixed between river sections. The recapture history of marked chinook salmon for other mark-recapture experiments conducted with chinook salmon from the Salcha River (Skaugstad 1988, 1989, 1990a, and 1992; Burkholder 1991) and Chena River (Skaugstad 1990b and Evenson 1991, 1992) also showed partial mixing. Partial mixing is expected due to the experimental design and life cycle of chinook salmon. When captured for marking (Event 1), most chinook salmon had finished or nearly finished spawning and were a few days from death. Dying fish would be less likely to move upstream or maintain a stationary position, and would probably drift into areas with lower velocities and pools. Therefore, any mixing that occurred would be mainly downstream.

When chinook salmon carcasses settle to the bottom they usually become covered with silt and sand which makes detection difficult during the carcass survey. The greater the period between death and the carcass survey, the more likely a a carcass would be covered and the less likely it would be detected. This would explain why chinook salmon marked during the first period in Event 1 were less likely to be recovered than chinook salmon marked during the second period in Event 1. The estimate of abundance would be affected only if the probabilities of capture (being collected) during the carcass survey were different for marked and unmarked carcasses. If marked carcasses were less likely to be collected then the estimate of abundance would have a positive bias.

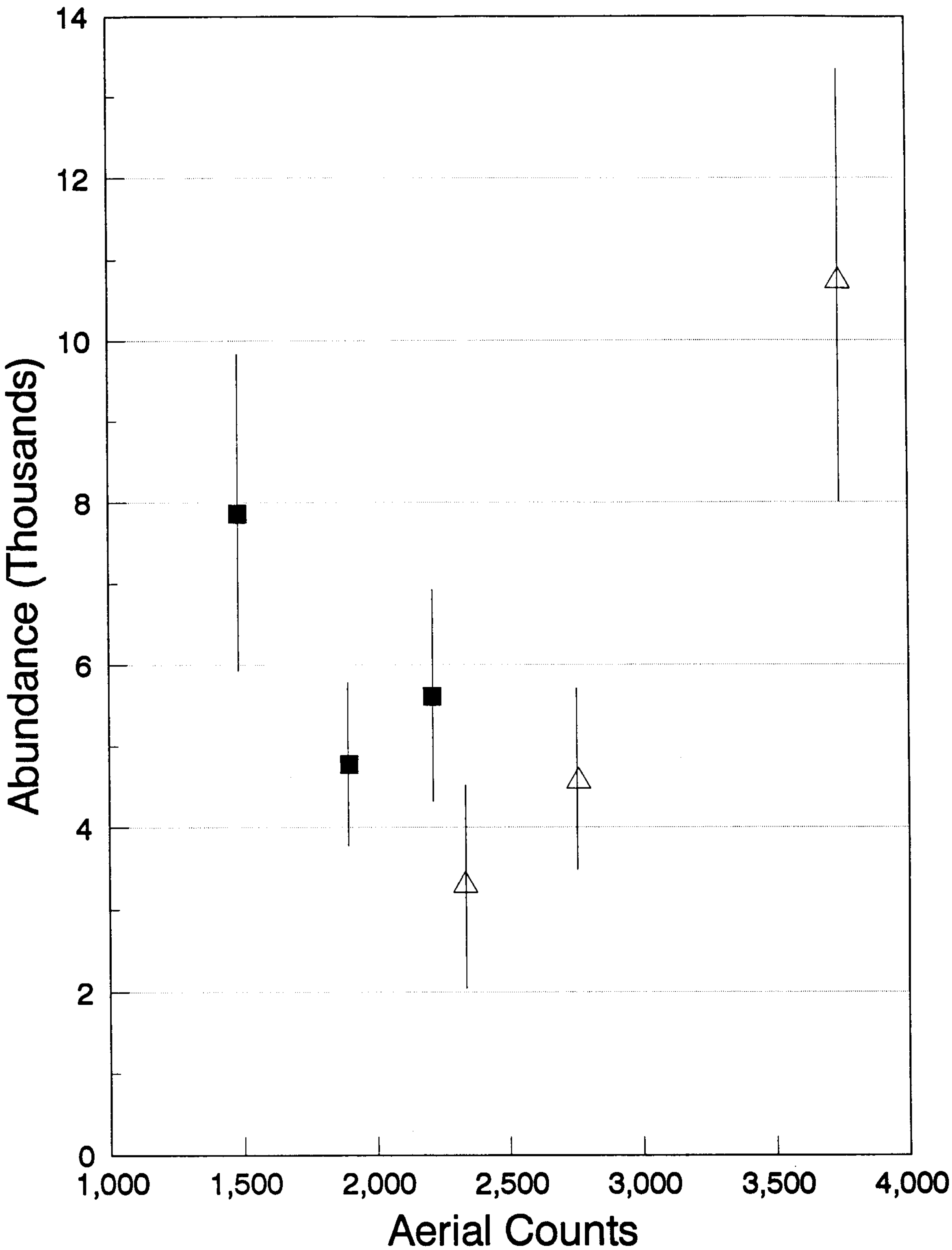

Figure 4. Plot of aerial survey counts and estimated abundance of spawning chinook salmon in the Salcha River, 1987-1992, when survey conditions were good (△) or were fair to poor (■). Vertical lines are 95% confidence intervals.

Table 14. Estimates of abundance and proportion of abundance observed during aerial counts based on Monte Carlo simulation of 500 data sets of Salcha River spawning chinook salmon.

Aerial Count	Abundance					Proportion		
	Mean	Variance	Standard Deviation	Minimum	Maximum	Mean	Minimum	Maximum
2,333	3,306	411,467	641.46	1,605	5,209	0.74	0.45	1.45
2,761	4,543	344,846	587.24	2,975	5,999	0.62	0.46	0.93
3,744	10,678	2,002,767	1,415.19	6,534	14,800	0.36	0.25	0.57

A potential problem with using pulsating direct current (pdc) electricity to stun fish is the possibility of injury that may affect stunned individuals differently than those not stunned. If chinook salmon suffered premature death from either electrofishing, handling during marking, or both, then probabilities of capture of marked and unmarked chinook salmon would be different. If marked individuals were less likely to be captured in Event 2, then the estimate of abundance would have a positive bias. However, if marked and unmarked chinook salmon die within a short period after spawning, then the probabilities of collecting marked and unmarked fish should be equal. This experiment was designed so premature death of marked fish would have little effect on the probability of recovery. Event 1 occurred after most chinook salmon spawned but were still alive. Collection of carcasses occurred 12 days after the start of Event 1 after most chinook salmon had died. Therefore, due to the short period between events, any injury suffered during Event 1 that may have caused premature death should have caused little, if any, difference between the probabilities of collecting marked and unmarked carcasses.

Six years of using electricity to stun chinook salmon has shown that electricity is an efficient method of capturing chinook salmon. The potential harm to unspawned chinook salmon is low because most fish have finished spawning. In Event 2, only one of 22 marked female chinook salmon carcasses was partially spawned out. This suggests the use of electricity with this study design did not injure females enough to prevent them from spawning.

The effect of continuous direct current (cdc) and pdc on egg viability and survival for chinook salmon has not been investigated under field conditions. Information for other species under laboratory and pseudo-field conditions is mixed. Fecundity of rainbow trout and survival of eggs were not affected by pdc (Maxfield et al. 1971). CDC caused higher mortality rates during early development of Atlantic salmon *Salmo salar* and brook trout *Salvelinus fontinalis* eggs that were placed in a concrete trough (Godfrey 1957). Mortality rates also increased with increased power. As egg development progressed, mortality rates decreased and increased power had little effect on increasing mortality rates. Mortality rates were less for eggs in gravel. These studies suggest egg survival in redds is probably dependent on development stage, electrical gradient, and duration of the electrical field. During Event 1 when electricity is used, most eggs were in redds from 0 to 7 days (based on observations of spawning during aerial surveys) and were exposed to the electrical field for no more than 10 seconds. The effect of electricity on chinook salmon eggs under these conditions is not known but is assumed to be negligible.

There is currently insufficient data to determine if a relationship exists between aerial survey counts and abundance of spawning chinook. The error associated with the count will differ depending on survey conditions and in the six years of data there are four different conditions noted. The low power of the test associated with each simulation data set also highlights the problem of insufficient data. The lower power translates into a high probability of making a Type II error: failing to detect a significant relationship when it really does exist.

It may be possible to include all six years in an analysis by weighting data according to survey conditions. Years when survey conditions are good, and perhaps when abundance of chinook salmon is low, would be given a greater weight than years when survey conditions were poor and/or abundance of chinook high.

As abundance increased the proportion of fish observed during the aerial counts decreased. This is largely expected given the data set and structure of the simulation. However, the simulation data sets also indicate that the variability in the observed proportion declines as abundance increased. Thus, at low abundance of spawning chinook the proportion of fish counted even under good conditions may vary a great deal. At higher abundances of chinook salmon the aerial counts will detect a smaller proportion of fish, but the proportion observed will tend to be less variable. The proportion of the population observed during an aerial survey is also dependent on environmental factors and timing of the survey with peak spawning.

The 95% confidence limits of the abundance estimate (+18% and -14% of the point estimate) were within the objectives set in the operational plan (within 25% of the actual value 95% of the time). This indicates the numbers of chinook salmon captured in Events 1 and 2 were more than adequate to meet the objective.

ACKNOWLEDGEMENTS

Alan Burkholder, Tim McKinley, Don Roach, Renate Reiff, and Alvin Ott Jr. conducted field work and data collection. James Hasbrouck, John Clark, and Peggy Merritt reviewed the data analysis and draft report. Sara Case prepared the draft and final report. The U.S. Fish and Wildlife Service provided partial funding for this study through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-8, Study S, Job No. 3-1(b).

LITERATURE CITED

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series No. 64, Juneau.

_____. 1989. Creel censuses in interior Alaska in 1988. Alaska Department of Fish and Game, Fishery Data Series No 95, Juneau.

Barton, L. H. 1984. A catalog of Yukon River salmon spawning escapement surveys. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report No. 121, Juneau.

_____. 1987a. Population estimate of chinook salmon escapement in the Chena River in 1986 based upon mark and recapture techniques. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon Salmon Escapement Report No. 31, Juneau.

_____. 1987b. Population size and composition of chinook salmon spawners in a small interior Alaska stream, 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon Salmon Escapement Report No. 32, Juneau.

_____. 1987c. Yukon area salmon escapement aerial survey manual. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks. Arctic, Yukon, and Kuskokwim Region, Yukon River Salmon Escapement Report No. 33.

Bernard, D. R., and P. A. Hansen. 1992. Mark-recapture experiments to estimate the abundance of fish. Alaska Department of Fish and Game, Division of Sport Fish, Anchorage. Special Publication Number 92-4.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5, ISSN 0362-1715, Bethesda, Maryland.

Burkholder, A. 1991. Abundance, egg production, and age-sex-length composition of the chinook salmon escapement in the Salcha River, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-5, Anchorage.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

Clark, R. A. 1985. Evaluation of sampling gears for fish population assessment in Alaska lakes. Master's Thesis. University of Alaska, Fairbanks, Alaska.

Clark, R. A., and W. P. Ridder. 1987. Tanana Drainage creel census and harvest surveys, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 12, Juneau.

Evenson, M. J. 1991. Abundance, egg production, and age-sex-size composition of the chinook salmon escapement in the Chena River, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-6, Anchorage.

_____. 1992. Abundance, egg production, and age-sex-size composition of the chinook salmon escapement in the Chena River, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-4, Anchorage.

Godfrey, H. 1957. Mortalities among developing trout and salmon ova following shock by direct-current electrical fishing gear. Journal of the Fisheries Research Board of Canada, 14(2).

Goodman, L. A. 1960. On the exact variance of products. Journal of American Statistical Association. Volume 55, pp. 708-713.

Hallberg, J. E. and A. E. Bingham. 1991. Creel surveys conducted in Interior Alaska during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-56, Anchorage.

Hallberg, J. E. and A. E. Bingham. 1992. Creel surveys conducted in interior Alaska during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-7, Anchorage.

_____. *In press*. Creel surveys conducted in interior Alaska during 1992. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Maxfield, G., R. Lander and K. Liscom. 1971. Survival, growth, and fecundity of hatchery-reared rainbow trout after exposure to pulsating direct current. Transaction of the American Fisheries Society. No. 3, pp. 546-552.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979 Project F-9-11, 20 (SW-I-A).

_____. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A).

_____. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

_____. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

_____. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A).

_____. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A).

_____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A).

_____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A).

_____. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-86, Project F-10-1, 27(RT).

_____. 1987. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game. Fishery Data Series No. 2, Juneau.

_____. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game. Fishery Data Series No. 52, Juneau.

_____. 1989. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game. Fisheries Data Series No. 122, Juneau.

_____. 1990. Harvest and participation in Alaska Sport Fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No.90-44, Anchorage.

_______. 1991. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage, Alaska.

_____. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Merritt, M. F., A. Bingham, and N. Morton. 1990. Creel Surveys conducted in Interior Alaska. Alaska Department of Fish And Game, Fishery Data Series No. 90-54, Anchorage.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company, Ltd.

Skaugstad, C. L. 1988. Abundance and age-sex-size composition of the 1987 Salcha River chinook salmon escapement. Alaska Department of Fish and Game, Fishery Data Series No. 37, Juneau.

_____. 1989. Abundance and age-sex-size composition of the 1988 Salcha River chinook salmon escapement. Alaska Department of Fish and Game, Fishery Data Series No. 75, Juneau.

_____. 1990a. Abundance, egg production, and age-sex-size composition of the chinook salmon escapement in the Salcha River, 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-23, Anchorage.

_____. 1990b. Abundance, egg production, and age-sex-size composition of the 1989 Chena River chinook salmon escapement. Alaska Department of Fish and Game, Fishery Data Series No. 90-13, Anchorage.

Skaugstad, C. L. and B. McCracken. 1991. Fecundity of chinook salmon, Tanana River, Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 91-8, Anchorage.

Welander, A.D. 1940. A study of the development of the scale of chinook salmon (*oncorhynchus tshawytscha*). Master's thesis, University of Washington, Seattle.

Appendix A

CAPTURE HISTORY OF CHINOOK SALMON ON THE SALCHA RIVER 1987 - 1992

Appendix A1. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1987.

Event - Period Date	River Section 3 (Upper) Recap No	Yes	2 (Middle) Recap No	Yes	1 (Lower) Recap No	Yes	Sub-Total Recap No	Yes	Total
Event 1:									
31 Jul 87					107			107	107
1 Aug 87			128					128	128
2 Aug 87	80							80	80
Sub-Total	80		128		107			315	315
Event 2[a] - Period 1:									
10 Aug 87	9	71					9	71	80
11 Aug 87	8	152					8	152	160
12 Aug 87			15	265			15	265	280
14 Aug 87					6	114	6	114	120
Sub-Total	17	223	15	265	6	114	38	602	640
Event 2[a] - Period 2:									
17 Aug 87	3	62					3	62	65
18 Aug 87			5	86			5	86	91
19 Aug 87					17	51	17	51	68
Sub-Total	3	62	5	86	17	51	25	199	224
Grand Total	20	285	20	351	23	165	63	801	864

[a] The dates reported by Skaugstad (1988) were incorrect.

Appendix A2. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1988.

Event - Period Date	River Section 1 (Lower) Recap No	Yes	2 (Middle) Recap No	Yes	3 (Upper) Recap No	Yes	Sub-Total Recap No	Yes	Total
Event 1 - Period 1:									
26-27 Jul 92	155						155		155
29 Jul 92			89				89		89
30 Jul 92					37		37		37
Sub-Total	155		89		37		281		281
Event 1 - Period 2:									
2 Aug 92	68						68		68
4 Aug 92			52				52		52
5 Aug 92					58		58		58
Sub-Total	68		52		58		178		178
Total	223		141		95		459		459
Event 2:									
3-4 Aug 92	240	25					240	25	265
5 Aug 92			141	24			141	24	165
5 Aug 92					339	43	339	43	382
Sub-Total	240	25	141	24	339	43	720	92	812
Grand Total	463	25	282	24	434	43	1,179	92	1,271

Appendix A3. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1989.

	River Section								
	3 (Upper)		2 (Middle)		1 (Lower)		Sub-Total		
Event - Period	Recap		Recap		Recap		Recap		
Date	No	Yes	No	Yes	No	Yes	No	Yes	Total
Event 1 - Period 1:									
2 Aug 89					60		60		60
3 Aug 89			32				32		32
4 Aug 89	38						38		38
Sub-Total	38		32		60		130		130
Event 1 - Period 2:									
7 Aug 89			42		36		78		78
8 Aug 89	15						15		15
Sub-Total	15		42		36		93		93
Total	53		74		96		223		223
Event 2:									
11 Aug 89	106	20					106	20	126
12 Aug 89			94	5			94	5	99
13 Aug 89					100	5	100	5	105
Sub-Total	106	20	94	5	100	5	300	30	330
Grand Total	159	20	168	5	196	5	523	30	553

Appendix A4. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1990.

Event - Period Date	River Section 1 (Upper) Recap No	Yes	2 (Middle) Recap No	Yes	3 (Lower) Recap No	Yes	Sub-Total Recap No	Yes	Total
Event 1 - Period 1:									
25 Jul 90					56		56		56
36 Jul 90			113		52		165		165
27 Jul 90	93						93		93
Sub-Total	93		113		108		314		314
Event 1 - Period 2:									
31 Jul 90					82		82		82
1 Aug 90			107				107		107
2 Aug 90	91						91		91
Sub-Total	91		107		82		280		280
Total	184		220		190		594		594
Event 2:									
6 Aug 90					440	38	440	38	478
7 Aug 90			260	17	209	11	469	28	497
8 Aug 90	115	1					115	1	116
9 Aug 90	268	13					268	13	281
Sub-Total	383	14	260	17	600	49	1,292	80	1,372
Grand Total	567	14	480	17	790	49	2,153	93	2,246

Appendix A5. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1991.

Event - Period	River Section: 1 (Upper) Recap		2 (Middle) Recap		3 (Lower) Recap		Sub-Total Recap		
Date	No	Yes	No	Yes	No	Yes	No	Yes	Total
Event 1 - Period 1:									
26 Jul 91	40						40		40
27 Jul 91	69		62		19		150		150
28 Jul 91					13		13		13
Sub-Total	109		62		32		203		203
Event 1 - Period 2:									
29 Jul 91	119						119		119
30 Jul 91			102		34		136		136
31 Jul 91					17		17		17
Sub-Total	119		102		51		272		272
Total	228		164		83		475		475
Event 2:									
5 Aug 91	127	15					127	15	142
6 Aug 91	153	10	202	20			355	30	385
8 Aug 91					165	14	165	14	179
Sub-Total	280	25	202	20	165	14	647	59	706
Grand Total	508	25	366	20	248	14	1,122	59	1,181

Appendix A6. Capture history of chinook salmon by date, period, and event during mark-recapture experiments on the Salcha River, 1992.

Event - Period Date	River Section 1 (Upper) Recap No	Yes	2 (Middle) Recap No	Yes	3 (Lower) Recap No	Yes	Sub-Total Recap No	Yes	Total
Event 1 - Period 1:									
29 July 92	118						118		118
30 July 92	72		32		11		115		115
31 July 92					13		13		13
Sub-Total	190		32		24		246		246
Event 1 - Period 2:									
03 Aug. 92	55						55		55
04 Aug. 92	91		13				104		104
05 Aug. 92			2		27		29		29
Sub-Total	146		15		27		188		188
Total	336		47		51		434		434
Event 2:									
10 Aug. 92	157	3					157	3	160
11 Aug. 92	271	29					271	29	300
12 Aug. 92	201	4	118	9			319	13	332
13 Aug. 92			93	6	65	1	158	7	165
Sub-Total	629	36	211	15	65	1	905	52	957
Grand Total	965	36	258	15	116	1	1,339	52	1,391