Fishery Data Series No. 96-17

Salmon Studies in Interior Alaska, 1995

by

Matthew J. Evenson

July 1996

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 96-17

SALMON STUDIES IN INTERIOR ALASKA, 1995

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ABSTRACT

Escapements of chinook salmon *Oncorhynchus tshawytscha* in the Salcha and Chena rivers near Fairbanks, Alaska in 1995 were estimated. A portion of the chum salmon *O. keta* escapements in the Salcha and Chena rivers was also estimated. A stratified systematic sampling design was used to count chinook and chum salmon during 20 min periods each hour as they passed beneath elevated counting structures on the Salcha and Chena rivers. High water and poor visibility led to an incomplete estimate for the Chena River. As a result, a mark-recapture experiment was conducted to estimate escapement of chinook salmon. Tower count estimates of escapement for chinook and chum salmon in the Salcha River were 13,643 (SE = 471) and 30,784 (SE = 605), respectively. The incomplete estimates of escapement for chinook and chum salmon in the Chena River from tower counts were 5,388 (SE = 275) and 3,519 (SE = 170), respectively. The mark-recapture estimate of escapement for chinook salmon in the Chena River using a maximum likelihood model was 9,680 (SE = 958). Chinook salmon carcasses were collected during early August from both rivers. Females comprised 0.56 (SE = 0.02) of the sample in the Salcha River and 0.66 (SE = 0.02) in the Chena River. Age class 1.4 comprised most of the females sampled in both rivers, while ages 1.2, 1.3, and 1.4 comprised most of the males in the samples. Aerial survey counts of chinook salmon at peak escapement were 3,978 for the Salcha River and 3,567 for the Chena River populations. These aerial counts were 0.44 and 0.46 of the respective abundance estimates.

A boat count was conducted in a section of the Chatanika River to index peak escapement of chinook salmon. The count was 444 chinook salmon. This count is the highest on record. Seventy carcasses were collected on a separate survey. Females comprised 0.63 (SE = 0.06) of this sample. Females were most represented by ages 1.3 and 1.4, while males were most represented by ages 1.2 and 1.3.

Coho salmon *O. kisutch* in the mainstem Delta Clearwater River near Delta Junction were counted from a drifting river boat at peak escapement on 23 October. Counts in spring areas adjacent to the mainstem river and in tributaries not accessible by boat were conducted from a helicopter on 2 November. The total count for the entire river was 26,383 coho salmon, which was an above average escapement. The count of coho salmon in the mainstem river was 20,100 (0.76 of total), while the count in tributaries and spring areas was 6,283 (0.24 of total). Three hundred eighty-one carcasses were collected on two separate sampling occasions. Males comprised 0.60 of the sample. Age 2.1 comprised 0.69 of the sample.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, chum salmon, *Oncorhynchus keta*, coho salmon, *Oncorhynchus kisutch*, Salcha River, Chena River, Chatanika River, Delta Clearwater River, age sex-length composition, aerial survey, abundance, mark-recapture, counting towers, carcass survey, escapement.

CHINOOK AND CHUM SALMON STUDIES IN THE SALCHA , CHENA, AND CHATANIKA RIVERS

INTRODUCTION

The Salcha and Chena rivers (Figures 1 and 2) have some of the largest chinook salmon escapements in the Yukon River drainage (Schultz et al. 1994). Popular sport fisheries occur in the lower 3 km of the Salcha River and in the lower 72 km of the Chena River. Annual harvests have ranged from 47-904 fish since 1978 in the Salcha River, and from 0 to 993 chinook salmon since 1978 in the Chena River (Mills 1979-1994 and Howe et al. 1995; Table 1). The Chatanika River (Figure 3) supports a small run of chinook salmon, however recent estimates of sport harvests (Table 1) have indicated that relative exploitation may be large. Before reaching their spawning grounds in the mid to upper reaches of these rivers, 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 4). Subsistence and personal use fishing also occur in each district.

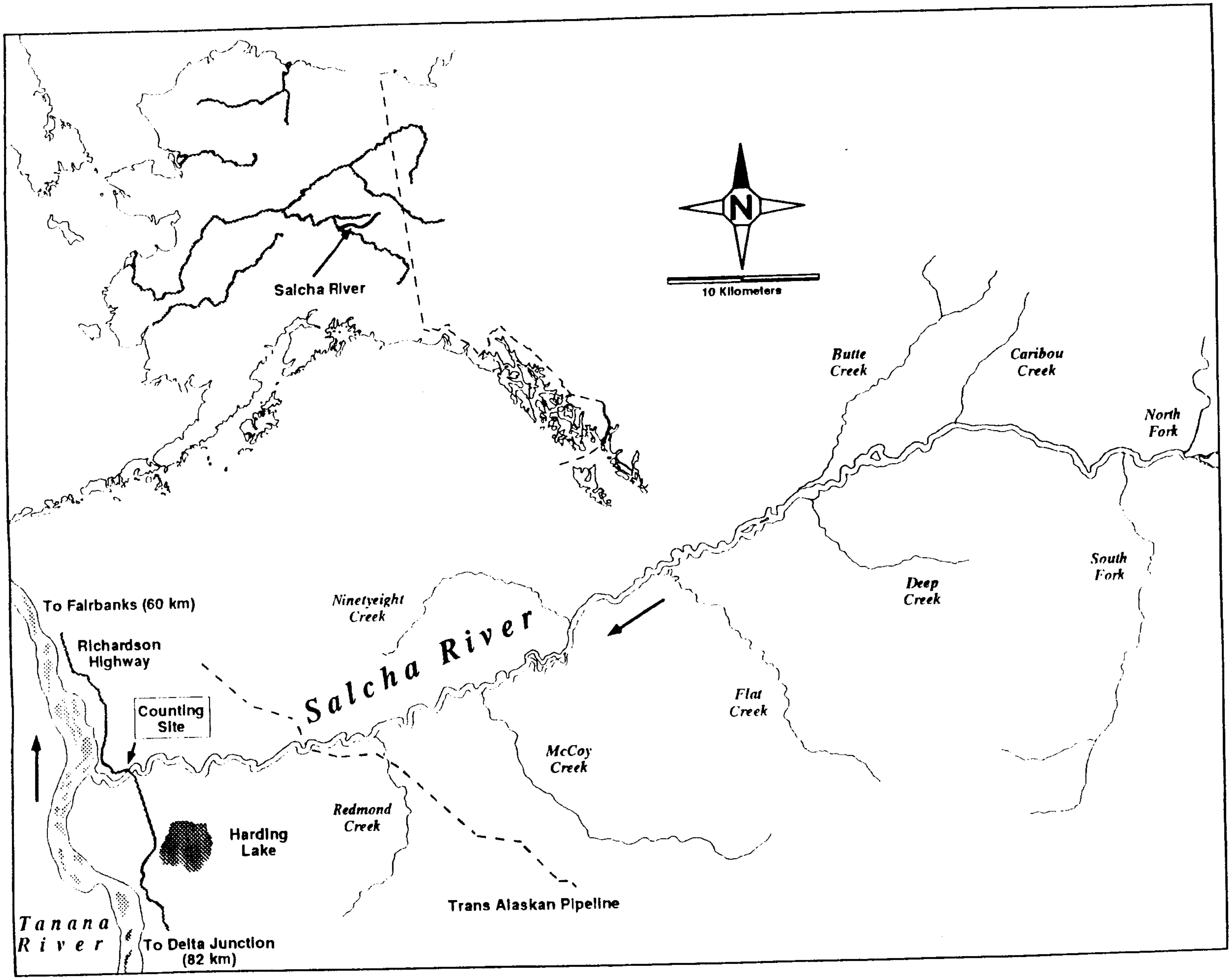

Figure 1.-Salcha River study area

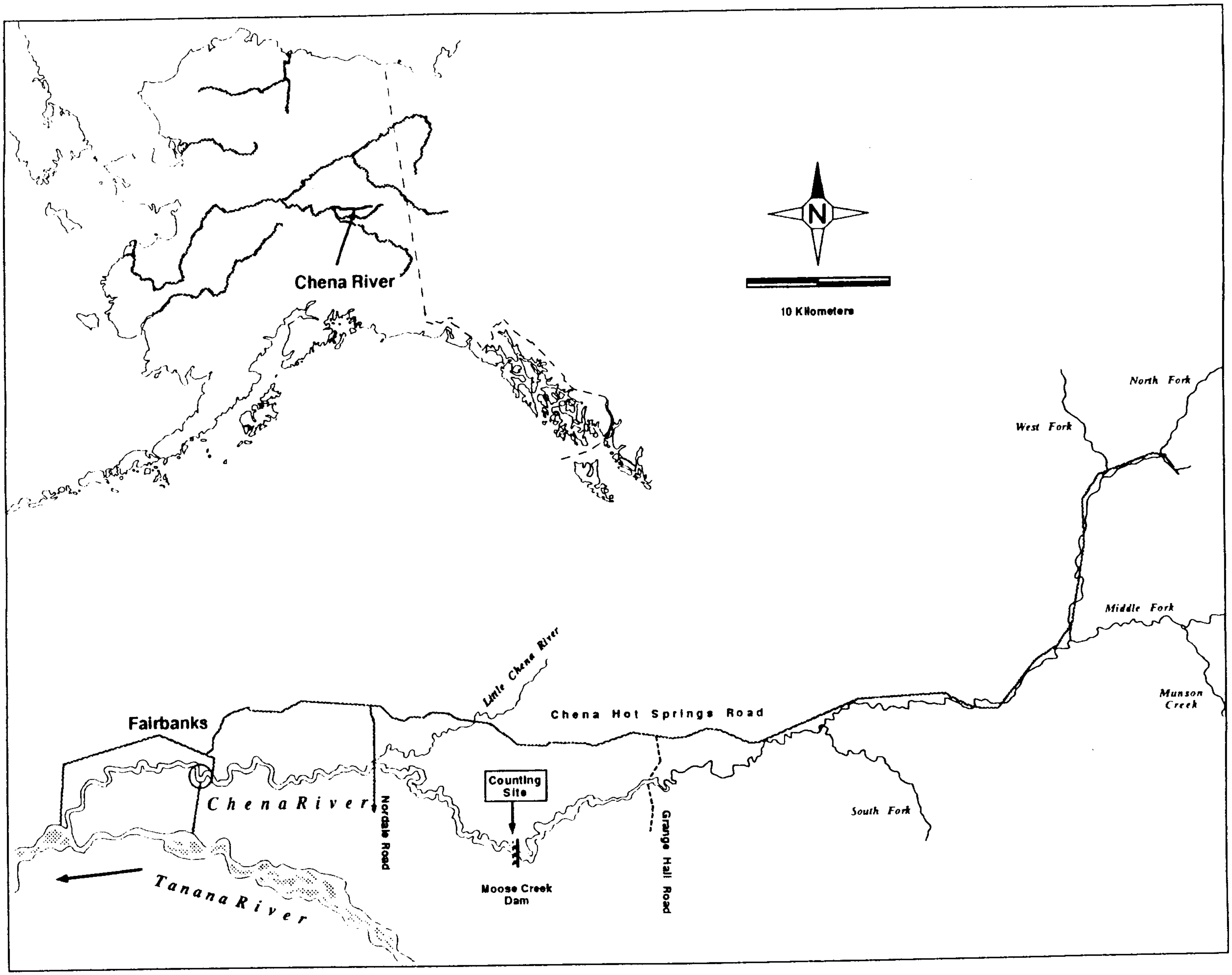

Figure 2.-Chena River study area.

Table 1.-Harvests of anadromous chinook salmon by sport, commercial, subsistence, and personal use fisheries, Tanana River drainage, 1978 - 1995.

	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	3,338	4,096	7,908
1988	567	19	73	236	345	36	54	744	762	5,189[d,e]	6,695
1989	685	123	375	231	231	39	87	963	1,741	1,546[d,e]	4,250
1990	24	200	64	291	37	0	0	439	2,156	3,069[d,e]	5,664
1991	none	362	110	373	82	11	54	630	1,072	2,515[d,e]	4,217
1992	none	4	39	47	16	0	0	118	752	2,438[d,e]	3,308
1993	none	54	733	601	192	0	19	1,573	1,445	2,098[d]	5,156
1994	none	776	993	714	105	0	59	1,871	2,606	2,568[d]	7,045
1995	none	NA[f]	NA	NA	NA	NA	NA	NA	2,748[d]	NA	NA

[a] Creel census estimates from Clark and Ridder (1987), Baker (1988, 1989), Merritt et al. (1990), and Hallberg and Bingham (1991-1995).

[b] Sport fishery harvest estimates from Mills (1979-1994) and Howe et al. 1995.

[c] Commercial, subsistence, and personal use estimates (Schultz et al. 1994, and, Keith Schultz, Personal Communication. Alaska Department of Fish and Game, Sport Fish Division, 1300 College Road, Fairbanks, AK 99701).

[d] Preliminary data and subject to change.

[e] The personal use designation was implemented in 1988 to account for non-rural fishermen participating in this fishery. Harvests by personal use fishermen were 623, 453, 451, 0, and 0 for 1988-1992, respectively.

[f] NA means data not available at this time.

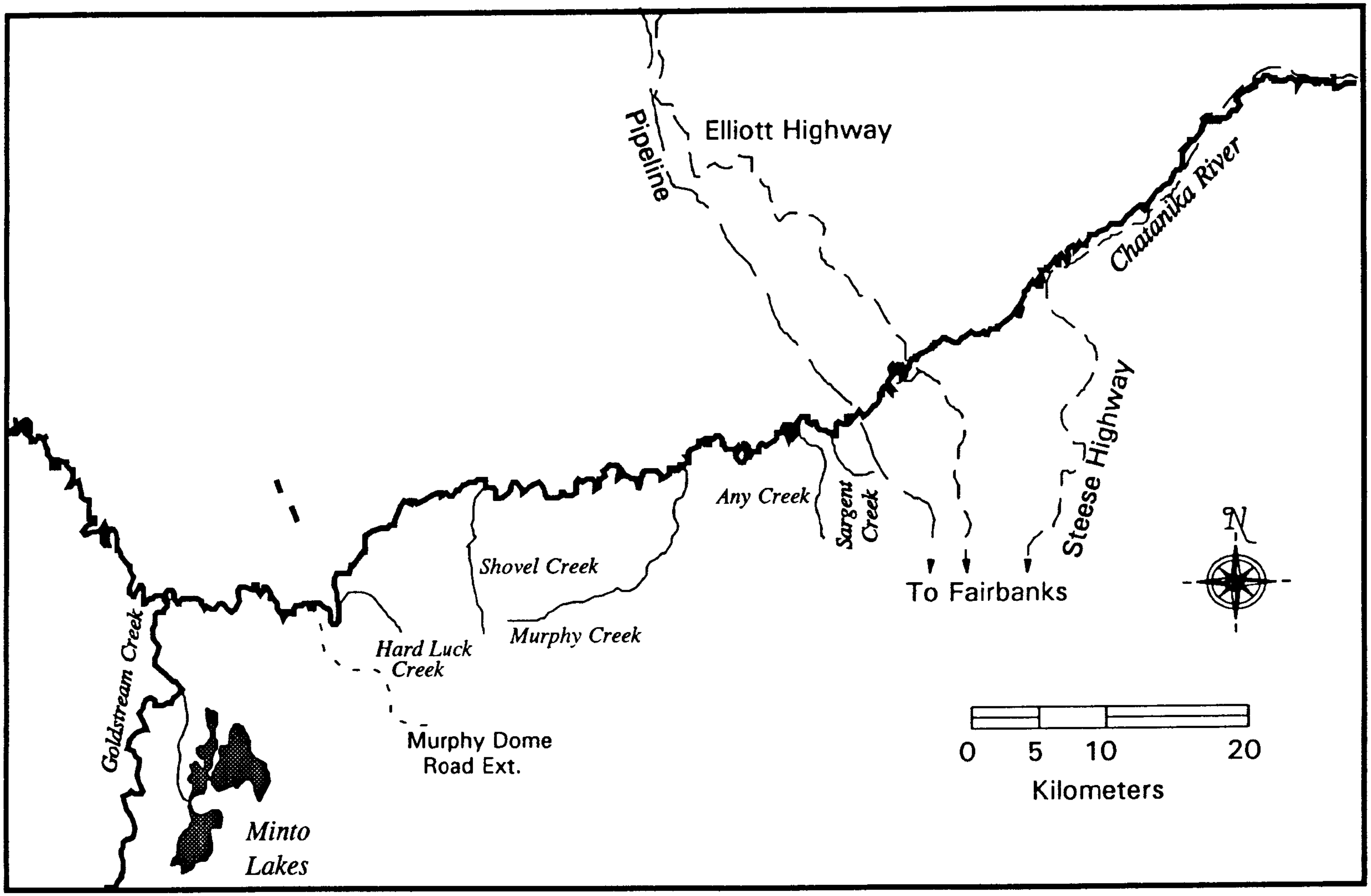

Figure 3.-Chatanika River study area.

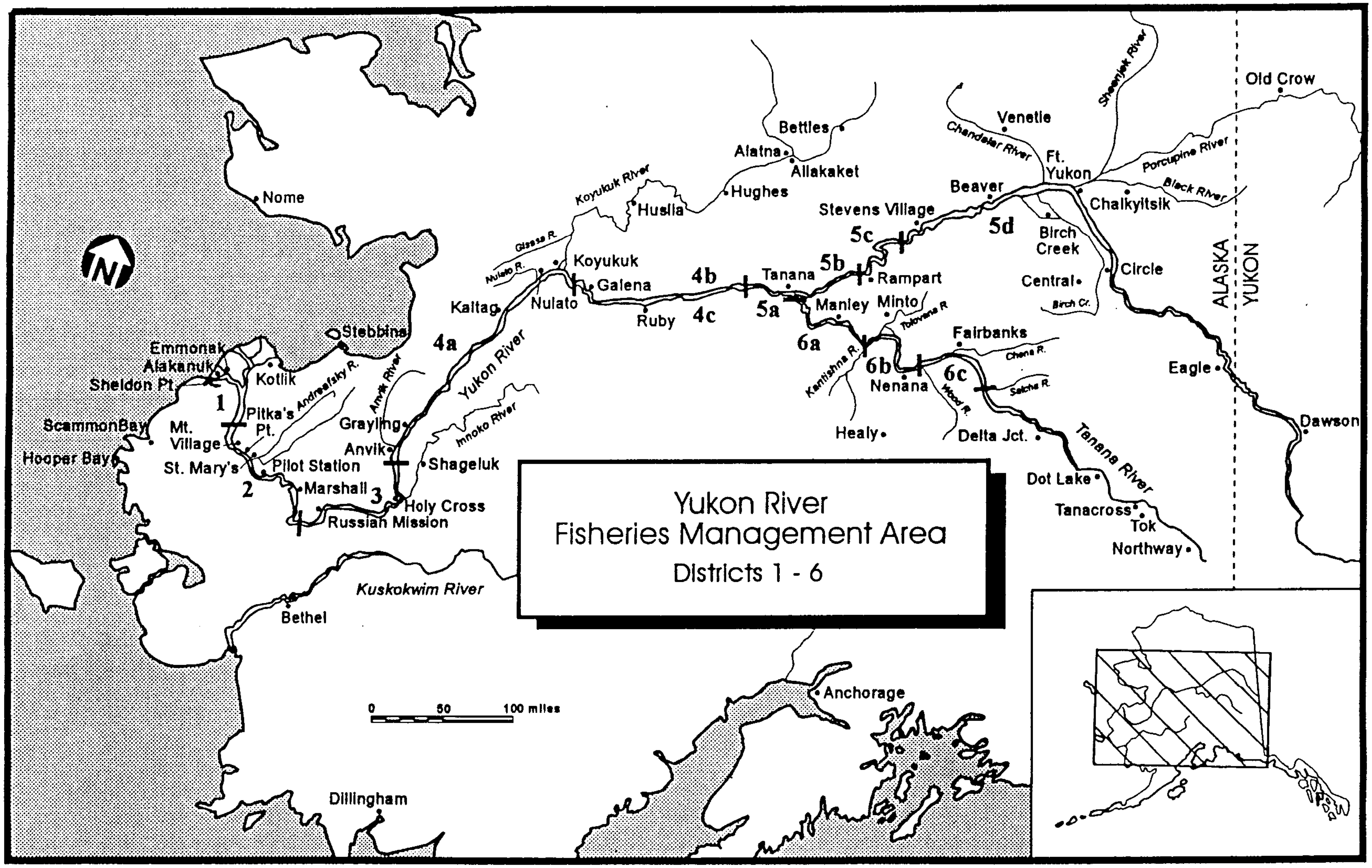

Figure 4.-Fishing districts in the Yukon River drainage.

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. Mark-recapture experiments occur after most of the escapement has passed through the various fisheries, and aerial surveys do not provide consistent indices of escapement. Tower counting methodology was initiated during the 1993 season for the Chena and Salcha rivers, and has been used subsequently as a means for estimating inseason escapement.

Escapements of chinook salmon in the Chatanika River have historically been assessed on a semi-annual basis with aerial surveys from fixed wing aircraft. This methodology seems to be inadequate as survey estimates from some years are less than harvest estimates for the same years.

Minimum escapement objectives for chinook salmon returning to the Salcha and Chena rivers have been established by the Alaska Department of Fish and Game (Appendix A). Objectives are to achieve aerial counts of 2,500 fish in the Salcha River and 1,700 fish in the Chena River. 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 using these expansions are 7,100 for the Salcha River and 6,300 for the Chena River (Appendix A). No escapement guidelines have been developed based on tower count estimates for the Chena or Salcha rivers, nor have escapement objectives of any kind been established for the Chatanika River.

In 1987 the Board of Fisheries 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 in the Salcha River is typically monitored with creel surveys, however, given the dispersed nature of the fishery in the Chena River, creel surveys are costly and have not been conducted since 1990.

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 of chinook salmon, but does overlap the chinook salmon migration. Because sport fisheries exploit these stocks, the abundance of the chum salmon escapements was monitored to ensure that the sport harvest did not adversely impact escapement. Currently there are no established harvest guidelines for chum salmon in either river. There is an escapement objective of 3,500 chum salmon from aerial surveys for the Salcha River, but no escapement objective exists for the Chena River.

The objectives and tasks of the chinook salmon projects in 1995 were to:

1. estimate the escapements of chinook salmon in the Salcha and Chena rivers using tower counts or mark-recapture experiments;
2. count chinook salmon in the Chatanika River from a drifting riverboat;
3. estimate age, sex, and length compositions of the escapements of chinook salmon in the Salcha, Chena, and Chatanika rivers; and,
4. count chum salmon in the Salcha and Chena rivers from towers during the period of the chinook salmon migration.

METHODS

Tower Counts

Chinook and chum salmon returning to the Salcha and Chena rivers were estimated by counting fish as they passed beneath elevated counting sites (the Richardson Highway Bridge on the Salcha River and the Moose Creek Dam on the Chena River; Figures 1 and 2). Little, or no spawning takes place downstream from these sites. Counting was conducted daily from 10 July through 30 July for the Chena River and from 5 July through 14 August for the Salcha River. High water levels in both rivers postponed the starting dates for counting beyond the planned start date of 1 July. Light-colored cloth panels were placed on the river bottom downstream from the counting structures to improve the visibility of fish moving over the panels. Lights were suspended from the counting towers and were used during periods of low ambient light. Because salmon often will avoid areas with artificial substrate or illumination, the panels and overhanging lights were positioned to form a continuous band from bank to bank. Once the artificial lighting was turned on, it was left on until ambient light was sufficient to observe salmon. This was done to ensure that salmon would pass over the panels at the same rate during counting periods as during noncounting periods.

Four persons were assigned to each river to conduct counts. Personnel were assigned 8 h shifts and counted salmon the first 20 min of every hour. This was a stratified systematic sampling design. The counts were limited to 20 min to alleviate eye strain and fatigue associated with this type of work. A week consisted of 21, eight hour shifts (three shifts each day). Shift I started at 0000 h (midnight) and ended at 0759 h; Shift II started at 0800 h and ended at 1559 h; Shift III started at 1600 h and ended at 2359 h.

The sampling design called for counting during 17 of the 21 possible shifts each week. The noncounting shifts were to be randomly assigned each week with the following constraints: 1) noncounting shifts would not occur consecutively; 2) noncounting shifts would not occur during the same shift on consecutive days; and, 3) each of the three shifts would receive at least one noncounting shift each week. This design was modified, however, due to high water events in one or both rivers. Counting was terminated on the Chena River on 30 July due to high water and poor counting conditions. After 1 August on the Salcha River, counts were conducted to a lesser degree due to financial constraints (Appendix B).

Abundance Estimator

Estimates of abundance were stratified by day to provide managers with a timely description of escapement. 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.

For each day sampled, the number of salmon to pass by the tower was estimated:

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

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

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 (total number moving upstream minus total number moving downstream);
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 during the sampling period;
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:

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

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

For days when only one shift was worked, there were no estimates of the shift to shift variation. In these cases, a coefficient of variation (CV) was calculated for each river and species using all days when more than one shift was worked. The average CV for each river and species was then used to estimate the daily variation for those days when only one shift was worked. The coefficient of variation was used because it is independent of the magnitude of the estimate and was relatively constant throughout the run. The CV was calculated for each river and species as:

$$CV = \frac{s}{N_h} * 100\% \tag{10}$$

For days that were not sampled at all, the daily estimate for each river and species was calculated as the average of the day(s) before and the day(s) after the missed day(s). The number of days used for the average was equal to the number of missed days. For example, if two consecutive days were missed, the estimate for the first missed day would be the average of the two days before and after that day (zero counts not included in average). The estimate of the daily variance for count estimates on missed days was calculated as the maximum estimated variance for the day(s) before and after.

Mark-Recapture Experiment: Chena River

Because of the large number of missed counts on the Chena River due to high water and poor counting conditions, the estimate of total chinook salmon passage was deemed inadequate, and a two-sample mark-recapture experiment was conducted to estimate abundance.

Marking Event

A river boat equipped with electrofishing gear (Clark 1985) was used to capture adult chinook salmon. Captured chinook salmon were measured to the nearest 5 mm (mid-eye to fork-of-tail), marked by attaching an individually numbered jaw tag and by removing a fin, and released alive. Fish were marked during two complete passes through the study section. Each pass required four days to complete. The first pass occurred 25-28 July, and the second occurred 1-4 August. The timing of the marking event was centered around the short period after completion of immigration and spawning and before fish began to die.

The study area was divided into three sections roughly equal in length. Due to potential loss of tags, a unique fin clip was given corresponding to time and location of tagging (Table 2).

Table 2.-River section designations and fin clips used in the mark-recapture experiment in the Chena River during 1995.

Section	River km	Event	Date	Fin Clip
Lower	72-97	First Pass	25-26 July	Left Ventral
		Second Pass	26-27 July	Left Pectoral
Middle	98-124	First Pass	27-28 July	Right Ventral
		Second Pass	1-2 August	Right Pectoral
Upper	125-161	First Pass	2-3 August	Adipose
		Second Pass	3-4 August	Anal

Recapture Event

One complete survey of the study area was conducted for the recapture event during 8-15 August. Long handled spears were used to collect carcasses. All chinook salmon carcasses that were found were examined for tags and missing fins, sex was determined, and length was measured. Three scales were removed from each carcass for age determination. River sections were as designated during the marking events. All carcasses encountered during the survey were cut in a distinctive manner to avoid resampling. Sample sizes for each event were determined using an *a priori* estimate of the population size and the desired precision and accuracy of the estimate (95%, ± 25%) according to Robson and Regier (1964).

Assumptions

An unbiased estimate of abundance from a two-event mark-recapture experiment (Seber 1982) requires that the following two assumptions must be fulfilled:

1. catching and handling the fish does not affect the probability of recapture; and,
2. marked fish do not lose their mark.

Catching and handling the fish should not have affected the probability of recapture because the experiment was designed to mark live fish and later recover carcasses. If jaw tags were lost, the fin clip given each fish would identify the river section where it was marked.

Of the following assumptions, at least one must be fulfilled:

1. every fish has an equal probability of being marked and released during electrofishing;
2. every fish has an equal probability of being collected during the carcass survey; or,
3. marked fish mix completely with unmarked fish between electrofishing and carcass surveys.

The procedures for testing these assumptions and the methods for alleviating bias due to gear selectivity are described in Appendix C.

Abundance Estimator

Three abundance estimators were investigated during the analysis. The unbiased Petersen estimator and associated sampling variance are (Chapman 1951):

$$\hat{N}^* = \left[\frac{(n_1+1)(n_2+1)}{(m_2+1)}\right] - 1 \qquad (11)$$

$$V(\hat{N}^*) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \qquad (12)$$

where:

$\hat{N}*$ = the estimated abundance of chinook salmon;

n_1 = the number of fish marked while electrofishing;

n_2 = the number of carcasses collected during the carcass survey; and,

m_2 = the number of marked carcasses collected during the carcass survey.

The Darroch estimator (Darroch 1961):

$$\hat{N}^{\sim} = \boldsymbol{n}' \boldsymbol{M}^{-1} \boldsymbol{a} \quad (13)$$

where:

$\hat{N}^{\sim}$ = the estimated abundance of chinook salmon

$\boldsymbol{n}'$ = a vector of the number of carcasses recovered in sections 1, 2, and 3;

$\boldsymbol{M}^{-1}$ = a matrix by river sections where the fish were marked and then recovered; and,

$\boldsymbol{a}$ = a vector of the number of fish marked and released in sections 1, 2, and 3.

The variance of $N^{\sim}$ was obtained using resampling techniques (bootstrapping) on the capture history (Efron and Gong 1983; Buckland, unpublished). A FORTRAN program[1] was used for the bootstrap sampling. Capture histories were summarized by strata, and included the number released and never recaptured, the number recaptured, the number captured during recovery event for the first time, the total number of unique individuals examined during the experiment, and a recapture matrix comparing the location of release to the location of capture for all recaptured fish. The capture history was sampled 1,000 times. The matrix $\boldsymbol{M}$ and the vectors $\boldsymbol{a}$ and $\boldsymbol{n}$ were constructed from each sample of the capture history. The individual bootstrap estimates of abundance and probabilities of capture were inspected as well as the overall statistical bias in the estimate. An estimate from Darroch's model that is free of statistical bias will have few or no negative stratified estimates of abundance among the bootstrap samples nor will there be many (if any) impossible probabilities of capture. The variance was calculated as the variance of the mean of all bootstrap estimates.

Darroch's model was investigated because the hypothesis test for equal probability of capture by river area and inspection of the recapture data indicated capture probabilities were dissimilar, and thus Petersen's model may have provided a biased estimate of abundance. This test and inspection did not reveal how large that bias may be. Therefore, the point estimates from each estimator were compared. Similar estimates would indicate that the bias in the estimate from Petersen's model is negligible, and the statistic with the lower variance (typically the Petersen estimate) is the

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[1] The FORTRAN program DARBT2 was written by Marianna Alexandersdottir, Alaska Department of Fish and Game, Sport Fish Division, 333 Raspberry Road, Anchorage, AK, 99518, and is available from the author.

better estimate. Dissimilar estimates would indicate that bias in the estimate from Petersen's model is significant, and bias in the estimate from Darroch's model is more parsimonious.

The third estimator investigated was the maximum likelihood (ML) estimate of the Darroch likelihood (Darroch 1961) found by the direct searching algorithm of Hooke and Jeeves (Mike Wallendorf, Alaska Department of Fish and Game, Fairbanks, personal communication). This estimator was examined because the Darroch model calculated a negative capture probability for the middle section. In addition, calculation of a variance estimate using bootstrap techniques was not possible due to the low number of recaptured fish from the lower section. The ML estimator required that for each tagging location, the movement probabilities were restricted to sum to 1 (consistent with the closure assumption). The objective function for the natural log of the Darroch likelihood was:

$$L = \sum_i \{(a_i - c_{i.})\log[1 - \sum_j \Theta_{ij} p_j]\} + \sum_i \sum_j c_{ij} \log(\Theta_{ij} p_j), \quad (14)$$

where:

a_i = number of fish tagged at location i;

c_{ij} = number tagged fish from location i recaptured at location j;

$c_{i.} = \sum_j c_{ij}$;

p_j = second sample capture probability for location j; and,

Θ_{ij} = probability of movement from tagging location i to recapture location j.

The estimate of untagged fish in the jth location of the second sample was:

$$\tilde{n}_j = b_j / \hat{p}_j \quad (15)$$

where b_j was the number of untagged fish caught in the second sample.

Total abundance was:

$$\tilde{N} = \sum_j \tilde{n}_j + \sum_i a_i \quad (16)$$

The covariance matrix for the capture probabilities and movement probabilities were estimated from the observed information matrix. The variance for the abundance estimate was then approximated using the delta method (Agresti 1990).

Chatanika River Boat Count

Chinook and chum salmon were counted in the Chatanika River during 25-27 July by two persons from a drifting canoe. Salmon were counted from the Cripple Creek confluence (river km 232) downstream to the Elliot Highway Bridge (river km 166; Figure 3).

Age-Sex-Length Compositions

Chinook salmon carcasses were collected from a drifting river boat using long-handled spears. Carcasses were collected in the Salcha River 0 to 96 km from the mouth, in the Chena River 72 to 161 km from the mouth, and in the Chatanika River 166 to 232 km from the mouth. Carcasses were collected in the Chena River during the recapture event for the mark-recapture experiment during 8-15 August. Carcasses were collected in the Salcha River on two separate occasions; the first sample was collected 1-4 August, and the second was collected 15-16 August. Carcasses were collected in the Chatanika River during a single occasion from 8-10 August. All collected carcasses were examined to determine sex and measured from mid-eye to fork-of-tail. Three scales were removed from each fish and placed directly on gum cards for 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 (Welander 1940). Ages were determined from scale patterns as described by Mosher (1969).

Mean lengths were estimated for combinations of age and sex using the sample mean and sample variance of the mean (Zar 1984). Proportions of female and male chinook salmon by ocean-age and the associated variances were estimated for each river using:

$$\hat{p}_g = \frac{n_g}{n} \tag{17}$$

$$\hat{V}(\hat{p}_g) = \frac{\hat{p}_g(1-\hat{p}_g)}{n-1} \tag{18}$$

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 (for the Salcha River) was estimated:

$$\hat{N}_g = \hat{p}_g \hat{N} \quad (19)$$

where $\hat{N}$ = population abundance estimate from the tower counts.

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

$$\hat{V}(\hat{N}_g) = \hat{N}^2\hat{V}(\hat{p}_g) + \hat{p}_g^2\hat{V}(\hat{N}) - \hat{V}(\hat{p}_g)\hat{V}(\hat{N}) \quad (20)$$

Aerial Counts

Aerial survey counts were conducted on two different occasions in the Salcha and Chena rivers. The first pair of counts (one for each rivers) were conducted on 9 July to determine the number of fish that had passed the tower sites prior to the start of counting. These counts were conducted by Sport Fish Division personnel from a Robertson (R-22) helicopter flying at 100 m above ground. The second pair of counts was conducted by Commercial Fisheries Management and Development Division personnel at peak escapement. The Chena River survey was conducted on 27 July, and the Salcha River survey was conducted on 28 July. Counts were made from low flying, fixed-wing aircraft. Barton (1987b) described the methods used for these aerial surveys. The proportion of salmon counted by the aerial survey to the total estimated escapement was calculated.

Data Archiving

Data for these analyses are archived as described in Appendix D.

RESULTS

High water and poor visibility during late June and early July postponed installation of flash panels and counting five days in the Salcha River and ten days in the Chena River from the planned start date of 1 July. Water levels and turbidity in both rivers were low through 15 July, however subsequent high water events prevented counting for two days (16-17 July) on the Salcha River and three days on the Chena River (16-18 July). High water starting on 31 July terminated tower counting on the Chena River. Counts continued on the Salcha River through 14 August, however three days (6-8 August) were missed due to another high water event.

Tower Counts: Salcha and Chena Rivers

Chinook salmon were observed on the first day of counting (10 July) in the Chena River, and on the second day of counting (5 July) in the Salcha River. The daily escapement pattern was unimodal for the Chena River with peak escapement occurring on 14 July (Table 3; Figure 5). The daily escapement pattern was bimodal for the Salcha River with peaks occurring on 13 July and 24 July (Table 4, Figure 5). Few chinook salmon were observed after 5 August in the Salcha River. Cumulative distributions of daily abundance were similar in configuration for both rivers (Figure 6). The estimated number of chinook salmon moving past the counting site in the Salcha River was 13,643 (SE = 471). The estimated passage of chinook salmon in the Chena River was 5,388 (SE = 275).

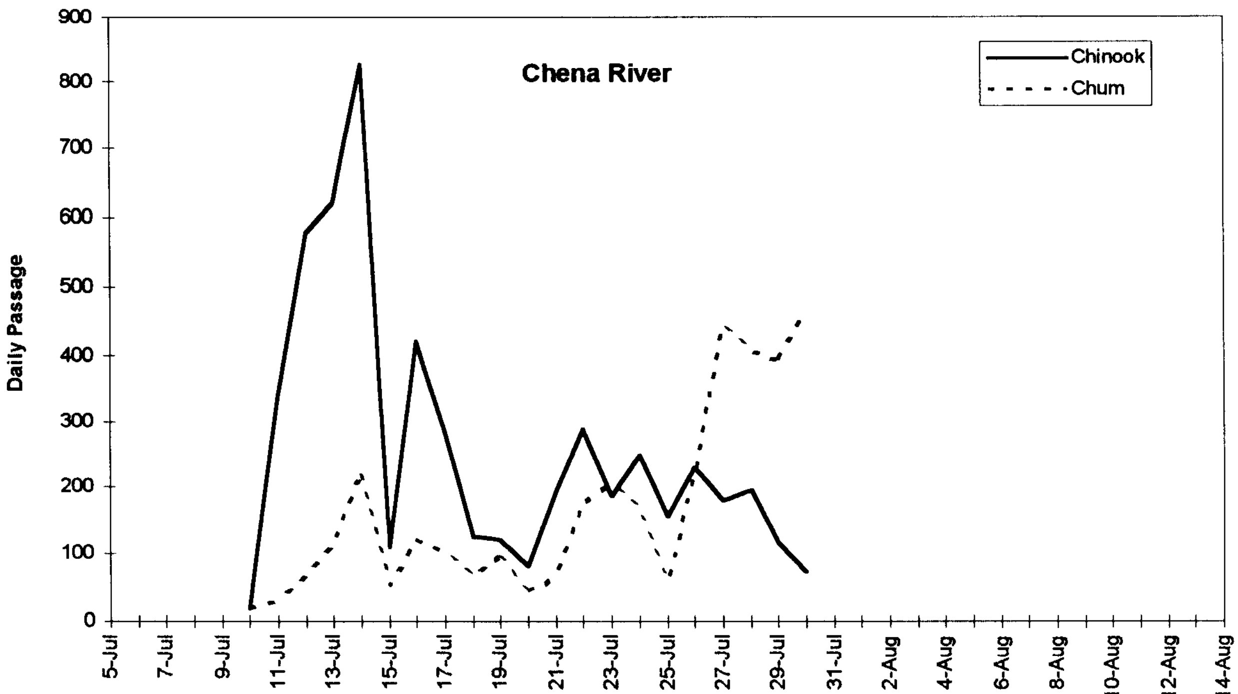
Table 3.-Daily counts and estimates of the number of chum and chinook salmon passing by the counting site in the Salcha River during 1995.

	Shifts	Chum			Chinook		
Date	Sampled	Count	Daily Passage	SE	Count	Daily Passage	SE
7/5/95	1	0	0	0	0	0	0
7/6/95	2	1	5	4	4	18	9
7/7/95	3	9	27	15	15	45	10
7/8/95	3	5	15	5	75	228	33
7/9/95	3	8	24	6	49	150	31
7/10/95	2	2	9	5	135	607	60
7/11/95	2	15	68	17	136	612	79
7/12/95	2	53	262	58	179	864	95
7/13/95	1	14	126	22	142	1,278	249
7/14/95	2.5	65	198	23	270	912	81
7/15/95	3	35	111	21	91	276	42
7/16/95	0	0	159	31	0	682	249
7/17/95	0	0	166	33	0	533	81
7/18/95	2	62	180	26	62	284	39
7/19/95	2	40	180	31	147	662	67
7/20/95	2	32	163	33	122	582	64
7/21/95	3	141	453	58	144	432	50
7/22/95	3	158	474	70	210	630	48
7/23/95	3	198	534	50	167	501	49
7/24/95	2	223	1,004	69	330	1,485	158
7/25/95	2	162	729	86	132	594	56
7/26/95	3	286	858	88	134	402	49
7/27/95	2	273	1,229	152	85	382	82
7/28/95	3	716	2,148	154	140	381	46
7/29/95	2	344	1,548	185	59	266	44
7/30/95	3	449	1,317	151	61	183	25
7/31/95	2.4	366	1,443	226	54	207	34
8/1/95	3	643	1,929	129	55	165	28
8/2/95	3	551	1,653	125	20	60	14
8/3/95	3	559	1,527	116	16	54	12
8/4/95	3	599	1,797	143	11	33	10
8/5/95	2.75	355	1,118	100	14	46	9
8/6/95	0	0	1,417	143	0	33	12
8/7/95	0	0	1,288	143	0	20	10

-continued-

Table 3.-Page 2 of 2.

Date	Shifts Sampled	Chum Count	Chum Daily Passage	Chum SE	Chinook Count	Chinook Daily Passage	Chinook SE
8/8/95	0	0	1,104	115	0	21	9
8/9/95	2	272	1,224	115	0	0	0
8/10/95	2	159	716	63	0	0	0
8/11/95	2	283	1,358	81	2	10	5
8/12/95	2	264	1,188	92	0	0	0
8/13/95	2	174	783	67	1	5	4
8/14/95	1	50	252	57	0	0	0
Total	111.7	13,966	30,784	605	2,819	13,643	471



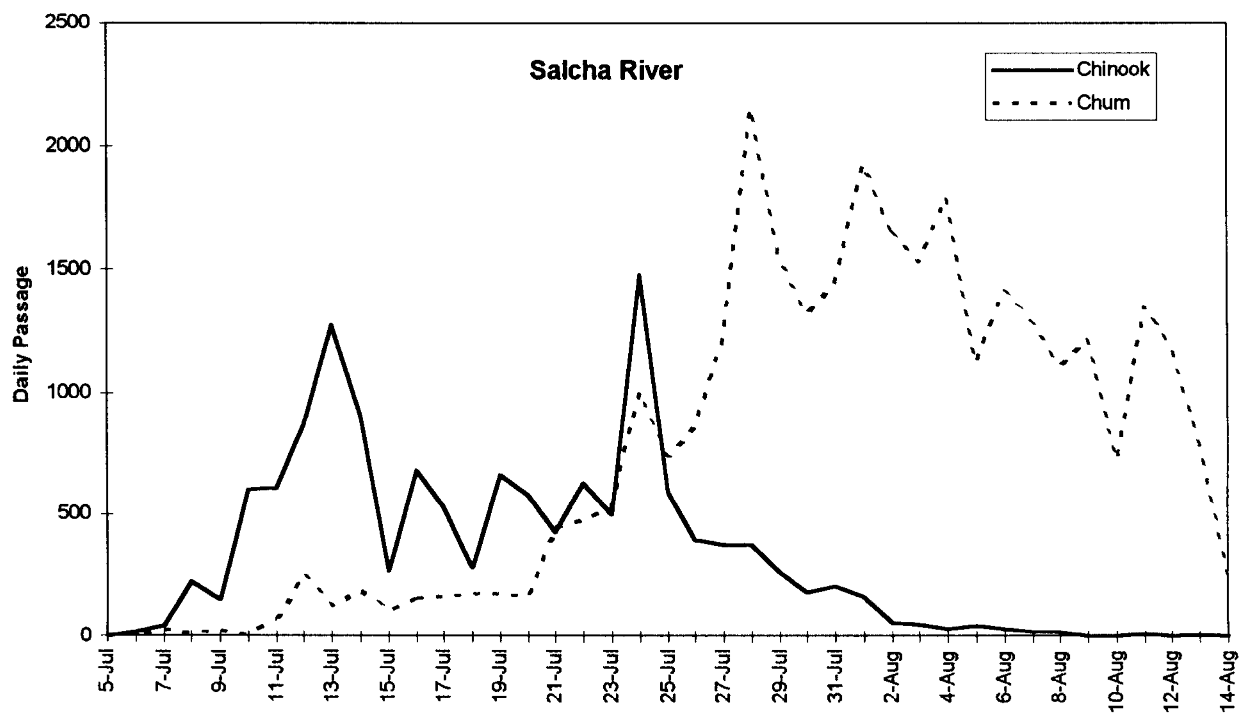
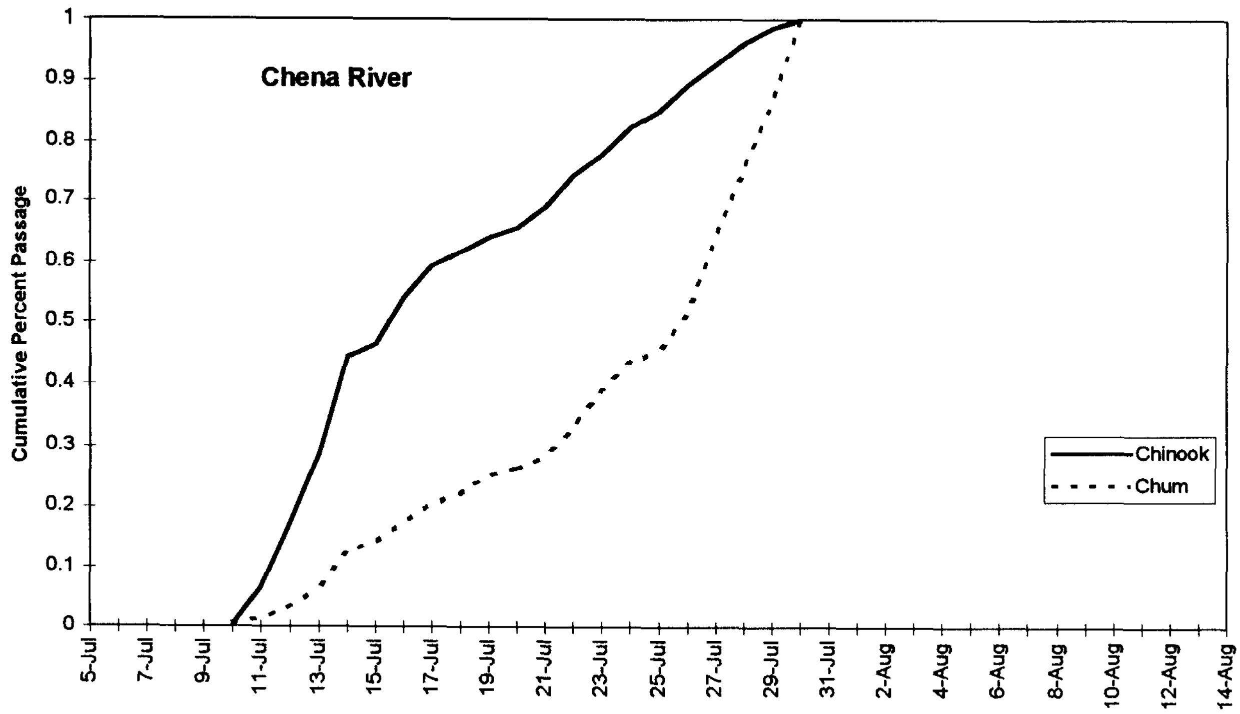


Figure 5.-Daily estimates of passage for chinook and chum salmon past the counting sites on the Chena and Salcha rivers during 1995.

Table 4.-Daily counts and estimates of the number of chum and chinook salmon passing by the counting site in the Chena River during 1995.

	Shifts	Chum			Chinook		
Date	Sampled	Count	Daily Passage	SE	Count	Daily Passage	SE
7/10/95	1	2	18	4	2	18	3
7/11/95	3	114	30	6	10	342	103
7/12/95	2	129	68	12	15	581	68
7/13/95	3	207	111	18	36	621	104
7/14/95	3	273	222	32	74	828	115
7/15/95	2	23	50	16	11	108	20
7/16/95	0	0	120	32	0	419	115
7/17/95	0	0	103	32	0	284	115
7/18/95	0	0	64	23	0	125	28
7/19/95	2	26	95	23	18	120	21
7/20/95	2	18	45	14	10	81	16
7/21/95	3	64	66	14	22	192	28
7/22/95	2	48	176	37	26	288	43
7/23/95	3	62	204	21	68	186	32
7/24/95	2	55	167	33	37	248	27
7/25/95	2	26	57	18	9	155	21
7/26/95	2	57	216	35	48	230	29
7/27/95	2	39	444	90	94	179	35
7/28/95	2	40	405	57	90	194	26
7/29/95	2	31	393	72	123	117	17
7/30/95	3	23	465	53	155	72	17
Total	40	1,237	3,519	170	848	5,388	275



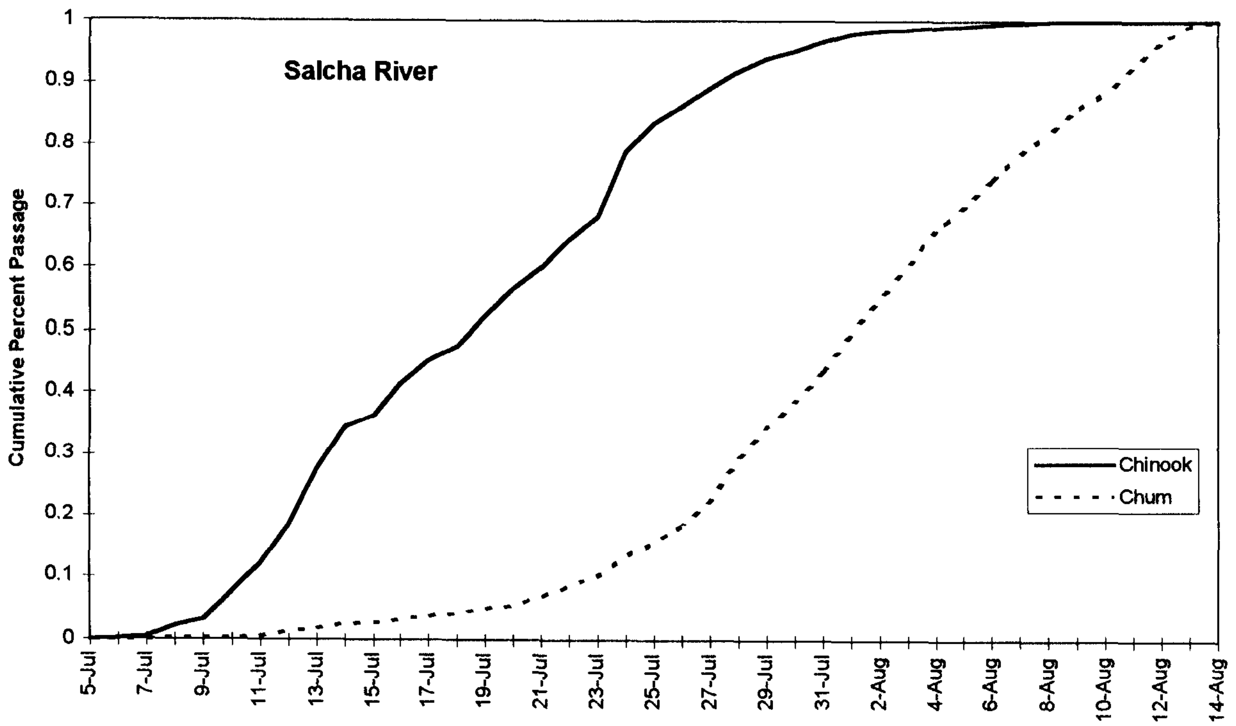


Figure 6.-Cumulative frequency distributions of daily estimates of passage for chinook and chum salmon past the counting sites in the Chena and Salcha rivers during 1995.

Chum salmon were first observed passing by the Salcha River counting site on 6 July and by the Chena River counting site on 10 July (Tables 3 and 4; Figures 5 and 6). Daily counts of chum salmon increased substantially after 25 July, and reached a peak count on 27 July in the Chena River and 28 July in the Salcha River. Run strength was quite high when counts were terminated on the Chena River (31 July), but was declining when counts were terminated on the Salcha River (14 August; Figures 5 and 6) The estimated passage of chum salmon in the Salcha River was 30,784 (SE = 605) and in the Chena River was 3,519 (SE = 170).

Mark-Recapture Experiment: Chena River

A total of 937 chinook salmon were captured, tagged, and released during the marking event. During the recapture event, 898 carcasses were collected and examined for tags and fin clips. Seventy-three of these fish were marked (Table 5). No marked fish had lost jaw tags.

The following results were based on data from the mark-recapture experiment to test the hypotheses (described in Appendix C) of equal probability of capture by sex, length, and river area during at least one sampling event.

Equal Probability of Capture by Sex:

Recapture rates for males and females differed significantly (males = 0.06; females = 0.10; χ^2 = 6.30, df = 1, P = 0.01; Table 6). However, the probabilities of capture during the first event (based on marked to unmarked ratio during the carcass survey) were similar (χ^2 = 0.01, df = 1, P = 0.93) for males and females (Table 7). Thus, there was no sex selectivity during the second event, and data from this event was used to estimate proportions of males and females in the population.

Equal Probability of Capture by Length

There were significant differences between the length distributions of all marked releases and all recaptures obtained during the carcass survey (DN = 0.18; P = 0.03), and between the length distribution of all marked fish and all fish captured during the carcass survey (DN = 0.11; P < 0.001; Figure 7). This indicated there was size selectivity during the carcass survey, while the selectivity of the marking event is unknown.

Equal Probability of Capture by River Area:

The marked-to-unmarked ratios of chinook salmon were dissimilar among the three river areas during the carcass sampling event (χ^2 = 13.7, df = 2, P = 0.001; Table 8). Examination of the recapture matrix (Table 9) indicated that there was movement out of sections between mark and recapture, but all movements were downstream. Recapture rates were 0.10, 0.08, and 0.01 for the upper, middle, and lower sections, respectively. A contingency table test indicated recapture rates in the upper and middle sections were similar (χ^2 = 0.92, df = 1, P = 0.34).

Abundance Estimate

To determine the extent of the bias associated with unequal capture rates due to size, a stratified Petersen estimate of abundance (Equation 11 for each strata) was calculated. A series of contingency table analyses were performed comparing numbers of recaptured and not recaptured fish for two length strata at various length breaks between 625 and 800 mm. The highest chi-square value was observed at 675 mm, so this was used as the break point for the two estimates. The stratified estimates were 9,514 for fish greater than 675 mm and 2,188 for fish 675 mm and less. The sum of these two estimates was 11,702 fish, which was nearly identical to the

Table 5.-Summary of capture histories of chinook salmon caught during the mark-recapture experiment in the Chena River during 1995.

Section Tagged	Section Recaptured Upper	Middle	Lower	Total Recaptured	Number not Recaptured	Total Marked
Upper	24	26	0	50	456	506
Middle	0	20	2	22	259	281
Lower	0	0	1	1	149	150
Total	24	46	3	73	864	937
Unmarked Carcasses	234	579	12	825	Total Number of Unique Fish Examined 1,762	
Total Carcasses	258	625	15	898		

Table 6.-Contingency table analysis of recapture rates of male and female chinook salmon caught during the mark-recapture experiment in the Chena River during 1995.

	Female	Male	Total
Recaptured	48	25	73
Not Recaptured	436	428	864
Total	484	453	937
Recapture Rate	0.10	0.06	0.08

$\chi^2 = 6.30$, df = 1; P = 0.01

Table 7.-Contingency table analysis of marked to unmarked ratios of male and female chinook salmon caught during the second sample of the mark-recapture experiment in the Chena River during 1995.

	Female	Male	Total
Marked	48	25	73
Unmarked	538	287	825
Total	586	312	898
Marked:Unmarked	0.08	0.09	0.09

$\chi^2 = 0.01$, df = 1; P = 0.93

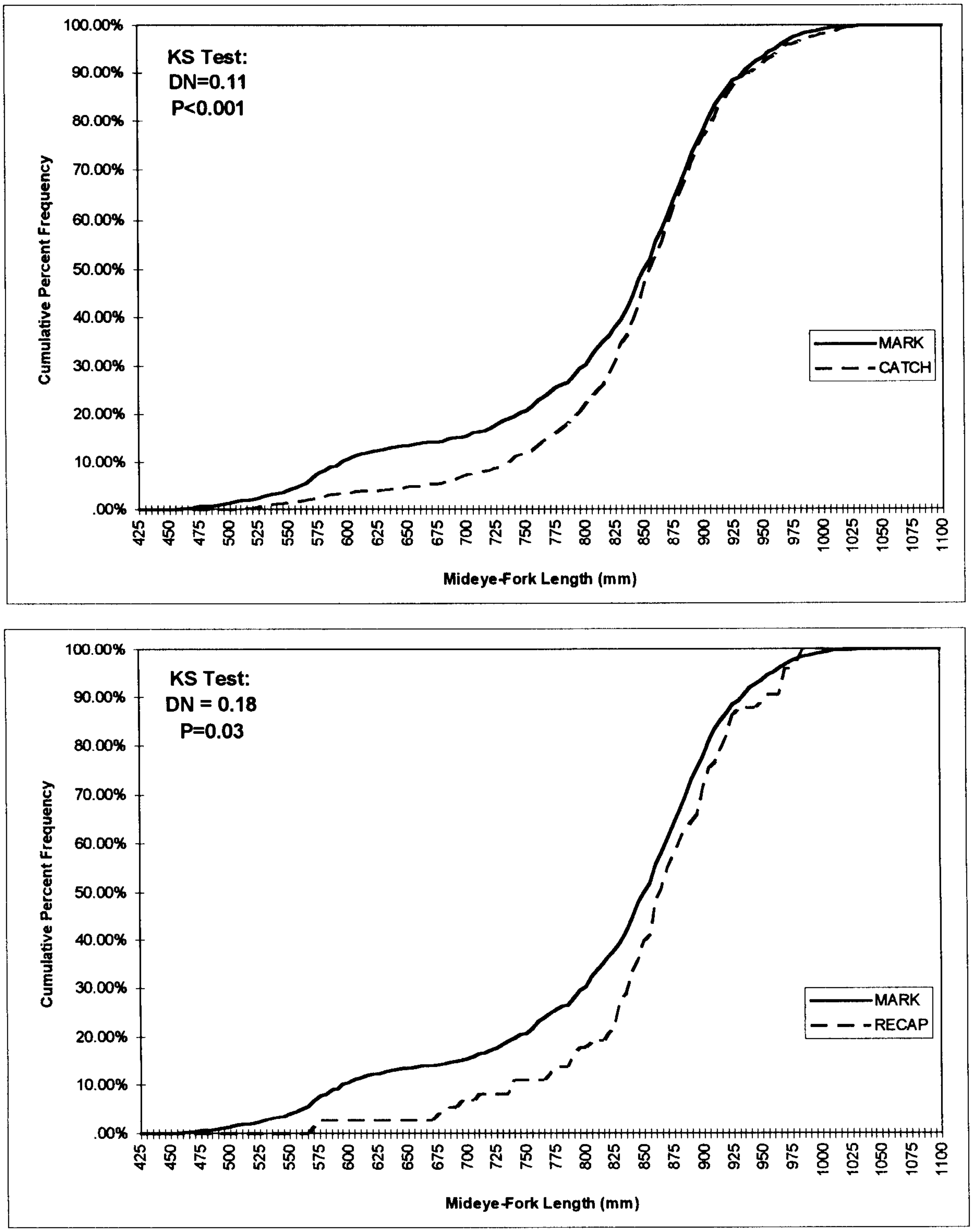


Figure 7.-Cumulative frequency distributions comparing all fish caught during the first and second events (top) and all fish caught during the first event and all recaptured fish caught during the second event (bottom) from the mark-recapture experiment in the Chena River during 1995.

Table 8.-Contingency table analysis of recapture rates of chinook salmon by river section caught during the mark-recapture experiment in the Chena River during 1995.

	Upper	Middle	Lower	Total
Recaptured	50	22	1	73
Not Recaptured	456	259	149	864
Total	506	281	150	937
Recapture Rate	0.10	0.08	0.01	0.08

$\chi^2 = 13.7$, df = 2; P = 0.001

Table 9.-Recapture matrix of location of capture and location of recapture by river section for chinook salmon caught during the mark-recapture experiment in the Chena River during 1995.

	Section of Recapture		
Section of Marking	Upper	Middle	Lower
Upper	24	26	0
Middle	0	20	2
Lower	0	0	1

unstratified estimate of 11,394 fish. Therefore, the statistical bias associated with the different length distributions was not meaningful in terms of the population estimate.

Because of the unequal probabilities of capture by river area, a Darroch estimate (Equation 13) was calculated. The total estimate using this model was 33,124. However, this method calculated a negative capture probability for stratum two, and therefore could not be considered valid.

Given the violations of the assumptions of the Petersen model and the failure of the Darroch model to produce a viable estimate, the ML estimator (Equation 16) was chosen to estimate abundance. The ML estimates for the upper and middle and lower sections were:

$$\hat{\Theta} = \begin{bmatrix} 0.488 & 0.518 & 0 \\ 0 & 0.513 & 0.488 \\ 0 & 0.088 & 0.913 \end{bmatrix};$$

$$\hat{p}' = \begin{pmatrix} 0.097 & 0.11 & 0.01 \end{pmatrix}; \text{ and,}$$

$$\tilde{n}' = \begin{pmatrix} 2{,}419 & 5{,}231 & 1{,}093 \end{pmatrix}.$$

The corresponding abundance estimate for both sections was 9,680 (SE = 958).

Boat Count: Chatanika River

Four hundred forty-four chinook salmon and 145 chum salmon were counted during the boat survey of the Chatanika River. One hundred eighteen chinook salmon and 28 chum salmon were counted between Cripple Creek and the Steese Highway Bridge, while 326 chinook salmon and 117 chum salmon were counted between the Steese and Elliott Highway bridges. This count is the highest on record (Table 10).

Age-Sex-Length Compositions of Chinook Salmon in the Salcha River

Six-hundred fifty-eight chinook salmon carcasses were collected from the Salcha River during two sampling occasions. The sex and length were determined and scale samples were collected from all carcasses. Tests to compare the two samples indicated that length compositions were similar for each sample ($DN = 0.15$, $P = 0.10$). However, sex ratios differed among the two samples ($\chi^2 = 15.07$, df = 1, $P < 0.001$). Age was determined for 545 fish (0.83 of the sample). Tests to compare the aged to not-aged samples indicated that sex ratios were similar for the two samples ($\chi^2 = 0.05$; df = 1; $P = 0.83$), and that length distributions of aged and not-aged fish were also similar ($DN = 0.06$; $P = 0.93$). The two samples were combined to estimate all compositions.

Sex composition was 0.44 (SE = 0.02) male and 0.56 (SE = 0.02) female. Abundances calculated from these proportions were 6,008 (SE = 357) male and 7,635 (SE = 392) female chinook salmon. Males were represented by age classes 1.3, 1.4, and 1.5 in near equal proportions, while a single age class (1.4) comprised most of the female sample. Mean lengths at age were also calculated (Table 11). Lengths were obtained from all 658 carcasses. Lengths of males ranged from 430 to 1,000 mm, while lengths of females ranged from 570 to 1,000 mm (Figure 8).

Age-Sex-Length Compositions of Chinook Salmon in the Chena River

Eight hundred ninety-eight chinook salmon carcasses were collected from the Chena River. Of these, 0.66 (SE = 0.02) were female. Age was determined for 787 fish (0.88 of the sample). Tests to determine whether the aged sample was similar to the total sample indicated that the

Table 10.-Aerial survey counts, boat counts, and sport harvest and catch estimates for the Chatanika River, 1980-1995.

Year	Method	Lower[a]	Middle[b]	Upper[c]	Total	Survey Condition	Sport Harvest[d]	Sport Catch[d]
1980	Aerial	NA[e]	NA	NA	37	Fair	37	NE[f]
1981			No Survey				5	NE
1982	Aerial	NA	NA	NA	159	Fair-Good	136	NE
1983			No Survey				147	NE
1984	Aerial	NA	NA	NA	9	Poor	78	NE
1985			No Survey				373	NE
1986	Aerial	NA	NA	NA	79	Fair	0	NE
1987			No Survey				21	NE
1988			No Survey				345	NE
1989	Aerial	NA	NA	NA	75	Fair	231	NE
1990	Aerial	10	46	5	61	Fair-Poor	37	164
1991	Aerial	2	84	18	104	Fair	82	181
1992	Aerial	NC[g]	78	NC[g]	IS[h]	Fair	16	31
1993	Aerial	6	46	23	75	Fair	192	625
1993	Boat	NC	253	NC[g]	IS	Good	192	625
1994	Aerial	49	NC	NC[g]	372	Fair	105	278
1995	Boat	NC	326	118	IS	Fair-Good	NE	NE

[a] Lower section runs from the Trans Alaska Pipeline upstream to the Elliott Highway Bridge.

[b] Middle section runs form the Elliott Highway Bridge upstream to the Steese Highway Bridge.

[c] Upper section runs from the Steese Highway Bridge upstream to the confluence of Faith and McManus Creeks (Figure 3).

[d] Data from Mills (1981-1994) and Howe et al. (1995).

[e] NA = section subtotals are not available.

[f] NE = no estimate is available.

[g] NC = no count was conducted during this survey.

[h] IS = incomplete survey. Total is cited only when a complete survey of the lower, middle, and upper sections was completed.

Table 11.-Estimated proportions, abundance, and mean length by age class of male and female chinook salmon in the Salcha River during 1995.

	Age[a]	Sample Size	Proportion	SE	Abundance	SE	Length Mean	Length SE	Length Min	Length Max
Male										
	1.2	71	0.13	0.01	1,777	206	550	65	430	775
	1.3	70	0.13	0.01	1,752	205	740	85	530	985
	1.4	93	0.17	0.02	2,328	234	845	80	540	995
	1.5	5	0.01	0.00	125	56	925	100	790	1,000
	2.4	1	0.00	0.00	25	25	770			
	All	240	0.44	0.02	6,008	357	730	145	430	1,000
Female										
	1.2	3	0.01	0.00	75	43	780	200	570	970
	1.3	42	0.08	0.01	1,051	160	810	60	670	965
	1.4	249	0.46	0.02	6,233	362	860	50	625	1,005
	1.5	9	0.02	0.01	225	75	930	65	830	1,010
	2.4	2	0.00	0.00	50	35	800	30	775	820
	All	305	0.56	0.02	7,635	392	855	55	570	1,010
Total		545	1.00		13,643	471	800	125	430	1,010

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence). One annulus is formed each year.

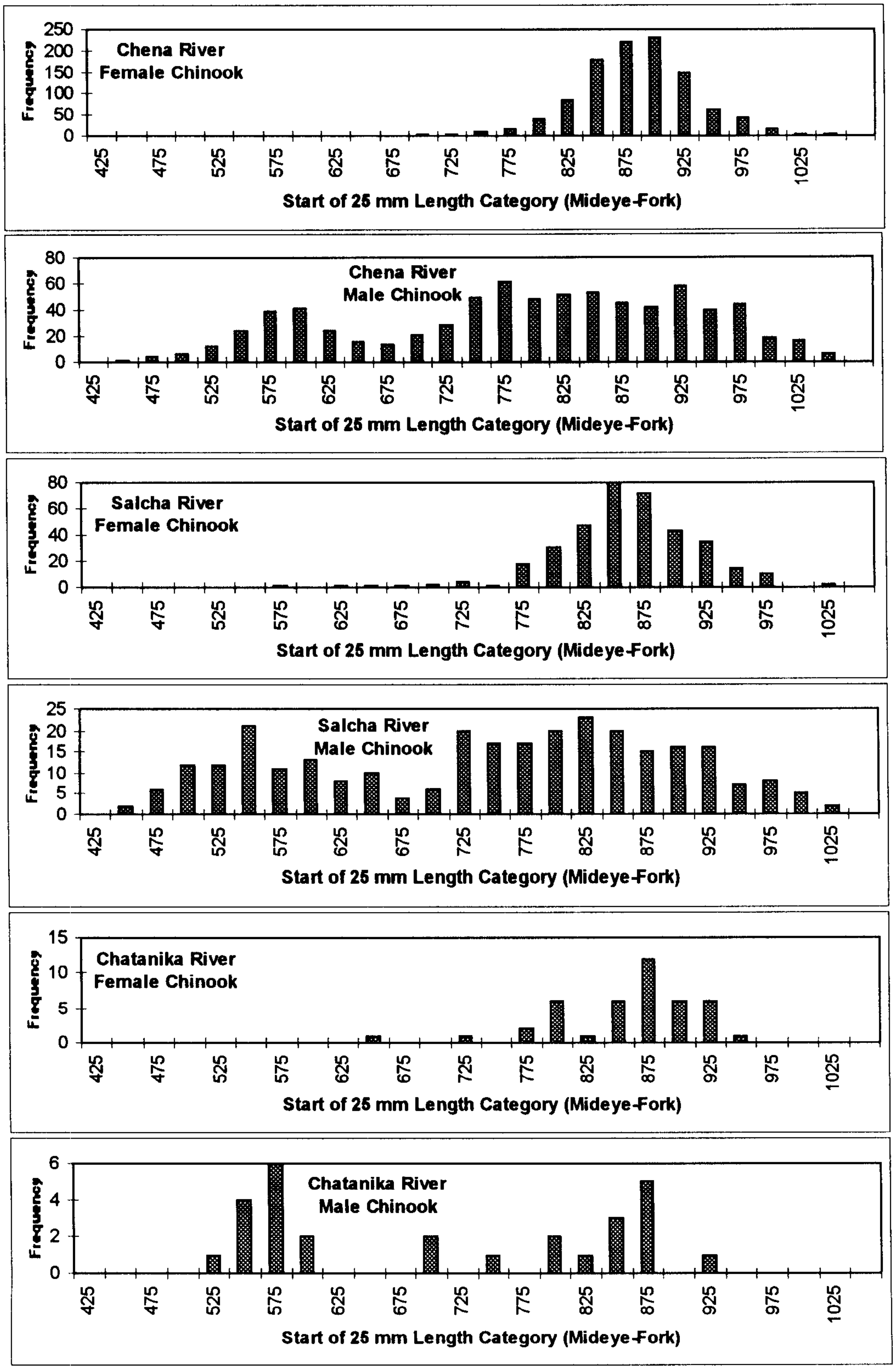


Figure 8.-Length frequency distributions of male and female chinook salmon carcasses collected in the Chena, Salcha, and Chatanika rivers during 1995.

proportions of not-aged males and females were similar to those that were aged ($\chi^2 = 1.88$; df = 1; $P = 0.17$), and that length distributions of aged and not-aged fish were also similar ($DN = 0.08$; $P = 0.53$). Males were most represented by age 1.3 fish (0.12 of total sample) and age 1.4 (0.17 of the total sample). Females were most represented by age 1.4 fish (0.54 of total sample). Mean lengths at age were also calculated (Table 12). Lengths were obtained from all 898 carcasses. Lengths of males ranged from 515 to 1,095 mm. Lengths of females ranged from 700 to 1,030 mm (Figure 8).

Age-Sex-Length Composition of Chinook Salmon in the Chatanika River

Seventy carcasses were collected during the sampling event on the Chatanika River. Of these, ages were determined for 59 samples. The sex composition of the entire sample was 0.70 females and 0.30 males. The sex ratio of the aged sample differed slightly with 0.63 females and 0.37 males. Ages 1.3 and 1.4 were the dominant age classes (Table 13). Lengths of males ranged from 515 to 910 mm. Lengths of females ranged from 645 to 945 mm (Figure 8).

Aerial Surveys: Salcha and Chena Rivers

During aerial surveys conducted on 9 July, 237 chinook salmon were counted in the Salcha River and 295 were counted in the Chena River. Visibility during the surveys ranged from poor to good in the Chena River and fair to good in the Salcha River. Aerial surveys were also conducted at peak escapement. Peak count for the Salcha River was 3,978, and peak count for the Chena River was 3,567. Visibility during both surveys was fair to good. These aerial counts represent about 0.29 and 0.37 of the respective abundance estimates. Since 1986, the proportion of the population observed during aerial surveys has ranged from 0.19 to 0.71 and averaged 0.44 for the Salcha River and ranged from 0.13 to 0.59 and averaged 0.30 for the Chena River (Table 14). The early survey was 0.06 of the peak survey in the Salcha River and 0.08 of the peak survey in the Chena River.

DISCUSSION

This was the third consecutive year tower counting methodology was used to estimate escapements of chinook salmon in the Chena and Salcha rivers. Tower counts offer a number of advantages over mark-recapture techniques or aerial surveys. The first obvious advantage is that tower counts allow managers to manipulate the fisheries in-season to achieve escapement goals. In fact, the sport fishing bag limit was increased by emergency order regulation from one to two chinook salmon per day in both 1993 and 1994 as a result of large, early escapements. Aerial surveys also offer managers the ability to manage inseason, and are usually less expensive than tower counts. However, in the Chena and Salcha rivers the relationship between aerial counts and actual abundance is unclear as counts can vary considerably depending upon water visibility (affected by turbidity, wind, or light conditions), and have been in all cases substantially lower than estimates obtained using mark-recapture techniques or tower counts (Table 14).

The precision of the estimates obtained from tower counts has been substantially better than the precision of mark-recapture estimates obtained from prior years (six from the Salcha River and eight from the Chena River; see Table 14). The high precision of the tower count estimates may, however, be misleading. The variance estimator assumes that during any given 20 min counting period all salmon that pass over the panels are seen, correctly identified and counted. This is likely not the case. During conditions of poor visibility, passing salmon may be missed or misidentified. Also, given the large width of channel a single observer must watch, it is likely that

Table 12.-Estimated proportions and mean length by age class of male and female chinook salmon in the Chena River during 1995.

	Age[a]	Sample Size	Proportion	SE	Length Mean	Length SE	Length Min	Length Max
Male	1.2	35	0.04	0.01	600	75	515	850
	1.3	96	0.12	0.01	760	85	530	990
	1.4	131	0.17	0.01	890	75	605	1,095
	1.5	4	0.01	0.00	985	55	920	1,035
	2.4	1	0.00	0.00	1,005			
	All	267	0.34	0.02	815	130	515	1,095
Female	1.2	0						
	1.3	68	0.09	0.01	830	65	700	990
	1.4	427	0.54	0.02	875	45	730	1,005
	1.5	23	0.03	0.01	920	60	780	1,030
	2.4	2	0.00	0.00	840	5	835	840
	All	520	0.66	0.02	870	50	700	1,030

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence). One annulus is formed each year.

Table 13.-Estimated proportions and mean length by age class of male and female chinook salmon in the Chatanika River during 1995.

	Age[a]	Sample Size	Proportion	SE	Length Mean	Length SE	Length Min	Length Max
Male	1.1	3	0.05	0.03	550	30	515	570
	1.2	6	0.10	0.04	575	55	535	685
	1.3	10	0.17	0.05	775	95	555	855
	1.4	3	0.05	0.03	885	25	865	910
	All	22	0.37	0.06	705	140	515	910
Female	1.2	1	0.02	0.02	840			
	1.3	22	0.37	0.06	855	50	725	950
	1.4	14	0.24	0.06	840	75	645	920
	All	37	0.63	0.06	850	60	645	950

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.3 represents one annulus formed during river residence and three annuli formed during ocean residence). One annulus is formed each year.

Table 14.-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 and Chena rivers.

River	Estimated		Aerial Survey		Proportion Observed During
Year	Abundance[a]	SE	Count	Condition[b]	Aerial Survey
Salcha:					
1987	4,771[c]	504	1,898	Fair	0.40
1988	4,562[c]	556	2,761	Good	0.61
1989	3,294[c]	630	2,333	Good	0.71
1990	10,728[c]	1,404	3,744	Good	0.35
1991	5,608[c]	664	2,212	Poor	0.39[d]
1992	7,862[c]	975	1,484	Fair-Poor[e]	0.19
1993	10,007[f]	360	3,636	Fair	0.36
1994	18,399[f]	549	11,823	Good	0.64
1995	13,643[f]	471	3,978	Fair-Good	0.29
					Avg=0.44
Chena:					
1986	9,065[c]	1,080	2,031	Fair	0.22
1987	6,404[c]	557	1,312	Fair	0.20
1988	3,346[c,g]	556	1,966	Fair-Poor[e]	0.59
1989	2,666[c]	249	1,180	Fair-Good[e]	0.44
1990	5,603[c]	1,164	1,436	Fair-Poor[e]	0.26
1991	3,025[c]	282	1,276	Poor	0.42
1992	5,230[c]	478	825	Fair-Poor[e]	0.16
1993	12,241[f]	387	2,943	Fair	0.24
1994	11,877[f]	479	1,570	Fair-Poor	0.13
1995	9,680[c]	958	3,567	Fair	0.37
					Avg=0.30

a Details of estimates can be found in Barton (1987a and 1988); Barton and Conrad (1989); Burkholder (1991); Evenson (1991, 1992, 1993, and 1995); and, Skaugstad (1988, 1989, 1990a, 1990b, 1992, 1993, and 1994).

b During these surveys, conditions were judged on a scale of "poor, fair, good, excellent" unless otherwise noted.

c Estimate was obtained from mark-recapture techniques.

d Aerial survey was made a few days before spawning peaked.

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

f Estimate was obtained from tower counts.

g 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.

fish pass by unnoticed in the peripheral areas. A number of options exist for alleviating these problems and should be considered in the design of future tower counts. First, to address some of the visibility problems, wider flash panels should be used so that salmon are visible for a longer period of time. Second, both rivers should be divided in half and a count should be conducted for each half during each hour of a shift. Finally, a second counter should be used during a sub-sample of counting periods to determine the variability among counters.

Another drawback of the tower count method is that it can only be assumed that a representative carcass sample is being taken to estimate age-sex-length compositions. Mark-recapture techniques allow for detection of, and possibly correction of, bias. Past mark-recapture experiments (a total of 11 have been conducted in the Chena and Salcha rivers where carcass sampling was used as a capture technique) have shown that size and sex composition estimates were biased during three experiments. In one of the two cases where size composition was biased (Chena River during 1992), the bias was not substantial enough to alter the estimated abundance and was thus not considered biologically significant (Evenson 1993). The extent of the bias associated with sex compositions in terms of its affect on estimates of population proportions is not known. The two carcass samples collected this year on the Salcha River showed a difference in sex compositions. Although combining the two samples for an estimate of sex composition might also be biased, it is likely a better approach than to estimate compositions from a single sample.

A limitation of tower counting methodology is that it requires low water conditions (good visibility) for most of the run. High water events persisting more than two days add a great deal of uncertainty to the estimate. Water conditions during the 1993 and 1994 seasons were nearly ideal, and few counts were missed. The high water during this season was severe enough in the Chena River to render the total escapement estimate useless. The Salcha River tends to respond better to high water events than does the Chena River in that water levels decline quicker and turbidity is less severe. If estimating total escapement remains an objective, then mark-recapture experiments need to be planned as a back-up means of estimating total escapement.

Mark-recapture techniques should, however, be considered a secondary means of estimating escapement. First, the estimates are obtained after all the fisheries have taken place. Thus, managers must rely on aerial survey estimates as a means of assessing escapement inseason. Second, the mark-recapture experiments likely do not provide a total estimate of escapement. Some chinook salmon spawn in areas upstream from the upper boundaries of the study areas. In the case of the Chena River, these areas are not accessible by river boat. In the case of the Salcha River, fish range extremely far upstream, making a total escapement estimate logistically difficult and costly. An understanding of the proportion of fish estimated during a mark-recapture experiment to the total escapement would be of value. Obtaining paired estimates of tower counts and mark-recapture experiments during the same year is one possible solution. Finally, obtaining a precise unbiased estimate is difficult using the current techniques. Electrofishing is an effective method for capturing large numbers of chinook salmon. To minimize injury to the population, fishing is conducted (for the most part) after fish have spawned, but before they have died. The second sample is collected after fish have died. Because different sampling techniques are used during the two events, capture probabilities are likely different. After chinook salmon have died, many drift downstream. In past experiments, very few recaptured fish have moved upstream between tagging and recapture. This sampling artifact leads to two problems. First, it leads to different probabilities of capture by river area. Second, it may violate the assumption that the population is closed to immigration and emigration (Fish may drift into the study section from upstream areas and may drift out of the study section in downstream areas).

To alleviate problems with unequal probabilities of capture by river area in this experiment a maximum likelihood model was developed which estimated transition (movement) probabilities from one river section to another. This model appears to be a promising method for estimating abundance using this sample design, however it still assumes the population is closed. Closure was suspect in this experiment because of the low probability of capture in the lower river section. The physical characteristics of this section are quite different from those in the upper two sections. In this section the river is more channelized, there are fewer riffle and shallow areas, and the turbidity is greater. In future studies, radio tagging should be considered as a means of determining the fate of lower stratum fish and identify problems with the assumption of closure. The transmitters could be short-lived and with relatively low output. Tracking could be conducted by boat. Other sampling modifications to improve the probability of capturing fish in this section might include intensifying sampling effort or sampling at an earlier time.

Estimates of chum salmon abundances for the Chena and Salcha rivers populations were minimal estimates because only the early portion of the migration was counted. Currently there is an escapement objective of 3,500 chums from aerial survey for the Salcha River, and there is no escapement objective for the Chena River. It may be of value in future years to extend tower counts of chum salmon to get complete estimates of escapement with which to develop escapement goals.

The boat count of chinook salmon in the Chatanika River was the highest count on record. Most of the historic counts have been from aerial surveys. It is likely that a greater proportion of the escapement is counted during a boat survey than during an aerial survey. The only paired estimate which exists is from 1993, when 253 were counted during a boat survey and 46 were counted during an aerial survey. A logistic drawback of the boat survey is that it takes 3-4 days to complete. Future studies should investigate the relationship of helicopter and boat counts. An escapement goal based on one of these two methods should be developed.

COHO SALMON STUDY IN THE DELTA CLEARWATER RIVER

INTRODUCTION

The Delta Clearwater River has the largest known coho salmon escapements in the Yukon River drainage (Parker 1991). The river is a spring-fed tributary to the Tanana River located near Delta Junction about 160 km southeast of Fairbanks (Figure 9). The main river is 32 km, with a 10 km north fork. There are a number of small, shallow spring areas adjacent to the mainstem river. Spawning occurs throughout the mainstem river and in the spring areas. The river supports a popular fall sport fishery. Annual harvests exceeded 1,000 coho salmon from 1986-1991, although in recent years catch has been high, but harvest relatively low (Mills 1979-1994; Howe et al. 1995; Table 15). Before reaching spawning grounds, the coho salmon travel about 1,700 km from the ocean and pass through six different commercial fishing districts in the Yukon and Tanana rivers (Figure 4). Subsistence and personal use fishing also occur in each district.

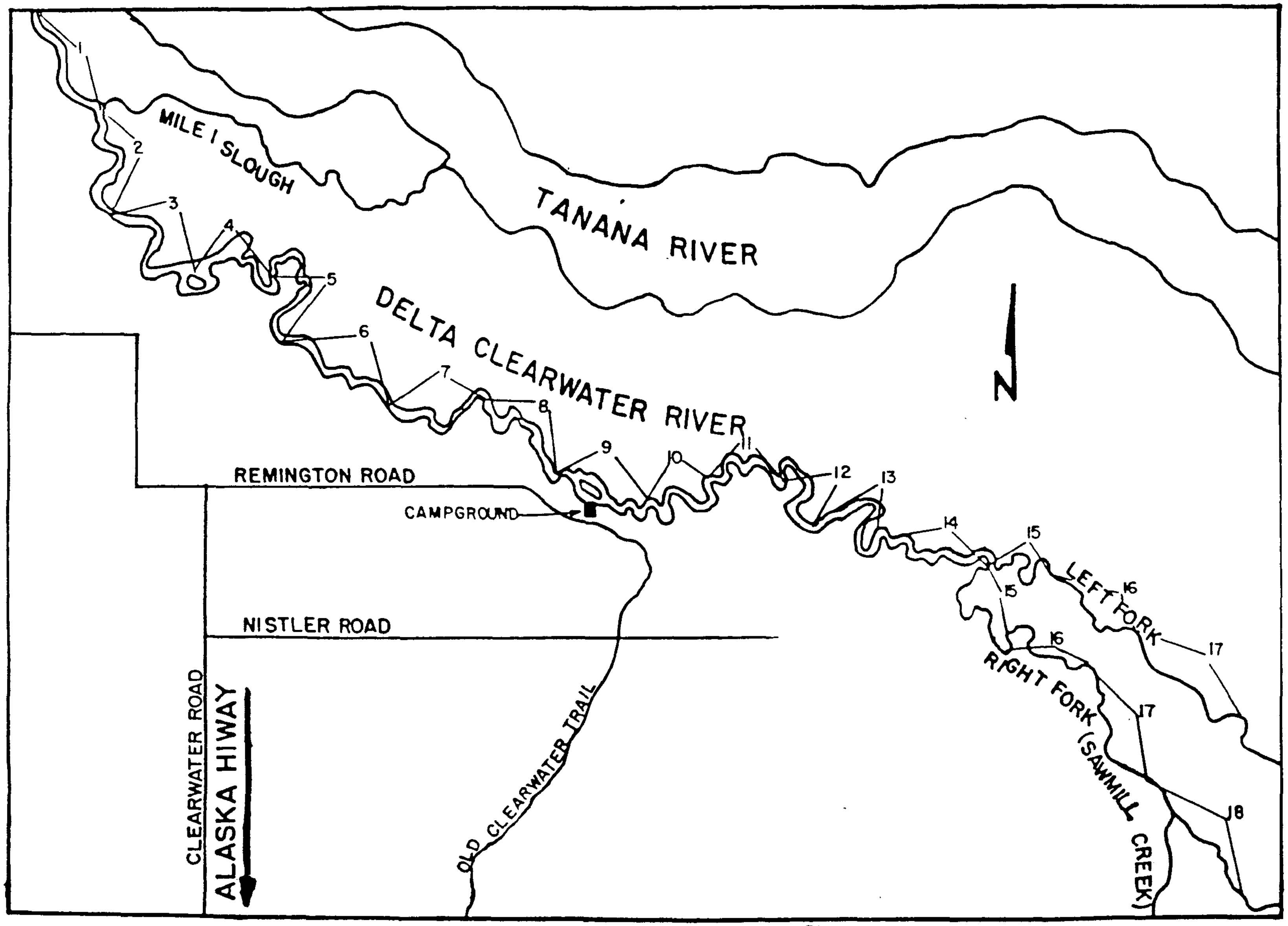


Figure 9.-Delta Clearwater River study area.

Table 15-Peak escapements, harvests, and catch of coho salmon in the Delta Clearwater River, 1972-1995.

	Peak Escapement Counts							
Year	Survey Date	Lower River[a]	Upper River[b]	Spring Areas	Total[c]	Previous 5 yr Avg.	Sport Harvest[d]	Sport Catch[d]
1972	9 Nov	NA[e]	NA	NA	632		NA	NA
1973	20 Oct	NA	NA	NA	3,322		NA	NA
1974	NA	NA	NA	NA	3,954[f]		NA	NA
1975	24 Oct	NA	NA	NA	5,100		NA	NA
1976	22 Oct	NA	NA	NA	1,920		NA	NA
1977	25 Oct	2,331	2,462	NA	4,793	2,986	31	NA
1978	26 Oct	2,470	2,328	NA	4,798	3,818	126	NA
1979	23 Oct	3,407	5,563	NA	8,970	4,113	0	NA
1980	28 Oct	2,206	1,740	NA	3,946	5,116	25	NA
1981	21 Oct	4,110	4,453	NA	8,563[g]	4,885	45	NA
1982	3 Nov	4,015	4,350	NA	8,365[g]	6,214	21	NA
1983	25 Oct	3,849	4,170	NA	8,019[g]	6,928	63	NA
1984	6 Nov	5,434	5,627	NA	11,061	7,573	571	NA
1985	13 Nov	NA	NA	NA	6,842[f]	7,991	722	NA
1986	21 Oct	5,490	5,367	NA	10,857	8,570	1,005	NA
1987	27 Oct	11,700	10,600	NA	22,300	9,029	1,068	NA
1988	28 Oct	5,300	16,300	NA	21,600	11,816	1,291	NA
1989	25 Oct	5,400	7,200	NA	12,600	14,532	1,049	NA
1990	26 Oct	4,525	3,800	NA	8,325	14,840	1,375	3,271
1991	23 Oct	11,525	12,375	NA	23,900	15,136	1,721	4,382
1992	26 Oct	1,118	2,845	NA	3,963	17,745	615	1,555
1993	21 Oct	3,425	7,450	NA	10,875	14,078	48	1,695
1994	24 Oct	19,450	43,225	17,565[h]	80,240[i]	11,933	509	3,009
1995	23 Oct	7,850	12,250	6,283[h]	26,383[i]	25,461	NA	NA
				All Years Average		12,555		

a Mile 0 to Mile 8.

b Mile 8 to Mile 17.5.

c Boat survey by Alaska Department of Fish and Game, Division of Sport Fish unless otherwise noted.

d Data were obtained from Mills (1979-1994) and Howe et al. (1995).

e Data are not available.

f Survey by Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development.

g Mark-recapture population estimate.

Escapements of coho salmon into the Delta Clearwater River have been historically monitored by counting fish from a drifting river boat. In recent years aerial surveys have been conducted to estimate escapement into non-boatable portions of the river (Table 15). 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. The Alaska Department of Fish and Game has established a minimum escapement goal of 9,000 coho salmon for the Delta Clearwater River. When counts indicate that the goal may not be achieved, the bag limit is reduced or the fishery is closed. If the count exceeds the minimum escapement, the bag limit may be increased. The objectives of the coho salmon escapement project for the Delta Clearwater River in 1995 were to count coho salmon in the Delta Clearwater River from a drifting riverboat at approximately weekly intervals throughout the run, and estimate total escapement through a combination of boat counts and aerial surveys. In addition, age, sex, and length compositions of the escapement were estimated.

METHODS

Counts

Adult coho salmon were counted from a drifting riverboat equipped with an observation 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 9). The sections were numbered from the mouth (mile 0) upstream. Many coho salmon spawn in shallow spring areas adjacent to the mainstem river. These areas historically have not been included in the surveys. To determine the proportion of fish which spawn in these areas relative to the main river, an aerial survey was conducted using a Robertson (R22) helicopter flying at approximately 100 m above ground level.

Age-Sex-Length Compositions

Coho salmon carcasses were collected from river kilometer 24 (mile 15) to 14 (mile 9) on two occasions (1 and 21 November). Carcasses were collected from a drifting river boat using long handled spears. Length was measured from mid-eye to fork-of-tail to the nearest 5 mm. Sex was determined from observation of body morphology or by cutting into the body cavity to examine the gonads. Three 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 (Scarnecchia 1979).

Ages were determined from scale patterns as described by Mosher (1969). The proportions of the population represented by combinations of age and sex were estimated using Equations 17 and 18. Mean lengths were estimated for combinations of age and sex using the sample mean and variance (Zar 1984).

In past years, a single sampling event (carcass sample) was conducted to estimate age, sex, and length compositions. Potential for bias associated with these estimates could not be tested. To investigate potential bias which might exist from a single sampling event, a series of tests were performed to compare the two samples. A Kolmogorov-Smirnov two sample test (KS test) was used to compare length distributions from each sample. Contingency table analyses were used to compare sex and age compositions of each sample. Nonsignificant statistics would indicate that there was no bias associated with a single sampling event, or that if there was bias, it was similar during both events. Significant statistics would suggest that estimates from a single sample may not be representative of the population. Typically, ages cannot be estimated for 10%-20% of the sample due to either improper mounting or natural phenomena such as scale resorption or regeneration. To test that the aged sample was representative of the entire sample, a KS test comparing length distributions of aged and not-aged samples, and a contingency table analysis comparing sex ratios of aged and not-aged samples were performed.

RESULTS

Counts

Boat counts were made on 28 September, 6 October, and 23 October. During the first two surveys, only the portion of the mainstem Delta Clearwater River from river kilometer 0 through 13 (mile 8) was covered. During the first survey 4,500 coho salmon were counted, while 7,960 were counted on the second survey. Because the latter count was close to the minimum escapement goal (9,000), and because only half the river was surveyed, another count was not conducted until it was felt that complete escapement had been reached.

The third count, conducted at peak escapement, covered the entire mainstem river (river kilometer 0-28; mile 0-17.5). The total count for the mainstem Delta Clearwater River was 20,100. Coho salmon were distributed throughout the entire stretch in densities ranging from 175 to 2,775 fish per mile (Table 16).

The aerial survey was conducted on 2 November. During this survey 15,575 coho salmon were counted in the mainstem river and 6,283 were counted in the adjacent spring areas. Counts for individual spring areas ranged from 0 to 1,225 (Table 16). Because visibility of the entire mainstem river bottom was thought to be best with the boat survey (overhanging vegetation blocked the near-bank areas from the air), the boat count of 23 October was used as the estimate for the mainstem river and the aerial survey of the spring areas was added to this count for the total escapement estimate. The total estimated escapement was 26,383 coho salmon. The count in the spring areas comprised 0.24 of the total count, and was similar to the proportion observed in 1994 (0.22).

Age-Sex-Length Compositions

Three hundred eighty-one coho salmon carcasses were collected and measured on two sampling occasions. The sex and length were determined and scale samples were collected from all carcasses. Age was determined for 335 (0.88) of these samples. Test results indicated that age and length compositions were similar for each sample ($\chi^2 = 2.5$, df = 2, $P = 0.29$; and, $DN = 0.06$, $P = 0.78$, respectively). However, sex ratios differed among the two samples ($\chi^2 = 5.07$, df = 1, $P = 0.02$). Length compositions and sex ratios were similar for aged and not-aged samples ($DN = 0.06$, $P = 0.78$; and, $\chi^2 = 0.51$, df = 1, $P = 0.47$, respectively). The two samples were combined to estimate all compositions.

Males comprised 0.60 of the sample. Brood year 1990 (age 3.1) comprised 0.01 of the sample, brood year 1991 (age 2.1) comprised 0.71, and brood year 1992 (age 1.1) comprised 0.28 (Table 17). Males were distributed over a larger length range (420-635 mm) than were females (455-615 mm; Figure 10).

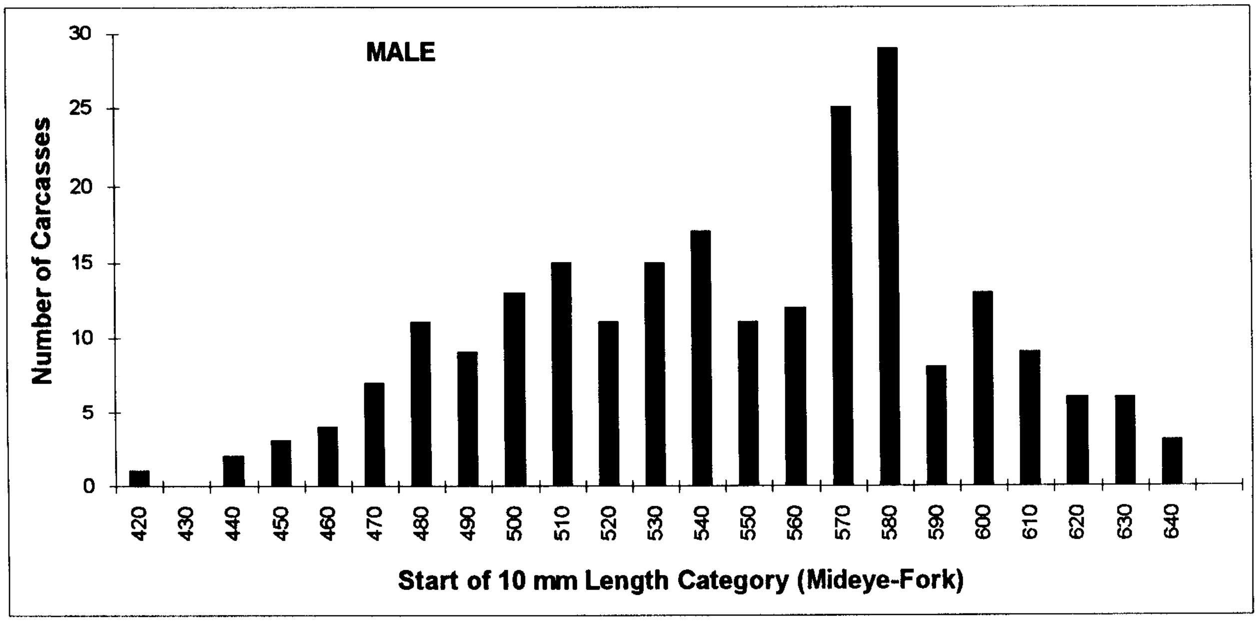
Table 16.-Counts of adult coho salmon in the Delta Clearwater River, 1995.

	Mainstem River (Boat Survey)	Mainstem River (Aerial Survey)	Nonboatable Portion (Aerial Survey)	
River Mile	Count (23 Oct)	Count (2 Nov)	Name of Spring	Count (2 Nov)
17.5-16	1,825		Sawmill Creek	600
16-15	2,025		Andersen	8
15-14	2,250		Granite	150
14-13	1,750		South Clearwater	400
13-12	1,200		Middle Clearwater	850
12-11	1,125		Peckham	50
11-10	900		Clearwater-Sec 1	450
10-9	675		Clearwater-Sec 2	1,225
9-8	500		Fronty	175
8-7	500		Jan	150
7-6	175		Jesse	50
6-5	625		Jennie	25
5-4	900		Chad	25
4-3	1,550		Buns	75
3-2	875		Patty	0
2-1	2,775		Dave	0
1-0	450		Travis	75
			Remmington	100
Summary			Dubois	0
17.5-8	12,250	8,100	Christie	225
8-0	7,850	7,475	Caleb	325
14-0	14,000	11,475	Isaac	225
17.5-0	**20,100**	**15,575**	Parker	200
			Kenna	100
Visibility	Excellent	Excellent	Dos Gris	0
			Barb	25
			Backy	0
			Ridder	125
			Pearse	150
			Hodges	25
			Stuga	100
			Salmon Alley	350
			Mallard	25
			Total	**6,283**

Table 17.-Statistics by age and sex for coho salmon carcasses collected from the Delta Clearwater River, 1995.

	Male			Female		
Age[a]	1.1	2.1	3.1	1.1	2.1	3.1
Brood Year	1993	1992	1991	1993	1992	1991
Count (First Sample)	31	66	0	24	57	1
Percent of Sample	17.3	36.9	0.0	13.4	31.8	0.6
Count (Second Sample)	25	77	1	14	37	2
Percent of Sample	16.0	49.4	0.6	9.0	23.7	1.3
Count (Total Sample)	56	143	1	38	94	3
Percent of Sample	16.7	42.7	0.3	11.3	28.1	0.9
Minimum Length (mm)	475	420	635	500	455	515
Maximum Length (mm)	625	635	635	590	615	555
Mean Length (mm)	555	540	635	555	550	535
Standard Error	40	50		25	30	20

[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 annuli formed during ocean residence). One annulus is formed each year.



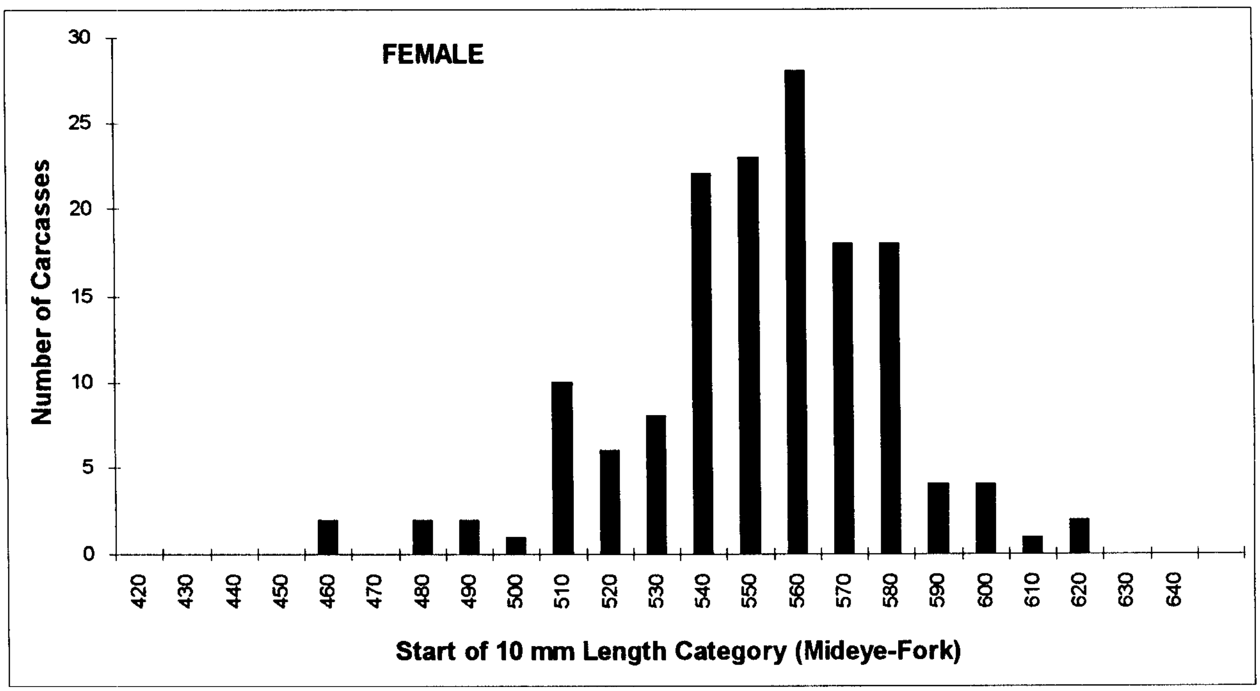


Figure 10.-Length frequency distributions of male and female coho salmon carcasses collected in the Delta Clearwater River during 1995.

DISCUSSION

Even excluding the aerial survey counts of the non-boatable portions of the river, the count in 1995 was well above average escapement (Table 15). The reasons for this large escapement may be attributed to small harvests and large parent year escapements. Commercial harvests for the entire Yukon drainage were lower than normal. Commercial harvest of coho salmon for the entire Yukon River drainage during 1994 was estimated to be 47,113, which was slightly larger than the previous five year average of 32,926. Subsistence and personal use harvests of coho salmon in the Yukon River drainage are estimated to be 27,222, which was slightly less than the previous five year average of 38,000 fish[2]. Parent year escapement in 1991 was above average, however escapement in 1992 was below average (Table 15).

Similar to what was seen with the Salcha River chinook salmon carcass samples, the two coho salmon carcass samples collected this year exhibited different sex ratios. A two event carcass sample should be continued in future studies to minimize bias of sex composition estimates.

This year was the second year that aerial surveys were conducted to estimate the number of coho salmon in the non-boatable waters adjacent to the mainstem river. The proportions of fish spawning in the spring areas were similar during both years (0.22 and 0.24, respectively). Similar counts should be conducted in future years to obtain a more accurate estimate of total escapement as well as to determine if the distribution of spawners in these areas varies annually. Counts of escapements are primarily conducted to ensure that the minimum escapement goal (9,000 coho salmon) is achieved. In cases when this escapement objective is not met, the sport fishery can be closed to achieve the goal. In cases of large abundance, as was the case this year, modifying sport fishing bag limits would likely be of little consequence. Current regulations already allow for three coho salmon bag and possession limit. In addition, most of the fish caught are released; few fish are harvested. It is not likely that increasing the bag and possession limit would cause a substantial increase in harvest.

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[2] Preliminary Estimate. Bonnie Borba, Personal Communication. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, 1300 College Road, Fairbanks, AK, 99701.

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APPENDIX A.
Expansions of Aerial Surveys in the Chena and Salcha Rivers to Determine Escapement Guidelines Based on Abundance Estimates

MEMORANDUM **STATE OF ALASKA**
Department of Fish and Game

TO:	Distribution Commercial Fisheries Management and Development Division Department of Fish and Game Fairbanks and Anchorage	DATE:	28 April 1993
		FILE:	042893A.DOC
		TELEPHONE NO:	456-8819
THRU:		SUBJECT:	Expansion of Aerial Surveys
FROM:	Cal Skaugstad, Biologist III Sport Fish Division Department of Fish and Game Fairbanks		

During the spring staff meeting for Commercial Fisheries Division, Louis Barton and I were assigned a task to examine the relation between aerial survey estimates and mark-recapture estimates of abundance for chinook salmon escapement to the Chena and Salcha Rivers. Louis and I were given this task because the expansion factors calculated by Sport Fish and Commercial Fisheries used slightly different methods which resulted in different expansion factors. An expansion factor is a number used to expand an aerial survey in to an abundance estimate. Louis and I were to review the data and agree on a method to calculate an expansion factor.

There are several possible ways to develop an expansion factor given the available data. The best method should consider the criteria and data used to establish the biological escapement goal. As a start, I reviewed the **"Salmon Escapement Goal Documentation Forms"** which describes the method for establishing the biological escapement goals for the Chena and Salcha Rivers (*see attachment*). For the **Chena River:** "Average from 1978 through 1983 of peak annual aerial surveys, with no years missing or excluded. Resulting average was rounded to the nearest one hundred chinook (1,800). However that number was reduced approximately 7% and rounded to the nearest one hundred chinook (1,700) for the index area Moose Creek dam to the Middle Fork River, based upon historic spawner distribution." For the **Salcha River:** "Goal is the midpoint of the range 1,500 to 3,500 chinook. Low end of range is average from 1972 through 1977 of peak annual aerial surveys, while upper end of range is average from 1978 through 1983 of peak annual aerial surveys, with no years missing or excluded for either average. Resulting averages were rounded to the nearest one hundred chinook."

The method used by Sport Fish to calculate an expansion factor did not exclude any years' data while the Commercial Fisheries method excluded data for years when the aerial survey was rated "incomplete and/or poor". However, data from incomplete and/or poor surveys (1979 and 1981) were used to establish the biological escapement goal. Since data from incomplete and/or poor surveys were used to establish biological Escapement goals, these data also should be used to calculate the expansion factor for the Chena River. No aerial surveys of the Salcha River were rated incomplete and/or poor and none were excluded, although the data used to establish the

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biological escapement goal was much more variable than data for the Chena River. Since none of the extremely low counts were exclude from the data used to establish the biological escapement goal, no counts should be excluded from the data used to calculate the expansion factor for the Salcha River.

The two methods presented at the staff meeting also differed by the use of data from an aerial survey of the entire spawning grounds (Sport Fish method) versus data from an aerial survey of an index area (Commercial Fisheries method). Using the index area is probably better because the escapement goal is now set for just the index area for each river.

To calculate the expansion factors for each river I divided the sum of the estimates of abundance (mark-recapture experiment) by the sum of the aerial surveys for the index area. No data were excluded. The expansion factor for the Chena River was 3.7 and for the Salcha River was 2.8 (*see attachment*).

cc: **CF:** Bergstrom, Hilsinger, Cannon, Buklis, Sandone, Schneiderhan, Hamner, Bromaghin, Barton, Schultz, Holder,
SF: Andersen, Clark, Merritt, Parker, Hallberg.

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ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES
ARCTIC-YUKON-KUSKOKWIM REGION

SALMON ESCAPEMENT GOAL DOCUMENTATION FORM

1. *Salmon Stock (Spawning Area and Species)*:
   Chena River Chinook Salmon

2. *Biological Escapement Goal and Units of Measure*:
   >1,700 aerial survey count for index area Moose Cr. Dam to Middle Fork R.

3. *Published Reference for This Biological Escapement Goal*:
   ADF&G. 1992. Yukon Area commercial and subsistence salmon fisheries 1992 management plan. ADF&G, Commercial Fisheries Division, RIR 3A92-10.

4. *In-River Run Goal and Units of Measure*:
   Does Not Apply

5. *Published Reference for This In-River Run Goal*:
   Does Not Apply

6. *Division Having Primary Management Responsibility*:
   Commercial Fisheries Division

7. *Method for Establishing This Biological Escapement Goal*:
   Average from 1978 through 1983 of peak annual aerial surveys, with no years missing or excluded. Resulting average was rounded to the nearest one hundred chinook (1,800). However, that number was reduced approximately 7% and rounded to the nearest one hundred chinook (1,700) for the index area Moose Creek dam to the Middle Fork River, based upon historic spawner distribution.

8. *Method for Establishing This In-River Run Goal*:
   Does Not Apply

9. *Historical Background Regarding Any Prior Escapement Goals for This Stock*:
   An aerial survey escapement goal range of 300 to 1,800 chinook salmon was proposed for the Chena River in 1981. In April 1982 a goal of 1,300 chinook salmon was proposed. In April 1984 a chinook salmon escapement goal range of 1,000 to 1,700 was established for the Chena River index area from Moose Creek Dam to the Middle Fork confluence. The low end of the range was the average peak aerial survey estimate for the years 1972-1977, while the upper end of the range was the average estimates for the years 1978-1983 (reference: ADF&G. 1984. Yukon Area 1984 annual management report. ADF&G, Commercial Fisheries Division). In 1988, the escapement goal was taken as 1,700 chinook, the upper end of the former range (reference: Whitmore, C. and six coauthors. 1990. Yukon Area annual management report, 1988. ADF&G, Commercial Fisheries Division, RIR 3A90-28).

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ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF COMMERCIAL FISHERIES
ARCTIC-YUKON-KUSKOKWIM REGION

SALMON ESCAPEMENT GOAL DOCUMENTATION FORM

1. *Salmon Stock (Spawning Area and Species)*:
   Salcha River Chinook Salmon

2. *Biological Escapement Goal and Units of Measure*:
   >2,500 aerial survey count for index area TAPS crossing to Caribou Cr.

3. *Published Reference for This Biological Escapement Goal*:
   ADF&G. 1992. Yukon Area commercial and subsistence salmon fisheries 1992 management plan. ADF&G, Commercial Fisheries Division, RIR 3A92-10.

4. *In-River Run Goal and Units of Measure*:
   Does Not Apply

5. *Published Reference for This In-River Run Goal*:
   Does Not Apply

6. *Division Having Primary Management Responsibility*:
   Commercial Fisheries Division

7. *Method for Establishing This Biological Escapement Goal*:
   Goal is the midpoint of the range 1,500 to 3,500 chinook. Low end of range is average from 1972 through 1977 of peak annual aerial surveys, while upper end of range is average from 1978 through 1983 of peak annual aerial surveys, with no years missing or excluded for either average. Resulting averages were rounded to the nearest one hundred chinook.

8. *Method for Establishing This In-River Run Goal*:
   Does Not Apply

9. *Historical Background Regarding Any Prior Escapement Goals for This Stock*:
   In 1979 a chinook salmon aerial survey escapement goal of 1,500 for the Salcha River was proposed. In 1981 an escapement goal range of 800 to 3,100 was proposed. In April 1982 a goal of 3,000 was proposed. In April 1984 an escapement goal range of 1,500 to 3,500 was established for the index area from the Trans Alaska Pipeline System (TAPS) crossing upstream to Caribou Creek. The low end of the range was the average peak aerial survey estimate for the years 1972-1977, while the upper end of the range was the average estimates for the years 1978-1983 (reference: ADF&G. 1984. Yukon Area 1984 annual management report. ADF&G, Commercial Fisheries Division). In 1988, the goal was taken as 3,500 chinook, the upper end of the former range (reference: Whitmore, C. and six coauthors. 1990. Yukon Area annual management report, 1988. ADF&G, Commercial Fisheries Division, RIR 3A90-28). The current goal was established beginning with the 1990 season (reference: ADF&G. 1991. Salmon fisheries in the Yukon Area, Alaska, 1990. A report to the Alaska Board of Fisheries. ADF&G, Commercial Fisheries Division, RIR 3F91-02).

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02/26/93

Appendix Table 9. Chinook salmon escapement counts for selected spawning areas in the Alaskan portion of the Yukon River drainage, 1961–1992.[a]

Year	Andreafsky River East Fork	Andreafsky River West Fork	Anvik River[b] River	Anvik River[b] Index Area	Nulato River North Fork[c]	Nulato River South Fork	Gisasa River	Chena River Population Estimate	Chena River River	Chena River Index Area[d]	Salcha River Population Estimate	Salcha River River	Salcha River Index Area[e]
1961	1,003	–	1,226	–	376 [f]	167	266 [f]	–	–	–	–	2,878	–
1962	675 [f]	762 [f]	–	–	–	–	–	–	61 [f,g]	–	–	937	–
1963	–	–	–	–	–	–	–	–	137 [f]	–	–	–	–
1964	867	705	–	–	–	–	–	–	–	–	–	450	–
1965	–	344 [f]	650 [f]	–	–	–	–	–	–	–	–	408	–
1966	361	303	638	–	–	–	–	–	–	–	–	800	–
1967	–	276 [f]	336 [f]	–	–	–	–	–	–	–	–	–	–
1968	380	383	310 [f]	–	–	–	–	–	–	–	–	739	–
1969	274 [f]	231 [f]	296 [f]	–	–	–	–	–	–	–	–	461 [f]	–
1970	665	574 [f]	368	–	–	–	–	–	6 [f]	–	–	1,882	–
1971	1,904	1,682	–	–	–	–	–	–	193 [f,g]	–	–	158 [f]	–
1972	798	582 [f]	1,198	–	–	–	–	–	138 [f,g]	–	–	1,193	1,034
1973	825	788	613	–	–	–	–	–	21 [f]	–	–	391	352 [h]
1974	–	285	471 [f]	–	55 [f]	23 [f]	161	–	1,016 [g]	959 [g]	–	1,857	1,620
1975	993	301	730	–	123	81	385	–	316 [g]	262 [g]	–	1,055	950 [h]
1976	818	643	1,053	–	471	177	332	–	531	496	–	1,641	1,473
1977	2,008	1,499	1,371	–	286	201	255	–	563	–	–	1,202	1,052
1978	2,487	1,062	1,324	–	498	422	45 [f]	–	1,726	–	–	3,499	3,258
1979	1,180	1,134	1,484	–	1,093	414	484	–	1,159 [f]	–	–	4,789	4,310 [h]
1980	958 [f]	1,500	1,330	1,192	954 [f]	369 [f]	951	–	2,541	–	–	6,757	6,126
1981	2,146 [f]	231 [f]	807 [f]	577 [f]	–	791	–	–	600 [f]	–	–	1,237	1,121
1982	1,274	851	–	–	–	–	421	–	2,073	–	–	2,534	2,346
1983	–	–	653 [f]	376 [f]	526	480	572	–	2,553	2,336	–	1,961	1,803
1984	1,573 [f]	1,993	641 [f]	574 [f]	–	–	–	–	501	494	–	1,031	906
1985	1,617	2,248	1,051	720	1,600	1,180	735	–	2,553	2,262	–	2,035	1,860
1986	1,954	3,158	1,118	918	1,452	1,522	1,346	9,065	2,031	1,935	–	3,368	3,031 [h]
1987	1,608	3,281	1,174	879	1,145	493	731	6,404	1,312	1,209	4,771	1,898	1,671
1988	1,020	1,448	1,805	1,449	1,061	714	797	3,346	1,966	1,760	4,562	2,761	2,553
1989	1,399	1,089	442 [f]	212 [f]	–	–	–	2,666	1,280	1,185	3,294	2,333	2,136
1990	2,503	1,545	2,347	1,595	568 [f]	430 [i]	884 [f]	5,603	1,436	1,402	10,728	3,744	3,429
1991	1,938	2,544	875 [f]	625 [f]	767	1,253	1,690	3,025	1,277 [f]	1,277 [f]	5,608	2,212 [f]	1,925 [f]
1992 [k]	1,030 [f]	2,002 [f]	1,536	931	348	231	910	5,230	825 [f]	799 [f]	8,410	1,484 [f]	1,436 [f]
E.O.[m]	>1500	>1400	>1,300[n]	>500[n]	>800	>500	>600	–	–	>1,700	–	–	>2,500

[a] Data obtained by aerial survey unless otherwise noted. Only peak counts are listed. Survey rating is fair to good, unless otherwise noted. Latest table revision: November 18, 1992.

[b] From 1961–1970, river count data are from aerial surveys of various segments of the mainstem Anvik River. From 1972–1979, counting tower operated; mainstem aerial survey counts below the tower were added to tower counts. From 1980–present, aerial survey counts for the river are best available minimal estimates for the entire Anvik River drainage. Index area counts are from the mainstem Anvik River between the Yellow River and McDonald Creek.

[c] Includes mainstem counts below the confluence of the North and South Forks, unless otherwise noted.

[d] Chena River index area for assessing the escapement objective is from Moose Creek Dam to Middle Fork River.

[e] Salcha River index area for assessing the escapement objective is from the TAPS crossing to Caribou Creek.

[f] Incomplete and/or poor survey conditions resulting in minimal or inaccurate counts.

[g] Boat survey.

[h] Data unavailable for index area. Calculated from historic (1972–91) average ratio of index area counts to total river counts (0.90:1.0).

[i] Mainstem counts below the confluence of the North and South Forks Nulato River included in the South Fork counts.

[k] Preliminary

[m] Interim escapement objectives. Established March, 1992.

[n] Interim escapement objective for the entire Anvik River drainage is 1,300 salmon. Interim escapement objective for mainstem Anvik River between the Yellow River and McDonald Creek is 500 salmon.

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ANALYSIS USING INDEX AREA ONLY AERIAL COUNTS

CHENA RIVER CHINOOK
ALL DATA SCENARIO:

YEAR	ABUND.	COUNT	EXPAN.	
1986	9,065	1,935	4.685	
1987	6,404	1,209	5.297	
1988	3,346	1,760	1.901	
1989	2,666	1,185	2.250	
1990	5,603	1,402	3.996	
1991	3,025	1,277	2.369	
1992	5,230	799	6.546	
		AVERAGE	3.863	
SUMS	35,339	9,567	3.694	estimate

GOAL = 1,700
1,700 x 3.694 = 6,280
ROUNDED = 6,300

SALCHA RIVER CHINOOK
ALL DATA SCENARIO:

YEAR	ABUND.	COUNT	EXPAN.	
1987	4,771	1,671	2.855	
1988	4,562	2,553	1.787	
1989	3,294	2,136	1.542	
1990	10,728	3,429	3.129	
1991	5,608	1,925	2.913	
1992	8,410	1,436	5.857	
		AVERAGE	3.014	
SUMS	37,373	13,150	2.842	estimate

GOAL = 2,500
2,500 x 2.842 = 7,105
ROUNDED = 7,100

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APPENDIX B.
Counting Schedules for the Salcha and Chena Rivers During 1995

Appendix B1.-Schedule for counting salmon in the Salcha River during 1995.

3-9 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800					COUNT	COUNT	COUNT
0800-1600				COUNT	COUNT	COUNT	COUNT
1600-0000			COUNT	COUNT	COUNT	COUNT	COUNT

10-16 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800	COUNT		COUNT	COUNT	COUNT	COUNT	
0800-1600		COUNT	COUNT		COUNT	COUNT	
1600-0000	COUNT	COUNT			COUNT	COUNT	

17-23 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800			COUNT	COUNT	COUNT	COUNT	COUNT
0800-1600		COUNT	COUNT	COUNT	COUNT	COUNT	COUNT
1600-0000		COUNT			COUNT	COUNT	COUNT

24-30 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800	COUNT		COUNT	COUNT	COUNT	COUNT	COUNT
0800-1600		COUNT	COUNT		COUNT	COUNT	COUNT
1600-0000	COUNT	COUNT	COUNT	COUNT	COUNT		COUNT

31 July-6 Aug	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	
0800-1600	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	
1600-0000	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	

7-13 August	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800							
0800-1600			COUNT	COUNT	COUNT	COUNT	COUNT
1600-0000			COUNT	COUNT	COUNT	COUNT	COUNT

14-20 August	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800							
0800-1600	COUNT						
1600-0000							

Appendix B2.-Schedule for counting salmon in the Chena River during 1995.

10-16 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800		COUNT	COUNT	COUNT	COUNT		COUNT
0800-1600		COUNT		COUNT	COUNT	COUNT	
1600-0000	COUNT	COUNT	COUNT	COUNT	COUNT	COUNT	

17-23 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800				COUNT	COUNT	COUNT	COUNT
0800-1600			COUNT		COUNT		COUNT
1600-0000			COUNT	COUNT	COUNT	COUNT	COUNT

24-30 July	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0000-0800			COUNT			COUNT	COUNT
0800-1600	COUNT	COUNT		COUNT	COUNT	COUNT	COUNT
1600-0000	COUNT	COUNT	COUNT	COUNT	COUNT		COUNT

Appendix C

Appendix C.-Statistical tests for analyzing data for gear bias, and for evaluating the assumptions of a two-event mark-recapture experiment.

The following statistical tests will be used to analyze the data for significant bias due to gear selectivity by sex and length (from Bernard and Hansen 1992):

1. A test for significant gear bias by sex will be based on a contingency table of the number of males and females that were recaptured and were not recaptured. The chi-square statistic will be used to evaluate the bias.

If Test 1 indicates a significant bias, the following tests will be done for males and females, separately. If Test 1 does not indicate a significant bias, males and females will be combined and the following tests will be done:

2. Tests for significant gear bias by size will be based on: (A) Kolmogorov-Smirnov goodness of fit test comparing the distributions of the lengths of all fish that were marked during electrofishing and all marked fish that were collected during the carcass survey; and, (B) Kolmogorov-Smirnov two sample test comparing the distributions of the lengths of all fish that were captured during electrofishing and all fish that were collected during the carcass survey. The null hypothesis is no difference between the distributions of lengths for Test A or for Test B.

For these two tests there are four possible outcomes:

Case I:

Accept $H_O(A)$ Accept $H_O(B)$

There is no size-selectivity during the first sampling event (when fish were marked) or during the second sampling event (when carcasses were collected).

Case II:

Accept $H_O(A)$ Reject $H_O(B)$

There is no size-selectivity during the second sampling event but there is size-selectivity during the first sampling event.

Case III:

Reject $H_O(A)$ Accept $H_O(B)$

There is size-selectivity during both sampling events.

Case IV:

Reject $H_O(A)$ Reject $H_O(B)$

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Depending on the outcome of the tests, the following procedures will be used to estimate the abundance of the population:

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Case I: Calculate one unstratified estimate of abundance, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of compositions.

Case II: Calculate one unstratified estimate of abundance, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified estimates of abundance for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias (*See* Adjustments in Compositions for Gear Selectivity) to data from the second event.

Case IVb: If the stratified and unstratified estimates of abundance for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

<u>Closed Population</u>

The following two assumptions must be fulfilled:

1. Catching and handling the fish does not affect the probability of recapture; and,
2. Marked fish do not lose their mark.

Catching and handling the fish should not affect the probability of recapture because the experiment is designed to mark live fish and later recover carcasses. If the jaw tag is lost, the fin clip given each fish will identify the river section where it was marked.

Of the following assumptions, only one must be fulfilled:

1. Every fish has an equal probability of being marked and released during electrofishing;
2. Every fish has an equal probability of being collected during the carcass survey; or,
3. Marked fish mix completely with unmarked fish between electrofishing and carcass surveys.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency table. The results will be used to determine the appropriate abundance estimator and if the estimate of abundance should be stratified by river section or period:

-continued-

1. Null hypothesis is that marked-to-unmarked ratio is the same at all sites. Columns 1, 2, and 3 in the table will be the corresponding river section where the fish were recovered. Row 1 will be the number of marked fish collected during the carcass sampling event and row 2 will be the number of unmarked fish collected during the carcass sampling event. The column totals will be equal to the number of fish marked during the electrofishing event.

If the test statistic is not significant, then either every fish had an equal probability of being marked (caught in the electrofishing gear) or marked fish mixed completely with unmarked fish between sampling events. In this case a Petersen estimate will be used to estimate abundance. If the test statistic is significant the following matrix will be created:

River Section of Release	River Section of Recapture		
	Lower	Middle	Upper
Lower			
Middle			
Upper			

If all the off-diagonal elements are zero, then a Petersen estimate will be calculated for each river section. The sum of the three estimates will be the overall abundance estimate. If the off-diagonal estimates are not zero, then Darroch's method will be used to estimate abundance. With these tests it is unknown whether the second assumption was fulfilled. Darroch's method will be used to insure an unbiased estimate.

Appendix D

Appendix D.-Data files used to estimate parameters of chinook, chum, and coho salmon populations during 1995.

Data File[a]	Description
U0020TA5.ARC	Hourly counts of adult chinook and chum salmon past the counting site on the Chena River, 1995.
U0020LB5.ARC	Data file of length, sex, and tag data for chinook salmon collected during the marking event of the mark-recapture experiment in the Chena River, 1995.
CHENKG95.AWL	Data file of length, sex, tag, and age data for chinook salmon carcass collected during the recapture event of the mark-recapture experiment in the Chena River, 1995.
U0050TA5.ARC	Hourly counts of adult chinook and chum salmon past the counting site on the Salcha River, 1995.
SALCKG95.AWL	Data file of length, sex, and age data for chinook salmon carcass collected from the Chena River, 1995.
DCLRCO95.AWL	Data file of length, sex, and age data for coho salmon carcasses collected from the Delta Clearwater River, 1995.

[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, 99518-1599.