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ABSTRACT

In 1991, the number of adult chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Chena River near Fairbanks, Alaska, was estimated using a mark-recapture experiment. A riverboat equipped with electrofishing gear was used to capture 612 chinook salmon in late July. Captured chinook salmon were marked with jaw tags, fin-clipped, and released. In early August, 389 chinook salmon carcasses were collected. Seventy-eight of these carcasses had been marked. The estimate of abundance was 3,025 (standard error = 282) chinook salmon. The estimates of the number of females and males were 954 (standard error = 99) and 2,071 chinook salmon (standard error = 198), respectively. Estimated egg production for the 1991 escapement was 8.5 million eggs (standard error = 600 thousand eggs). Mean length-at-age statistics and age class composition estimates are presented. During aerial surveys, the highest count of live and dead chinook salmon was 1,276, or about 42 percent of the mark-recapture point estimate.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, Chena River, abundance, age-sex-size composition, aerial survey, egg production, tag loss.

INTRODUCTION

Management of stocks of Yukon River chinook salmon *Oncorhynchus tshawytscha* is complex and requires that accurate estimates of escapement be made in a number of major spawning streams. During a 1,440 km migration from the ocean to their spawning grounds in the Chena River, chinook salmon pass through five different sub-districts of the Yukon River commercial fishery. Chinook salmon returning to the Chena River contribute to these down river commercial fisheries as well as to several subsistence and personal use fisheries. A sport fishery takes place in the lower 72 km of the Chena River (Table 1).

To perpetuate the fisheries and stocks of chinook salmon, fishery managers set commercial, subsistence, personal use, and sport harvest limits on each fishery with the goal of allowing an adequate number of chinook salmon to reach their spawning grounds. Harvest levels for the current year are set based on estimates of the number of chinook salmon that enter the Yukon River along with results from prior years of the number of chinook salmon that were harvested, and the number of chinook salmon that reached their spawning grounds. The sport fisheries in the Chena and Salcha rivers are managed based on a guideline harvest range. In the Chena River this annual guideline harvest range is 300 to 600 chinook salmon, while in the Salcha River it is 300 to 700 chinook salmon.

The Chena River has one of the largest chinook salmon escapements in the Yukon River drainage. Estimates of abundance and age-sex-size compositions using mark-recapture techniques have been obtained since 1986 in the Chena River (Barton 1987a and 1988; Barton and Conrad 1989; Skaugstad 1990a; and Evenson 1991). The "in-season" escapements for various spawning stocks have historically been determined by aerial counts of chinook salmon on or near the spawning grounds. From 1974 to 1990 the highest annual count of chinook salmon in the Chena River during aerial surveys has ranged from less than 500 to more than 2,500 fish (Barton pers. comm.[1]). However, only a portion of the population is usually present during a single aerial survey, and the number of chinook salmon counted is influenced by weather, water level, water clarity, and overhanging vegetation. Numbers of mature chinook salmon counted during aerial surveys of the Chena River from 1986 through 1990 were 22, 20, 59, 44, and 26% respectively, of the estimated abundance from mark-recapture experiments. In addition to underestimating abundance, aerial surveys do not provide estimates of age-sex-size compositions, or potential egg production, which are needed to better assess the quality of the spawning escapement.

The specific objectives in 1991 were to estimate:

1. the abundance of adult chinook salmon in the Chena River; and,

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

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[1] Barton, Louis. 1990. Personal Communication. ADF&G, 1300 College Rd., Fairbanks, AK 99701

Table 1. Harvests of anadromous chinook salmon by sport, commercial, subsistence, and personal use fisheries, Tanana River drainage, 1978 through 1991.

	On-Site Sport Harvest Estimates[a]		Statewide Survey Estimates of Sport Harvest[b]						Estimated Harvest by User Group		
Year	Chena River	Salcha River	Chena River	Salcha River	Chatanika River	Nenana River	Other Streams	All Waters	Commercial Harvests[c]	Subsistence and Personal Use Harvests[c]	Total Known Harvest
1978	none	none	23	105	35	none	0	163	635	1,231	2,029
1979	none	none	10	476	29	none	0	515	772	1,333	2,620
1980	none	none	0	904	37	none	0	941	1,947	1,826	4,714
1981	none	none	39	719	5	none	0	763	987	2,085	3,835
1982	none	none	31	817	136	none	0	984	981	2,443	4,408
1983	none	none	31	808	147	none	10	1,048	911	2,706	4,665
1984	none	none	0	260	78	none	0	338	867	3,599	4,804
1985	none	none	37	871	373	none	75	1,356	1,142	7,375	9,873
1986	none	526	212	525	0	none	44	781	950	3,701	5,432
1987	none	111	195	244	21	7	7	474	1,202	4,096	5,772
1988	567	19	73	236	345	36	54	744	786[d]	5,584[eg]	7,090
1989	685	123	375	231	231	39	87	963	2,181[d]	2,297[eg]	5,001
1990	24	200	64	291	37	0	0	439	2,989[d]	3,759[eg]	7,140[g]
1991	none	308[h]	N.A.[f]	N.A.	N.A.	N.A.	N.A.	N.A.	1,163[dg]	N.A.	N.A.

[a] Creel census estimates from Clark and Ridder (1987), Baker (1988, 1989), Merritt et al. (1990), and Hallberg and Bingham (1991).
[b] Sport fishery harvest estimates from Mills (1979-1991).
[c] Commercial, subsistence, and personal use estimates (Schultz, Keith. 1991. Personal Communication. Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701.
[d] Includes chinook salmon sold from ADF&G test fisheries occurring near Nenana and Manley (24 fish in 1988, 440 fish in 1989, 833 fish in 1990, and 91 fish in 1991).
[e] The personal use designation was implemented in 1988 to account for non-rural fishermen participating in this fishery. Harvest by personal use fishermen was 395 fish in 1988 and 495 fish in 1989.
[f] N.A. means data not available at this time.
[g] Preliminary data and subject to change.
[h] Data from Hallberg and Bingham *In press*.

Potential egg production resulting from the 1991 escapement was estimated, and abundance was compared to aerial counts of spawning chinook salmon. Also included in this report are age-sex-size compositions of chinook salmon sampled during 1991 from the Goodpaster and Chatanika rivers.

MATERIALS AND METHODS

Capture and Marking

Adult chinook salmon were captured from 26 July through 31 July using a riverboat equipped with electrofishing gear (Clark 1985; Table 2). The chinook salmon were stunned using pulsating direct current electricity, dipped from the river with long handled nets and placed in an aerated holding box. An area of the river from about river kilometer 72 to river kilometer 145 (measured from the mouth) was sampled in this manner. Past aerial surveys of the Chena River have shown that almost all chinook salmon spawn in this area (Skaugstad 1990a). The sample area was divided into three approximately equal sections (Figure 1). During the first marking event (26, 27, and 28 July), one pass was made through each section. Each pass through a section started at the upstream end of the section and progressed downstream. Similarly, during the second marking event (29, 30, and 31 July), one pass was made through all three sections.

All captured chinook salmon were tagged, fin-clipped, measured, and released. A uniquely numbered metal tag was attached to the lower jaw of each fish. A combination of adipose, pectoral, and pelvic fin clips were used to monitor tag loss and to identify the location and period of capture of those fish loosing tags. Length was measured from mid-eye to fork-of-tail (ME-FK) to the nearest 5 mm. Sex was determined from observation of body morphology, and from the presence of stripped eggs or milt.

Recovery

Tags were recovered from chinook salmon carcasses from the same three river sections in which electrofishing was performed. One pass was made through each section in a drifting riverboat starting at the upstream end of each section. Long handled spears were used to collect carcasses. The carcasses were measured and examined for fin clips and jaw tags. The sex was determined from observation of body morphology. Three scales were removed from each carcass for age analysis. Scales were taken from the left side approximately two rows above the lateral line and along a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956).

Abundance Estimator

Abundance was estimated separately using two different models. First, an unstratified estimate was calculated using procedures described by Chapman (1951). Tests of the assumptions for use of this estimator (Appendix A1) indicated that it may have been biased. Therefore, a stratified estimate (Darroch 1961) was also calculated. The two estimates were then compared for

Table 2. Description of equipment and control settings used while electrofishing.

Generator characteristics:	4,000 KW, 60 Hz, 120 V
VVP:	Coffelt (no model number) Manufactured around 1967.
Pulse duration:	2.5 milliseconds (ms).
Duty cycle:	50%
Frequency:	40 pulses per second (pps).
Voltage:	100 - 250 volts (peak).
Amperage:	2 - 4 amperes.
Cathode:	The boat served as the cathode.
Anode:	16 mm (5/8 ") dia. flexible electrical conduit.

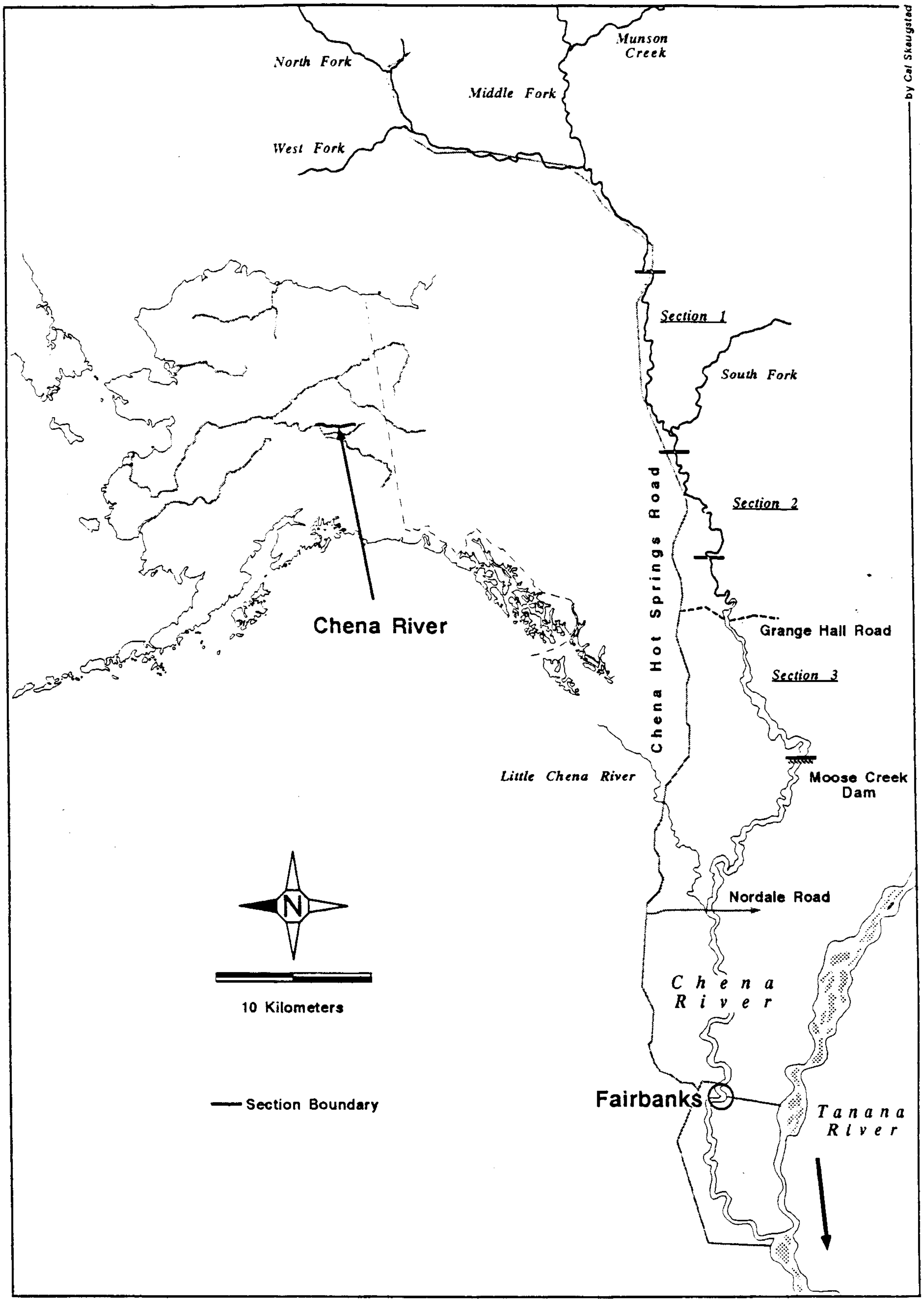

Figure 1. Chena River study area.

significant difference using a goodness-of-fit method described by Seber (1982). Ultimately, the unstratified estimator was chosen as the appropriate model. Both estimators are described below. The unstratified model (Chapman 1951) was:

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

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

where:

N = estimated abundance of chinook salmon;
n_1 = number of chinook salmon marked during Event 1;
n_2 = number of chinook salmon marked during Event 2;
m_2 = number of chinook salmon with marks in Event 2; and,
$V(\hat{N})$ = variance of $\hat{N}$.

The stratified estimator (Darroch 1961) was:

$$\underline{\hat{N}} = D_u M^{-1} \underline{a} \qquad (3)$$

where:

$\underline{\hat{N}}$ = a vector of the estimated abundance of unmarked chinook salmon in each recovery stratum j;

D_u = a diagonal matrix of the number of unmarked chinook salmon carcasses examined for tags in recovery stratum j.

M = a matrix of n_{ij} the number of tagged fish in each recovery stratum j, which were released in tagging stratum i; and,

$\underline{a}$ = a vector of the number of chinook salmon marked and released in tagging stratum i.

The total abundance was then estimated as $\underline{\hat{N}}$ + the number of marked chinook salmon.

The variance-covariance matrix of $\underline{\hat{N}}$ was estimated as follows:

$$E[(\hat{N}-N)(\hat{N}-N)']=D_N B^{-1} D_u D^{-1}{}_a B'^{-1} D_N + D_N(D_q - I) \qquad \text{(Seber 1982)} \qquad (4)$$

where,

D_N = diagonal matrix of estimated abundance in each stratum;

D_q = diagonal matrix of reciprocals of p_i, which is the estimated probability of an animal surviving and being caught;

B = matrix of B_{ij}, the probability that a member of a_i is in stratum j at sampling and that it is alive; and,

B = $D^{-1}{}_a M D_q$.

Bootstrap procedures (Efron and Gong 1983) were used to estimate sampling bias for both estimates of abundance. Five hundred bootstrap samples were drawn randomly from the mark-recapture histories of all fish captured in the experiment. Each bootstrap sample was randomly drawn with replacement from all the mark-recapture histories. An estimate of abundance was calculated for each bootstrap sample with Equation 1 and 3 giving 500 estimates of abundance for each model. A measure of the sampling bias for each estimator was the difference between the point estimate from the original sample and the average of the bootstrap estimates.

Tag Loss

The proportion of tags lost during the study and the associated variance were estimated using:

$$\hat{p}_t = n_u/n_r \quad (5)$$

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

where:

$\hat{p}_t$ = the proportion of tags lost;

n_u = the number of recaptured fish without tags; and,

n_r = the total number of fish recaptured.

Age, Length, and Sex Compositions

Age compositions were calculated from those chinook salmon sampled during the carcass survey for which scales were collected. Length and sex compositions were calculated from all chinook salmon sampled during both events. The proportion of females and males by ocean age or length and associated variance were estimated using:

$$\hat{p}_k = a_k/n \quad (7)$$

$$\hat{V}(\hat{p}_k) = \hat{p}_k(1-\hat{p}_k)/(n-1) \quad (8)$$

a_o = y intercept (-7,940, from Skaugstad and McCracken 1991);
b_o = slope (20, from Skaugstad and McCracken 1991);
MSE_o = mean square error from the regression of F on L (2,365,812, from Skaugstad and McCracken 1991); and,

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

Potential egg production of the spawning chinook salmon was estimated using:

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

$$V(\hat{E}) = \sum V(\hat{N}_k \hat{F}_k); \text{ and} \quad (14)$$

$$V(\hat{N}_k \hat{F}_k) = \hat{N}_k^2 V(\hat{F}_k) + \hat{F}_k^2 V(\hat{N}_k) - V(\hat{N}_k) V(\hat{F}_k) \quad (15)$$

where:

$\hat{E}$ = the production of eggs from the spawning chinook salmon population;

$\hat{N}_k$ = the estimated number of females of length interval k;

$\hat{F}_k$ = the mean fecundity for females of length interval k as determined by Skaugstad and McCracken (1991) for chinook salmon in the Tanana River drainage;

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

$V(\hat{F}_k)$ = the variance of the mean fecundity for females of length k; and,

$V(\hat{N}_k)$ = the variance of the estimated number of females of length interval k.

Aerial Survey

Personnel from the Division of Commercial Fisheries of the Alaska Department of Fish and Game attempted to count the total number of spawning chinook salmon in the Chena River on four different occasions. High, turbid water and fog prevented counts on three of these occasions. A successful count was conducted 21 July. Counts were made from low flying, fixed-wing aircraft. Barton (1987b) describes the methods used by the Division of Commercial Fisheries for aerial surveys.

Goodpaster and Chatanika Rivers

Chinook salmon carcasses were collected from the Goodpaster River on 16 August, and from the Chatanika River on 13 July and 18 August. Age and sex compositions for chinook salmon collected in the Goodpaster River were estimated using the procedures described above (Equations 7 and 8). Proportions of male and female chinook salmon within 50 mm length categories were calculated in the same manner. Because too few chinook salmon were collected from the Chatanika River, estimates of age-sex-size compositions were not calculated.

RESULTS

A total of 612 chinook salmon were captured, tagged, and released from 26 July to 31 July. During the recapture event, 389 carcasses were collected and examined for tags and fin clips from 6 August to 9 August. Seventy-eight of these fish were marked. Three marked fish had lost tags.

Tests of Assumptions for a Petersen Estimator

The following results were based on a series of statistical tests (described in Appendix A1) conducted with data from the mark-recapture experiment.

Sex and Size Selectivity:

No selectivity in the carcass survey was indicated. Males and females were recovered at similar rates (males = 0.12; females = 0.14; $\chi^2 = 0.31$, df = 1, $0.75 > P > 0.5$; Table 3). There was no significant difference between the length distribution of all marked releases and recaptures during the carcass sample ($P = 0.094$; Figure 2). The length distribution of marked fish was not significantly different than the length distribution of all fish captured during the carcass survey ($P > 0.99$; Figure 2). These tests indicate that no size or sex selectivity occurred during either sampling event. Lengths and sexes from both events were combined to estimate length and sex compositions.

Closed Population:

The marked-to-unmarked ratio of chinook salmon was significantly different among the three sampling sites during the carcass sampling event ($\chi^2 = 12.48$, df = 2, $P = 0.002$; Table 4). Therefore, all fish did not have an equal probability of capture by area during the first sampling event, and marked fish did not mix completely with unmarked fish between the two sampling events. Mixing was not complete, but did occur to some extent (Table 4). It is unknown if marked and unmarked chinook salmon had an equal probability of being collected during the second event.

Abundance Estimate

The unstratified estimate of abundance (Chapman 1951) of all chinook salmon was 3,025 (SE = 282). The stratified estimate of abundance (Darroch 1961) of all chinook salmon was 3,172 (SE = 575). Although there was bias associated

Table 3. Number of male and female chinook salmon marked while electrofishing that were recovered and not recovered during carcass sampling.

	Males	Females	Total
Recovered	51	27	78
Not Recovered	366	168	534
Total Released	417	195	612
Recovery Rate	0.12	0.14	0.13

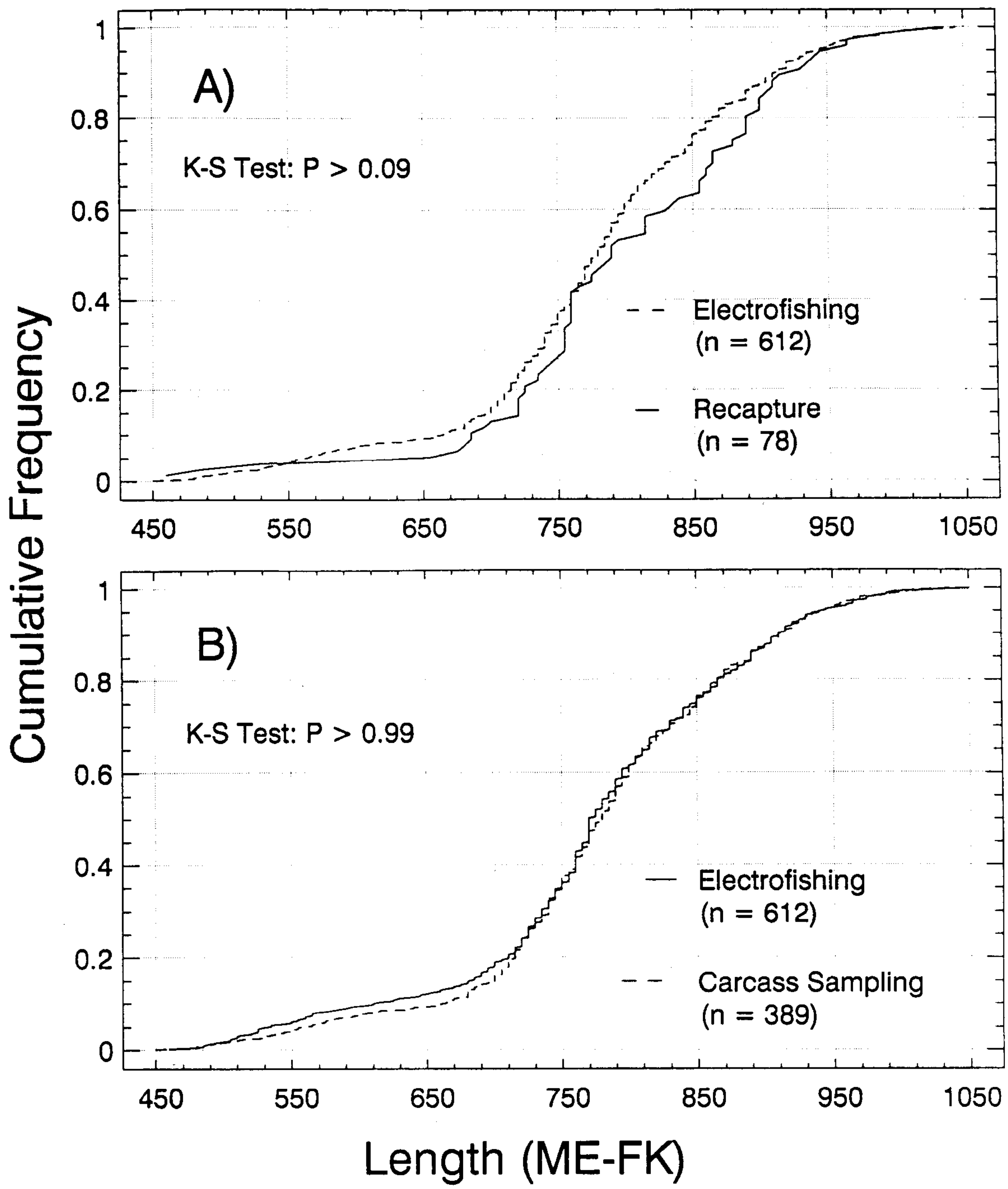

Figure 2. Cumulative length frequency distributions comparing lengths of all chinook salmon captured during the marking event to: A) lengths of all recaptured chinook salmon; and, B) lengths of all chinook salmon capture during the recapture event.

Table 4. Capture and recapture history of all chinook salmon sampled during the mark-recapture experiment.

River Section Where Marks Were Released	River Section Where Marks Were Recaptured: Upper	Middle	Lower	Total	Number Marked	Number Not Recaptured
Upper	19	22	1	42	260	218
Middle	0	28	4	32	279	247
Lower	0	0	4	4	73	69
Total	19	50	9	78	612	534
Unmarked Carcasses	121	130	60	311	Total Number of Unique Fish Examined	
Total Carcasses	140	180	69	389	923	

with the unstratified estimate, it was not meaningful as there was no significant difference between these two estimates ($P = 0.409$). Because the unstratified estimate had a much lower variance, it was selected as the appropriate estimator. The bootstrap mean estimates of abundance were 3,060 (SE = 273) for the unstratified estimate and 4,148 (SE = 983) for the stratified estimates (Figure 3). The sampling bias was 35 fish (1%) and 976 (31%) for the two estimates respectively.

Tag Loss

Because all marked fish received both a metal jaw tag and a fin clip, the proportion of tags lost during the mark recapture experiment could be estimated. Seventy-eight marked chinook salmon carcasses were recovered; 75 had tags, and only three had a distinguishable fin clip and no tag attached. The estimated proportion of tags lost during the mark-recapture experiment was 0.04 (SE = 0.02).

Age, Length, and Sex Compositions

Age data were obtained from 339 of the 389 chinook salmon collected during the carcass survey. These fish spent two to five years in the ocean and nearly all fish spent just one year in freshwater (Table 5). The dominant age class for females was 1.4 (brood year 1985), and for males was 1.3 (brood year 1986).

Chinook salmon from both sampling events were used to estimate the proportions of males and females in the population. Females comprised 31.9% (SE = 1.5) of the population, while males comprised 68.5% (SE = 1.5). The estimates of abundance were 954 female chinook salmon (SE = 99) and 2,071 male chinook salmon (SE = 198; Table 5).

Lengths of females ranged from 645 to 980 mm, while males ranged from 460 to 1,085 mm. Chinook salmon less than 750 mm were predominantly males. The mean lengths of females were usually greater than the mean lengths of males for a given age (Table 6).

Potential Egg Production

The estimate of total potential egg production was 8,532,000 eggs (SE = 616,000; Table 7).

Aerial Survey

Survey conditions were judged to be "poor" on a scale of "poor, fair, and good". The count was 1,276 total live and dead chinook salmon on 21 July, and was conducted just prior to the first marking event. This count was 42% of the point estimate from the mark-recapture experiment, and was within the range of observed proportions from aerial counts conducted since 1986 (Table 8).

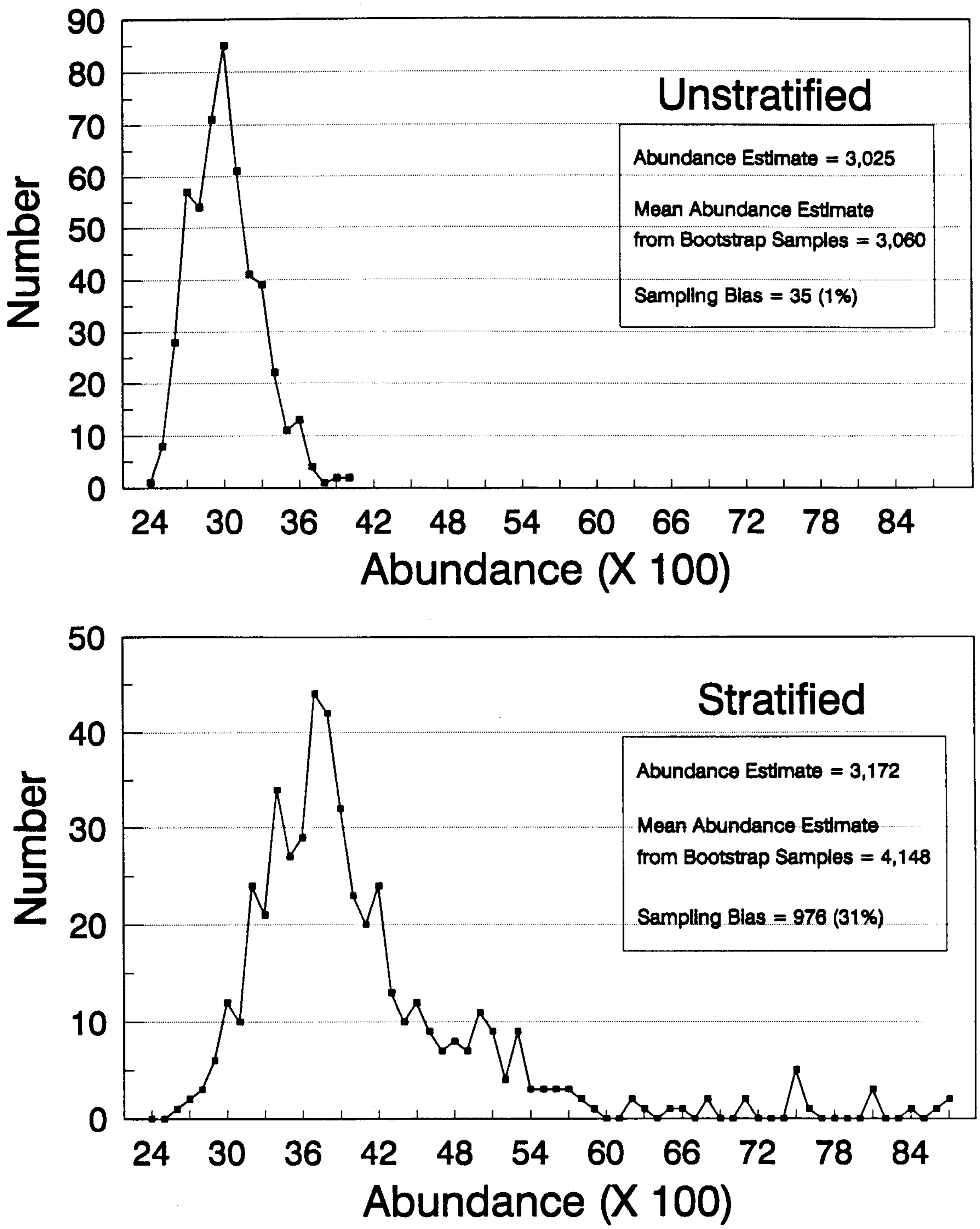

Figure 3. Frequency of 500 estimates of abundance using bootstrap procedures on the capture histories of all chinook salmon captured during the mark-recapture experiment using an unstratified estimator (top panel) and a stratified estimator (bottom panel).

Table 5. Estimates of proportions and abundance of female and male chinook salmon by age class collected during carcass sampling, Chena River, 1991.

Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
Females:					
1.3	13	0.038	0.010	116	33
1.4	67	0.198	0.022	598	86
1.5	25	0.074	0.014	223	48
2.4	1	0.003	0.003	9	9
1.6	1	0.003	0.003	9	9
2.5	1	0.003	0.003	9	9
Totals	108	0.315	0.025	964	118
	315[a]	0.318[a]	0.015[a]	954[a]	99[a]
Males:					
1.2	29	0.086	0.015	259	52
1.3	113	0.333	0.026	1,008	122
1.4	72	0.212	0.022	642	90
1.5	17	0.050	0.012	152	38
Totals	231	0.681	0.025	2,061	207
	684[a]	0.685[a]	0.015[a]	2,071[a]	198[a]
Females and Males:					
1.2	29	0.086	0.015	259	52
1.3	126	0.372	0.026	1,124	131
1.4	139	0.410	0.027	1,240	141
1.5	42	0.124	0.018	375	64
2.4	1	0.003	0.003	9	9
1.6	1	0.003	0.003	9	9
2.5	1	0.003	0.003	9	9
Totals	339	1.000		3,025	282
	999[a]	1.000		3,025[a]	282[a]

[a] Based on chinook salmon captured during both sampling events.

Table 6. Estimated length-at-age of Chena River chinook salmon, 1991.

Ocean Age	Sample Size	Length (mm) Mean	SE	Range
Females:				
3	13	738	14	645 - 820
4	68	827	6	740 - 925
5	26	905	8	830 - 975
6	1	980	-	980
Total	108	836	6	645 - 980
Males:				
2	29	540	11	460 - 770
3	113	726	4	580 - 820
4	72	815	7	695 - 955
5	17	965	12	830 - 1,085
Total	231	749	8	460 - 1,085
Females and Males:				
2	29	540	11	460 - 770
3	126	728	4	580 - 820
4	140	822	5	695 - 925
5	43	930	8	830 - 1,085
6	1	980	-	980
Total	339	772	6	460 - 1,085

Table 7. Estimated potential egg production of Chena River chinook salmon by length category, 1991.

Length Class (mm)	No. of Females in Sample	Estimated No. of Females in Population	Standard Error	Estimated Egg Production (eggs)	Standard Error
640-680	2	6	5	34,641	25,793
690	1	3	3	17,934	17,934
700	1	3	3	18,547	18,547
710	2	6	4	38,319	28,269
720	0	0	0	0	0
730	4	12	6	81,543	45,299
740	6	18	8	125,993	60,175
750	8	25	9	172,896	74,570
760	17	52	14	377,826	131,456
770	10	31	10	228,381	90,362
780	20	61	15	469,024	153,311
790	12	37	11	288,771	106,368
800	20	61	15	493,547	157,532
810	20	61	15	505,808	159,715
820	11	34	11	284,938	105,299
830	14	43	12	371,232	126,587
840	22	68	16	596,852	178,920
850	13	40	12	360,655	124,078
860	17	52	14	482,048	152,174
870	13	40	12	376,595	128,090
880	18	55	14	532,475	163,254
890	11	34	11	332,145	118,289
900	15	46	13	462,121	147,964
910	15	46	13	471,317	150,204
920	10	31	10	320,342	116,736
930	8	25	9	261,178	103,194
940	5	15	7	166,302	79,371
950	5	15	7	169,367	80,726
960	7	21	8	241,406	99,933
970	4	12	6	140,398	73,552
980	0	0	0	0	0
990	2	6	4	72,651	52,173
1,000	1	3	3	36,939	36,939
Totals	314	964		8,532,194	616,207[a]

[a] The standard error was calculated as the square root of the sum of the variances of the estimated fecundities for each length.

Table 8. Estimated abundance, maximum aerial counts, and survey conditions for chinook salmon in the Chena River, 1986-1991.

Year	Estimated Abundance	S.E.	Aerial Survey Count	Aerial Survey Condition	Proportion Observed During Aerial Survey
1986	9,065	1,080	2,031	Fair	0.22
1987	6,404	563	1,312	Fair	0.20
1988	3,346[a]	---	1,966	Fair-Poor[b]	0.59
1989	2,666	249	1,180	Fair-Good[b]	0.44
1990	5,603	1,164	1,436	Fair-Poor[b]	0.26
1991	3,025	575	1,276	Poor	0.42

[a] Original estimate was 3,045 (SE = 561) for a portion of the river. The estimate was then expanded from distribution of spawners based upon aerial counts.

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

Goodpaster and Chatanika Rivers

Ninety-three chinook salmon carcasses were collected from the Goodpaster River. Sex was determined for 86 of these fish. The proportions of females and males in this sample was 0.357 (SE = 0.053) and 0.643 (SE = 0.053), respectively. The dominant age class was 1.4 (19% of total sample; SE = 4.3) for females and 1.3 (41.7% of total sample; SE = 5.4) for males (Appendix B1). Most of the sample was comprised of fish 650 mm and larger. Of those fish smaller than 650 mm, nearly all were males (Appendix B2).

Only eight chinook salmon were collected from the Chatanika River. Four were females, two were males, and two were of unknown sex. Lengths ranged from 693 mm to 930 mm. Age classes 1.3, 1.4, and 1.5 were represented in the sample (Appendix C1).

DISCUSSION

The success of this annual mark-recapture experiment is heavily dependant on timing of the sampling events. Ideally, electrofishing should take place at a time when virtually all chinook salmon are in the river, have completed spawning, and have not yet died. Carcass sampling should take place immediately after all chinook salmon have died, but before they begin to decompose or become covered with silt on the river bottom. If sampling occurs under these conditions, then achieving equal probabilities of capture during both sampling events is most likely. During the electrofishing events, most fish captured had already spawned. Very few carcasses were noticed along the course of the study area. During the carcass survey only a few carcasses had decomposed to the extent that sex and length could not be determined. This indicated that most fish were not dead for more than a few days. However, a moderate number of live fish were still in the river during the carcass sampling, but most all appeared to be in post-spawning condition. Relatively few carcasses were sampled compared to previous years (Skaugstad 1990a; Evenson 1991). This does not necessarily indicate that a large proportion of the population was still alive. Adverse weather and water conditions were more likely reasons for the relatively low number of collected carcasses. The presence of live fish during carcass sampling does not bias the estimate unless the marked to unmarked ratio of live fish is different from that of dead fish. If electrofishing and handling facilitates a premature death, then the marked to unmarked ratio of the carcasses would be greater than that of the live fish and the estimate would be biased low. To test for this, either the remaining live fish would need to be sampled, or a separate carcass sample would need to be conducted at a later date.

In this experiment there was no size or sex selectivity during either sampling event, however the ratios of marked to unmarked fish from the carcass survey varied among river sections. This indicates that there was incomplete mixing of marked and unmarked fish among river sections, and there was an unequal probability of capture during the first sampling event. An unbiased Chapman (1951) estimator requires the gear to capture all chinook salmon in the population with equal probability during at least one of the sampling events, or that marked fish mix completely with unmarked fish between sampling events.

The Darroch (1961) estimate is considered unbiased even though there are unequal probabilities of capture. Because the estimates of abundance from the Chapman and Darroch estimators were similar, the bias due to differing marked to unmarked ratios among river sections was meaningless in terms of the estimate of abundance. Incomplete mixing tends to be inherent with the present sampling design. Marked fish tend to be recaptured in the section they were tagged or in sections downstream. When captured for marking, most chinook salmon had finished or nearly finished spawning and were a few days from death. Dying fish would be less able to move upstream or maintain a stationary position and would probably drift downstream and settle into areas with lower velocities (as with pools). Unequal probabilities of capture among river sections during the first sampling event is also inherent, especially in the lower river section. This section tends to be more difficult to sample due to its general morphometry: river velocity is slower, water is deeper and more turbid, there are fewer gravel bars, and there are more fallen trees. These factors make it difficult to see and capture chinook salmon during both sampling events. The sampling design was set up such that equal fishing effort was expended in each of the three river areas during both sampling events, and the intent was to estimate abundance using the Chapman model. Allocating proportionally more sampling effort in one or more river sections would require that a stratified estimator be used. While this design modification might alleviate problems with capture probabilities or mixing, it would most likely result in a less accurate estimate of abundance than if an unstratified estimator was used, or it would cost more in terms of sampling effort.

Bias of the abundance estimate associated with tag losses in this investigation and similar studies (Skaugstad 1988, 1989, 1990a, and 1990b; Evenson 1991; Burkholder 1991) was minimal or nonexistent. The jaw tags were securely attached around the lower jaw (dentary bone) and decomposition of the flesh did not facilitate tag loss. The three tags that were lost in this experiment were easily identified by the presence of fin-clips.

Too few carcasses were collected to estimate all proportions of male and female chinook salmon by age class within the objective criteria for accuracy and precision (within five percentage points of the actual proportions 95% of the time). To meet these criteria, 193 additional carcasses were needed (Thompson 1987). Because both samples were combined to estimate length and sex compositions, objective criteria for estimating these proportions (same as above) were achieved. Accurate estimation of the proportions of female chinook salmon by length categories in turn provided an accurate estimate of population egg production (relative precision = 15%). The same methodology (mark by electrofishing, recapture by collecting carcasses) has been used to estimate age-sex-size compositions in the Salcha River since 1987 (Skaugstad 1988, 1989, 1990b, and *In press*; Burkholder 1991) and in the Chena River since 1989 (Skaugstad 1990a: Evenson 1991, and this study). These studies have indicated that there is generally no sex selectivity within either sampling event. When there is size selectivity, it is typically during the electrofishing event. The best way to ensure that all objective criteria are met for age-sex-size compositions in the future is to establish sample sizes based on the carcass sampling event.

Attempts to estimate a relationship between the proportion of the population of chinook salmon observed during aerial surveys and estimates of abundance from mark-recapture experiments indicate that: (1) there is an inverse relationship between the proportion of the population observed during an aerial survey and the size of the population; and, (2) the proportion of the population observed during an aerial survey is dependant on environmental factors and timing of the survey relative to peak spawning. Because of the various effects of these factors, the number of paired aerial surveys and mark-recapture experiments since 1986 does not yet provide enough information to adequately describe the relationship.

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APPENDIX A

Appendix A1. Statistical tests for analyzing data from a mark-recapture + experiment 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:

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.

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

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.

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Closed Population

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:

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.

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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 B

Appendix B1. Estimates of the proportions of female and male chinook salmon by age class, and mean length-at-age estimates for chinook salmon sampled in the Goodpaster River, 1991.

Age Class	Sample Size	Proportion of Sample	Standard Error	Mean Length	Standard Error
Females:					
1.2	1	0.012	0.012	575	
1.3	9	0.107	0.034	737	14
1.4	16	0.190	0.043	828	14
1.5	4	0.048	0.023	909	14
Totals	30	0.357	0.053	803[a]	16
Males:					
1.2	5	0.060	0.026	572	13
1.3	35	0.417	0.054	728	12
1.4	12	0.143	0.038	827	14
1.5	2	0.024	0.017	975	25
Totals	54	0.643	0.053	744[b]	14
Males and Females:					
1.2	6	0.071	0.028	573	11
1.3	44	0.524	0.055	729	10
1.4	28	0.333	0.052	827	10
1.5	6	0.071	0.028	931	18
Totals	84	1.000		768[c]	10

[a] Total sample size was 34 and included four female chinook for which an age was not assigned.

[b] Total sample size was 57 and included three male chinook for which an age was not assigned.

[c] Total sample size was 93 and included seven chinook for which an age was not assigned and two chinook for which neither sex nor age was assigned.

Appendix B2. Length compositions of male and female chinook salmon carcasses sampled in the Goodpaster River, 1991.

Length Category	Sample Size	Proportion of Sample	Standard Error
Female:			
<500	0	0	0
500-549	0	0	0
550-599	1	0.011	0.011
600-649	0	0	0
650-699	3	0.033	0.018
700-749	6	0.066	0.026
750-799	5	0.055	0.024
800-849	7	0.077	0.028
850-899	8	0.088	0.029
900-949	3	0.033	0.018
950+	0	0	0
Totals:	33	0.363	0.051
Male:			
<500	1	0.011	0.011
500-549	1	0.011	0.011
550-599	5	0.055	0.024
600-649	2	0.022	0.015
650-699	6	0.066	0.026
700-749	13	0.143	0.036
750-799	16	0.176	0.039
800-849	6	0.066	0.026
850-899	5	0.055	0.024
900-949	2	0.022	0.015
950+	1	0.011	0.011
Totals:	58	0.637	0.051
Female and Male:			
<500	1	0.011	0.011
500-549	1	0.011	0.011
550-599	6	0.065	0.026
600-649	2	0.022	0.015
650-699	9	0.097	0.031
700-749	19	0.204	0.042
750-799	22	0.237	0.044
800-849	13	0.140	0.036
850-899	14	0.151	0.037
900-949	5	0.054	0.024
950+	1	0.011	0.011
Totals:	93[a]	1.000	0

[a] Total sample included two fish for which sex was not determined.

APPENDIX C

Appendix C1. Age, length, and sex data collected from chinook salmon carcasses in the Chatanika River, 1991.

Date of Collection	Sex	Length	Age
7/13/91	Unknown	693	1.3
8/08/91	Unknown	840	1.5
8/08/91	Male	790	1.3
8/08/91	Male	830	1.4
8/08/91	Female	790	1.4
8/08/91	Female	810	1.4
8/08/91	Female	900	1.5
8/08/91	Female	930	1.5