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Abundance, Egg Production, and Age-Sex-Length Composition of the Chinook Salmon Escapement in the Salcha River, 1990

by

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ABSTRACT

In 1990, the abundance of chinook salmon *Oncorhynchus tschawytscha* that returned to spawn in the Salcha River near Fairbanks, Alaska, was estimated using a mark-recapture experiment. A riverboat equipped with electrofishing gear was used to capture 594 chinook salmon in early August. Captured chinook salmon were marked with jaw tags, fin clipped, and released. In mid August, 1,322 chinook salmon carcasses were collected. Eighty of these carcasses had been marked. The estimate of abundance was 10,728 (standard error = 1,405). The ratio of females to males was about 1 to 1. Forty-nine percent of the spawners spent four years at sea with three ocean fish being the next most abundant age class. During aerial surveys, the highest count of chinook salmon was 3,744, about 35 percent of the mark-recapture point estimate. The estimate of egg production for the 1990 escapement was 52 million eggs (standard error = 2.7 million).

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

INTRODUCTION

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

To perpetuate the stocks of chinook salmon, fishery managers set harvest levels for the various fisheries such that a desired number of chinook salmon are allowed to reach their spawning grounds. Harvest levels for the current year are based on estimates of 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 that reached their spawning grounds. An important fact when evaluating stock status of chinook salmon is the number of spawners that successfully reach their spawning grounds. When the number of spawners is less than desired, then the overall harvest level was probably too high. This information can be used in the future to better estimate harvest levels that will allow an optimal number of chinook salmon to reach spawning habitat.

The Salcha River is a 250 km long, clear, runoff river flowing into the Tanana River about 60 km east of Fairbanks (Figure 1). From 1972 to 1988, the number of mature chinook salmon counted in the Salcha River during aerial surveys has ranged from 391 to 6,757 (Barton 1984, Skaugstad 1990a). These counts imply that the Salcha River supports one of the largest chinook salmon spawning populations in the entire Yukon River drainage. Only a portion of the entire spawning population is usually present during a single aerial survey and the number of chinook salmon counted is also affected by weather, water level, water clarity, and overhanging vegetation. Skaugstad (1988, 1989, and 1990a) found that the number of chinook salmon counted during surveys of the Salcha River in 1987, 1988, and 1989 was about 40%, 61%, and 71% respectively, of the estimated abundance from mark-recapture experiments. Barton (1987a, 1987b) found that the number of mature chinook salmon counted during an aerial survey was less than 20% of the estimated abundance based on mark-recapture experiments in the Chena River (near Fairbanks), and based on fish counts through a weir in Clear Creek (near Nenana).

The objectives of the chinook salmon project for the Salcha River in 1990 were to:

1. estimate the abundance of spawning chinook salmon in the Salcha River, and compare this estimate of abundance with aerial survey counts of abundance;

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

Table 1. Harvests of anadromous chinook salmon by sport, commercial, subsistence, and personal use fisheries, Tanana Drainage, 1978 through 1990.

	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	N.A.[f]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	2,989[dg]	N.A.	N.A.

[a] Creel census estimates from Clark and Ridder (1987), Baker (1988, 1989), and Merritt et al. (1990).
[b] Sport fishery harvest estimates from Mills (1979-1990).
[c] Commercial, subsistence, and personal use estimates from ADFG (1990) and ADFG (in press).
[d] Includes chinook salmon sold from ADFG test fisheries occurring near Nenana and Manley (24 fish in 1988, 440 fish in 1989, and 833 fish in 1990).
[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.

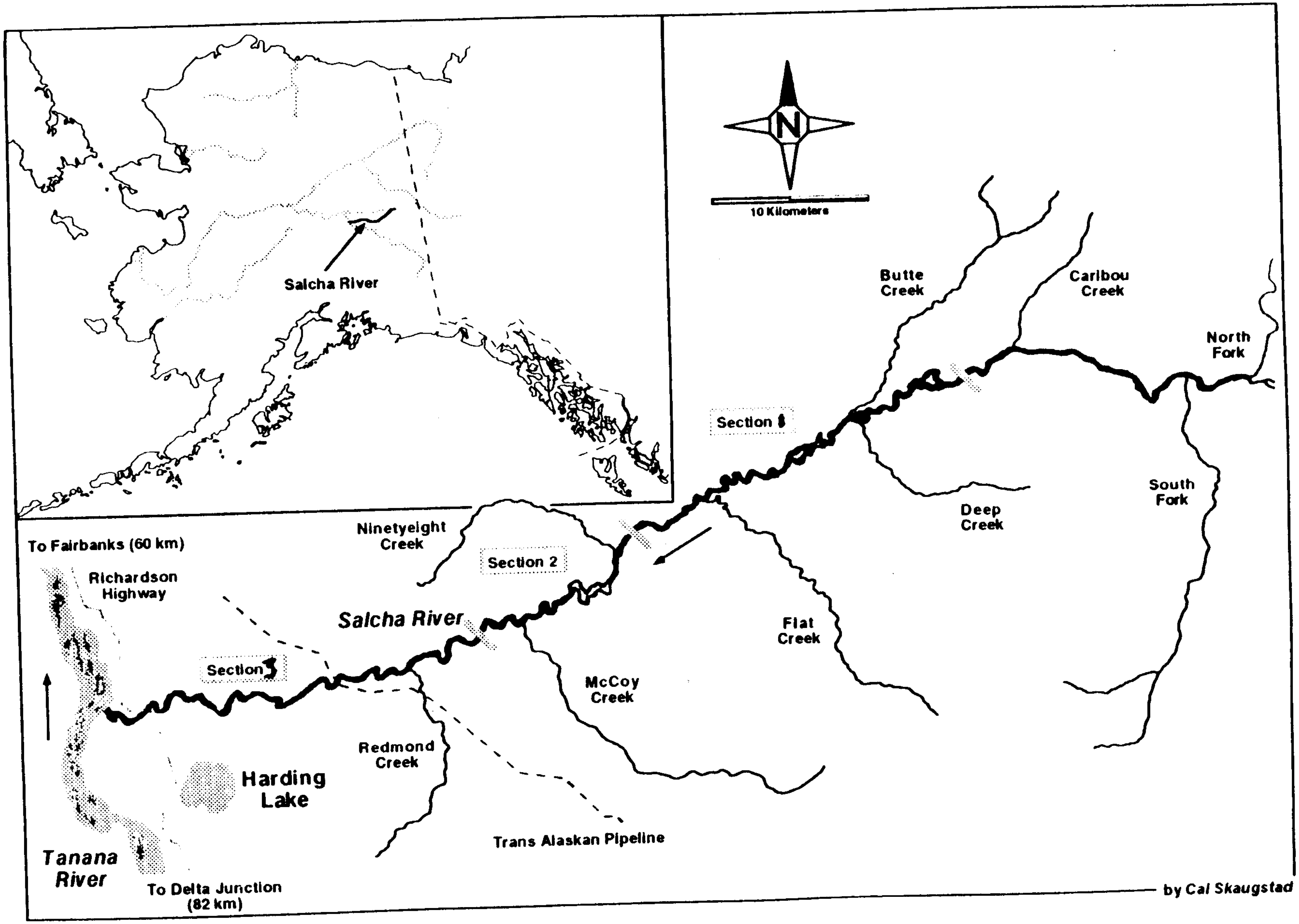

Figure 1. Salcha River study area.

3. estimate potential egg production for the escapement of chinook salmon in the Salcha River.

METHODS

Capture and Marking

Adult chinook salmon were captured from 25 July through 2 August 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 dip nets and placed in an aerated holding box. Since past aerial surveys of the Salcha River have shown that few chinook salmon spawn above Caribou Creek (Fred Andersen pers. comm[1]), only the lower 97 km of the Salcha River, between the confluences of the Salcha River with Caribou Creek and the Tanana River, were sampled. The sample area was divided into three sections (Figure 1). The length of each section was based on the estimated number of chinook salmon present (from aerial surveys), and the number of chinook salmon that could be captured and tagged in one day. During the first marking event, one pass was made through sections 3, 2, and 1 on 25, 26, and 27 August, respectively. Each pass through a section started at the upstream end of the section. During the second marking event, one pass was again made in all three sections. Sections 3, 2, and 1 were sampled on 30 July through 2 August.

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 was used to identify the location and period of capture. Length was measured from mid-eye to fork-of-tail (ME-FK) to the nearest 5 mm. Sex was determined from observation of body morphology.

Recovery

Tags were recovered from chinook salmon carcasses from the same three river sections in which electrofishing was performed. Carcasses were collected starting with section 3 and ending with section 1 on 6 August through 9 August.

One pass was made through each section in a drifting riverboat starting at the upstream end of each section. Carcasses were collected with long handled spears. The carcasses were measured and examined for jaw tags and fin clips. Sex was determined from observation of body morphology. Three scales were removed from each of the first 600 carcasses for age analysis.

Abundance Estimator

After investigating results from the mark-recapture experiment with a battery of statistical tests (described Appendix A1), a Darroch estimator stratified

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

Table 2. Description of equipment, control settings, and water conductivity while electrofishing the Salcha River in 1990.

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 in) diameter flexible electrical conduit.
Water conductivity:	90 - 120 microsiemens/cm^3.

by geographical location was selected as the appropriate estimator. The Darroch estimator (Darroch 1961, cited in Seber 1982) used is summarized below:

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

where:

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

Du = 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 stratumj, which were released in tagging stratum i; and,

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

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

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

$$E[(\hat{N}-N)(\hat{N}-N)']=D_N B^{-1} D_u D^{-1}_a B'^{-1} D_N + D_N(D_q - I) \qquad \text{(Seber 1982)} \qquad (2)$$

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 investigate statistical bias in the estimate of abundance. Five hundred bootstrap samples were drawn randomly from the mark-capture histories of all 1,074 fish in the experiment. Each bootstrap sample was built by randomly drawing 1,074 samples with replacement from the body of mark-capture histories. An estimate of abundance was calculated for each bootstrap sample with Equation 1 giving 500 estimates of abundance. A measure of the statistical bias 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 was estimated using:

$$\hat{p}_t = n_u/n_r; \text{ and,} \tag{3}$$

$$V(\hat{p}_t) = \hat{p}_t(1-\hat{p}_t)/(n_r-1); \tag{4}$$

where:

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

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

n_r = the total number of marked fish recaptured.

Age, Sex, and Length Compositions

The proportion of females and males by ocean age or length and associated variances were estimated using:

$$\hat{p}_i = a_i/n; \text{ and,} \tag{5}$$

$$V(\hat{p}_i) = \hat{p}_i(1-\hat{p}_i)/(n-1); \tag{6}$$

where:

$\hat{p}_i$ = the estimated proportion of females (or males) of ocean age or length;

a_i = the number of females (or males) of ocean age or length i sampled; and,

n = the total number of females and males sampled.

The abundance of females (or males) of ocean age or length i in the population was estimated using:

$$\hat{N}_i = \sum \hat{p}_i(\hat{N}) \tag{7}$$

The variance of the product N_i was estimated using Goodman's (1960) exact variance of products:

$$V(\hat{N}_i) = \sum[\hat{N}^2 V(\hat{p}_i) + \hat{p}_i^2 V(\hat{N}) - V(\hat{p}_i)V(\hat{N})] \tag{8}$$

Egg Production From Escapement

Predictions of fecundity for a given length were estimated as follows (Skaugstad and McCracken in press):

$$\hat{F} = a + b\,L_j \qquad (9)$$

$$\hat{V}(F_j) = MSE \left\{ 1 + \frac{1}{n} + \frac{(L_j - L)^2}{\sum L_j^2 - (\sum L_j)^2/n} \right\} \qquad (10)$$

where:

F_j = fecundity of fish j;
L_j = length of of fish j;
n = sample size; and,
MSE = mean squared error from the regression of F on L.

The total egg production of the spawning chinook salmon was estimated using:

$$\hat{E} = \sum \hat{N}_i \hat{F}_i; \qquad (11)$$

$$\hat{V}(\hat{E}) = \sum \hat{V}(\hat{N}_i \hat{F}_i); \text{ and,} \qquad (12)$$

$$\hat{V}(\hat{N}_i \hat{F}_i) = \hat{N}_i^2 \hat{V}(\hat{F}_i) + \hat{F}_i^2 \hat{V}(\hat{N}_i) - \hat{V}(\hat{N}_i)\hat{V}(\hat{F}_i); \qquad (13)$$

where:

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

$\hat{N}_i$ = the estimated number of females of length interval i;

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

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

$\hat{V}(F_i)$ = the variance of the mean fecundity for females of length interval i; and,;

$\hat{V}(N_i)$ = the variance of the estimated number of females of length interval i.

Aerial Survey

Personnel from the Fairbanks office of the Division of Commercial Fisheries of the Alaska Department of Fish and Game counted the number of live and dead adult chinook salmon in the Salcha River on 16, 18, 20, and 27 July. Counts were made from low flying, fixed-wing aircraft. Barton (1987c) described the methods used by the Division of Commercial Fisheries staff for these aerial surveys.

RESULTS

A total of 594 chinook salmon were captured, tagged, and released from 25 July to 2 August. During the recapture event 1,322 carcasses were collected and examined for tags and fin clips from 6 August to 9 August; 80 of these fish were marked.

Tests of Assumptions for Abundance Estimator

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

Gear Bias:

No selectivity in the carcass survey was indicated. Males were recovered with similar rates as were females (males = 0.13; females = 0.20; χ^2 = 3.10, df = 1, $0.05 < p < 0.10$; Table 3). Nor were large chinook salmon captured at different rates than were smaller salmon (Kolmogorov-Smirnov two sample test on lengths of marked fish versus lengths of recaptured fish, P = 0.17; Figure 2). Since the length distributions of marked fish were different from the length distribution of all fish captured during the carcass survey (Kolmogorov-Smirnov two sample test on lengths of fish captured electrofishing versus lengths of fish captured in the carcass survey $P < 0.001$; Figure 3), and since no size selectivity was observed in the carcass survey, electrofishing gear used in the first sampling event was size-selective. Therefore, the estimate of abundance was not stratified by length or sex categories, but only those chinook salmon collected during the carcass survey (second event) were used for estimating sex and age compositions.

Closed Population:

The marked-to-unmarked ratio of chinook salmon was significantly different at all sites during the carcass sampling event (χ^2 = 6.98, df = 2, 0.025 < p <

Table 3. Number of male and female chinook salmon that were recovered during carcass sampling.

	Males	Females	Total
Recovered	44	36	80
Not recovered	335	179	514
Total released	379	215	594
Recovery rate	0.09	0.10	0.10

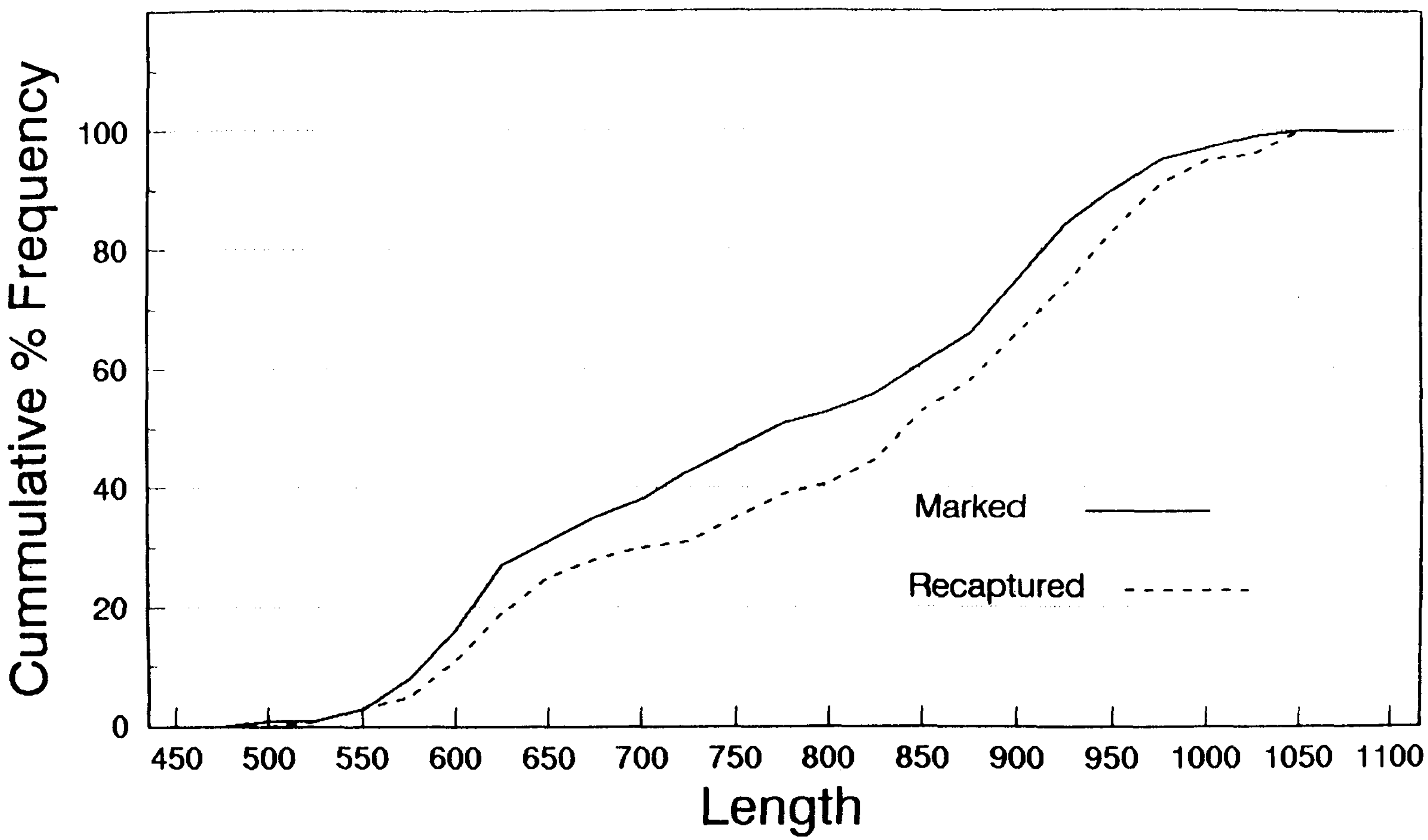

Figure 2. Cumulative percent frequency of chinook salmon marked during electrofishing, and marked chinook salmon recaptured during carcass sampling.

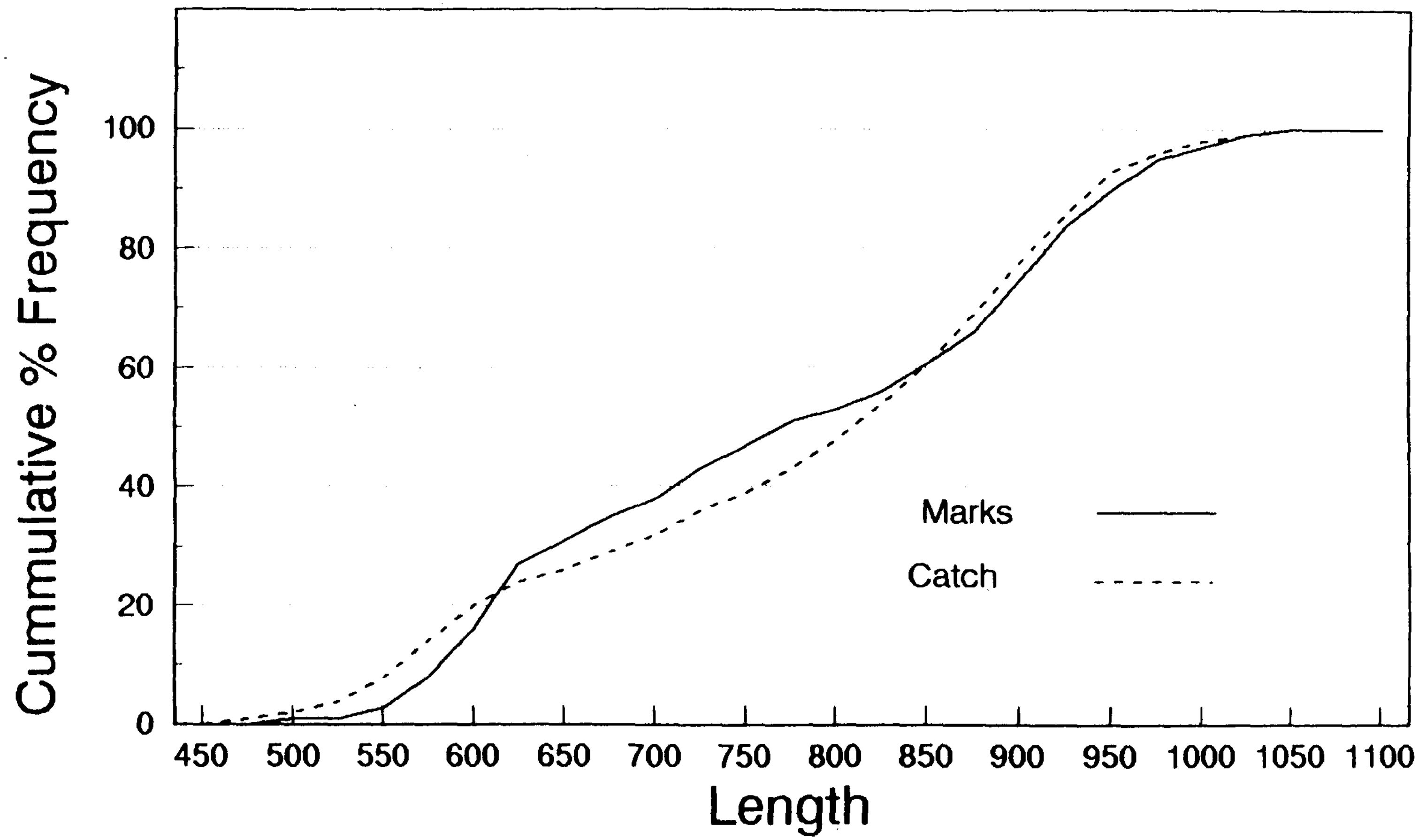

Figure 3. Cumulative perecnt frequency of chinook salmon marked during electrofishing, and chinook salmon caught during carcass sampling.

0.05; Table 4). Therefore, all fish did not have an equal probability of capture during either sampling event, and marked chinook did not mix completely with unmarked chinook between the two sampling events. Mixing was not complete, but did occur to some extent (Table 5).

Abundance Estimate

Based on the results of the above tests, abundance was estimated using Darroch's method to adjust for unequal recapture rates among the three river sections. The estimated abundance for chinook salmon in the Salcha River was 10,728 fish (SE = 1,405). The bootstrap methods used to evaluate potential statistical bias of the abundance estimate resulted in a difference of 1,849 fish (Figure 4).

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. Eighty chinook salmon carcasses were recovered: 79 had tags and one had only a fin clip. The estimated proportion of tags lost was 0.01 (SE = 0.01)

Age, Sex, and Length Compositions

Age data were obtained from 525 chinook salmon collected during the carcass survey. These fish spent one to five years in the ocean and all fish spent just one year in freshwater (Table 6). The dominant age class for females was 1.4 (brood year 1984) and for males was 1.3 (brood year 1985). The sex ratio of males to female was about 1:1. Based on these proportions, estimates of abundance were 5,322 (SE = 735) for males and 5,406 (SE = 745) for females.

Lengths of females ranged from 600 to 1,035 mm while males ranged from 315 to 1,065 mm. Chinook salmon less than 750 mm were predominantly males. The mean length of females was greater than the mean length of males for ocean age two and three. Mean length of males was greater than females for ocean ages four and five (Table 7).

Population Egg Production

The estimate of egg production was 52 million eggs (SE = 2.7 million; Table 8).

Aerial Survey

Counts of live and dead chinook salmon during aerial surveys on 16, 18, 20, and 27 July were 1,527, 2,297, 1,983, and 3,744, respectively (Table 9). Survey conditions ranged from "good" to "fair" on a scale of "poor, fair, and good". The maximum count on 27 July was about 35% of the point estimate from the mark-recapture experiment.

Table 4. Number of marked and unmarked chinook salmon collected during carcass sampling by river section.

	River Section			
	Lower	Middle	Upper	Total
Marked	49	17	14	80
Unmarked	600	260	382	1,242
Total collected	649	277	396	1,322
Recovery rate	0.08	0.07	0.04	0.06

Table 5. Capture and recapture history of chinook salmon by river section[a].

River Section Where Marked Fish Were Released	River Section Where Marked Fish Were Recaptured: Lower	Middle	Upper	Total	Number Marked	Number Not Recaptured
Lower	43	0	0	43	190	147
Middle	6	14	0	20	220	200
Upper	0	3	14	17	184	167
Total	49	17	14	80	594	514
Unmarked Carcasses	600	260	382	1,242		
Total Carcasses	649	277	396	1,322		

[a] These data were used to estimate abundance of chinook salmon with Darroch's estimator.

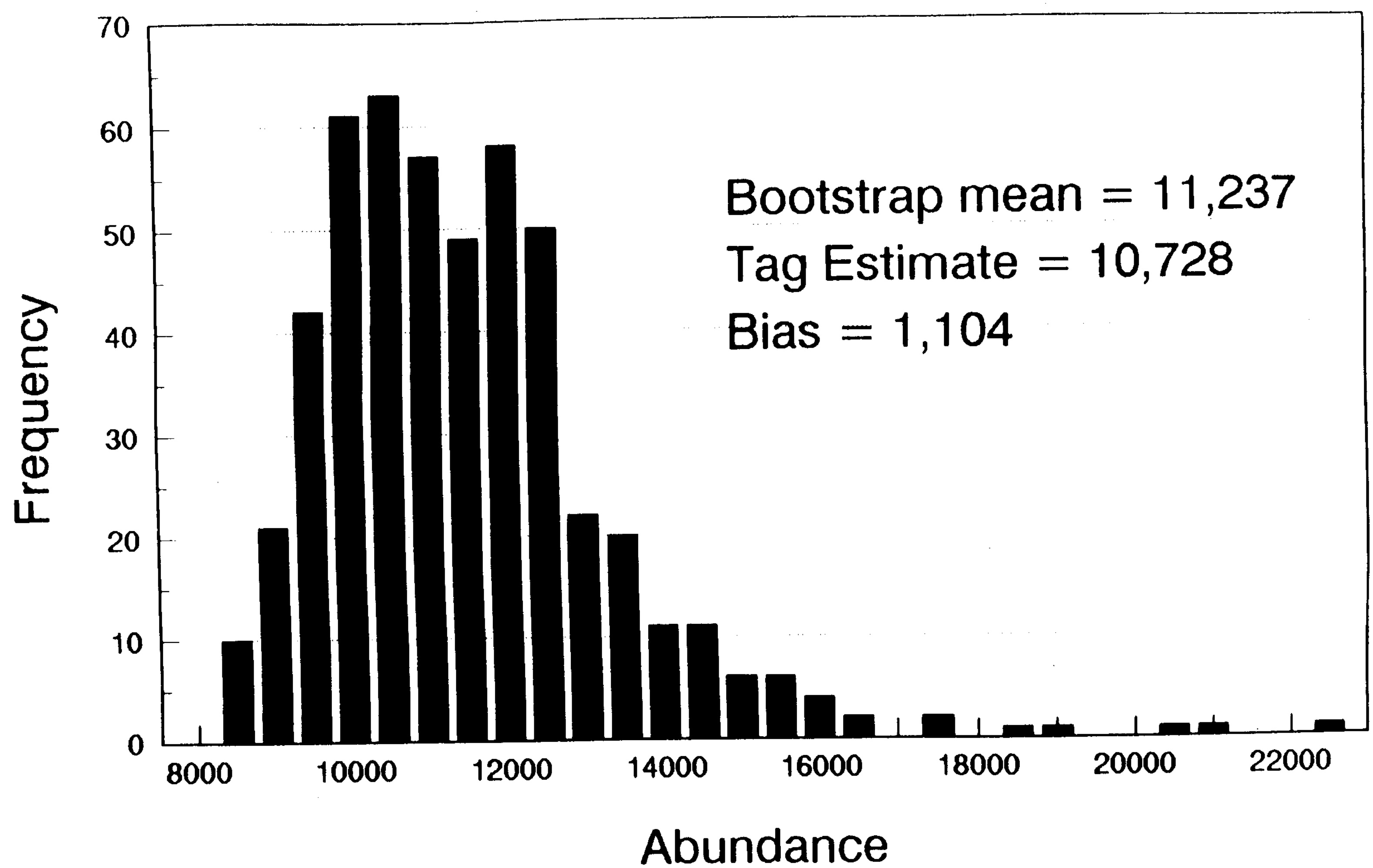

Figure 4. Frequency of the 500 bootstrap abundance estimates.

Table 6. Estimates of the proportions and abundance of female and male chinook salmon by age class.

Age Class	Sample Size	Proportion	Standard Error	Abundance	Standard Error
Females:					
1.1					
1.2	2	< 0.01	< 0.01	41	29
1.3	39	0.07	0.01	795	160
1.4	189	0.36	0.02	3,856	552
1.5	35	0.07	0.01	714	149
Sub-totals	265	0.50	0.02	5,406	745
Males:					
1.1	1	< 0.01	< 0.01	20	20
1.2	87	0.17	0.02	1,774	289
1.3	92	0.17	0.02	1,876	302
1.4	70	0.13	0.01	1,428	245
1.5	11	0.02	0.01	224	73
Sub-totals	261	0.50	0.02	5,322	735
Sexes combined:					
1.1	1	< 0.01	< 0.01	20	19
1.2	89	0.17	0.02	1,815	84
1.3	131	0.25	0.02	2,672	319
1.4	259	0.49	0.02	5,283	407
1.5	46	0.09	0.01	938	99
Total	526	1.00		10,728	1,406

Table 7. Estimated length-at-age of chinook salmon.

Ocean Age	Sample Size	Length (mm)		
		Mean	SE	Range
Females:				
1	0			
2	2	603	3	600 - 605
3	39	810	13	585 - 955
4	188	898	4	735 - 1,015
5	35	926	8	820 - 1,035
Males:				
1	1	315		
2	87	592	6	455 - 755
3	92	727	10	500 - 1,010
4	70	933	10	625 - 1,095
5	11	990	17	900 - 1,065
Females and males:				
1	1	315		
2	89	593	5	455 - 755
3	131	751	9	500 - 1,010
4	258	908	4	625 - 1,090
5	46	941	8	820 - 1,065

Table 8. Estimated potential egg production of female chinook salmon from the Salcha River, 1990.

Length (mm)	Number of Fish	Egg Production (eggs)	SE (eggs)
520-620	72	260,000	315,000
630-720	45	252,000	197,000
730	54	356,000	131,000
740	18	122,000	44,000
750	27	190,000	65,000
760	27	194,000	65,000
770	72	533,000	172,000
780	117	889,000	279,000
790	36	281,000	86,000
800	162	1,296,000	384,000
810	117	959,000	276,000
820	198	1,663,000	466,000
830	226	1,944,000	531,000
840	235	2,068,000	551,000
850	307	2,763,000	718,000
860	289	2,659,000	675,000
870	280	2,632,000	653,000
880	316	3,034,000	737,000
890	335	3,283,000	781,000
900	335	3,350,000	781,000
910	307	3,131,000	715,000
920	379	3,942,000	884,000
930	271	2,873,000	632,000
940	298	3,218,000	696,000
950	253	2,783,000	592,000
960	162	1,814,000	379,000
970	180	2,052,000	422,000
980	126	1,462,000	296,000
990	63	743,000	149,000
1,000	18	216,000	43,000
1,010	36	439,000	85,000
1,020	9	112,000	21,000
1,030	27	340,000	64,000
1,040	9	115,000	22,000
Totals	5,406	51,968,000	2,727,366[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 9. Abundance of chinook salmon counted during aerial surveys of the Salcha River, 1990[a].

Date	Total	Survey Conditions[b]
16 July	1,527	Good
18 July	2,297	Good, Fair[c]
20 July	1,983	Fair
27 July	3,744	Good

[a] Barton, Louis. 1990. Personal Communication. ADFG, Div. of Commercial Fisheries, 1300 College Rd., Fairbanks, AK 99701.

[b] The scale used for survey conditions was "poor, fair, good".

[c] Some areas of the river were rated good and some areas were rated fair during the survey.

DISCUSSION

Examination of data from the mark-recapture experiment indicated that marked chinook salmon partially mixed between river sections. The recapture history of marked chinook salmon for other mark-recapture experiments conducted with Salcha River chinook salmon (Skaugstad 1988, 1989, and 1990a), and the Chena River (Skaugstad 1990b) also showed partial mixing. Partial mixing is expected due to the experimental design and death of chinook salmon after spawning. When captured for marking, most chinook salmon had finished or nearly finished spawning and these fish 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 into areas with lower velocities and pools. Therefore, any mixing that occurred would be in a downstream direction.

A potential problem with using electricity to stun fish is the possibility of injury that may affect the probability of recapture. If chinook salmon suffer premature death from either electrofishing, handling during marking, or both, then there is a greater chance during the carcass survey that marked carcasses will be less available than unmarked carcasses. Carcasses are less likely to be collected if they are covered with silt, drift out of the study area, or decompose. Because of these factors, the probability of recovery of a carcass decreases with time. However, if marked and unmarked chinook salmon die within a short period after spawning, then the probabilities of recapture of marked and unmarked fish should be equal. This experiment was designed so that premature death would have little effect on the probability of recapture. The marking event occurred after most chinook salmon in the river spawned but were still alive. Collection of carcasses occurred after most of the chinook salmon died (about two weeks after the start of the first marking event). Therefore, due to the short time period between events, any injury suffered during the marking event that may have caused premature death should have had little, if any, effect on the probability of recapture of marked fish. Based on four years of sampling, it has been shown that electrofishing is an efficient method of capturing chinook salmon. Very few fish have been killed and the potential harm to unspawned females is low because electrofishing was used after most of the females had spawned.

Since most chinook salmon had already spawned when marked, the ability of electroshocked (marked) females to spawn could not be tested. Because no marked female carcasses were found with greater than 25% of their eggs retained, this suggests that electroshocking did not impair their spawning success.

In terms of the effects of pulsating direct current (d.c.) on egg viability, Maxfield et al. (1971) found that fecundity of rainbow trout and survival of eggs was not influenced by pulsating D.C. electrical shock. Godfrey (1957) found that while pink salmon eggs in the pre-eyed condition are susceptible to disturbance (including electrical shock) eggs buried under gravel were offered protection from the current of electrical fishing gear.

The estimated abundance of adult chinook salmon in 1990 was higher than the estimated abundance of adult chinook salmon in 1987, 1988, and 1989, while the proportion observed during the aerial count was lower in 1990 than in 1987, 1988, and 1989 (Table 10). As the estimated abundance increased, the proportion observed during peak aerial counts decreased.

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Table 10. Estimated abundance, peak aerial counts, aerial survey conditions, and proportions observed during peak aerial surveys for chinook salmon escapement in the Salcha River, 1987-1990.

Year	Estimated Abundance	SE	Aerial Survey Count	Aerial Survey Condition[a]	Proportion Observed During Peak Aerial Survey
1987	4,771	504	1,898	Fair	0.40
1988	4,562	556	2,761	Good	0.61
1989	3,294	630	2,333	Good	0.71
1990	10,728	1,404	3,744	Good	0.35

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

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APPENDIX A

Appendix A1. Statistical tests for analyzing data from a mark-recapture experiment for gear bias and 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 collected during the carcass sampling 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 ensure an unbiased estimate.