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A Mark-Recapture Experiment to Estimate the Escapement of Chinook Salmon in the Unuk River, 2000

by

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and

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September 2002

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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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

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ABSTRACT

The abundance of medium and large chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Unuk River in 2000 was estimated using a two-event mark-recapture experiment. Biological data were collected during both events. Fish were captured during event 1 in the lower Unuk River using set gillnets from June through early August. Each healthy fish was individually marked with a solid-core spaghetti tag sewn through its back and was given two secondary batch marks in the form of an upper-left operculum punch and removal of the left axillary appendage. In event 2, fish were examined on the spawning grounds from July through August.

We captured a total of 768 chinook salmon during event 1; 698 of these were marked and released alive. Of the marked and released fish, 570 were large (≥660 mm mid-eye to fork [MEF]), 128 were medium (401–659 mm MEF) and none were small (≤400 mm MEF) in size. In event 2, we sampled 886 fish; 719 were large fish, and of these, 69 were recaptures that had been previously marked in the lower river with spaghetti tags. One hundred fifty-eight (158) medium fish were sampled, and 8 of these were recaptures. Nine (9) small fish were sampled.

A modified Petersen model was used to estimate 5,872 large, 2,278 medium, for a total of 8,150 adult chinook salmon >400 mm MEF in length returning to the Unuk River in 2000. An estimated 20% of the spawning population was sampled during the project. Peak survey counts in August totaled 1,341 large chinook salmon, about 23% of the mark-recapture estimate of large fish, similar to fractions seen in previous years. The mean expansion factor through 2000 is 4.93 (SE = 0.59) for estimating total escapement from survey counts. Of the spawning population >400 mm MEF, 38.5% (SE = 7.2%) were age-1.2 fish from the 1997 brood year, 42.9% (SE = 5.1%) were age-1.3 fish, and 17.8% (SE = 2.5%) were age-1.4 fish.

Key words: escapement, large and medium chinook salmon, Unuk River, mark-recapture, set gillnet, spaghetti tag, operculum punch, axillary appendage, Petersen model, peak survey counts

INTRODUCTION

The Unuk, Chickamin, Blossom, and Keta rivers in Southeast Alaska (SEAK) are four of eleven escapement indicator streams for chinook salmon *Oncorhynchus tshawytscha* (Pahlke 1997a). These four systems traverse the Misty Fjords National Monument and flow into Behm Canal, a narrow saltwater passage east of Ketchikan (Figure 1). Peak single-day aerial and foot survey counts of "large" chinook salmon ≥660 mm mid-eye to fork of tail (MEF) are used as indices of escapement in each of these systems. These indices are roughly dome-shaped when plotted against time (since 1975) with peak values occurring between 1987 and 1990 (Pahlke 1997a). Peak 1987–1990 values of escapement are two to five times greater than the "baseline" (1975–1980) or current values of the index.

Several consecutive low survey counts in the early 1990s generated concern by 1992 for the health of the Behm Canal chinook stocks. In response, the Division of Sport Fish of the Alaska Department of Fish and Game (ADF&G) began a research program on the Unuk River which is the largest chinook salmon producer in Behm Canal. Goals of the program were to estimate smolt production and overwinter survival, adult escapement, total run size, exploitation rates, harvest distribution, and marine survival.

The current escapement goal for the Unuk River is 650–1,400 large fish counted in surveys, or about 3,000–7,000 large fish total escapement (McPherson and Carlile 1997). Only large fish are counted in aerial surveys, because they can be distinguished with more confidence from other species that may be present because of their size and color. For our purposes, chinook salmon ≥660 mm MEF are considered large and generally consist of fish 3-ocean age or older. Nearly all females in the spawning population are large in size. Chinook salmon 401 mm–659 mm MEF are considered medium fish, and chinook salmon ≤400 mm MEF are considered small fish.

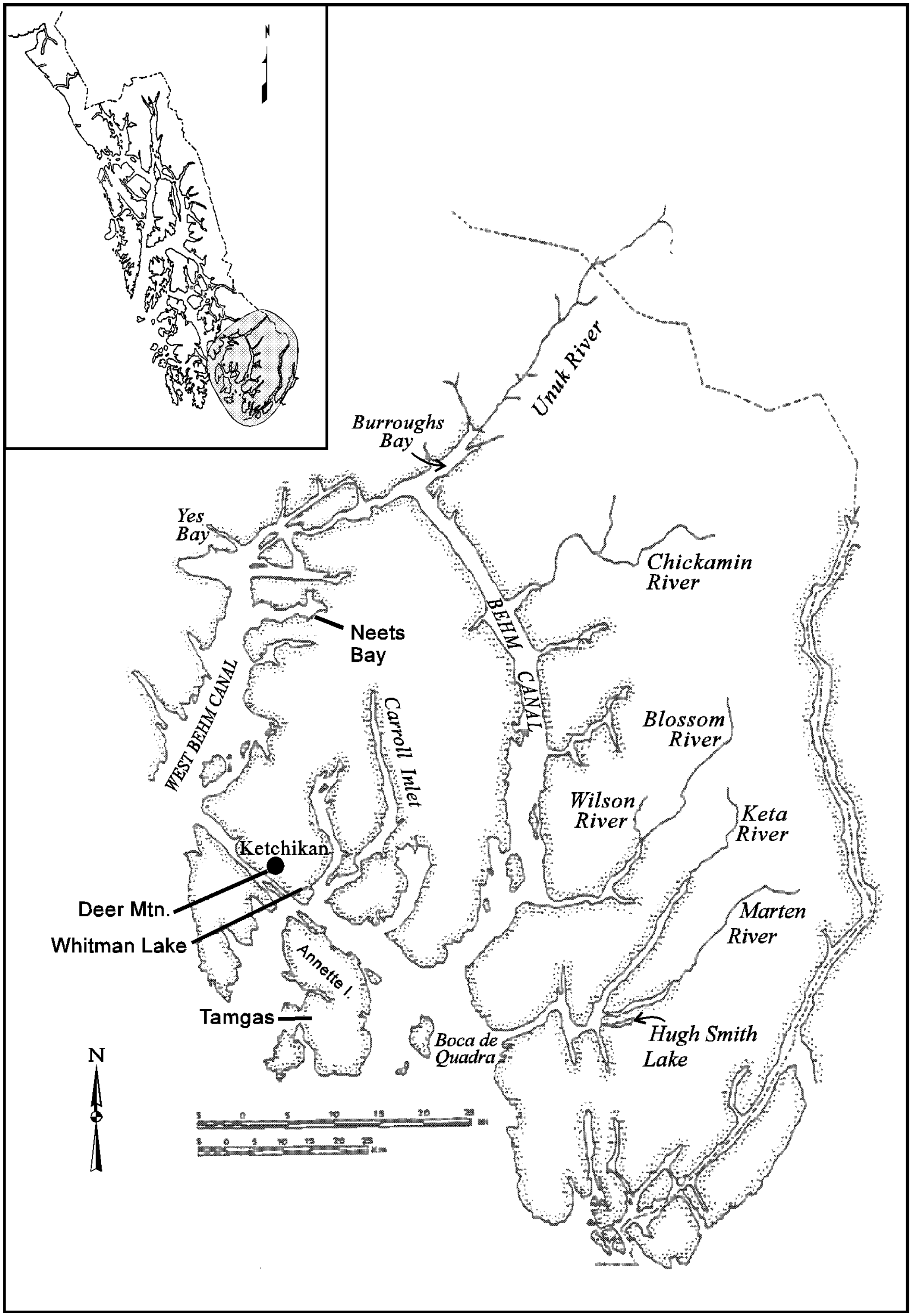

Figure 1.–Behm Canal area in Southeast Alaska and location of major chinook salmon systems and hatcheries.

Indices of escapement on the Unuk River are determined each year by summing the peak counts of large spawners observed during aerial and foot surveys in six tributaries: Cripple, Gene's Lake, Kerr, Clear, and Lake creeks plus the Eulachon River (Pahlke 1997a).

Mark-recapture and radiotelemetry studies were conducted in 1994 (Pahlke et al. 1996). Mark-recapture studies also took place in 1997, 1998, and 1999 (Jones et al. 1998; Jones and McPherson 1999, 2000). The radiotelemetry study indicated that 83% (SE = 9%) of all spawning occurred in the six tributaries surveyed. The mark-recapture experiments in 1994, 1997, 1998, and 1999 estimated that 4,623, 2,970, 4,132, and 3,914 large chinook salmon entered the river in each of these years. Survey counts of 711, 636, 840, and 680 represented 15%, 21%, 20%, and 17% of these estimates. The highest recorded survey count of 2,126 large fish occurred in 1986 (Pahlke 1997a). Average peak survey counts in the six index tributaries of the Unuk River from 1977–1999 are distributed as follows: Cripple Creek (424 fish, 39%), Gene's Lake Creek (325 fish, 30%), Eulachon River (180 fish, 17%), Clear Creek (95 fish, 9%), Lake Creek (25 fish, 2%), and Kerr Creek (37 fish, 3%). Cripple Creek and Gene's Lake Creek are not surveyed from the air because of heavy canopy cover; survey counts in these areas are made on foot. All other index areas are surveyed by helicopter or on foot (Pahlke et al. *In press*).

Other studies on the Unuk River were based on coded-wire tags (CWTs) inserted in chinook salmon juveniles from the 1982–1986 brood years (Pahlke 1995). Indications from this research were that commercial and sport harvest rates on the Unuk River chinook salmon stock (age-1.1–1.5) ranged between 14% and 24%; however, the precision of the harvest estimates was low, and escapement was inferred from the 1994 mark-recapture study expansion of 15% and an alternative expansion of 25% of spawners counted.

Beginning in 1993, chinook salmon young-of-the-year (YOY) fingerlings and smolt collected in the spring were tagged with CWTs on the Unuk River. The numbers of YOY fingerlings tagged were 13,789 in 1993, 18,826 in 1994, 40,206 in 1995, 39,177 in 1996, 61,905 in 1997, 33,888 in 1998, and 16,661 in 1999. The numbers of smolt tagged were 2,642 in 1994, 3,227 in 1995, 7,456 in 1996, 12,517 in 1997, 17,121 in 1998, 7,948 in 1999, and 13,333 in 2000 (Appendix A1). The first large fish from the 1992 brood year returned in 1997.

The current stock assessment program for adult chinook salmon returning to the Unuk River has three primary goals: (1) to estimate escapement; (2) to estimate age, sex, and length distribution in the escapement; and (3) to sample escapement for the fraction of fish possessing CWTs by brood year. The results are essential to estimate the marked fraction of each brood for CWTd fish and to estimate harvest of this stock in current and future sport and commercial fisheries. These harvest and escapement data will enable us to estimate total run size, exploitation rates, harvest distribution, and marine survival for this stock of chinook salmon indicator stock in southern Southeast Alaska. This stock is used as an indicator of the status of other chinook salmon stocks in SEAK.

STUDY AREA

The Unuk River originates in a heavily glaciated area of northern British Columbia and flows for 129 km where it empties into Burroughs Bay, 85 km northeast of Ketchikan, Alaska. The Unuk River drainage encompasses an area of approximately 3,885 km^2 (Pahlke et al. 1996).

The lower 39 km of the Unuk River are in Alaska (Figure 2), and in most years, the Unuk River is the fourth or fifth largest producer of king salmon in Southeast Alaska. Fish trapping efforts in the CWT project indicate that the majority of chinook salmon rear in the U.S. portion of the river.

METHODS

A two-event mark-recapture experiment for a closed population was used to estimate the number of immigrant medium and large chinook salmon to the Unuk River in 2000. Fish were captured by using set gillnets in the lower river for the first event and were sampled for marks with a variety of gear types on the spawning grounds for the second event.

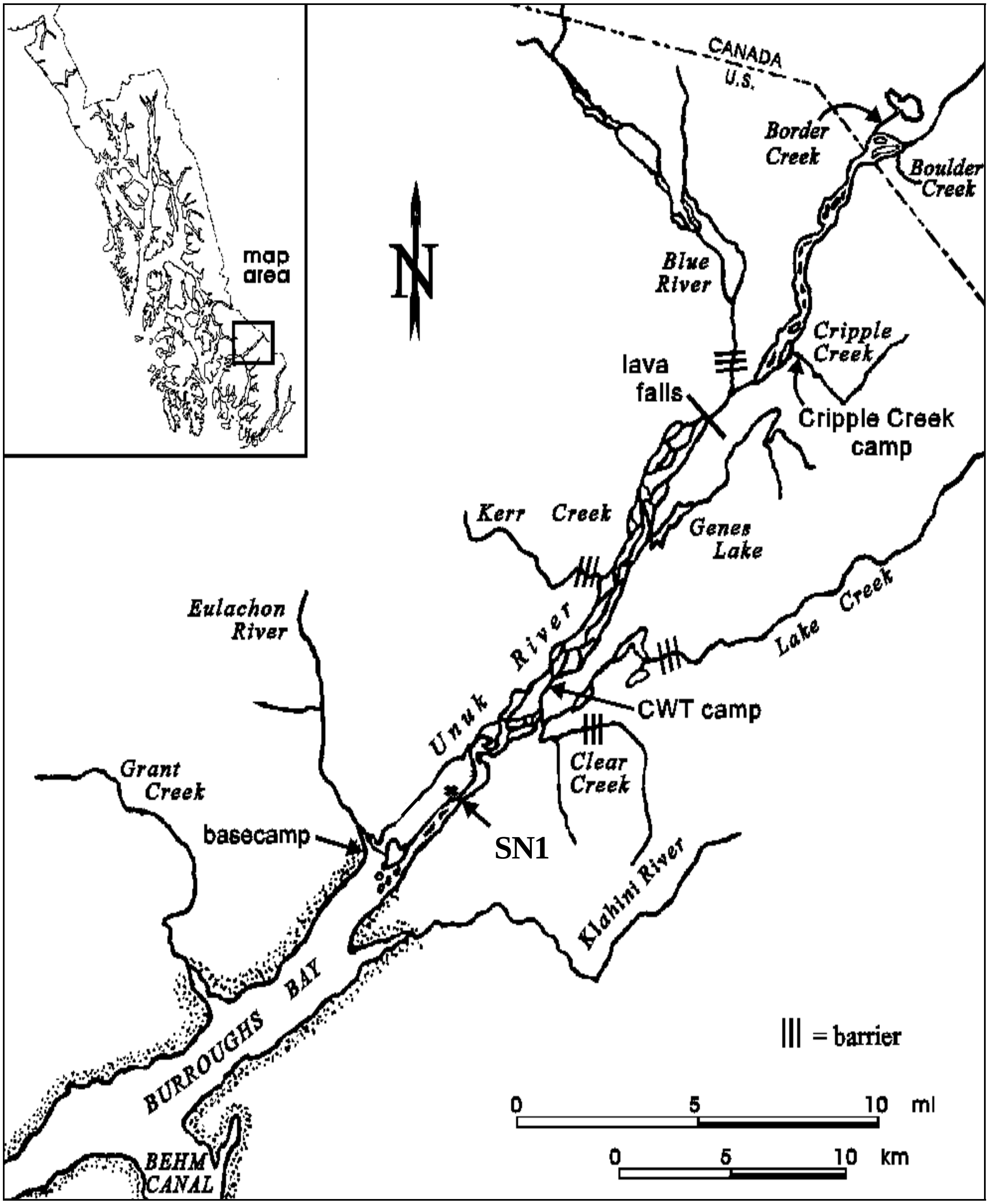

Figure 2.–Unuk River area in Southeast Alaska, showing major tributaries, barriers to chinook salmon migration, and location of ADF&G research sites. Dog Salmon Creek (not shown) flows into the Unuk River about 2 miles upstream of Gene's Lake on the opposite shore.

EVENT 1: SAMPLING IN THE LOWER RIVER

Adult chinook salmon were captured using set gillnets as they immigrated into the lower Unuk River between 15 June and 30 August 2000. The set gillnets were 37 m (120 ft) long by 4 m (14 ft) deep with 18 cm (7.25 in) stretch mesh. One site (SN1) was used exclusively for set gillnet fishing in 2000 and has remained the same since 1997. This site (SN1) is located approximately 2 miles upstream on the south channel or mainstem of the lower Unuk River well below all known spawning areas, with the exception of the Eulachon River (Figure 3).

Using two back-to-back shifts of personnel, two set gillnets were fished at SN1 (Figure 4) 12 hours per day, six days per week. One net was set perpendicular to the main flow of the Unuk River. It was attached to shore and ran directly across a small slough to a fixed buoy placed about 3 meters downstream of a small island. Another net was attached to the same fixed buoy and trailed downstream along the eddy line formed between the Unuk River mainstem and the side slough.

All fish captured, regardless of health, were sampled for age, sex, and length (ASL) prior to release. Length in MEF was measured to the nearest 5 mm and sex was estimated from secondary maturation characteristics. Four scales were taken about 1" apart from the preferred area on the left side of the fish. The preferred area is two to three rows above the lateral line and between the posterior terminus of the dorsal fin and the anterior margin of the anal fin (Welander 1940). Scales were mounted on gum cards that held scales from ten fish, as described in ADF&G (1993). The age of each fish was later determined from the pattern of circuli (Olsen 1995), seen on images of scales impressed into acetate cards magnified 70× (Clutter and Whitesel 1956). The presence or absence of an adipose fin was also noted for each sampled fish. Those fish missing adipose fins were sacrificed, and their heads were sent to the ADF&G Tag and Otolith Lab for detection and decoding of CWTs.

All captured fish judged healthy and possessing adipose fins were given three different marks: a uniquely numbered solid-core spaghetti tag, a clip of the left axillary appendage (LAA), and a left upper operculum punch (LUOP) 0.63 cm (¼") in diameter then released. The two marks enable the detection of primary tag loss. The spaghetti tag consisted of a 5.71 cm (2¼") section of laminated Floy tubing shrunk onto a 38 cm (15") piece of 80-lb test monofilament fishing line. The monofilament was sewn through the back just behind the dorsal fin and secured by crimping both ends of the monofilament in a line crimp. The excess monofilament was then trimmed off. Each spaghetti tag was individually numbered and stamped with an ADF&G phone number.

EVENT 2: SAMPLING ON THE SPAWNING GROUNDS

Chinook salmon of all sizes were sampled on Dog Salmon, Clear, Cripple, Gene's Lake, Kerr, and Lake creeks, the Eulachon River, and the Unuk River mainstem in 2000 (Figure 2). Various methods were used to capture these fish, including rod and reel, spear, dip net, set gillnet, and random carcass pickups. Use of a variety of gear types has been shown to produce unbiased estimates of age, sex, and length composition (McPherson et al. 1997; Jones et al. 1998; Jones and McPherson 1999, 2000). All inspected fish were given a left lower operculum punch (LLOP) the first time they were sampled to prevent double sampling. These fish were closely examined for the presence of the primary tag, the LUOP, the LLOP, and the LAA, for a missing adipose fin, and were sampled for ASL data using the same techniques employed in the lower river. Foot survey counts were also performed on each of the sampled tributaries on at least one occasion. Multiple counts were spaced approximately one week apart and coincided with the historical peak observed abundance.

ABUNDANCE BY SIZE

We stratified by size because we desired $\hat{N}_{lg}$ for comparison with the aerial survey counts to estimate an expansion factor. Abundance of medium (401–659 mm MEF) and large (≥660 mm MEF) fish was estimated separately, using Chapman's modification of the Petersen estimator (Seber

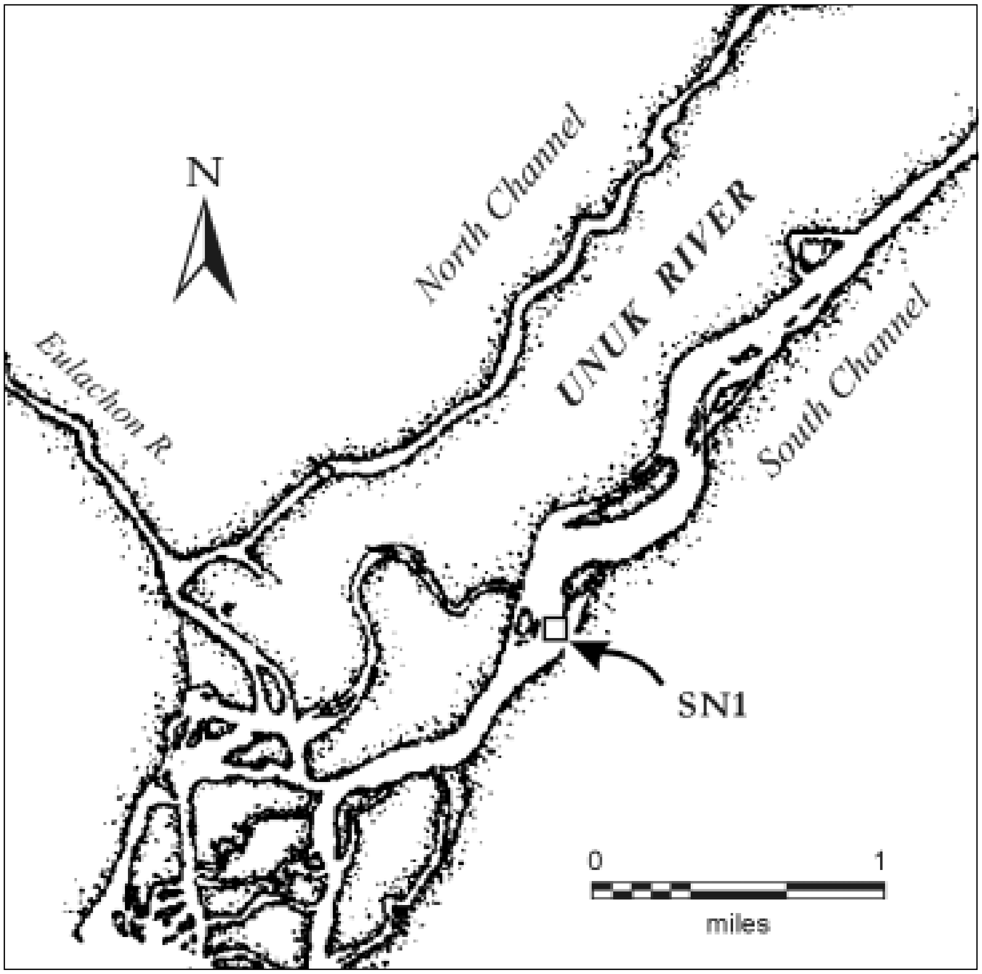

Figure 3.–Location of the set gillnet site (SN1) on the lower Unuk River in 2000.

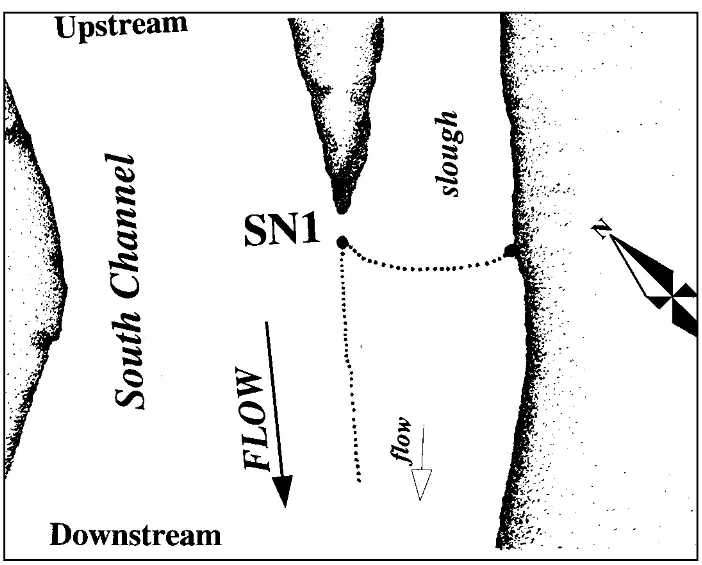

Figure 4.–Detailed drawing of the net placement used at the set gillnet site (SN1) on the lower Unuk River in 2000.

1982). Estimated abundance ($\hat{N}_i$) for each group was calculated

$$\hat{N}_i = \frac{(M_i+1)(C_i+1)}{(R_i+1)} - 1 \quad (1)$$

where M_i is the number of fish of size *i* (medium or large) sampled and marked during event 1, C_i is the number of fish of size *i* inspected for marks during event 2, and R_i is the number of C_i that possessed marks applied during event 1. The general assumptions that must hold for $\hat{N}_i$ to be a suitable estimate of abundance are in Seber (1982) and may be cast as follows:

(a) every fish has an equal probability of being marked in event 1, or every fish has an equal probability of being captured in event 2, or marked fish mix completely with unmarked fish;

(b) both recruitment and death (emigration) do not occur between sampling events;

(c) marking does not affect the catchability of an animal;

(d) animals do not lose their marks in the time between the two events;

(e) all marks are reported on recovery in event 2; and

(f) double sampling does not occur.

To provide evidence that assumption *a* was met, two chi-square tests were performed: (1) for equal proportions of marks by capture area in event 2; and (2) equal probabilities of recapture in event 2 independent of the stratum of origin. If the null hypothesis of either test was accepted, the pooled Petersen estimator (equation 1) was or would be used to model the mark-recapture data; otherwise a temporally or spatially stratified estimator would be employed. Tests were made separately using the SPAS software program (Arnason et al. 1996).

The possibility of size and sex selective sampling was also investigated, because assumption *a* can also be violated in this manner. The hypothesis that fish of different sizes were captured with equal probability was tested using two Kolmogorov-Smirnov (K-S) 2-sample tests (α = 0.1, Appendix A2). Sex selective sampling was investigated using simple chi-squared analyses. Because sampling in the lower river spanned the entire known immigration of fish into the Unuk River and continued without interruption, the experiment is, due to the life history of salmon, closed to recruitment (assumption *b*). We were not able to test assumption *c*; however, we were careful to not harm or stress fish and we did not mark obviously injured fish. Radiotelemetry studies in 1994 and 1996 have shown that chinook salmon survive and spawn using this type of capture method (Pahlke et al. 1996; Pahlke 1997b). The effect of tag loss (assumption *d*) is virtually eliminated by using the two secondary marks, and all fish captured during event 2 were inspected for marks (assumption *e*). Double sampling (assumption *f*) of fish was avoided by marking all sampled fish during event 2 with a LLOP.

Variance, bias, and confidence intervals for $\hat{N}_i$ were estimated with modifications of bootstrap procedures in Buckland and Garthwaite (1991). Fish were divided into four capture histories (Table 1). A bootstrap sample was built by drawing with replacement a sample of size $\hat{N}_i$ from the empirical distribution defined by the capture histories. A new set of statistics from each bootstrap sample $\{\hat{M}_i^*, \hat{C}_i^*, \hat{R}_i^*\}$ was generated, along with a new estimate for abundance $\hat{N}_i^*$, and 1,000 such bootstrap samples were drawn creating the empirical distribution $F(\hat{N}_i^*)$, which is an estimate of $F(\hat{N}_i)$. The difference between the average $\hat{N}_i^*$ of bootstrap estimates and $\hat{N}_i$ is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Confidence intervals were estimated from $\hat{F}(\hat{N}_i^*)$ with the percentile method (Efron and Tibshirani 1993, Section 13.3).

Variance was estimated as

$$\operatorname{var}(\hat{N}_i^*) = (B-1)^{-1} \sum_{b=1}^{B} (\hat{N}_{i(b)}^* - \overline{\hat{N}}_i^*)^2 \quad (2)$$

where *B* is the number of bootstrap samples.

Table 1.–Capture histories for medium and large chinook salmon in the population spawning in the Unuk River in 2000 (notation explained in text)**.**

Capture history	Medium	Large	Source of Statistics
Marked and not recaptured in tributaries	120	501	$\hat{M}_i - R_i$
Marked and recaptured in tributaries	8	69	R_i
Not marked, but captured in tributaries	150	650	$C_i - R_i$
Not marked and not sampled in tributaries	2,000	4,652	$\hat{N}_i - \hat{M}_i - C_i + R_i$
Effective population for simulations	2,278	5,872	$\hat{N}_i^+$

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age within the medium or large fish size classes was estimated as a binomial variable:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \quad (3)$$

with

$$\text{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_i - 1} \quad (4)$$

where $\hat{p}_{ij}$ is the estimated proportion of the population of age j in sized group i, n_{ij} is the number of chinook salmon of age j of size group i, and n_i is the number of chinook salmon in the sample n of size group i. Information gathered during event 1 was not used to estimate age or sex composition as tests (described above) showed sampling in event 1 was biased towards catching large fish. Samples gathered at each spawning tributary were pooled together because no differences in age composition were apparent between tributaries sampled. Numbers of spawning fish by age were estimated as the sum of the products of estimated age composition and estimated abundance within a size category

$$\hat{N}_j = \sum_i (\hat{p}_{ij}\hat{N}_i) \quad (5)$$

and

$$\text{var}(\hat{N}_j) = \sum_i \begin{pmatrix} \text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)\hat{p}_{ij}^2 \\ -\text{var}(\hat{p}_{ij})\,\text{var}(\hat{N}_i) \end{pmatrix} \quad (6)$$

with variance calculated according to procedures in Goodman (1960).

The proportion of the spawning population >400 mm MEF composed of a given age was estimated as the summed totals across size categories

$$\hat{p}_j = \frac{\hat{N}_j}{\hat{N}} \quad (7)$$

and

$$\text{var}(\hat{p}_j) = \frac{\sum_i (\text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)(\hat{p}_{ij} - \hat{p}_j)^2)}{\hat{N}^2} \quad (8)$$

where variance is approximated according to procedures in Seber (1982, p. 8-9).

Sex composition and age-sex composition for the entire spawning population and its associated variances were also estimated using the above equations by first redefining the binomial variables in samples to produce estimated proportions by sex $\hat{p}_k$, where k denotes gender (male or female), such that $\sum_k \hat{p}_k = 1$, and by age-sex $\hat{p}_{jk}$, such that $\sum_{jk} \hat{p}_{jk} = 1$.

EXPANSION FACTOR

An expansion factor ($\hat{\pi}_t$) for Unuk River chinook salmon in a calendar year is

$$\hat{\pi}_i = \hat{N}_i / C_i \quad (9)$$

$$\text{var}(\hat{\pi}_t) = \text{var}(\hat{N}_i) / C_i^2 \quad (10)$$

where i is the year (with a mark-recapture experiment), $\hat{N}_i$ is the mark-recapture estimate of large chinook and C_i is the peak aerial survey count.

The mean expansion factor ($\bar{\pi}$) is

$$\bar{\pi} = \sum_{i=1}^{k} \hat{\pi}_i \; / \; k \qquad (11)$$

$$\text{var}(\bar{\pi}) = \sum_{i=1}^{k} \left(\hat{\pi}_i - \bar{\pi}\right)^2 / \; (k-1) \qquad (12)$$

where k is the number of years with mark-recapture experiments (four for the Unuk River at present, from 1997–2000).

The estimator for expanding peak survey counts into estimates of spawning abundance is

$$\hat{N}_t = \bar{\pi} \; C_t \qquad (13)$$

$$\text{var}(\hat{N}_t) = C_t^2 \; \text{var}(\bar{\pi}) \qquad (14)$$

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

Of 768 chinook salmon sampled in the lower river, 698 were tagged and released (Table 2). Ninety-five percent (95%) of the catches occurred between 15 June and 31 July. Nineteen (19) fish were considered unhealthy upon capture and were not tagged. Of the 698 fish tagged, none were small, 128 were medium, and 570 were large. Sixty-five (65) fish sampled using gillnets were missing adipose fins; furthermore, 25 of these were sacrificed and the rest were tagged and released in good condition. Of the total fish that were missing adipose fins and of those sacrificed, 75% and 96% were males, respectively. In general, the numbers of recaptures sampled on the spawning grounds in each tributary and the dates when they were first marked appeared proportional to the daily gillnet catches (Figure 5). We sampled a total of 886 fish in event 2; 9 of these were small, 158 were medium, and 719 were large in size. For the total event 2 sample, 77 recaptures (i.e., fish

Table 2.–Numbers of chinook salmon marked in the lower Unuk River and inspected for marks on the spawning grounds of the Unuk River in 2000 by size group.

	Length (MEF)			
	0–400 mm	**401–659 mm**	**≥660 mm**	**Total**
A. Released in event 1 with marks (*M*)	0	**128**	**570**	698
B. Inspected at:				
1. Upriver[a]				
Inspected (C)	4	**66**	**250**	320
Recaptured (R)	0	**3**	**20**	23
Recaptured/captured	0	**0.045**	**0.080**	0.072
2. Downriver[b]				
Inspected (C)	5	**92**	**469**	566
Recaptured (R)	0	**5**	**49**	54
Recaptured/captured	0	**0.054**	**0.104**	0.095
Total inspected				
Inspected (C)	9	**158**	**719**	886
Recaptured (R)	0	**8**	**69**	77
Recaptured/captured	0	**0.051**	**0.096**	0.087

[a] Includes Cripple Creek.

[b] Includes Dog Salmon, Clear, Gene's Lake, Kerr, and Lake creeks, Eulachon River, and the Unuk mainstem.

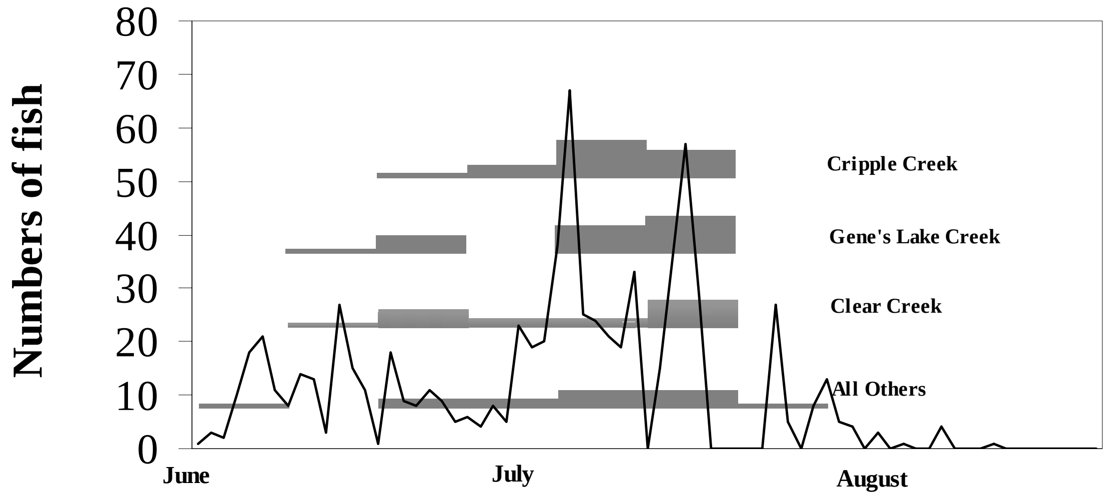

Figure 5.–Daily set gillnet catches in the lower Unuk River (line graph) by date, and recoveries grouped into one week periods of the marked fish (bars) by recovery area and the date of marking in the lower river. 'All Others' includes Boundary, Dog Salmon, Kerr, and Lake creeks, the Eulachon River, and the Unuk mainstem, combined.

previously marked in event 1) were sampled. Of these, none were small, 8 were medium, and 69 were large in size. A total of 95 adipose fin-clipped fish were sampled during event 2. Of these, 1 was small, 24 were medium, and 70 were large in size. Fifty-two (52) of these were sacrificed for CWT sampling purposes, comprising 1 small, 23 medium, and 28 large fish. Primary tag loss was 14% for all recoveries and these fish were identified as being previously marked by the presence of the left upper operculum punch and a missing left axillary appendage.

The length distributions of marked medium, large, and medium and large fish combined were not significantly different than length distributions for fish *recaptured* on the spawning grounds (P = 0.99, P = 0.99, and P = 0.35; Figure 6). Thus, sampling on the spawning grounds was not size selective, and the mark-recapture data did not need length stratification. Length distributions of marked chinook salmon were not comparable to those fish *inspected* on the spawning grounds for medium, large, and medium and large fish (P = 0.03, P < 0.001, P < 0.001); Figure 7). Because there was no selectivity in event 2, there must have been selectivity in event 1 (i.e., it was easier to catch a large fish in the lower river set gillnets than a medium fish). Also, the fractions of medium and large chinook salmon sampled in event 2 with marks (Table 2) were significantly different (P = 0.09). Thus, only fish sampled on the spawning grounds were used to estimate length and age compositions of the escapement.

Tests to determine temporal or spatial stratification were performed by stratifying the mark-recapture data into two time and recovery periods (Table 3). Results indicated that large chinook salmon marked early in the experiment (before July 15) and late in the experiment were equally likely to be recaptured (χ^2 = 1.13, df = 1, P = 0.29). Similarly, the recapture rate during event 2 did not vary by sampling date (χ^2 = 1.77, df = 1, P = 0.18). Thus, a pooled Petersen estimator was used to estimate the abundance of large fish ($\hat{N}_{lg}$) on the spawning grounds in 2000 (n_1 = 570, n_2 = 719, m_2 = 69) was 5,872 (SE = 644) (Table 2). Statistical bias of the estimate was negligible (1.1%) and the 95% bootstrap confidence interval for the estimated abundance of large fish is 4,848 to 7,347. Similar results were obtained for medium sized fish. Medium

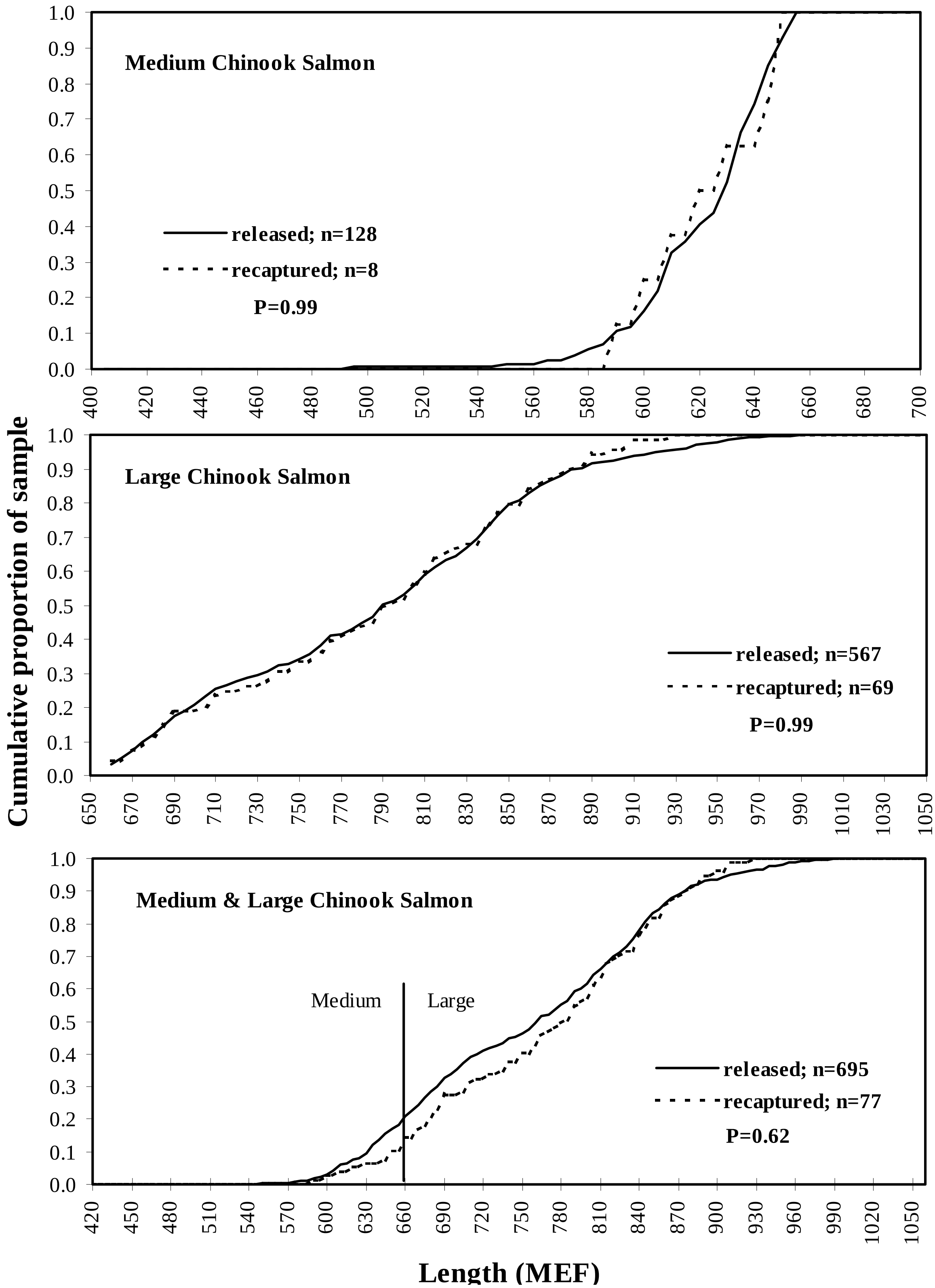

Figure 6.–Cumulative relative frequencies of medium, large, and medium and large chinook salmon (combined) marked in the lower Unuk River in 2000 versus those recaptured on the spawning grounds at eight tributary sampling sites. Lengths not taken on 3 large chinook salmon**.**

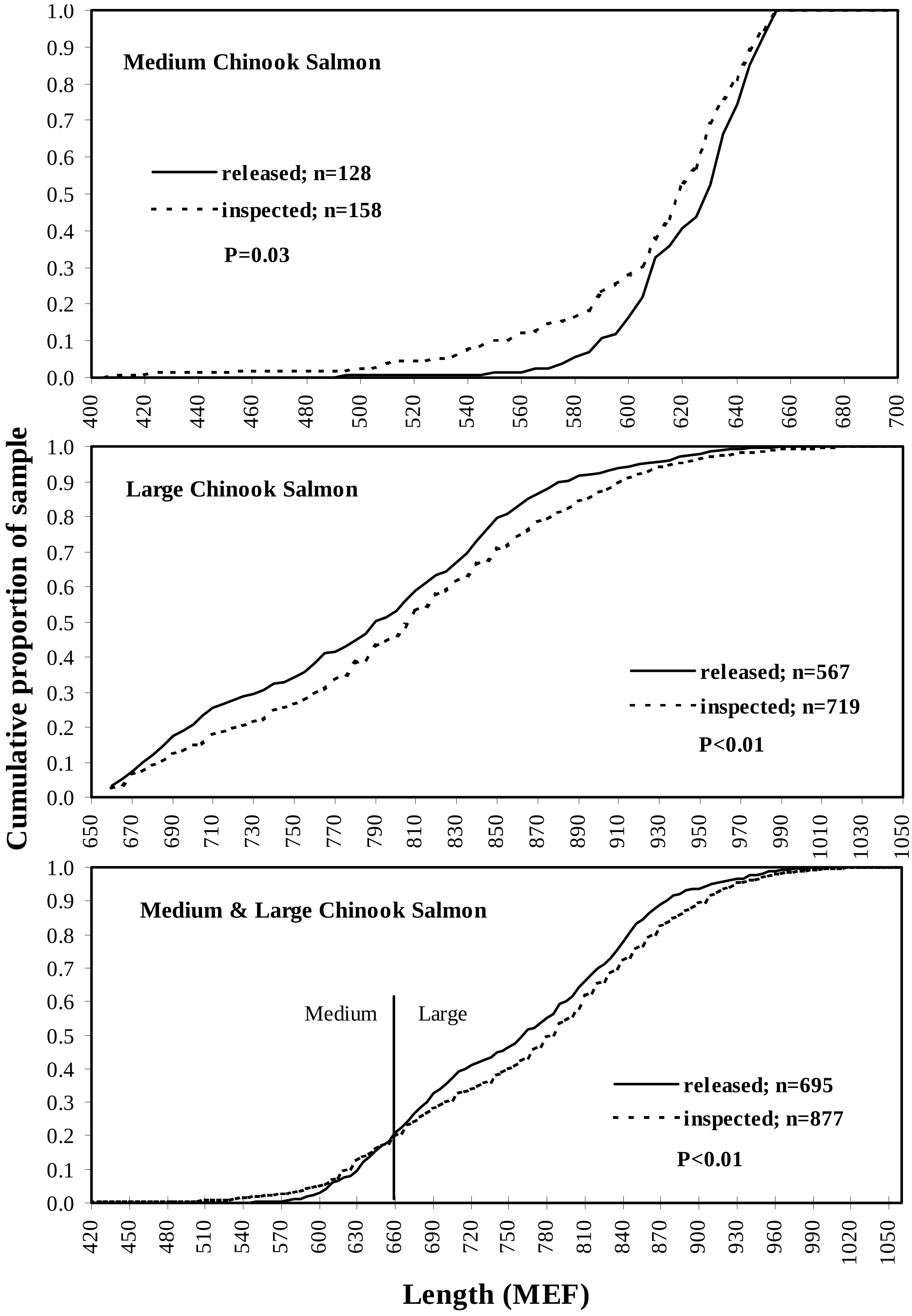

Figure 7.–Cumulative relative frequencies of medium, large, and medium and large chinook salmon (combined) marked in the lower Unuk River in 2000 versus those inspected on the spawning grounds at eight tributary sampling sites. Lengths not taken on 3 large chinook salmon.

Table 3. Number of marked large and medium chinook salmon released in the lower Unuk River and recaptured, by marking period and recovery location, and the number examined for marks at each recovery location, 2000.

Marking dates	Number marked	Estimated fraction recovered	Recovery location		
			Downriver[a]	Upriver[b]	Total
Large chinook salmon					
6/15 to 7/14	307	0.104	11	21	32
7/15 to 8/30	263	0.141	9	28	37
Total/Average	570	0.121	20	49	69
Number inspected			250	469	719
Fraction marked			0.080	0.104	0.096
Medium chinook salmon					
6/15 to 7/14	69	0.058	1	3	4
7/15 to 8/30	59	0.068	2	2	4
Total/Average	128	0.063	3	5	8
Number inspected			66	92	158
Fraction marked			0.045	0.054	0.051

[a] Includes Dog Salmon, Clear, Gene's Lake, Kerr, and Lake creeks, the Eulachon River, and the Unuk River mainstem.

[b] Includes Cripple Creek

chinook salmon marked early and late in the experiment were equally likely to be recaptured (χ^2 = 0.06, df = 1, P = 0.80) and the recapture rate did not vary by sampling date (χ^2 = 0.05, df = 1, P = 0.82). Therefore, a pooled Petersen estimator was used to estimate the abundance of medium fish ($\hat{N}_{med}$) on the spawning grounds in 2000 (n_1 = 128, n_2 = 158, m_2 = 8) was 2,278 (SE = 675) (Table 2). Statistical bias of the estimate was relatively small (9.6%) and the 95% bootstrap confidence interval for the estimated abundance of medium fish is 1,358 to 5,042. Estimated abundance of all fish >400 mm MEF ($\hat{N} = \hat{N}_{med} + \hat{N}_{\lg}$) for 2000 is 8,150 (SE = 1,163).

ESTIMATES OF AGE AND SEX COMPOSITION

Age-1.2, age-1.3 and age-1.4 chinook salmon dominated the age compositions of fish >400 mm MEF sampled during event 2 on the spawning grounds (Appendix A3, Figure 8). Age-1.2 fish were 39% (SE = 7.2%), age-1.3 fish 43% (SE = 5.1%), and age-1.4 fish 18% (SE = 2.5%) of the escapement of medium and large fish; 69% (SE = 4.0%) of these were males (Table 4). Relative to samples taken in event 1, event 2 samples were richer in males (P = 0.003), and among large fish, richer in age-1.2 fish (P = 0.00003). As noted above, this was the result of selectivity for larger fish in event 1. Interestingly, 16% (SE = 1.4%) of the large fish in event 2 were age-1.2. There were an estimated 2,506 (SE = 296) spawning females in 2000 (Table 4).

Length compositions were similar between samples gathered in events 1 and 2 for sexes combined and age-1.2, age-1.3, and age-1.4 fish (t_3 = 4.30, P = 0.63) (Table 5). These differences were less for males (P = 0.93) versus females (P = 0.46). In general, the length composition gathered in event 2 during spawning grounds sampling is most appropriate using a multitude of gear types to gather samples which has been shown to reduce bias in age, sex, and length sampling for chinook salmon (Jones and McPherson 1999).

DISCUSSION

In previous years of study, chinook salmon tagged and released during event 1 have shown a "sulking" behavior or a delay in upstream

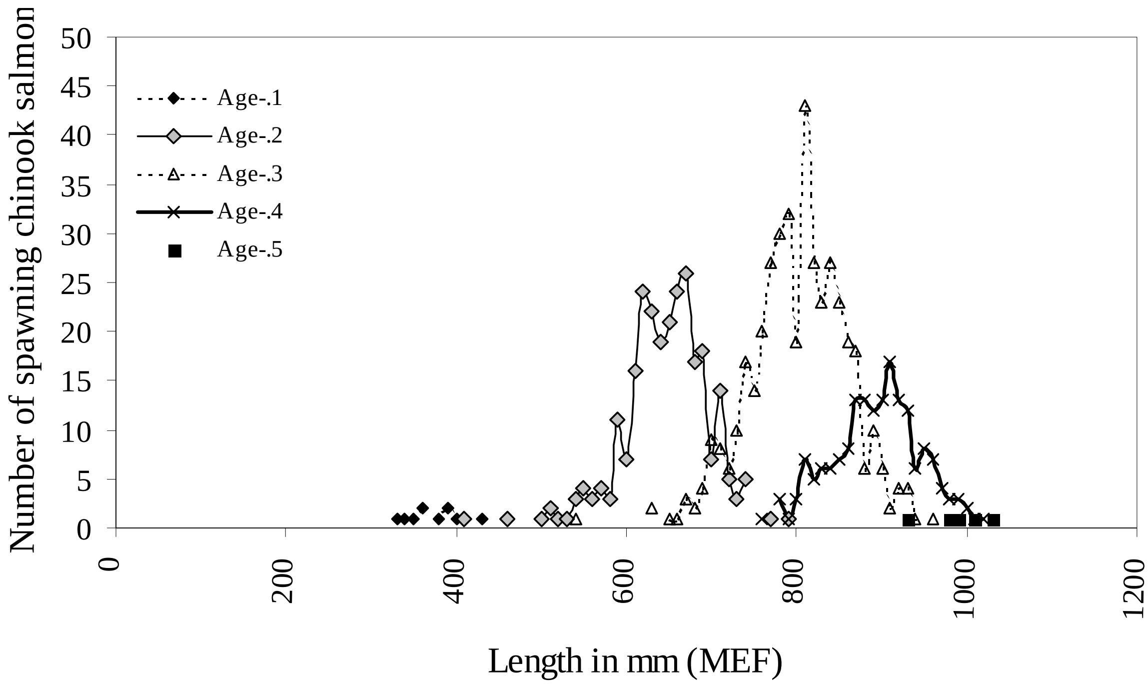

Figure 8.–Numbers of chinook salmon sampled by length and ocean-age at all eight tributary spawning sites on the Unuk River in 2000.

migration (Pahlke et al. 1996). In 2000, 38 fish marked in Event 1 were subsequently recaptured again in Event 1. For these fish, the average time between release and recapture (e.g., an estimate of the "sulk" rate) was nearly 7 days with a maximum period of over 26 days and a minimum of 4 minutes (Table 6). This rate does not appear vary by length or age; however, a noticeable trend exists when looked at by marking date. The "sulk" rate appears to be higher for fish marked earlier versus later in the project (Figure 9). This could be a direct effect of tagging with early run fish appearing more fragile being fresh in condition and bright chrome in color. Whereas later run fish have scales that are often embedded and often appear rosy or dark in color. Later run fish also have a limited amount of time to get to the spawning grounds to spawn and do not have the luxury of "sulking" for prolonged periods of time versus early run fish that might be ripening and preparing for spawning while "sulking." This backing-down phenomenon has been observed in other studies as well (Milligan et al. 1984; Johnson et al. 1992; Johnson 1993; Bendock and Alexandersdottir 1993; Eiler et al. *In prep*).

The success of this mark-recapture experiment rests largely on the assumptions. An important assumption is that fish were marked in proportion to their passing abundance, or that every fish had an equal chance of being inspected on the spawning grounds. Results of the statistical tests regarding this assumption are consistent with the conclusion that medium and large fish were marked in proportion to their abundance, and that fish marked at different times were captured with equal probabilities at different recovery locations. Also, an earlier radiotelemetry study (Pahlke et al. 1996) showed that our selection of a tagging site led to proportional marking in event 1. In the 1994 study, 86% of radio tagged fish were successfully tracked to a spawning tributary. These and other mark-recapture experiments in SEAK suggest that marked and unmarked fish died at the same rate (Seber 1982).

Loss of primary tags was higher this year than in previous years of study. For the 77 recaptures seen in Event 2, 11 of these fish (14%) were missing their primary tag. This was likely a result of applying too much pressure on the crimping

Table 4.–Estimated age and sex composition of the escapement of medium (401 mm–659 mm MEF) and large (≥660 mm MEF) chinook salmon escapement in the Unuk River in 2000.

		BROOD YEAR AND AGE CLASS					
		1996	1995	1994	1993	1992	
		1.1	1.2	1.3	1.4	1.5	Total
PANEL A: MEDIUM CHINOOK SALMON							
Males	n	1	152	4			157
	Age %	0.6	96.8	2.5			100
	SE of %	0.6	1.4	1.3			
	Escapement	15	2,205	58			2,278
	SE of esc.	15	937	36			968
Females	n						
	Age %						
	SE of %						
	Escapement						
	SE of esc.						
Sexes combined	n	1	152	4			157
	Age %	0.6	96.8	2.5			100
	SE of %	0.6	1.4	1.3			
	Escapement	15	2,205	58			2,278
	SE of esc.	15	937	36			968
PANEL B: LARGE CHINOOK SALMON							
Males	n		108	242	55	2	407
	Age %		15.2	34.1	7.7	0.3	57.3
	SE of %		1.3	1.8	1.0	0.2	1.9
	Escapement		893	2,001	455	17	3,366
	SE of esc.		126	243	77	12	385
Females	n		5	174	120	4	303
	Age %		0.7	24.5	16.9	0.6	42.7
	SE of %		0.3	1.6	1.4	0.3	1.9
	Escapement		41	1,439	992	33	2,506
	SE of esc.		19	184	136	17	296
Sexes combined	n		113	416	175	6	710
	Age %		15.9	58.6	24.6	0.8	100
	SE of %		1.4	1.8	1.6	0.3	
	Escapement		935	3,441	1,447	50	5,872
	SE of esc.		130	393	185	21	644
PANEL C: MEDIUM AND LARGE CHINOOK SALMON							
Males	Age %	0.2	38.0	25.3	5.6	0.2	69.3
	SE of %	0.2	7.3	3.1	1.0	0.1	4.0
	Escapement	15	3,099	2,060	455	17	5,644
	SE of esc.	15	946	246	77	12	1,042
Females	Age %		0.5	17.7	12.2	0.4	30.7
	SE of %		0.2	2.5	1.8	0.2	4.0
	Escapement		41	1,439	992	33	2,506
	SE of esc.		19	184	136	17	296
Sexes combined	Age %	0.2	38.5	42.9	17.8	0.6	100
	SE of %	0.2	7.2	5.1	2.5	0.3	
	Escapement	15	3,140	3,499	1,447	50	8,150
	SE of esc.	15	946	394	185	21	1,163

Table 5.–Estimated average length (MEF in mm) by age and sex of chinook salmon sampled in the Unuk River in 2000, by sampling event and location.

		BROOD YEAR AND AGE CLASS					
		1997	1996	1995	1994	1993	
		1.1	1.2	1.3	1.4	1.5	Total
PANEL A: EVENT 1, LOWER UNUK RIVER GILLNET							
Males	n		11	141	50	3	205
	Avg. length		654	815	877	980	824
	SD		35	42	40	35	77
	SE		11	4	6	20	5
Females	n		275	213	39		527
	Avg. length		655	785	910		727
	SD		42	60	42		84
	SE		3	4	7		4
Sexes combined	n		286	354	89	3	732
	Avg. length		655	797	892	980	754
	SD		42	55	44	35	89
	SE		2	3	5	20	3
PANEL B: EVENT 2, SPAWNING GROUNDS							
Males	n	10	260	246	55	2	573
	Avg. length	370	642	789	910	938	727
	SD	30	50	64	60	124	163
	SE	10	3	4	8	88	7
Females	n		5	174	120	4	303
	Avg. length		726	816	884	975	843
	SD		38	42	46	36	81
	SE		17	3	4	18	5
Sexes combined	n	10	265	420	175	6	876
	Avg. length	370	644	800	892	963	767
	SD	30	51	57	52	65	117
	SE	10	3	3	4	27	4

tool, which can burn the monofilament leader and decrease its strength. For the 66 fish recaptured possessing primary tags, 68% were male, and for the 11 fish missing primary tags, 64% were male. In all cases, secondary marks were clearly visible on recaptured fish, once fish were in hand.

Gillnets were selective toward bigger medium fish in 2000. This also occurred in 1997 when the age-1.1 fish were smaller than average. Age-1.1 fish captured on the spawning grounds were, on average, 363 mm MEF in 1997, 433 mm MEF in 1998, 434 mm MEF in 1999, and 370 mm MEF in 2000 (Table 7). Age-1.1 fish were, on average, much smaller in 1997 and 2000 versus 1998 and 1999. As a result, only fish sampled in event 2 are used to estimate age, size, and sex compositions.

Female chinook salmon tend to die on or near their redds whereas males usually drift downstream in a moribund state after spawning (Kissner and Hubartt 1986). Because of this behavior, estimates of age, sex, and size composition for fish sampled in carcass-only surveys tend to be biased towards females, which are also larger fish on average. This occurred in 2000 with the carcass samples being dominated by female fish (73%). We used various sampling techniques such as rod and reel snagging and lure fishing, spear, gillnet, dipnet, and carcass-only surveys to reduce our chances for introducing such bias during sampling on the spawning grounds.

Foot surveys of abundance were used to approximate the amount of effort required to

Table 6.–Chinook salmon recaptured during Event 1 in the lower Unuk River in 2000 and the number of days, hours, and minutes seen between release and recapture.

Spaghetti tag number	Release date/time	Recapture date/time	Sulking period	Day	Hr	Min
0098	06/17/00 11:45	06/28/00 06:41	10 days, 18 hours, and 56 minutes	10	18	56
0100	06/18/00 12:10	07/04/00 10:05	15 days, 21 hours, and 55 minutes	15	21	55
0419	06/19/00 13:37	06/19/00 13:41	0 days, 0 hours, and 04 minutes			4
0419	06/19/00 13:41	06/23/00 16:13	4 days, 2 hours, and 32 minutes	4	2	32
0424	06/19/00 17:51	06/24/00 16:23	4 days, 22 hours, and 32 minutes	4	22	32
0426	06/20/00 06:45	07/11/00 14:29	21 days, 7 hours, and 44 minutes	21	7	44
0447	06/21/00 11:45	07/18/00 10:00	26 days, 22 hours, and 15 minutes	26	22	15
0473	06/23/00 13:04	06/23/00 12:27	0 days, 0 hours, and 37 minutes			37
0479	06/24/00 08:10	07/03/00 14:57	9 days, 6 hours, and 47 minutes	9	6	47
0487	06/24/00 16:35	06/24/00 17:12	0 days, 0 hours, and 37 minutes			37
2404	06/26/00 16:10	07/17/00 17:30	21 days, 1 hours, and 20 minutes	21	1	20
2406	06/26/00 16:58	06/26/00 17:09	0 days, 0 hours, and 11 minutes			11
2419	06/27/00 14:25	07/13/00 09:42	15 days, 19 hours, and 17 minutes	15	19	17
2428	06/28/00 12:15	06/30/00 11:25	1 days, 23 hours, and 10 minutes	1	23	10
2431	06/28/00 15:00	07/14/00 06:41	15 days, 15 hours, and 41 minutes	15	15	41
2437	06/30/00 07:50	07/13/00 17:01	13 days, 9 hours, and 11 minutes	13	9	11
2450	06/30/00 17:49	07/04/00 16:33	3 days, 22 hours, and 44 minutes	3	22	44
2453	07/01/00 08:55	07/01/00 09:30	0 days, 0 hours, and 35 minutes			35
2453	07/01/00 09:30	07/22/00 18:55	21 days, 9 hours, and 25 minutes	21	9	25
2460	07/02/00 06:17	07/16/00 16:22	14 days, 10 hours, and 05 minutes	14	10	5
2467	07/02/00 18:24	07/05/00 16:52	2 days, 22 hours, and 28 minutes	2	22	28
2474	07/03/00 15:42	07/04/00 16:00	1 days, 0 hours, and 18 minutes	1		18
2496	07/07/00 16:51	07/08/00 16:14	0 days, 23 hours, and 23 minutes		23	23
2497	07/07/00 17:33	07/16/00 14:20	8 days, 20 hours, and 47 minutes	8	20	47
2496	07/08/00 16:14	07/15/00 16:20	7 days, 0 hours, and 06 minutes	7		6
2323	07/10/00 13:38	07/13/00 15:41	3 days, 2 hours, and 03 minutes	3	2	3
2367	07/12/00 18:08	07/15/00 08:32	2 days, 14 hours, and 24 minutes	2	14	24
2377	07/13/00 12:24	07/17/00 13:51	4 days, 1 hours, and 27 minutes	4	1	27
2380	07/13/00 13:12	07/13/00 14:00	0 days, 0 hours, and 48 minutes			48
2395	07/13/00 17:50	07/22/00 08:12	8 days, 14 hours, and 22 minutes	8	14	22
2431	07/14/00 06:41	07/18/00 16:31	4 days, 9 hours, and 50 minutes	4	9	50
2510	07/14/00 07:12	07/16/00 12:45	2 days, 5 hours, and 33 minutes	2	5	33
2497	07/16/00 14:20	07/16/00 16:35	0 days, 2 hours, and 15 minutes		2	15
2644	07/18/00 16:47	07/23/00 10:25	4 days, 17 hours, and 38 minutes	4	17	38
2693	07/21/00 15:55	07/23/00 15:55	2 days, 0 hours, and 00 minutes	2		
2721	07/22/00 14:02	07/24/00 16:02	2 days, 2 hours, and 00 minutes	2	2	
2846	07/31/00 06:40	07/31/00 10:20	0 days, 3 hours, and 40 minutes		3	40
2851	08/02/00 06:40	08/02/00 11:12	0 days, 4 hours, and 32 minutes		4	32

Average = 6 days, 17 hours, and 42 minutes.

Maximum = 26 days, 22 hours, and 15 minutes.

Minimum = 4 minutes.

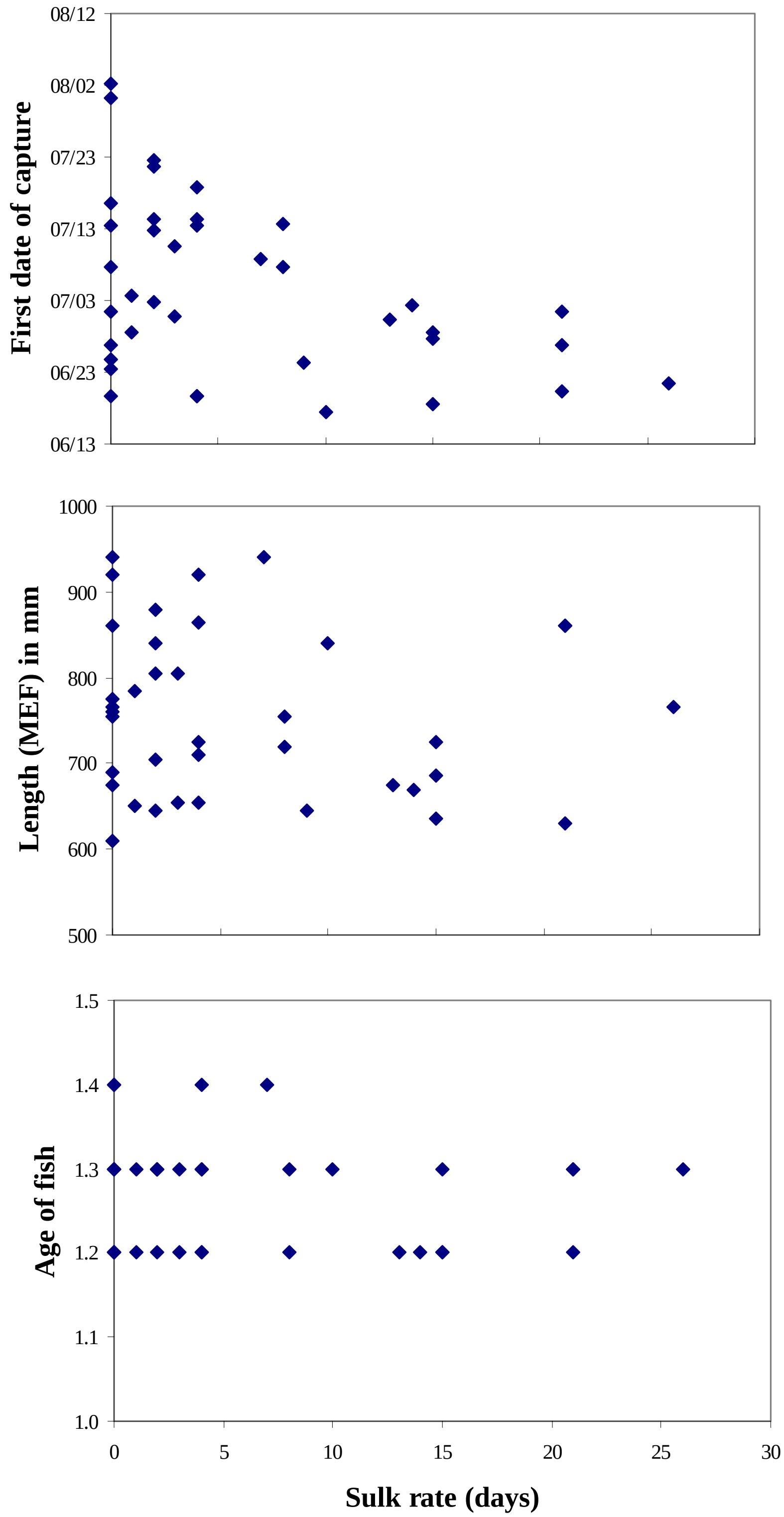

Figure 9.–The average time between captures for fish caught multiple times in the event 1 gillnets used in the lower Unuk River in 2000 compared by first date of capture, length of fish, and age of fish.

Table 7.–Estimated average length (MEF in mm) of age-1.1 chinook salmon sampled by event in the Unuk River in 1997 through 2000.

	SAMPLE YEAR				
	1997	1998	1999	2000	Average
EVENT 1 SAMPLING					
n		5	3	1	9
Avg. length		447	493	380	455
SD		20	28		35
SE		9	16		12
EVENT 2 SAMPLING					
n	51	40	24	10	125
Avg. length	363	433	434	370	372
SD	39	24	24	30	60
SE	5	4	5	10	5

sample the various spawning sites in proportion to abundance. This helps us to obtain unbiased samples of length and age composition should small differences exist among tributaries.

The 95% relative precision (RP) of mark-recapture estimates of abundance has been shown to improve in consecutive years of study. For instance, on the Chickamin River RPs of ±61% and ±25% occurred in 1995 and 1996 (Pahlke 1996, 1997b). On the Unuk River, RPs of ±54%, ±18%, ±20%, and ±25% occurred in 1994, 1997, 1998, and 1999. These results suggest that the knowledge gained from previous mark-recapture studies is beneficial and positively influences the success of future studies. This year our goal was to achieve results similar to those obtained since 1997, and a 95% RP of ±22% (CV = 11%) was obtained, an excellent level of precision for any detailed stock assessment study.

As was the case in previous years, the estimated abundance of large fish was considerably greater than corresponding estimates obtained from the peak survey counts. Observer bias resulting in underestimation of the actual abundance is a common pattern seen in other studies of chinook salmon in Southeast Alaska and in northern British Columbia (Johnson et al. 1992; Pahlke et al. 1996; McPherson et al. 1997; Jones et al. 1998; Jones and McPherson 1999) and of salmon in general (Jones 1995). This year, about 23% (1,341) of the estimated 5,872 large fish immigrating to the Unuk River were counted in the peak survey count. This percentage is similar to those seen in previous years of study on the Unuk River (Table 8) (Pahlke et al. 1996; Jones et al. 1998; Jones and McPherson 1999, 2000). Past studies on salmon have shown that accuracy of observer counts tends to decrease as abundance increases. Many of these studies pertain to pink salmon that concentrate in such dense numbers that observers tend to count in multiples of a hundred or even a thousand. Although not proven, it is doubtful with chinook salmon that abundance frequently, if ever, reaches levels that overwhelm the observer to the extent that accuracy decreases with an increase in abundance. The accuracy of observer counts does not appear to vary over the range of abundance seen in the years in which mark-recapture estimates were performed on the Unuk River (Figure 10).

The mean expansion factor is 4.93 (SE = 0.59), calculated from the 1997–2000 mark-recapture estimates and peak survey counts (Table 8). With further development, these data might one day enable estimation of total escapement for large spawners based entirely on expanded observer counts in years not having detailed mark-recapture study (e.g., 1977–1993 and 1995–1996). This would lead to improved spawner-recruit analyses and the calculation of a new escapement goal range for Unuk River chinook salmon. Note the current escapement goal is a survey count goal range.

This study is one part of a program to estimate total run size, exploitation rate, harvest distribution, marine survival, and other population parameters for Unuk River chinook salmon. Between 3% and 13% of the chinook salmon smolt have been tagged each year with CWTs since the fall of 1993 (1992 brood year, Appendix A1, A4). Analysis of these data is in progress and a manuscript describing Unuk River chinook salmon production for the 1993 to 1997 brood years is in progress. Preliminary results suggest production of smolt has ranged between 150,000 to 350,000, with juvenile overwinter survival between 34% to 80%.

In recent years, peak survey counts of escapement have been at or below the 20-year

Table 8.–Peak survey counts, mark-recapture estimates of abundance, expansion factors and other statistics for large chinook salmon (≥660 mm MEF) in the Unuk River (1994, 1997–2000).

	1994[a]	1997	1998	1999	2000	Average 1997–2000
Survey count	711	636	840	680	1,341	**874**
Mark-recapture (M-R) estimate	4,623	2,970	4,132	3,914	5,872	**4,222**
SE (M-R)	1,266	271	413	490	644	**455**
Survey count/(M-R) (%)	15.4%	21.4%	20.3%	17.4%	22.8%	**20.5%**
CV (M-R)	27%	9%	10%	13%	11%	**11%**
95% RP M-R Nhat	54%	18%	20%	25%	22%	**21%**
Expansion factor (EF)	6.50	4.67	4.92	5.76	4.38	**4.93**
SE (EF)	1.78	0.43	0.49	0.72	0.48	**0.59**
CV (EF)	27%	9%	10%	13%	11%	**12%**
95% RP (EF)	54%	18%	20%	25%	21%	**24%**

[a] 1994 was not included in the average due to the high relative precision in the mark-recapture estimate.

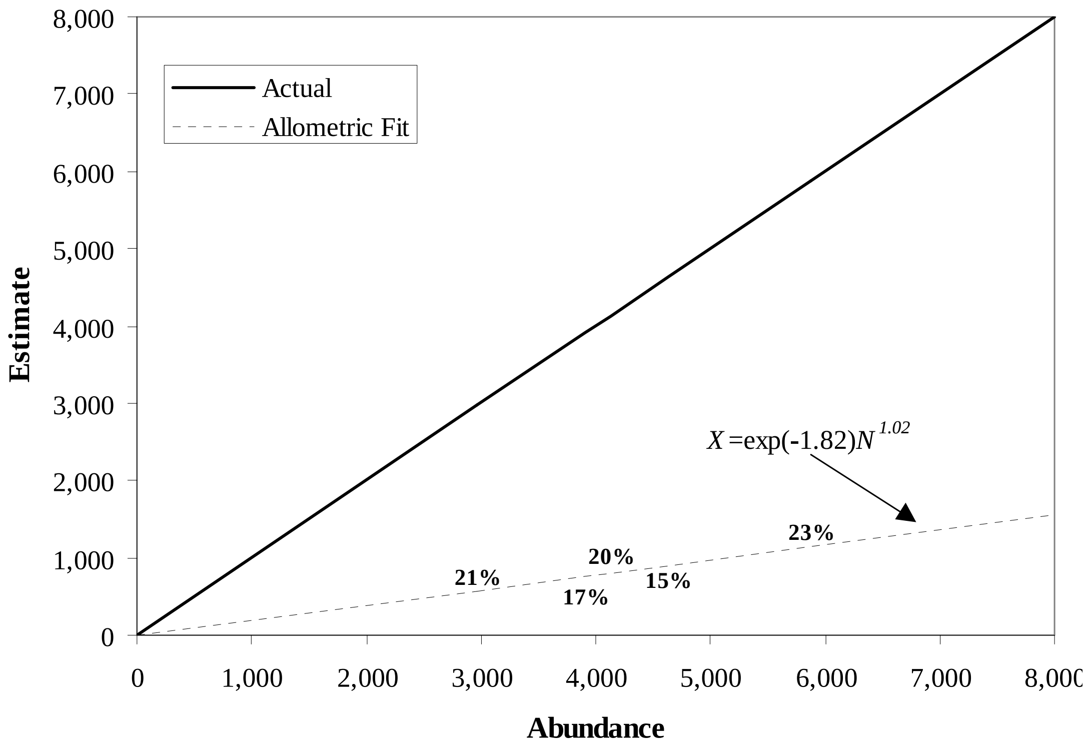

Figure 10.–Observer counts of chinook salmon (percent of actual shown in bold**) compared to the estimated actual number as determined through mark-recapture studies in the Unuk River 1994, 1997–2000.**

average of 1,087 large fish. However, an estimated 3,140 (SE = 946) age-1.2 (1996 brood year) fish returned to the Unuk River in 2000 (Table 4). This unusually high percentage (39%) and number of age-1.2 fish in the overall escapement was greater than that seen in any of the previous years of mark-recapture study (Jones and McPherson 2000). In 2001, age-1.3 and age-1.4 fish will be returning from the 1995 and 1996 brood years, and if the brood year strength seen in 2000 continues, we expect the 2001 escapement to be much larger than that seen in 2000.

CONCLUSIONS AND RECOMMENDATIONS

Because this project will be performed again in 2001, we recommend some strategies for continued success. As in previous years, effort should concentrate on maximizing the numbers of fish tagged during Event 1 and those sampled for tags in Event 2. SN1 should continue to be used as the tagging site since it has produced more than adequate results in prior years. Knowledge of run timing gathered in prior years should be used as an indicator of peak spawning abundance and optimum sampling periods. This year an unusually high number of fish lost their primary tags (14%). Likely this was the result of poor crimping during the tagging procedure and effort should be made to ensure that crimps are applied correctly. We recommend that survey counts continue in a similar manner as those made in the past and that observers attempt to maintain consistency in counting efficiency from year to year. Further, we recommend that more effort be applied to the foot survey counts to increase the probability of performing a count during the period of peak abundance. Finally, the age, sex, and length composition estimates from previous years of study have been relatively unbiased, which can be primarily attributed to the use of multiple capture gear during spawning grounds sampling. We will continue this practice in future years.

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LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1993. Length, sex, and scale sampling procedure for sampling using the ADF&G adult salmon age-length mark-sense form version 3.0. Commercial Fisheries Management and Development Division, Douglas.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences. 2106: 37 p.

Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management 13:540-549.

Buckland, S. T. and P. H. Garthwaite. 1991. Quantifying precision of mark-recapture estimates using the bootstrap and related methods. Biometrics 47:255-268.

Clutter R. and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon

Fisheries Commission 9, New Westminster, British Columbia.

Efron, B. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York.

Eiler, J., M. M. Masuda, J. Pella, H. R. Carlson, R. F. Bradshaw, and B. D. Nelson. *In prep.* Stock composition, escapement estimate, and timing of chinook salmon returns in the Taku River, Alaska and British Columbia.

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

Johnson, R. E. 1993. Chilkat River chinook salmon studies, 1992. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 93-50, Anchorage.

Johnson, R. E., R. P. Marshall, and S. T. Elliott. 1992. Chilkat River chinook salmon studies, 1991. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 92-49, Anchorage.

Jones, E. L. III. 1995. Observer variability and bias in estimation of Southeast Alaska pink salmon escapement. Master's thesis, University of Alaska Fairbanks, Juneau.

Jones, E. L. III. and S. A. McPherson. 1999. A mark-recapture experiment to estimate the escapement of chinook salmon in the Unuk River, 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-14, Anchorage.

Jones, E. L. III., S. A. McPherson, and D. L. Magnus. 1998. A mark-recapture experiment to estimate the escapement of chinook salmon in the Unuk River, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-23, Anchorage.

Kissner, P. D., Jr. and D. J. Hubartt. 1986. A study of chinook salmon in Southeast Alaska. Alaska Department of Fish and Game, Annual Report 1985-1986, Project F-10-1, 27 (AS-41).

McPherson, S. A. and J. K. Carlile. 1997. Spawner-recruit analysis of Behm Canal chinook salmon stocks. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 1J97-08, Juneau.

McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1997. Spawning abundance of chinook salmon in the Taku River in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-14, Anchorage.

Milligan, P. A., W. O. Rublee, D. D. Cornett, and R. A. C. Johnston. 1984. The distribution and abundance of chinook salmon in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982–1983. Department of Fisheries and Oceans, Yukon River Basin Study, Technical Report 35. Whitehorse, Yukon Territory.

Olsen, M. A. 1992. Abundance, age, sex and size of chinook salmon catches and escapements in Southeast Alaska in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-07, Juneau.

Pahlke, K. A. 1995. Coded-wire tagging studies of chinook salmon on the Unuk and Chickamin rivers, 1983-1993. Alaska Department of Fish and Game, Alaska Fishery Research Bulletin Series 2(2):93-113.

Pahlke, K. A. 1996. Abundance of the chinook salmon escapement on the Chickamin River, 1995. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 96-37, Anchorage.

Pahlke, K. A. 1997a. Escapements of chinook salmon in Southeast Alaska and transboundary rivers in 1996. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 97-33, Anchorage.

Pahlke, K. A. 1997b. Abundance and distribution of the chinook salmon escapement on the Chickamin River, 1996. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 97-28, Anchorage.

Pahlke, K. A. Escapements of chinook salmon in Southeast Alaska and transboundary rivers in 2000. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 01-32, Anchorage.

Pahlke, K. A., S. A. McPherson, and R. P. Marshall. 1996. Chinook salmon research on the Unuk River, 1994. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 96-14, Anchorage.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, second edition. MacMillan and Company, New York.

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

APPENDIX A

Appendix A1.–Numbers of Unuk River chinook salmon fall fry and spring smolt captured and tagged with coded-wire tags, 1992 brood year to present.

PANEL B. TOTAL NUMBERS OF FALL AND SPRING CHINOOK JUVENILES AND SMOLT TAGGED BY YEAR AND SUMMED BY BROOD YEAR

Brood year	Year tagged	Fall/ spring	Tag code	Number tagged	Valid tagged
1992	1993	Fall	043803	10,316	10,263
1992	1993	Fall	043804	441	433
1992	1993	Fall	043805	3,202	3,093
1992	1994	Spring	044206	2,653	2,642
		1992 BROOD YEAR TOTAL			**16,431**
1993	1994	Fall	043349	1,706	1,700
1993	1994	Fall	043350	11,152	11,139
1993	1994	Fall	043557	7,688	7,687
1993	1995	Spring	044213	3,228	3,227
		1993 BROOD YEAR TOTAL			**23,753**
1994	1995	Fall	043556	11,540	11,476
1994	1995	Fall	043558	11,654	11,645
1994	1995	Fall	043559	10,825	10,825
1994	1995	Fall	044231	6,324	6,260
1994	1996	Spring	044207	6,143	6,099
1994	1996	Spring	044208	1,362	1,357
		1994 BROOD YEAR TOTAL			**47,662**
1995	1996	Fall	044712	24,252	24,224
1995	1996	Fall	044236	11,202	11,200
1995	1996	Fall	044218	3,755	3,753
1995	1997	Spring	043829	12,521	12,517
		1995 BROOD YEAR TOTAL			**51,694**
1996	1997	Fall	044713	24,309	24,176
1996	1997	Fall	044714	22,996	22,583
1996	1997	Fall	044715	15,401	15,146
1996	1998	Spring	044646	11,193	11,134
1996	1998	Spring	044339	5,991	5,987
		1996 BROOD YEAR TOTAL			**79,026**
1997	1998	Fall	040139	22,389	22,366
1997	1998	Fall	040140	11,664	11,522
1997	1999	Spring	040144	7,954	7,948
		1997 BROOD YEAR TOTAL			**41,836**
1998	1999	Fall	40142	16,677	16,661
1998	2000	Spring	40256	11,127	11,124
1998	2000	Spring	40257	2,209	2,209
		1998 BROOD YEAR TOTAL			**29,994**
1999	2000	Fall	40374	21,918	21,853
1999	2000	Fall	40288	10,082	10,072
1999	2001	Spring	40145	16,565	16,561
		1999 BROOD YEAR TOTAL			**48,486**

Appendix A2.–Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of hypothesis tests (K-S and χ^2) on lengths of fish MARKED during the first event and RECAPTURED during the second event	Results of hypothesis tests (K-S) on lengths of fish CAPTURED during the first event and CAPTURED during the second event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_o	Reject H_o
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

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

Case II: Calculate one unstratified abundance estimate, 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 abundance for each stratum. Add abundance estimates 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 (p. 17).

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A3.–Numbers by sex and age for chinook salmon sampled on the Unuk River spawning grounds in 2000 by location (Panel A), gear (Panel B), and size group (Panel C), and in the lower river gillnet samples (Panel D). Results were not stratified by size class; for estimates of the age composition of the escapement, see Table 4.

				BROOD YEAR AND AGE CLASS					
				1996	1995	1994	1993	1992	
				1.1	1.2	1.3	1.4	1.5	Total
PANEL A: EVENT 2 SAMPLING BY SITE									
Cripple Creek	Medium- and large-sized	Males	n		89	79	22	1	191
			%		28.2	25.0	7.0	0.3	60.4
		Females	n		1	74	48	2	125
			%		0.3	23.4	15.2	0.6	39.6
		Total	n		90	153	70	3	316
			%		28.5	48.4	22.2	0.9	100
Gene's Lake Creek	Medium- and large-sized	Males	n	1	121	32	3		157
			%	0.5	59.9	15.8	1.5		77.7
		Females	n		1	30	14		45
			%		0.5	14.9	6.9		22.3
		Total	n	1	122	62	17		202
			%	0.5	60.4	30.7	8.4		100
Clear Creek	Medium- and large-sized	Males	n		39	81	16	1	137
			%		19.8	41.1	8.1	0.5	69.5
		Females	n		3	36	21		60
			%		1.5	18.3	10.7	0.0	30.5
		Total	n		42	117	37	1	197
			%		21.3	59.4	18.8	0.5	100
Kerr Creek	Medium- and large-sized	Males	n		9	34	6		49
			%		10.1	38.2	6.7		55.1
		Females	n			18	20	2	40
			%			20.2	22.5	2.2	44.9
		Total	n		9	52	26	2	89
			%		10.1	58.4	29.2	2.2	100
Lake Creek	Medium- and large-sized	Males	n		1	17	7		25
			%		1.8	30.4	12.5		44.6
		Females	n			15	16		31
			%		0.0	26.8	28.6		55.4
		Total	n		1	32	23		56
			%		1.8	57.1	41.1		100
All other tributaries[1]	Medium- and large-sized	Males	n		1	3	1		5
			%		14.3	42.9	14.3		71.4
		Females	n			1	1		2
			%			14.3	14. %		28.6
		Total	n		1	4	2		7
			%		14.3	57.1	28.6		100

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				BROOD YEAR AND AGE CLASS					
				1996	1995	1994	1993	1992	
				1.1	1.2	1.3	1.4	1.5	Total
PANEL B: EVENT 2 SAMPLING BY GEAR									
		Males	n	1	198	209	42	1	451
			%	0.2	30.3	32.0	6.4	0.2	69.1
Rod and reel snag	Medium- and large-sized	Females	n		4	117	79	2	202
			%		0.6	17.9	12.1	0.3	30.9
		Total	n	1	202	326	121	3	653
			%	0.2	30.9	49.9	18.5	0.5	100
		Males	n		44	32	12	1	89
			%		25.9	18.8	7.1	0.6	52.4
Spear	Medium- and large-sized	Females	n		1	43	35	2	81
			%		0.6	25.3	20.6	1.2	47.6
		Total	n		45	75	47	3	170
			%		26.5	44.1	27.6	1.8	100
		Males	n		17	2			19
			%		65.4	7.7			73.1
Rod and reel lure	Medium- and large-sized	Females	n			5	2		7
			%			19.2	7.7		26.9
		Total	n		17	7	2		26
			%		65.4	26.9	7.7		100
		Males	n		1	1	1		3
			%		9.1	9.1	9.1		27.3
Carcass	Medium- and large-sized	Females	n			5	3		8
			%			45.5	27.3		72.7
		Total	n		1	6	4		11
			%		9.1	54.5	36.4		100
		Males	n			2			2
			%			28.6			28.6
Other gear[2]	Medium- and large-sized	Females	n			4	1		5
			%			57.1	14.3		71.4
		Total	n			6	1		7
			%			85.7	14.3		100
PANEL C: EVENT 2 ALL TRIBUTARIES COMBINED									
		Males	n	1	152	4			157
			%	0.6	96.8	2.5			100
	Medium-sized	Females	n						
			%						
		Total	n	1	152	4			157
			%	0.6	96.8	2.5			100
		Males	n		108	242	55	2	407
			%		15.2	34.1	7.7	0.3	57.3
Spawning grounds[3]	Large-sized	Females	n		5	174	120	4	303
			%		0.7	24.5	16.9	0.6	42.7
		Total	n		113	416	175	6	710
			%		15.9	58.6	24.6	0.8	100
		Males	n	1	260	246	55	2	564
			%	0.1	30.0	28.4	6.3	0.2	65.1
	Medium- and large-sized	Females	n		5	174	120	4	303
			%		0.6	20.1	13.8	0.5	34.9
		Total	n	1	265	420	175	6	867
			%	0.1	30.6	48.4	20.2	0.7	100

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				BROOD YEAR AND AGE CLASS					
				1996	1995	1994	1993	1992	
				1.1	1.2	1.3	1.4	1.5	Total
PANEL D: EVENT 1 LOWER UNUK RIVER GILLNET SAMPLES									
Lower Unuk River gillnet samples[4]	Medium-sized	Males	n		144	2			146
			%		94.1	1.3			95.4
		Females	n		6	1			7
			%		3.9	0.7			4.6
		Total	n		150	3			153
			%		98.0	2.0			100
	Large-sized	Males	n		131	211	39		381
			%		22.6	36.4	6.7		65.8
		Females	n		5	140	50	3	198
			%		0.9	24.2	8.6	0.5	34.2
		Total	n		136	351	89	3	579
			%		23.5	60.6	15.4	0.5	100
	Medium- and large-sized[5]	Males	n		275	213	39		527
			%		37.6	29.1	5.3		72.0
		Females	n		11	141	50	3	205
			%		1.5	19.3	6.8	0.4	28.0
		Total	n		286	354	89	3	732
			%		39.1	48.4	12.2	0.4	100

[1]Includes the Eulachon River, Dog Salmon Creek, and the Unuk River mainstem.

[2]Other gear: dipnet, eggs, and gillnet.

[3]Not included are 10 fish for which age was not determined.

[4]Not included are 12 fish for which age was not determined. Sex was not identified for an additional fish.

[5]Numbers at age added across all size classes; results differ from those in Table 3.

Appendix A4.–Numbers of adult Unuk River chinook salmon examined for adipose finclips, sacrificed for CWT sampling purposes, valid CWTs tags decoded, percent of the marked fraction carrying germane CWTs, percent adipose clipped, and estimated fraction of the sample carrying valid CWTs, 1992 brood year to present.

NUMBERS OF ADULT CHINOOK SALMON AND ADIPOSE FINCLIPPED FISH SAMPLED AND THE ASSOCIATED MARKED FRACTION OBTAINED FOR EACH BROOD YEAR

Brood year	Age class	Year sampled	Number examined	Adipose clips	Number sacrificed	Number of valid tags				Percent adipose	Marked fraction (θ)	
						Fall	Spring	Total	Valid		Valid	Event
1992	1.2	1996	33	0	0	0	0	0				1+2
1992	1.3	1997	136	7	7	6	1	7	100.0%	5.1%	5.1%	1
1992	1.3	1997	273	5	4	4	0	4	100.0%	1.8%	1.8%	2
1992	2.2	1997	1	0	0	0	0	0				2
1992	1.4	1998	129	6	4	2	2	4	100.0%	4.7%	4.7%	1
1992	1.4	1998	187	9	4	2	2	4	100.0%	4.8%	4.8%	2
1992	1.5	1999	2	0	0	0	0	0				2
1992 Brood year total			761	27	19	14	5	19	100.0%	3.5%	3.5%	
1993	1.1	1996	4	1	1	1	0	1	100.0%	25.0%	25.0%	2
1993	1.2	1997	89	9	9	8	1	9	100.0%	10.1%	10.1%	1
1993	1.2	1997	186	30	26	20	2	22	84.6%	16.1%	13.6%	2
1993	1.3	1998	319	31	28	24	4	28	100.0%	9.7%	9.7%	1
1993	1.3	1998	402	29	15	11	4	15	100.0%	7.2%	7.2%	2
1993	2.2	1998	1	0	0	0	0	0				2
1993	1.4	1999	131	9	1	1	0	1	100.0%	6.9%	6.9%	1
1993	1.4	1999	192	27	16	12	4	16	100.0%	14.1%	14.1%	2
1993	1.5	2000	3	0	0	0	0	0				1
1993	1.5	2000	5	0	0	0	0	0				2
1993 Brood year total			1,332	136	96	77	15	92	95.8%	10.2%	9.8%	
1994	1.1	1997	55	4	4	2	2	4	100.0%	7.3%	7.3%	2
1994	1.2	1998	94	10	9	4	5	9	100.0%	10.6%	10.6%	1
1994	1.2	1998	211	20	16	10	6	16	100.0%	9.5%	9.5%	2
1994	2.1	1998	1	0	0	0	0	0				2
1994	1.3	1999	161	18	1	1	0	1	100.0%	11.2%	11.2%	1
1994	1.3	1999	231	27	11	6	5	11	100.0%	11.7%	11.7%	2
1994	1.4	2000	78	2	0	0	0	0				1
1994	1.4	2000	147	11	7	3	3	6	85.7%	7.5%	6.4%	2
1994 Brood year total			978	92	48	26	21	47	97.9%	9.4%	9.2%	
1995	1.1	1998	7	1	1	1	0	1	100.0%	14.3%	14.3%	1
1995	1.1	1998	64	14	12	12	0	12	100.0%	21.9%	21.9%	2
1995	1.2	1999	179	21	20	15	5	20	100.0%	11.7%	11.7%	1
1995	1.2	1999	257	40	26	15	11	26	100.0%	15.6%	15.6%	2
1995	1.3	2000	311	22	1	0	1	1	100.0%	7.1%	7.1%	1
1995	1.3	2000	378	46	18	10	6	16	88.9%	12.2%	10.8%	2
1995 Brood year total			1,196	144	78	53	23	76	97.4%	12.0%	11.7%	
1996	0.1	1998	1	0	0	0	0	0				2
1996	1.1	1999	4	0	0	0	0	0				1
1996	1.1	1999	53	6	5	4	1	5	100.0%	11.3%	11.3%	2
1996	1.2	2000	262	36	24	16	8	24	100.0%	13.7%	13.7%	1
1996	1.2	2000	249	36	25	17	6	23	92.0%	14.5%	13.3%	2
1996 Brood year total			569	78	54	37	15	52	96.3%	13.7%	13.2%	
1997	1.1	2000	1	0	0	0	0	0				1
1997	1.1	2000	10	1	1	0	1	1	100.0%	10.0%	10.0%	2
1997 Brood year total			11	1	1	0	1	1	100.0%	9.1%	9.1%	

Appendix A5.–Computer files used to estimate the spawning abundance of chinook salmon in the Unuk River in 2000.

File name	Description
00unk41.xls	Spreadsheet containing all the mark-recapture data with various pivot table results, Tables 1 - 8, Figures 5, 8-10, Appendices A1, A3, and A4, abundance estimates, SPAS results, bootstrap results, and chi-squared analyses.
00unk41ks.xls	Spreadsheet containing the Kolmogorov-Smirnov (K-S) 2-sample test results and various figures and data sets used in these calculations. Figures 6 and 7 used in 00unk41.doc are also included.
BootVar.bas	QBASIC program used for bootstrapping abundance estimates to estimate variance and bias.
00unk41lg.dat	File containing data for large chinook salmon used in the program BootVar.exe.
00unk41md.dat	File containing data for medium chinook salmon used in the program BootVar.exe.
00unk41lg.out	Output from BootVar.bas on large chinook salmon.
00unk41md.out	Output from BootVar.bas on medium chinook salmon.
SPAS.exe	Stratified Population Analysis System (SPAS) lets the user perform computer analysis of 2-sample mark-recovery data where each sample is from a geographically or temporally stratified population.
00spas41lg.dat	File containing data for large chinook salmon used in the program SPAS.exe.
00spas41md.dat	File containing data for medium chinook salmon used in the program SPAS.exe.
00spas41lg.out	Output from SPAS.exe on large chinook salmon.
00spas41md.out	Output from SPAS.exe on medium chinook salmon.