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Estimation of the Escapement of Chinook Salmon in the Unuk River in 2005

by

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and

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November 2006

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

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

General	
Alaska Department of Fish and Game	ADF&G
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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ABSTRACT

A two-event mark-recapture experiment was used to estimate the abundance of Chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Unuk River in 2005. Biological data were collected during both events. Fish were captured during event 1 in the lower Unuk River using set gillnets from 10 June through 2 August. Each apparently healthy fish was marked with a numbered solid-core spaghetti tag sewn through its back and 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 13 July through 18 August to estimate the fraction of the population that had been marked. Abundance of large Chinook salmon (≥660 mm MEF) was estimated to be 4,742 (SE = 396). The estimate was made from 644 marked and 101 recaptured fish out of 749 examined upstream. Abundance of medium-sized fish (401–659 mm MEF) was estimated to be 679 (SE = 176). The estimate was made from 70 marked and 13 recaptured fish out of 133 examined on the spawning grounds. Using indirect methods, the abundance of small sized fish (<401 mm MEF) was estimated to be 123 (SE = 29). An estimated 27% of the spawning population (fish of all sizes) was sampled during the project. Peak survey counts in August totaled 929 large Chinook salmon, or about 20% of the mark-recapture estimate of large fish, similar to fractions seen in previous years. The mean expansion factor through 2005 is 4.87 (SD = 0.24) for estimating total escapement from survey counts. The estimated spawning population of 5,547 Chinook salmon was composed of 68.6% (SE = 2.4%) age-1.3 fish, 15.1% (SE = 1.3%) age-1.4 fish, 9.2% (SE = 1.7%) age-1.2 fish, and 6.7% (SE = 1.3) age-1.1 fish. Females composed an estimated 35.3% (1,956 fish) of spawners (SE = 2.0%), and an estimated 99% of those were age-1.3 and -1.4 fish.

Key words: escapement, Chinook salmon, Unuk River, mark-recapture, set gillnet, spaghetti tag, operculum punch, axillary appendage, peak survey counts, expansion factor

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 1997b). 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 MEF have been used as indices of escapement in each of these systems. These indices are roughly dome-shaped when plotted against time (1975–1999) with peak values occurring between 1987 and 1990 (Pahlke 1997b). Since 1999, survey counts and estimated total escapement have increased to near the former peak values in the Unuk and Chickamin rivers.

Several consecutive low survey counts in the early 1990s generated concern for the health of the Chinook salmon stocks in Behm Canal. In 1992, 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 overwinter survival of fingerlings, production and marine survival of smolts, escapement and harvest of adults, total run size, and exploitation rates. These goals are being accomplished with inriver mark-recapture experiments on adults and smolts and with marine catch sampling programs.

The current escapement goal for the Unuk River is 650–1,400 large fish counted in surveys, or an actual escapement of about 3,000–7,000 large fish (McPherson and Carlile 1997). Only large fish are counted in aerial surveys because smaller Chinook salmon are readily mistaken for other salmon species of similar size and color. For our purposes, Chinook salmon ≥660 mm MEF are considered large and are generally fish 3-ocean age (age-.3) or older. Nearly all females in the spawning population are classified as large. Chinook salmon 401-659 mm MEF are considered medium fish, and Chinook salmon ≤400 mm MEF are considered small fish. An index of escapement on the Unuk River is determined each year as the peak count of large spawners observed during several aerial and foot surveys of six tributaries: Cripple, Gene's Lake, Kerr, Clear, and Lake creeks plus the Eulachon River (Pahlke 1997b; Figure 2).

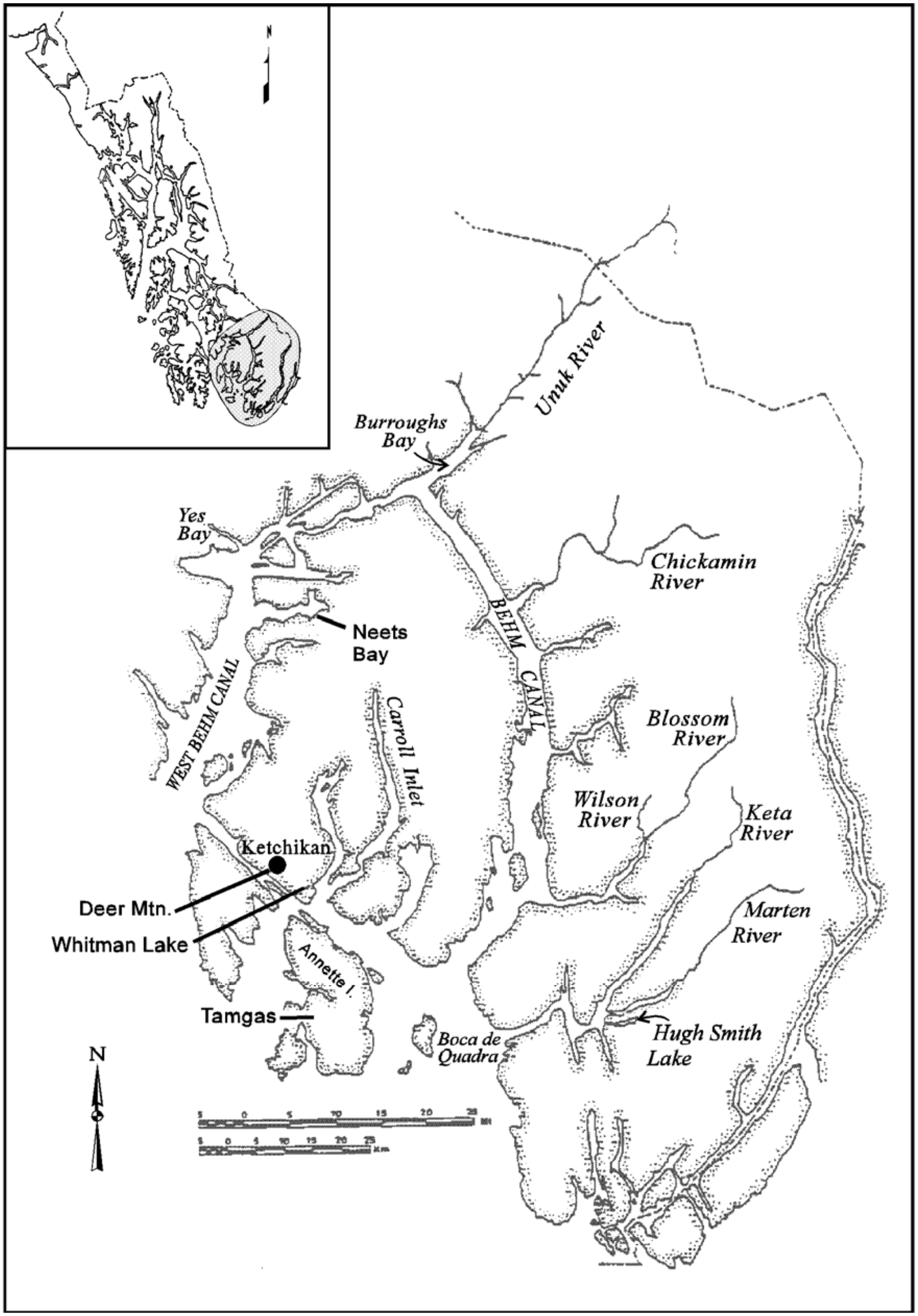

Figure 1.–Behm Canal area in Southeast Alaska and location of selected Chinook salmon systems and hatcheries.

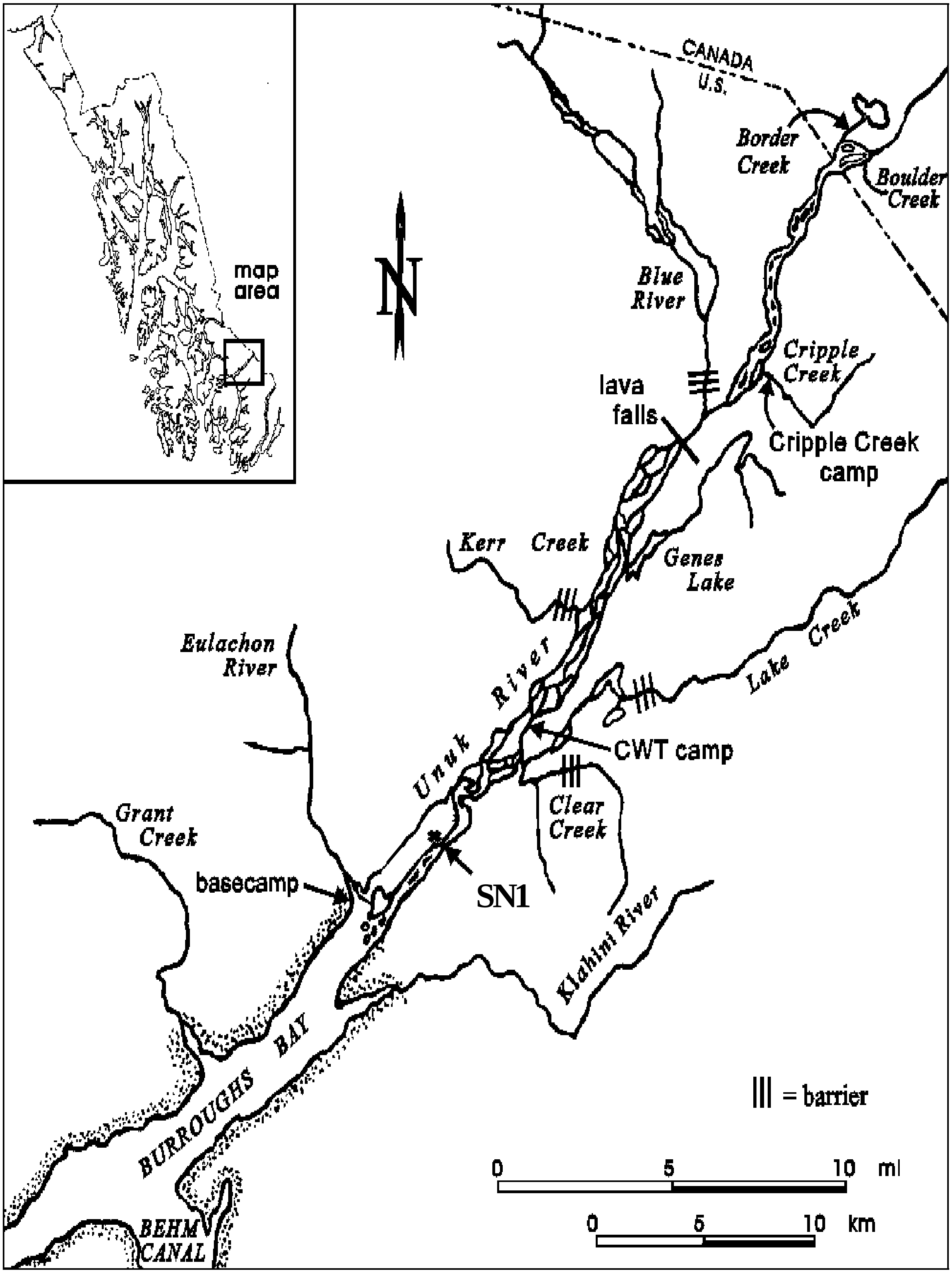

Figure 2.–Unuk River area in Southeast Alaska, showing major tributaries, barriers to Chinook salmon migration, and location of ADF&G research sites.

Mark-recapture and radio telemetry studies were conducted in 1994 (Pahlke et al. 1996). Mark-recapture studies have also been conducted annually from 1997 through 2004 (Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002; Weller and McPherson 2003a-b, 2004, 2006). The radio telemetry study indicated that 83% (SE = 9%) of all spawning occurred in the six tributaries surveyed. The 1997–2004 mark-recapture experiments estimated that an average of 5,408 large Chinook salmon entered the river during those years and ranged from 2,970 (1997) to 10,541 (2001). Indices during those years averaged 1,072 large Chinook salmon, or 20.6% of the mark-recapture estimates, and ranged from 636 (1997) to 2,019 (2001). The highest recorded index of 2,126 large fish occurred in 1986 (Pahlke 1997b). From 1977 to 2004, average peak survey counts in the six index tributaries of the Unuk River were distributed as follows: Cripple Creek (412 fish, 37%), Gene's Lake Creek (363 fish, 33%), Eulachon River (162 fish, 15%), Clear Creek (103 fish, 9%), Kerr Creek (40 fish, 4%), and Lake Creek (32 fish, 3%). Cripple Creek and Gene's Lake Creek are not surveyed from the air because of heavy canopy cover; surveys of these areas are made on foot. All other index areas are surveyed by helicopter or on foot (Pahlke *In prep.*).

Other studies on the Unuk River were based on coded wire tags (CWTs) inserted into Chinook salmon juveniles from the 1982–1986 brood years (Pahlke 1995). This research showed that commercial and sport harvest rates on the Unuk River Chinook salmon stock (age-1.1–1.5) ranged from 14% to 24%; however, the precision of the harvest estimates was low, as was confidence in the expansion factor used to estimate escapements (McPherson and Carlile 1997; Pahlke 1995).

Starting in 1993, young-of-the-year (YOY) fingerlings were tagged with CWTs (Appendix A1). From 1993 through 2005, 452,920 Chinook (fall) fingerlings have been tagged, at an annual average of 34,840 and a range of 13,789 (1993) to 61,905 (1997). Tagging of smolt commenced in spring 1994, and 127,591 smolt have been tagged through 2005 at an annual average of 10,633 and a range of 2,642 (1994) to 17,121 (1998).

The current stock assessment program for adult escapement of Chinook salmon to the Unuk River has three primary objectives: (1) to estimate escapement; (2) to estimate age, sex, and length distribution in the escapement; and (3) to estimate the fraction of fish possessing CWTs by brood year. Meeting this last objective is essential to estimating harvest of this stock in current and future sport and commercial fisheries. Together harvest and escapement data will enable us to estimate run size, exploitation rates, harvest distribution, and return rates for this stock.

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 Chinook salmon in Southeast Alaska.

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 2005. Fish were captured 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.

EVENT 1: SAMPLING IN THE LOWER RIVER

Adult Chinook salmon were captured using set gillnets at the SN1 site (Figure 2) as they immigrated into the lower Unuk River between 10 June and 2 August 2005. The set gillnets were 37 m (120 ft) long by 4 m (14 ft) deep with 18 cm (7¼ in.) stretch mesh and a loose hanging ratio of about 2.2:1. The SN1 site has been used exclusively for set gillnet fishing since 1997. This site is located approximately 2 miles upstream of saltwater on the south channel, mainstem of the lower Unuk River well below all known spawning areas except the Eulachon River (Figure 3).

Two back-to-back shifts of personnel fished two set gillnets at SN1 12 hours per day, 6 days per week. Crew shifts were staggered during the week so that at least one shift fished each day of the week whenever possible. 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 m downstream of a small island. Another net was attached to the same fixed buoy and trailed downstream along the eddy line formed between the mainstem and the side slough (Figure 4). Fish captured in the set gillnet were immediately and carefully untangled or cut loose and placed in a live tank aboard the set gillnet skiff.

All fish captured, regardless of health, were sampled to estimate the age, sex, and length (ASL) composition of the escapement. Length in MEF was measured to the nearest 5 mm, and sex was determined from external, dimorphic characteristics. Five scales were taken about 1″ apart within the preferred area on the left side of each 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 (*Unpublished*). 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 and <700 mm MEF (jacks) were sacrificed, and their heads were sent to the ADF&G Commercial Fishery Division's Mark Tag and Age Laboratory (Tag Lab) for detection and decoding of CWTs.

With the exception of fish <700 mm MEF that were missing an adipose fin, all captured fish judged healthy were marked with a uniquely numbered solid-core spaghetti tag sewn through the back, a clip of the left axillary appendage (LAA), and a left upper operculum punch (LUOP) 0.63 cm (¼″) in diameter. The axillary clip and operculum punch enabled detection of 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 Boundary Lake Creek (also known as Border Creek); on Clear, Cripple, Gene's Lake, Kerr, and Lake creeks; and on the Eulachon River in 2005 (Figure 2). Various methods were used to capture fish including rod and reel, spears, dip nets, gillnets, and carcass surveys. Use of a variety of gear types has been shown to produce unbiased estimates of age, sex, and length composition (Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002; McPherson et al. 1997). A hole was punched into the left lower operculum (LLOP) of all newly inspected fish to prevent double sampling. Inspected fish were closely examined for a tag, an LUOP, an LLOP, an LAA, a missing adipose fin, and were sampled to obtain ASL data by the same techniques used in the lower river. For Chinook salmon missing adipose fins, all fish <700 mm MEF as well as spawned-out fish of all sizes were sacrificed to retrieve CWTs. Heads so collected were sent to the Tag Lab for dissection and decoding of tags. Foot surveys were also conducted on each of the sampled tributaries on at least one occasion. Multiple surveys were spaced approximately one week apart and when possible, a survey was conducted on the historical peak of observed abundance.

ABUNDANCE BY SIZE

Abundance of medium (401-659 mm MEF) and large (≥ 660 mm MEF) fish was estimated separately so that the estimate for large fish $\hat{N}_L$ could be compared to the index. Using Chapman's modification of the Petersen estimator (Seber 1982), estimated abundance $\left(\hat{N}_i\right)$ for each group was calculated as:

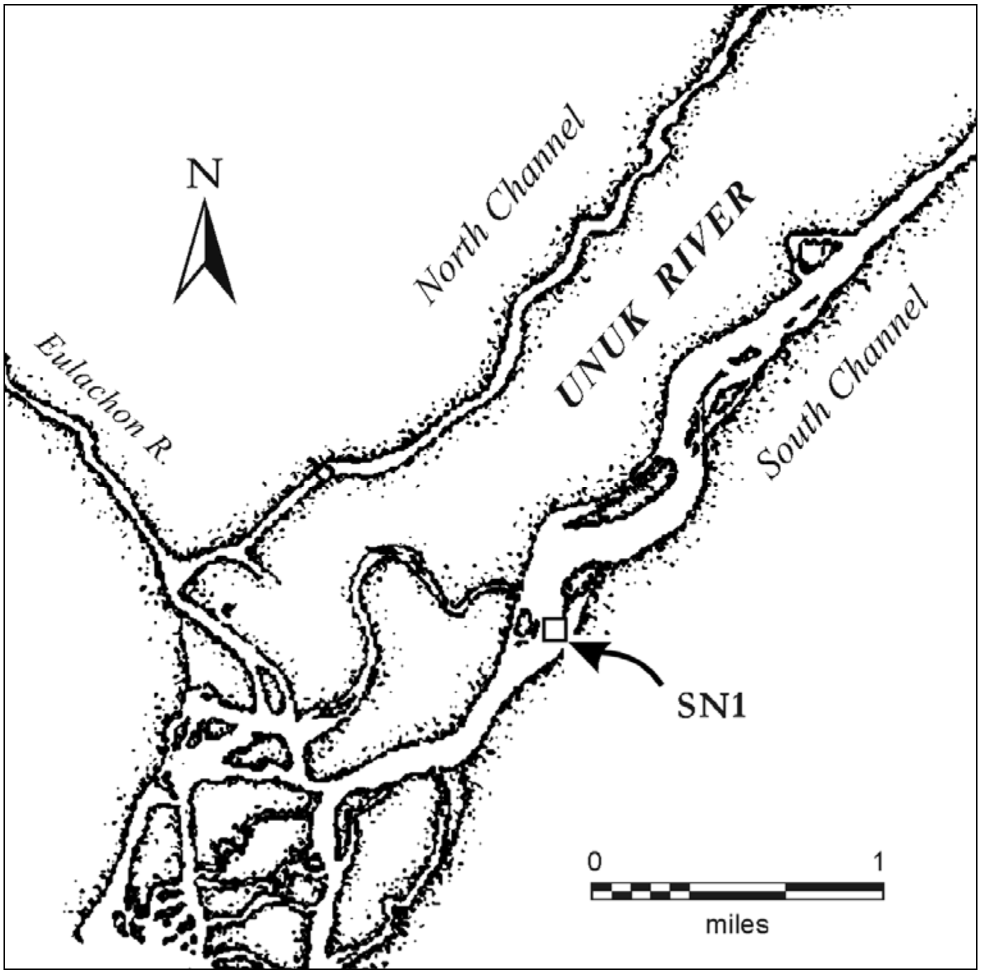

Figure 3.–Location of the set gillnet site (SN1) on the lower Unuk River in 2005.

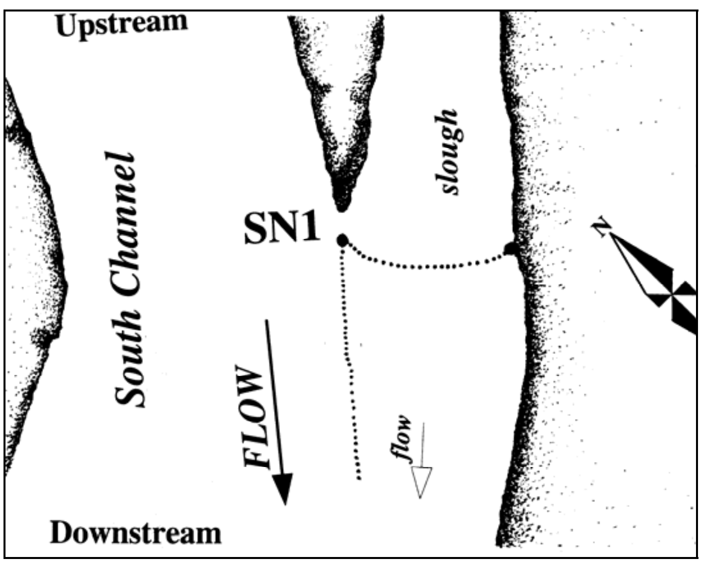

Figure 4.–Detailed drawing of the net placement used at the set gillnet site (SN1) on the lower Unuk River in 2005.

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

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 conditions that must hold for $\hat{N}_i$ to be a consistent estimate of abundance are in Seber (1982) and may be cast as follows:

(a) Every fish had an equal probability of being marked in event 1, or every fish had an equal probability of being inspected for marks in event 2, or marked fish mixed completely with unmarked fish in the population between events; and

(b) There is no mark-induced mortality; and

(c) Fish did not lose their marks in the time between events and all marks are recognizable; and

(d) There is no recruitment to the population between events.

To provide evidence that condition *a* was met, two chi-square tests were performed with the following null hypotheses: (1) for equal proportions of marked fish in samples across areas sampled in event 2; and (2) for equal probabilities of recapture in event 2 relative to when fish had been marked. If the null hypothesis of either test was not rejected, the pooled Petersen model (equation 1) was considered a consistent estimator; otherwise a temporally or spatially stratified estimator was employed. Tests were made separately using the SPAS software program (Arnason et al. 1996).

Because condition *a* is relevant to other attributes of salmon besides when and where they are captured, the possibility of size- and gender-selective sampling was also investigated. The hypothesis that fish of different sizes were captured with equal probability was tested using two Kolmogorov-Smirnov (K-S) 2-sample tests ($\alpha = 0.1$) to compare size distributions of marked, captured, and recaptured fish (Appendix A2). Evidence for gender-selective sampling was sought using a simple 2x2 chi-square test. The test examined probability of capture in the second event by looking at the recapture rate of tagged males versus that of tagged females; the rows in this test were male/female and the columns were recaptured/not recaptured.

We were not able to investigate condition *b*; however, we were careful to not harm or stress fish, and we did not mark obviously injured fish. Radiotelemetry studies in 1994 and 1996 showed that Chinook salmon survive and spawn after having been captured in a manner identical to that used in this project (Pahlke et al. 1996; Pahlke 1997a). The effect of tag loss (condition *c*) is virtually eliminated by using the two secondary marks, and all fish captured during event 2 were inspected for marks. Double sampling of fish was avoided by marking all sampled fish during event 2 with a LLOP. Condition *d* was met because the life history of Chinook salmon isolates those fish returning to the Unuk River as a "closed" population, and sampling efforts at SN1 spanned the entire immigration.

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).

Table 1.–Capture histories for medium and large Chinook salmon in the population spawning in the Unuk River in 2005 (notation explained in text).

Capture history	Medium	Large	Source of Statistics
Marked and not captured in tributaries			$M_i - R_i$
Marked and captured in tributaries			R_i
Not marked, but captured in tributaries			$C_i - R_i$
Not marked and not captured in tributaries			$\hat{N}_i - M_i - C_i + R_i$
Effective population for simulations			$\hat{N}_i$

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 $\hat{N}_i^*$. A thousand 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:

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

where B is the number of bootstrap samples (1,000).Due to our failure to capture any small sized fish during event 1, the mark-recapture experiment could not be used to directly estimate the abundance of small Chinook salmon. Consequently the abundance of small sized fish was estimated indirectly by expanding the estimate for large and medium fish by the estimated size composition of the spawning escapement:

$$\hat{N}_S = \hat{N}_{LM}\left(\frac{1}{\hat{\phi}} - 1\right), \qquad (3)$$

where $\hat{N}_S$ is the estimated spawning escapement of small-sized fish, $\hat{N}_{LM}$ is the estimated spawning escapement of large plus medium fish, and $\hat{\phi}$ is the estimated fraction of large and medium sized fish in the spawning population Chinook salmon (McPherson et al. 1997).

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age within a size class was estimated as a binomial variable:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \qquad (4)$$

$$\text{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_i - 1} \qquad (5)$$

where $\hat{p}_{ij}$ is the estimated proportion of the population of age j in size 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) showedsampling 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 among 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:

$$\hat{N}_j = \sum_i(\hat{p}_{ij}\hat{N}_i) \qquad (6)$$

and

$$\text{var}(\hat{N}_j) = \sum_i\begin{pmatrix}\text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)\hat{p}_{ij}^2 \\ -\text{var}(\hat{p}_{ij})\,\text{var}(\hat{N}_i)\end{pmatrix} \qquad (7)$$

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

The proportion of the spawning population composed of a given age was estimated as the summed totals across size categories:

$$\hat{p}_j = \frac{\hat{N}_j}{\hat{N}} \qquad (8)$$

and

$$\text{var}(\hat{p}_j) = \frac{\sum_i(\text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)(\hat{p}_{ij} - \hat{p}_j)^2)}{\hat{N}^2} \qquad (9)$$

where $\hat{N}$ is the sum of fish of all sizes, and 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 ($\hat{\pi}$) for Unuk River Chinook salmon in a calendar year is

$$\hat{\pi}_i = \hat{N}_i / C_i \quad (10)$$

$$\text{var}(\hat{\pi}_i) = \text{var}(\hat{N}_i) / C_i^2 \quad (11)$$

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

The expansion factor for a year for which we have no mark-recapture experiment is anticipated as the mean of the $\hat{\pi}_i$ over the *k* years for which we have mark recapture experiments (eight for the Unuk River at present, from 1997 to 2005, omitting 2002):

$$\tilde{\pi} = \sum_{i=1}^{k} \hat{\pi}_i \;/\; k \quad (12)$$

The variance of this anticipated expansion factor is estimated by subtracting an estimate of the average measurement variance from the year to year variance over the *k* years for which we have mark-recapture experiments:

$$\text{var}(\tilde{\pi}) = \frac{\sum_{i=1}^{k}\left(\hat{\pi}_i - \bar{\pi}\right)^2}{(k-1)} - \frac{\sum_{i=1}^{k}\text{var}(\hat{\pi}_i)}{k} \quad (13)$$

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

$$\hat{N}_t = \tilde{\pi}\; C_t \quad (14)$$

$$\text{var}(\hat{N}_t) = C_t^2\; \text{var}(\tilde{\pi}) \quad (15)$$

MIGRATORY TIMING

The mean date of migration for Unuk River stock (Boundary Creek, Clear Creek, Cripple Creek, Gene's Lake Creek, Kerr Creek, Lake Creek or the Eulachon River) was calculated as:

$$\bar{d}_w = \frac{\sum_{i=1}^{n_w} d_{wi}}{n_w} \quad (16)$$

where n_w is the number of marked fish recovered at location *w* and d_{wi} is the day the i^{th} fish was marked at the SN1 gillnet site, with variance estimated as:

$$\text{var}(\bar{d}_w) = \frac{\sum_{i=1}^{n_w}(d_{wi} - \bar{d})^2}{(n_w - 1)n_w} \quad (17)$$

RESULTS

TAGGING, INRIVER RECOVERY AND SPAWNING ABUNDANCE

Between 10 June and 2 August, 723 Chinook salmon were sampled in the lower river, of which 714 (644 large and 70 medium) were marked and released (Table 2). Approximately 95% of the Chinook salmon marked during the first sampling event were captured between 22 June (statistical week 26) and 25 July (statistical week 31), a period of time also characterized by relatively constant fishing effort at the set gillnets (Figure 5). A total of 67 fish were missing adipose fins, of which 9 were sacrificed and 2 died prior to marking; the rest were marked and released in good condition. Of the 11 heads recovered during event 1, one had no CWT, one was lost, and the remaining nine had valid CWTs for this stock. Among the fish that were missing adipose fins and of those sacrificed, 60% and 89%, respectively, were males.

During event 2, 902 fish were inspected (20 small, 133 medium, and 749 large), of which 114 were

Table 2.–Numbers of Chinook salmon marked by size group in the lower Unuk River and inspected for marks on the spawning grounds of the Unuk River, 2005.

	Length (MEF)			
	0-400 mm	401-659 mm	>659 mm	Total
Released in event I with marks (*M*)	0	70	644	714
Inspected at:				
1. Upriver [a]				
Inspected (*C*)	5	50	355	410
Recaptured (*R*)	0	3	47	50
Recaptured/Captured		0.060	0.132	0.122
2. Downriver [b]				
Inspected (*C*)	15	83	394	492
Recaptured (*R*)	0	10	154	64
Recaptured/Captured		0.120	0.137	0.130
Total Inspected				
Inspected (*C*)	20	133	749	902
Recaptured (*R*)	0	13	101	114
Recaptured/Captured		0.098	0.135	0.126

[a] Includes Boundary and Cripple creeks.

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

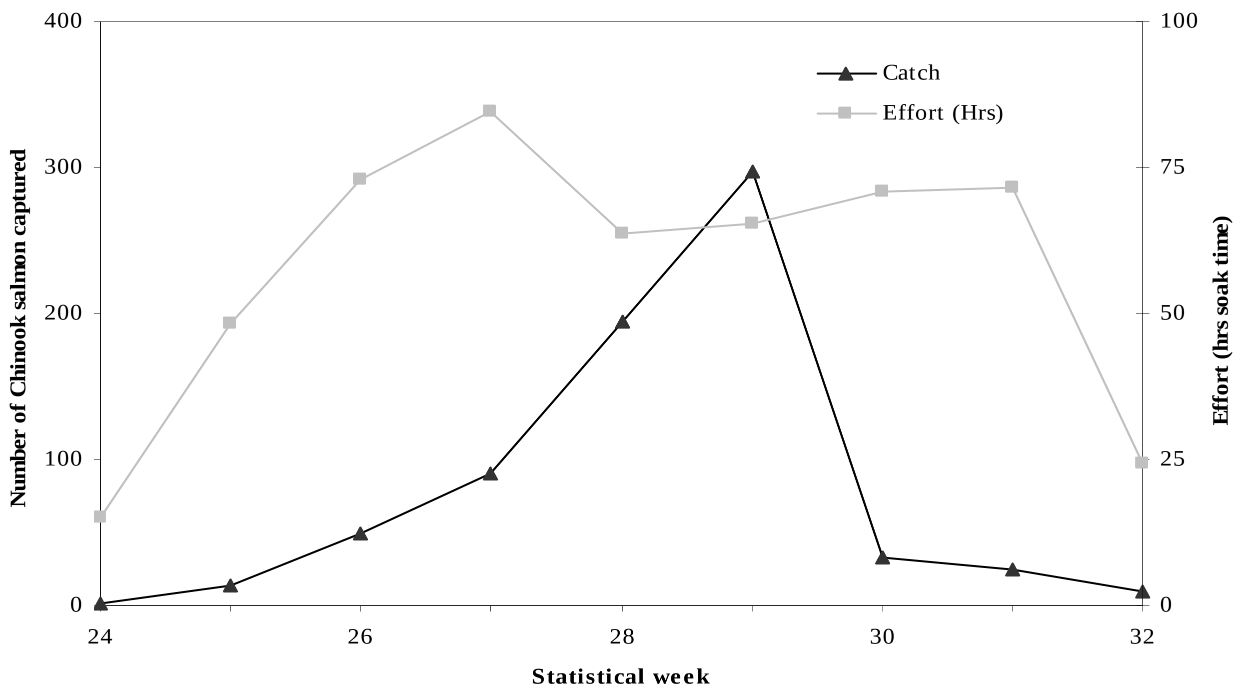

Figure 5.–Effort (in hours of soak time) and catch of Chinook salmon by statistical week at SN1 on the Unuk River, 2005.

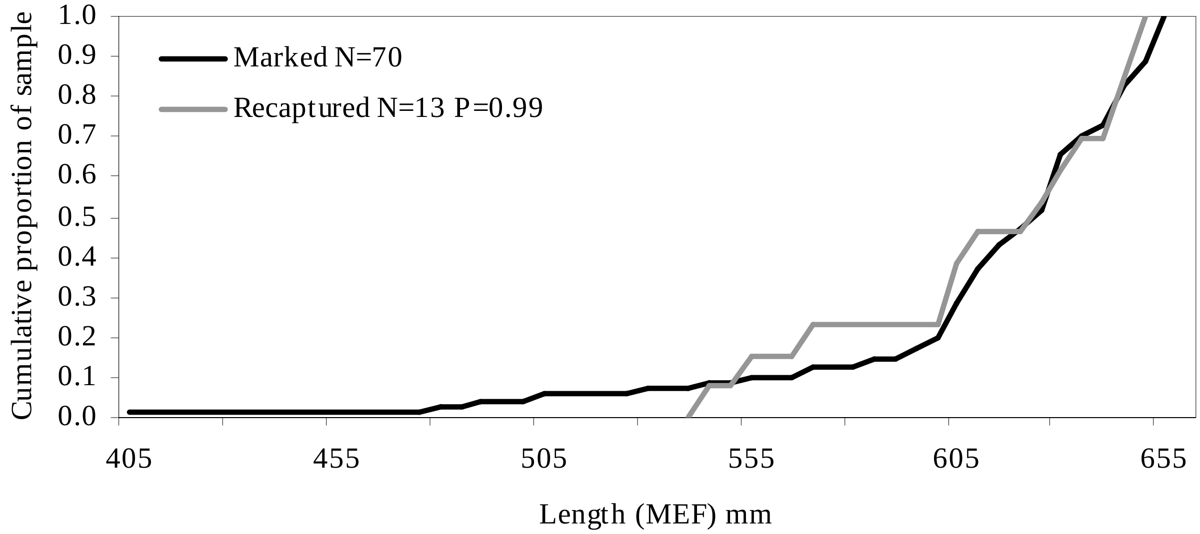

Figure 6.–Cumulative relative frequencies of medium Chinook salmon (401-659 mm MEF) marked in the lower Unuk River in 2005 compared with those recaptured on the spawning grounds.

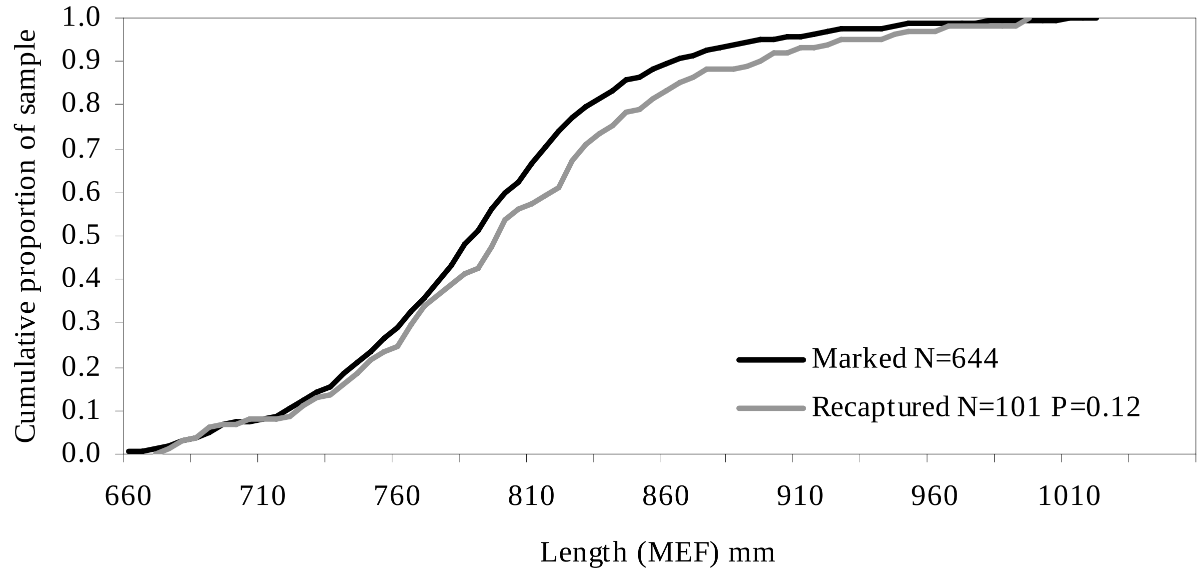

Figure 7.–Cumulative relative frequencies of large Chinook salmon (>659 mm MEF) marked in the lower Unuk River in 2005 compared with those recaptured on the spawning grounds.

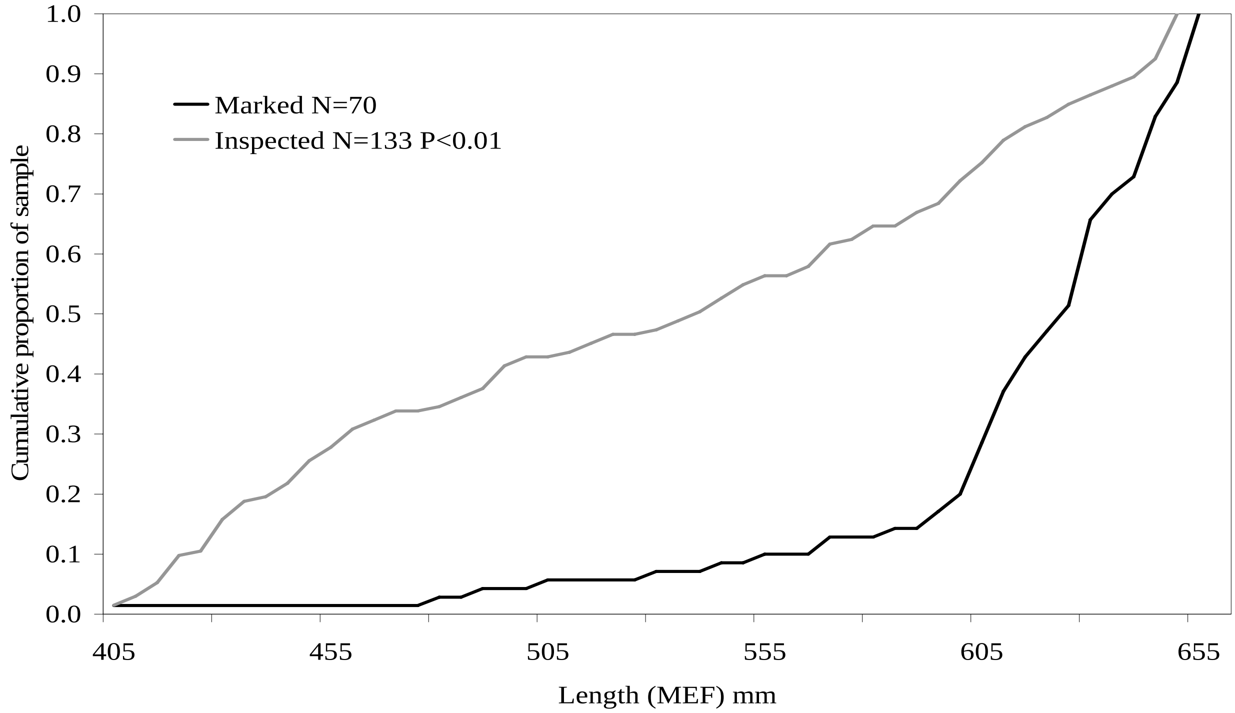

Figure 8.–Cumulative relative frequencies of medium Chinook salmon (401-659 mm MEF) marked in the lower Unuk River in 2005 compared with those inspected on the spawning grounds**.**

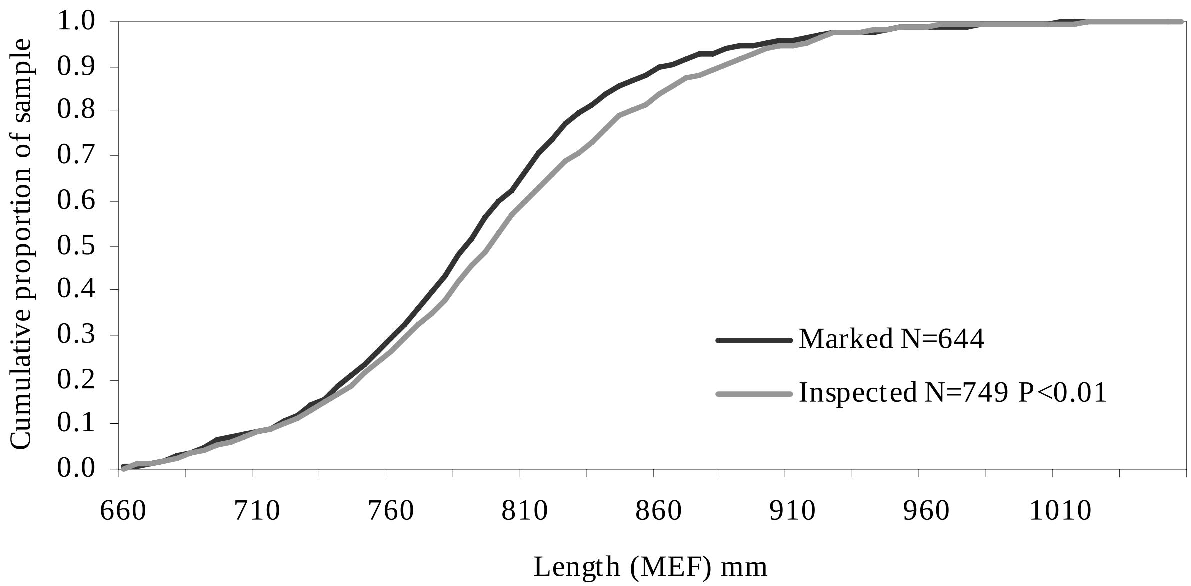

Figure 9.–Cumulative relative frequencies of large Chinook salmon (>659 mm MEF) marked in the lower Unuk River in 2005 compared with those inspected on the spawning grounds.

recaptured fish (13 medium and 101 large; Table 2). All recaptured fish had spaghetti tags. Adipose fins were missing on 95 fish sampled during event 2, and 36 of these were sacrificed. Of the 36 adipose clipped fish sacrificed, 28 carried a valid CWT for this stock.

Length distributions of medium and large fish that were marked and recaptured were not significantly different (P = 0.99, P = 0.12; Figures 6 and 7), but length distributions of marked and inspected fish were (P < 0.01, P < 0.01; Figures 8 and 9). Therefore, sampling was not size selective during event 2 and the mark-recapture data did not require length stratification (Appendix A2).

There was evidence of gender selectivity between sampling events for large fish (χ^2 = 15.68, df = 1, P < 0.01) but not medium fish (χ^2 = 1.91, df = 1, P = 0.17). However, the recapture rates were similar for large males and females during event 2 (χ^2 < 0.01, df = 1, P = 0.94), indicating that the selectivity occurred during event 1 and the mark-recapture data therefore did not require stratification by gender. Because gender (large fish) and size selectivity (medium and large) occurred during event 1, only fish sampled on the spawning grounds were used to estimate length and age compositions of the escapement.

Results from the diagnostic tests above indicated that the pooled estimator (equation 1) was appropriate for estimating abundance of both medium and large salmon. Samples from spawning grounds had near equal fractions of marked fish regardless of where samples were taken (χ^2 = 1.29, df = 1, P = 0.26 for medium fish and χ^2 = 0.35, df = 1, P = 0.85 for large fish; Table 2), and marked fish had a near equal chance of being recaptured regardless of when they were marked (χ^2 = 1.63, df = 1, P = 0.20 for medium fish and χ^2 = 1.13, df = 1, P = 0.29 for large fish; Table 3). Estimated abundance of medium fish is 679 (n_1 = 70; n_2 = 133; m_2 = 13; SE = 176). Statistical bias of the estimate is 3.4% and the 95% confidence interval for the estimated abundance is 450 to 1,149. Estimated abundance of large fish is 4,742 (n_1 = 644; n_2 = 749; m_2 = 101; SE = 396). Statistical bias of the estimate is 0.5% and the 95% confidence interval for the estimated abundance is 4,094 to 6,489 (Table 4). Estimated abundance of small fish is 123 (SE = 29).

ESTIMATES OF AGE AND SEX COMPOSITION

There was evidence of gender (large fish) and size selectivity during event 1; therefore only event 2 samples were used to estimate the age, sex, and length composition of the spawning population. In 2005, an estimated 68.7% of the spawning population of Chinook salmon was comprised of age-1.3 fish and 15.2% were age-1.4 (Appendix A3, Figure 10). Both estimates represent extreme values relative to estimates from the preceding 10 years. From 1995 to 2004, the percentage of age- 1.3 fish in the spawning population ranged from 20.0% (1995) to 61.6% (2003), averaging 41.8%. The percentage of age-1.4 fish in the spawning population ranged from 17.6% (2000) to 47.5% (1995) and averaged 29.6%.

Approximately 35% of the spawning population was female in 2005, in contrast to the previous 7-year average of 39% (Table 5, Appendix A3). There were an estimated 1,956 (SE = 184) spawning females in 2005 (Table 5).

Estimated average lengths by age and sex were similar between events 1 and 2 in 2005, although age-1.2 fish were generally larger in event 1 (Table 6). This result is consistent with the K-S test depicted in Figure 8.

PEAK SURVEY COUNTS AND THE EXPANSION FACTOR

The peak survey count of large Chinook salmon in the six index streams of the Unuk River was 929 fish in 2005 (Pahlke *In prep*; Appendix A4).

Table 3.–Number of marked large and medium Chinook salmon released in the lower Unuk River and recaptured, by marking period, and the number examined for marks at each recovery location, 2005.

			Recovery location		
Marking dates	Number marked	Estimated fraction recovered	Downriver[a]	Upriver[b]	Total
		Large Chinook salmon			
6/10 to 7/9	314	0.175	27	28	55
7/10 to 8/2	330	0.139	27	19	46
Total/Proportion	644	0.157	54	47	101
Number inspected			394	355	749
Fraction marked			0.137	0.132	0.135
		Medium Chinook salmon			
6/10 to 7/9	35	0.114	2	2	4
7/10 to 8/2	35	0.257	8	1	9
Total/Proportion	70	0.186	10	3	13
Number inspected			83	50	133
Fraction marked			0.120	0.060	0.098

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

[b] Includes Boundary and Cripple creeks.

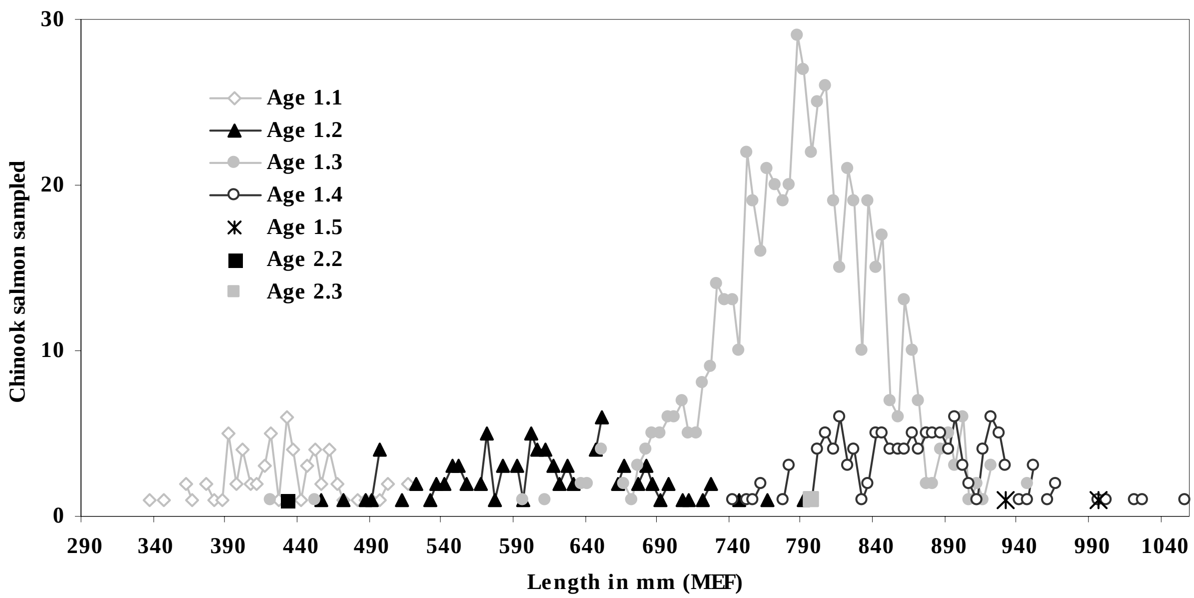

Figure 10.–Numbers of Chinook salmon sampled by age and length at all seven tributary spawning sites sampled on the Unuk River in 2005.

Table 4.–Peak survey counts, mark-recapture estimates of abundance, expansion factors, and other statistics for medium (401-659 mm MEF) and large (>659 mm MEF) Chinook salmon in the Unuk River (1997–2005).

	1997		**1998**		**1999**		**2000**		**2001**		**2002**		**2003**		**2004**		**2005**		**Average 1997-2005**	
	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Survey count (SC)		636		840		680		1,341		2,019		897		1,121		1,008		929		1,072
m2	16	78	15	79	13	50	8	69	3	74	9	66	2	114	30	105	13	101	12	82
n1	75	307	87	466	125	380	128	570	71	778	148	725	52	646	189	501	70	644	105	557
n2	156	761	217	707	251	523	158	719	74	1,014	109	644	124	985	344	836	133	749	174	771
Mark-recapture (M-R) estimate	701	2,970	1,198	4,132	2,267	3,914	2,278	5,872	769	10,541	1,638	6,988	698	5,546	2,114	3,963	679	4,742	1,371	5,408
SE (M-R)	158	277	290	413	602	490	675	644	124	1,181	690	805	80	433	339	325	176	396	348	552
SC/M-R (%)		21.4		20.3		17.4		22.8		19.2		12.8		20.2		25.4		19.6		20.6
CV (M-R) (%)	22.5	9.3	24.2	10.0	26.6	12.5	29.6	11.0	16.1	11.2	42.1	11.5	11.5	7.8	16.0	8.2	26.0	8.4	23.9	10.0
95% RP M-R estimate (%)	44.2	18.3	47.4	19.6	52.0	24.5	58.1	21.5	31.6	22.0	82.6	22.6	22.5	15.3	31.4	16.1	51.0	16.4	46.8	19.6
Expansion factor (EF) [a]		4.67		4.92		5.76		4.38		5.22		7.79		4.95		3.93		5.10		4.87
SE (EF) [a]		0.44		0.49		0.72		0.48		0.58		0.90		0.39		0.32		0.43		0.24
CV (EF) [a]		9		10		13		11		11		12		8		8		8		5
95% RP (EF) [a]		18		20		25		21		22		23		15		16		16		10
M-R lower 95% C.I.	489	2,499	815	3,433	1,506	3,110	1,358	4,848	557	8,705	1,017	5,775	557	4,814	1,602	3,406	450	4,094	689	4,327
M-R upper 95% C.I.	1,109	3,636	1,903	4,974	3,811	5,071	5,042	7,347	1,068	13,253	3,331	8,845	1,068	6,530	2,907	4,684	1,149	5,579	2,054	6,489
Estimated bias (%)	2.3	0.1	3.0	0.6	3.4	1.5	9.6	1.1	1.5	0.9	7.5	0.6	0.4	0.03	1.4	0.50	3.4	0.5	3.6	0.6

[a] Average expansion factor and associated statistics are for 1997–2001 and 2003–2005.

Table 5.–Estimated age and sex composition of the escapement of small (<401 mm MEF), medium (401-659 mm MEF), and large (>659 mm MEF) Chinook salmon in the Unuk River in 2005 as determined from spawning grounds samples.

		Brood year and age class							
		2002	2001	2000	2000	1999	1999	1998	
		1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON									
Males	Sample size	20							20
	p_{ijk} x100	100.0							100.0
	SE(p_{ijk}) x100								
	N_{ijk}	123							123
	SE(N_{ijk})	29							29
Females	Sample size								
	p_{ijk} x100								
	SE(p_{ijk}) x100								
	N_{ijk}								
	SE(N_{ijk})								
Sexes combined	Sample size	20							20
	p_{ij} x100	100.0							100.0
	SE(p_{ij}) x100								
	N_{ij}	123							123
	SE(N_{ij})	29							29
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON									
Males	Sample size	48	72	1	12				133
	p_{ijk} x100	36.1	54.1	0.8	9.0				100.0
	SE(p_{ijk}) x100	4.2	4.3	0.7	2.5				
	N_{ijk}	245	367	5	61				679
	SE(N_{ijk})	69	100	5	23				176
Females	Sample size								
	p_{ijk} x100								
	SE(p_{ijk}) x100								
	N_{ijk}								
	SE(N_{ijk})								
Sexes combined	Sample size	48	72	1	12				133
	p_{ij} x100	36.1	54.1	0.8	9.0				100.0
	SE(p_{ij}) x100	4.2	4.3	0.7	2.5				
	N_{ij}	245	367	5	61				679
	SE(N_{ij})	69	100	5	23				176
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON									
Males	Sample size		22		378		39	1	440
	p_{ijk} x100		2.9		50.5		5.2	0.1	58.7
	SE(p_{ijk}) x100		0.6		1.8		0.8	0.1	1.8
	N_{ijk}		139		2,393		247	6	2,785
	SE(N_{ijk})		31		218		44	6	248
Females	Sample size		1		213	1	93	1	309
	p_{ijk} x100		0.1		28.4	0.1	12.4	0.1	41.3
	SE(p_{ijk}) x100		0.1		1.6	0.1	1.2	0.1	1.8
	N_{ijk}		6		1,348	6	589	6	1,956
	SE(N_{ijk})		6		137	6	75	6	184
Sexes combined	Sample size		23		591	1	132	2	749
	p_{ij} x100		3.1		78.9	0.1	17.6	0.3	100.0
	SE(p_{ij}) x100		0.6		1.5	0.1	1.4	0.2	0.0
	N_{ij}		146		3,741	6	836	13	4,742
	SE(N_{ij})		32		321	6	96	9	396

-continued-

Table 5.–Page 2 of 2.

		Brood year and age class							
		2002	2001	2000	2000	1999	1999	1998	
		1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM AND LARGE CHINOOK SALMON									
Males	Sample size	68	94	1	390		39	1	593
	p_{ik} x100	6.6	9.1	0.1	44.3		4.5	0.1	64.7
	SE(p_{ik}) x100	1.3	1.7	0.1	2.0		0.7	0.1	2.0
	N_{jk}	368	507	5	2,454		247	6	3,587
	SE(N_{jk})	75	104	5	219		44	6	306
Females	Sample size		1		213	1	93	1	309
	p_{ik} x100		0.1		24.3	0.1	10.6	0.1	35.3
	SE(p_{ik}) x100		0.1		1.6	0.1	1.1	0.1	2.0
	N_{jk}		6		1,348	6	589	6	1,956
	SE(N_{jk})		6		137	6	75	6	184
Sexes combined	Sample size	68	95	1	603	1	132	2	902
	p_j x100	6.6	9.2	0.1	68.6	0.1	15.1	0.2	100.0
	SE(p_j) x100	1.3	1.7	0.1	2.4	0.1	1.3	0.2	
	N_j	368	513	5	3,803	6	836	13	5,543
	SE(N_j)	75	105	5	321	6	96	9	435

Table 6.–Estimated average length (MEF in mm) by age, sex, and sampling event of Chinook salmon sampled in the Unuk River in 2005.

		Brood year and age class							
		2002	2001	2000	2000	1999	1999	1998	
		1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL A: EVENT 1, LOWER UNUK RIVER SET GILLNET									
Males	Sample size	2	87		265	1	24	3	382
	Avg. length	443	632		775	805	876	965	749
	SD	53	45		59		65	26	93
	SE	38	5		4		13	15	5
Females	Sample size		2		284	2	42	1	331
	Avg. length		685		796	845	849	1,010	803
	SD		35		42	21	44		48
	SE		25		2	15	7		3
Sexes combined	Sample size	2	89		549	3	66	4	713
	Avg. length	443	634		786	832	859	976	774
	SD	53	45		52	28	54	31	80
	SE	38	5		2	16	7	16	3
PANEL B: EVENT 2, SPAWNING GROUNDS									
Males	Sample size	63	93	1	385		39	1	582
	Avg. length	430	607	430	776		891	995	719
	SD	39	67		63		71		139
	SE	5	7		3		11		6
Females	Sample size		1		209	1	91	1	303
	Avg. length		765		806	795	858	930	822
	SD				43		49		51
	SE				3		5		3
Sexes combined	Sample size	63	94	1	594	1	130	2	885
	Avg. length	430	608	430	786	795	868	963	754
	SD	39	69		59		59	46	127
	SE	5	7		2		5	33	4

Cripple and Gene's Lake creeks accounted for 70% of these fish, identical to the average from 1977 to 2004 (Weller and McPherson 2006).

Of the estimated 4,742 large Chinook salmon immigrating to the Unuk River in 2005, 19.6% were counted during peak survey counts. This percentage is similar to that of previous years, which ranged from 15% in 1994 to 23% in 2000 (Table 4; Pahlke et al. 1996). Using the 1997–2001 and 2003–2005 mark recapture estimates and peak survey counts, the mean expansion factor is 4.87 (SD = 0.24, Table 4). The expansion factor for 2002 is not included because the survey counts were relatively poor compared to other years (Weller and McPherson 2003b).

MIGRATORY TIMING

Migration past SN1 in 2005 was similar to migration in other years. The mean date of migration past SN1 was estimated to be 8 July for those Chinook salmon marked at the set net site and subsequently recovered on the spawning grounds and for all fish marked at SN1 (Appendix A5). This compares to an average date of 11 July from 1997 through 2004. The earliest estimated mean migration dates were for fish destined for Lake Creek (3 July) and Cripple Creek (6 July).

The latest mean migration date was 11 July for the Gene's Lake Creek stock.

DISCUSSION

In previous years of study, Chinook salmon tagged and released during event 1 have shown a "sulking" behavior or a delay in upstream migration (Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002; Pahlke et al. 1996; Weller and McPherson 2003a-b). In 2005, 36 fish were marked, released, and subsequently recaptured in event 1. One fish was recaptured twice. For these fish, the average time between release and recapture (i.e., an estimate of the "sulk" rate) was approximately 3 days and 11 hours, with a maximum period of over 17 days and a minimum of 2 minutes (Table 7). This phenomenon has been observed in other studies (Bendock and Alexandersdottir 1993; Johnson et al. 1992, 1993; Milligan et al. 1984) and has been shown to be a benign result of handling-induced behavior (Bernard et al. 1999).

The average rate of primary tag loss from 1997 to 2004 was approximately 7.5%, with a range of 0.1% observed in 2004 to 15% in 2002. In 2005, each of the 135 fish recaptured in event 2 retained their primary tags. Tag retention was likely a result of samplers applying greater attention to the amount of pressure exerted with the crimping tool; too much pressure can burn the monofilament leader and decrease its strength, not enough pressure on the crimping tool results in an inadequate crimp. In all cases, secondary marks were clearly visible on recaptured fish once fish were in hand.

The validity of the abundance estimate rests in part upon the degree to which the second sampling event was devoid of size-selectivity. Size-selective sampling occurred during the spawning grounds surveys prior to 1995, primarily as a result of an over reliance upon sampling carcasses and small sample size (Pahlke et al. 1996). Beginning in 1995, sample sizes were increased and diverse techniques were used to obtain spawning grounds samples to reduce bias in age, gender, and length composition estimates (Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002; Weller and McPherson 2003a-b, 2004; 2006; Appendix A6). The approach apparently worked because there has been no indication of size-selective sampling on the spawning grounds since 1997.

Partial counts of large Chinook salmon have been conducted on the Unuk River since 1977. Using the expansion factor of 4.87 to estimate annual spawning abundance prior to 1997, the estimated abundance of large Chinook salmon on the Unuk River has averaged 5,519 from 1979 to 2004 with a range of 2,870 in 1979 to 10,592 in 1986 (Appendix A4). The 2005 abundance estimate of 4,742 large Chinook salmon represents a smaller than average spawning population.

CONCLUSIONS AND RECOMMENDATIONS

Because this project will be repeated in 2006, 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

Table 7.–Elapsed time between release and recapture of Chinook salmon in the lower Unuk River in 2005.

Spaghetti tag no.	Release date/time	Recapture date/time	Sulking period	Day	Hour	Min
9041	06/23/05 16:52	06/23/05 17:05	0 days, 0 hours, and 13 minutes	0	0	13
9043	06/24/05 16:20	07/01/05 06:52	6 days, 14 hours, and 32 minutes	6	14	32
9069	06/26/05 08:18	06/26/05 08:50	0 days, 0 hours, and 32 minutes	0	0	32
9073	06/26/05 12:32	07/08/05 07:44	11 days, 19 hours, and 12 minutes	11	19	12
9075	06/26/05 14:35	07/13/05 16:05	17 days, 1 hour, and 3 minutes	17	1	3
9095	06/27/05 18:00	07/10/05 14:19	12 days, 19 hours, and 41 minutes	12	19	41
9175	07/07/05 09:31	07/09/05 17:33	2 days, 8 hours, and 2 minutes	2	8	2
9185	07/07/05 15:08	07/07/05 15:10	0 days, 0 hours, and 2 minutes	0	0	2
9191	07/07/05 16:51	07/08/05 11:01	0 days, 18 hours, and 10 minutes	0	18	10
9204	07/08/05 06:01	07/09/05 14:09	1 day, 8 hours, and 8 minutes	1	8	8
9209	07/08/05 07:40	07/13/05 09:45	5 days, 2 hours, and 5 minutes	5	2	5
9226	07/08/05 13:35	07/08/05 15:06	0 days, 1 hour, and 31 minutes	0	1	31
9232	07/08/05 15:04	07/09/05 13:45	0 days, 22 hours, and 41 minutes	0	22	41
9233	07/08/05 15:07	07/12/05 14:00	3 days, 22 hours, and 53 minutes	3	22	53
9251	07/09/05 07:38	07/09/05 17:30	0 days, 9 hours, and 52 minutes	0	9	52
9264	07/09/05 09:00	07/10/05 16:09	1 day, 7 hours, and 9 minutes	1	7	9
9272	07/09/05 10:51	07/10/05 16:13	1 day, 5 hours, and 22 minutes	1	5	22
9329	07/09/05 17:56	07/10/05 17:32	0 days, 23 hours, and 36 minutes	0	23	36
9336	07/09/05 18:35	07/16/05 15:16	6 days, 20 hours, and 41 minutes	6	20	41
9383	07/10/05 08:23	07/12/05 16:00	2 days, 7 hours, and 37 minutes	2	7	37
9435	07/10/05 13:22	07/11/05 16:05	1 day, 2 hours, and 43 minutes	1	2	43
9454	07/10/05 14:52	07/13/05 16:04	3 days, 1 hour, and 12 minutes	3	1	12
9488	07/10/05 18:14	07/13/05 06:50	2 days, 12 hours, and 36 minutes	2	12	36
9502	07/10/05 19:55	07/11/05 15:30	0 days, 19 hours, and 35 minutes	0	19	35
9505	07/11/05 11:30	07/23/05 09:00	11 days, 21 hours, and 30 minutes	11	21	30
9510	07/11/05 12:19	07/11/05 12:59	0 days, 0 hours, and 40 minutes	0	0	40
9518	07/11/05 15:47	07/11/05 16:45	0 days, 0 hours, and 58 minutes	0	0	58
9519	07/11/05 16:00	07/11/05 16:13	0 days, 0 hours, and 13 minutes	0	0	13
9519	07/11/05 16:13	07/25/05 08:35	13 days, 16 hours, and 22 minutes	13	16	22
9523	07/12/05 06:35	07/12/05 06:55	0 days, 0 hours, and 20 minutes	0	0	20
9530	07/12/05 10:49	07/29/05 14:24	17 days, 3 hours, and 35 minutes	17	3	35
9539	07/12/05 13:40	07/12/05 15:15	0 days, 1 hour, and 35 minutes	0	1	35
9560	07/13/05 07:39	07/13/05 10:15	0 days, 2 hours, and 36 minutes	0	2	36
9567	07/13/05 08:25	07/13/05 13:05	0 days, 4 hours, and 40 minutes	0	4	40
9571	07/13/05 09:00	07/14/05 15:15	1 day, 6 hours, and 15 minutes	1	6	15
9573	07/13/05 09:15	07/13/05 14:02	0 days, 4 hours, and 47 minutes	0	4	47
9598	07/13/05 14:30	07/13/05 14:48	0 days, 0 hours, and 18 minutes	0	0	18

Average = 3 days, 11 hours, 3 minutes; maximum = 17 days, 3 hours, 35 minutes; minimum = 2 minutes.

because it has yielded adequate sample sizes in this and prior years. Knowledge of run timing gathered in prior years should be used as an indicator of peak spawning abundance and optimum sampling periods. 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. 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 gear types during spawning grounds sampling. We recommend continuing this practice in future years.

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APPENDIX A

Appendix A1.–Number of fingerlings and smolt captured and tagged with coded wire tags, 1992 brood year to present in the Unuk River.

Brood year	Year tagged	Fall/spring	Tag code	Dates tagged	Number tagged	Valid tagged
1992	1993	Fall	04-38-03	10/13–10/22/93	10,316	10,263
1992	1993	Fall	04-38-04	10/25/1993	441	433
1992	1993	Fall	04-38-05	10/16–10/21/93	3,202	3,093
1992	1994	Spring	04-42-06	5/05–5/23/94	2,653	2,642
1992 Brood year total					16,612	**16,431**
1993	1994	Fall	04-33-49	10/07–10/24/94	1,706	1,700
1993	1994	Fall	04-33-50	10/07–10/22/94	11,152	11,139
1993	1994	Fall	04-35-57	10/22–11/01/94	7,688	7,687
1993	1995	Spring	04-42-13	4/10–5/05/95	3,228	3,227
1993 Brood year total					23,774	**23,753**
1994	1995	Fall	04-35-56	10/07–10/10/95	11,540	11,476
1994	1995	Fall	04-35-58	10/11–10/16/65	11,654	11,645
1994	1995	Fall	04-35-59	10/17–10/24/95	10,825	10,825
1994	1995	Fall	04-42-31	10/25–10/26/95	6,324	6,260
1994	1996	Spring	04-42-07	4/13–4/23/96	6,143	6,099
1994	1996	Spring	04-42-08	4/23–4/27/96	1,362	1,357
1994 Brood year total					47,848	**47,662**
1995	1996	Fall	04-47-12	9/30–9/15/96	24,252	24,224
1995	1996	Fall	04-42-36	10/16–10/19/96	11,202	11,200
1995	1996	Fall	04-42-18	10/20–10/21/96	3,755	3,753
1995	1997	Spring	04-38-29	3/31–4/18/97	12,521	12,517
1995 Brood year total					51,730	**51,694**
1996	1997	Fall	04-47-13	10/04–10/11/97	24,309	24,176
1996	1997	Fall	04-47-14	10/06–10/11/97	22,996	22,583
1996	1997	Fall	04-47-15	10/11–10/20/97	15,401	15,146
1996	1998	Spring	04-46-46	3/29–4/05/98	11,193	11,134
1996	1998	Spring	04-43-39	4/08–4/13/98	5,991	5,987
1996 Brood year total					79,890	**79,026**
1997	1998	Fall	04-01-39	10/04–10/13/98	22,389	22,366
1997	1998	Fall	04-01-40	10/13–10/23/98	11,664	11,522
1997	1999	Spring	04-01-44	4/08–5/01/99	7,954	7,948
1997 Brood year total					42,007	**41,836**
1998	1999	Fall	04-01-42	10/04–10/17/99	16,677	16,661
1998	2000	Spring	04-02-56	4/01–4/27/00	11,127	11,124
1998	2000	Spring	04-02-57	4/29–5/04/00	2,209	2,209
1998 Brood year total					30,013	**29,994**
1999	2000	Fall	04-03-74	10/06–10/20/00	21,918	21,853
1999	2000	Fall	04-02-88	10/20–10/29/00	10,082	10,072
1999	2001	Spring	04-01-45	4/02–4/23/01	16,565	16,561
1999 Brood year total					48,565	**48,486**
2000	2001	Fall	04-02-92	9/29–10/05/01	10,967	10,950
2000	2001	Fall	04-04-57	10/05–10/09/01	11,252	11,231
2000	2001	Fall	04-04-58	10/09–10/14/01	11,259	11,201
2000	2001	Fall	04-04-60	10/14–10/23/01	11,007	10,990
2000	2002	Spring	04-05-38	4/04–4/24/02	10,908	10,904
2000	2002	Spring	04-05-39	4/25–4/26/02	1,093	1,067
2000 Brood year total					56,486	**56,343**

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Brood year	Year tagged	Fall/spring	Tag code	Dates tagged	Number tagged	Valid tagged
2001	2002	Fall	04-05-23	9/28-10/05/02	11,449	11,402
2001	2002	Fall	04-05-24	10/05-10/13/02	11,564	11,538
2001	2002	Fall	04-05-25	10/13-10/17/02	11,798	11,778
2001	2002	Fall	04-05-26	10/17-10/20/02	11,467	11,425
2001	2002	Fall	04-46-52	10/20-10/25/02	8,419	8,403
2001	2003	Spring	04-08-07	4/08-5/10/03	11,360	11,354
2001	2003	Spring	04-08-43	5/10/03	483	483
2001 Brood year total					66,540	**66,383**
2002	2003	Fall	04-08-42	9/29-10/10/03	23,416	23,255
2002	2003	Fall	04-08-10	10/10-10/14/03	11,609	11,464
2002	2003	Fall	04-04-61	10/14-10/18/03	9,792	9,779
2002	2004	Spring	04-09-75	3/29-4/10/04	11,678	11,666
2002	2004	Spring	04-09-76	4/10-4/17/04	2,732	2,730
2002 Brood year total					58,227	**58,894**
2003	2004	Fall	04-09-77	9/19-10/03/04	11,799	11,789
2003	2004	Fall	04-09-78	10/3-10/19/04	11,464	11,417
2003	2004	Fall	04-09-81	10/19-10/21/04	3,923	3,923
2003	2005	Spring	04-09-80	4/10-4/28/05	8,618	8,584
2003 Brood year total					35,804	**35,713**
2004	2005	Fall	04-11-55	9/24-10/18/05	23,328	23,328
2004	2005	Fall	04-11-56	10/18/05	941	941
2004 Brood year total					24,269	**24,269**

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.

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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.–Estimated annual escapement of Chinook salmon in the Unuk River by age class and gender, 1995–2005.

		Age class					
Year	Gender	1.1	1.2	1.3	1.4	1.5	Total
	Male		1,628	751	626		3,005
1995	%		32.5	15.0	12.5		60.0
Estimated	Female			250	1,753		2,003
escapement	%			5.0	35.0		40.0
	Total		1,628	1,002	2,379		5,009
	%		32.5	20.0	47.5		100.0
	Male	57	459	1,888	961	58	3,423
1996	%	0.9	7.5	31.0	15.8	1.0	56.3
Estimated	Female			1,173	1,359	129	2,661
escapement	%			19.3	22.3	2.1	43.7
	Total	57	459	3,061	2,320	187	6,084
	%	0.9	7.5	50.3	38.1	3.1	100.0
	Male	233	920	720	319	14	2,206
1997	%	6.0	23.8	18.6	8.3	0.4	57.1
Estimated	Female		5	519	1,089	46	1,658
escapement	%		0.1	13.4	28.2	1.2	42.9
	Total	233	925	1,240	1,408	59	3,864
	%	6.0	23.9	32.1	36.4	1.5	100.0
	Male	400	1,269	1,411	328	6	3,414
1998	%	7.3	23.0	25.6	6.0	0.1	62.0
Estimated	Female			1,184	879	29	2,092
escapement	%			21.5	16.0	0.5	38.0
	Total	400	1,269	2,595	1,207	35	5,506
	%	7.3	23.0	47.1	21.9	0.6	100.0
	Male	496	2,411	1,062	460	8	4,438
1999	%	7.7	37.4	16.5	7.1	0.1	68.9
Estimated	Female		25	855	1,120	8	2,008
escapement	%		0.4	13.3	17.4	0.1	31.1
	Total	496	2,436	1,918	1,581	16	6,447
	%	7.7	37.8	29.7	24.5	0.3	100.0
	Male	98	3,099	2,059	455	17	5,728
2000	%	1.2	37.6	25.0	5.5	0.2	69.6
Estimated	Female		41	1,439	992	33	2,506
escapement	%		0.5	17.5	12.1	0.4	30.4
	Total	98	3,140	3,499	1,447	50	8,234
	%	1.2	38.1	42.5	17.6	0.6	100.0
	Male	208	935	3,680	894	21	5,738
2001	%	1.8	8.2	32.2	7.8	0.2	50.2
Estimated	Female		10	3,243	2,443		5,697
escapement	%		0.1	28.4	21.4		49.8
	Total	208	946	6,923	3,337	21	11,435
	%	1.8	8.3	60.5	29.2	0.2	100.0

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Year	Gender	Age class 1.1	1.2	1.3	1.4	1.5	Total
	Male	23	2,437	1,675	1,146	22	5,303
2002	%	0.3	28.2	19.4	13.3	0.3	61.3
Estimated	Female		48	1,212	2,042	44	3,346
escapement	%		0.6	14.0	23.6	0.5	38.7
	Total	23	2,485	2,887	3,188	66	8,649
	%	0.3	28.7	33.4	36.9	0.8	100.0
	Male	349	580	2,140	447	11	3,528
2003	%	5.4	9.1	33.4	7.0	0.2	55.1
Estimated	Female		11	1,801	1,027	34	2,873
escapement	%		0.2	28.1	16.0	0.5	44.9
	Total	349	592	3,941	1,474	46	6,401
	%	5.4	9.2	61.6	23.0	0.7	100.0
	Male	184	2,909	912	523		4,528
2004	%	3.0	47.0	14.7	8.4		73.2
Estimated	Female		27	377	1,234	19	1,658
escapement	%		0.4	6.1	19.9	0.3	26.8
	Total	184	2,937	1,289	1,756	19	6,185
	%	3.0	47.5	20.8	28.4	0.3	100.0
	Male	368	507	2,460	247	6	3,588
2005	%	6.6	9.1	44.4	4.5	0.1	64.7
Estimated	Female		6	1,349	595	6	1,956
escapement	%		0.1	24.3	10.7	0.1	35.3
	Total	368	513	3,808	842	13	5,544
	%	6.6	9.3	68.7	15.2	0.2	100.0
	Male	205	1,665	1,630	616	16	4,131
1995–2004	%	3.0	24.5	24.0	9.1	0.2	60.9
Mean annual	Female		17	1,205	1,394	34	2,650
estimated	%		0.2	17.8	20.6	0.5	39.1
escapement	Total	205	1,681	2,835	2,010	50	6,781
	%	3.0	24.8	41.8	29.6	0.7	100.0

Appendix A4.–Estimated abundance of the spawning population of large (>659 mm MEF) Chinook salmon in the Unuk River, 1977–2005. The mean expansion factor is 4.87 (SD = 0.24). The expansion factor was calculated from m-r experiment and survey results, 1997–2001, and 2003–2005[a].

		Abundance estimated from expanded count		Abundance estimated from m–r experiment		Preferred abundance estimate	
Year	Peak count from surveys	$\hat{N}$	SE ($\hat{N}$)	$\hat{N}$	SE ($\hat{N}$)	$\hat{N}$	SE ($\hat{N}$)
1977	974	4,739	238			4,739	238
1978	1,106	5,382	271			5,382	271
1979	576	2,803	141			2,803	141
1980	1,016	4,944	249			4,944	249
1981	731	3,557	179			3,557	179
1982	1,351	6,574	331			6,574	331
1983	1,125	5,474	275			5,474	275
1984	1,837	8,939	450			8,939	450
1985	1,184	5,761	290			5,761	290
1986	2,126	10,345	520			10,345	520
1987	1,973	9,601	483			9,601	483
1988	1,746	8,496	427			8,496	427
1989	1,149	5,591	281			5,591	281
1990	591	2,876	145			2,876	145
1991	655	3,187	160			3,187	160
1992	874	4,253	214			4,253	214
1993	1,068	5,197	261			5,197	261
1994	711	3,460	174	4,623	1,266	3,460	174
1995	772	3,757	189			3,757	189
1996	1,167	5,679	286			5,679	286
1997	636	3,095		2,970	277	2,970	277
1998	840	4,087		4,132	413	4,132	413
1999	680	3,309		3,914	490	3,914	490
2000	1,341	6,525		5,872	644	5,872	644
2001	2,019	9,824		10,541	1,181	10,541	1,181
2002	897	4,365		6,988	805	6,988	805
2003	1,121	5,527		5,546	433	5,546	433
2004	1,008	4,905		3,963	325	3,963	325
2005	929	4,520		4,742	396	4,742	396

[a] 2002 is not included because of the poor quality of survey counts relative to other years.

Appendix A5.–Estimated mean date of migration of Chinook salmon stocks past SN1 on the Unuk River from 1997–2005 (Panel A), standard deviation (Panel B), and sample size (Panel C).

PANEL A: ESTIMATED MEAN DATE OF MIGRATION AT SN1									
		Tributary							
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Gene's Lake Creek	Cripple Creek	Boundary Creek	Tributaries combined
1997	7-Jul	12-Jul	6-Jul		7-Jul	6-Jul	9-Jul		8-Jul
1998	3-Jul	10-Jul	5-Jul	21-Jun	29-Jun	2-Jul	4-Jul	3-Jul	3-Jul
1999	12-Jul		11-Jul		14-Jul	11-Jul	13-Jul		12-Jul
2000	11-Jul	15-Jul	121Jul	10-Jul	14-Jul	13-Jul	15-Jul		13-Jul
2001	15-Jul	21-Jul	16-Jul	4-Jul	17-Jul	15-Jul	10-Jul	9-Jul	13-Jul
2002	15-Jul	19-Jul	11-Jul	22-Jul	20-Jul	17-Jul	17-Jul	26-Jul	17-Jul
2003	12-Jul	14-Jul	13-Jul	13-Jul	14-Jul	9-Jul	6-Jul	8-Jul	11-Jul
2004	9-Jul	18-Jul	8-Jul	10-Jul	9-Jul	7-Jul	9-Jul		9-Jul
2005	8-Jul	10-Jul	8-Jul	3-Jul	10-Jul	11-Jul	6-Jul	9-Jul	8-Jul
1997-2004 average[a]	11-Jul	16-Jul	10-Jul	9-Jul	12-Jul	10-Jul	11-Jul	12-Jul	11-Jul
PANEL B: STANDARD DEVIATION (in days)									
1997	0.36	3.59	1.54		1.28	1.36	0.73		0.59
1998	0.44	2.50	2.41		1.71	2.24	1.39		0.94
1999	0.43		1.56		4.01	1.92	1.67		1.02
2000	0.48		2.46	5.11	3.56	2.24	1.50		1.11
2001	0.38	3.84	3.46	6.81	0.33	1.67	1.65	6.67	1.15
2002	0.34	4.89	2.13	6.50	2.27	1.29	1.85	6.00	0.95
2003	0.39	5.50	2.10	2.70	1.70	1.28	2.90	7.37	0.87
2004	0.42	3.40	2.38	2.28	3.24	1.28	1.60		0.84
2005	0.32	0.79	1.11	5.07	3.45	0.98	1.02	0.49	0.61
PANEL C: NUMBER OF FISH MARKED AT SN1 AND RECAPTURED ON TRIBUTARIES									
1997	383	5	20		9	18	38		90
1998	550	2	21	1	13	18	37	1	93
1999	504		13		6	11	29		59
2000	697	1	15	7	6	19	18		66
2001	853	3	13	3	3	15	28	3	68
2002	873	5	5	2	5	25	22	2	66
2003	703	2	22	9	21	37	10	4	105
2004	690	9	17	10	13	53	27		129
2005	714	6	18	4	7	26	46	6	113

[a] For non-leap year.

Appendix A6.–Numbers by gender and age for Chinook salmon sampled on the Unuk River spawning grounds in 2005 by location (Panel A) and gear (Panel B), and by size group (Panel C), in the lower river gillnet samples. Results were not stratified by size class; for the age composition of the escapement, see Table 5.

			Brood year and age class							
			2002	2001	2000	2000	1999	1999	1998	
			1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL A: EVENT 2 SAMPLES BY LOCATION										
	Males	n		1		10		2		13
		%		3.3		33.3		6.7		43.3
Boundary Creek	Females	n				10		7		17
		%				33.3		23.3		56.7
	Total	n		1		20		9		30
		%		3.3		66.7		30.0		100.0
	Males	n	6	10		54		5	1	76
		%	5.1	8.5		46.2		4.3	0.9	65.0
Clear Creek	Females	n				30		11		41
		%				25.6		9.4		35.0
	Total	n	6	10		84		16	1	117
		%	5.1	8.5		71.8		13.7	0.9	100.0
	Males	n	18	36		177		17		248
		%	4.7	9.5		46.6		4.5		65.3
Cripple Creek	Females	n				92	1	39		132
		%				24.2	0.3	10.3		34.7
	Total	n	18	36		269	1	56		380
		%	4.7	9.5		70.8	0.3	14.7		100.0
	Males	n	1	3		17		1		22
		%	2.9	8.6		48.6		2.9		62.9
Eulachon River	Females	n				8		5		13
		%				22.9		14.3		37.1
	Total	n	1	3		25		6		35
		%	2.9	8.6		71.4		17.1		100.0
	Males	n	36	36	1	85		3		161
		%	16.1	16.1		37.9		1.3		71.9
Gene's Lake Creek	Females	n		1		46		15	1	63
		%		0.4		20.5		6.7	0.4	28.1
	Total	n	36	37		131		18	1	224
		%	16.1	16.5		58.5		8.0	0.4	100.0
	Males	n	2	2		29		7		40
		%	3.0	3.0		43.9		10.6		60.6
Kerr Creek	Females	n				13		13		26
		%				19.7		19.7		39.4
	Total	n	2	2		42		20		66
		%	3.0	3.0		63.6		30.3		100.0
	Males	n	5	6		18		4		33
		%	10.0	12.0		36.0		8.0		66.0
Lake Creek	Females	n				14		3		17
		%				28.0		6.0		34.0
	Total	n	5	6		32		7		50
		%	10.0	12.0		64.0		14.0		100.0

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			Brood year and age class							
			2002	2001	2000	2000	1999	1999	1998	
			1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL B: EVENT 2 SAMPLES BY GEAR										
Carcass	Males	n	4	2		6		1		13
		%	12.9	6.5		19.4		3.2		41.9
	Females	n				14		4		18
		%				45.2		12.9		58.1
	Total	n	4	2		20		5		31
		%	12.9	6.5		64.5		16.1		100.0
Dipnet	Males	n	3	4		16		5		28
		%	7.3	9.8		39.0		12.2		68.3
	Females	n				11		2		13
		%				26.8		4.9		31.7
	Total	n	3	4		27		7		41
		%	7.3	9.8		65.9		17.1		100.0
Rod and reel lure	Males	n	7	6		14		2		29
		%	14.3	12.2		28.6		4.1		59.2
	Females	n				16		4		20
		%				32.7		8.2		40.8
	Total	n	7	6		30		6		49
		%	14.3	12.2		61.2		12.2		100.0
Rod and reel snag	Males	n	49	78	1	327		29	1	485
		%	6.8	10.8	0.1	45.1		4.0	0.1	66.9
	Females	n		1		160	1	78		240
		%		0.1		22.1	0.1	10.8		33.1
	Total	n	49	79		487	1	107	1	725
		%	6.8	10.9		67.2	0.1	14.8	0.1	100.0
Gill net	Males	n	5	4		19		1		29
		%	10.9	8.7		41.3		2.2		63.0
	Females	n				12		4	1	17
		%				26.1		8.7	2.2	37.0
	Total	n	5	4		31		5	1	46
		%	10.9	8.7		67.4		10.9	2.2	100.0
Other/unknown	Males	n				8		1		9
		%				80.0		10.0		90.0
	Females	n						1		1
		%						10.0		
	Total	n				8		2		10
		%				80.0		20.0		100.0

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				Brood year and age class							
				2002	2001	2000	2000	1999	1999	1998	
				1.1	1.2	2.2	1.3	2.3	1.4	1.5	Total
PANEL C: EVENT 1-LOWER UNUK RIVER SET GILLNET SAMPLES											
		Males	n	2	67		4				73
			%	2.7	90.5		5.4				98.6
	Medium-sized	Females	n				1				1
			%				1.4				1.4
		Total	n	2	67		5				74
			%	2.7	90.5		6.8				100.0
		Males	n		22		263	1	25	3	314
			%		3.4		40.5	0.2	3.9	0.5	48.4
Event 1	Large-sized	Females	n		2		287	2	43	1	335
			%		0.3		44.2	0.3	6.6	0.2	51.6
		Total	n		24		550	3	68	4	649
			%		3.7		84.7	0.5	10.5	0.6	100.0
		Males	n	2	89		267	1	25	3	387
			%	0.3	12.3		36.9	0.1	3.5	0.4	53.5
	Medium- and large-sized	Females	n		2		288	2	43	1	336
			%		0.3		39.8	0.3	5.9	0.1	46.5
		Total	n	2	91		555	3	68	4	723
			%	0.3	12.6		76.8	0.4	9.4	0.6	100.0

Appendix A7.–Computer files used to estimate the spawning abundance of Chinook salmon in the Unuk River in 2005.

File name	Description
05unk41a.xls	Spreadsheet containing Tables 1 and 4– 7, Figures 5, 10 and 11, Appendices A1 and A7, bootstrap results, and chi-squared analyses.
05unuk41c.xls	Spreadsheet containing Tables 2 and 3.
Ks05unuk41.xls	Spreadsheet containing Figures 6 – 9.
U41migratory05.xls	Spreadsheet containing Appendix A5.
05Unuk41ASL.xls	Spreadsheet containing mark-recapture data.