Fishery Data Series No. 12-85

Production of Unuk River Chinook Salmon through 2009 from the 1992–2006 Broods

by

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and

David G. Evans

December 2012

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

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
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 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)

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 2009.

Abundance of large Chinook salmon (≥660 mm MEF) was estimated to be 3,157 (SE = 354) in 2009. The estimates were made from 287 marked and 56 recaptured fish out of 624 examined upstream. Using indirect methods, abundance of fish 555–659 mm MEF was estimated to be 1,346 (SE = 180) and the abundance of fish <555 mm MEF was estimated to be 238 (SE = 45).

As part of a stock assessment program that began in fall 1993 (1992 brood year), coded wire tags (CWTs) were implanted in juvenile Chinook salmon on the Unuk River each fall and spring from 2005 to 2009. Harvest, harvest distribution, incidental harvest mortality, and total fishing mortality were estimated for the 1992–2006 brood year returns through 2009. Estimates of spawning abundance derived from the inriver mark-recapture studies (1994 and 1997-2009), escapement age-sex-length data (1995–2009), and CWT study results were used to estimate total production, marine survival, and exploitation rates for the 1992–2006 broods, through 2009.

The adipose fins of CWT-tagged fish were also excised as the first event in a two-event mark recapture study to estimate smolt abundance for the 1992–2006 broods. Smolt abundance and CWT release and recovery information were used to estimate parr abundance and the overwinter survival rate of Chinook salmon parr from the 1992–2006 broods.

Key words: abundance, Chinook salmon, Unuk River, mark-recapture, spaghetti tag, axillary appendage, coded wire tags, harvest, harvest distribution, incidental mortality, fishing mortality, marine survival, exploitation rates, production, overwinter survival, parr, smolt

INTRODUCTION

The Unuk River is 1 of 11 index streams used to evaluate Chinook salmon *Oncorhynchus tshawytscha* escapements in Southeast Alaska (SEAK; Pahlke 1997). This system traverses the Misty Fjords National Monument and flows into Behm Canal, a narrow saltwater passage north and east of Ketchikan (Figure 1). The Unuk River is the largest Chinook salmon producer in Behm Canal. Peak single-day aerial and foot survey counts of “large” Chinook salmon ≥660 mm MEF have been used as an index of escapement for the Unuk River. From 1979 to 1989, the index is roughly dome shaped, with peak values occurring in 1984 (1,837 fish) and 1986 (2,126 fish; Pahlke 1997); the survey count averaged 1,347 during this period. From 1990 to 1999 the index values declined, averaging only 799 fish, or 59% of the previous 11-year period. Survey counts increased from 2000 to 2007, averaging 1,121 fish, with a peak count of 2,019 fish in 2001 (Weller and Evans 2012). Survey counts were incomplete in 2008 due to an extended period of high water during the peak of spawning.

Low Unuk River survey counts in the early 1990s coincided with similar declines in the three other Behm Canal indicator stocks, the Chickamin, Blossom, and Keta river stocks (Figure 1; Pahlke 1996), and prompted concern over the health of the Chinook salmon population in Behm Canal. In 1992, the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish began a research program on the Unuk River. Goals of the program were to estimate overwinter survival of parr, production and marine survival of smolts, escapement and harvest of adults, total production, exploitation rates, and ultimately to estimate a biological escapement goal (BEG) for this stock. These goals are being accomplished with inriver mark-recapture experiments on adult and juvenile Chinook salmon, and with marine catch sampling programs.

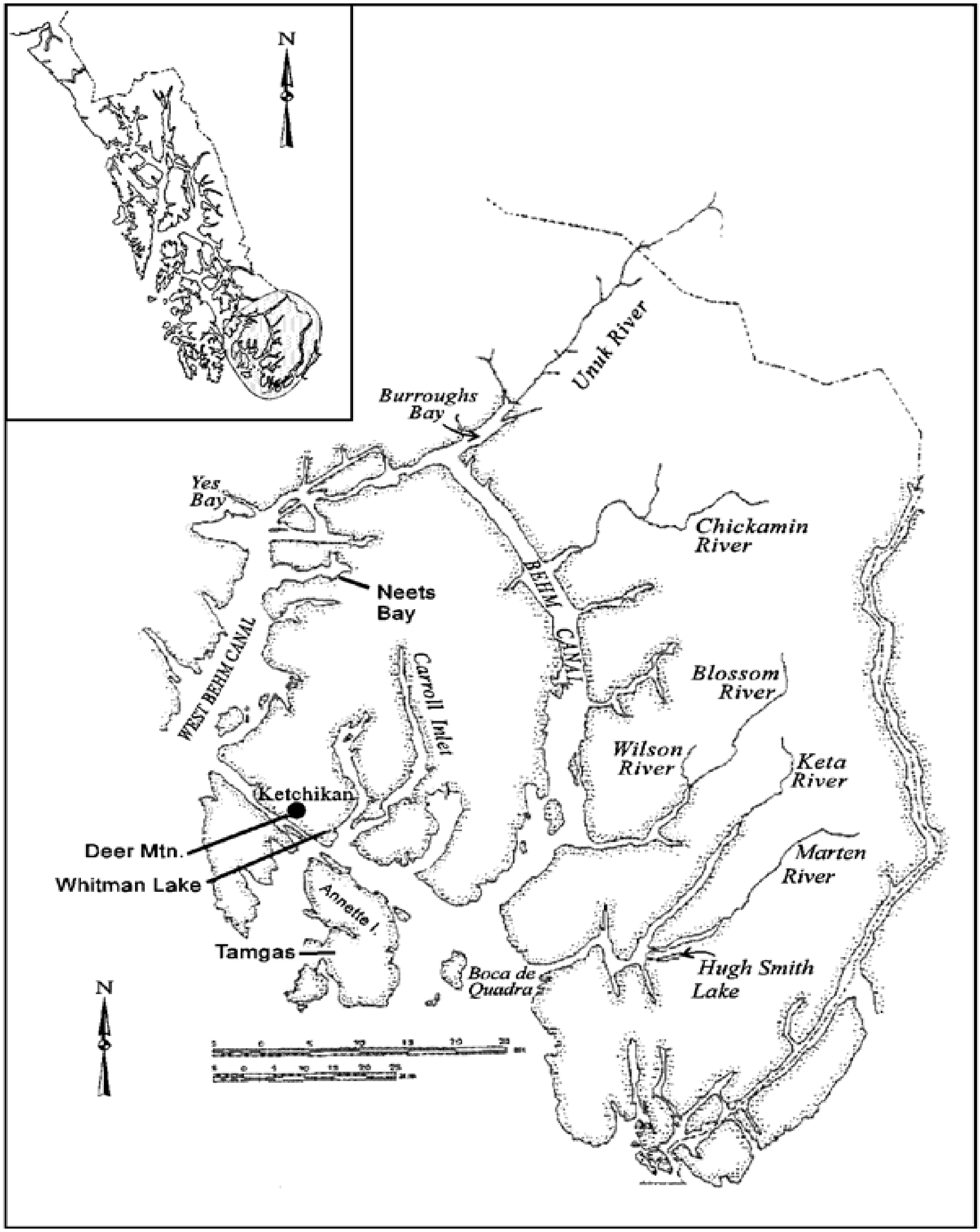

Figure 1.–Behm Canal area in Southeast Alaska and the location of selected Chinook salmon systems and hatcheries.

A biological escapement goal (BEG) for the Unuk River of 650–1,400 large fish counted in surveys, or an actual escapement of about 3,000–7,000 large fish, was established in 1997 (McPherson and Carlile 1997). Only large fish are counted in 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 3-ocean age (age-.3) or older. Nearly all females in the spawning population are classified as large. 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 (Figure 2; Pahlke 1997).

Mark-recapture (1994, 1997–2008) and radiotelemetry studies (1994) were conducted in the Unuk River to estimate abundance and spawning distribution (Pahlke et al. 1996; Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002; Weller and McPherson 2003a-b, 2004, 2006a-b; Weller and Evans 2009, 2012). The radiotelemetry study indicated that 83% (SE = 9%) of all spawning occurred in the six tributaries surveyed. The 1997–2007 mark-recapture experiments estimated that an average of 5,453 large Chinook salmon entered the river during those years and ranged from 2,970 (1997) to 10,541 (2001; Weller and Evans 2012). Indices during those years averaged 1,011 large Chinook salmon, or 18.5% 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 1997). From 1977 to 2007, average peak survey counts in the six index tributaries of the Unuk River were distributed as follows: Cripple Creek (399 fish, 37%), Gene's Lake Creek (364 fish, 33%), Eulachon River (155 fish, 14%), Clear Creek (105 fish, 10%), Kerr Creek (38 fish, 3%), 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 2010).

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 estimated 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 et al. 1996). Since 1993, young-of-the-year (YOY) parr were tagged with CWTs. From 1993 through 2009, 592,302 Chinook salmon (fall) parr were tagged, with an annual average of 34,841 and a range of 13,789 (1993) to 61,905 (1997; Hendrich et al. 2008; Weller and Evans 2012). Tagging of smolt commenced in spring 1994, and 164,646 smolt were tagged through 2009 with an annual average of 9,685 and a range of 2,642 (1994) to 17,121 (1998; Hendrich et al. 2008; Weller and Evans 2012).

Based on data collected through 2004, an adult-to-adult spawner-recruit model incorporating a marine survival parameter was used to revise the BEG range to 1,800–3,800 large spawners (Hendrich et al. 2008). In index equivalents this represents a peak survey count of between 375 and 800 large fish, significantly less than the previous BEG of 650–1,400 large fish counted in surveys (McPherson and Carlile 1997). The difference stem from the methods used to estimate the BEGs. The dataset used in the BEG estimate of Hendrich at al. (2008) included a longer time series relative to the BEG estimate of 1997, was able to incorporate improved estimates of the age composition of the spawning population, marine survival, incidental mortality, and harvest, and used an expansion factor based on seven years of mark-recapture data to estimate spawning abundance as opposed to the single year of mark-recapture data available in 1997.

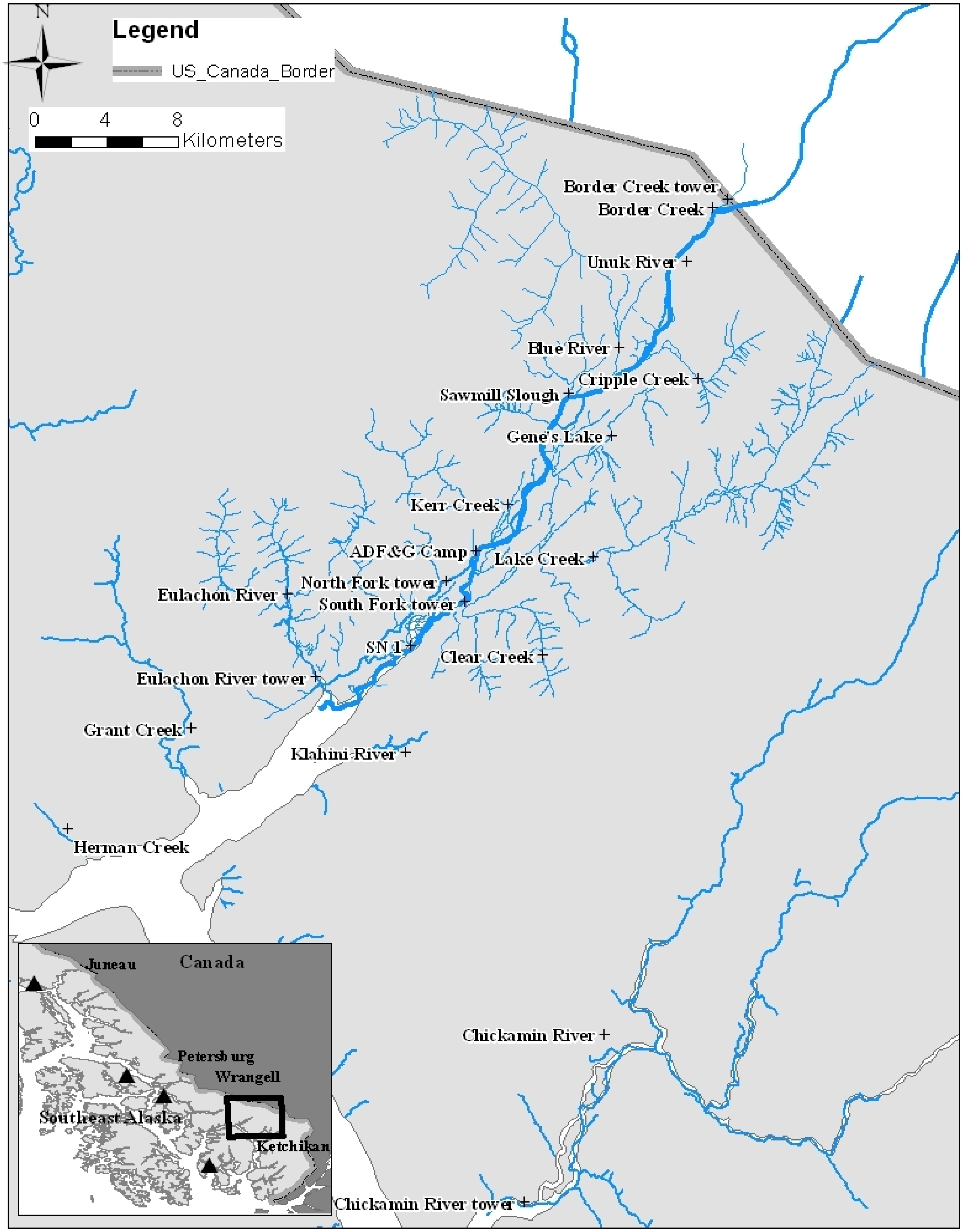

Figure 2.–Unuk River area in Southeast Alaska, showing major tributaries, the location of the U.S./Canada border, and the location of ADF&G research sites and telemetry towers. SN = setnet.

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 (ASL) distribution in the escapement; and (3) to estimate the fraction of fish possessing CWTs/adipose fin clips by brood year. Meeting this last objective is essential to estimating: a) harvest of this stock (CWTs) in current and future sport and commercial fisheries, and b) smolt abundance (adipose fin clips). Together, harvest and escapement data enables estimation of total production and exploitation rates, and the combination of production and smolt abundance allows for marine survival estimation.

OBJECTIVES

In 2009, the research objectives for this escapement project were to:

1. estimate the abundance of large (length ≥660 mm MEF) and medium (length 555–659 mm MEF) Chinook salmon in the Unuk River;
2. estimate the age and sex compositions of large and medium Chinook salmon in the Unuk River;
3. estimate the proportion of spawning Chinook salmon in each major spawning area within the Unuk River watershed comprising greater than 5% of the population; and
4. estimate the reciprocal of the fraction of each brood stock (1/θ) marked with a CWT.

Results of the CWT study from 2009 are also reported, as are revisions and updates to previously published results of the CWT project (Hendrich et al. 2008; Weller and Evans 2012).

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 SEAK.

METHODS

ADULT ABUNDANCE

Two-event mark-recapture experiments for closed populations were used to estimate the number of immigrant large Chinook salmon to the Unuk River in 2009. 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. We also planned to use mark-recapture techniques to estimate the abundance of medium fish, with the lower length limit defined as the smallest length of radio-tagged fish (i.e., 555 mm MEF); however abundance of fish in this length class was ultimately estimated using a combination of ASL data and the estimated abundance of large fish (see below) because off sample sizes.

Event 1: Sampling in the Lower River

Adult Chinook salmon were captured using set gillnets at the setnet (SN) 1 site (Figure 2) as they immigrated into the lower Unuk River between 13 June and 27 July during 2009. 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 for event 1 fish capture since 1997. This site is located approximately 3 km (2 mi) upstream of saltwater in the south channel of the mainstem of the lower Unuk River, below all known spawning areas except the Eulachon River (Figures 2 and 3).

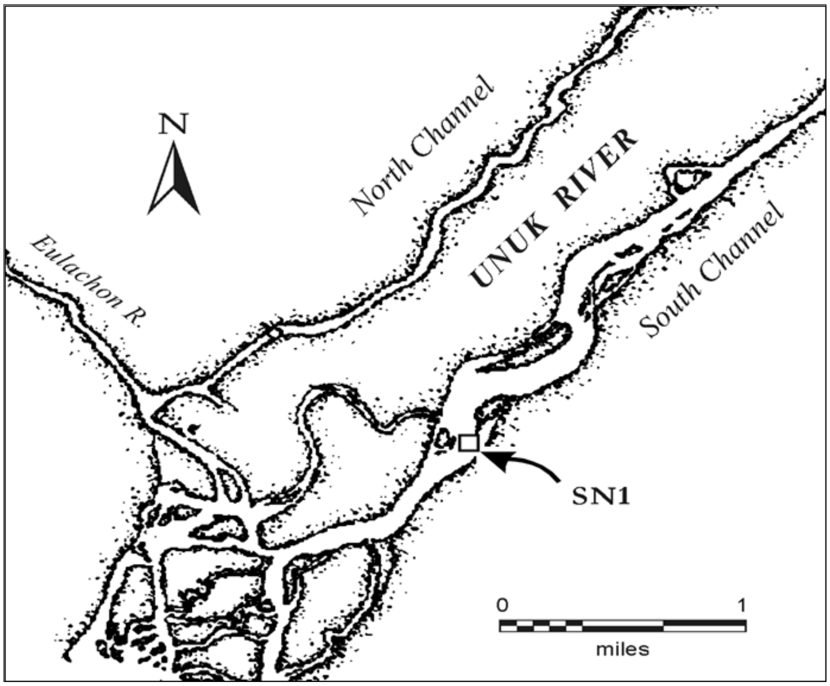

Figure 3.–Location of the set gillnet site (SN1) on the lower Unuk River in 2009. SN = setnet.

Back-to-back shifts fished two set gillnets at SN1 12 hours per day, six 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 for ASL data. Length was measured to the nearest 5 mm MEF, and sex was determined from external, dimorphic characteristics. Five scales were taken about 25 mm 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 10 fish, as described in ADF&G (1994). 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 <700 mm MEF(jacks) missing adipose fins were sacrificed, and their heads were sent to the ADF&G Division of Commercial Fisheries Mark, Tag and Age Laboratory (Tag Lab) for detection and decoding of CWTs.

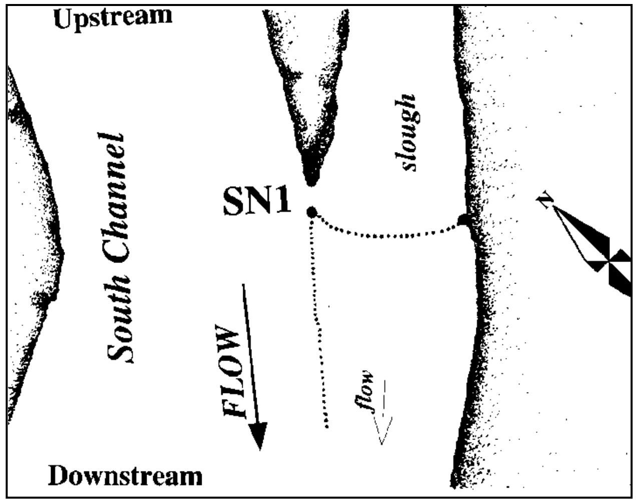

Figure 4.–Net placement used at the set gillnet site (SN1) on the lower Unuk River in 2009. SN = setnet.

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 (0.25 in) in diameter. The axillary clip and operculum punch enabled detection of tag loss. The spaghetti tag consisted of a 5.71 cm (2.25 in) section of laminated Floy™[1] tubing shrunk onto a 38-cm (15 in) 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 2009 (Figure 2). These tributaries received an estimated 84% of the escapement in the telemetry study of Pahlke et al. (1996). Various methods were used to capture fish including rod and reel, 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 et al. 1998; Jones 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 postspawn fish of all sizes, were sacrificed to retrieve CWTs. The heads collected were sent to the Tag Lab for dissection and decoding of tags. Foot, boat, or aerial 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.

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[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement.

Abundance by Size

Abundance of large ($\hat{N}_L$) fish was estimated separately so that the estimate for $\hat{N}_L$ could be compared to the survey index. Abundance was estimated using Chapman's modification of the Petersen estimator (Seber 1982):

$$\hat{N}_L = \frac{(M_L + 1)(C_L + 1)}{(R_L + 1)} - 1 \text{ and} \tag{1}$$

$$\text{var}(\hat{N}_L) = \frac{(M_L + 1)(C_1 + 1)(M_L - R_L)(C_L - R_L)}{(R_L + 1)^2 (R_L + 2)}, \tag{2}$$

where M_L is the number of large fish marked during event 1, C_L is the number of large fish inspected for marks during event 2, and R_L is the number of C_L that possessed marks applied during event 1. The general conditions that must be met to obtain an unbiased estimate of abundance are in Seber (1982) and may be cast as follows:

(a) every fish had an equal probability of being marked in the first event, <u>or</u> that every fish had an equal probability of being captured in the second event, <u>or</u> that marked fish mixed completely with unmarked fish;

(b) both recruitment and mortality did not occur between events;

(c) marking did not affect the catchability of a fish;

(d) fish did not lose their marks in the time between the two events;

(e) all marks were reported on recovery in the second event; and,

(f) double sampling did not occur.

Condition (a) may be violated if size- or sex-selective sampling occurs. Kolmogorov-Smirnov (K-S; Conover 1980) two-sample tests were used to test the hypothesis that fish of different lengths were captured with equal probability during both sampling events. These test procedures are described in Appendix A1, as well as corrective measures (stratification) should size-selectivity be found. These measures are designed to minimize bias in estimation of abundance and composition parameters. Tests for gender bias in 2009 were not conducted because of errors detected in gender classification during first event sampling.

Three consistency tests (Appendix A2) described by Seber (1982) and Arnason et al. (1996) were used to test for temporal and/or spatial violations of condition (a). Contingency table analyses were used to test three null hypotheses: 1) for all marked fish recovered during event 2, time of marking is independent of when/where recovery occurs; 2) the probability that a fish inspected during event 2 is marked is independent of when/where it was caught during the second event; and 3) the probability that a marked fish is recovered during event 2 is independent of when it was marked. If all three hypotheses were rejected, the "partially" stratified abundance estimator described by Darroch (1961) was necessary to estimate abundance. Failure to reject at least one of these three hypotheses was sufficient to conclude that at least one of the assumptions in condition (a) was satisfied, and a Petersen-type model was appropriate to estimate abundance.

The experiment was assumed closed to recruitment because first event sampling spanned the entire immigration. Marking was assumed to have little effect on behavior of released fish or the catchability of fish on the spawning grounds because only fish in good condition were tagged and released, and because the 1994 radiotelemetry study indicated minimal mortality from handling in the marking event for Chinook salmon (Pahlke et al. 1996). The use of multiple marks during event 1, careful inspection of all fish captured during event 2, and additional marking of all fish inspected helped to ensure assumptions (d), (e), and (f) were met.

Confidence intervals for $\hat{N}_L$ 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 $\hat{N}_L$ from the empirical distribution defined by the capture histories. A new set of statistics from each bootstrap sample $\{\hat{M}_L^*, \hat{C}_L^*, \hat{R}_L^*\}$ was generated, along with a new estimate for abundance $\hat{N}_L^*$. Ten thousand such bootstrap samples were drawn, creating the empirical distribution $\hat{F}(\hat{N}_L^*)$, which is an estimate of $F(\hat{N}_L)$. Confidence intervals were estimated from $\hat{F}(\hat{N}_L^*)$ with the percentile method (Section 13.3 in Efron and Tibshirani 1993).

Table 1.–Capture histories for large (≥660 mm MEF) Chinook salmon in the population spawning in the Unuk River in 2009 (notation explained in text).

Capture history	Number of large Chinook salmon	Source of statistics
Marked and not captured in tributaries	231	M_i - R_i
Marked and captured in tributaries	56	R_i
Not marked, but captured in tributaries	568	C_i - R_i
Not marked and not captured in tributaries (Estimated)	2,302	$\hat{N}_i$ - M_i- C_i + R_i
Effective population for simulations	3,157	$\hat{N}_i$

The abundance of small (<555 mm MEF) and medium fish (≥555 mm and <660 mm MEF) were estimated indirectly by expanding the estimate for large fish by the estimated size composition of the spawning escapement:

$$\hat{N}_S = \hat{N}_L \frac{\hat{\phi}_S}{\hat{\phi}_L} \text{ and} \tag{3}$$

$$\hat{N}_M = \hat{N}_L \frac{\hat{\phi}_M}{\hat{\phi}_L}, \tag{4}$$

where $\hat{\phi}_k$ is the estimated fraction of k-sized (small, medium or large) fish in the Chinook salmon spawning population:

$$\hat{\phi}_k = \frac{n_k}{n_{sp}}, \tag{5}$$

where

n_{sp} = Number of fish sampled on the spawning grounds

n_k = Number of k-sized fish found in n_{sp},

The variance of the estimate for the abundance of small fish was estimated:

$$\text{var}(\hat{N}_S) = \hat{N}_L{}^2 \,\text{var}\left[\frac{\hat{\phi}_S}{\hat{\phi}_L}\right] + \left[\frac{\hat{\phi}_S}{\hat{\phi}_L}\right]^2 \text{var}(\hat{N}_L) - \text{var}\left[\frac{\hat{\phi}_S}{\hat{\phi}_L}\right]\text{var}(\hat{N}_L), \tag{6}$$

where by the delta method (note that $Cov(\hat{\phi}_S, \hat{\phi}_L) = -\frac{\hat{\phi}_S \hat{\phi}_L}{n_{sp}}$),

$$\text{var}\left[\frac{\hat{\phi}_S}{\hat{\phi}_L}\right] \approx \left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)^2 \left(\frac{\text{var}(\hat{\phi}_S)}{\hat{\phi}_S^2} + \frac{\text{var}(\hat{\phi}_L)}{\hat{\phi}_L^2} + \frac{2}{n_{sp}}\right). \tag{7}$$

Similarly,

$$\text{var}(\hat{N}_M) = \hat{N}_L{}^2 \,\text{var}\left[\frac{\hat{\phi}_M}{\hat{\phi}_L}\right] + \left[\frac{\hat{\phi}_M}{\hat{\phi}_L}\right]^2 \text{var}(\hat{N}_L) - \text{var}\left[\frac{\hat{\phi}_M}{\hat{\phi}_L}\right]\text{var}(\hat{N}_L) \text{ and} \tag{8}$$

$$\text{var}\left[\frac{\hat{\phi}_M}{\hat{\phi}_L}\right] \approx \left(\frac{\hat{\phi}_M}{\hat{\phi}_L}\right)^2 \left(\frac{\text{var}(\hat{\phi}_M)}{\hat{\phi}_M^2} + \frac{\text{var}(\hat{\phi}_L)}{\hat{\phi}_L^2} + \frac{2}{n_{sp}}\right). \tag{9}$$

The abundance of all fish was estimated as:

$$\hat{N}_{All} = \frac{\hat{N}_L}{\hat{\phi}_L}, \tag{10}$$

with variance estimated as:

$$\text{var}(\hat{N}_{All}) = \text{var}(\hat{N}_L)\left[\frac{1}{\hat{\phi}_L}\right]^2 + \hat{N}_L^2 \,\text{var}\left(\frac{1}{\hat{\phi}_L}\right) - \text{var}\left(\frac{1}{\hat{\phi}_L}\right)\text{var}(\hat{N}_L), \tag{11}$$

with

$$\text{var}\left(\frac{1}{\hat{\phi}_L}\right) \approx \left(\frac{1}{\hat{\phi}_L}\right)^4 \frac{\hat{\phi}_L(1-\hat{\phi}_L)}{n_{sp}-1}. \tag{12}$$

Confidence intervals for medium, small and all fish were derived from simulation, where for each bootstrap realization of the abundance of large fish, a multinomial random variable was drawn (~multinomial [trials = number of fish inspected on the spawning grounds, probability vector $\underline{\phi}=\{\hat{\phi}_L, \hat{\phi}_M, \hat{\phi}_S\}$]) and a simulated $\underline{\phi}$ produced. Simulated N_S N_M and N_{ALL} were calculated and confidence intervals derived using the same methods utilized for large fish.

EXPANSION FACTOR

The expansion factor ($\hat{\pi}$) for large Unuk River Chinook salmon in a calendar year is:

$$\hat{\pi}_i = \hat{N}_{Li} / C_i \tag{13}$$

$$\text{var}(\hat{\pi}_i) = \text{var}(\hat{N}_i) / C_i^2 , \tag{14}$$

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

The expansion factor for a year in which no mark-recapture experiment is anticipated is the mean of the $\hat{\pi}_i$ over the k years for which mark recapture experiments are available (12 for the Unuk River at present, from 1997 to 2007 and 2009; 2008 is not included because of incomplete survey counts):

$$\bar{\pi} = \sum_{i=1}^{k} \hat{\pi}_i \ / \ k \ . \tag{15}$$

The variance associated with use of $\bar{\pi}$ in a prediction, var (π_p), is described in Appendix A3.

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

$$\hat{N}_p = \bar{\pi} \ C_p \tag{16}$$

$$\text{var}(\hat{N}_p) = C_p^2 \ \text{var}(\pi_p) \ . \tag{17}$$

MIGRATORY TIMING

The mean date of migration for Unuk River stocks (Boundary Creek, Clear Creek, Cripple Creek, Genes Lake Creek, Kerr Creek, Lake Creek or the Eulachon River) passing the SN1 site was calculated as:

$$\bar{d}_w = \frac{\sum_{i=1}^{n_w} d_{wi}}{n_w} , \tag{18}$$

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:

$$\text{var}(\bar{d}_w) = \frac{\sum_{i=1}^{n_w} (d_{wi} - \bar{d})^2}{(n_w - 1) n_w} . \tag{19}$$

AGE AND SEX COMPOSITION

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

$$\hat{p}_{gc} = \frac{n_{gc}}{n_c} \tag{20}$$

$$\text{var}(\hat{p}_{gc}) = \frac{\hat{p}_{gc}(1-\hat{p}_{gc})}{n_c - 1}, \tag{21}$$

where n_c is the number of Chinook salmon of size class c in the sample that are successfully aged or sexed, and n_{gc} is the subset of n_c that belongs to group g. Information gathered during event 1 was not used to estimate age or sex composition as some gender misidentification was found to have occurred at SN1. Samples gathered at each spawning tributary were pooled together because no differences in age composition were apparent among tributaries sampled. Estimated abundance of age/sex group g across size classes is:

$$\hat{N}_g = \sum_c \hat{p}_{gc}\hat{N}_c . \tag{22}$$

Because the $\hat{N}_c$ in Eq 22 are correlated ($\hat{N}_S$ and $\hat{N}_M$ are both estimated from $\hat{N}_L$ by Equations 3 and 4), the $\text{var}(\hat{N}_g)$ was estimated by simulation.

The estimated proportion of the spawning population in age/sex group g across the large or small population classes is:

$$\hat{p}_g = \frac{\hat{N}_g}{\hat{N}_{ALL}} . \tag{23}$$

The $\text{var}(\hat{p}_g)$ was also estimated through simulation.

Standard sample summary statistics were used to calculate estimates of mean length-at-age and its variance (Cochran 1977).

RADIOTELEMETRY STUDY

Chinook salmon captured at the set gillnet site were fitted with Model F1845 (19x51x15mm, 24 gram) 150–151 MHz Advanced Telemetry Systems™ (ATS) radio transmitters. Radio transmitters were inserted esophageally into the stomach (Eiler 1990), and the frequency of each was checked immediately before the fish was released to verify it was operating correctly and to note any deviations from its listed frequency. Only healthy fish ≥555 mm MEF were fitted with radio transmitters; radio transmitter size precluded insertion in smaller fish without possible injury to the fish.

A combination of five pulse codes and 33 frequencies gave each radio transmitter a unique identity. Each transmitter was equipped with a programmable motion sensor/switch, which is referred to as a "mortality sensor." The mortality sensor was set with a trigger time of 12 hours. If the transmitter remained motionless for 12 hours, the trigger was tripped, the transmitter output was doubled, and the transmitter mode changed from active (alive or moving) to inactive (dead or not moving). The signal reverted to the active mode if the motion sensor was retriggered. Transmitter output was coded by receivers as active or inactive based on the rate of signal output. Minimum battery life for the F1845 transmitters was 162 days.

One goal of the telemetry study was to estimate the proportion of spawning Chinook salmon in each major spawning area within the Unuk River watershed comprising greater than 5% of the population such that all estimates were within 10 percentage points of their true values 95% of the time. Assuming that 13% of transmitters released would be regurgitated, lost, never found, or subject to emigration or an ambiguous fate (Pahlke et al. 1996), a sample of 146 fish was found to be sufficient to meet this goal (Thompson 1987). If the spawning distribution was identical to that found by Pahlke et al. (1996), we would be approximately 97% sure that at least one of the 146 radio-tagged fish would migrate to each of the sites identified in their study. Based on sibling analysis of the 1992–2004 brood year returns, assuming an average level of marine harvest in 2009, and using the average proportion of the inriver run that is annually captured at the set gillnet site, we estimated that 486 healthy fish would be captured and marked at the set gillnet site in 2009. Consequently every third healthy fish (approximately486/146) ≥555 mm MEF captured at the set gillnet site was fitted with a transmitter. A logistical problem that delayed shipment of the last batch of transmitters resulted in approximately every sixth healthy fish being radiotagged after 16 July.

Implanted radio transmitters were located using receivers operated from the air and ground. The components of each ground-based tracking station (tower) were an ATS R4500C integrated receiver and datalogger, two directional Yagi antennae, and a solar panel and battery power system. Each tower had one antenna directed upstream and one antenna directed downstream. Each tower receiver was programmed to scan through the 33 frequencies used in this study. The data recorded each time a transmitter was identified included the date and time, antenna used (upstream, downstream, or both), frequency, pulse code, activity pattern (active or inactive), and the signal strength. For each antenna, transmitter data associated with the strongest signal within each 10-minute period was stored in long-term memory. The location of each identified transmitter relative to the tower (upriver or downriver from the site) was deduced by comparing signal strengths from upstream and downstream antenna within each 10-minute period. A signal from a reference transmitter located near each tower was recorded once per hour to verify that the tower components were functioning. Dataloggers were downloaded weekly using a laptop computer.

One tower was placed near the U.S./Canada border (Border tower; Figure 2) to determine the proportion of fish fitted with transmitters that migrated into the Canadian portion of the watershed. Towers were also placed on the lower Eulachon River, at the confluence of the mainstem (or South Fork) and Clear Creek/Lake Creek (South Fork tower), and on the North Channel (also known as Johnson Slough; North Fork tower) approximately the same distance from the mouth of the river as was the South Fork tower (Figure 2). All known spawning grounds are located upriver from these three towers (Anthony et al. 1965; Pahlke et al. 1996); all fish had to pass at least one of these towers to access any of the spawning grounds within the watershed, and all of these towers were >6 km from the set gillnet location. Radio-tagged fish that passed these towers were presumed to have suffered no lethal affects from the tagging process, i.e., handling mortality.

The Unuk River supports the largest population of Chinook salmon in what the Pacific Salmon Commission terms the SEAK Southern Inside, or Behm Canal, aggregate of stocks. Several strategies were employed to determine the proportion of radio-tagged fish that left the Unuk River to spawn elsewhere, i.e., strays. A tower was located on the Chickamin River, which supports the second largest population of Chinook salmon in Behm Canal, just above tidal influence (Figure 1). Aerial surveys were flown on the Blossom and Keta rivers, the third and fourth largest populations in the Behm Canal stock aggregate, in conjunction with annual ASL and peak survey count activities on these systems (Figure 2). Aerial surveys also occurred on the Klahini River and Grant Creek (Figure 2). These systems only support small populations of Chinook salmon, but they are adjacent to the Unuk River.

Aerial tracking surveys of the Unuk River drainage were flown using a helicopter equipped with two directional antennae aimed to either side of the flight path, one R4500C receiver, and a switch box. During aerial surveys the R4500C receiver scanned and recorded transmitter frequencies and pulse codes, the corresponding signal strength, and the GPS coordinates for each frequency received. For each transmitter frequency and pulse code received, the GPS location of the strongest signal indicated the most likely position of the fish at the time of the survey. The escapement sampling crew used a hand-held antenna and receiver to locate transmitters during ASL sampling activities, as well as to attempt to clarify ambiguous data obtained during aerial surveys.

After the data from the towers, aerial surveys, and hand-held receivers were combined, each radio-tagged fish was assigned one of three possible fates: 1) probable spawner, 2) probable death or regurgitation of the transmitter prior to spawning or, 3) unknown, or remained in the lower river and neither spawning nor mortality were documented. The Unuk River watershed was segmented into 16 areas or locations in order to quantify where the transmitters were ultimately tracked (Table 2, Figure 2). A 17th location included all areas outside the Unuk River watershed. Fish tracked to more than one spawning location were assigned to the location to which they were last tracked. Fish that passed upriver from the Border tower (location code 9) or were tracked to another watershed (location code 14) were presumed to have spawned, as signal data from those areas was limited. Fish that were tracked to known spawning tributaries of the Unuk River (location codes 1–8) were presumed to have spawned. Fish that were tracked to mainstem locations of the Unuk River between the North or South Fork towers and the Border tower (location codes 6 and 10–13) were presumed to have spawned in the mainstem if their transmitters were still generating active signals 14 days after having been released at the set gillnet site, or if fish passed above the South or North Fork towers and their transmitters were never again located. Fish that were tracked to mainstem locations of the Unuk River between the North or South Fork towers and the Border tower would have been assigned to fate 2 if their transmitters began generating sustained inactive signals <14 days after having been released at the set gillnet site. Fish whose transmitters generated sustained inactive signals without having passed upstream of one of the three lower river towers, regardless of the time interval between release at the set gillnet site and the detection of inactive signals, were relegated to fate 2 (prespawn mortality/transmitter regurgitation). Fish allocated to fate 3 (unknown fate) consisted of fish whose transmitters were never located after the fish were released at the set gillnet site, or fish whose transmitters did not pass upstream of the three lower river towers and from which only active signals were detected, regardless of the time interval between release at the set gillnet site and the last active signal received.

Table 2.–Location code, location description, and fate 1 designation for radio-tagged Chinook salmon on the Unuk River, 2009.

Location code	Fate 1 location	Location description
1	Yes	Eulachon River.
2	Yes	Clear Creek.
3	Yes	Lake Creek.
4	Yes	Kerr Creek.
5	Yes	Genes Lake and Genes Lake Creek.
6	Yes	Sawmill Slough.
7	Yes	Cripple Creek.
8	Yes	Border (aka Boundary) Creek.
9	Yes	Canada. Upstream of the Border Creek tower on the mainstem; does not include Border Creek.
10	Yes	Mainstem of the river from the North Fork and South Fork towers to Kerr Creek.
11	Yes	Mainstem of the river from the mouth of Genes Lake to the mouth Cripple Creek; does not include Sawmill Slough.
12	Yes	Mainstem of the river from the mouth of Cripple Creek to the U.S./Canada border; does not include Border Creek.
13	Yes	Mainstem of the river above the North Fork and South Fork towers; no specific location therein identified.
14	Yes	Outside of the Unuk River watershed.
15	No	Tidal flats. Transmitter did not pass the Eulachon River, North Fork, or South Fork towers. Transmitter ultimately located in the intertidal zone at the mouth of the Unuk River emitting inactive signals.
16	No	Lower Unuk River. Last active signals received above tidal waters but below the Eulachon River, North Fork, and South Fork towers.
17	No	Mainstem of the river from the mouth of Kerr Creek to the mouth of Genes Lake.

Three conditions were necessary to reliably estimate spawning distribution in this study:

(a) the fates of the fish receiving transmitters were accurately determined;

(b) fish were captured and inserted with transmitters in proportion to the abundance of the inriver return and that subpopulations were represented in the catch according to their relative abundance inriver; and

(c) insertion of transmitters did not change the fate of a fish.

Towers, aerial surveys, and hand-held receivers were used to the greatest extent possible in order to satisfy condition (a). In order to satisfy condition (b), effort at SN1 was held as consistent as possible throughout the duration of the run and we planned on implanting a transmitter in every third captured fish; however circumstances dictated that the proportion of captured fish that received a transmitter changed during the study (see above). Spawning distribution was therefore estimated by adjusting (weighting) for the change in transmitter implantation rate, i.e., before and after the change in transmitter insertion rate, using methods in Richards et al. (2008). The proportion of Chinook salmon ≥555 mm MEF that spawned in each location $\hat{K}_q$ (Fate 1 location codes 1–14) was estimated as:

$$\hat{K}_q = \sum_h \hat{z}_h \hat{K}_{q,h}, \tag{24}$$

where

$$\hat{K}_{q,h} = \frac{s_{q,h}}{b_h - x_h} \tag{25}$$

and

$$\hat{z}_h = \frac{B_h}{\sum_{h=1}^{H} B_h}, \tag{26}$$

where

$s_{q,h}$ = the number of fish released with transmitters during period *h* that survived to spawn in location *q* (location codes 1 through 14);

b_h = the number of fish released with transmitters during period *h*;

x_h = the number of fish released with transmitters during period *h* that either 1) died or regurgitated their transmitters prior to spawning (Fate 2) or 2) it was unknown whether they had successfully spawned (Fate 3);

$\hat{B}_h$ = the number of fish ≥555 mm MEF captured by the set gillnets during period *h*;

$\hat{z}_h$ = estimated weight.

SMOLT ABUNDANCE AND OVERWINTER SURVIVAL

Juvenile Chinook Salmon Capture, Tagging, and Sampling

Chinook salmon from the Unuk River are almost all (>99%; Hendrich et al. 2008) from a single freshwater age, overwintering one year as parr and emigrating as age-1 smolt. Nearly all Chinook salmon parr tagged in the fall of year $j+1$, and smolt tagged in the spring of year $j+2$ are thus from brood year j. Minnow traps (type G-40), baited with salmon roe, were fished daily for 24 hours in the mainstem of the Unuk River, between approximately river km 3 and 19 (Figure 1) in spring and fall of 2009. Minnow traps were checked daily, at which time juvenile Chinook salmon were removed from the minnow traps, counted, and subsequently transported to holding pens at camp. Chinook salmon were then separated from other species by using a combination of external morphological characteristics (Jones III et al. 1999). All live Chinook salmon were tranquilized in a water solution of tricain methane-sulfonate (MS 222) buffered with sodium bicarbonate. To alleviate stress, the anesthetic solution was kept near ambient river temperature by frequent water changes, and numbers of smolt tranquilized at any one time was limited (approximately 100). All smolt ≥50 mm FL not missing adipose fins were tagged following procedures described in Koerner (1977) and their adipose fins were excised. All captured smolt missing an adipose fin were subsequently passed through a magnetic tag detector to test for the presence of a CWT. Unique codes were used each spring and fall. Codes were ordered in spools of approximately 5,000, 10,000, or 20,000 tags, and spools were only changed when depleted or when the seasonal tagging period ended.

All tagged fish were held overnight. A random subsample of 50–100 fish was checked each morning for tag retention. The daily estimate of fish tagged and released (valid tagged) equaled the number tagged, minus the number of overnight mortalities, times the proportion estimated to have retained their tags. The number of fish tagged, the number that died in the holding pen, and the estimated number of fish that had shed their tags were compiled and recorded on ADF&G CWT Tagging Summary and Release Information Forms. These forms were submitted to the Tag Lab in Juneau after each field season.

Parr and smolt were systematically sampled and measured to the nearest 1 mm FL and weighed to the nearest 0.1 g. Standard sample summary statistics were used to calculate estimates of mean length and weight and associated variances (Cochran 1977).

Smolt Abundance

Experience has shown that estimates of the proportion of adults from a given brood year with adipose fin clips does not change appreciably over return years, and thus recovery data were pooled over the i years (maximum = 5, represting ages 1.1 through 1.5) in which fish from brood year j return. Smolt abundance ($\hat{N}_{smolt,j}$) from brood year j was estimated using a version of the Chapman-modified Petersen formula:

$$\hat{N}_{smolt,j} = \frac{(\hat{M}_j + 1)(n_{\bullet j} + 1)}{(a_{\bullet j} + 1)} - 1, \quad (27)$$

where

$n_{\bullet j}$ = $\sum_{i=1}^{L} n_{ij}$ where n_{ij} is the number of adults examined in year i from brood year j for missing adipose fins;

L = number of years over which fish from a given brood return (maximum = 5).

$a_{\bullet j}$ = $\sum_{i=1}^{L} a_{ij}$, where a_i is the number of adipose fin clips observed in n_{ij}; and

$\hat{M}_j$ = estimated number of outmigrating smolt originating from brood year j that bore an adipose fin clip; these fish may be from either the fall (f; year $j+1$) or spring (s; year $j+2$) tagging programs. $\hat{M}_j$ is the sum of the estimated number of parr with adipose fin clips from brood year j surviving to the spring ($\hat{M}_{f\rightarrow s,j}$) and the number of smolt with adipose fin clips from brood year j ($M_{s,j}$), where:

$$\hat{M}_{f\rightarrow s,j} = M_{f,j}\hat{S}_j, \quad (28)$$

and

$M_{f,j}$ = number of parr released with adipose fin clips in the fall of year $j+1$; and

$\hat{S}_j$ = estimated proportion of $M_{f,j}$ that survived to the spring of $j+2$ (overwinter survival) (see Weller and McPherson 2003a; Appendix A7), where:

$$\hat{S}_j = \frac{\hat{M}_{s,valid,j} v_{\bullet,f,j}}{\hat{M}_{f,valid,j} v_{\bullet,s,j}}, \tag{29}$$

and

$\hat{M}_{s,valid,j}$ = estimated number of adipose-finclipped smolt released with valid CWTs in the spring of year $j+2$;

$\hat{M}_{f,valid,j}$ = estimated number of adipose-finclipped parr released with valid CWTs in the fall of year $j+1$;

$v_{\bullet,f,j}$ = $\sum_{i=1}^{L} v_{i,f,j}$, where $v_{i,f,j}$ is the total number of fish from brood year j implanted with valid CWTs in the fall of year $j+1$ that were subsequently recovered, regardless of recovery circumstances (for instance recovery location; marine fishery, escapement, etc, or sample type; random, select, or voluntary; see Harvest section below); and

$v_{\bullet,s,j}$ = $\sum_{i=1}^{L} v_{i,s,j}$, where $v_{i,s,j}$ is the total number of fish from brood year j implanted with valid CWTs in the spring of year $j+2$ that were subsequently recovered, regardless of recovery location or sample type.

The variance of the smolt estimate was estimated as:

$$\text{var}\left(\hat{N}_{smolt,j}\right) = \left(n_{\bullet}+1\right)^2 \text{var}\left[\left(\hat{M}_{f\to s,j} + M_{s,j} + 1\right)\frac{1}{\left(a_{\bullet}+1\right)}\right], \tag{30}$$

where, by Goodman (1960) for independent variables:

$$\text{var}\left[\left(\hat{M}_{f\to s,j} + M_{s,j} + 1\right)\frac{1}{\left(a_{\bullet,j}+1\right)}\right] = \left(M_{s,j} + \hat{M}_{f\to s,j} + 1\right)^2 \text{var}\left[\frac{1}{a_{\bullet,j}+1}\right] + \left[\frac{1}{a_{\bullet,j}+1}\right]^2 \text{var}\left(\hat{M}_{f\to s,j}\right) - \text{var}\left[\frac{1}{a_{\bullet,j}+1}\right]\text{var}\left(\hat{M}_{f\to s,j}\right) \tag{31}$$

and

$\text{var}\left(\hat{M}_{f\to s,j}\right)$ is obtained as described in Weller and McPherson (2003a; Appendix A7).

According to the delta method:

$$\mathrm{var}\left[\frac{1}{a_{\bullet}+1}\right]=\left[\frac{1}{a_{\bullet,j}+1}\right]^4 n_{\bullet,j}\,\hat{p}_a\left(1-\hat{p}_a\right), \tag{32}$$

where $\hat{p}_{a,j}=\dfrac{a_{\bullet,j}}{n_{\bullet,j}}$ is the estimated proportion of inspected adults from brood year j with an adipose fin clip.

The two components in Equation 31 are not independent, but a simulation using data from studies on seven brood years of Unuk River Chinook salmon to establish realistic population parameters showed the correlation to be negligible. The simulation showed the simulated variance of smolt abundance to be almost identical to that provided by the average of the Goodman-derived estimates (Eq. 31) over the simulation.

Parr abundance $\hat{N}_f$ for brood year j was estimated as:

$$\hat{N}_{f,j}=\hat{N}_{smolt,j}\frac{1}{\hat{S}_j}, \tag{33}$$

$$\mathrm{var}(\hat{N}_{f,j})\approx\hat{N}_{f,j}^2\left|cv^2\left(\hat{N}_{smolt,j}\right)+cv^2\left(\hat{S}_j\right)\right|, \tag{34}$$

HARVEST, INCIDENTAL FISHING MORTALITY, TOTAL FISHING MORTALITY, PRODUCTION, AND EXPLOITATION RATE ESTIMATES

Estimation of Fraction of Adults Bearing CWTs

All adult Chinook salmon captured during the 2009 mark-recapture experiment were sampled for age (scale) data. Scales with regenerated or otherwise unknown freshwater age were assumed to have a freshwater age of 1 (Hendrich et al. 2008). The age of fish with regenerated or otherwise unknown marine-water (MW) ages were estimated from their lengths using estimated length-at-age relationships according to methods in Hendrich et al. (2008; Appendix E1).

The fraction of adults from brood year j that possessed a valid Unuk River CWT was estimated as:

$$\hat{\theta}_j=\frac{\sum_{i=1}^{L}a_{ij}\rho_{ij}}{\sum_{i=1}^{L}n_{ij}} \tag{35}$$

where

n_{ij} = number of adults examined in year i from brood year j for adipose fin clips;

a_{ij} = number of adipose fin clips observed in n_{ij};

ρ_{ij} = $\frac{t_{ij}}{a_{ij}^{'}}$, the proportion of sacrificed adults from brood year *j* in year *i* that also possess a valid Unuk CWT; where

$a_{ij}^{'}$ = number of heads examined for CWTs from the a_{ij} fish with adipose fin clips;

t_{ij} = number of CWTs found in $a_{ij}^{'}$; and

L = number of years over which fish from a given brood return (maximum = 5, representing ages 1.1 through 1.5).

The variance of $\hat{\theta}_j$ was estimated using a parametric bootstrap simulation (e.g., Geiger 1990). For each year of recovery i, adipose clips were generated as a_{ij}^{*} ~ binomial$\left(n_{ij}, \frac{a_{ij}}{n_{ij}}\right)$, and then CWTs were generated as, t_{ij}^{*} ~ hypergeometric ($m = t_{ij} / a_{ij}^{'} a_{ij}^{*}$, $n = a_{ij}^{*} - t_{ij} / a_{ij}^{'} a_{ij}^{*}$, $k = a_{ij}^{'} / a_{ij} a_{ij}^{*}$). Notation for hypergeometric parameters follows that of the R language (R Development Core Team 2005). ρ_{ij}^{*} was then calculated as $t_{ij}^{*} / (a_{ij}^{*} a_{ij}^{'} / a_{ij})$, and $\hat{\theta}_j^{*}$ as:

$$\hat{\theta}_j^{*} = \frac{\sum_{i=1}^{L} a_i^{*} \rho_i^{*}}{\sum_{i=1}^{L} n_i} \quad (36)$$

Many values of $\hat{\theta}_j^{*}$ were simulated and the variance of $\hat{\theta}_j$ and of $\hat{\theta}_j^{-1}$ were estimated as the sample variance of the respective simulated values. Returning Chinook salmon were/will be inspected for marks (missing adipose fins) and sampled for age (scale) data annually through 2013 (to complete recoveries of fish from brood year 2006) during mark-recapture operations. Each Chinook salmon was/will be examined for presence of the adipose fin, and a fish missing its adipose fin will be noted. Furthermore, heads were/will be removed from all adipose-finclipped Chinook salmon that are dead, post spawn, or <700 mm MEF (jacks) in length, with the resulting heads collected and shipped to the Tag Lab in Juneau for CWT processing. Scales (age) and length data were/will be collected from all adult Chinook salmon sampled to determine the marked rate by brood year.

Harvest

Landed catch (hereafter referred to as harvest) and CWT sampling data from fisheries managed by the State of Alaska were obtained from the Tag Lab database (http://tagotoweb.adfg.state.ak.us). Oliver (1990) and Hubartt et al. (1999) present details of sampling commercial and recreational fisheries in SEAK, respectively. The Regional Mark Processing Center (RMPC, http://www.rmpc.org/), which maintains the coastwide CWT central database (Regional Mark Information System or RMIS), provided recovery information, harvest numbers, and CWT sampling statistics from fisheries not included in the Tag Lab database. For details on recoveries from the 1992–2001 broods see Weller and Evans (2012).

Fishery strata are defined as a combination of gear and harvest type with specific spatial and temporal characteristics. Commercial fishery harvest types in SEAK of relevance to this study were traditional fisheries, experimental area (troll) fisheries, terminal fisheries, and private nonprofit hatchery harvests in the Neets Bay terminal area. The traditional and experimental area fisheries are managed by ADF&G to achieve harvest targets (quotas) pursuant to the Pacific Salmon Treaty and as determined by the Chinook Technical Committee (CTC) of the Pacific Salmon Commission. Experimental area fisheries target Alaska hatchery returns of Chinook salmon in SEAK each spring (approximately May through June), although fish other than Alaskan hatchery fish (treaty fish) are also harvested. The proportion of treaty fish harvested in each experimental fishery determines the total catch limit for each fishery (See Lynch and Skannes 2009a for further details on these fisheries). Experimental area fisheries are spatially small (subdistrict specific; Figure 5) and harvest by fishery is tallied by statistical week.

The Neets Bay terminal area fishery is a fishery managed jointly by ADF&G and the Southern Southeast Aquaculture Association to harvest returns to the Neets Bay hatchery (Lynch and Skannes 2009c). Harvest is primarily for cost recovery and brood stock, but some common property terminal harvest does occur (Davidson et al. 2009a). This fishery is confined to District 101-95 (Figure 5), harvest is tallied by statistical week, and gear is undefined.

The Hidden Falls terminal area fishery is a fishery managed jointly by ADF&G and the Northern Southeast Aquaculture Association to harvest returns to the Hidden Falls hatchery (Lynch and Skannes 2009c). This fishery is confined to District 112-12 (Figure 5) and is managed for cost recovery, brood stock, common property terminal harvest (Davidson et al. 2009a), and common property experimental area troll harvest (Lynch and Skannes 2009a). Harvest is tallied by statistical week, harvest type, and gear.

Traditional fisheries are mixed stock interception fisheries; terminal area, aboriginal, experimental area, and test fisheries are not considered traditional fisheries. Harvest from SEAK traditional purse seine (see Davidson et al. 2009a for details on these fisheries), drift gillnet fisheries (see Davidson et al. 2009b for details on these fisheries) are tallied by statistical week and district fished (Figure 6). In SEAK the traditional troll fishery is comprised of winter and summer components. The winter fishery begins 11 October and ends when 45,000 Chinook salmon have been harvested, or on 30 April, whichever occurs first (Lynch and Skannes 2009b). The summer troll fishery begins 1 July and ends 20 September, unless the fishery is extended (Lynch and Skannes 2009c).

Traditional troll harvests in SEAK are tallied by quadrant and period. A quadrant is a group of combined contiguous districts that divides SEAK into four large troll reporting areas (NE, NW, SE, and SW; Figure 7). Period is a group of consecutive statistical weeks. Period 1 starts on 1 January (statistical week 1) and ends when the winter troll fishery closes. Period 2 encompasses the spring, or experimental area, fishery. Period 3 begins when the summer troll fishery opens, generally 1 July, and for traditional Chinook salmon harvest, effectively ends when an inseason assessment of harvest sampling data determines the summer quota of Chinook salmon has been reached and the fishery is closed to Chinook salmon retention (note that the summer troll fishery generally remains open to retention of other salmon species and Period 3 extends throughout this time). If during the summer fishery the entire salmon troll fishery is closed and then reopened, or if Chinook salmon harvest during Period 3 was found to be substantially less than the quota and management reopens the fishery to Chinook retention, an additional period or periods are used to define each additional fishery opening. The final period of each calendar year is from 1 October to 31 December. Note that as Unuk River Chinook salmon have completed spawning by 1 October, harvest contributions of Unuk River Chinook salmon during the final period of a calendar year are accredited to returns of the following calendar year. Canadian troll harvests are tallied by statistical week and management area (Figure 8).

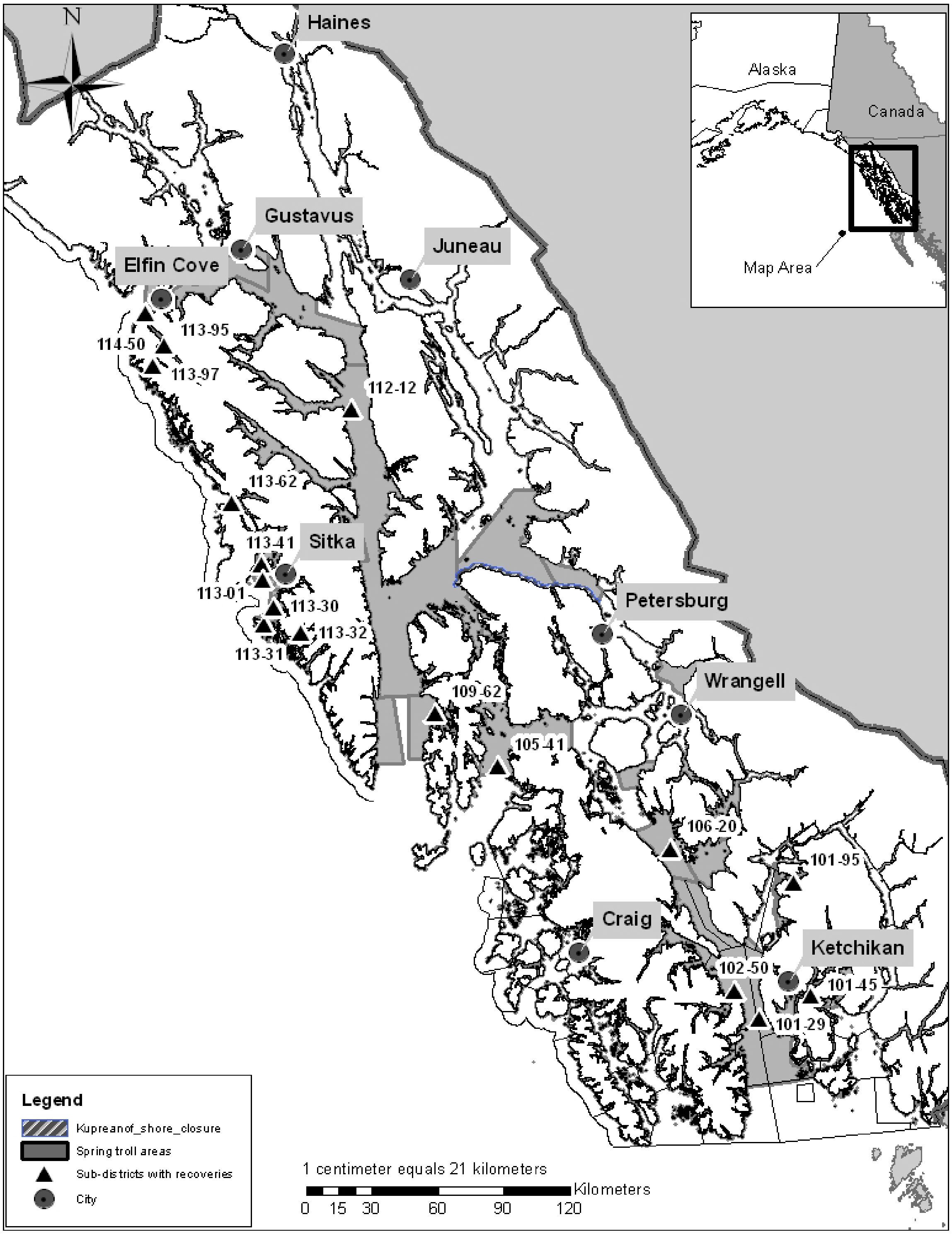

Figure 5.–Southeast Alaska experimental troll fishing areas (district-subdistrict).

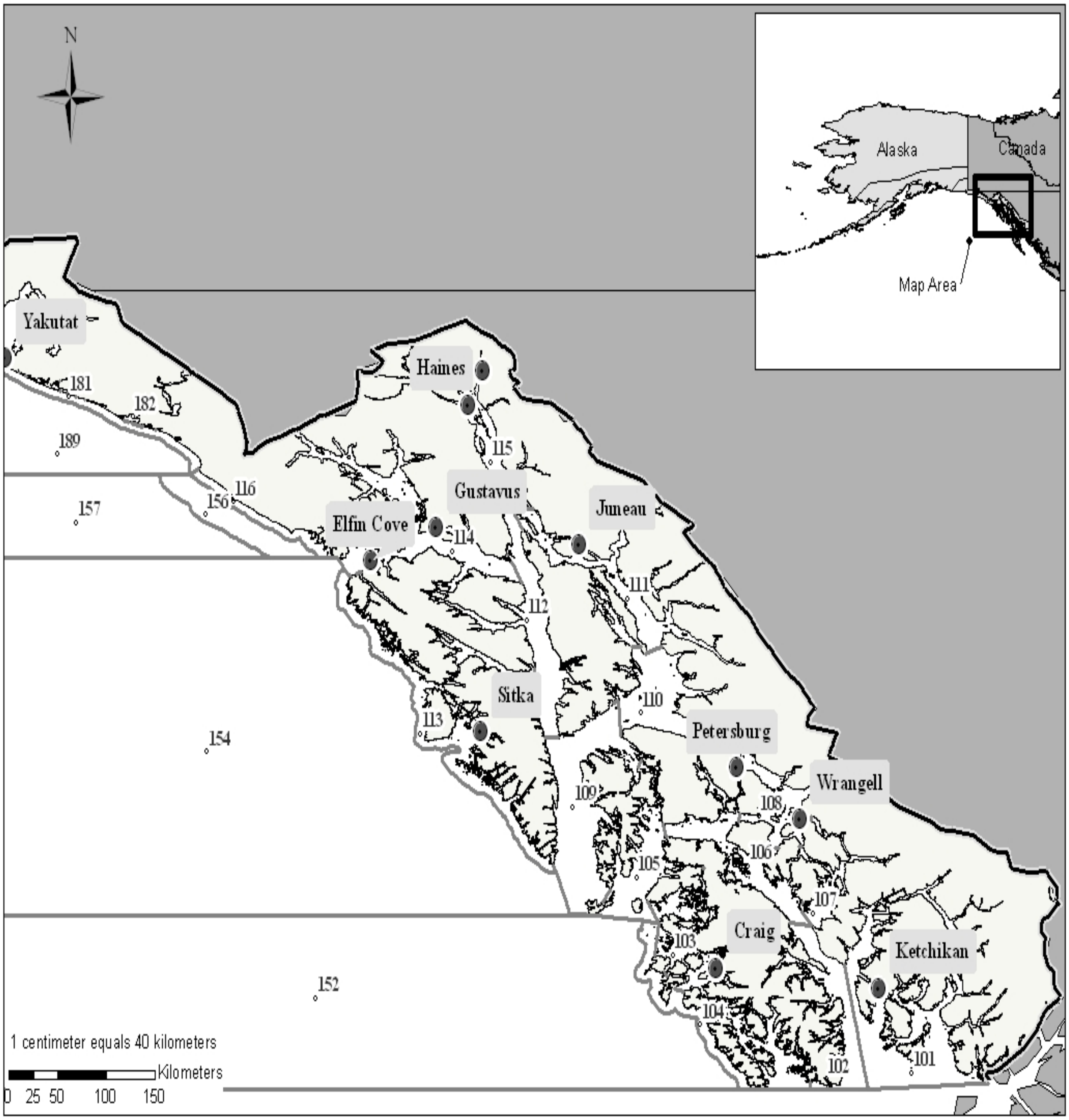

Figure 6.–Southeast Alaska commercial fishing districts and creel census ports.

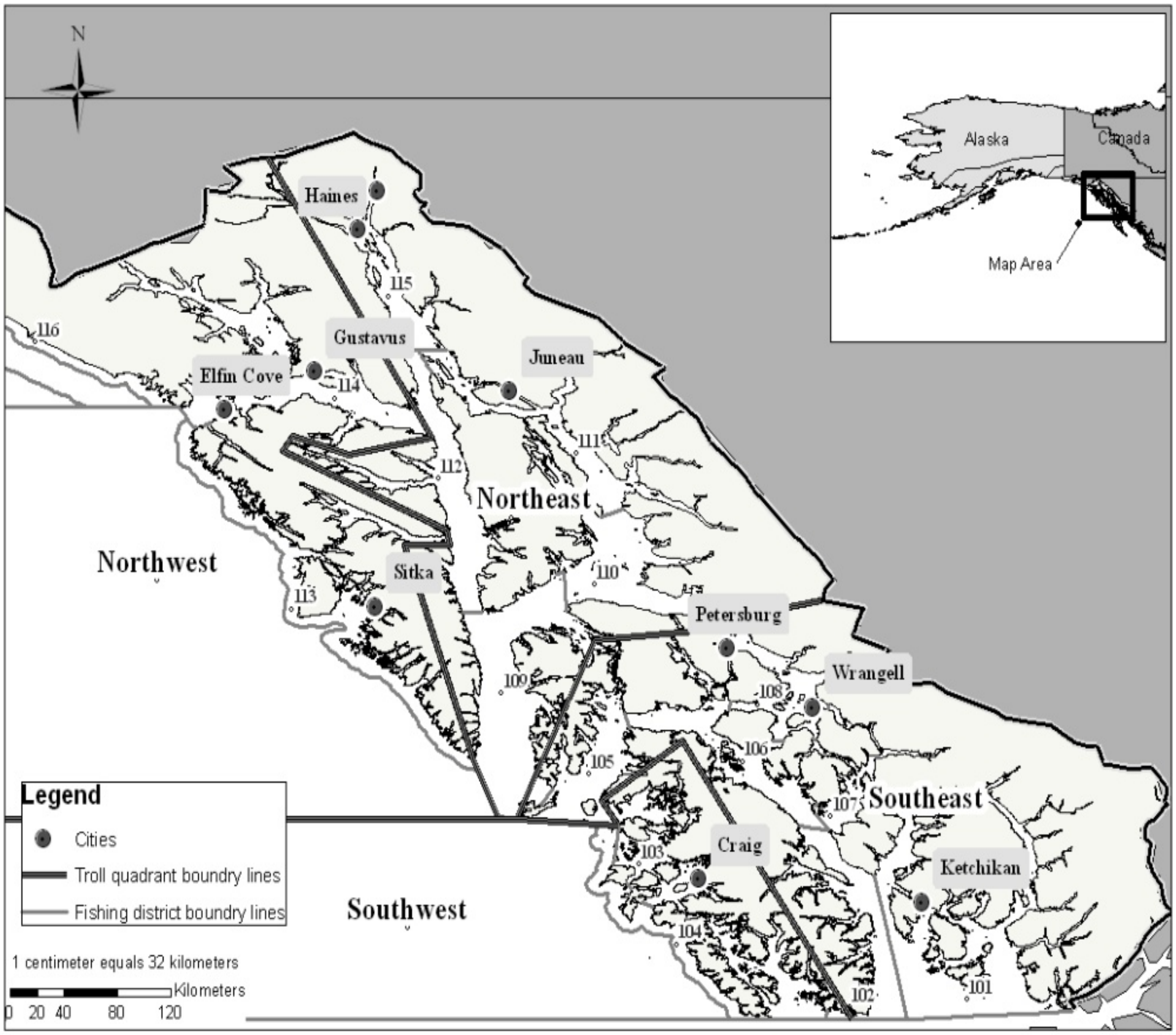

Figure 7.–Southeast Alaska troll fishery quadrants.

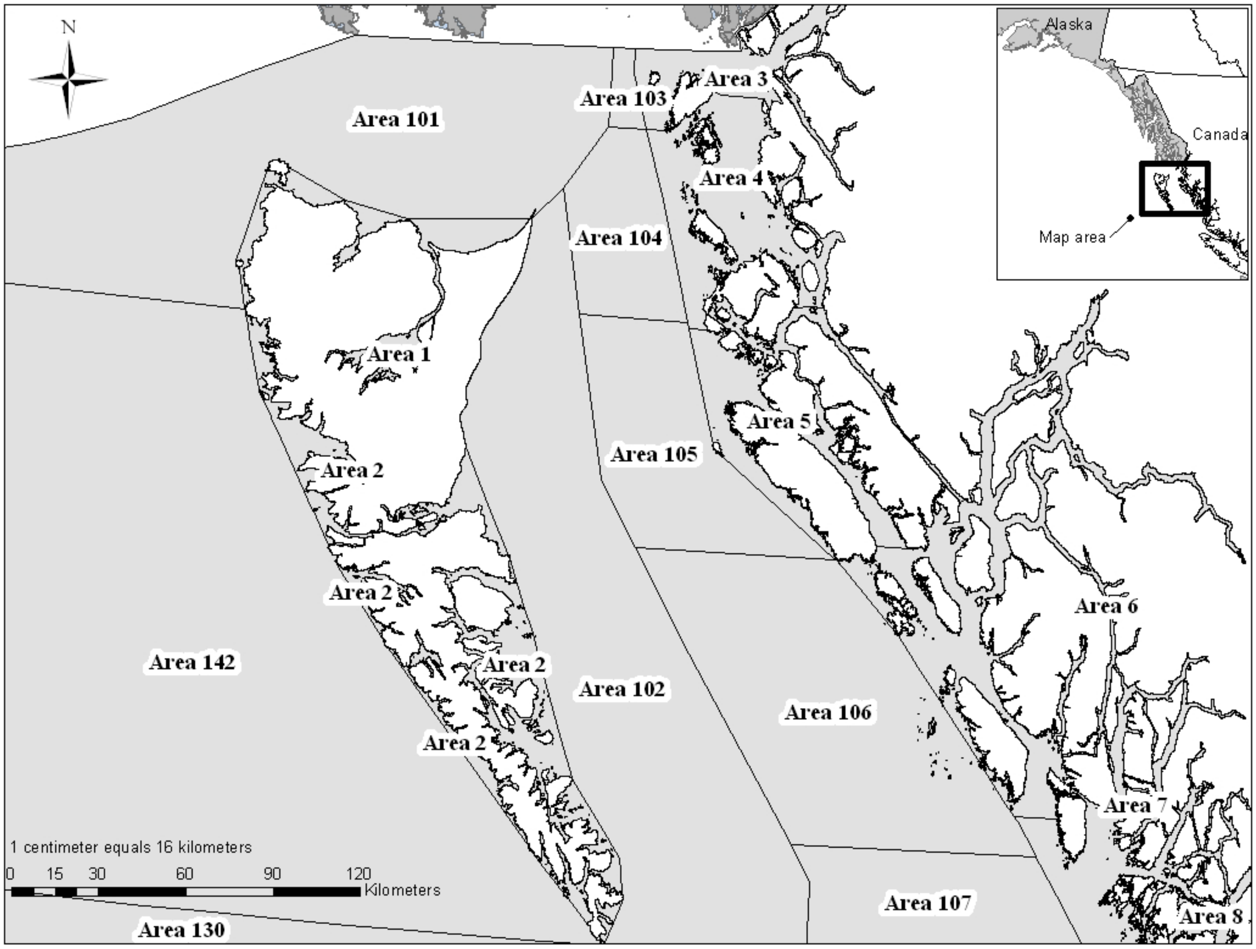

Figure 8.–Northern British Columbia fishery management areas.

Creel surveys and/or catch sampling of recreational fisheries were randomly conducted in SEAK at marine boat landing sites in Haines, Petersburg, Wrangell, Sitka, Juneau, Craig, Ketchikan, Elfin Cove, and Gustavus during times of peak sport fishing activity, e.g., April through September (Figure 6). Information collected from individual fishers included harvest type, harvest date, harvest location, number of Chinook salmon inspected for missing adipose fins, and the number of Chinook salmon observed with missing adipose fins. Harvest types relevant to this study were marine boat (MB) and derby fishing in which the sampled fish was entered in a derby (DE). Each sample was classified as either random, select, or voluntary. Creel surveys were used to estimate recreational harvest by fortnight, harvest type, and port of landing (e.g., Wendt and Jaenicke 2011). Recoveries from Canadian recreational fisheries in northern British Columbia. Are strictly voluntary.

Random recoveries of Unuk River CWTs from sampled fisheries with known or estimated catch were used to estimate harvest contributions. The contribution r_{uj} of a release group or brood of interest *j* to 1 fishery stratum *u* is:

$$\hat{r}_{uj} = H_u \left[\frac{m_{uj}}{\lambda_u n_u} \right] \theta_j^{-1}; \qquad \lambda_u = \frac{a'_u t'_u}{a_u t_u}, \tag{37}$$

where H_u = total harvest in fishery stratum u, n_u = number of fish inspected (the sample) from fishery stratum *u*, a_u = number of fish in n_u that are missing an adipose fin, a'_u = number of heads from a_u that arrive at the lab, t_u = number of heads from a'_u with CWTs detected, t'_u = number of CWTs from t_u that are dissected from heads and decoded, m_{uj} = number of CWTs with code(s) of interest from n_u, and θ_j = fraction of the brood year *j* tagged with code(s) of interest. Separate strata are used for fish ≥28 in MEF and fish <28 in MEF (jacks) as harvest and sampling data for these fish are reported separately in Alaska's commercial and recreational fisheries. When H_u and θ_j are known without error, an unbiased estimate of the variance of $\hat{r}_{uj}$ can be calculated as shown by Clark and Bernard (1987). However, in this situation, H_u is estimated with error for sport fisheries, and θ_j is estimated with error on the Unuk River because it is not possible to count or tag all outmigrating smolt. For these reasons, unbiased estimates of the variance of $\hat{r}_{uj}$ were obtained using equations in Table 2 of Bernard and Clark (1996), which show the formulations for large samples.

Select (CWT-tagged fish sampled in a nonrandom fashion) and voluntary (CWT-tagged fish recovered from other than established sampling programs) recoveries were not used to estimate harvest contributions.

Incidental and Total Fishing Mortality

Estimates of incidental fishing mortality of Unuk River Chinook salmon, by brood year and age class, were provided by the northern U.S. co-chair of the Pacific Salmon Commission's Chinook Technical Committee CTC (John Carlile, ADF&G, Division of Commercial Fisheries, Juneau, personal communication). Incidental fishing mortality (IM) is mortality caused by the act of fishing but is not part of the actual landed catch, and is defined as the difference between reported (or landed) catch and total fishing mortality (FM) in Aggregate Abundance Based Management (AABM) fisheries (CTC 2005). See CTC (1997, 2004, 2005), and Weller and Evans (2012) for details on the methodology of incidental mortality estimation.

The CTC algorithms that generate estimates of incidental mortality do not calculate associated estimates of variance. However, assuming that for brood year *j* the relative precision of the total estimated fishing mortality $F\hat{M}_j$ (landed catch plus incidental mortality) was equal to that of the total estimated landed catch $\hat{R}_j$, the variance of the estimated incidental mortality $I\hat{M}_j$ can be indirectly estimated as (Hendrich et al. 2008):

$$\mathrm{var}\left(I\hat{M}_j\right) = \left(F\hat{M}_j \frac{\sqrt{\mathrm{var}\left(\hat{R}_j\right)}}{\hat{R}_j}\right)^2 - \mathrm{var}\left(\hat{R}_j\right). \tag{38}$$

Computer program memory limitations resulted in the grouping of some fisheries in the CTC's incidental mortality estimation algorithm. SEAK traditional purse seine and drift gillnet fisheries are one such example. These two fisheries have separate Chinook salmon harvest limits (quotas), management plans, and in the case of the purse seine fishery, size limits. The purse seine fishery has often been subject to periods of nonretention in order to avoid surpassing the annual harvest limit. Since 1995, however, the period of interest in this instance, the drift gillnet fishery, has had no periods of nonretention or size limitations on catch. The CTC algorithm, however, automatically estimates Chinook salmon nonreteintion (CNR) mortality for the drift gillnet fishery during periods of purse seine nonretention. It was not possible to excise the CTC-generated CNR estimates for the drift net fishery from the total incidental mortality estimates used herein, nor was it possible to separate incidental mortality by category type.

Production, Exploitation Rate, and Marine Survival Estimation

The total estimated production (total return) of adults $\hat{T}$ from brood year j is:

$$\hat{T}_j = \sum_{i=1}^{L} \hat{N}_{ji} + \sum_{i=1}^{L} \hat{R}_{ji} \left(AEQ_{ji} \right) + \sum_{i=1}^{L} I\hat{M}_{ji} \left(AEQ_{ji} \right), \tag{39}$$

where

$\hat{N}_{ji}$ = estimated spawning abundance in year i from brood year j,

L = number of years over which fish from a given brood return (maximum = 5, representing ages 1.1 through 1.5),

$\hat{R}_{ji}$ = estimate of landed catch (harvest) in year i from brood year j,

$I\hat{M}_{ji}$ = incidental mortality in year i from brood year j, and

AEQ_{ji} = adult equivalent in year i from brood year j.

AEQ_{ji} is the probability that a fish of a given age (year i from brood year j) will return to the Unuk River in the absence of fishing in the current and all future years (Morishima 2004). AEQs reduce $\hat{R}_{ji}$ and $I\hat{M}_{ji}$ to account for the fact that fish that are harvested and experience incidental mortality were not necessarily returning to the Unuk River that year (they were feeder fish). Adult equivalents are stock, brood, and age specific. AEQs for the Unuk River stock are derived from returns to hatcheries with Unuk River brood stock (McPherson and Carlile 1997) and were provided by the northern U.S. CTC co-chair (John Carlile, ADF&G, Division of Commercial Fisheries, Juneau, personal communication).

The estimated variance of $\hat{T}_j$ was calculated as:

$$\text{var}(\hat{T}_j) = \sum_{i=1}^{L} \text{var}(\hat{N}_{ji}) + \sum_{i=1}^{L} \text{var}(\hat{R}_{ji}) AEQ_{ji}^2 + \text{var}\left[\sum_{i=1}^{L} I\hat{M}_{ji} AEQ_{ji} \right], \tag{40}$$

where $\text{var}\left[\sum_{i=1}^{L} I\hat{M}_{ji} AEQ_{ji} \right]$ was calculated using Eq 40 with terms adjusted for AEQ.

For brood year j, the exploitation rate $\hat{U}_j$ was estimated as:

$$\hat{U}_j = \frac{F\hat{M}_j}{\hat{T}_j}, \tag{41}$$

where total production and fishing mortality are expressed in AEQs. An approximation of the variance of $\hat{U}_j$, incorporating the covariance between $F\hat{M}_j$ and $\hat{T}_j\,(=\text{var}(\hat{R}_j)+\text{var}(\hat{I}_j))$ was calculated using the delta method (Seber 1982, p. 8):

$$\text{var}\left(\hat{U}_j\right) \approx \frac{F\hat{M}_j^{\,2}}{\hat{T}_j^{\,2}}\left[\frac{\text{var}(F\hat{M}_j)}{F\hat{M}_j^{\,2}} + \frac{\text{var}(\hat{T}_j)}{\hat{T}_j^{\,2}} - 2\frac{\text{var}(F\hat{M}_j)}{(F\hat{M}_j)\hat{T}_j}\right], \tag{42}$$

and

$$\text{var}\left(F\hat{M}_j\right) = \text{var}\left(I\hat{M}_j\right) + \text{var}\left(\hat{R}_j\right). \tag{43}$$

Simulation shows the approximation in equation 42 to be excellent.

Marine survival $\hat{Q}$ for brood year j was estimated as:

$$\hat{Q}_j = \frac{\hat{T}_j}{\hat{N}_{smolt,j}} \tag{44}$$

$$\text{var}\left(\hat{Q}_j\right) = \left[\frac{\hat{T}_j}{\hat{N}_{smolt,j}}\right]^2 \left[\frac{\text{var}\left(\hat{T}_j\right)}{\hat{T}_j^2} + \frac{\text{var}\left(\hat{N}_{smolt,j}\right)}{\hat{N}^2_{smolt,j}}\right] \tag{45}$$

RESULTS

2009 MARK RECAPTURE STUDY

Event 1: Sampling in the Lower River

Between 13 June and 27 July 2009, 495 Chinook salmon were sampled in the lower river, of which 476 (287 large fish, 176 fish 555–659 mm MEF, and 13 fish <555 mm MEF) were marked and released (Table 3). Fishing effort at the set gillnets was maintained at relatively constant levels (Figure 9). A total of 35 fish were missing adipose fins, of which 18 were sacrificed, one died immediately after release and was recovered, and 16 were marked and released in good condition. Of the 19 heads recovered during event 1, 15 had valid CWTs for this stock and four were without CWTs. Among the fish that were missing adipose fins and of those sacrificed, 26% and 95%, respectively, were males. The fish that died after it was released was a female.

Event 2: Sampling on the Spawning Grounds

During event 2, 937 fish were inspected (624 large fish, 266 fish 555–659 mm MEF, and 47 fish <555 mm MEF), of which 78 were recaptured fish (56 large fish and 22 fish 555–659 mm MEF; Table 3). The smallest recaptured fish was 555 mm MEF and no sampled fish had shed their spaghetti tag. Adipose fins were missing on 87 fish sampled during event 2, and 44 of these were sacrificed. Of the 44 adipose-clipped fish sacrificed, 33 carried a valid CWT for this stock and one fish carried a CWT from the Crystal Lake Hatchery (Neets Bay release site). Among the fish that were missing adipose fins and of those sacrificed, 40% and 91%, respectively, were males.

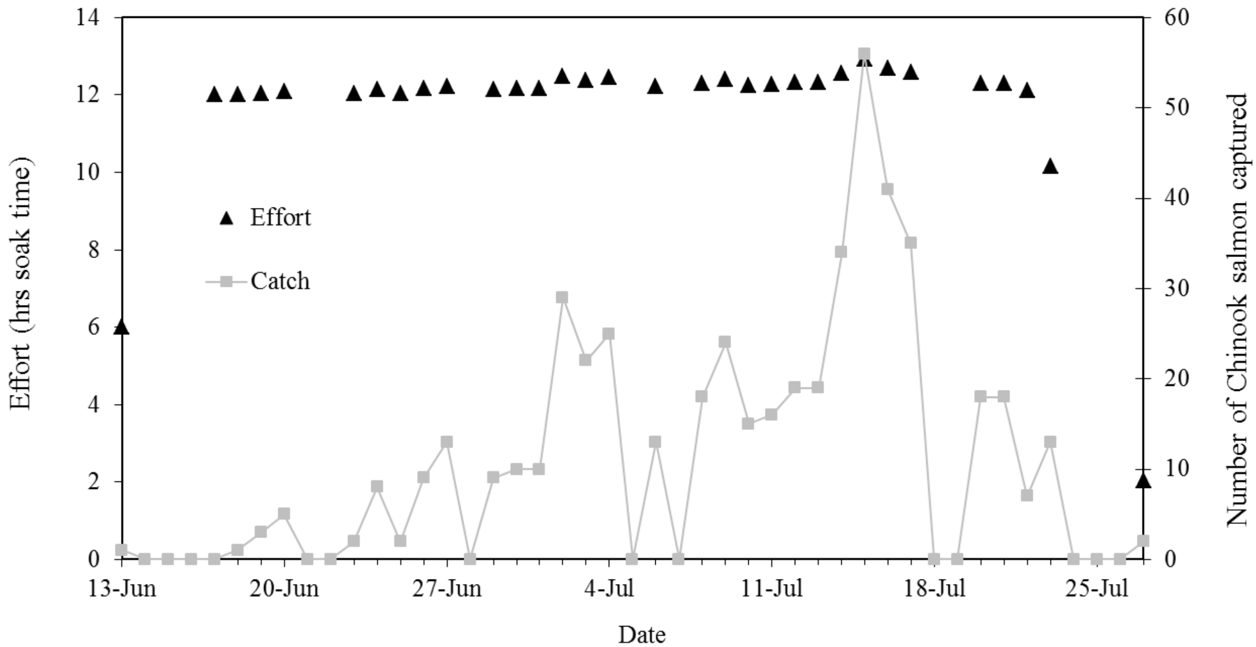

Figure 9.–Effort (in hours of soak time) and catch of Chinook salmon by date at SN1 on the Unuk River, 2009. SN = setnet.

Table 3.–Numbers of marked Chinook salmon ≥660 mm MEF (large; PANEL A) and 555–659 mm MEF (PANEL B) released in the lower Unuk River in 2009 by marking period, and the number inspected for marks and recaptured at each recovery location.

PANEL A: LARGE (≥660 mm MEF) CHINOOK SALMON

		Recovery location								
Marking dates	Number marked	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Cripple Creek	Boundary Creek	Total recovered	Fraction recovered
13 June – 3 July	66				1	1	2	1	5	0.076
4 July – 11 July	76	1	3	2	2	5	5		18	0.237
12 July – 15 July	75		3	1	2	7	4	2	19	0.253
16 July – 27 July	70		6	2	1	1	4		14	0.195
Total	287	1	12	5	6	14	15	3	56	0.195
Number inspected		9	111	29	105	177	176	17	624	
Fraction marked		0.11	0.11	0.17	0.06	0.08	0.09	0.18	0.09	

PANEL B: CHINOOK SALMON 555–659 mm MEF

		Recovery location								
Marking dates	Number marked	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Cripple Creek	Boundary Creek	Total recovered	Fraction recovered
13 June – 3 July	47									
4 July – 11 July	34		3			2	1		6	0.176
12 July – 15 July	43				1		4		5	0.116
16 July – 27 July	52		4			3	4		11	0.212
Total	176	3	7	5	1	5	9	3	22	0.125
Number inspected			40		28	91	96		266	
Fraction marked			0.18		0.04	0.05	0.09		0.08	

Abundance by Size

Length distributions of large fish that were marked and recaptured were not significantly different (P = 0.976, D = 0.066; Figure 10; M vs. R in Appendix A1). Likewise, no difference was detected in the length distributions of large fish that were marked and inspected (P = 0.730, D = 0.048, Figure 11; M vs. C in Appendix A1), or inspected and recaptured (P = 0.994, D = 0.057, Figure 12; C vs. R in Appendix A1). These results indicate that size selective sampling did not occur during either event for large-sized fish (Case I, Appendix A1).

The gender of approximately 7% (4 of 56) of recaptured fish were misidentified during event 1; consequently only fish sampled on the spawning grounds were used to estimate the ASL composition of the escapement. From 2004 to 2008 gender misidentifications during event 1 averaged 8.6% and ranged from 3.9% (2006; Weller and Evans 2009) to 13.5% (2004; Weller and McPherson 2006a).

The results of the tests outlined in Appendix A2, using data presented in Table 3, are as follows. The complete mixing test was significant (χ^2 = 8.5, df = 3, P = 0.037), while the equal proportions test was not significant (χ^2 = 9.2, df = 6, P = 0.16). The mixing test (χ^2 = 24.2, df = 21, P = 0.29) was also not significant, but the contingency table upon which this test was based was sparse (even upon pooling of recovery strata) and the criteria for a valid test (e.g., Agresti 1990) were not met. The mixing test result is therefore uninformative. (Table 3; Appendix A2). The nonsignificant equal proportions test indicates, however, that the pooled estimator (Eq 1) was appropriate for estimating abundance of large Chinook salmon. Estimated abundance of large fish is 3,157 (M_L = 287; C_L = 624; R_L = 56; SE = 354; 95% CI = 2,568–4,012), within the BEG range of 1,800–3,800 (Table 4, Figure 13; Hendrich et al. 2008).

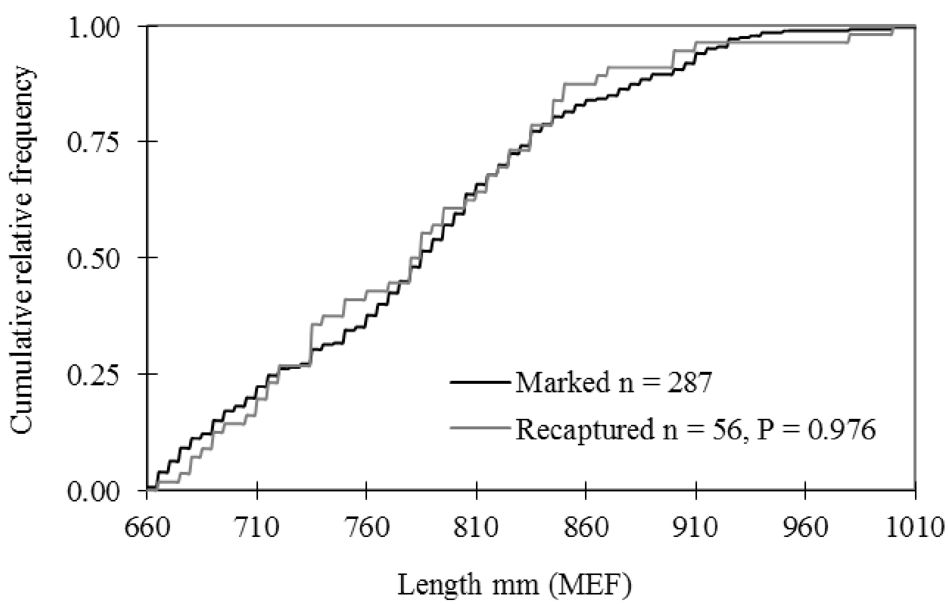

Figure 10.–Cumulative relative frequencies of large Chinook salmon (≥660 mm MEF) marked in the lower Unuk River in 2009 compared with those recaptured on the spawning grounds.

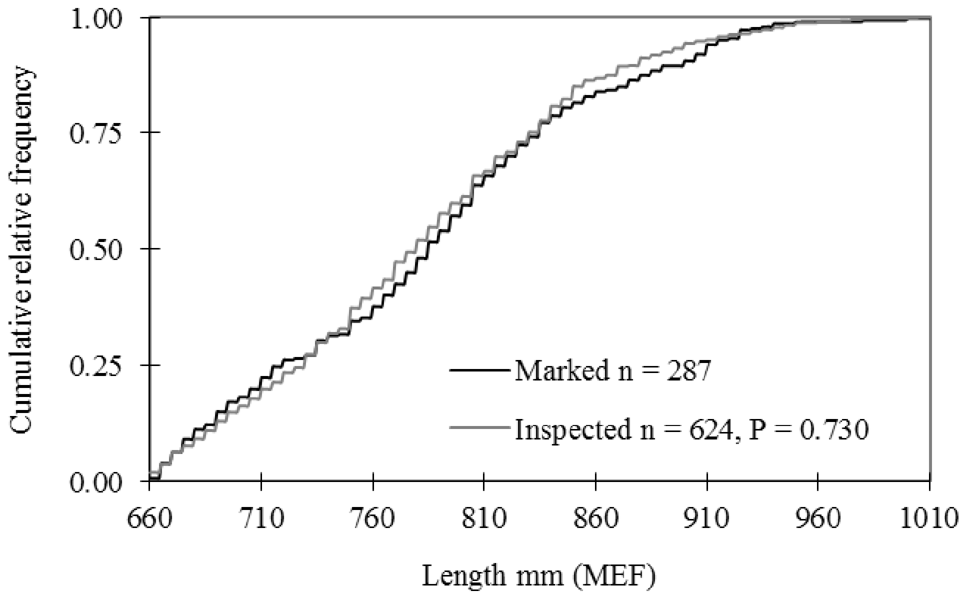

Figure 11.–Cumulative relative frequencies of large Chinook salmon (≥660 mm MEF) marked in the lower Unuk River in 2009 compared with those inspected on the spawning grounds.

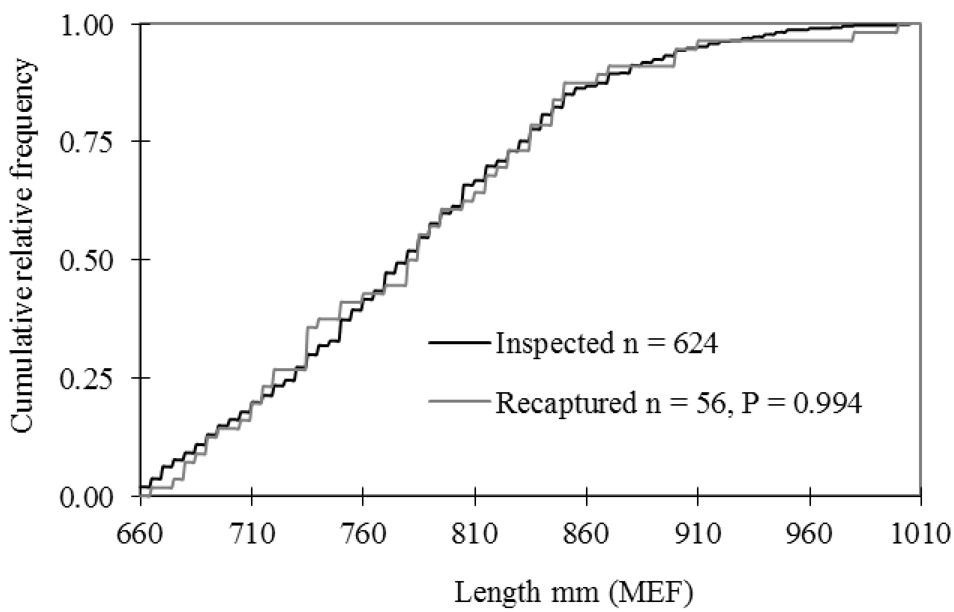

Figure 12.–Cumulative relative frequencies of large Chinook salmon (≥660 mm MEF) inspected on the spawning grounds in 2009 compared with those recaptured on the spawning grounds.

Length distributions of fish between 555 mm MEF, the size of the smallest recaptured fish (and the smallest fish that received a radio transmitter), and 659 mm MEF were significantly different between fish that were marked and inspected (P = 0.026; Figure 14; M vs. C in Appendix A1). No difference was detected in the length distributions of fish 555–659 mm MEF that were marked and recaptured (P = 0.523; Figure 15; M vs. R in Appendix A1), or inspected and recaptured (P = 0.802; Figure 16; C vs. R in Appendix A1). These results indicated that further evaluation was required (Appendix A1) to determine if size-selective sampling occurred. The statistics did not fit any of the A–D scenarios in Appendix A1. *Case IV* would be the conservative choice in this instance. *Case IV,* however, recommends stratification of data for one or both sampling events, which given the sparse number of recaptured fish, was an unsuitable alternative. The efficacy of stratification would also be impaired due to the fact that of 176 fish marked at SN1, no recaptures occurred from the initial 29% of fish marked. Consequently, abundance of fish between 555 mm MEF and 659 mm MEF was estimated indirectly by expanding the estimate for large fish by the estimated size composition of the spawning escapement (Eq 4). Testing of the samples collected from the spawning grounds in 1994 and 1997–2005 has consistently found no evidence of size or gender selectivity (Pahlke et al. 1996; Jones III et al. 1998; Jones III and McPherson 1999, 2000, 2002, Weller and McPherson 2003a-b. 2004, 2006a-b). Estimating the abundance between 555 mm MEF and 659 mm allowed comparison with the spawning distribution estimates from the telemetry study for fish 555–659 mm MEF. Estimated abundance of fish 555–659 mm MEF is 1,346 (SE = 180), based on 266 fish <555 mm MEF and 615 large samples collected on the spawning grounds. Statistical bias of the estimate is 1.5% and the bootstrap-derived 95% confidence interval for the estimated abundance is 1,044 to 1,782.

Abundance was further estimated separately for fish <555 mm MEF (Eq 3). Estimated abundance of fish <555 mm MEF is 238 (SE = 44), based on 47 fish <555 mm MEF and 615 large fish samples collected on the spawning grounds. Statistical bias of the estimate is 1.4% and the bootstrap-derived 95% confidence interval for the estimated abundance is 162 to 342.

EXPANSION FACTOR

The peak survey count of large Chinook salmon in the six index streams of the Unuk River was 687 fish in 2009 (Table 4; Appendix A4). Of the estimated 3,157 large Chinook salmon immigrating to the Unuk River in 2009, 21.8% were counted during peak survey counts. This percentage was the second highest on record (Table 4), and was attributed to excellent survey conditions during the peak of spawning. Using the 1997–2007 and 2009 mark recapture estimates and peak survey counts, the long-term mean expansion factor is 5.52 (Table 4); the mean SE (expansion factor) is 0.53, and the SE (prediction) is 1.66 (Eq 14 in Appendix A3). The latter value is required for calculation of variances of predicted escapements for years in which there was no mark-recapture estimate (Appendix A4, column 6).

AGE AND SEX COMPOSITION

There was evidence of gender misidentification during event 1; therefore only event 2 samples were used to estimate the ASL composition of the spawning population. An estimated 45.7% (SE = 1.6%) of the spawning population of Chinook salmon was comprised of age-1.3 fish (Table 5), on par with the 1997–2008 average of 46.0% (Appendix A7). Age-1.4 fish comprised only 12.0% (SE = 1.1%) of the estimated spawning population, the lowest contribution to the escapement from 1997–2009 (Appendix A7). Conversely, age-1.2 fish comprised 40.4% (SE = 1.6%) of the estimated spawning population. Since 1997, the percentage of age-1.2 fish in the spawning population has ranged from 8.4% (2001) to 48.3% (2004), and averaged 24.4% (Appendix A7).

Table 4.–Peak survey counts, mark-recapture estimates of abundance, expansion factors, and other statistics for large (≥660 mm MEF) Chinook salmon in the Unuk River (1997–2009 and 1997–2009 average). RP = relative precision.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average 1997–2009
Survey count	636	840	680	1,341	2,019	897	1,121	1,008	929	940	709	242	687	947
Recaptures, R	78	79	50	69	74	66	114	105	101	102	114	54	56	84
Marked, M	307	466	380	570	778	725	646	501	644	853	577	557	287	583
Inspected, C	761	707	523	719	1,014	644	985	836	749	680	1,127	305	624	754
Abundance, $\hat{N}_L$	2,970	4,132	3,914	5,872	10,541	6,988	5,546	3,963	4,742	5,645	5,668	3,104	3,157	5,257
SE ($\hat{N}_L$)	277	413	490	644	1,181	805	433	325	396	476	446	357	354	520
Survey count/$\hat{N}_L$, %	21.4	20.3	17.4	22.8	19.2	12.8	20.2	25.4	19.6	16.7	12.5	7.8	21.8	18.0
CV ($\hat{N}_L$), %	9.3	10.0	12.5	11.0	11.2	11.5	7.8	8.2	8.4	8.4	8.0	11.5	11.2	9.8
95% RP $\hat{N}_L$, %	18.3	19.6	24.5	21.5	22.0	22.6	15.3	16.1	16.4	16.5	15.4	22.5	22.0	19.2
Expansion factor (EF)[a], $\hat{\pi}_i$	4.67	4.92	5.76	4.38	5.22	7.79	4.95	3.93	5.10	6.01	7.99	12.83	4.60	5.52
SE (EF)[a, b]	0.44	0.49	0.72	0.48	0.58	0.90	0.39	0.32	0.43	0.50	0.63	1.48	0.52	0.53
CV (EF)[a]	9	10	13	11	11	12	8	8	8	8	17	12	11	10
95% RP (EF)[a]	18	20	25	21	22	23	15	16	16	16	32	23	22	19
$\hat{N}_L$ lower 95% C.I.	2,499	3,433	3,110	4,848	8,705	5,775	4,814	3,406	4,094	4,808	4,900	2,528	2,568	4,410
$\hat{N}_L$ upper 95% C.I.	3,636	4,974	5,071	7,347	13,253	8,845	6,530	4,684	5,579	6,786	6,685	3,991	4,012	6,448
Estimated bias, %	0.1	0.6	1.5	1.1	0.9	0.6	0.03	0.50	0.5	0.5	0.3	1.6	1.3	0.7

[a] 1997–2009 average does not include the 2008 EF.

[b] The standard error for prediction ($\sqrt{var(\pi_p)}$ as defined in Eq 15 in Appendix A3 using 1997–2007 and 2009 data is 1.66. The value is used in Appendix A4 in calculation of SE ($\hat{N}$) for years when there was no mark-recapture estimate.

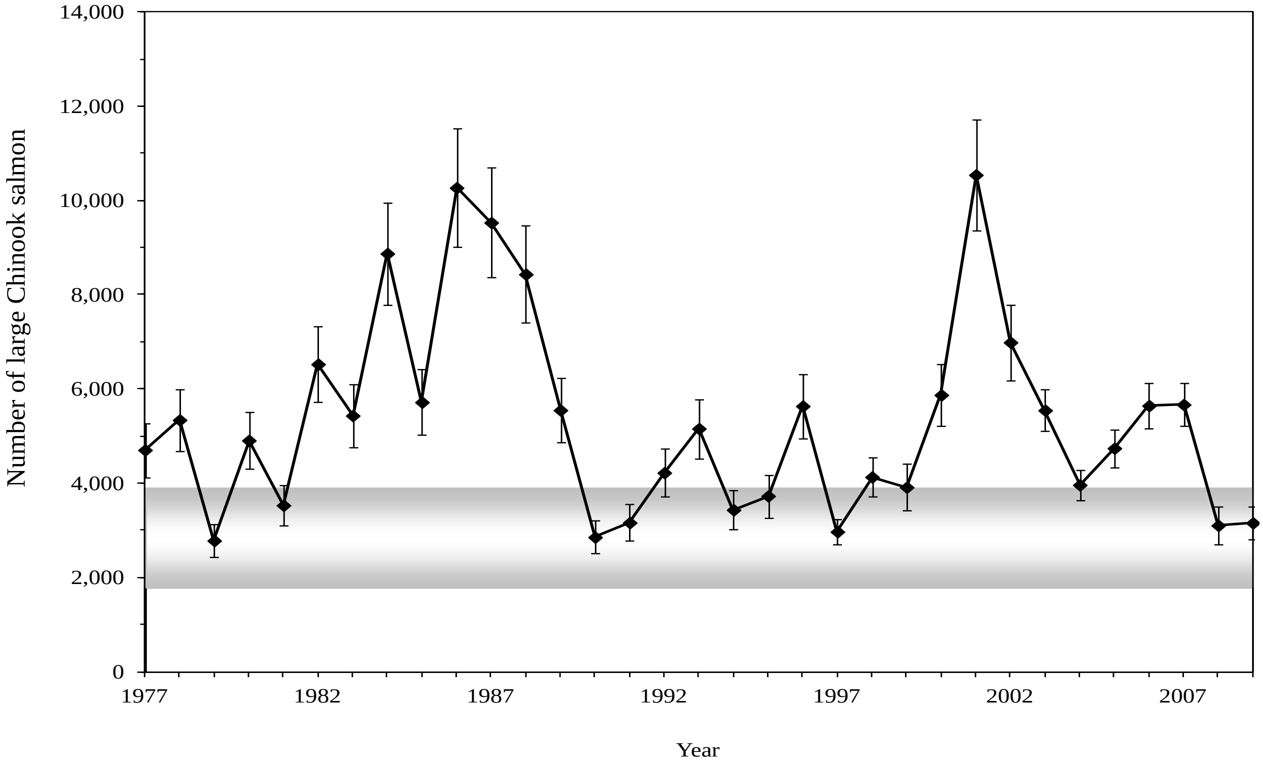

Figure 13.–Preferred estimates of spawning abundance and associated standard errors for large (≥660 mm MEF) Chinook salmon in the Unuk River relative to the biological escapement goal range (1,800–3,800; gray shaded bar), 1977–2009 (see Appendix A4 for numerical values).

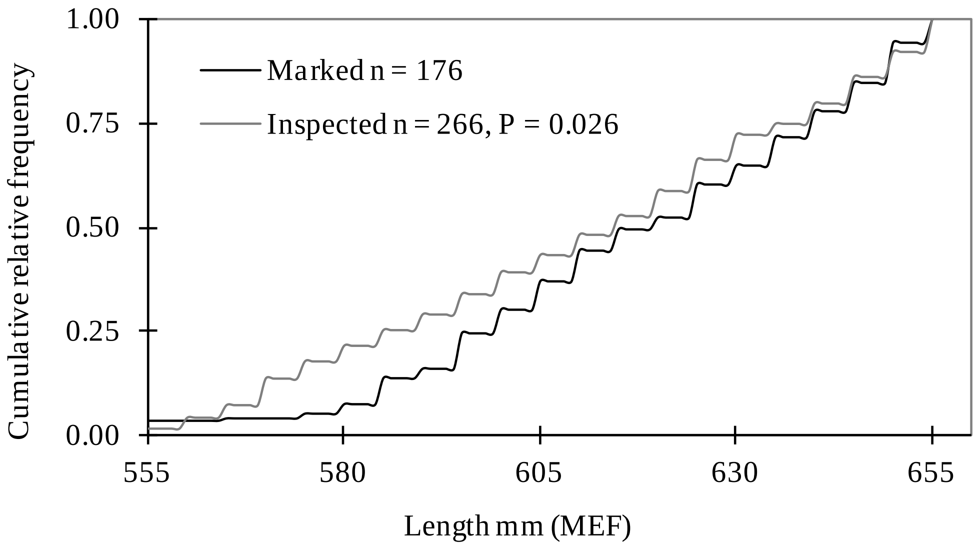

Figure 14.–Cumulative relative frequencies of Chinook salmon 555–659 mm MEF marked in the lower Unuk River in 2009 compared with those inspected on the spawning grounds.

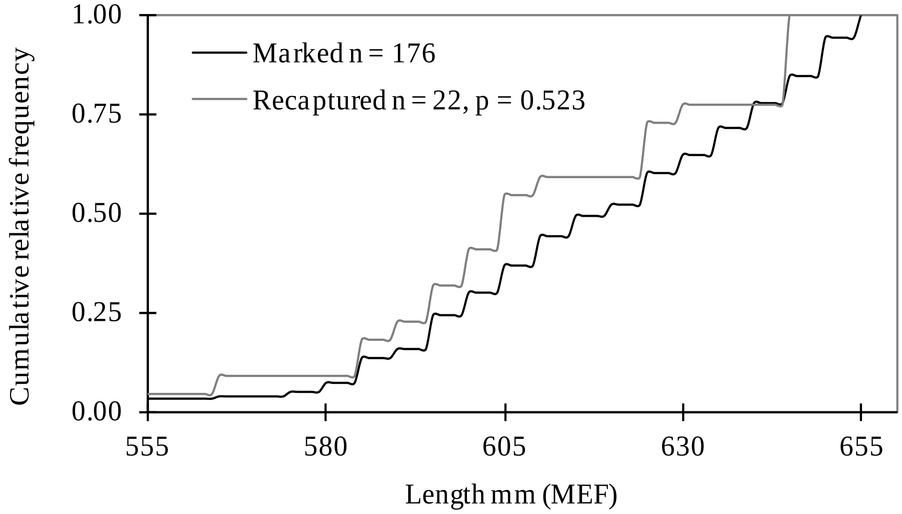

Figure 15.–Cumulative relative frequencies of Chinook salmon 555–659 mm MEF marked in the lower Unuk River in 2009 compared with those recaptured on the spawning grounds.

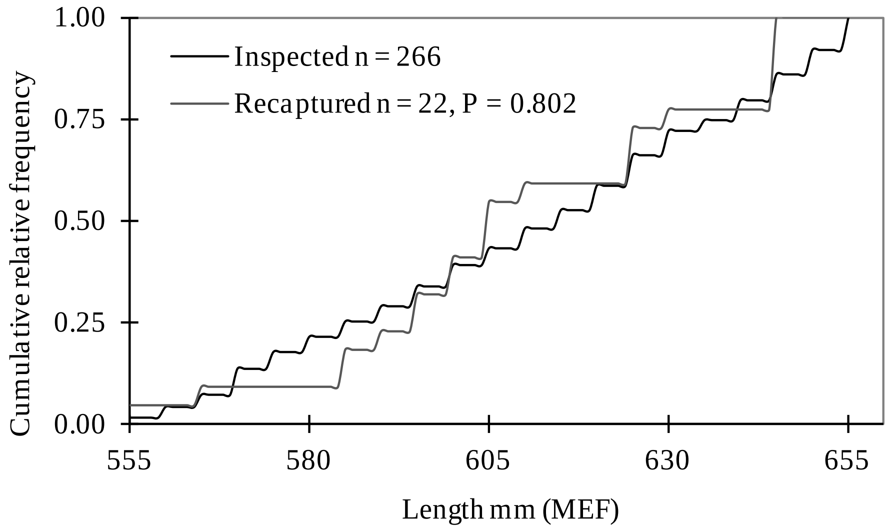

Figure 16.–Cumulative relative frequencies of Chinook salmon 555–659 mm MEF inspected on the spawning grounds in 2009 compared with those recaptured on the spawning grounds.

An estimated 28.5% (SE = 1.5%) of the spawning population was female in 2009, well below the previous 12-year average of 39.1% (Table 5, Appendix A7). There were an estimated 1,350 (SE = 164) spawning females in 2009, the fewest observed in the period from 1997–2009 (Table 5, Appendix A7). Estimated average lengths by age and sex were similar between events 1 and 2 in 2009 (Table 6).

Radiotelemetry Study

Transmitter Implantation

The fourth fish captured and marked at SN1 (19 June) was the first fish that was implanted with a radio transmitter. From 13 June through 15 July (Period 1; *h*) a total of 341 fish ≥555 mm MEF were captured and marked at SN1, and 117 of these fish also received a transmitter. The proportion of marked fish that received transmitters was 0.314 for fish 555–659 mm MEF (39 fish with transmitters and 85 without), and 0.333 for fish ≥ 660 mm MEF (39 fish with transmitters and 78 without).

A logistical problem delayed shipment of the final batch of transmitters. On 16 July, few unused transmitters remained while catch rates remained relatively high (Figure 9), consequently the rate of transmitter implantation was reduced from approximately every third marked fish to approximately every sixth marked fish in order to ensure transmitter implantation spanned the entire return. From 16 July to 27 July (Period 2; *h*) a total of 122 fish were marked at SN1, of which 23 received transmitters. The proportion of marked fish that received transmitters was 0.12 for fish 555–659 mm MEF (six fish with transmitters and 46 without) versus 0.24 for fish ≥ 660 mm MEF (17 fish with transmitters and 53 without).

Table 5.–Estimated age and sex composition of the escapement of small (<555 mm MEF; PANEL A), medium (555–659 mm MEF; PANEL B), large (≥660 mm MEF; PANEL C), and combined small, medium, and large sized (PANEL D) Chinook salmon in the Unuk River in 2009, as determined from spawning grounds samples.

		Brood year and age class						
		2006	2005	2004	2003	2003	2002	
		1.1	1.2	1.3	1.4	2.3	1.5	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON								
Males	Sample size	13	34					47
	p_{ijk} x100	27.7	72.3					100.0
	SE(p_{ijk}) x100	6.6	6.6					
	N_{ijk}	66	172					238
	SE(N_{ijk})	20	36					45
Sexes combined	Sample size	13	34					47
	p_{ij} x100	27.7	72.3					100.0
	SE(p_{ij}) x100	6.6	6.6					
	N_{ij}	66	172					238
	SE(N_{ij})	20	36					45
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON								
Males	Sample size		250	15				265
	p_{ijk} x100		94.0	5.6				99.6
	SE(p_{ijk}) x100		1.5	1.4				0.4
	N_{ijk}		1,265	76				1,341
	SE(N_{ijk})		170	21				179
Females	Sample size			1				1
	p_{ijk} x100			0.4				0.4
	SE(p_{ijk}) x100			0.4				0.4
	N_{ijk}			5				5
	SE(N_{ijk})			5				5
Sexes combined	Sample size		250	16				266
	p_{ij} x100		94.0	6.0				100.0
	SE(p_{ij}) x100		1.5	1.5				
	N_{ij}		1,265	81				1,346
	SE(N_{ij})		170	22				180

-continued-

Table 5.–Page 2 of 2.

		Brood year and age class						
		2006	2005	2004	2003	2003	2002	
		1.1	1.2	1.3	1.4	2.3	1.5	Total
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON								
Males	Sample size		90	229	31	1	2	353
	p_{ijk} x100		14.6	37.2	5.0	0.2	0.3	57.4
	SE(p_{ijk}) x100		1.4	2.0	0.9	0.2	0.2	2.0
	N_{ijk}		462	1,176	159	5	10	1,812
	SE(N_{ijk})		68	145	33	5	7	213
Females	Sample size		3	177	80		2	262
	p_{ijk} x100		0.5	28.8	13.0		0.3	42.6
	SE(p_{ijk}) x100		0.3	1.8	1.4		0.2	2.0
	N_{ijk}		15	909	411		10	1,345
	SE(N_{ijk})		9	117	63		7	163
Sexes combined	Sample size		93	406	111	1	4	615
	p_{ij} x100		15.1	66.0	18.0	0.2	0.7	100.0
	SE(p_{ij}) x100		1.4	1.9	1.6	0.2	0.3	
	N_{ij}		477	2,084	570	5	21	3,157
	SE(N_{ij})		70	241	80	5	10	354
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM, AND LARGE CHINOOK SALMON								
Males	Sample size	13	374	244	31	1	2	665
	p_{ik} x100	1.4	40.1	26.4	3.4	0.1	0.2	71.5
	SE(p_{ik}) x100	0.4	1.6	1.5	0.6	0.1	0.2	1.5
	N_{jk}	66	1,899	1,251	159	5	10	3,391
	SE(N_{jk})	20	241	156	33	5	7	402
Females	Sample size		3	178	80		2	263
	p_{ik} x100		0.3	19.3	8.7		0.2	28.5
	SE(p_{ik}) x100		0.2	1.3	0.9		0.2	1.5
	N_{jk}		15	914	411		10	1,350
	SE(N_{jk})		9	118	63		8	164
Sexes combined	Sample size	13	377	422	111	1	4	928
	p_{j} x100	1.4	40.4	45.7	12.0	0.1	0.4	100.0
	SE(p_{j}) x100	0.4	1.6	1.6	1.1	0.1	0.2	
	N_{j}	66	1,914	2,165	570	5	21	4,741
	SE(N_{j})	20	243	253	80	5	11	543

Table 6.–Estimated average length (MEF in mm) by age class, sex, and sampling event of Chinook salmon sampled in the Unuk River in 2009.

		Brood year and age class							
		2006	2005	2005	2004	2003	2003	2002	
		1.1	0.3	1.2	1.3	1.4	2.3	1.5	Total
PANEL A: EVENT 1, LOWER UNUK RIVER SET GILLNET									
Males[a]	Sample size	7		238	92	18		1	359
	Avg. length	381		628	756	885		1,000	670
	SD	17		43	70	48			99
	SE	6		3	7	11			5
Females[b]	Sample size		1	1	100	33			136
	Avg. length		815	715	797	884			817
	SD				40	55			59
	SE				4	10			5
Sexes combined[c]	Sample size	7	1	239	192	51		1	495
	Avg. length	381	815	628	777	885		1,000	711
	SD	17		43	60	52			111
	SE	6		3	4	7			5
PANEL B: EVENT 2, SPAWNING GROUNDS									
Males[d]	Sample size	13		374	244	31	1	2	670
	Avg. length	381		621	754	883	735	973	679
	SD	56		52	59	72		39	105
	SE	16		3	4	13		28	4
Females[c]	Sample size			3	178	80		2	267
	Avg. length			685	797	865		923	817
	SD			28	43	44		39	56
	SE			16	3	5		28	3
Sexes combined[e]	Sample size	13		377	422	111	1	4	937
	Avg. length	381		622	772	870	735	948	718
	SD	56		53	57	54		43	112
	SE	16		3	3	5		21	4

[a] Total includes three fish of undetermined age.
[b] Total includes one fish of undetermined age.
[c] Total includes four fish of undetermined age.
[d] Total includes five fish of undetermined age.
[e] Total includes nine fish of undetermined age.

Transmitter Tracking

The South Fork ground-based tracking station (tower) was operational from 10 June to 1 July and from 9 July to 23 August. The North Fork tower was operational from 20 June through 1 July and from 9 July through 21 August. Battery failure, and the inability of the attached solar panels to adequately recharge batteries given extended overcast conditions, was responsible for the gaps in coverage at the South and North Fork towers.

The Eulachon River tower was operational from 30 June through 22 August. This tower was installed in mid-June, but a switch failed shortly after installation; procurement and installation of a replacement switch caused this tower to be inoperable until 11 days after the first transmitter was released at SN1.

The Border tower was operational from 5 July to 26 July and from 5 August to 23 August. Bear damage was responsible for the loss of coverage from 26 July to 5 August. River conditions were unfavorable for safe transit to Border Creek prior to 5 July.

The tower located just above the mouth of the Chickamin River was operational from 25 June to 25 August.

Aerial surveys of the U.S. portion of the watershed occurred on 15 July and 6 August. Herman Creek and the Klahini River were included in the 15 July and 6 August surveys, respectively. The entire Unuk River watershed was surveyed on 15 August. The Blossom and Keta rivers were surveyed on 14 August.

Transmitter Fate Designations and Spawning Distribution

Of the 140 fish released with transmitters, 123 were determined to have successfully spawned (fate code 1; Appendix A5). The 6 U.S. index tributaries ($q = 1$–5 and 7) accounted for an estimated 69.8% of spawners ≥555 mm MEF, ranging from 23.5% in Cripple Creek to 3.5% in the Eulachon River (Table 7; Figure 2). An estimated 10.2% of spawners were bound for Canada ($q = 9$), and the transboundary Border Creek tributary ($q = 8$) accounted for 6% of the spawning population. Fish that spawned in the U.S. portion of the mainstem, including Sawmill Slough, accounted for 9.6% ($q = 6, 10, 11, 12$) of the population, and an additional 2.8% of the population spawned in an undefined portion of the mainstem ($q = 13$). Of fish designated as mainstem spawners, 83.4% received transmitters during the initial marking period (13 June to 15 July). One transmitter was tracked to the Chickamin River, resulting in an estimated rate of straying of 1.6%.

During the mark-recapture study, fish 555–659 mm MEF that were captured and marked at SN1 during the early portion of the return were not recaptured on the spawning grounds, as previously noted. To determine if this was due to the spawning location of these fish, spawning distribution of fish 555–659 mm MEF was estimated separately using four marking periods ($h = 4$; Table 8), each period composing approximately 25% of the total weighted estimate of spawning distribution. Results indicate that fish 555–659 mm MEF that received transmitters during the first marking period, 13 June to 15 July, were primarily bound for Canada (40%) and mainstem spawning locations (40%); locations not sampled during event 2.

A total of nine fish that received transmitters were determined to have either died prior to spawning or regurgitated their transmitters (fate code 2; Appendix A5). The maximum estimated rate of handling mortality would therefore be 6.8%. All nine fish received transmitters during the initial marking period (Table 7).

The fate of eight fish that received transmitters was unknown (fate code 3; Appendix A5). Of these eight fish, no post-release signal was ever received from seven of the transmitters. The eighth transmitter never passed upstream of the lower river towers; active signals were received from the transmitter 17 days after release, but no inactive signal was ever received. All eight fish received transmitters during the initial marking period (Table 7).

MIGRATORY TIMING

The estimated mean date of migration past SN1 in 2009, based on the recapture of marked fish in the major U.S. tributaries, was 10 July, slightly earlier than the 1997–2008 average of 12 July (Table 9). The earliest estimated mean migration date was for fish destined for Boundary Creek (6 July). The latest mean migration date was 15 July for the Lake Creek and Genes Lake Creek stocks.

Mean date of migration past SN1 was also estimated using fate 1 locations of radio-tagged fish, with the understanding that the differential rate of transmitter implantation during event 1 (of fish captured at SN1, the latter 22% received transmitters at roughly half the rate as the preceding 78%) would cause these estimates to be biased. Estimated mean dates of migration at SN1 were similar to estimates based on the recapture of marked fish for stocks from the major U.S tributaries (9–14 July) and for the total inriver return (9 July; Table 9). The mean date of migration for fish bound for Canada was 6 July. The mean date of migration past SN1 for "mainstem spawners," defined as fate 1 fish that did not spawn in the six index streams, Boundary Creek, the Chickamin River, or Canada, was 2 July.

For fish captured more than once at SN1, an average of 4.4 days elapsed between the time fish were tagged and released (sulking period) and when they were subsequently recaptured at SN1 (Appendix A6). The average sulking period for fish that received transmitters (6.7 days) was roughly twice the period for fish that did not receive transmitters (3.7 days). The maximum sulking period observed was 13.8 days.

SMOLT ABUNDANCE AND OVERWINTER SURVIVAL

Details of daily catch, CPUE, and tagging of juvenile Chinook salmon from 1993–2004 are reported in Hendrich et al. (2008; Tables D1–D3), and from 2005 through spring 2009 in Weller and Evans (2012: Appendices B1–B3). Details of daily catch, CPUE, and tagging of juvenile Chinook salmon from fall 2009 through spring 2010 are provided in Appendices B1–B3, and mean length and weight of juvenile Chinook salmon from 1978 through spring of 2010 are provided in Appendix B4. Details of parr abundance, overwinter survival, and smolt abundance estimation from the 1992–2001 broods are reported in Weller and Evans (2012).

<u>Brood Year 2002</u>

A total of 44,498 parr and 14,396 smolt from the 2002 brood were released with valid CWTs (Table 10; Appendix B1). Overwinter survival was estimated to be 0.599 (SE = 0.108), resulting in an estimated total of 41,044 finclipped smolt emigrating from the Unuk River in 2004 (Table 10). The estimated abundance of brood year 2002 parr and smolt was 752,455 (SE = 168,738) and 450,612 (SE = 59,793; cv_{smolt} = 13.3%), respectively (Table 11).

Table 7.–Spawning location information for Chinook salmon $\geq$555 mm MEF that were equipped with radio transmitters in the lower Unuk River in 2009.

		Period (h)												
		Period 1 (13 June – 15 July)						Period 2 (16 July – 27 July)						
Spawning location code (q)	Location name	$s_{q,h}$	b_h	x_h	$\hat{z}_h$	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$s_{q,h}$	b_h	x_h	$\hat{z}_h$	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$\hat{K}_q$
1	Eulachon River	3	117	17	0.639	0.030	0.019	1	23	0	0.361	0.043	0.016	0.035
2	Clear Creek	11	117	17	0.639	0.110	0.070	4	23	0	0.361	0.174	0.063	0.133
3	Lake Creek	5	117	17	0.639	0.050	0.032	1	23	0	0.361	0.043	0.016	0.048
4	Kerr Creek	8	117	17	0.639	0.080	0.051	4	23	0	0.361	0.174	0.063	0.114
5	Gene's Lake	11	117	17	0.639	0.110	0.070	4	23	0	0.361	0.174	0.063	0.133
6	Sawmill Slough	3	117	17	0.639	0.030	0.019		23	0	0.361			0.019
7	Cripple Creek	27	117	17	0.639	0.270	0.172	4	23	0	0.361	0.174	0.063	0.235
8	Border Creek	7	117	17	0.639	0.070	0.045	1	23	0	0.361	0.043	0.016	0.060
9	Canada[a]	11	117	17	0.639	0.110	0.070	2	23	0	0.361	0.087	0.031	0.102
10	Mainstem from North and South Fork towers to Kerr Creek	1	117	17	0.639	0.010	0.006		23	0	0.361			0.006
11	Mainstem from Genes Lake to Cripple Creek[b]	4	117	17	0.639	0.040	0.026		23	0	0.361			0.026
12	Mainstem from Cripple Creek to the Canadian border[c]	7	117	17	0.639	0.070	0.045		23	0	0.361			0.045
13	Mainstem undefined[d]	2	117	17	0.639	0.020	0.013	1	23	0	0.361	0.043	0.016	0.028
14	Chickamin River		117	17	0.639			1	23	0	0.361	0.043	0.016	0.016
Total		100					0.638	23					0.363	1.000

Note: h = temporal period when fish received transmitters; $s_{q,h}$ = number of fish released with transmitters during period h that survived to spawn in location q; b_h = number of fish released with transmitter during period h; x_h = number of fish with transmitters during period h that either died or regurgitated their transmitters prior to spawning; $\hat{z}_h$ = estimated weight for period h (proportion of all fish $\geq$555 mm MEF captured at the tagging site during period h); $\hat{K}_{q,h}$ = unweighted estimates of spawning distribution probabilities by location and period; $\hat{z}_h \hat{K}_{q,h}$ = weighted estimates of spawning distribution probabilities by location and period; $\hat{K}_q$ = weighted estimates of spawning distribution probabilities by location.

[a] Upstream from the Border Creek tower; does not include Border Creek.

[b] Does not include Sawmill Slough.

[c] Does not include Border Creek.

[d] Transmitter(s) passed upstream of the North or South Fork towers, but no specific location therein was identified.

Table 8.–Spawning location for Chinook salmon 555–659 mm MEF that were equipped with radio transmitters in the lower Unuk River in 2009.

		Temporal period h ($\sum h = 4$) when fish received transmitters																
		Period 1 (13 June – 4 July; *b* = 13; *z* = 0.261)				Period 2 (5–13 July; *b* = 17; *z* = 0.240)				Period 3 (14–16 July; *b* = 13; *z* = 0.259)				Period 4 (17–27 July; *b* = 23; *z* = 0.239)				
Spawning location code (q)	Location name ($\sum q = 14$)	$s_{q,h}$	x_h	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$s_{q,h}$	x_h	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$s_{q,h}$	x_h	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$s_{q,h}$	x_h	$\hat{K}_{q,h}$	$\hat{z}_h \hat{K}_{q,h}$	$\hat{K}_q$
1	Eulachon River		3			1	4	0.077	0.018									0.018
2	Clear Creek		3			1	4	0.077	0.018	2	0	0.154	0.040					0.058
3	Lake Creek		3			1	4	0.077	0.018	1	0	0.077	0.020					0.038
4	Kerr Creek		3				4							2		1.000	0.239	0.239
5	Gene's Lake		3			2	4	0.154	0.037	2	0	0.154	0.040					0.077
6	Sawmill Slough		3				4											
7	Cripple Creek	1	3	0.100	0.026	5	4	0.385	0.092	5	0	0.385	0.100					0.218
8	Border Creek	1	3	0.100	0.026	1	4	0.077	0.018									0.045
9	Canada[a]	4	3	0.400	0.105	2	4	0.154	0.037	2	0	0.154	0.040					0.181
10	Mainstem from North and South Fork towers to Kerr Creek		3				4											
11	Mainstem from Genes Lake to Cripple Creek[b]	1	3	0.100	0.026		4											0.026
12	Mainstem from Cripple Creek to the Canadian border[c]	3	3	0.300	0.078		4											0.078
13	Mainstem undefined[d]		3				4			1	0	0.077	0.020					0.020
14	Chickamin River		3				4											
		10			0.261	13			0.240	13			0.259	2			0.239	1.000

Note: $s_{q,h}$ = number of fish released with transmitters during period h that survived to spawn in location q; b_h = number of fish released with transmitters during period h; x_h = number of fish released with transmitters during period h that either died or regurgitated their transmitters prior to spawning; $\hat{z}_h$ = estimated weight for period h (the proportion of all fish 555–659 mm MEF captured at the tagging site during period h); $\hat{K}_{q,h}$ = unweighted estimates of spawning distribution probabilities by location and period; $\hat{z}_h \hat{K}_{q,h}$ = weighted estimates of spawning distribution probabilities by location and period; $\hat{K}_q$ = weighted estimates of spawning distribution probabilities by location.

[a] Upstream from the Border Creek tower; does not include Border Creek.

[b] Does not include Sawmill Slough.

[c] Does not include Border Creek.

[d] Transmitter(s) passed upstream of the North or South Fork towers, but no specific location therein was identified.

Table 9.–Estimated mean date of migration of Chinook salmon stocks past the set gill net site (SN1) on the Unuk River (Panel A), standard error (Panel B), and sample size (Panel C), as determined from mark-recapture (1997–2009) and radio telemetry (RT; 2009) studies.

		Tributary									
Year[a]	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Cripple Creek	Boundary Creek	Canada[b]	Mainstem[c]	Tributaries combined
PANEL A: ESTIMATED MEAN DATE OF MIGRATION AT SN1											
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	11-Jul	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
2006	9-Jul	14-Jul	11-Jul	5-Jul	3-Jul	9-Jul	11-Jul	12-Jul			10-Jul
2007	21-Jul	27-Jul	21-Jul	23-Jul	22-Jul	22-Jul	23-Jul	23-Jul			22-Jul
2008	19-Jul		22-Jul	20-Jul	29-Jul	21-Jul	13-Jul				22-Jul
2009	10-Jul	9-Jul	15-Jul	15-Jul	10-Jul	12-Jul	12-Jul	6-Jul			12-Jul
2009 RT[d]	9-Jul	13-Jul	13-Jul	14-Jul	12-Jul	14-Jul	11-Jul	9-Jul	6-Jul	2-Jul	
1997–2008 average[e]	12-Jul	16-Jul	12-Jul	11-Jul	14-Jul	12-Jul	12-Jul	13-Jul			13-Jul
PANEL B: STANDARD ERRORS OF THE MEAN DATE OF MIGRATION (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
2006	0.35		3.41	1.85		1.19	1.65	5.98			0.86
2007	0.31	0.97	0.86	1.21	1.54	0.47	0.77	2.50			0.34
2008	0.37		1.38	1.45	1.00	2.21					1.07
2009	0.37		0.88	2.71	3.68	1.04	1.17	8.50			0.69
2009 RT[d]	0.65	1.65	1.86	1.77	1.96	1.29	0.97	3.55	1.82	1.42	
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
2006	1,004	1	9	7	2	54	40	4			117
2007	623	9	21	8	5	60	17	2			122
2008	649		29	5	2	20	1				57
2009	476	1	19	5	7	19	24	3			78
2009 RT[d]	140	4	15	6	12	15	31	8	13	18	122

[a] Note that 2000, 2004, and 2008 are leap years.

[b] Canada includes all locations above the US/Canada border with the exception of Boundary Creek/Lake.

[c] Mainstem includes all locations below the US/Canada border, with the exception of the seven tributary systems listed.

[d] Results from the telemetry data are presented for comparative purposes only due to known bias present in the estimates; see Discussion.

[e] Average does not include the 2009 RT results.

Table 10.–Number of fall parr (M_f) and spring smolt (M_s) released with adipose fin clips, 1992–2006 brood years.

Brood year	Year tagged	Season fish were marked	M_f , M_s	$\hat{M}_{f,valid}$, $\hat{M}_{s,valid}$	$\hat{v}_{\bullet,f}$, $\hat{v}_{\bullet,s}$	Recovery years	Recovery ages	$\hat{S}$	$SE(\hat{S})$	$\hat{M}_{f \to s}$	$SE(\hat{M}_{f \to s})$	$\hat{M}$
1992	1993	Fall	13,935	13,789	21	1996–1999	1.2–1.5	0.805	0.400	11,214	5,518	
1992	1994	Spring	2,642	2,642	5	1996–1999	1.2–1.5					13,856
1993	1994	Fall	20,526	20,526	108	1996–2000	1.1–1.5	0.738	0.169	15,153	3,468	
1993	1995	Spring	3,227	3,227	23	1996–2000	1.1–1.5					18,380
1994	1995	Fall	40,206	40,206	50	1997–2001	1.1–1.5	0.343	0.082	13,807	3,293	
1994	1996	Spring	7,456	7,456	27	1997–2001	1.1–1.5					21,263
1995	1996	Fall	39,177	39,177	133	1998–2002	1.1–1.5	0.574	0.083	22,497	3,255	
1995	1997	Spring	12,517	12,517	74	1998–2002	1.1–1.5					35,014
1996	1997	Fall	61,905	61,905	154	1999-2003	1.1–1.5	0.636	0.093	39,353	5,749	
1996	1998	Spring	17,121	17,121	67	1999–2003	1.1–1.5					56,474
1997	1998	Fall	33,888	33,888	52	2000–2004	1.1–1.5	0.678	0.185	22,961	6,273	
1997	1999	Spring	7,948	7,948	18	2000–2004	1.1–1.5					30,909
1998	1999	Fall	16,661	16,661	57	2001–2005	1.1–1.5	0.736	0.135	12,258	2,245	
1998	2000	Spring	13,333	13,333	62	2001–2005	1.1–1.5					25,591
1999	2000	Fall	31,925	31,925	27	2002–2006	1.1–1.5	0.483	0.129	15,419	4,121	
1999	2001	Spring	16,561	16,561	29	2002–2006	1.1–1.5					31,980
2000	2001	Fall	44,394	44,371	124	2003–2007	1.1–1.5	0.531	0.082	23,574	3,637	
2000	2002	Spring	11,971	11,971	63	2003–-2007	1.1–1.5					35,545
2001	2002	Fall	54,546	54,546	49	2004–2008	1.1–1.5	0.273	0.058	14,872	3,188	
2001	2003	Spring	11,837	11,837	39	2004–2008	1.1–1.5					26,709
2002	2003	Fall	44,498	44,498	87	2005–2009	1.1–1.5	0.599	0.108	26,648	4,817	
2002	2004	Spring	14,396	14,396	47	2005–2009	1.1–1.5					41,044

-continued-

Table 10.–Page 2 of 2.

Brood year	Year tagged	Season fish were marked	M_f, M_s	$\hat{M}_{f,valid}$, $\hat{M}_{s,valid}$	$\hat{v}_{\bullet,f}$, $\hat{v}_{\bullet,s}$	Recovery years	Recovery ages	$\hat{S}$	$SE(\hat{S})$	$\hat{M}_{f \to s}$	$SE(\hat{M}_{f \to s})$	$\hat{M}$
2003	2004	Fall	27,129	27,129	21	2006–2009	1.1–1.4	0.266	0.079	7,211	2,133	
2003	2005	Spring	8,618	8,585	25	2006–2009	1.1–1.4					15,829
2004	2005	Fall	24,271	24,271	23	2007–2009	1.1–1.3	0.514	0.142	12,473	3,455	
2004	2006	Spring	16,371	16,269	30	2007–2009	1.1–1.3					28,844
2005	2006	Fall	32,799	32,799	58	2007–2009	1.0–1.2	0.253	0.055	8,298	1,805	
2005	2007	Spring	4,731	4,721	33	2007–2009	1.0–1.2					13,029
2006	2007	Fall	45,089	45,089	11	2009	1.1	0.512	0.276	23,076	12,444	
2006	2008	Spring	10,489	10,489	5	2009	1.1					33,565

Note: $\hat{M}_{f,valid}$, $\hat{M}_{s,valid}$ = estimated number of fall parr and spring smolt that were released with valid coded wire tags; $\hat{v}_{\bullet,f}$, $\hat{v}_{\bullet,s}$ = number of fish with valid CWTs that were subsequently recovered; $\hat{S}$ = estimated proportion of coded wire tagged parr that survived to the following spring; $\hat{M}_{f \to s}$ = estimated number of adipose-finclipped parr that survived to smolt; $\hat{M}$ = estimated total number of adipose-finclipped smolt. Estimates for the 2003–2006 brood years are preliminary, pending complete brood year returns.

Table 11.–The estimated total number of smolt released with adipose fin clips $\hat{M}$, the number of returning adults that were examined in river for the presence of an adipose fin clip $n_\bullet$, the number of fish examined that possessed an adipose fin clip $a_\bullet$, the estimated abundance of smolt $\hat{N}_{smolt}$ and the associated standard error of the estimate $SE(\hat{N}_{smolt})$, the estimated abundance of parr $\hat{N}_{fingerling}$ and the associated error of the estimate $SE(\hat{N}_{fingerling})$, 1992–2006 brood years.

Brood year	Recovery ages	$\hat{M}$	Recovery years	$n_\bullet$	$a_\bullet$	$\hat{N}_{smolt}$	$SE(\hat{N}_{smolt})$	$\hat{N}_{fingerling}$	$SE(\hat{N}_{fingerling})$
1992	1.1–1.5	13,856	1995–1999	795	26	408,521	176,932	507,650	334,752
1993	1.1–1.5	18,380	1996–2000	1,375	133	188,746	38,709	255,674	78,576
1994	1.1–1.5	21,263	1997–2001	1,040	92	238,023	43,531	693,103	208,312
1995	1.1–1.5	35,014	1998–2002	1,805	200	314,609	35,875	547,876	100,921
1996	1.1–1.5	56,474	1998–2003	2,343	271	486,678	56,694	765,584	143,055
1997	0.1–1.5	30,909	2000–2004	1,186	116	313,589	69,072	462,826	162,422
1998	1.1–1.5	25,591	2001–2005	2,112	198	271,735	30,003	369,347	78,984
1999	1.1–1.5	31,980	2002–2006	752	79	301,019	49,889	623,264	196,006
2000	1.1–1.5	35,545	2003–2007	2,573	220	414,007	49,935	779,643	152,740
2001	1.1–1.5	26,709	2004–2008	1,119	114	260,132	38,476	954,079	248,475
2002	1.1–1.5	41,044	2005–2009	2,557	232	450,612	59,793	752,455	168,738
2003	1.1–1.4	15,829	2006–2009	723	68	166,103	29,178	624,875	214,951
2004	1.1–1.3	28,844	2007–2009	837	80	298,419	47,385	580,693	185,392
2005	0.1–1.2	13,029	2007–2009	611	46	169,660	33,105	670,644	195,964
2006	1.1	33,565	2009	20	2	234,960	130,811	459,100	355,846

Note: Estimates for the 2003–2006 brood years are preliminary, pending complete brood year returns.

Brood Year 2003

A total of 27,129 parr and 8,585 smolt from the 2003 brood were released with valid CWTs (Table 10; Appendix B1). Overwinter survival was estimated to be 0.266 (SE = 0.079), resulting in an estimated total of 15,829 finclipped smolt emigrating from the Unuk River in 2005 (Table 10). The estimated abundance of brood year 2003 parr and smolt was 624,875 (SE = 214,951) and 166,103 (SE = 29,178), respectively (Table 11). Brood year 2003 estimates are preliminary pending returns of age-1.5 fish in 2010.

Brood Year 2004

A total of 24,271 parr and 16,269 smolt from the 2004 brood were released with valid CWTs (Table 10; Appendix B1). Overwinter survival was estimated to be 0.514 (SE = 0.142), resulting in an estimated total of 28,844 finclipped smolt emigrating from the Unuk River in 2006 (Table 10). The estimated abundance of brood year 2004 parr and smolt was 580,693 (SE = 185,392) and 298,419 (SE = 47,385), respectively (Table 11). Brood year 2004 estimates are preliminary pending returns of age-1 to -4 fish in 2010 and age-1.5 fish in 2011.

Brood Year 2005

A total of 32,799 parr and 4,721 smolt from the 2005 brood were released with valid CWTs (Table 10; Appendix B1). Overwinter survival was estimated to be 0.253 (SE = 0.055), resulting in an estimated total of 13,029 finclipped smolt emigrating from the Unuk River in 2007 (Table 10). The estimated abundance of brood year 2005 parr and smolt was 670,644 (SE = 195,964) and 169,660 (SE = 33,105), respectively (Table 11). Brood year 2005 estimates are preliminary pending returns of age-1.3 fish in 2010, age-1to -4 fish in 2011, and age-1.5 fish in 2012.

Brood Year 2006

A total of 45,089 parr and 10,489 smolt the 2006 brood were released with valid CWTs (Table 10; Appendix B1). Overwinter survival was estimated to be 0.512 (SE = 0.055), resulting in an estimated total of 33,565 finclipped smolt emigrating from the Unuk River in 2008 (Table 10). The estimated abundance of brood year 2006 parr and smolt was 459,100 (SE = 355,846) and 234,960 (SE = 130,811), respectively (Table 11). Brood year 2006 estimates are preliminary pending returns of age-1.2 fish in 2010, age-1.3 fish in 2011, age-1 to 4 fish in 2012, and age-1.5 fish in 2013.

Brood Year 2007

A total of 16,595 parr and 5,573 smolt from the 2007 brood were released with valid CWTs (Appendix B1).

Brood Year 2008

A total of 44,927 parr and 8,190 smolt from the 2008 brood were released with valid CWTs (Appendix B1).

HARVEST, INCIDENTAL FISHING MORTALITY, TOTAL FISHING MORTALITY, PRODUCTION, EXPLOITATION RATE, AND MARINE SURVIVAL RATE ESTIMATES

Results for the 1992–2001 broods are detailed in Weller and Evans (2012) and are summarized below for comparative purposes. Minor updates to the 1992–2001 brood year return estimates, primarily due to revised estimates of the adult equivalent conversion factors, are incorporated. Results presented below for the 2003–2006 broods are incomplete, pending further cohort returns. Results in tables presented by age class and brood or return year are subject to rounding error.

Estimation of Fraction of Adults Bearing CWTs

The estimated fractions of Chinook salmon bearing a valid CWT ($\hat{\theta}$) from the 1992–2002 brood years (broods with completed returns) ranged from .0282 (SE = 0.0055) for brood year 1992 to 0.1075 (SE = 0.0065) for brood year 1996 (Table 12; Appendix B5; Hendrich et al. 2008). Preliminary estimates of $\hat{\theta}$ from the 2003–2005 broods, pending further returns, are 0.0840 (SE = 0.0105), 0.0590 (SE = 0.0088) and 0.0636 (SE = 0.0093), respectively.

Fishing Mortality, Production, Exploitation, and Marine Survival

Brood Year 2002

Brood year 2002 returns were completed in 2009. A nominal estimate of 2,697 (SE = 335) fish were harvested from brood year 2002 returns (Table 13; Appendix B6). The half-width of the calculated 95% confidence interval is 24.3% of the harvest estimate. Use of AEQ conversion factors (Table 14) results in an estimated harvest of 2,518 (SE = 313) AEQs (Table 15). An estimated 1,761 (SE = 265) fish were harvested by commercial troll gear, approximately 65% of the total harvest (Table 16). Drift gillnet (469 fish; SE = 149), recreational (315 fish; SE = 114), and purse seine (152; SE = 83) gear accounted for approximately 17%, 12%, and 6% of the total estimated harvest, respectively (Table 16). Harvest occurred primarily in the Southeast (45%; 1,218 fish; SE = 220), Northwest (30%; 813 fish; SE = 202), and Southwest (13%; 356 fish; SE = 110) Quadrants of SEAK (Table 17). Approximately 5% of harvest occurred in the waters of British Columbia (131 fish; SE = 79; Table 17). Age-1.3, -1.2, and -1.4 fish accounted for roughly 59% (1,588 fish; SE = 259), 26% (711 fish; SE = 181), and 14% (383; SE = 110) of the estimated harvest, respectively (Table 13).

An estimated 1,589 fish (SE = 414) from the 2002 brood died as a result of incidental fishing mortality (nominal fish; Table 13). Use of AEQ factors (Table 14) results in an estimated incidental mortality of 1,132 (SE = 328) AEQs (Table 15).

Total fishing mortality for the 2002 brood was estimated to be 3,649 (SE = 453) AEQs (Table 18). Based on an estimated spawning abundance of 9,648 (SE = 603) fish (Weller and McPherson 2006b; Weller and Evans 2009; Table 12 in Weller and Evans 2012), production was estimated to be 13,318 AEQs (SE = 754), and the exploitation rate was therefore estimated to be 27.4% (SE = 2.8%; Table 18). The marine survival rate was estimated to be 2.96% (SE = 0.43%; Table 18).

Table 12.–The number of returning adults that were examined inriver for the presence of an adipose fin clip n_i, the number of fish examined that possessed an adipose fin clip a_i, the number of adipose-finclipped fish that were sacrificed for coded wire tag verification a_i', the number of sacrificed fish that possessed a valid Unuk River Chinook salmon coded wire tag t_i, the estimated fraction of adults that possessed a valid Unuk River Chinook salmon coded wire tag $\hat{\theta}$ and the associated standard error, and the estimated variance (var) and squared coefficient of variability (G) for $\widehat{\theta^{-1}}$, 1992–2006 brood years.

Brood year	n_i	a_i	a_i'	t_i	$\hat{\theta}$	$SE(\hat{\theta})$	$var(\widehat{\theta^{-1}})$	$G(\widehat{\theta^{-1}})$
1992	795	26	22	19	0.0282	0.0055	61.1659	0.0488
1993	1,375	133	103	94	0.0883	0.0074	0.9397	0.0073
1994	1,040	92	53	46	0.0768	0.0080	2.0153	0.0119
1995	1,805	200	99	94	0.1052	0.0071	0.4273	0.0047
1996	2,343	271	113	105	0.1075	0.0065	0.3270	0.0038
1997	1,186	116	37	29	0.0767	0.0088	2.4286	0.0143
1998	2,112	198	53	53	0.0938	0.0063	0.5259	0.0046
1999	752	79	22	19	0.0907	0.0117	2.3067	0.0190
2000	2,573	220	74	71	0.0820	0.0054	0.6639	0.0045
2001	1,119	114	36	33	0.0934	0.0094	1.2189	0.0106
2002	2,557	232	74	54	0.0662	0.0057	1.7981	0.0079
2003	723	68	28	25	0.0840	0.0105	2.4434	0.0172
2004	837	80	34	21	0.0590	0.0088	7.3049	0.0255
2005	611	46	45	38	0.0636	0.0093	6.1596	0.0249
2006	20	2	2	1	0.0500	0.0274	23.1475	0.0579

Note: Estimates for the 2003–2006 brood years are preliminary, pending complete brood year returns.

Table 13.–Nominal estimates of landed catch, incidental mortality, spawning abundance, and total returns of Unuk River Chinook salmon, by age class, for brood years 1992–2006. Associated estimates of standard error are noted in gray font. Rounding error is present.

	Landed catch						Incidental mortality						Spawning abundance[a]						Total return					
	Age class						Age class						Age class						Age class					
Brood	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1992	35	81	267	155		538	134	111	15	6		266		736	1,240	1,207	16	3,199	169	928	1,523	1,368	16	4,003
	35	80	157	155		237						263		349	128	140	12	397						532
1993		161	420	707		1,288	207	200	15	40		462		916	2,595	1,581	50	5,142	207	1,276	3,030	2,329	50	6,892
		67	134	198		249						229		151	267	215	21	375						505
1994		147	573	362		1,082	219	117	29	9		374	49	1,269	1,918	1,447	21	4,704	268	1,533	2,520	1,818	21	6,160
		73	186	132		240						216	18	235	255	185	15	394						509
1995	101	223	1,204	608		2,135	292	342	125	18		776	224	2,427	3,499	3,337	66	9,553	617	2,991	4,828	3,962	66	12,464
	73	81	219	118		271						252	62	540	394	404	28	784						867
1996	19	686	1,046	755		2,506	705	444	81	16		1,245	240	3,140	6,923	3,188	46	13,537	964	4,270	8,050	3,958	46	17,289
	13	228	181	154		330						367	78	947	789	392	17	1,296						1,387
1997		96	630	566	23	1,315	266	125	17	13		421	15	946	2,887	1,474	19	5,341	281	1,167	3,534	2,053	42	7,077
		50	164	187	23	254						219	15	127	358	139	10	405						526
1998	59	244	829	222	41	1,396	296	212	26	9		542	83	2,485	3,941	1,756	13	8,278	438	2,941	4,796	1,987	54	10,216
	58	86	191	67	41	231						223	31	697	317	160	9	783						846
1999		81	658	493	59	1,291	132	97	94	49		373		592	1,289	842		2,723	132	770	2,041	1,383	59	4,386
		53	414	142	59	445						362		69	122	97		170						598
2000	12	488	2,083	906		3,490	505	768	60	17		1,350	191	2,937	3,808	2,100	30	9,066	708	4,193	5,951	3,024	30	13,906
	12	205	311	188		417						401	37	335	321	215	13	513						773
2001	21	67	572	462		1,122	222	193	19	8		441	76	521	2,147	1,045	11	3,800	319	781	2,737	1,515	11	5,363
	5	34	140	141		201						195	24	106	215	105	8	263						384
2002	15	711	1,588	383		2,697	840	602	132	17		1,589	237	3,256	4,522	1,633	21	9,669	1,092	4,568	6,242	2,032	21	13,955
	15	181	259	110		335						414	67	436	360	198	11	603						805
2003	16	44	355	162		577	176	225	18	4		422	221	842	1,229	575		2,867	412	1,112	1,601	741		3,866
	15	26	104	74		131						186	47	95	155	80		204						306
2004		101	667			768	331	119	28			478	184	943	2,165			3,292	515	1,163	2,859			4,538
		53	180			187						239	34	149	253			296						424
2005		292				292	299	287				587	163	1,914				2,077	462	2,493				2,956
		122				122						346	46	243				247						443
2006	20					20	219					219	66					66	305					305
	20					20						232	20					20						234

[a] Estimates of spawning abundance (and associated standard errors) of fish from minor age classes are included in the spawning abundance estimates for fish from major age classes of the same total age and brood year, e.g, an estimated spawning abundance of 10 age-2.3 fish from brood year 2001 are included in the spawning abundance estimate of age-1.4 fish in brood year 2001.

Table 14.–Adult equivalent conversion factors for Unuk River Chinook salmon by age class and brood year (1992–2006).[a]

	Age class				
Brood year	1.1	1.2	1.3	1.4	1.5
1992	0.5572	0.7960	0.9460	1.0000	1.0000
1993	0.5507	0.7868	0.9493	1.0000	1.0000
1994	0.5643	0.8032	0.9489	1.0000	1.0000
1995	0.5641	0.7992	0.9449	1.0000	1.0000
1996	0.5698	0.8088	0.9616	1.0000	1.0000
1997	0.5548	0.7918	0.9554	1.0000	1.0000
1998	0.5757	0.8194	0.9623	1.0000	1.0000
1999	0.5529	0.7881	0.9517	1.0000	1.0000
2000	0.5713	0.8110	0.9535	1.0000	1.0000
2001	0.5555	0.7874	0.9585	1.0000	1.0000
2002	0.5837	0.8274	0.9682	1.0000	
2003	0.5879	0.8184	0.9599		
2004	0.5657	0.8031	0.9550		
2005	0.5657	0.8031			
2006	0.5657				

[a] Conversion factors provided by John Carlile, Fisheries Scientist, Division of Commercial Fisheries, Alaska Department of Fish and Game, Juneau.

Brood Year 2003

Brood year 2003 returns are incomplete pending the return of age-1.5 fish in 2010. Through 2009, a nominal estimate of 577 (SE = 131) fish have been harvested from brood year 2003 returns (Table 13; Appendix B6). Use of AEQ conversion factors (Table 14) results in an estimated harvest of 548 (SE = 127) AEQs (Table 15). An estimated 416 (SE = 113) fish were harvested by commercial troll gear, approximately 72% of the total harvest (Table 16).Recreational (121 fish; SE = 64), purse seine (28 fish; SE = 19), and drift gillnet (12 fish; SE = 12) gear accounted for approximately 21, 5%, and 2% of the total estimated harvest, respectively (Table 16). Harvest only occurred in the Southeast (376 fish; SE = 109), Northwest (129 fish; SE = 64), and Northeast (72 fish; SE = 36) Quadrants of SEAK (Table 17). An estimated 422 fish (SE = 186) from the 2003 brood died as a result of incidental fishing mortality (nominal fish; Table 13).Use of AEQ factors (Table 14) results in an estimated incidental mortality of 308 (SE = 152) AEQs (Table 15).

Brood Year 2004

An estimated 101 (SE = 53) age-1.2 fish were harvested in 2008 and 667 (SE = 180) age-1.3 fish were harvested in 2009; no harvest of age-1.1 fish occurred in 2007 (Table 13; Appendix B6). Incidental mortality was estimated to be 478 (SE = 239) fish (Table 13).

Brood Year 2005

An estimated 292 (SE = 122) age-1.2 fish were harvested in 2009; no age-1.1 fish were harvested from the 2005 brood in 2008 (Table 13; Appendix B6). Incidental mortality was estimated to be 587 (SE = 346) fish (Table 13).

Brood Year 2006

An estimated 20 (SE = 20) age-1.1 fish were harvested in 2009 (Table 13; Appendix B6). Incidental mortality was estimated to be 219 (SE = 232) fish (Table 13).

Estimates by return year

Total nominal returns averaged 9,084 fish from 1998 to 2009, and ranged from an estimated 6,548 (SE = 1,777) fish in 1998 to 13,639 (SE = 925) fish in 2001 (Table 19). In AEQs, total production averaged 8,774 AEQs from 1998 to 2009, and ranged from 6,303 AEQs (SE = 442) in 1998 to 13,399 AEQs (SE = 922) in 2001 (Table 20). During this period, harvest and incidental mortality averaged 1,566 and 510 AEQs, respectively, for an average annual fishing mortality of 2,076 AEQs.

DISCUSSION

Estimates of fishing mortality for age-1.1 Chinook salmon should be considered minimum estimates. Most age-1.1 fish are harvested by purse seine gear, as these fish are generally too small to be entangled by drift gillnet gear, and except in relatively rare situations, length restrictions forbid the retention of Chinook salmon of this size in recreational and commercial troll fisheries. However, the number of jacks (<28 in TL or approximately 710 mm TL) documented as landed catch are known to be under reported. ADF&G management regulations for SEAK traditional purse seine fisheries allow retention, but not sale, of Chinook salmon between 21 and 28 in TL (approximately 530–710 mm TL). These fish are consequently rarely reported and almost never sampled for CWTs. ADF&G management regulations permit the retention and sale of purse seine-caught Chinook salmon <21 in TL. Most individual purse seiners sell their catch to tenders, larger vessels that purchase fish from multiple purse seiners, and subsequently transport the fish to processing plants. In most such instances, pink salmon are kept in separate holds from “money” fish (the more valuable Chinook, sockeye, coho, and chum salmon), or separate vessels purchase pink salmon and “money” fish. For a number of reasons, Chinook salmon <21 in TL are bought by tenders as pink salmon: they are similar in size and appearance to pink salmon, inexperienced purse seine crews often do not distinguish between pink salmon and small Chinook salmon, and the value of these fish is comparable. Dockside samplers rarely sample pink salmon deliveries for jack Chinook salmon CWTs because of cost inefficiencies or fish having been bought from multiple districts and their consequent undesirability for CWT harvest expansion purposes. So, many if not most, Chinook salmon <21 in TL delivered by tenders go unreported and unsampled. Most CWT samples from jack Chinook salmon occur in the increasingly uncommon event that individual purse seiners deliver their catch directly to a processor, and a CWT sampler is present to look for tagged Chinook and coho salmon. Although sampling of jacks likely represents a relatively small fraction of the catch under these circumstances, the number of jacks sampled is still generally larger than reported catch, and can be 3 times the reported catch from some SEAK districts.

Voluntary recoveries of Unuk River Chinook salmon possessing CWTs occurred in four recreational fisheries from 1995 to 2009; the northern British Columbia (NBC) recreational fishery (five recoveries), the Ketchikan recreational fishery (six recoveries), the Cook Inlet (Homer) recreational fishery (one recovery), and in the District 101 recreational fishery as part of a special ADF&G genetic sampling program of sublegal Chinook salmon (four recoveries; Appendix B7). Hendrich et al. (2008) used an awareness factor, based on extrapolations of data from previous years by the CTC of the PSC, to expand the NBC and Ketchikan recreational fishery recoveries:

$$\hat{r}_{uj} = 4m_{uj}\hat{\theta}_j^{-1}; \quad \mathrm{var}\left(\hat{r}_{uj}\right) = \left(\hat{r}_{uj}\right)^2. \tag{38}$$

where 4 equals the awareness approximation, m_{uj} equals the number of voluntary CWT recoveries with relevant tag codes from brood year j in fishery stratum u, and $\hat{\theta}_j$ equals the estimated fraction of juveniles tagged from brood year j. We feel however that the awareness factor is not a defensible scientific method, is in essence little better than a guess, and have therefore not used it to estimate harvest from voluntary recoveries. The presence of the voluntary recoveries in the Canadian recreational fisheries of NBC, where all recoveries are strictly voluntary, indicates that Canadian harvest of Chinook salmon originating from the Unuk River is underestimated to some unknown degree in 1999, 2000, 2002, and 2005 (Appendix B7). In 5 of the 6 cases when voluntary recoveries occurred in the Ketchikan recreational fishery, recoveries occurred during the period that ADF&G was conducting creel sampling of harvest for CWTs. Expansion of those 5 recoveries would result in overestimation of harvest therefore, and inclusion in the harvest estimation process is contraindicated.

Spawning distribution estimates remained relatively constant over time with 86.2% spawning in U.S. waters in 1994 and 88.2% spawning in US waters in 2009. There were differences between the studies, mostly in distribution of fish within the watershed. The previous study saw approximately 2.2% of the tagged fish spawning on the mainstem. In 2009, tags were located in 4 areas (Table 7), of which approximately 10.5% were designated as mainstem spawning. This change in distribution could be the result of changes in the river in that area. The area from the border down to the outlet of Gene's Lake is very dynamic and is dominated by large log jams and braided channel though a mosaic of gravel bars, except for the first canyon, which is a well-defined, cut channel running through a lava field. Due to the dynamic nature of the river, this section changes almost constantly and could open up, or remove, spawning habitat in the mainstem from year to year. Overall, distribution among the main spawning tributaries seem fairly stable, with the exception of the mainstem, and this may be relatively variable do to homing/straying rates and stability of the habitat within the mainstem of the river.

Visual confirmation of spawning activity was not conducted in either the 1994 or 2008 studies due to the turbidity of the mainstem water. We know that mainstem spawning is likely occurring, but little is known about it due to the difficulties associated with poor water visibility.

CONCLUSIONS AND RECOMMENDATIONS

Annex IV Chapter 3 of the 2008 Pacific Salmon Treaty provides for harvest opportunities on abundant stocks, and mandates harvest regimes be established based on annual estimates of stock abundance and maximum sustained yield (MSY). The escapement range that provides MSY for the Unuk River Chinook salmon stock has recently been estimated by Hendrich et al. (2008) as 1,800–3,800 large spawning fish, and the revision has been approved by ADF&G and the Pacific Salmon Commission. Based on point estimates of spawning abundance from 1997–2006, as determined by annual mark-recapture experiments, the upper range of MSY was exceeded by a minimum of 17,000 fish during this period. No directed fishery on the Unuk River stock has existed since the 1950s because of stock concerns. One prerequisite to the development of increased harvest opportunities on returns surplus to escapement is to develop a reliable forecast model for the Unuk River stock, as noted in Chapter 3, Paragraph 13 of the Pacific Salmon Treaty. The forecast model would be based on cohort analysis and be dependent on high quality harvest and escapement estimation. Consequently we recommend continued collection of high quality harvest and escapement information on this stock, refinement of the current rudimentary forecast model, and development by relevant management entities of possible strategies to harvest returns surplus to escapement.

Table 15.–Estimates of landed catch, incidental mortality, spawning abundance, total return, and exploitation rate of Unuk River Chinook salmon in adult equivalents (AEQs) for the 1992–2006 broods through return year 2009 (rounding error present). Associated estimates of standard error are noted in gray font.

	Landed catch						Incidental mortality						Spawning abundance						Total return					
	Age class						Age class						Age class						Age class					
Brood	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1992	20	64	253	155		492	74	88	14	6		183		736	1,240	1,207	16	3,199	94	889	1,507	1,368	16	3,874
	19	64	148	155		224						211		349	128	140	12	397						503
1993		126	399	707		1,233	114	157	14	40		326		916	2,595	1,581	50	5,142	114	1,199	3,008	2,329	50	6,700
		53	128	198		242						187		151	267	215	21	375						484
1994		118	544	362		1,024	123	94	28	9		254	49	1,269	1,918	1,447	21	4,704	172	1,481	2,489	1,818	21	5,982
		58	177	132		229						171	18	235	255	185	15	394						486
1995	57	178	1,138	608		1,980	165	273	118	18		573	224	2,427	3,499	3,337	66	9,553	446	2,878	4,755	3,962	66	12,107
	41	65	207	118		250						193	62	540	394	404	28	784						848
1996	11	555	1,006	755		2,327	402	359	78	16		854	240	3,140	6,923	3,188	46	13,537	653	4,054	8,007	3,958	46	16,718
	7	185	174	154		297						277	78	947	789	392	17	1,296						1,358
1997		76	602	566	23	1,267	148	99	16	13		276	15	946	2,887	1,474	19	5,341	163	1,121	3,505	2,053	42	6,884
		40	156	187	23	248						172	15	127	358	139	10	405						505
1998	34	200	798	222	41	1,296	170	173	25	9		377	83	2,485	3,941	1,756	13	8,278	287	2,858	4,764	1,987	54	9,951
	34	71	184	67	41	215						176	31	697	317	160	9	783						831
1999		64	626	493	59	1,242	73	77	90	49		288		592	1,289	842		2,723	73	733	2,004	1,383	59	4,253
		42	394	142	59	425						306		69	122	97		170						551
2000	7	396	1,986	906		3,295	289	623	57	17		986	191	2,937	3,808	2,100	30	9,066	486	3,956	5,851	3,024	30	13,347
	7	166	296	188		388						322	37	335	321	215	13	513						719
2001	12	53	548	462		1,074	123	152	18	8		301	76	521	2,147	1,045	11	3,800	211	726	2,713	1,515	11	5,175
	3	27	134	141		196						157	24	106	215	105	8	263						363
2002	9	588	1,538	383		2,518	490	498	127	17		1,132	237	3,256	4,522	1,633	21	9,669	736	4,342	6,187	2,032	21	13,318
	9	150	251	110		313						328	67	436	360	198	11	603						754
2003	9	36	341	162		548	103	184	17	4		308	221	842	1,229	575		2,867	333	1,063	1,586	741		3,724
	9	21	100	74		127						152	47	95	155	80		204						284
2004		81	637			718	187	95	27			309	184	943	2,165			3,292	371	1,120	2,828			4,319
		42	171			177						181	34	149	253			296						389
2005		235				235	169	231				400	163	1,914				2,077	332	2,379				2,712
		98				98						247	46	243				247						363
2006	11					11	124					124	66					66	201					201
	11					11						131	20					20						133

Table 16.–Nominal harvest estimates of Unuk River Chinook salmon from the 1992–2006 broods, by gear type, through 2009. Associated standard errors are below harvest estimates in gray font. Rounding error is present.

		Gear type							
Brood year	Age classes	Troll	Recreational	Drift gillnet	Purse seine	PNP[a]	Trawl	Other[b]	Total
1992	1.1–1.5	205	155	143	35				538
		144	155	101	35				237
1993	1.1–1.5	645	486	77			43	36	1,288
		158	178	46			43	36	249
1994	1.1–1.5	471	573	38					1,082
		125	203	26					240
1995	1.1–1.5	1,212	489	99	101	51	94	89	2,135
		169	174	51	73	26	66	46	271
1996	1.1–1.5	1,034	1,118	130	19	4	75	65	2,506
		140	280	56	4	53	53	46	330
1997	1.1–1.5	810	432			73			1,315
		189	154			73			254
1998	1.1–1.5	844	487	46			19		1,396
		163	160	32			18		231
1999	1.1–1.5	405	364	505				16	1,291
		127	135	404				16	445
2000	1.1–1.5	1,929	933	603	12			12	3,490
		262	247	209	12			12	417
2001	1.1–1.5	659	287	66	89			21	1,122
		145	121	37	57			14	201
2002	1.1–1.5	1,761	315	469	152				2,697
		265	114	149	83				335
2003	1.1–1.4	416	121	12	28				577
		113	64	12	19				131
2004	1.1–1.3	600	67	45	17	39			768
		173	50	32	16	39			187
2005	1.1–1.2	89	151	52					292
		62	98	37					122
2006	1.1				20				20
					20				20
Total		11,079	5,979	2,285	474	228	232	241	20,517
		628	615	503	133	101	96	78	1,034
Percent		54	29	11	2	1	1	1	100

[a] Private non-profit fisheries in this case have unknown gear type.

[b] Includes all Canadian mixed net and seine, test fishery, and set gillnet gear.

Table 17.–Nominal harvest estimates of Unuk River Chinook salmon from the 1992–2006 broods, by harvest location, through 2009. Associated standard errors are below harvest estimates in gray font. Rounding error is present.

Brood year	Age classes	Harvest location: Kodiak	Cook Inlet	Gulf of Alaska	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	British Columbia	Total
1992	1.1–1.5				255	35		248		538
					184	35		146		237
1993	1.1–1.5			43	418	197	64	530	36	1,288
				43	137	90	64	167	36	249
1994	1.1–1.5		34		444	58		546		1,082
			33		139	41		188		240
1995	1.1–1.5	16	73	94	823	148	15	884	83	2,135
		15	41	66	154	78	14	188	45	271
1996	1.1–1.5			75	396	38	203	1,678	116	2,506
				53	99	18	96	288	62	330
1997	1.1–1.5		50		366	94	20	614	170	1,315
			49		129	54	20	162	126	254
1998	1.1–1.5			19	353	95	20	909		1,396
				18	120	66	20	185		231
1999	1.1–1.5				293	82	58	778	80	1,291
					125	67	57	412	65	445
2000	1.1–1.5				1,052	393	151	1,874	20	3,490
					210	131	81	325	19	417
2001	1.1–1.5				375	26	27	678	17	1,122
					114	18	26	163	17	202
2002	1.1–1.5				813	180	356	1,218	131	2,697
					202	68	110	220	79	335
2003	1.1–1.4				129	72		376		577
					64	36		109		131
2004	1.1–1.3				119	108	52	489		768
					71	47	52	158		187
2005	1.1–1.2				114			178		292
					67			102		122
2006	1.1							20		20
								20		20
Total		16	156	232	5,047	1,526	966	11,020	65	20,517
		15	72	96	513	234	199	813	185	1,034
Percent		0.1	0.8	1.2	29.0	7.4	4.7	53.7	3.2	100

Table 18.–Estimated spawning abundance $\hat{N}$, landed catch $\hat{R}$, incidental fishing mortality $I\hat{M}$, fishing mortality $F\hat{M}$ (rounding error present), total return or production $\hat{T}$, exploitation rate $\hat{U}$, and marine survival rate $\hat{Q}$ for the 1992–2006 broods, through 2009, using adult equivalents. Associated standard errors are below estimates in gray font.

Brood year	$\hat{N}$	$\hat{R}$	$I\hat{M}$	$F\hat{M}$	$\hat{T}$	$\hat{U}$ (%)	$\hat{Q}$ (%)
1992	3,199	492	183	675	3,874	17.4	0.95
	397	224	211	308	503	6.8	0.43
1993	5,142	1,233	326	1,558	6,700	23.2	3.55
	375	242	187	305	484	3.7	0.77
1994	4,704	1,024	254	1,278	5,982	21.4	2.51
	394	229	171	285	486	4.0	0.50
1995	9,553	1,980	573	2,554	12,107	21.1	3.85
	784	250	204	322	848	2.5	0.52
1996	13,537	2,327	854	3,181	16,718	19.0	3.44
	1,296	297	277	406	1,358	2.5	0.49
1997	5,341	1,267	276	1,543	6,884	22.4	2.20
	405	248	172	302	505	3.7	0.51
1998	8,278	1,296	377	1,673	9,951	16.8	3.66
	783	215	176	277	831	2.7	0.51
1999	2,723	1,242	288	1,530	4,253	36.0	1.41
	170	425	306	524	551	8.0	0.30
2000	9,066	3,295	986	4,281	13,347	32.1	3.22
	513	388	322	504	719	2.9	0.43
2001	3,800	1,074	301	1,375	5,175	26.6	1.99
	263	196	157	251	363	3.8	0.33
2002	9,669	2,518	1,132	3,649	13,318	27.4	2.96
	603	313	328	453	754	2.8	0.43
2003[a]	2,867	548	308	857	3,724	23.0	2.24
	204	127	152	198	284	4.3	0.43
2004[a]	3,292	718	309	1,027	4,319	23.8	1.45
	296	177	181	253	389	4.8	0.26
2005[a]	2,077	235	400	635	2,712	23.4	1.60
	247	98	247	265	363	7.8	0.38
2006[a]	66	11	124	135	201	67.2	0.09
	20	11	131	132	133	22.5	0.07

[a] Brood year returns are incomplete pending the return of additional age class(es).

Table 19.–Nominal estimates of landed catch, incidental mortality, spawning abundance, and total returns of Unuk River Chinook salmon, by age class and return year, 1995–2009. Associated estimates of standard error are noted in gray font. Rounding error is present.

	Landed catch						Incidental mortality						Spawning abundance						Total return					
	Age class						Age class						Age class						Age class					
Return	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1995	35					35	134					134						0	169					169
	35					35												0						35
1996		81				81	207	111				318		736				736	207	928				1,134
		80				80								349				349						358
1997		161	267			428	219	200	15			434	49	916	1,240			2,205	268	1,276	1,523			3,067
		67	157			171							18	151	128			199						262
1998	101	147	420	155		823	292	117	15	6		430	224	1,269	2,595	1,207		5,295	617	1,533	3,030	1,368		6,548
	73	73	134	707		727							62	235	267	1,581		1,622						1,777
1999	19	223	573	707		1,522	705	342	29	40		1,116	240	2,427	1,918	1,581	16	6,182	964	2,991	2,520	2,329	16	8,820
	13	81	186	198		284							78	540	255	215	12	640						700
2000		686	1,204	362		2,252	266	444	125	9		844	15	3,140	3,499	1,447	50	8,151	281	4,270	4,828	1,818	50	11,247
		228	219	132		343							15	947	394	185	21	1,043						1,098
2001	59	96	1,046	608		1,809	296	125	81	18		520	83	946	6,923	3,337	21	11,31	438	1,167	8,050	3,962	21	13,639
	58	50	181	118		229							31	127	789	404	15	896						925
2002		244	630	755		1,629	132	212	17	16		377		2,485	2,887	3,188	66	8,626	132	2,941	3,534	3,958	66	10,631
		86	164	154		240								697	358	392	28	877						909
2003	12	81	829	566		1,488	505	97	26	13		641	191	592	3,941	1,474	46	6,244	708	770	4,796	2,053	46	8,373
	12	53	191	187		273							37	69	317	139	17	355						448
2004	21	488	658	222	23	1,413	222	768	94	9		1,093	76	2,937	1,289	1,756	19	6,077	319	4,193	2,041	1,987	42	8,582
	5	205	414	67	23	467							24	335	122	160	10	392						610
2005	15	67	2,083	493	41	2,699	840	193	60	49		1,141	237	521	3,808	842	13	5,421	1,092	781	5,951	1,383	54	9.261
	15	34	311	142	41	346							67	106	321	97	9	358						498
2006	16	711	572	906	59	2,264	176	602	19	17		813	221	3,256	2,147	2,100		7,724	412	4,568	2,737	3,024	59	10,801
	15	181	140	188	59	302							47	436	215	215		534						613
2007[a]		44	1,588	462		2,095	331	225	132	8		696	184	842	4,522	1,045	30	6,623	515	1,112	6,242	1,515	30	9,413
		26	259	141		296							34	95	360	105	13	389						489
2008		101	355	383		839	299	119	18	17		452	163	943	1,229	1,633	11	3,979	462	1,163	1,601	2,032	11	5,270
		53	104	110		160							46	149	155	198	8	296						337
2009	20	292	667	162		1,141	219	287	28	4		538	66	1,914	2.165	575	21	4,741	305	2,493	2,859	741	21	6,420
	20	122	180	74		230							20	243	253	80	11	361						428

[a] Estimated spawning abundance in 2007 does not include an estimated 5 age-1.0 fish; rounding error also present.

Table 20.–Estimates of landed catch, incidental mortality, spawning abundance, and total returns of Unuk River Chinook salmon in adult equivalents (AEQs), by age class and return year, 1995–2009. Associated estimates of standard error are noted in gray font. Rounding error is present.

	Landed catch						Incidental mortality						Spawning abundance						Total return					
	Age class						Age class						Age class						Age class					
Return	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1995	20					20	74					74							94					94
	19					19																		19
1996		64				64	114	88				202		736				736	114	889				1,002
		64				64								349				349						355
1997		126	253			379	123	157	14			295	49	916	1,240			2,205	172	1,199	1,507			2,879
		53	148			158							18	151	128			199						254
1998	57	118	399	155		729	165	94	14	6		279	224	1,269	2,595	1,207		5,295	446	1,481	3,008	1,368		6,303
	41	58	128	155		213							62	235	267	140		387						442
1999	11	178	544	707		1,440	402	273	28	40		743	240	2,427	1,918	1,581	16	6,182	653	2,878	2,489	2,329	16	8,365
	7	65	177	198		273							78	540	255	215	12	640						696
2000		555	1,138	362		2,055	148	359	118	9		633	15	3,140	3,499	1,447	50	8,151	163	4,054	4,755	1,818	50	10,839
		185	207	132		307							15	947	394	185	21	1,043						1,087
2001	34	76	1,006	608		1,724	170	99	78	18		365	83	946	6,923	3,337	21	11,310	287	1,121	8,007	3,962	21	13,399
	34	40	174	118		217							31	127	789	404	15	896						922
2002		200	602	755		1,557	73	173	16	16		278		2,485	2,887	3,188	66	8,626	73	2,858	3,505	3,958	66	10,461
		71	156	154		230								697	358	392	28	877						906
2003	7	64	798	566		1,434	289	77	25	13		403	191	592	3,941	1,474	46	6,244	486	733	4,764	2,053	46	8,082
	7	42	184	187		266							37	69	317	139	17	355						444
2004	12	396	626	222	23	1,279	123	623	90	9		844	76	2,937	1,289	1,756	19	6,077	211	3,956	2,004	1,987	42	8,201
	3	166	394	67	23	434							24	335	122	160	10	392						584
2005	9	53	1,986	493	41	2,582	490	152	57	49		748	237	521	3,808	842	13	5,421	736	726	5,851	1,383	54	8,751
	9	27	296	142	41	332							67	106	321	97	9	358						489
2006	9	588	548	906	59	2,111	103	498	18	17		636	221	3,256	2,147	2,100		7,724	333	4,342	2,713	3,024	59	10,471
	9	150	134	188	59	281							47	436	215	215		534						603
2007[a]		36	1,538	462		2,036	187	184	127	8		507	184	842	4,522	1,045	30	6,623	371	1,063	6,187	1,515	30	9,166
		21	251	141		288							34	95	360	105	13	389						484
2008		81	341	383		805	169	95	17	17		298	163	943	1,229	1,633	11	3,979	332	1,120	1,586	2,032	11	5,082
		42	100	110		155							46	149	155	198	8	296						334
2009	11	235	637	162		1,045	124	231	27	4		385	66	1,914	2,165	575	21	4,741	201	2,379	2,828	741	21	6,171
	11	98	171	74		211							20	243	253	80	11	361						418

[a] Estimated spawning abundance in 2007 does not include an estimated 5 age-1.0 fish; rounding error also present.

The current algorithm used by the CTC, in some instances, combines dissimilar fisheries when estimating incidental fishing mortality. This practice can lead to significant error in the estimation of incidental fishing mortality for certain relevant fisheries, such as the SEAK gillnet fishery, as previously noted. Although this practice was necessary when the algorithm was first developed as a result of computer memory limitations at that time, we recommend that the CTC incidental fishing mortality algorithm be updated to preclude grouping of dissimilar fisheries.

The Chinook salmon recreational fishery in NBC is a mixed stock interception fishery. Reliable harvest and harvest contribution estimates from this fishery are therefore of interest to numerous entities in both the United States and Canada. We recommend the initiation of a defensible scientific sampling program for this fishery.

Future telemetry studies would greatly benefit from the use of helicopter over the traditional fixed wing aircraft. The ability to stop over an area with a conglomeration of tags was invaluable compared to circling the area in a fixed wing aircraft. The use of the helicopter also allowed us to fly up small, closed in drainages that the fixed wing was unable to fly into, such as Kerr Creek. The use of the helicopter and integrated GPS into the data receiver were vast improvements over the study done in 1994. We would also recommend having a dedicated crew that could check the receivers every two to three days, rather than weekly. That would have eliminated some of the data gaps when towers went down due to overcast weather or animal damage. Integrating the telemetry study with normal crew operations was a money saving option; however, by the time the crew finished a shift on the net, there was not enough time to run to the farthest telemetry towers for downloading. This resulted in further crew fatigue, and if there was a problem, it required an additional day to get or repair the damage due to travel times. The addition of two people would have increased the amount of time drifting or the number of telemetry foot surveys that could have been done, thus increasing the number of samples and data, particularly in areas of the mainstem where spawning was likely to be taking place.

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APPENDIX A

Appendix A1.–Detection of size- and/or sex-selective sampling during a two-sample mark-recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student’s t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

-continued-

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

-continued-

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} , \tag{1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right). \tag{2}$$

where:

j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A2.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Mixing Test[a]

Area/time	Time/area where recaptured				Not recaptured
where marked	1	2	…	t	(n_1-m_2)
1					
2					
…					
s					

II.-Equal Proportions Test (SPAS terminology)[b]

	Area/time where examined			
	1	2	…	t
Marked (m_2)				
Unmarked (n_2-m_2)				

III.-Complete Mixing Test (SPAS terminology)[c]

	Area/time where marked			
	1	2	…	s
Recaptured (m_2)				
Not recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, s) to section j (j = 1, 2, t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i\theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i. Note that failure to reject H_0 means the Pooled Petersen estimator can be considered consistent only if the degree of closure among tagging strata is constant ($\Sigma_j\theta_{ij} = \lambda$,) (Schwarz and Taylor 1998). One way this may be achieved is to sample all or the large majority of spawning areas.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j\theta_{ij}p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

The expansion factor provides a means of predicting escapement in years where only an index count of the escapement is available, i.e., no weir counts or mark-recapture experiments were conducted. The expansion factor is the average over several years of the ratio of the escapement estimate (or weir count) to the index count.

Systems where escapement is known

On systems where escapement can be completely enumerated with weirs or other complete counting methods, the expansion factor is an estimate of the expected value of the "population" of annual expansion factors (π's) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \pi_y}{k}, \tag{1}$$

where $\pi_y = N_y / C_y$ is the observed expansion factor in year *y*, N_y is the known escapement in year *y*, C_y is the index count in year *y*, and *k* is the number of years for which these data are available to calculate an annual expansion factor.

The estimated variance for expansion of index counts needs to reflect two sources of uncertainty for any predicted value of π, (π_p). First is an estimate of the process error (*var*(π)-the variation across years in the π's, reflecting, for example, weather or observer-induced effects on how many fish are counted in a survey for a given escapement), and second is the sampling variance of $\bar{\pi}$ (*var*($\bar{\pi}$)), which will decline as we collect more data pairs.

The variance for prediction will be estimated (Neter and Wasserman 1990):

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}), \tag{2}$$

where

$$v\hat{a}r(\pi) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1}, \tag{3}$$

and

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k(k-1)}, \tag{4}$$

such that

$$v\hat{a}r(\pi_p) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1} + \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k(k-1)}. \tag{5}$$

-continued-

Systems where escapement is estimated

On systems where escapement is estimated, the expansion factor is an estimate of the expected value of the “population” of annual expansion factors (π ’s) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \hat{\pi}_y}{k}, \qquad (6)$$

where $\hat{\pi}_y = \hat{N}_y / C_y$ is the estimate of the expansion factor in year *y*, $\hat{N}_y$ is the estimated escapement in year *y*, and other terms are as described above.

The variance for prediction will again be estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}) . \qquad (7)$$

The estimate of *var*(π) should again reflect only process error. Variation in $\hat{\pi}$ across years, however, represents process error **plus** measurement error within years (e.g. the mark-recapture induced error in escapement estimation) and is described by the relationship (Mood et al. 1974):

$$V(\hat{\pi}) = V[E(\hat{\pi})] + E[V(\hat{\pi})]. \qquad (8)$$

This relationship can be rearranged to isolate process error, that is:

$$V[E(\hat{\pi})] = V[\hat{\pi}] - E[V(\hat{\pi})]. \qquad (9)$$

An estimate of *var*(π) representing only process error therefore is:

$$v\hat{a}r(\pi) = v\hat{a}r(\hat{\pi}) - \frac{\sum_{y=1}^{k} v\hat{a}r(\hat{\pi}_y)}{k}, \qquad (10)$$

where $v\hat{a}r(\hat{\pi}_y) = v\hat{a}r(\hat{N}_y) / C_y^2$ and $v\hat{a}r(\hat{N}_y)$ is obtained during the experiment when N_y is estimated.

We can calculate:

$$v\hat{a}r(\hat{\pi}) = \frac{\sum_{y=1}^{k} (\hat{\pi}_y - \bar{\pi})^2}{k-1}, \qquad (11)$$

and we can estimate $var(\bar{\pi})$ similarly to as we did above:

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^{k} (\hat{\pi}_y - \bar{\pi})^2}{k(k-1)}, \qquad (12)$$

where both process and measurement errors need to be included.

For large *k* (*k* > 30), equations (11) and (12) provide reasonable parameter estimates, however for small *k* the estimates are imprecise and may result in negative estimates of variance when the results are applied as in equation (7).

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Because *k* is typically < 10, we will estimate $var(\hat{\pi})$ and $var(\overline{\pi})$ using parametric bootstrap techniques (Efron and Tibshirani 1993). The sampling distributions for each of the $\hat{\pi}_y$ are modeled using Normal distributions with means $\hat{\pi}_y$ and variances $v\hat{a}r(\hat{\pi}_y)$. At each bootstrap iteration, a bootstrap value $\hat{\pi}_{y(b)}$ is drawn from each of these Normal distributions and the

bootstrap value $\hat{\pi}_{(b)}$ is randomly chosen from the *k* values of $\hat{\pi}_{y(b)}$. Then, a bootstrap sample of size *k* is drawn from the *k* values of $\hat{\pi}_{y(b)}$ by sampling with replacement, and the mean of this bootstrap is the bootstrap value $\overline{\pi}_{(b)}$. This procedure is repeated *B* = 1,000,000 times. We can then estimate $var(\hat{\pi})$ using:

$$v\hat{a}r_B(\hat{\pi}) = \frac{\sum_{b=1}^{B}(\hat{\pi}_{(b)} - \overline{\hat{\pi}_{(b)}})^2}{B-1}, \tag{13}$$

where

$$\overline{\hat{\pi}_{(b)}} = \frac{\sum_{b=1}^{B}\hat{\pi}_{(b)}}{B}, \tag{14}$$

and we can calculate $var_B(\overline{\pi})$ using equations (13) and (14) with appropriate substitutions. The variance for prediction is then estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r_B(\hat{\pi}) - \frac{\sum_{y=1}^{k}\text{v}\hat{\text{a}}\text{r}(\hat{\pi}_y)}{k} + v\hat{a}r_B(\overline{\pi}). \tag{15}$$

As the true sampling distributions for the $\hat{\pi}_y$ are typically skewed right, using a Normal distribution to approximate these distributions in the bootstrap process will result in estimates of $var(\hat{\pi})$ and $var(\overline{\pi})$ that are biased slightly high, but simulation studies using values similar to those realized for this application indicated that the bias in equation (15) is < 1%.

<u>Predicting Escapement</u>

In years when an index count (C_p) is available but escapement (N_p) is not known, it can be predicted:

$$\hat{N}_p = \overline{\pi}\, C_p, \tag{16}$$

and

$$v\hat{a}r(\hat{N}_p) = C_p^2 v\hat{a}r(\pi_p). \tag{17}$$

Appendix A4.–Peak survey counts, and abundance estimates with associated estimates of standard error, of the spawning population of large ($\geq$660 mm MEF) Chinook salmon in the Unuk River using the 1997–2004[a,b] mean expansion factor (EF), the 1997–2007 mean expansion factor, and the results from mark-recapture studies, 1977–2009. The 1997–2004 mean expansion factor is 4.83 (SE = 0.59). The mean expansion factor using 1997–2009 data is 5.52 and the standard error for prediction ($\sqrt{\text{var}(\pi_p)}$ as defined in Equation 15 in Appendix A3 is 1.66. Preferred abundance estimates are in bold font.

		Abundance estimated using the 1997–2004 mean EF		Abundance estimated using the 1997–2009 mean EF		Abundance estimated using mark-recapture experiments	
Year	Peak count from surveys	$\hat{N}$	$SE(\hat{N})$	$\hat{N}$	$SE(\hat{N})$	$\hat{N}$	$SE(\hat{N})$
1977	974	**4,704**	**575**	5,299	1,617		
1978	1,106	**5,342**	**653**	6,017	1,836		
1979	576	**2,782**	**340**	3,133	956		
1980	1,016	**4,907**	**599**	5,527	1,687		
1981	731	**3,531**	**431**	3,977	1,213		
1982	1,351	**6,525**	**797**	7,349	2,243		
1983	1,125	**5,434**	**664**	6,120	1,868		
1984	1,837	**8,873**	**1,084**	9,993	3,049		
1985	1,184	**5,719**	**699**	6,441	1,965		
1986	2,126	**10,269**	**1,254**	11,565	3,529		
1987	1,973	**9,530**	**1,164**	10,733	3,275		
1988	1,746	**8,433**	**1,030**	9,498	2,898		
1989	1,149	**5,550**	**678**	6,251	1,907		
1990	591	**2,855**	**349**	3,215	981		
1991	655	**3,164**	**386**	3,563	1,087		
1992	874	**4,221**	**516**	4,755	1,451		
1993	1,068	**5,158**	**630**	5,810	1,773		
1994	711	**3,434**	**419**	3,868	1,180	4,623	1,266
1995	772	**3,729**	**455**	4,200	1,282		
1996	1,167	**5,637**	**689**	6,348	1,937		
1997	636	3,072	375	3,460	1,056	**2,970**	**277**
1998	840	4,057	496	4,570	1,394	**4,132**	**413**
1999	680	3,284	401	3,699	1,129	**3,914**	**490**
2000	1,341	6,477	791	7,295	2,226	**5,872**	**644**
2001	2,019	9,752	1,191	10,983	3,352	**10,541**	**1,181**
2002	897	4,333	529	4,880	1,489	**6,988**	**805**
2003	1,121	5,527	661	6,098	1,861	**5,546**	**433**
2004	1,008	4,869	595	5,484	1,673	**3,963**	**325**
2005	929	4,487	548	5,054	1,542	**4,742**	**396**
2006	940	4,540	555	5,114	1,560	**5,645**	**476**
2007	709	3,424	418	3,857	1,177	**5,668**	**446**
2008	242	1,169	143	1,316	402	**3,104**	**390**
2009	687	3,318	405	3,737	1,140	**3,157**	**354**

[a] Excludes 2002 due to relatively poor survey counts in that year (Weller and McPherson 2006a).

[b] This EF is currently the ADF&G- and Pacific Salmon Commission-approved predictive EF.

Appendix A5.–Transmitter frequency, transmitter release date, fish gender, fish length (mm MEF), fate code, fate 1 spawning location code, location name, and number of days elapsed between transmitter release and reception of final active signal for Chinook salmon implanted with transmitters on the lower Unuk River in 2009.

Transmitter frequency	Release date	Sex	Length mm (MEF)	Fate code[a]	Fate 1 spawning location code	Location name	Days elapsed between transmitter release and last active signal received
151.205.1	19 June	F	790	3		Unknown	0
151.164.1	20 June	M	650	2		Lower Unuk[c]	8
151.224.1	20 June	F	905	1	8	Border Creek	55
151.143.1	23 June	F	840	1	2	Clear Creek	5
151.022.1	24 June	M	635	1	12	Mainstem - Cripple Ck to Border Ck[b]	23
151.245.1	24 June	M	690	1	11	Mainstem - Genes Lake to Cripple Ck[c]	14
151.104.1	26 June	F	825	1	6	Sawmill Slough	63
151.164.2	26 June	M	690	2		Lower Unuk[c]	39
151.264.1	26 June	F	795	1	12	Mainstem - Cripple Ck to Border Ck[b]	57
151.022.2	27 June	M	625	2		Flats[e]	13
151.143.2	27 June	M	585	1	9	Canada	49
151.205.2	27 June	F	820	3		Unknown	0
151.245.2	27 June	M	710	1	12	Mainstem - Cripple Ck to Border Ck[b]	17
151.264.2	27 June	M	615	1	12	Mainstem - Cripple Ck to Border Ck[b]	39
151.104.2	29 June	F	860	3		Unknown	0
151.224.2	29 June	M	620	3		Unknown	0
151.164.3	30 June	M	915	1	11	Mainstem - Genes Lake to Cripple Ck[c]	54
151.205.3	30 June	M	650	1	11	Mainstem - Genes Lake to Cripple Ck[c]	53
151.224.3	30 June	M	605	1	9	Canada	54
151.022.3	1 July	F	850	1	4	Kerr Creek	43
151.104.3	1 July	F	815	1	9	Canada	45
151.245.3	1 July	F	800	1	7	Cripple Creek	45
151.264.3	1 July	M	685	1	9	Canada	45
151.022.4	2 July	M	785	1	7	Cripple Creek	16
151.104.5	2 July	M	670	1	11	Mainstem - Genes Lake to Cripple Ck[c]	49
151.143.3	2 July	M	655	1	9	Canada	49
151.143.4	2 July	M	735	1	12	Mainstem - Cripple Ck to Border Ck[b]	44
151.143.5	2 July	F	775	1	7	Cripple Creek	14
151.205.5	2 July	F	815	1	9	Canada	35
151.224.4	2 July	M	680	1	12	Mainstem - Cripple Ck to Border Ck[b]	24
151.224.5	2 July	M	820	1	5	Genes Lake/Creek	38
151.245.5	2 July	M	585	1	7	Cripple Creek	57
151.022.5	3 July	M	625	1	8	Border Creek	38
151.104.6	3 July	M	705	1	4	Kerr Creek	43
151.143.6	3 July	M	710	1	6	Sawmill Slough	43
151.164.5	3 July	F	785	1	13	Mainstem - undefined[f]	56
151.205.6	3 July	F	925	2		Lower Unuk[d]	4
151.264.5	3 July	M	650	1	12	Mainstem - Cripple Ck to Border Ck[b]	17
151.264.6	3 July	M	640	1	9	Canada	51
151.022.6	4 July	M	715	1	8	Border Creek	32

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Transmitter frequency	Release date	Sex	Length mm (MEF)	Fate code[a]	Fate 1 spawning location code	Location name	Days elapsed between transmitter release and last active signal received
151.022.7	4 July	M	710	1	7	Cripple Creek	42
151.104.7	4 July	M	645	1	7	Cripple Creek	36
151.164.6	4 July	M	760	1	7	Cripple Creek	32
151.205.7	4 July	M	630	3		Unknown	0
151.224.6	4 July	M	675	1	6	Sawmill Slough	55
151.245.6	4 July	M	595	1	9	Canada	39
151.245.7	4 July	F	930	2		Flats[e]	6
151.143.7	6 July	F	880	1	7	Cripple Creek	8
151.164.7	6 July	M	885	1	10	Mainstem - Clear Ck to Kerr Ck[g]	41
151.224.7	6 July	M	695	1	7	Cripple Creek	30
151.264.7	6 July	F	875	1	4	Kerr Creek	53
151.303.1	8 July	F	815	2		Flats[e]	1
151.324.1	8 July	M	770	1	4	Kerr Creek	51
151.344.1	8 July	M	655	1	5	Genes Lake/Creek	50
151.404.1	8 July	M	655	3		Unknown	0
151.423.1	8 July	F	805	1	8	Border Creek	38
151.443.1	8 July	M	645	1	9	Canada	46
151.303.2	9 July	M	685	1	1	Eulachon River	29
151.324.2	9 July	F	840	1	2	Clear Creek	45
151.344.2	9 July	M	635	1	3	Lake Creek	28
151.383.1	9 July	M	705	1	7	Cripple Creek	37
151.383.2	9 July	M	555	1	7	Cripple Creek	50
151.443.2	9 July	M	735	1	5	Genes Lake/Creek	31
151.474.1	9 July	M	595	2		Flats[e]	4
151.474.2	9 July	M	910	1	2	Clear Creek	50
151.383.3	10 July	M	640	1	7	Cripple Creek	17
151.404.3	10 July	F	795	1	9	Canada	44
151.423.2	10 July	M	815	1	3	Lake Creek	36
151.423.3	10 July	M	875	1	7	Cripple Creek	36
151.443.3	10 July	F	795	1	2	Clear Creek	49
151.303.3	11 July	M	790	2		Flats[e]	1
151.324.3	11 July	M	1000	1	2	Clear Creek	43
151.344.3	11 July	M	645	1	1	Eulachon River	41
151.443.5	11 July	M	855	1	7	Cripple Creek	35
151.474.3	11 July	M	825	1	7	Cripple Creek	35
151.474.5	11 July	M	645	1	2	Clear Creek	48
151.303.4	12 July	M	605	1	7	Cripple Creek	34
151.324.4	12 July	M	675	1	7	Cripple Creek	34
151.344.4	12 July	F	780	1	3	Lake Creek	28
151.383.5	12 July	M	780	1	4	Kerr Creek	31
151.423.4	12 July	M	875	1	4	Kerr Creek	46
151.443.4	12 July	M	610	1	5	Genes Lake/Creek	10
151.324.5	13 July	M	665	3		Unknown	17
151.344.5	13 July	M	645	1	7	Cripple Creek	26

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Transmitter frequency	Release date	Sex	Length mm (MEF)	Fate code[a]	Fate 1 spawning location code	Location name	Days elapsed between transmitter release and last active signal received
151.404.5	13 July	M	635	1	8	Border Creek	34
151.404.6	13 July	F	760	1	5	Genes Lake/Creek	33
151.423.6	13 July	M	635	2		Flats[e]	2
151.443.6	13 July	F	810	3		Unknown	0
151.303.5	14 July	F	935	1	5	Genes Lake/Creek	44
151.303.7	14 July	F	845	1	7	Cripple Creek	32
151.324.6	14 July	F	785	1	5	Genes Lake/Creek	32
151.324.7	14 July	M	600	1	13	Mainstem - undefined[f]	7
151.344.6	14 July	M	645	1	9	Canada	32
151.344.7	14 July	M	740	1	2	Clear Creek	22
151.404.7	14 July	F	830	1	5	Genes Lake/Creek	32
151.423.7	14 July	F	795	1	3	Lake Creek	31
151.443.7	14 July	M	795	1	7	Cripple Creek	32
151.474.6	14 July	M	585	1	7	Cripple Creek	27
151.474.7	14 July	M	665	1	4	Kerr Creek	6
151.303.6	15 July	M	640	1	7	Cripple Creek	31
151.383.7	15 July	F	845	1	5	Genes Lake/Creek	43
151.483.1	15 July	F	805	1	7	Cripple Creek	31
151.483.2	15 July	M	690	1	7	Cripple Creek	31
151.504.1	15 July	M	705	1	8	Border Creek	24
151.504.2	15 July	M	800	1	2	Clear Creek	31
151.524.1	15 July	M	615	1	5	Genes Lake/Creek	39
151.524.2	15 July	F	785	1	2	Clear Creek	26
151.544.1	15 July	M	625	1	7	Cripple Creek	31
151.544.2	15 July	F	735	1	7	Cripple Creek	31
151.581.1	15 July	M	600	1	3	Lake Creek	44
151.584.2	15 July	M	650	1	2	Clear Creek	44
151.604.1	15 July	M	625	1	7	Cripple Creek	31
151.604.2	15 July	F	815	1	4	Kerr Creek	43
151.624.1	15 July	F	855	1	2	Clear Creek	38
151.624.2	15 July	M	760	1	5	Genes Lake/Creek	34
151.644.1	15 July	F	780	1	1	Eulachon River	39
151.644.2	15 July	F	750	1	8	Border Creek	39
151.383.6	16 July	F	800	1	4	Kerr Creek	43
151.483.3	16 July	F	795	1	7	Cripple Creek	42
151.504.3	16 July	M	615	1	9	Canada	30
151.524.3	16 July	F	715	1	2	Clear Creek	43
151.544.3	16 July	M	605	1	2	Clear Creek	43
151.584.3	16 July	F	925	1	1	Eulachon River	38
151.604.3	16 July	F	820	1	13	Mainstem - undefined[f]	10
151.644.3	16 July	M	555	1	7	Cripple Creek	30
151.483.4	17 July	M	610	1	5	Genes Lake/Creek	29

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Transmitter frequency	Release date	Sex	Length mm (MEF)	Fate code[a]	Fate 1 spawning location code	Location name	Days elapsed between transmitter release and last active signal received
151.504.4	17 July	M	790	1	7	Cripple Creek	42
151.584.4	17 July	F	750	1	14	Chickamin River	4
151.604.4	17 July	M	700	1	5	Genes Lake/Creek	41
151.624.3	17 July	M	665	1	9	Canada	37
151.504.5	20 July	M	910	1	2	Clear Creek	39
151.524.4	20 July	F	695	1	5	Genes Lake/Creek	38
151.544.4	20 July	M	605	1	4	Kerr Creek	38
151.584.5	21 July	M	680	1	4	Kerr Creek	38
151.604.5	21 July	M	585	1	4	Kerr Creek	32
151.624.4	21 July	M	980	1	3	Lake Creek	17
151.644.5	22 July	F	850	1	7	Cripple Creek	19
151.544.5	23 July	M	695	1	5	Genes Lake/Creek	35
151.624.5	23 July	F	810	1	8	Border Creek	20
151.483.5	27 July	F	800	1	2	Clear Creek	30

[a] Fates:1 = successful spawner, 2 = died prior to spawning or regurgitated transmitter, and 3 = unknown.

[b] Does not include Border Creek.

[c] Does not include Sawmill Slough.

[d] Last active signals received above tidal waters but below the Eulachon River, North Fork, and/or South Fork towers.

[e] Transmitter did not pass the Eulachon River, North Fork, or South Fork towers. Transmitters located in the inter-tidal zone at the mouth of the river emitting inactive signals.

[f] Transmitter passed upstream of the North or South Fork towers, but no specific location therein was identified.

[g] Transmitter located between the South/North Fork towers and Kerr Creek.

Appendix A6.–Elapsed time between release and recapture (sulking period) of Chinook salmon in the lower Unuk River in 2009.

			Sulking period		
Spaghetti tag no.	Release date/time	Recapture date/time	Days	Hours	Minutes
1018	06/24/2009 14:01	07/02/2009 12:49	7	22	48
1064[a]	07/01/2009 11:01	07/02/2009 13:14	1	2	13
1115	07/03/2009 16:31	07/17/2009 11:40	13	19	9
1115	07/17/2009 11:40	07/21/2009 13:24	4	1	44
1141	07/04/2009 16:02	07/17/2009 9:20	12	17	18
1146[a]	07/06/2009 6:02	07/14/2009 6:08	8		6
1156	07/06/2009 17:02	07/13/2009 13:25	6	20	23
1158[a]	07/08/2009 5:25	07/16/2009 13:06	8	7	41
1159	07/08/2009 5:40	07/08/2009 13:04		7	24
1163	07/08/2009 8:03	07/11/2009 6:10	2	22	7
1170[a]	07/08/2009 15:39	07/20/2009 12:07	11	19	28
1196	07/09/2009 16:46	07/17/2009 15:30	7	22	44
1205	07/10/2009 8:15	07/11/2009 5:35		21	20
1243	07/12/2009 13:42	07/12/2009 14:26			44
1276	07/14/2009 9:50	07/15/2009 17:30	1	7	40
1304	07/15/2009 6:27	07/16/2009 17:20	1	10	53
1318	07/15/2009 13:16	07/16/2009 14:47	1	1	31
1324	07/15/2009 14:35	07/15/2009 15:15			40
1325[a]	07/15/2009 14:45	07/20/2009 15:58	5	1	13
1327	07/15/2009 15:00	07/17/2009 15:49	2		49
1328[a]	07/15/2009 15:04	07/21/2009 17:30	6	2	26
1383	07/16/2009 17:29	07/20/2009 7:15	3	13	46
1388	07/17/2009 5:35	07/17/2009 12:50		7	15
1394	07/17/2009 8:05	07/21/2009 15:40	4	7	35
1423	07/20/2009 6:13	07/20/2009 15:01		8	48
1437	07/20/2009 16:37	07/23/2009 12:26	2	19	49
Average			4	10	17

[a] Fish was also implanted with a transmitter. Average sulking period of the 6 fish with transmitters was 6.7 days.

Appendix A7.–Estimated annual escapement of Chinook salmon in the Unuk River by age class and gender, 1997–2009.

		Age class													
Year		1.0	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	1.4	2.3	1.5	2.4	Total
1997	Male			46		881			724	5	323		14		1,992
	%			1.3		24.0			19.7	0.1	8.8		0.4		54.3
	Female					5			526		1,102		46		1,679
	%					0.1			14.3		30.0		1.3		45.7
	Total			46		885			1,250	5	1,425		60		3,671
	%			1.3		24.1			34.0	0.1	38.8		1.6		100.0
1998	Male			232		1,299			1,392	6	325		6		3,259
	%			4.4		24.4			26.1	0.1	6.1		0.1		61.2
	Female								1,172		870		29		2,071
	%								22.0		16.3		0.5		38.8
	Total			232		1,299			2,564	6	1,195		35		5,330
	%			4.4		24.4			48.1	0.1	22.4		0.7		100.0
1999	Male			211		2,189			1,134		492		9		4,036
	%			3.4		35.4			18.3		8.0		0.1		65.3
	Female					26			914		1,196		9		2,145
	%					0.4			14.8		19.3		0.1		34.7
	Total			211		2,216			2,049		1,688		18		6,181
	%			3.4		35.8			33.1		27.3		0.3		100.0
2000	Male			9		2,444			2,312		517		19		5,302
	%			0.1		30.0			28.4		6.3		0.2		65.1
	Female					47			1,636		1,128		38		2,848
	%					0.6			20.1		13.8		0.5		34.9
	Total			9		2,491			3,948		1,645		56		8,150
	%			0.1		30.6			48.4		20.2		0.7		100.0
2001	Male			83		936			3,680		894		21		5,613
	%			0.7		8.3			32.5		7.9		0.2		49.6
	Female					10			3,243		2,443				5,697
	%					0.1			28.7		21.6				50.4
	Total			83		946			6,923		3,337		21		11,310
	%			0.7		8.4			61.2		29.5		0.2		100.0
2002	Male					2,437			1,675		1,146		22		5,280
	%					28.3			19.4		13.3		0.3		61.2
	Female					48			1,212		2,042		33	11	3,346
	%					0.6			14.1		23.7		0.4	0.1	38.8
	Total					2,485			2,887		3,188		55	11	8,626
	%					28.8			33.5		37.0		0.6	0.1	100.0
2003	Male			192		580		6	2,135		447		11		3,371
	%			3.1		9.3		0.1	34.2		7.2		0.2		54.0
	Female					11			1,795	6	1,027		34		2,874
	%					0.2			28.7	0.1	16.4		0.5		46.0
	Total			192		592		6	3,930	6	1,474		46		6,244
	%			3.1		9.5		0.1	62.9	0.1	23.6		0.7		100.0

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Year		Age class 1.0	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	1.4	2.3	1.5	2.4	Total
2004	Male			75		2,909			912		523				4,419
	%			1.2		47.9			15.0		8.6				72.7
	Female					27			377		1,234		19		1,658
	%					0.4			6.2		20.3		0.3		27.3
	Total			75		2,936			1,289		1,756		19		6,077
	%			1.2		48.3			21.2		28.9		0.3		100.0
2005	Male			368		507			2,454	5	247		6		3,587
	%			6.6		9.1			44.3	0.1	4.5		0.1		64.7
	Female					6			1,348		589	6	6		1,956
	%					0.1			24.3		10.6	0.1	0.1		35.3
	Total			368		513			3,802	5	836	6	12		5,543
	%			6.6		9.3			68.6	0.1	15.1	0.1	0.2		100.0
2006	Male			221		3,197			1,209		631				5,258
	%			2.9		41.4			15.7		8.2				68.1
	Female					58			938		1,469				2,465
	%					0.8			12.1		19.0				31.9
	Total			221		3,255			2,147		2,100				7,723
	%			2.9		42.1			27.8		27.2				100.0
2007	Male	5	5	179		837	5		2,619		325	5			3,980
	%	0.1	0.1	2.7		12.6	0.1		39.5		4.9	0.1			60.0
	Female								1,903		710	5	30		2,649
	%								28.7		10.7	0.1	0.5		40.0
	Total	5	5	179		837	5		4,522		1,035	10	30		6,629
	%	0.1	0.1	2.7		12.6	0.1		68.2		15.6	0.2	0.5		100.0
2008	Male			163	6	937			692		459		6		2,262
	%			4.1	0.1	23.5			17.4		11.5		0.1		56.8
	Female								537		1,174		6		1,717
	%								13.5		29.5		0.1		43.2
	Total			163	6	937			1,229		1,633		11		3,979
	%			4.1	0.1	23.5			30.9		41.0		0.3		100.0
2009	Male			66		1,899			1,251		159	5	10		3,391
	%			1.4		40.1			26.4		3.4	0.1	0.2		71.5
	Female					15			914		411		10		1,350
	%					0.3			19.3		8.7		0.2		28.5
	Total			66		1,914			2,165		570	5	21		4,741
	%			1.4		40.4			45.7		12.0	0.1	0.4		100.0
1997–2008 mean annual estimated escapement	Male	<1	<1	148	<1	1,596	<1	<1	1,745	1	527	<1	10		4,030
	%	<0.1	<0.1	2.2	<0.1	24.1	<0.1	<0.1	26.3	<0.1	8.0	<0.1	0.1		60.9
	Female					20			1,300	<1	1,249	1	21	1	2,592
	%					0.3			19.6	<0.1	18.9	<0.1	0.3	<0.1	39.1
	Total	<1	<1	148	<1	1,616	<1	<1	3,045	2	1,776	1	30	1	6,622
	%	<0.1	<0.1	2.2	<0.1	24.4	<0.1	<0.1	46.0	<0.1	26.8	<0.1	0.5	<0.1	100.0

APPENDIX B

Appendix B1.–Numbers of Unuk River Chinook salmon fall parr and spring smolt captured and released after excision of the adipose fin (adipose fin clips) and the number of adipose-clipped fish implanted with coded wire tags and estimated to have retained their tags for 24 hours (valid coded wire tags), 1993 through spring of 2010. CWT = coded wire tag.

Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number released with adipose clips[a]	Estimated number released with valid CWTs
1992	1993	Fall	04-38-03	10/13–10/22/93	10,304	10,263
1992	1993	Fall	04-38-04	10/25/1993	439	433
1992	1993	Fall	04-38-05	10/16–10/21/93	3,192	3,093
1992	1994	Spring	04-42-06	5/05–5/23/94	2,642	2,642
1992 brood year total					16,577	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	3,227	3,227
1993 brood year total					23,773	23,753
1994	1995	Fall	04-35-56	10/07–10/10/95	11,537	11,476
1994	1995	Fall	04-35-58	10/11–10/16/65	11,645	11,645
1994	1995	Fall	04-35-59	10/17–10/24/95	11,100	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	6,099	6,099
1994	1996	Spring	04-42-08	4/23–4/27/96	1,357	1,357
1994 brood year total					48,062	47,662
1995	1996	Fall	04-47-12	9/30–9/15/96	24,224	24,224
1995	1996	Fall	04-42-36	10/16–10/19/96	11,200	11,200
1995	1996	Fall	04-42-18	10/20–10/21/96	3,753	3,753
1995	1997	Spring	04-38-29	3/31–4/18/97	12,517	12,517
1995 brood year total					51,694	51,694
1996	1997	Fall	04-47-13	10/04–10/11/97	24,303	24,176
1996	1997	Fall	04-47-14	10/06–10/11/97	22,975	22,583
1996	1997	Fall	04-47-15	10/11–10/20/97	15,396	15,146
1996	1998	Spring	04-46-46	3/29–4/05/98	11,188	11,134
1996	1998	Spring	04-43-39	4/08–4/13/98	5,987	5,987
1996 brood year total					79,849	79,026
1997	1998	Fall	04-01-39	10/04–10/13/98	22,374	22,366
1997	1998	Fall	04-01-40	10/13–10/23/98	11,640	11,522
1997	1999	Spring	04-01-44	4/08–5/01/99	7,948	7,948
1997 brood year total					41,962	41,836
1998	1999	Fall	04-01-42	10/04–10/17/99	16,661	16,661
1998	2000	Spring	04-02-56	4/01–4/27/00	11,124	11,124
1998	2000	Spring	04-02-57	4/29–/4/00	2,209	2,209
1998 brood year total					29,994	29,994
1999	2000	Fall	04-03-74	10/06–10/20/00	21,853	21,853
1999	2000	Fall	04-02-88	10/20–10/29/00	10,072	10,072
1999	2001	Spring	04-01-45	4/2–4/23/01	16,561	16,561
1999 brood year total					48,486	48,486

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Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number released with adipose clips[a]	Estimated number released with valid CWTs
2000	2001	Fall	04-02-92	9/29–10/05/01	10,950	10,950
2000	2001	Fall	04-04-57	10/05–10/09/01	11,231	11,231
2000	2001	Fall	04-04-58	10/09–10/14/01	11,223	11,200
2000	2001	Fall	04-04-60	10/14–10/23/01	10,990	10,990
2000	2002	Spring	04-05-38	4/4–4/24/02	10,904	10,904
2000	2002	Spring	04-05-39	4/25–4/26/02	1,067	1,067
2000 brood year total					56,365	56,342
2001	2002	Fall	04-05-23	9/28–10/05/02	11,402	11,402
2001	2002	Fall	04-05-24	10/05–10/13/02	11,538	11,538
2001	2002	Fall	04-05-25	10/13–10/17/02	11,778	11,778
2001	2002	Fall	04-05-26	10/17–10/20/02	11,425	11,425
2001	2002	Fall	04-46-52	10/20–10/25/02	8,403	8,403
2001	2003	Spring	04-08-07	4/8–5/10/03	11,354	11,354
2001	2003	Spring	04-08-03	5/10/2003	483	483
2001 brood year total					66,383	66,383
2002	2003	Fall	04-08-42	9/29–10/10/03	23,255	23,255
2002	2003	Fall	04-08-10	10/10–10/14/03	11,464	11,464
2002	2003	Fall	04-04-61	10/14–10/18/03	9,779	9,779
2002	2004	Spring	04-09-75	03/29–04/10/04	11,666	11,666
2002	2004	Spring	04-09-76	04/10–04/17/04	2,730	2,730
2002 brood year total					58,894	58,894
2003	2004	Fall	04-09-77	9/19–10/03/04	11,789	11,789
2003	2004	Fall	04-09-78	10/03–10/19/04	11,417	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	8,585
2003 brood year total					35,747	35,714
2004	2005	Fall	04-11-55	9/24–10/18/05	23,330	23,330
2004	2005	Fall	04-11-56	10/18/05	941	941
2004	2006	Spring	04-11-52	4/2–4/23/06	16,371	16,269
2004 brood year total					40,642	40,540
2005	2006	Fall	04-13-05	10/3–10/12/06	23,406	23,406
2005	2006	Fall	04-11-51	10/12–10/19/06	9,393	9,393
2005	2007	Spring	04-12-81	4/9–4/27/07	4,731	4,721
2005 brood year total					37,530	37,520
2006	2007	Fall	04-12-82	9/30–10/03/07	11,777	11,777
2006	2007	Fall	04-12-83	10/03–10/07/07	11,716	11,716
2006	2007	Fall	04-12-84	10/07–10/13/07	11,756	11,756
2006	2007	Fall	04-12-85	10/13–10/21/07	9,840	9,840
2006	2008	Spring	04-14-62	4/19–4/27/08	10,489	10,489
2006 brood year total					55,578	55,578
2007	2008	Fall	04-14-65	10/03–10/21/08	16,595	16,595
2007	2009	Spring	04-14-63	4/17–5/02/09	5,578	5,573
2007 brood year total					22,173	22,168

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Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number released with adipose clips[a]	Estimated number released with valid CWTs
2008	2009	Fall	04-13-87	09/28–10/05/09	22,252	22,222
2008	2009	Fall	04-13-89	10/05–10/09/09	11,556	11,556
2008	2009	Fall	04-13-85	10/09–10/14/09	11,149	11,149
2008	2010	Spring	04-13-86	4/09–4/24/10	8,190	8,190
2008 brood year total					53,147	53,117

[a] Refer to Table 10 for estimates of the number of adipose-finclipped fish, by brood year, that survived to smolt.

Appendix B2.–Number of Unuk River Chinook salmon smolt caught in the spring and subsequently released with valid coded wire tags, mean smolt length and weight, and water temperature and depth, 2010.

Date	Traps checked[a]	Catch[b]	CPUE	Recaptures with tags	Recaptures without tags	Total tagged	Overnight mortalities	Tag retention (%)	Total valid tagged[d]	Mean length (mm)	Mean weight (g)	Water temperature (°C)	Water depth (in)[e]
7-Apr												4.0	4.5
8-Apr	97	646	6.7									3.0	3.5
9-Apr	112	745	6.7	177	8	1,391	0	100.0	1,391	68.6	3.5	2.5	2.5
10-Apr	124	575	4.6									2.5	1.5
11-Apr	127	589	4.6									3.0	0.5
12-Apr	127	589	4.6	169	5	1,752	0	100.0	1,752	68.1	3.3	3.0	0.0
13-Apr	113	567	5.0									2.5	0.0
14-Apr	116	582	5.0									3.0	0.0
15-Apr	117	587	5.0	167	6	1,735	0	100.0	1,735	69.9	3.6	3.0	1.8
16-Apr	120	528	4.4									3.5	7.3
17-Apr	118	519	4.4									5.0	11.8
18-Apr	125	550	4.4	213	10	1,598	0	100.0	1,598	70.5	3.7	4.5	14.5
19-Apr	126	330	2.6									4.5	16.0
20-Apr	142	372	2.6									4.5	25.5
21-Apr	110	288	2.6	159	7	990	0	100.0	990	70.8	3.8	4.0	29.5
22-Apr	104	220	2.1									4.5	23.0
23-Apr	120	253	2.1									4.0	18.5
24-Apr	119	251	2.1	92	5	724	0	100.0	724	69.4	3.7	4.5	16.0
Total	2,017	8,190		977	41	8,190	0	100.0	8,190				
Max	142	745	6.7	213	10	1,752		100.0	1,752	70.8	3.8	5.0	29.5
Min	97	220	2.1	92	5	724		100.0	724	68.6	3.3	2.5	0.0
Mean	119	482	4.1	163	7	1,170		100.0	1,170	69.5[f]	3.6[f]	3.6	9.8

[a] Equals the total number of trap checks that day, i.e., individual traps checked twice daily would count as two traps checked.

[b] Equals the number of previously untagged Chinook salmon smolt captured.

[c] Equals the average number of previously untagged Chinook salmon smolt captured per trap check.

[d] Total valid tagged equals total tagged minus overnight mortalities times percent tag retention.

[e] Depth standardized such that 0 in represents minimal depth recorded each season.

[f] Of all lengths or weights collected.

Appendix B3.–Number of Unuk River Chinook salmon parr caught in the fall and subsequently released with valid coded wire tags, mean smolt length and weight, and water temperature and depth, 2009.

Date	Traps checked[a]	Catch[b]	CPUE[c]	Recaptures with tags	Recaptures without tags	Total tagged	Overnight mortalities	Tag retention (%)	Total valid tagged[d]	Mean length (mm)	Mean weight (g)	Water temperature (°C)	Water depth (in)[e]
25-Sep													45.0
26-Sep													53.0
27-Sep													35.0
28-Sep	108	1,347	12.5			1,347	2	100.0	1,345	59.4	2.5	6.0	25.0
29-Sep	157	2,982	19.0			2,982		99.0	2,952	60.9	2.8	5.5	19.0
30-Sep	165	4,056	24.6	31	1	4,056	2	100.0	4,054	59.4	2.7	5.5	15.5
1-Oct	172	2,582	15.0	30		2,582		100.0	2,582	58.3	2.4	6.0	15.5
2-Oct	63	2,283	36.2	56		2,283		100.0	2,283	62.1	2.8	5.5	14.0
3-Oct	167	4,194	25.1	147	1	4,194	3	100.0	4,191	60.0	2.5	5.0	11.5
4-Oct	160	3,276	20.5	314	3	3,276	2	100.0	3,274	58.9	2.5	5.0	9.0
5-Oct	171	4,529	26.5	263	2	4,529	3	100.0	4,526	60.7	2.8	5.5	7.5
6-Oct	190	3,424	18.0	226	2	3,424	6	100.0	3,418	62.8	3.1	7.5	23.5
7-Oct	146	1,480	10.1									6.0	16.0
8-Oct	165	1,672	10.1	284	5	3,152	4	100.0	3,148	59.9	2.5	6.5	12.0
9-Oct	183	3,262	17.8	369	5	3,262	1	100.0	3,261	65.5	3.6	6.5	9.5
10-Oct	184	3,497	19.0	524	10	3,497		100.0	3,497	61.6	2.7	6.0	7.5
11-Oct	180	3,113	17.3	520	10	3,113	1	100.0	3,112	59.3	2.5	5.0	6.0
12-Oct	106	1,480	14.0	271	4	1,480		100.0	1,480	64.5	3.4	4.5	3.5
13-Oct	97	1,804	18.6									4.0	2.0
14-Oct						1,804		100.0	1,804	60.8	2.8	4.0	1.0
15-Oct												4.0	0.0
Total	2,414	44,981		3,035	43	44,981	24		44,927				
Max	190	4,529	36.2	524	10	4,529	6	100.0	4,526	65.5	3.6	7.5	53.0
Min	63	1,347	10.1	0	0	1,347	0	99.0	1,345	58.3	2.5	4.0	0.0
Mean	151	2,811	18.6	217	3	2,999	2	99.9	2,995	60.7[f]	2.7[f]	5.4	15.8

[a] Equals the total number of trap checks that day, i.e., individual traps checked twice daily would count as two traps checked.

[b] Equals the number of previously untagged juvenile Chinook salmon captured, either as smolt or as parr.

[c] Equals the average number of previously untagged Chinook salmon parr captured per trap check.

[d] Total valid tagged equals total tagged minus overnight mortalities times percent tag retention.

[e] Depth standardized such that 0 in represents minimal depth recorded each season.

[f] Of all lengths or weights collected.

Appendix B4.–Mean length, weight, and associated statistics of Unuk River Chinook salmon spring smolt and fall parr, 1978 through spring of 2010.

			Length						Weight					
Sample year	Brood year	Spring/ fall	Mean sample date	Sample size	Mean length	Variance	SD	SE	Mean sample date	Sample size	Mean weight	Variance	SD	SE
1978	1977	Fall	1-Dec	50	64.7									
1982	1980	Spring	15-Apr	650	67.4									
1982	1981	Fall	13-Dec	246	68.2									
1983	1981	Spring	10-Apr	703	69.0									
1983	1982	Fall	30-Oct	500	63.8									
1984	1982	Spring	7-Apr	650	67.4									
1985	1983	Spring	11-Apr	703	69.0	44.0	6.6	0.25						
1986	1984	Spring	2-Apr	400	66.0	49.4	7.0	0.35						
1988	1986	Spring	13-Apr	423	69.6	41.4	6.4	0.31						
1994	1992	Spring	14-May	327	75.3	52.3	7.2	0.40	14-May	327	4.6	1.9	1.4	0.08
1994	1993	Fall	16-Oct	393	69.2	40.3	6.4	0.32	16-Oct	393	3.6	1.5	1.2	0.06
1995	1993	Spring	24-Apr	260	73.2	60.6	7.8	0.48						
1995	1994	Fall	20-Oct	823	65.3	38.9	6.2	0.22						
1996	1994	Spring	19-Apr	291	70.2	41.2	6.4	0.38	19-Apr	291	3.5	1.2	1.1	0.06
1996	1995	Fall	11-Oct	804	67.3	33.9	5.8	0.21	11-Oct	804	3.4	0.8	0.9	0.03
1997	1995	Spring	7-Apr	327	71.2	36.2	6.0	0.33	7-Apr	327	3.6	0.9	1.0	0.05
1997	1996	Fall	10-Oct	624	61.6	44.8	6.7	0.27	11-Oct	133	2.7	1.0	1.0	0.09
1998	1996	Spring	2-Apr	421	65.8	61.8	7.9	0.38	2-Apr	421	2.8	1.3	1.1	0.06
1998	1997	Fall	14-Oct	398	67.4	46.3	6.8	0.34	17-Oct	243	3.3	1.2	1.1	0.07
1999	1997	Spring	18-Apr	266	70.6	67.4	8.2	0.50	18-Apr	266	3.7	1.7	1.3	0.08
1999	1998	Fall	13-Oct	93	63.4	52.5	7.2	0.75	15-Oct	93	2.9	1.2	1.1	0.12
2000	1998	Spring	17-Apr	271	71.5	56.9	7.5	0.46	17-Apr	270	3.8	1.7	1.3	0.08
2000	1999	Fall	17-Oct	257	65.9	43.5	6.6	0.41	17-Oct	257	3.5	1.2	1.1	0.07
2001	1999	Spring	12-Apr	173	67.4	30.3	5.5	0.42	12-Apr	173	3.3	0.7	0.8	0.06
2001	2000	Fall	13-Oct	485	62.7	45.8	6.8	0.31	13-Oct	485	2.9	0.9	0.9	0.04
2002	2000	Spring	20-Apr	367	68.6	43.4	6.6	0.34	20-Apr	367	3.5	1.2	1.1	0.06
2002	2001	Fall	14-Oct	540	60.8	37.5	6.1	0.26	14-Oct	540	2.6	0.7	0.8	0.03
2003	2001	Spring	23-Apr	333	66.1	57.7	7.6	0.42	23-Apr	333	3.2	1.2	1.1	0.06
2003	2002	Fall	9-Oct	443	64.0	54.3	7.4	0.35	9-Oct	443	3.0	1.5	1.2	0.06
2004	2002	Spring	7-Apr	383	66.6	44.2	6.7	0.35	7-Apr	383	3.1	1.0	1.0	0.05
2004	2003	Fall	7-Oct	597	60.9	50.7	7.1	0.29	7-Oct	597	2.9	0.8	0.9	0.04
2005	2003	Spring	15-Apr	284	68.1	40.6	6.4	0.38	15-Apr	383	2.7	0.6	0.7	0.04
2005	2004	Fall	6-Oct	448	68.2	50.2	7.1	0.33	6-Oct	448	3.8	1.6	1.3	0.06
2006	2004	Spring	13-Apr	343	69.2	34.8	5.9	0.32	13-Apr	343	3.4	0.8	0.9	0.05
2006	2005	Fall	10-Oct	596	62.8	40.2	6.3	0.26	10-Oct	596	2.8	0.8	0.9	0.04
2007	2005	Spring	18-Apr	299	66.4	34.3	5.9	0.32	18-Apr	299	3.1	0.7	0.9	0.05
2007	2006	Fall	7-Oct	522	60.7	40.5	6.4	0.28	7-Oct	522	2.7	0.8	0.9	0.04
2008	2006	Spring	24-Apr	392	67.6	38.1	6.2	0.31	24-Apr	392	3.2	0.9	1.0	0.05
2008	2007	Fall	12-Oct	390	58.6	39.1	6.3	0.32	12-Oct	390	2.3	0.6	0.8	0.04
2009	2007	Spring	25-Apr	336	64.8	55.1	7.4	0.40	25-Apr	336	2.8	1.2	1.1	0.06
2009	2008	Fall	4-Oct	478	60.7	48.4	7.0	0.32	4-Oct	478	2.7	1.1	1.1	0.05
2010	2008	Spring	17-Apr	232	69.5	47.0	6.9	0.45	17-Apr	232	3.6	1.3	1.1	0.07

Appendix B5.–Numbers of Unuk River Chinook salmon examined for adipose fin clips, sacrificed for coded wire tag sampling purposes, valid coded wire tags decoded, percentage of sacrificed fish with valid coded wire tags, percentage of fish examined with adipose fin clips, the estimated fraction of examined fish with valid tags (marked fraction or θ), by age class and mark-recapture sampling event, 2002 brood through 2009 returns.

						Number of valid tags						
Brood year	Age class	Year examined	Number examined	Adipose fin clips	Number sacrificed	Fall	Spring	Total	Percent valid tags	Percent adipose fin clips	Marked fraction (θ)	Event[a]
2002	1.1	2005	1									1
2002	R.1 → 1.1	2005	1									1
2002	1.1	2005	62	4	4		1	1	25.0	6.5	0.016	2
2002	R.1 → 1.1	2005	1	1	1	1		1	100.0	100.0	1.000	2
2002	R.R → 1.1	2005	5									2
2002	1.2	2006	311	14	11	6	2	8	72.7	4.5	0.033	1
2002	R.2 → 1.2	2006	75	3	3	2	1	3	100.0	4.0	0.040	1
2002	R.R → 1.2	2006	4	1	1		1	1	100.0	25.0	0.250	1
2002	1.2	2006	333	37	28	11	10	21	75.0	11.1	0.083	2
2002	R.2 → 1.2	2006	55	2	2	2		2	100.0	3.6	0.036	2
2002	R.R → 1.2	2006	16	1	1					6.3		2
2002	1.3	2007	383	32	3	2	1	3	100.0	8.4	0.084	1
2002	R.3 → 1.3	2007	89	7	1					7.9		1
2002	1.3	2007	663	65	14	8	3	11	78.6	9.8	0.077	2
2002	R.3 → 1.3	2007	131	16	1					12.2		2
2002	1.4	2008	244	24	1					9.8		1
2002	R.4 → 1.4	2008	53	4						7.5		1
2002	1.4	2008	99	17	3	3		3	100.0	17.2	0.172	2
2002	R.4 → 1.4	2008	26	3						11.5		2
2002	R.R → 1.4	2008	1									2
2002	1.5	2009	1									1
2002	1.5	2009	3	1						33.3		2
2002 brood year total			2,557	232	74	35	19	54	73.0	9.1	0.066	1&2
2003	R.R → 1.1	2006	1									1
2003	1.1	2006	22	1	1	1		1	100.0	4.5	0.045	2
2003	R.1 → 1.1	2006	2	1	1		1	1	100.0	50.0	0.500	2
2003	R.R → 1.1	2006	3									2
2003	2.1	2007	1									2
2003	1.2	2007	54	4	4	2	2	4	100.0	7.4	0.074	1
2003	R.2 → 1.2	2007	10	1	1		1	1	100.0	10.0	0.100	1
2003	1.2	2007	135	16	15	6	7	13	86.7	11.9	0.103	2
2003	R.2 → 1.2	2007	19	1	1					5.3		2
2003	1.3	2008	176	15						8.5		1
2003	R.3 → 1.3	2008	46	3						6.5		1
2003	R.R → 1.3	2008	1									1
2003	1.3	2008	81	9	1	1		1	100.0	11.1	0.111	2
2003	R.3 → 1.3	2008	20	3	1		1	1	100.0	15.0	0.150	2
2003	1.4	2009	37	2	1	1		1	100.0	5.4	0.054	1

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Brood year	Age class	Year examined	Number examined	Adipose fin clips	Number sacrificed	Number of valid tags: Fall	Spring	Total	Percent valid tags	Percent adipose fin clips	Marked fraction (θ)	Event[a]
2003	R.4 → 1.4	2009	14	3						21.4		1
2003	1.4	2009	75	7	2		2	2	100.0	9.3	0.093	2
2003	R.4 → 1.4	2009	25	2						8.0		2
2003	2.3	2009	1									2
2003 brood year total			723	68	28	11	14	25	89.3	9.4	0.084	1&2
2004	1.1	2007	2									1
2004	R.1 → 1.1	2007	1									1
2004	1.1	2007	29	5	5	2	3	5	100.0	17.2	0.172	2
2004	R.1 → 1.1	2007	6									2
2004	0.2	2007	1									2
2004	1.2	2008	110	6	4	2	1	3	75.0	5.5	0.041	1
2004	R.2 → 1.2	2008	19	1						5.3		1
2004	R.R → 1.2	2008	2									1
2004	0.3	2008	1									1
2004	1.2	2008	72	10	9	2	3	5	55.6	13.9	0.077	2
2004	R.2 → 1.2	2008	12	1	1					8.3		2
2004	R.R → 1.2	2008	1									2
2004	1.3	2009	162	12	3		1	1	33.3	7.4	0.025	1
2004	R.3 → 1.3	2009	29	3						10.3		1
2004	R.R → 1.3	2009	1									1
2004	1.3	2009	315	33	9	3	2	5	55.6	10.5	0.058	2
2004	R.3 → 1.3	2009	73	9	3	1	1	2	66.7	12.3	0.082	2
2004	R.R → 1.3	2009	1									2
2004 brood year total			837	80	34	10	11	21	61.8	9.6	0.059	1&2
2005	0.1	2007	1									2
2005	1.1	2008	8	1	1	1		1	100.0	12.5	0.125	1
2005	1.1	2008	16	1	1	1		1	100.0	6.3	0.063	2
2005	R.R → 1.1	2008	1									2
2005	0.3	2009	1									1
2005	1.2	2009	209	14	14	7	5	12	85.7	6.7	0.057	1
2005	R.2 → 1.2	2009	30									1
2005	1.2	2009	295	27	26	12	10	22	84.6	9.2	0.077	2
2005	R.2 → 1.2	2009	48	3	3	1	1	2	66.7	6.3	0.042	2
2005	R.R → 1.2	2009	2									2
2005 brood year total			611	46	45	22	16	38	84.4	7.5	0.064	1&2
2006	1.1	2009	5	1	1	1		1	100.0	20.0	0.200	1
2006	R.1 → 1.1	2009	1									1
2006	R.R → 1.1	2009	1									1
2006	1.1	2009	6	1	1					16.7		2
2006	R.1 → 1.1	2009	4									2
2006	R.R → 1.1	2009	3									2
2006 brood year total			20	2	2	1		1	50.0	10.0	0.050	1&2

[a] Fish captured in both events are only listed in event 1 to avoid double counting.

Appendix B6.–Estimated marine harvest ($\hat{r}_{uj}$) of Chinook salmon from the 2002–2006 broods (Panels A–G), bound for the Unuk River, and associated statistics, by harvest strata, through 2009.

Fishery	Fishery location	Year	Sample type	Sampling period type	Sampling period	Estimation level	H_u	$\text{var}(H_u)$	n_u	a_u	a'_u	t_u	t'_u	m_{uj}	$\hat{r}_{uj}$	$SE(\hat{r}_{uj})$
	PANEL A: 2002 BROOD YEAR															
Terminal purse seine, jack	District 101	2005	1	7	28	4	17		17	5	5	3	3	1	15	15
Drift gill net	District 108	2006	1	7	38	4	16		5	3	3	3	3	1	48	48
Drift gill net, jack	District 108	2006	1	7	30	4	22		7	1	1	1	1	1	47	47
Experimental troll	District 101-29	2006	1	7	23	5	1,141		482	27	24	21	20	1	42	42
Recreational MB	Ketchikan	2006	1	2	16	4	544	97,141	167	14	14	10	10	1	49	49
Recreational MB	Ketchikan	2006	1	2	17	4	196	1,777	76	3	3	3	3	1	39	38
Recreational MB, jack	Ketchikan	2006	1	2	13	4	56	568	19	2	2	1	1	1	45	44
Recreational DE	Sitka	2006	1	2	11	4	846		846	41	40	33	33	1	15	15
Traditional purse seine	District 102	2006	1	7	27	4	296		70	9	9	7	7	1	64	63
Traditional purse seine	District 104	2006	1	7	27	4	343		143	7	7	5	5	1	36	36
Traditional purse seine	District 104	2006	1	7	29	4	901		367	6	6	4	4	1	37	37
Traditional troll	NE Quadrant	2006[a]	1	7	5	3	1,575		908	214	214	204	204	2	52	36
Traditional troll	NW Quadrant	2006	1	7	3	3	96,526		27,048	1,274	1,225	910	909	2	112	79
Traditional troll	NW Quadrant	2006	1	7	4	3	42,231		13,226	591	558	408	407	1	51	51
Traditional troll	SE Quadrant	2006	1	7	4	3	5,651		1,906	146	44	102	102	1	45	45
Traditional troll	SW Quadrant	2006	1	7	4	3	13,435		4,338	215	213	158	157	1	48	47
Traditional troll	Area 001 CDFO	2006	1	7	25	3	24,177		11,778	348	348	314	313	1	31	31
Mixed net and seine	Area 000 CDFO	2007	1	7	25	3	3,679		863	17	17	17	17	1	64	64
Drift gill net	District 106	2007	1	7	2	4	634		198	14	14	11	11	1	48	48
Drift gill net	District 106	2007	1	7	29	4	85		20	3	3	3	3	1	64	64
Drift gill net	District 106	2007	1	7	30	4	50		29	4	4	4	4	1	26	26
Drift gill net	District 108	2007	1	7	25	4	1,265		316	20	19	16	16	1	64	63
Experimental troll	District 101-29	2007	1	7	22	5	202		113	5	5	5	5	1	27	26
Experimental troll	District 101-29	2007	1	7	23	5	423		239	22	22	14	14	1	7	26
Experimental troll	District 101-29	2007	1	7	24	5	1,165		516	20	20	13	13	1	34	34
Experimental troll	District 101-29	2007	1	7	25	5	2,151		737	33	32	23	23	1	45	45
Experimental troll	District 101-29	2007	1	7	26	5	1,908		623	39	39	31	31	1	46	46
Experimental troll	District 105-41	2007	1	7	21	5	78		68	8	8	8	8	1	17	17
Experimental troll	District 105-41	2007	1	7	26	5	442		188	8	8	7	7	1	36	35

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Fishery	Fishery location	Year	Sample type	Sampling period type	Sampling period	Estimation level	H_u	$\mathrm{var}(H_u)$	n_u	a_u	a'_u	t_u	t'_u	m_{uj}	$\hat{r}_{uj}$	$SE(\hat{r}_{uj})$
Experimental troll	District 106-20	2007	1	7	24	5	33		33	4	4	4	4	1	15	15
Experimental troll	District 106-30	2007	1	7	24	5	543		214	15	15	14	14	1	38	38
Experimental troll	District 108-41	2007	1	7	20	5	298		135	8	8	8	8	1	33	33
Experimental troll	District 108-41	2007	1	7	23	5	464		260	8	8	8	8	1	27	26
Experimental troll	District 108-41	2007	1	7	24	5	384		171	10	10	9	9	1	34	33
Experimental troll	District 109-62	2007	1	7	21	5	1,443		1,036	98	98	94	94	2	42	29
Experimental troll	District 112-12	2007	1	7	25	5	1,242		796	189	189	178	178	1	24	23
Recreational MB	Craig	2007	1	2	13	4	398		366	11	11	11	11	1	16	16
Recreational DE	Ketchikan	2007	1	2	12	4	322		188	26	26	23	23	1	26	25
Recreational DE	Sitka	2007	1	2	11	4	809		809	43	43	36	36	1	15	15
Recreational MB	Sitka	2007	1	2	10	4	2,261	567,179	467	12	12	11	11	1	73	73
Traditional troll	NE Quadrant	2007	1	7	3	3	4,921		2,009	192	185	173	173	1	38	38
Traditional troll	NW Quadrant	2007	1	7	3	3	103,464		32,704	1,529	1,426	1,098	1,093	7	360	138
Traditional troll	SE Quadrant	2007	1	7	3	3	7,357		3,459	185	180	127	127	2	66	46
Traditional troll	SW Quadrant	2007	1	7	1	3	3,477		2,483	116	116	73	72	2	43	30
Traditional troll	SW Quadrant	2007	1	7	3	3	24,807		10,193	316	311	224	223	4	150	75
Traditional troll	Area 001 CDFO	2007	1	7	25	3	18,076		7,710	167	167	144	144	1	35	35
Drift gill net	District 101	2008	1	7	28	4	182		98	8	8	6	6	1	28	28
Drift gill net	District 106	2008	1	7	26	4	175		100	10	10	10	10	1	26	26
Drift gill net	District 108	2008	1	7	21	4	1,591		1,041	40	40	39	39	1	23	23
Drift gill net	District 108	2008	1	7	24	4	1,267		655	29	29	29	29	1	29	29
Experimental troll	District 108-41	2008	1	7	24	5	331		222	15	15	15	15	1	23	22
Experimental troll	District 112-12	2008	1	7	19	5	356		232	34	34	32	32	1	23	23
Recreational DE	Ketchikan	2008	1	2	11	4	358		286	22	21	20	20	1	20	19
Recreational MB	Yakutat	2008	1	2	10	4	79		74	2	2	2	2	1	16	16
Traditional troll	NW Quadrant	2008	1	7	1	3	10,799		3,854	241	238	173	172	3	129	74
Traditional troll	NW Quadrant	2008	1	7	3	3	48,029		18,729	1,286	1,258	906	900	1	40	39
Traditional troll	SW Quadrant	2008	1	7	3	3	10,064		6,137	284	278	195	195	1	25	25
2002 brood year total							443,585	666,665	159,774	7,999	7,749	6,001	5,982	73	2,697	335

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Fishery	Fishery location	Year	Sample type	Sampling period type	Sampling period	Estimation level	H_u	$\text{var}(H_u)$	n_u	a_u	a'_u	t_u	t'_u	m_{uj}	$\hat{r}_{uj}$	$SE(\hat{r}_{uj})$
						PANEL B: 2003 BROOD YEAR										
Terminal purse seine, jack	District 112-22	2006	1	7	28	5	207		157	26	26	24	24	1	16	15
Drift gill net	District 108	2007	1	7	27	4	731[b]		731	62	61	59	59	1	12	12
Recreational DE	Ketchikan	2007	1	2	12	4	322		188	26	26	23	23	1	20	20
Traditional purse seine	District 107	2007	1	7	28	4	64[b]		64	1	1	1	1	1	12	11
Experimental troll	District 101-29	2008	1	7	21	5	175		85	7	7	6	5	1	29	29
Experimental troll	District 101-29	2008	1	7	23	5	315		173	12	12	12	12	2	43	30
Experimental troll	District 101-45	2008	1	7	23	5	13[b]		13	2	2	2	2	1	12	11
Experimental troll	District 105-41	2008	1	7	23	5	217		159	10	10	10	10	1	16	16
Experimental troll	District 106-30	2008	1	7	26	5	107		20	2	2	2	2	1	64	63
Experimental troll	District 109-62	2008	1	7	21	5	698		595	91	91	87	87	1	14	13
Experimental troll	District 109-62	2008	1	7	24	5	1,854		983	186	185	170	170	1	23	22
Recreational DE	Ketchikan	2008	1	2	11	4	358		286	22	21	20	20	1	16	15
Traditional troll	NE Quadrant	2008	1	7	1	3	1,455		863	95	95	83	83	1	20	20
Traditional troll	NW Quadrant	2008	1	7	3	3	48,029		18,729	1,286	1,258	906	900	2	63	44
Traditional troll	NW Quadrant	2008	1	7	4	3	24,386		8,788	813	806	506	502	1	34	33
Traditional troll	SE Quadrant	2008	1	7	1	3	3,319		1,872	75	74	66	66	1	21	21
Experimental troll	District 101-29	2009	1	7	26	5	1,852		769	53	53	46	46	1	29	28
Experimental troll	District 105-41	2009	1	7	23	5	218		166	9	9	8	8	1	16	15
Recreational DE	Ketchikan	2009	1	2	11	4	713		572	44	43	35	35	2	30	21
Recreational MB	Ketchikan	2009	1	2	12	4	965		209	21	21	15	15	1	55	54
Traditional troll	NW Quadrant	2009	1	7	1	3	15,584		5,773	495	490	361	361	1	32	32
2003 brood year total							101,582		41,195	3,338	3,293	2,442	2,431	24	577	131
						PANEL C: 2004 BROOD YEAR										
Drift gill net	District 106	2008	1	7	27	4	318		206	17	17	14	14	1	26	26
Drift gill net, jack	District 108	2008	1	7	22	4	67		60	3	3	3	3	1	19	18
Private non-profit	District 101-95	2008	1	7	28	5	2,511		1,080	95	95	91	91	1	39	39
Terminal purse seine, jack	District 107	2008	1	7	30	4	7[b]		7	2	2	2	2	1	17	16
Experimental troll	District 101-29	2009	1	7	24	5	910		528	45	45	42	42	1	29	29
Experimental troll	District 101-29	2009	1	7	26	5	1,852		769	53	53	46	46	1	41	40
Experimental troll	District 101-29	2009	1	7	25	5	1,828		509	33	33	28	28	1	61	60

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Fishery	Fishery location	Year	Sample type	Sampling period type	Sampling period	Estimation level	H_u	$\mathrm{var}(H_u)$	n_u	a_u	a'_u	t_u	t'_u	m_{uj}	$\hat{r}_{uj}$	$SE(\hat{r}_{uj})$
Experimental troll	District 105-41	2009	1	7	25	5	326		64	3	3	3	3	1	86	86
Experimental troll	District 105-41	2009	1	7	26	5	208		54	5	5	4	4	1	65	65
Experimental troll	District 105-41	2009	1	7	23	5	218		166	9	9	8	8	1	22	22
Experimental troll	District 109-10	2009	1	7	26	5	215		179	54	54	47	47	1	20	20
Experimental troll	District 109-62	2009	1	7	23	5	1,211		842	110	110	88	88	1	24	24
Experimental troll	District 109-62	2009	1	7	26	5	473		370	49	49	37	37	2	43	30
Experimental troll	District 109-62	2009	1	7	22	5	497		430	55	55	46	46	1	20	19
Experimental troll	District 114-50	2009	1	7	25	5	729		527	31	31	18	18	1	23	23
Recreational DE	Ketchikan	2009	1	2	11	4	713		572	44	43	35	35	1	22	21
Recreational MB	Sitka	2009	1	2	11	4	779		291	34	34	20	20	1	45	45
Traditional troll	NW Quadrant	2009	1	7	1	3	75,088		25,935	2,632	2,597	1,126	1,123	1	50	49
Traditional troll	SE Quadrant	2009	1	7	3	3	3,162		867	62	62	38	38	1	62	61
Traditional troll	SW Quadrant	2009	1	7	1	3	5,375		1,776	142	139	56	56	1	52	52
2004 brood year total							96,487		35,232	3,478	3,439	1,752	1,749	21	768	187
PANEL D: 2005 BROOD YEAR																
Drift gill net	District 101	2009	1	7	26	4	473		252	11	11	6	6	1	30	29
Drift gill net	District 106	2009	1	7	25	4	540		372	17	17	16	16	1	23	22
Recreational MB	Ketchikan	2009	1	2	13	4	1,347		240	20	20	18	18	1	88	88
Recreational MB	Ketchikan	2009	1	2	16	4	141		59	6	6	5	5	1	38	37
Recreational MB	Yakutat	2009	1	2	10	4	58		37	6	6	6	6	1	25	24
Traditional troll	NW Quadrant	2009	1	7	1	3	15,584		5,773	495	490	361	361	1	43	42
Traditional troll	NW Quadrant	2009	1	7	1	3	75,088		25,935	2,632	2,597	1,126	1,123	1	46	46
2005 brood year total							93,231		32,668	3,187	3,147	1,538	1,535	7	292	122
PANEL E: 2006 BROOD YEAR																
Terminal purse seine, jack	District 107	2009	1	7	28	4	46[b]		46	5	5	3	3	1	20	20
2006 brood year total							46		46	5	5	3	3	1	20	20

[a] This recovery is considered an age-1.3 fish as it was harvested in the 2006–2007 winter troll fishery.

[b] Recorded harvest was less than number sampled; recorded harvest was therefore changed to equal the number sampled.

Appendix B7.–Voluntary recoveries of Chinook salmon possessing a valid Unuk River Chinook salmon CWT from 1995 to 2009. CDFO = Canadian Department of Fisheries and Oceans.

Fishery	Fishery location	Year	Recovery date	Tag code	Brood year
Recreational	CDFO Area 001	1999	05/21/1999	44213	1993
Recreational	CDFO Area 002	2000	05/21/2000	43829	1995
Recreational	CDFO Area 001	2000	06/09/2000	44712	1995
Recreational	Ketchikan	2001	06/17/2001	44712	1995
Recreational	Ketchikan	2001	06/21/2001	44236	1995
Recreational	Ketchikan	2001	10/10/2001	44713	1996
Recreational	CDFO Area 000	2002	05/18/2002	44339	1996
Recreational	Homer	2003	06/17/2003	40256	1998
Recreational	Ketchikan	2004	06/24/2004	40142	1998
Recreational	Ketchikan	2004	06/29/2004	40142	1998
Recreational	Ketchikan	2004	07/01/2004	40256	1998
Recreational, sublegal research	District 101-85	2005	05/27/2005	40810	2002
Recreational	CDFO Area 009	2005	06/21/2005	40145	1999
Recreational, sublegal research	District 101-85	2005	07/25/2005	40810	2002
Recreational, sublegal research	District 101-90	2005	08/07/2005	40842	2002
Recreational, sublegal research	District 101-45	2009	06/20/2009	41462	2006

APPENDIX C

Appendix C1.–Computer files used in the creation of this manuscript.

File name	Description
app A5.xlsx	Telemetry data, appendix a5
App A6.xlsx	Appendix A6, Sulking data
App A7.xlsx	Appendix A7, yearly age, sex.
Table 1&2.xlsx	2009 capture histories and spawning locations.
Unuk ASL Migration, table5,6,9.xlsx	Table,5,6,9; ASL data from event 1&2 and migration data.
UnukRT,table 7&8xlsx.	Radio tagging stratification and tables 7&8.
Unuk41Theta09 tables4,10-20 &App B1,5,6.xlsx	Adult harvest, CWT, theta , IM, AEQ, and estimates of adult escapement data. Table 4, 10-20 and data for appendix A4
Unuk Smolt 2010_appB2:2.xlsx	Appendix B2, smolt trapping and tagging data.
Unuk YOY_App B3.xlsx	Appendix B2, YOY spring tagging data.
Appendix B7.docx	Appendix B7, voluntary cwt recoveries.
Unkeffort97-09xls	Figure 9, setnet effort and catch data.
09KStests.xls	Figures10,11 and 12: KS tests for length on Mark, Captures, and Recaptures of large fish.
KS medium 09.xls	Figures 14,15,16; KS test for length on Mark, Capture, and Recaptures of medium fish.