Fishery Data Series No. 05-21

Production of Coho Salmon from the Unuk River, 2002–2003

by

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and

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May 2005

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

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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May 2005

Development and publication of this manuscript were partially financed by the Federal Aid in Sport fish Restoration Act(16 U.S.C.777-777K) under Project F-10-17 and F-10-19, Job No. S-1-8.

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This document should be cited as:
Weller, J .L., E. L. Jones III, and A. B. Holm. 2005. Production of coho salmon from the Unuk River, 2002–2003. Alaska Department of Fish and Game, Fishery Data Series No. 05-21, Anchorage.

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ABSTRACT

The Unuk River stock of coho salmon *Oncorhynchus kisutch* was assessed in 2002–2003. Baited minnow traps were fished daily on the Unuk River from 2 April through 27 April 2002. Captured smolt were marked with coded-wire tags and excision of adipose fins. Different codes were used for small (70–84 mm FL) and large (≥85 mm FL) smolt. Sampled smolt averaged 84.5 mm FL and 6.7 g in weight. In 2003, port and creel sampling projects recovered 116 of these coded-wire tags, which with expansion represent an estimated harvest of 21,735 (SE = 2,896) in U.S. marine waters. Of this harvest, the troll fishery took an estimated 44%; purse seine fisheries, 32%; drift gillnet fisheries, 20%; and recreational fisheries, 4%. An estimated 26,934 (SE = 6,495) adults returned to the Unuk River, as determined by a mark-recapture study using radiotelemetry to estimate the loss of tags due to handling-induced mortality (23.5%). Estimated run size (i.e., escapement, harvest, and in-river handling-induced loss) in 2003 for this stock is 48,953 (SE = 7,111); marine exploitation rate was an estimated 44% (SE = 7%). Estimated smolt abundance in 2002 was 755,905 (SE = 239,117) after adjustment for size-specific capture rates and size-specific marine survival rates. Estimated marine survival rate regardless of smolt size was 6.5% (SE = 2.3%) from 2002–2003.

Key words: coho salmon, *Oncorhynchus kisutch*, Unuk River, harvest, troll fishery, seine fishery, drift gillnet fishery, recreational fishery, mark-recapture, radiotelemetry, loss of tags, handling-induced mortality, escapement, run size, exploitation rate, smolt abundance, size-specific, marine survival

INTRODUCTION

The Unuk River (Figure 1) 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 lower 39 km of the river are in Alaska (Figure 2). The total coho salmon *Oncorhynchus kisutch* production originating from the Canadian portion of the river has not been estimated directly; however, information gathered during the five years of study indicates that as much as 30% of the production likely occurs in Canada (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003). The primary spawning tributary within Canada is at Boundary Lake (also known as Border Lake), located about 2 km upriver of the border. While this lake itself offers rearing habitat, any movement by juvenile fish out of the lake and downriver will essentially mean the fish have moved into the U.S. portion of the river. Some coho salmon systems in Southeast Alaska are surveyed annually for estimates of spawning abundance, but the Eulachon River is typically the only Unuk River tributary surveyed annually. Peak counts since 1990 range from 235 in 1990 to 1,105 in 2002 and average 583 fish.

The Unuk River has produced estimated annual runs (harvest and escapement) of adult coho salmon of 57,811 in 1998, 55,147 in 1999, 31,740 in 2000, 68,080 in 2001, and 71,242 in 2002 (Table 1). Many (22%–79%) of these fish are harvested in marine and recreational fisheries throughout Southeast Alaska (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003). Coho salmon returning to the Unuk River must pass through a series of commercial (i.e., troll, purse seine, and drift gillnet) and recreational fisheries as they travel in a southward migration along the northern outside coast of Southeast Alaska before entering the inside waters of southern Southeast Alaska (Figure 3). Some members of this stock are also harvested in the marine fisheries of northern British Columbia, Canada. Perceived changes in stock run strength in streams near Ketchikan have prompted concerns over the status of coho salmon in Southeast Alaska. Since the Unuk River stock has been shown to produce relatively large returns of coho salmon, and has early to mid run timing (important for inseason management), it was selected as an ideal site for estimating trends in exploitation and survival of wild stocks from the inside waters of southern Southeast Alaska.

Harvests from this stock have been estimated through programs based on coded-wire tags (CWTs). Juvenile coho salmon were marked with CWTs from 1983 through 1986, and from 1996 through 2003. Recapture of adult coho salmon with tags indicates that on average the majority of marine harvest occurs in the Southeast (49%) and Northwest (33%) Quadrants of Southeast Alaska, primarily by troll gear (53%) and to a lesser extent by

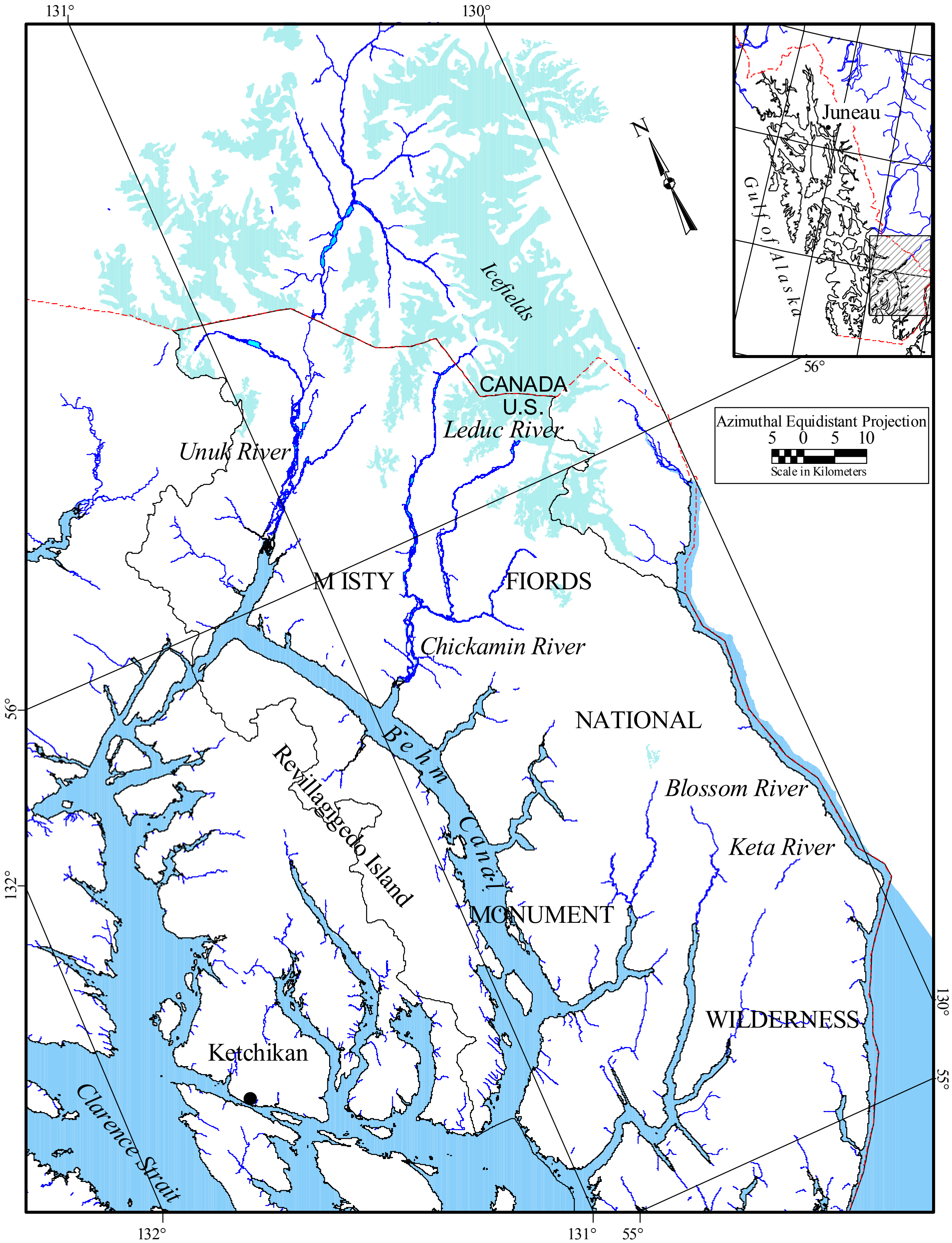


Figure 1.–Behm Canal and surrounding area in Southeast Alaska with streams supporting major coho salmon stocks noted.

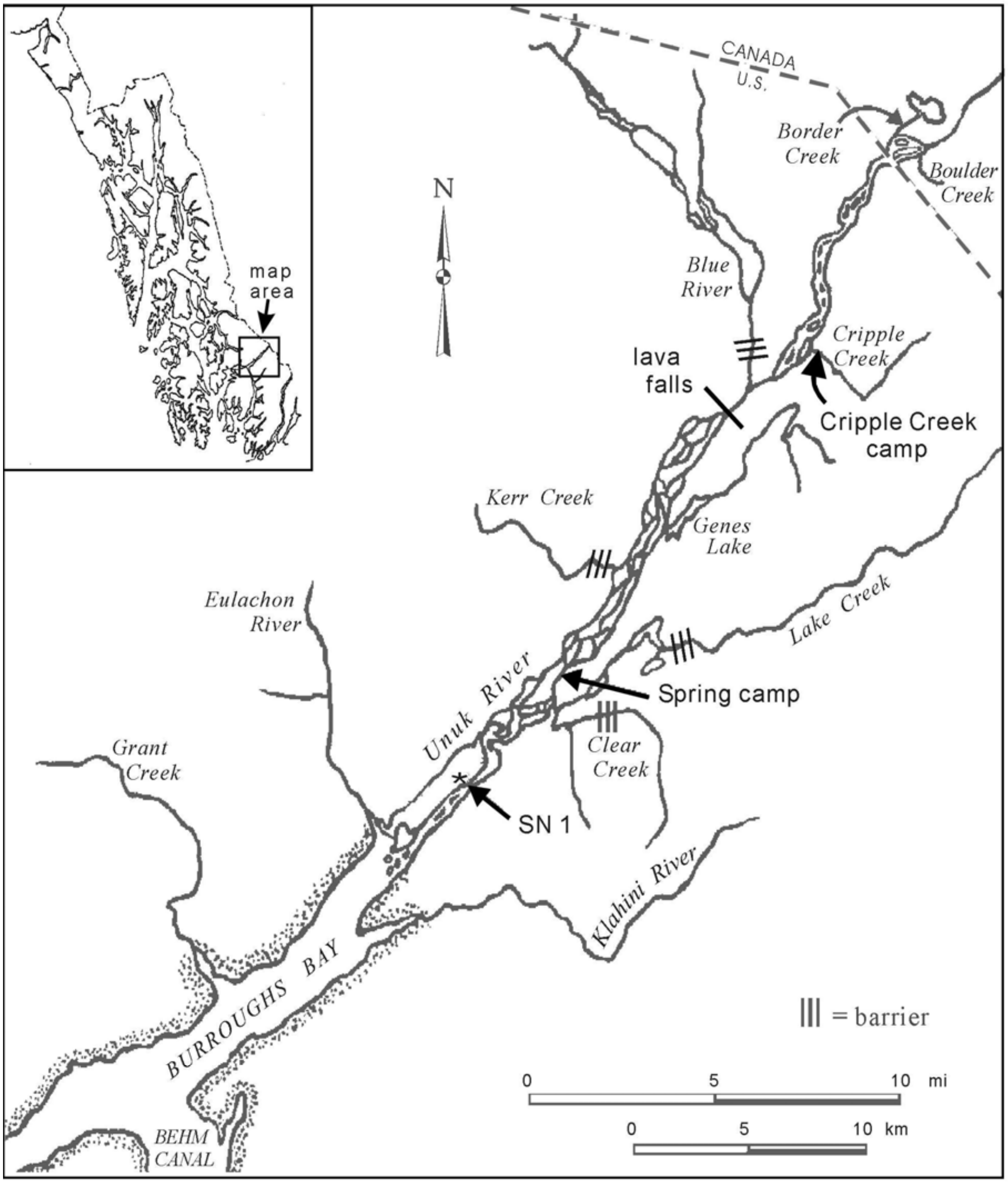


Figure 2.–Unuk River and surrounding area showing major tributaries, barriers to salmon migration, and locations of ADF&G research sites.

Table 1.–Estimates of run size, harvest, escapement, marine survival rate, exploitation rate, handling-induced mortality of adults, smolt abundance, and smolt size for the Unuk River stock of coho salmon, 1998–2003.

Parameters	1997	1998	1999	2000	2001	2002	2003
Run size		57,811	55,147	31,740	68,080	71,242	48,953
SE		8,158	13,201	6,764	9,522	12,253	7,111
Harvest		45,388	29,300	14,826	32,633	15,584	21,735
SE		7,461	2,950	3,510	6,276	2,033	2,896
Escapement		12,422	25,846	16,845	35,022	55,409	26,934
SE		3,298	12,867	5,782	7,161	12,084	6,495
Relative precision (α=0.05)		52	65	54	40	43	47
Marine survival rate (%)		7.1	9.8	3.9	11.8	9.4	6.5
SE (%)		2.0	2.9	1.5	2.2	2.4	2.3
Exploitation rate (%)		79	53	47	48	22	44
SE (%)		5	12	10	7	4	7
M-R handling-induced mortality		181	258	69	425	249	285
% M-R handling-induced mortality		24.4	28.2	15.2	26.5	14.3	23.5
Smolt abundance	809,677	562,796	819,475	577,343	757,080	755,905	
SE	189,345	101,122	257,309	70,720	142,167	239,117	
Smolt mean length (mm FL)	84.04	88.87	86.47	83.88	84.24	84.50	
SE	0.51	0.62	0.56	0.42	0.80	0.57	
Smolt mean weight (gm)	5.76	6.92	6.51	6.12	6.43	6.70	
SE	0.28	0.15	0.13	0.10	0.18	0.13	

purse seine (21%), drift gillnet (17%), and recreational gear (9%) (Figure 3) (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003). On average, an estimated 5% of the Ketchikan marine recreational harvest was comprised of Unuk River coho salmon from 1998-2002. A small inriver recreational fishery harvests up to 200 coho salmon each year.

A comprehensive assessment of coho salmon from the Unuk River began in 1997, when tagging smolt with CWTs resumed. Assessment included estimation of escapement, harvest, marine survival rate, and exploitation rate. Between 1998 and 2002 escapement averaged 29,109, with a range of 12,422 (1998) to 55,409 (2002). Harvest averaged 27,546, with a range of 14,826 (2000) to 45,388 (1998), and total run averaged 56,804 with a range of 31,740 (2000) to 71,242 (2002) (Table 1). During these years the marine survival rate averaged 8.4%, with a range of 3.9% (2000) to 11.8% (2001), and the exploitation rate averaged 50% with a range of 22% (2002) to 79% (1998) (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003).

Objectives of the 2002–2003 study were to estimate: (1) abundance and mean length of Unuk River coho salmon smolt in 2002; (2) marine recreational and commercial harvests of adult coho salmon bound for the Unuk River in 2003 and (3) abundance and age, sex, and length compositions of the escapement in 2003. These objectives were accomplished by placing coded wire tags in smolt during the spring of 2002, and by sampling adults in marine recreational and commercial fisheries, and conducting an in-river mark-recapture study of escapement in 2003.

METHODS

SMOLT CAPTURE, TAGGING, AND SAMPLING

Between 53 and 168 G-40 minnow traps, baited with salmon roe, were fished daily for 24 hours per day (h/d) from 4 April to 27 April 2002. Traps were located between river km 10 and 26 along mainstem banks and in some backwater areas of the Unuk River. Minnow traps were checked at the beginning of each day when water levels were stable and more frequently throughout the day when water levels were not stable. Two teams consisting of two personnel each were used to set and fish traps on a regular basis. Generally,

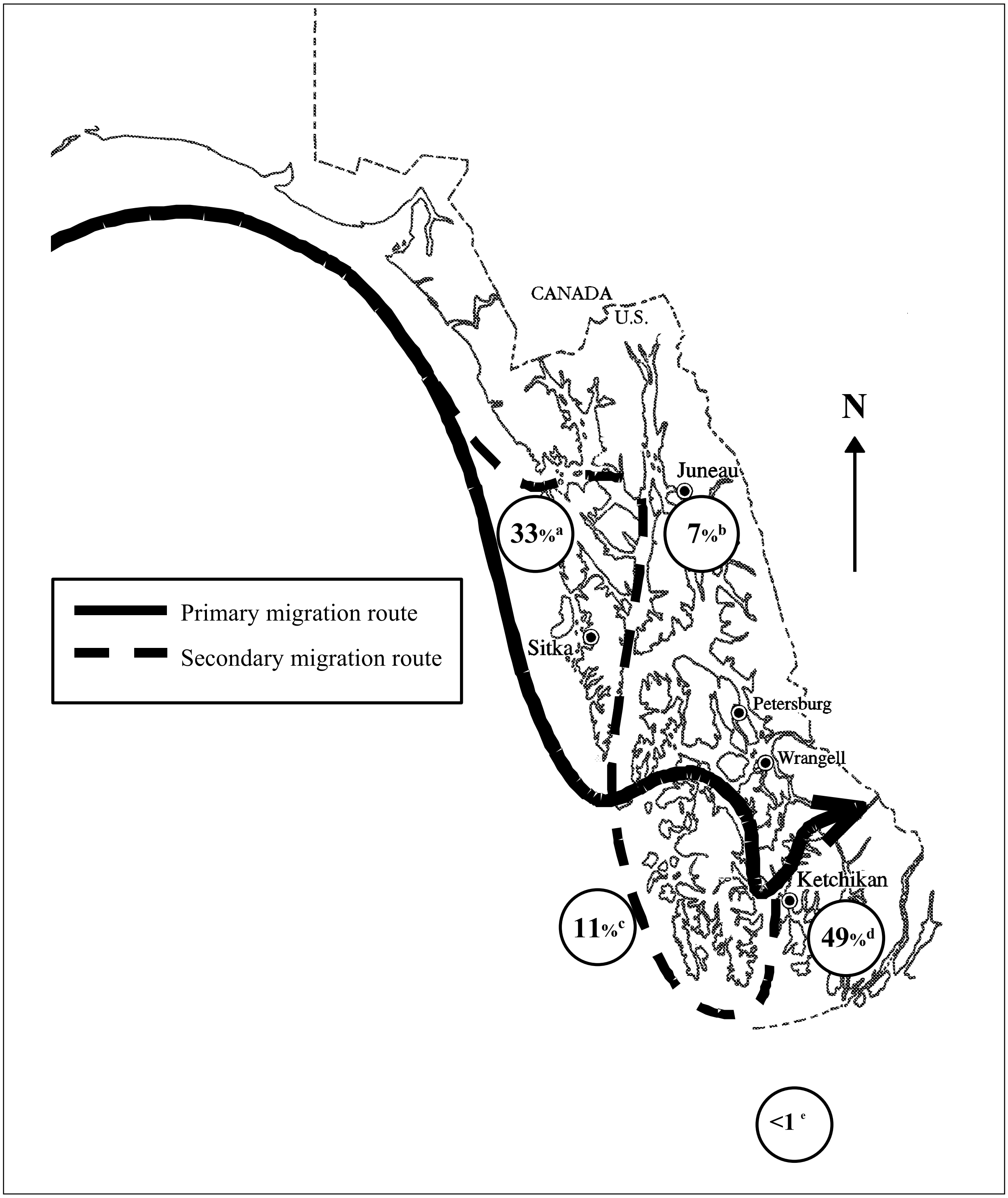


Figure 3.–Migration routes through Southeast Alaska and average percentage of marine harvest (1998–2003) by quadrant for the Unuk River stock of coho salmon.

Superscripts denote quadrants: [a]Northwest, [b]Northeast, [c]Southwest, [d]Southeast, and [e]Canadian.

one crew was responsible for traps set upstream of Spring Camp (km 14) and one crew was responsible for downstream traps. Early in the season, water levels were low and ice and snow restricted fishing to the mainstem of the river. These conditions slowly changed as the season progressed, enabling trapping in backwater and side channel areas.

Juvenile fish were removed from minnow traps during each visit, transported to holding pens at camp, and tagged and marked each day. Coho and Chinook salmon *O. tshawytscha* smolt were separated from other species of salmon and fish like Dolly Varden *Salvelinus malma* by using a combination of external morphological characteristics (McConnell and Snyder 1972; Meehan and Vania 1961; Pollard et al. 1997).

All live, smolting coho salmon were tranquilized in a water solution of tricain methane-sulfonate (MS 222) buffered with sodium bicarbonate. To alleviate stress on smolts, the anesthetic solution was kept near ambient river temperature by frequent water changes, and numbers of smolt tranquilized at any one time were kept small to limit their exposure. All smolt ≥70 mm FL not missing adipose fins were tagged following procedures described in Koerner (1977) and their adipose fins were excised. Different codes were used on CWTs implanted in small smolt (70–84 mm FL) and large smolt (≥85 mm FL) to permit subsequent detection of possible size-specific differences in marine survival rates. All Chinook salmon smolt ≥50 mm FL were also tagged, albeit with different codes. All captured smolt missing an adipose fin were subsequently passed through a magnetic tag detector to test for presence of CWT.

All tagged fish were held overnight and released the following morning after being checked for tag retention and mortality. The number of fish tagged, the number that died in the holding pen, and the 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 ADF&G Mark, Tag, and Age Laboratory in Juneau after the field season. Length and weight composition of coho salmon smolt was estimated by systematically sampling every 37th fish captured. In addition, each sampled smolt was measured to the nearest mm FL and weighed to the nearest 0.1 g.

ESTIMATING SMOLT ABUNDANCE

Abundance of smolt in 2002 was to be estimated with a two-event mark-recapture study using Chapman's modification of the Petersen estimate (Chapman 1951). To be consistent, this estimator had to meet the following conditions:

(a) regardless of its size, every smolt had an equal probability of being tagged and marked, or every tagged smolt had an equal probability of being captured as an adult (proportional sampling); or

(b) marked fish mixed completely with unmarked fish in the population between events; and

(c) there was no recruitment to the population between sampling events; and

(d) there was no tag-induced mortality; and

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

(f) all marked fish were recognized.

Evidence indicates that conditions $b-f$ were met. Temporal and spatial variation in marked fractions of escapement indicated that marked fish had mixed completely with unmarked fish. The fidelity of coho salmon to their natal watershed precludes recruitment. No short-term, tag-induced mortality was indicated, nor was any significant loss of CWTs discovered in sampled adults. Coastwide experience indicates that excised adipose fins do not grow back. However, both marking and survival rates were demonstrably different between small (70–84 mm FL) and large smolt (≤ 85 mm FL). For this reason, the estimator was modified to remove the implied bias:

$$\hat{N}_S^* = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}R_1 + R_2 + 1} \quad (1)$$

where N_s was number of smolt emigrating in 2002, M_1 and M_2 were the number of small and large smolt marked in 2002, C was the number of adults sampled during in 2003, R_1 and R_2 were the number of marked small and large smolts recaptured as adults, and A is the adjustment for consistency. Evidence of these differences and the methodology used to estimate smolt abundance is provided in Appendix A1. This appendix also includes a description of simulations used to estimate the variance and potential statistical bias in the adjusted estimate.

ESTIMATING ESCAPEMENT

A second two-event mark-recapture study was used to estimate the escapement of adult coho salmon into the Unuk River in 2003. In the first event, fish were captured in the lower river at SN1 between 26 July and 4 October using two set gillnets. Site SN1 is located on the south channel of the lower Unuk River, approximately 3 km downstream of all known coho salmon spawning tributaries with the exception of the Eulachon River (Figure 4). Both gillnets were 37 m (120 ft) long by 4 m (14 ft) deep, with one having 14-cm (5⅜") stretch mesh and the other having 11.5-cm (4½") stretch mesh. Similar studies conducted on the Unuk River from 1998 to 2002 indicated that a sufficient number of coho salmon could be captured using set gillnets fished at SN1 (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003). Conditions permitting, set gillnets were fished 8 h/d by two people. One net (a cross net) was attached to the shore and ran directly across a small slough to a fixed buoy placed just downstream of a small island perpendicular to the main flow of the Unuk River. Another net (a lead net) was attached to the same buoy and fished downstream along the eddy line created between the mainstem flow and the side slough (Figure 5). The 11.5- and 14-cm stretch mesh gillnets were alternated daily between cross and lead net positions.

All fish captured, except recaptures, were sampled to determine their age, sex, and length regardless of condition (ASL). Length was measured to the nearest 5 mm MEF, and gender was determined from external characteristics. Five scales approximately 2 cm apart were taken from the preferred area on the left side of the fish. The preferred area is two to three rows above the lateral line and between the posterior terminus of the dorsal fin and the anterior margin of the anal fin (Scarnecchia 1979). Scales were mounted on gum cards capable of holding scales from 10 fish. The age of each fish was later determined from the pattern of circuli as seen on images of scales impressed into acetate cards (Clutter and Whitesel 1956; Mosher 1969) under 70× magnification. Fish missing adipose fins were noted as such and then sacrificed by having their heads removed and sent to the ADF&G Mark, Tag, and Age Laboratory in Juneau for detection and decoding of CWTs.

Each captured fish possessing an adipose fin and not previously sampled was marked with a primary tag, a uniquely numbered solid-core spaghetti tag consisting of a 5.71-cm (2¼") section of laminated Floy tubing shrunk onto a 38-cm (15") piece of 80-lb-test monofilament fishing line. Application of the primary tag required threading the monofilament line into a hollow needle and then puncturing the fish with the needle through the back just behind the dorsal fin. Each tag was then secured by crimping both ends of the monofilament in an aluminum line crimp. Any excess line was trimmed. Each spaghetti tag was printed with a unique number and an ADF&G contact phone number. Two secondary marks, a clip of the left auxiliary appendage (LAA) and a left upper operculum punch (LUOP) ¼" in diameter, were also applied as an aid in determining primary tag loss.

Radiotelemetry was used to estimate the proportion of adults marked during the first event that suffered handling-induced mortality. Encapsulated in the handling-induced mortality estimate are a small number of fish that left the Unuk River to spawn elsewhere. Between 2 August and October, transmitters from Advanced Telemetry Systems™ [1] (151 MHz) were inserted through the esophagus into the stomachs (as per methods described in Eiler 1990) of healthy adult

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

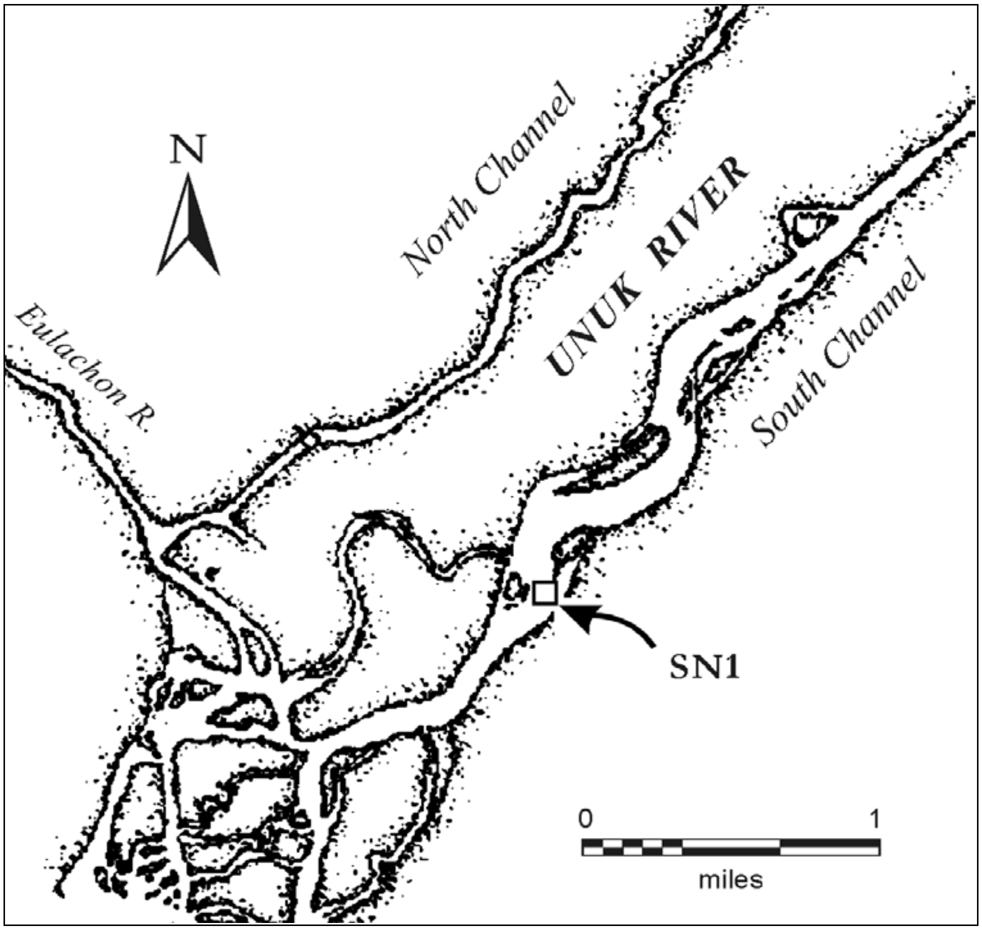


Figure 4.–Location of the set gillnet site (SN1) on the lower Unuk River, 2003.

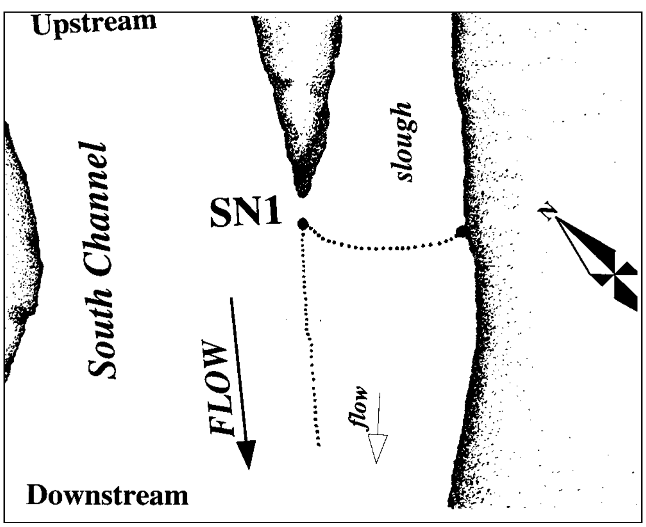


Figure 5.– Detailed drawing of net placement used at the set gillnet site (SN1) on the lower Unuk River, 2003.

coho salmon. One out of every 24 captured fish was chosen systematically for implantation. Fish <501 mm MEF were implanted with a model F1840 (17x51x15mm, 20 gram) transmitter while those >500 mm MEF received a modelF1845(19x51x15mm, 24 gram) transmitter. Every fish that received a radio transmitter was also tagged, marked, and sampled as described above.

In the second event of the mark-recapture experiment, adult salmon were captured on the spawning grounds in the Eulachon River and Lake, Boundary, Gene's Lake, Cripple, Hell Roaring, and Clear creeks (Figure 2). Various gear types, such as rod and reel (snagging, bait, and lures) and pieces of gillnet were used to capture fish. The use of multiple gear types has been shown to reduce bias in estimates of age, sex, and length compositions when sampling Chinook salmon (McPherson et al. 1997; Jones III et al. 1998; Jones III and McPherson 1999; 2000; 2002). All fish captured during the second event were marked with a left lower operculum punch (LLOP) to prevent double sampling in subsequent sampling visits. Sampled fish were closely examined for the presence of an adipose fin and the mark-recapture primary tag, secondary marks, and LLOP. All fish were sampled to obtain ASL data using the same techniques applied at SN1.

Fixed-wing aircraft and radio tracking towers containing data loggers were used to locate radio tag transmitters. On 16 August, 15 September, 30 September, and 6 November, a pilot along with an experienced member of the crew surveyed the entire U.S. portion of the Unuk River and into Canada as far as river km 65. In addition to tracking flights, two tracking towers were placed near camp at approximately river km 14; towers were constructed and operated as described in Eiler (1995), except that they did not have satellite uplink capabilities. A reference radio transmitter was used to check whether or not each tower was operational, and data loggers were checked periodically for the indication of fish movement. Fish were presumed to have successfully spawned if they were tracked by a positive reading at one of the radio towers upstream of the tagging site (beyond river km 6), or to the Eulachon River, or if they were recovered on the spawning grounds. Fish not located by any method, located only below the set gillnet site (SN1; Figure 4, 5), or located outside the system, were considered mortalities.

Escapement of adult coho salmon in 2003 was estimated using an adaptation of Chapman's modification of the Petersen's estimator (Seber 1982):

$$\hat{N}_e = \frac{(\hat{n}_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \qquad (2)$$

where $\hat{N}_e$ is the number of adult coho salmon immigrating into the Unuk River in 2003, $\hat{n}_1$ is the estimated number of fish marked during the first event that continued up the river, n_2 is the number inspected for marks during the second event, and m_2 is the subset of n_2 that possessed marks applied during the first event. The estimate $\hat{n}_1$ was calculated as:

$$\hat{n}_1 = n_1'(1 - \hat{y}) \qquad (3)$$

where n_1' is the number of salmon marked and $\hat{y}$ is the estimated proportion of marked fish that suffered handling-induced mortality.

Consistency conditions *a* – *f* described in the previous section are germane to this estimator as well, except condition (*a*) now refers to adults. To provide evidence that (*a*) was met, two χ^2 tests were performed: (1) for equal marked fractions across sampling locations in the second event; and (2) equal probabilities of recapture in the second event independent of when fish had been marked. Because the null hypothesis in either test was not rejected, the pooled Petersen estimator (equation 3) was used to model the mark-recapture data. Hypotheses were tested separately using the SPAS software program (Arnason et al. 1996). We also tested the hypothesis that the marked fraction sampled in the second event did not vary with time.

The possibility of size- and sex-selective sampling was also investigated, because assumption (*a*) can be violated in this manner. The hypothesis that fish of different sizes were captured with equal probability was tested with two Kolmogorov-Smirnov (K-S) two-sample tests (α = 0.1) (Appendix

B1). Sex-selective sampling was investigated with a χ^2 test comparing the number of males and females caught in the lower river with those caught on the spawning grounds. If sex compositions differed significantly, either marking or spawning grounds samples alone could be used to estimate sex composition, although sex is more difficult to determine early in the season from external characteristics (Ericksen 1999).

Because sampling in the lower river spanned the known migratory timing of coho salmon into the Unuk River and continued without interruption, the study was essentially closed to recruitment (*c*). Condition (*d*) was met with adjustments obtained from radiotelemetry. The effect of tag loss (*e*) was virtually eliminated by using the two secondary marks, and all fish captured during the second event were inspected for marks (*f*). Double sampling (*f*) was avoided by marking all fish captured in the second event with the LLOP.

Variance, bias, and confidence intervals for $\hat{N}_e$ were estimated using modifications of bootstrap procedures found in Buckland and Garthwaite (1991). A stochastic value $\hat{n}_1^*$ for $\hat{n}_1$ was obtained by first drawing a new number of fish with transmitters that failed to spawn from the binom ($\hat{y}$, *k*) where *k* equals the number of fish possessing transmitters, such that $(1-\hat{y}^*) = [1-\text{binom}(\hat{y},k)/k]$. A bootstrap sample was drawn with replacement from a sample of size $\hat{N}_e^+$, using the empirical distribution defined by the capture histories (Table 2). A new set of statistics $\{\hat{n}_1^*, n_2^*, m_2^*\}$ was generated from each bootstrap sample, along with a new estimate for abundance $\hat{N}_e^*$, and this process was repeated a thousand times creating the empirical distribution $\hat{F}(\hat{N}^*)$ that is an estimate of $\hat{F}(\hat{N}_e)$. The difference between the average $\hat{N}_e^*$ of bootstrap estimates and $\hat{N}_e$ is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993). Confidence intervals were estimated from $\hat{F}(\hat{N}_e^*)$ with the percentile method (Efron and Tibshirani 1993).

Variance was estimated as:

$$\text{var}(\hat{N}_e^*) = (B-1)^{-1}\sum_{b=1}^{B}(\hat{N}_{eb}^* - \overline{\hat{N}}_e^*)^2 \qquad (4)$$

where *B* is the number of bootstrap samples.

Table 2.–Capture histories for coho salmon immigrating back to the Unuk River, 2003.

(Notation explained in text.)

Capture history	Sample size	Source of statistics
Number marked	1,210	n_1
Number marked that survived	925	$n_1(1-\hat{y})$
Estimated number that failed to move upriver	285	$n_1\hat{y}$
Estimated number marked, survived, and not sampled in tributaries	903	$\hat{n}_1 - m_2$
Estimated number marked, survived, and recaptured in tributaries	22	m_2
Not marked, but captured in tributaries	646	$n_2 - m_2$
Estimated number not marked and not sampled in tributaries	25,363	$\hat{N}_e - \hat{n}_1 - n_2 + m_2$
Effective population for simulations	27,218	$\hat{N}_e^+ = \hat{N}_e + n_1\hat{y}$

AGE, SEX, AND LENGTH

The proportion of the escapement composed of a given age was estimated as a binomial variable from fish sampled during the second event of the mark-recapture experiment:

$$\hat{p}_j = \frac{n_j}{n} \qquad (5)$$

$$\text{var}(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \qquad (6)$$

where $\hat{p}_j$ is the estimated proportion of the sample of age *j*, n_j is the number of coho salmon of age *j*, and *n* is the number of coho salmon sampled during the first event for which age was determined.

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

ESTIMATING HARVEST

The 2003 harvest of coho salmon originating from the Unuk River was estimated from catch samples in U.S. marine fisheries. In 2003 several fisheries harvested coho salmon bound for the Unuk River; consequently harvest was estimated over several strata, each a combination of time, area, and fishery type. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant. Statistics for drift gillnet and seine fisheries were stratified by statistical week and by fishing district. Statistics from the recreational fishery were stratified by fortnight and location. Estimates of harvest $\hat{r}_i$ were calculated for each stratum and summed across strata to obtain an estimate of the total $\hat{T}$:

$$\hat{T} = \sum_i \hat{r}_i \tag{7}$$

$$\text{var}\left[\hat{T}\right] = \sum_i \text{var}\left[\hat{r}_i\right] \tag{8}$$

Variance of the sum of estimates was estimated as the sum of variances across strata, because sampling was independent across strata.

A subset of the catch (H_i) in each stratum was counted and inspected to find fish missing their adipose fin. Of those a_i salmon in this sample without the adipose fin, heads were retrieved from a subset, marked, and sent to the ADF&G Mark, Tag, and Age Laboratory in Juneau for dissection. Of the a_i' heads that arrived in Juneau, all were passed through a magnetometer to detect a CWT. Of the t_i tags detected, t_i' were successfully decoded under a microscope, after dissection of which m_i had come from the Unuk River (Appendix B2). Oliver (1990) and Hubartt et al. (1999) present details of sampling commercial and recreational fisheries, respectively. The fraction of the return having CWTs was estimated as $\hat{\theta} = m_e/n_e$, where m_e is the number of adults sampled at SN1 in 2003 that possessed valid CWTs and n_e is the total number of adults sampled at SN1 in 2003 (note that $n_e > n_1$). Information from catch and field sampling programs was expanded to estimate harvest and the associated variance of coho salmon bound for the Unuk River for each stratum, using methods and equations from Bernard and Clark (1996).

MEAN DATE OF HARVEST

Estimates of the mean dates of harvest for marine commercial and recreational fisheries were calculated from the time series of estimated proportions of catches by strata within a fishery following the methods of Mundy (1982):

$$\hat{P}_d = \frac{\hat{H}_d}{\sum_i H_i} \tag{9}$$

where P_d is the fraction of harvest realized in a fishery on day d. The mean date of harvest $\bar{d}$ in each fishery was calculated as

$$\hat{\bar{d}} = \sum_d d\hat{P}_d \tag{10}$$

MIGRATORY TIMING

Migratory timing is defined as a time density function of the relative abundance of the individual Unuk River coho salmon stocks (Boundary, Clear, Cripple, Genes Lake, Hell Roaring, Kerr, and Lake creeks and the Eulachon River) w as they pass the set gillnet site (SN1) during discrete time interval i (Mundy Unpublished):

$$f(w_i) = \frac{d_i}{d} \tag{11}$$

where: $f(w_i)$ is the probability distribution of those fish spawning in location w, d is the number of marked fish recovered in location w, and d_i is the number of fish bound for location w that were marked on the i^{th} day.

The mean day of migration past SN1 for a particular population is defined as:

$$\overline{w} = \sum_{i=1}^{l} w_i f(w_i) \tag{12}$$

with

$$\text{var}(\overline{w}) = \sum_{i=1}^{l} (w_i - \overline{w})^2 f(w_i) \tag{13}$$

where: l equals the total number of days (subsequently recaptured) fish were captured and marked at SN1. Skewness, a measure of the deviation of $f(w_i)$ from a normal curve was estimated as:

$$z = \frac{\sum_{i=1}^{d} (w_i - \overline{w})^3 f(w_i)}{\text{var}(\overline{w})^3} \tag{14}$$

Kurtosis, a measure of the peakedness or flatness of $f(w_i)$ compared to a normal distribution was estimated as:

$$g = \frac{\sum_{i=1}^{d} (w_i - \overline{w})^4 f(w_i)}{\text{var}(\overline{w})^4} \tag{15}$$

RUN SIZE, EXPLOITATION RATE, AND MARINE SURVIVAL RATE

Estimates of run size for coho salmon returning to the Unuk River in 2003 and the associated exploitation rate in marine recreational and commercial fisheries are based on the sum of the estimated harvest and escapement:

$$\hat{N}_R = \hat{T} + \hat{N}_e \tag{16}$$

The variance was estimated as the sum of the estimated variances for statistics on escapement and harvest:

$$\text{var}[\hat{N}_R] = \text{var}[\hat{T}] + \text{var}[\hat{N}_e] \tag{17}$$

An estimate of the exploitation rate for this stock and its estimated variance were calculated as

$$\hat{U} = \frac{\hat{T}}{\hat{N}_R} \tag{18}$$

$$\text{var}[\hat{U}] \approx \frac{\text{var}[\hat{T}]\hat{N}_e^2}{\hat{N}_R^4} + \frac{\text{var}[\hat{N}_e]\hat{T}^2}{\hat{N}_R^4} \tag{19}$$

Estimates of marine survival rate of smolt to adults and its variance were calculated as

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \tag{20}$$

$$\text{var}[\hat{S}] \approx \hat{S}^2 \left[\frac{\text{var}[\hat{N}_R]}{\hat{N}_R^2} + \frac{\text{var}[\hat{N}_s]}{\hat{N}_s^2} \right] \tag{21}$$

Variances in equations (19) and (21) were approximated by the delta method (Seber 1982).

RESULTS

SMOLT CAPTURE, TAGGING, AND SAMPLING

Smolt trapping commenced on 2 April, tagging began on 4 April, and both activities ceased on 27 April. Dramatic changes in water level result in drastically reduced trapping efficiency. In 2002, the river was initially low and rose at a relatively slow steady rate as snow melt commenced, and no dramatic changes occurred. As a result, the overall trapping conditions were considered above average (Figure 6).

Between 4 April and 27 April 2002, 8,048 (= M_1) small (70-84 mm FL) and 5,454 (= M_2) large (≥ 85 mm FL) coho salmon smolt were tagged with codes 04-05-36 and 04-05-37, respectively. Of this total, 6 small and 151 large fish died overnight and none were estimated to have lost their tags. This resulted in a final release of 13,345 (i.e., 8,042 small and 5,303 large) coho salmon smolt with valid CWTs in 2002. Coho salmon smolt averaged 84.5 mm FL and 6.7 g. in weight (Table 3; Figure 7).

Chinook salmon smolt were also captured during minnow trapping efforts. Of 12,001 Chinook salmon smolt tagged with CWTs, 10,908 carried code 04-05-38 and 1,093 had code 04-05-39. Of these, 4 with code 04-05-38 and 26 with code 04-05-39 died overnight and none were estimated to

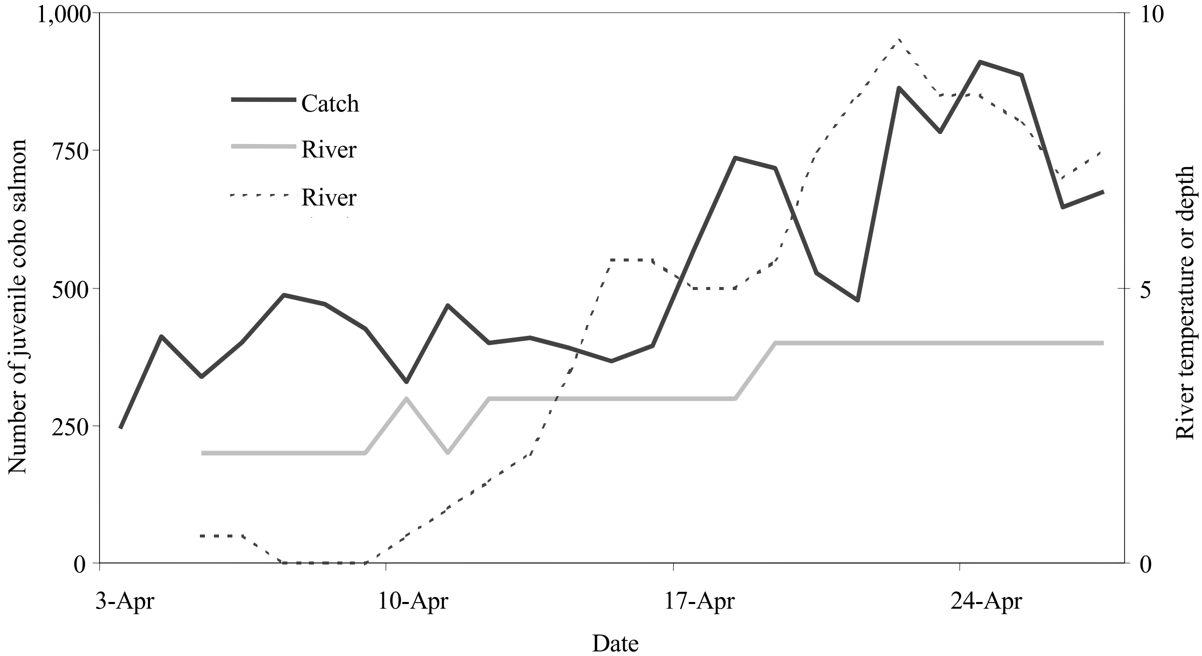


Figure 6.–Catches of coho salmon smolt ≥70 mm FL, daily water temperature (^{o}C), and water depth (cm) in the Unuk River, 2002.

have lost their tags. This resulted in a total release of 11,971 Chinook salmon smolt having valid CWTs. Chinook salmon smolt averaged 68.6 mm FL and 3.5 g in weight (Figure 7). Detailed analysis of the data on Chinook salmon will be reported in a separate document.

SMOLT ABUNDANCE

After adjusting for size-selectivity, the estimated abundance $\hat{N}_s^*$ of coho salmon smolt outmigrating from the Unuk River in 2002 was 755,905 (SE = 239,117). Of the 8,042 small smolt released with CWTs in 2002, 53 were recovered in 2003 from adults harvested in various marine commercial and recreational fisheries and 13 were recovered during inriver sampling. Of the 5,303 large smolts released, 63 were recovered in marine fisheries and 20 were sampled inriver in 2003. Recovery rates by smolt size are significantly different (χ^2 = 16.30, df = 1, P < 0.0001), implying that the survival rate for larger smolt was an estimated 1.936 times the rate for smaller smolt. Considering the age composition of all adults sampled at SN1 and those carrying CWTs, such a disparity in survival rates implies a disparity in capture rates for smolts as well (Appendix A1), with large smolts an estimated 2.83 ($= \hat{A}$) times more likely to have been tagged in 2002. This lower capture rate for small smolt is consistent with some, but not necessarily all, coho salmon <70 mm smolting in 2002 (Appendix A1).

Given that 27 ($= R'$) smolt were subsequently recaptured inriver as adults from the 1,268 ($=C'$) adults inspected at SN1, the unadjusted estimate of smolt abundance is 604,860, about 20% lower than the unbiased estimate given above. Variance and statistical bias of the adjusted estimated were estimated through bootstrap simulations, with bias estimated at 2.5%.

RADIOTELEMETRY

Of the 51 adult coho salmon released with transmitters in 2003, 39 (76.5%) were subsequently found in the Unuk River or its tributaries and presumed to have spawned (Figure 8; Appendix B3). We consequently estimated $\hat{y}$ = 12/51, to adjust for the proportion of those fish tagged during the first event of the mark-recapture

Table 3.– Number of coho salmon caught and subsequently released with valid coded-wire tags on the Unuk River, 2002.

		Smolt 70-84 mm (FL)				Smolt >84 mm (FL)				All Smolt					Water	Water
Date	Traps checked [a]	Captured [b]	Tagged	Overnight mortalities	Valid tagged [c]	Captured	Tagged	Overnight mortalities	Valid tagged [c]	CPUE [d]	Valid tagged [c]	Recaps	Average length (mm)	Average weight (g)	temp (°C)	depth [e] (in)
04/03/02	53	128				117				4.6						
04/04/02	89	216	344		344	197	314		314	4.6	658	0				
04/05/02	98	196				145				3.5					2	0.5
04/06/02	116	231	427	2	425	172	317		317	3.5	742	2			2	0.5
04/07/02	135	266				222				3.6					2	0.0
04/08/02	130	257	523	1	522	213	435		435	3.6	957	9	82.6	6.2	2	0.0
04/09/02	143	251	251		251	175	175		175	3.0	426	3			2	0.0
04/10/02	93	185				144				3.5					3	0.5
04/11/02	133	264	449		449	205	349		349	3.5	798	24			2	1.0
04/12/02	141	224	224		224	177	177		177	2.8	401	30			3	1.5
04/13/02	134	251				159				3.1					3	2.0
04/14/02	128	239	490		490	152	311		311	3.1	801	83			3	3.5
04/15/02	146	213				156				2.5					3	5.5
04/16/02	157	230	443	2	441	168	324		324	2.5	765	68			3	5.5
04/17/02	157	361	361		361	209	209		209	3.6	570	27			3	5.0
04/18/02	166	495	495		495	241	241		241	4.4	736	32	84.0	6.3	3	5.0
04/19/02	168	468				252				4.3					4	5.5
04/20/02	123	343	811		811	184	436	1	435	4.3	1,246	48			4	7.5
04/21/02	161	278	278		278	199	199		199	3.0	477	18			4	8.5
04/22/02	138	595				344				6.8					4	9.5
04/23/02	126	544	1,139		1,139	314	658	149	509	6.8	1,648	120	85.1	7.1	4	8.5
04/24/02	129	509	509		509	402	402		402	7.1	911	50			4	8.5
04/25/02	129	525	525		525	362	362		362	6.9	887	55	84.6	6.4	4	8.0
04/26/02	128	392	392	1	391	257	257	1	256	5.1	647	35			4	7.0
04/27/02	125	387	387		387	288	288		288	5.4	675	54			4	7.5
Total	3,246	8,048	8,048	6	8,042	5,454	5,454	151	5,303		13,345	658				
Max.	168	595	1,139	2	1,139	402	658	149	509	7.1	1,648	120	85.1	7.1	4	9.5
Min.	53	128	224	0	224	117	175	0	175	2.5	401	0	82.6	6.2	2	0.0
Average	130	322	473	0.4	473	218	321	8.9	312	4.2	785	39	84.50	6.70	3.1	4.4
Total measured													364	364		
SD													10.5	2.4		
SE													0.57	0.13		

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 uncaptured coho smolt captured.

c Total valid tagged equals total tagged minus overnight mortalities times percent tag retention. Retention was 100% in every case.

d Equals the average number of previously uncaptured coho smolt per trap check.

e Depth standardized such that 0 inches represents minimal depth recorded.

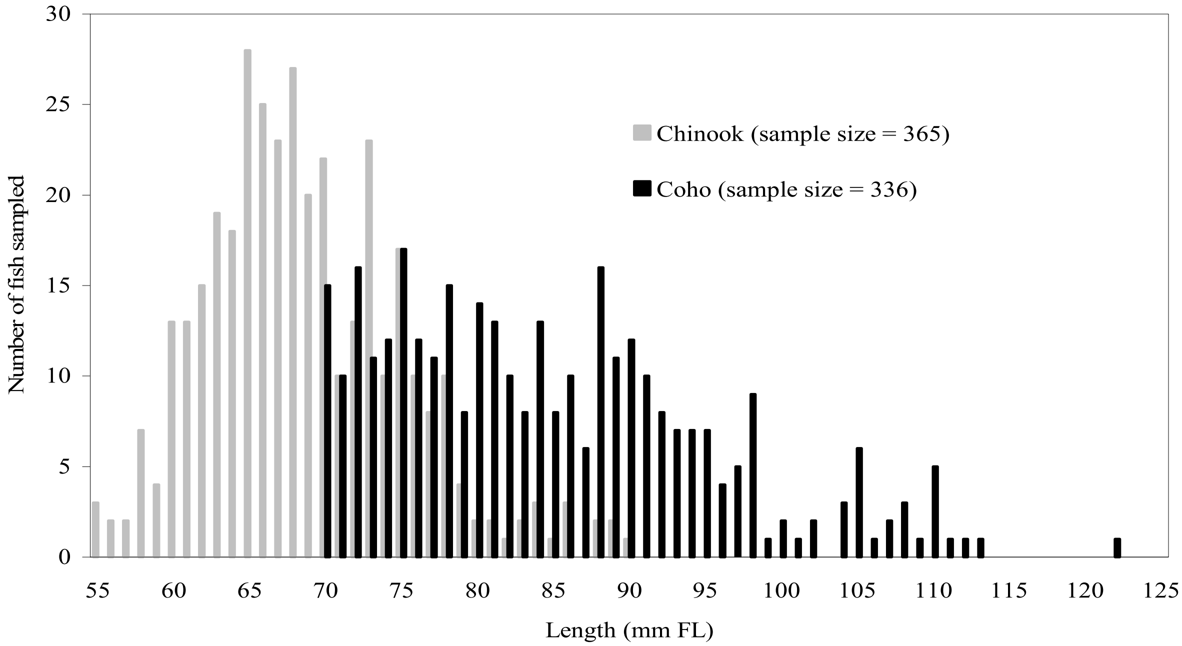


Figure 7.–Length frequency of coho salmon smolt ≥70 mm FL and Chinook salmon smolt captured and measured in the Unuk River, 2002.

experiment which failed to successfully spawn in the Unuk River (as described in equation 3).

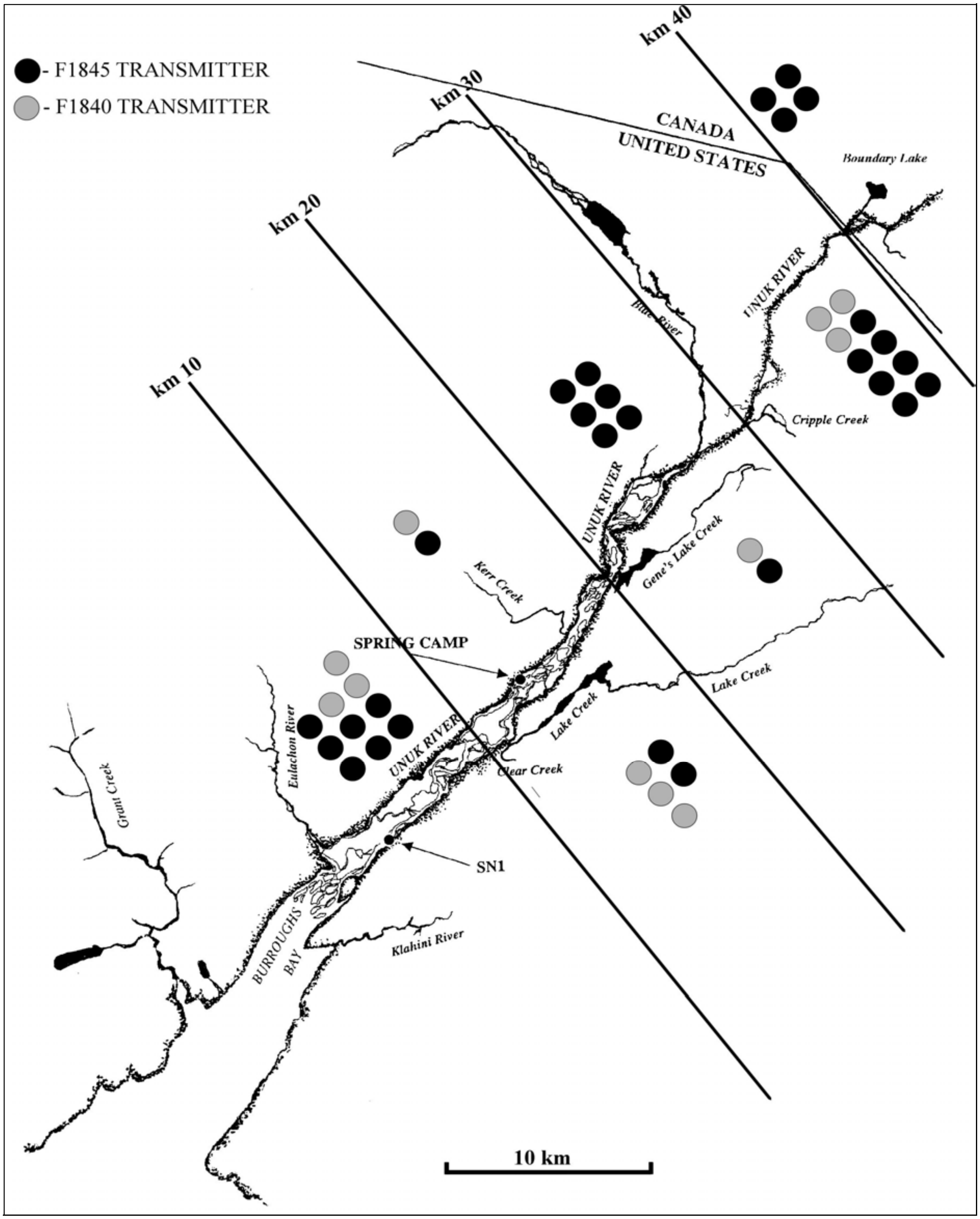
Coho salmon with radio transmitters were released between 2 August and 4 October and tracked from the Eulachon River to river km 39 on the Unuk River in Canada (Figure 8). Of the 39 fish presumed to have successfully spawned within the Unuk River watershed, 23% were tracked to the Eulachon River, 10% to Boundary Lake, 7.5% to Lake Creek, 5% to both Clear Creek and Genes Lake, 2.5% to both Kerr and Cripple creeks, and 44% were located in the main river. About 10% were ultimately located above river km 39 on the Canadian side of the border. Three radio tagged fish were recaptured during spawning grounds sampling and two were recaptured at SN1. For the 12 radio tagged fish that presumably did not spawn in the Unuk River, 8 were never located, 3 were mortalities located at or near SN1, and 1 was located in the nearby Chickamin River (Appendix B3). Persistent unresolved problems rendered the tracking towers dysfunctional throughout the course of this study.

The proportion of fish that survived to spawn within the Unuk River was similar regardless of transmitter size (χ^2 = 0.08, df = 1, P = 0.77). However the distribution of radio tagged fish did vary depending on transmitter size. Of those fish equipped with large transmitters, half remained in the mainstem and approximately two-thirds were located 20 km or more upriver. Only a quarter of the fish equipped with small transmitters remained in the mainstem and roughly two-thirds were located in tributaries within 20 km of the mouth of the river (Table 4)

ESCAPEMENT

The estimated escapement of coho salmon in the Unuk River in 2003 was 26,934 (SE = 6,495, $RP_{\alpha=0.05}$ = 47%). From bootstrapping, statistical bias in $\hat{N}_e$ was estimated at 5.1% and the 95% confidence interval for the estimate is 19,620 to 43,692. Of 1,268 coho salmon captured during the first event, 1,210 were successfully marked and released (n_1), and 925 were estimated to have survived and spawned ($\hat{n}_1$) in the Unuk River (Table 2, Table 5). Approximately 95% of the catch at SN1 occurred between 5 August and 23 September (Figure 9). Fifty-six (56) fish were not marked; 27 were sacrificed for CWTs, 24 died in the nets, and 5 were judged unhealthy and too weak to tag. Two (2) marked fish were removed from the study; one died in the set gillnet when

Figure 8.– Destinations of coho salmon fitted with radio transmitters in 2003 and the major spawning tributaries for coho salmon in the Unuk River.



Each circle refers to the farthest upstream location identified for a radio tagged fish in 2003.

Table 4.–Distribution of radio tagged coho salmon presumed to have spawned in the Unuk River, by transmitter size and location, 2003.

Unuk River Area	Location	Transmitter size	
		Small	Large
Unuk River tributaries	Eulachon River	27%	21%
	Lake/Clear Creeks	27%	7%
	Kerr Creek	9%	
	Genes Lake	9%	4%
	Cripple Creek		4%
	Boundary Lake		14%
	Subtotal	**73%**	**50%**
Unuk River mainstem	0-10 km		4%
	11-20 km		4%
	21-30 km		21%
	31-40 km	27%	21%
	>40 km		
	Subtotal	**27%**	**50%**

recaptured and the other was determined to be a select recovery. Of the 668 coho salmon sampled during the second event (n_2), 22 (m_2) had spaghetti tags, and all of these had easily identifiable secondary marks. No fish were recaptured having lost their primary mark (tag).

During the second event, samples were collected from Lake Creek (283 fish with 12 recoveries), the Eulachon River (141 fish with 1 recovery), Boundary Creek (118 fish with 6 recoveries), Hell Roaring Creek (40 fish with no recoveries), Genes Lake Creek (37 fish with 1 recovery), Cripple Creek (35 fish with 1 recovery), and Clear Creek (14 fish with 1 recovery). Fish were sampled on the spawning grounds from 30 July through 18 October. Eight (8) fish were missing adipose fins and were sacrificed. Seven of these fish carried a CWT from tagging operations on the Unuk River in 2002; the eighth fish was absent a CWT.

With some exceptions, fishing effort during the first event was maintained at a relatively consistent level throughout the experiment (Figure 9). From 1 August to 4 October, the set gillnets were fished for 386 hours. High water and large amounts of debris precluded fishing on 17 August, 2, 3, 25, 26, and 27 September, and 1, 2, and 3 October. The number of coho salmon captured per hour, or catch per unit effort (CPUE), averaged approximately 3.3 during this period, with a maximum value of 6.9 on 25 August.

Forty-four (44) coho salmon captured at SN1 and released during the first event were subsequently recaptured at SN1; two were recaptured twice. The time elapsed between captures at SN1 (sulking time) averaged approximately 6.25 days (Appendix B4). The minimum sulking time was 11 minutes as opposed to a maximum of nearly 30 days.

The length of coho salmon captured at SN1 remained relatively constant through 21 August (Figure 10), averaging 490 mm MEF (SD = 49). After 21 August average length steadily increased to 663 mm MEF (SD =41) on 4 October. This characteristic of the Unuk River coho salmon

Table 5.–Number of marked coho salmon released in the Unuk River and recaptured by marking period and recovery location, and the number examined for marks at each recovery location, 2003.

Marking dates	Estimated number marked[a]	Estimated fraction recovered	Recovery location		
			Downriver	Upriver	Total
7/25–9/1	521	0.017	7	2	9
9/2–10/4	404	0.032	8	5	13
Total/average	925	0.024	15	7	22
Number inspected			475	193	68
Fraction marked			0.032	0.036	0.033

[a] Number marked discounted by the estimated handling-induced mortality (0.235); total includes rounding error.

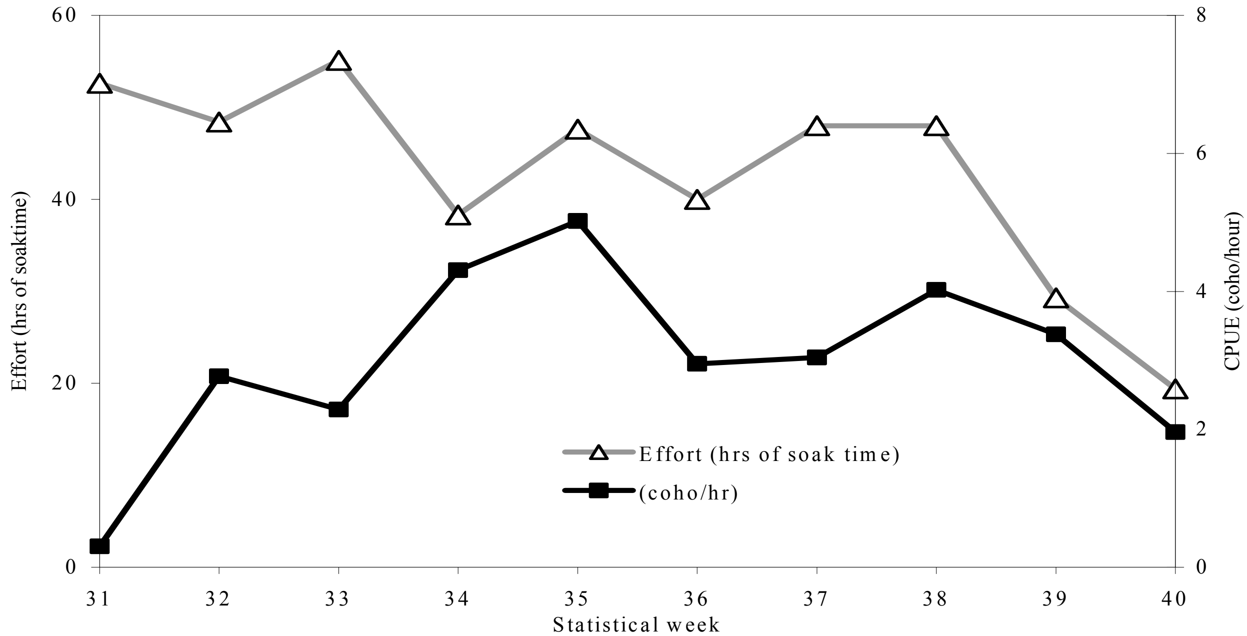


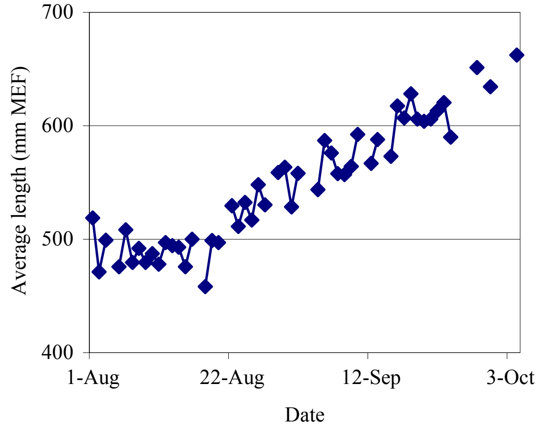
Figure 9.–Effort and catch per unit effort (CPUE) of adult coho salmon at SN1 on the Unuk River by statistical week, 2003.

return whereby the initial component is composed primarily of small-sized fish is consistent with findings from studies in previous years (Weller et al. 2002, 2003). For comparative purposes, we define these small coho salmon to be 335-540 mm MEF, the mean length plus 1 standard deviation (rounded to the nearest 5 mm) of fish captured at SN1 from 1-21 August. Of the small fish captured at SN1, 25% were captured prior to 11 August, 50% by 22 August, and 75% before 30 August (Figure 11). This compares to 3%, 10%, and 27% of the cumulative proportion of larger sized fish captured at SN1 by the same dates. The mean date of capture at SN1 for large coho salmon (>540 mm MEF) was 12 September.

Results from hypothesis tests provided evidence that conditions had been met for getting a generally unbiased abundance estimate from the experiment. Coho salmon marked early in the experiment (before 2 September) and late in the experiment were equally likely to be recaptured ($\chi^2 = 2.07$; df = 1; P = 0.15). Similarly, the recapture rate during the second event did not vary by sampling date (before or after 2 October; $\chi^2 = 0.80$; df = 1; P = 0.37) or sampling location (downstream or upstream—i.e., Lake, Clear, and Genes Lake creeks and the Eulachon River vs. Boundary Lake and Cripple and Hell Roaring creeks; $\chi^2 = 0.09$; df = 1; P = 0.77). These results are consistent with every fish having an equal chance of being marked at SN1 regardless of when they were caught.

The length distributions of fish marked in the first Event were not significantly different than the length distributions for fish recaptured in the second Event (P = 0.44, Figure 12). The length distributions of marked fish were significantly different from those of fish inspected on the spawning grounds (P < 0.001; Figure 13) indicating some size-selective sampling in the first event. Length distribution of fish sampled on the spawning grounds was broader than the distribution of fish caught at SN1 with a dominance of larger fish. Such a dichotomy is expected given the selectivity of gillnets and the variety of gears used upstream to capture fish. Because size-selective sampling was indicated for the first event, but not the second, samples taken during the second event were used to estimate mean length of individuals. The largest fish sampled in the second event was 750 mm MEF, the smallest was

Figure 10.–Average length of coho salmon captured at SN1 on the Unuk River, 2003.



320 mm, and the mean was 580 mm (SE = 1.8 mm) (Appendix B5).

Once on the spawning grounds, coho salmon did not have an equal chance of being sampled across the watershed. For instance, 44% of the transmitters were tracked to mainstem spawning locations not sampled during the second event. The average length of fish with transmitters tracked to mainstem sites was 597 mm MEF (SD = 74 mm) compared to 569 mm MEF (SD = 96 mm) for radio tagged fish tracked to Unuk River tributaries, which suggests that smaller fish may have been over-represented in the Event 2 samples. However, the difference in length distributions was not statistically significant ($P = 0.50$), indicating that disproportionate sampling during the second event had no effect on the accuracy of the abundance estimate.

AGE, SEX, AND LENGTH

Age-1.1 fish accounted for an estimated 88.4% (SE = 1.4%) and age-2.1 fish for 10.9% (SE = 1.3) of escapement, of which an estimated 62.5% (SE = 2.0%) were males (Appendix B5). Tests showed significant differences in sex composition ($\chi^2 = 8.38$; df = 1; $P = 0.004$) and age composition ($\chi^2 = 9.05$; df =1; $P = 0.003$) between events. For this reason only samples from the second event were used to calculate the statistics above. No significant difference in sex composition was indicated for fish >540 mm MEF ($\chi^2 = 2.31$; df = 1; $P = 0.13$), in contrast to indications of a significant difference in the age composition for small fish (< 541 mm MEF; $\chi^2 = 34.94$; df = 1; $P < .0001$). Of the 1,936 fish sampled in both events, ages were determined for 1,625 (about 84%). For the escapement, an estimated 23,807 (SE = 5,752) were age-1.1 and 2,934 (SE = 787) were age-2.1 with 16,833 (SE = 4,094) estimated to be males (Appendix B5).

MIGRATORY TIMING

Emigration of adults past SN1 was slightly early in 2003. The mean date of migration past SN1 in 2003 was estimated to be 31 August for all fish marked at SN1 and 5 September for those coho salmon marked at the set site and subsequently gillnet-recovered on the spawning grounds (Appendix B6). The mean date of migration for all fish marked at SN1 from 1998-2003 is 3 September with a range of 31 August (2003) to 5 September (1999, 2000). For those fish recovered on the spawning grounds, the mean date of migration past SN1 from 1998-2003 is 6 September with a range of 26 August (2001) to 13 September (1998).

As previously noted, multiple recoveries of marked fish recaptured on the spawning grounds only occurred on Lake (12) and Boundary (6) creeks in 2003. The mean migration date for fish destined for Lake Creek was 2 September, one day earlier than the average date from 1998-2003. The migratory timing distribution for the Lake Creek stock was platykurtic and relatively unskewed (Appendix B6). The mean migration date for the Boundary Lake stock was 6 September, compared to the 2000-2003 average of 8 September. The migratory timing distribution for the Boundary Creek stock was platykurtic and skewed rightward (Appendix B6).

HARVEST, MEAN DATE OF HARVEST, RUN SIZE, EXPLOITATION RATE, AND MARINE SURVIVAL RATE

An estimated 21,735 (SE = 2,896) coho salmon originating from the Unuk River were harvested in marine commercial and recreational fisheries in 2003 throughout Southeast Alaska (Table 6). These fish were harvested primarily from the Southeast (63%) and Northwest (20%) Quadrants (Appendix B7).

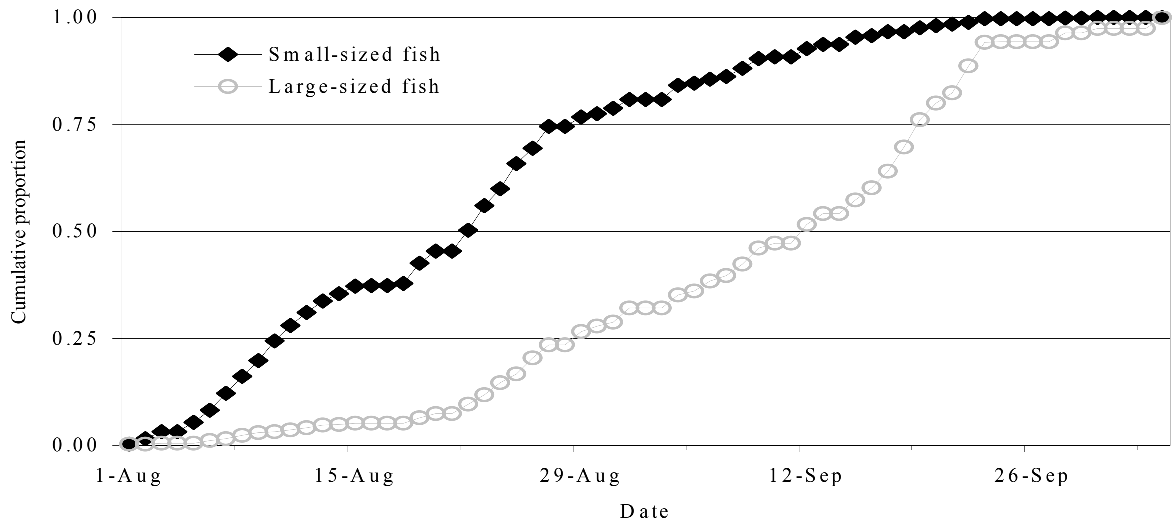


Figure 11.–Cumulative proportion of small (<541 mm MEF) and large (>540 mm MEF) coho salmon captured at SN1 on the Unuk River, 2003.

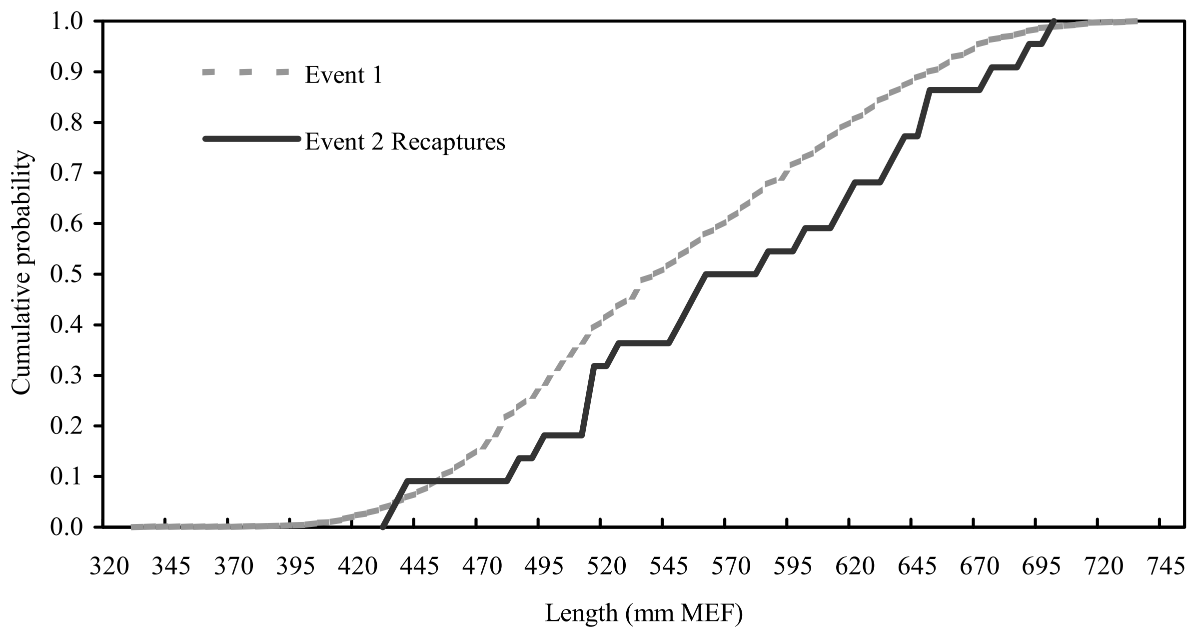


Figure 12.–Cumulative relative frequencies of adult coho salmon marked (n_1 = 1,210) in the lower Unuk River in 2003 compared with those recaptured (m_2 = 22) upstream.

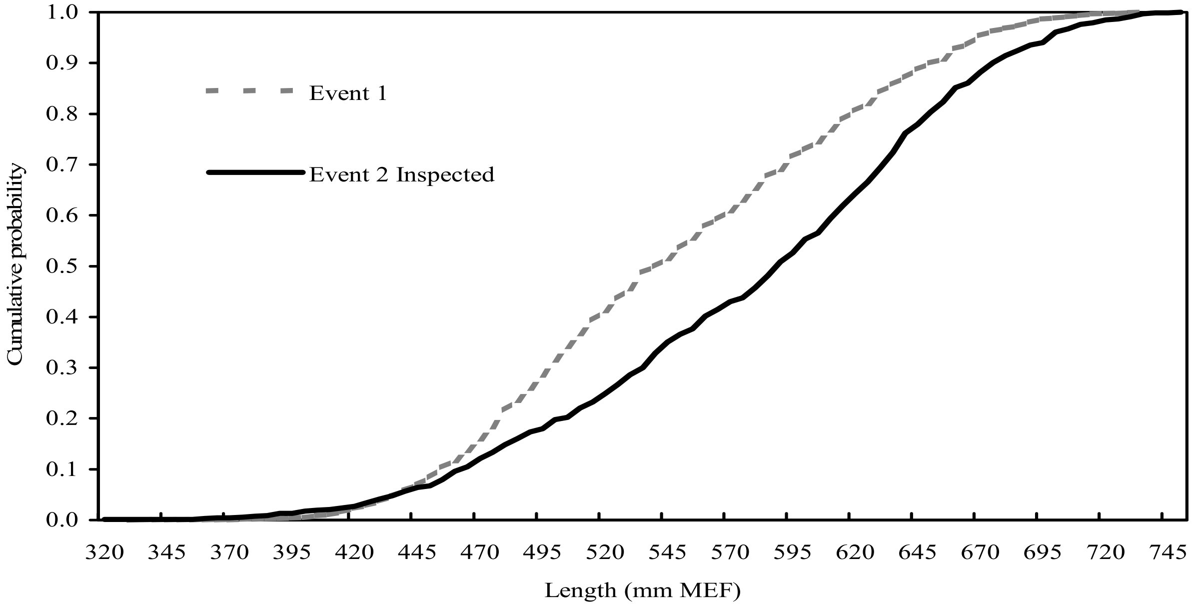


Figure 13.–Cumulative relative frequencies of adult coho salmon marked **(n_1 = 1,210)** in the lower Unuk River in 2003 compared with those inspected **(n_2 = 667)** upstream.

In the Unuk River at SN1, of the 1,268 fish sampled for CWTs, 29 were missing adipose fins; 2 of these had no tags, 1 was inadvertently released, and 26 carried a CWT implanted in 2002. The fraction of fish sampled at SN1 with valid 2002 CWTs was estimated to be 0.0213 (SE = 0.0041). Of fish captured during Event 1, the length distributions of fish with CWTs were not significantly different than for those without CWTs (P = 0.63; Figure 14).

In 2003, 116 coho salmon with CWTs released in the Unuk River in 2002 and 1 coho salmon released with a CWT in 2001 were recovered from various U.S. marine fisheries by the port and creel census sampling programs. The first marine recovery of a CWT occurred on 24 June in the recreational fishery near Sitka, while the last marine recoveries of the year occurred in the Southeast Quadrant of the troll fishery on 30 September. In total, 3.5% of the marine recoveries occurred after 19 September and <1% after 28 September.

The length distributions of coho salmon with Unuk River CWTs recovered in the troll and drift gillnet fisheries were significantly different than the length distributions for fish captured on the spawning grounds (P = 0.0002 and P < 0.001, respectively; Figure 15), indicating a size-selective harvest of larger fish in these fisheries. Size-selectivity in the troll fishery was more pronounced in the NW Quadrant (P = 0.0008) than in the SE Quadrant (P = 0.0533; Figure 16), a likely consequence of trollers targeting Chinook salmon as the initial component of the Unuk River run of coho salmon transited the NW Quadrant. There is no significant difference between the length distributions of CWTd fish recovered from either the commercial purse seine (P = 0.59) or recreational fisheries (P = 0.13) and those fish sampled on the spawning grounds (Figure 17). Lengths of all marine recoveries were first converted from FL to MEF using conversion equations (Pahlke 1989).

To approximate harvest by fish size, length distributions of fish recovered from marine fisheries were used to apportion the estimated harvest (Figure 18). Similarly, length distributions of fish sampled on the spawning grounds were used to apportion the estimated escapement. Small coho salmon (<541 mm MEF) comprised an estimated 33% of the escapement, 12% of the estimated marine harvest, and 24% of the estimated return in 2003 (Table 7). Of large sized (>540 mm MEF) coho salmon returning to Unuk

Table 6.–Estimated marine harvest of adult coho salmon bound for the Unuk River in 2003, where (V(□) = 82 and G(1/□) = 0.043).

TROLL FISHERY

SW[a]	Date	Per.	Quad.	*H*	var(*H*)	*n*	*a*	*a′*	*t*	*t′*	*mc*	$\hat{r}$	SE($\hat{r}$)	RP($\hat{r}$)	var($\hat{r}$)
27-33	6/29-8/16	3	SE	82,608	0	26,656	402	382	290	290	5	766	366	94%	33,954
34-40	8/17-10/4	4	SE	108,985	0	31,011	759	750	632	631	14	2,342	761	64%	578,481
34-40	8/17-10/4	4	SE*	358	0	358	3	3	3	3	1	47	46	194%	2,160
27-33	6/29-8/16	3	SW	164,144	0	81,032	1,424	1,394	1,137	1,135	3	292	174	117%	30,259
34-40	8/17-10/4	4	SW	30,147	0	21,083	498	495	431	431	7	473	196	81%	38,606
27-33	6/29-8/16	3	NE	68,439	0	22,092	448	444	369	368	6	883	391	87%	153,260
34-40	8/17-10/4	4	NE	63,455	0	20,412	469	469	408	408	4	584	307	103%	94,182
27-33	6/29-8/16	3	NW	259,598	0	73,397	1,389	1,377	1,142	1,142	7	1,173	489	82%	239,117
34-40	8/17-10/4	4	NW	440,210	0	128,461	3,480	3,452	2,961	2,959	18	2,922	878	59%	770,753
		Subtotal troll fishery		1,217,944	0	404,502	8,872	8,766	7,373	7,367	65	9,482	1,429	30%	2,040,772

SEINE FISHERY

SW[a]	Date	Dist.	*H*	var(*H*)	*n*	*a*	*a′*	*t*	*t′*	*mc*	$\hat{r}$	SE($\hat{r}$)	RP($\hat{r}$)	var($\hat{r}$)
28	7/6-7/12	101	2,975	0	618	16	16	16	16	1	226	226	196%	50,893
33	8/10-8/16	101	8,452	0	459	8	8	6	6	1	865	864	196%	747,000
34	8/17-8/23	101	8,895	0	1,790	19	15	15	15	2	591	425	141%	180,677
33	8/10-8/16	102	9,318	0	272	3	3	3	3	1	1,609	1,608	196%	2,586,775
35	8/24-8/30	102	9,051	0	781	9	9	9	9	1	544	544	196%	295,688
36	8/31-9/6	102	4,138	0	1,044	30	30	22	22	1	186	186	195%	34,470
33	8/10-8/16	104	7,967	0	1,177	16	16	12	12	2	636	457	141%	208,989
34	8/17-8/23	106	11,160	0	1,506	38	38	29	29	4	1,392	733	103%	537,016
33	8/10-8/16	109	9,994	0	2,376	53	53	48	48	2	395	284	141%	80,556
29	7/13-7/19	112	2,208	0	221	1	1	1	1	1	469	469	196%	219,701
	Subtotal seine fishery		74,158	0	10,244	193	189	161	161	16	6,913	2,223	63%	4,941,764

RECREATIONAL FISHERY

Biweek	Date	Area	*H*	var(*H*)	*n*	*a*	*a′*	*t*	*t′*	*mc*	$\hat{r}$	SE($\hat{r}$)	RP($\hat{r}$)	var($\hat{r}$)
15	7/21-8/3	Ketchikan	5,107	1,927,223	1,535	39	38	33	33	2	321	238	146%	56,711
16	8/4-8/17	Ketchikan	3,821	534,701	1,370	25	25	23	23	1	131	131	195%	17,035
17	8/18-8/31	Ketchikan	6,122	1,723,261	1,367	22	22	20	20	1	210	210	196%	44,041
18	9/1-9/14	Ketchikan	8,417	5,187,783	2,749	77	76	71	70	1	148	147	195%	21,703
13	6/23-7/6	Sitka	5,529	2,635,075	1,657	35	35	31	31	1	157	156	195%	24,418
	Subtotal recreational fishery		28,996	12,008,043	8,678	198	196	178	177	6	966	405	82%	163,908

GILLNET FISHERY

SW[a]	Date	Dist.	*H*	var(*H*)	*n*	*a*	*a′*	*t*	*t′*	*mc*	$\hat{r}$	SE($\hat{r}$)	RP($\hat{r}$)	var($\hat{r}$)
35	8/24-8/30	106-30	6,157	0	647	14	14	13	13	3	1,341	801	117%	642,344
35	8/24-8/30	106-41	11,942	0	2,258	48	48	35	35	2	497	357	141%	127,479
36	8/31-9/6	106-30	2,773	0	1,487	36	36	31	31	1	88	87	195%	7,586
36	8/31-9/6	106-41	14,325	0	6,808	149	149	118	17	6	598	265	87%	70,071
37	9/7-9/13	106-41	26,797	0	11,637	281	280	242	242	6	651	288	87%	83,152
38	9/14-9/20	106-41	21,375	0	8,719	282	282	238	238	3	345	206	117%	42,383
35	8/24-8/30	101	4,992	0	1,118	34	34	28	28	1	210	209	196%	43,770
38	9/14-9/20	101[b]	8,845	0	1,858	42	41	37	37	1	229	229	196%	52,230
39	9/21-9/27	101[b]	7,349	0	877	20	19	18	18	1	414	414	196%	171,203
Subtotal gillnet fishery			104,555	0	35,409	906	903	760	759	24	4,373	1,114	50%	1,240,216
		Total	1,425,653	12,008,043	458,833	10,169	10,054	8,472	8,464	111	21,735	2,896	26%	8,386,661

[a] Statistical week.

[b] Indicates MIC.

Note: Table terms defined on page 11.

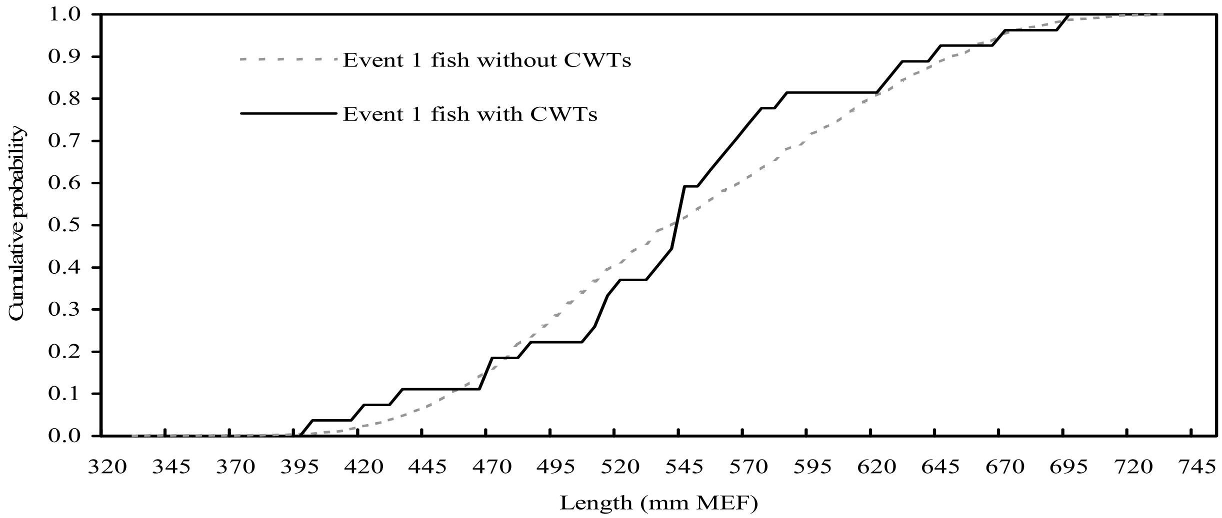


Figure 14.–Cumulative relative frequencies of adult coho salmon captured in the lower Unuk River in 2003 with CWTs compared to those without CWTs.

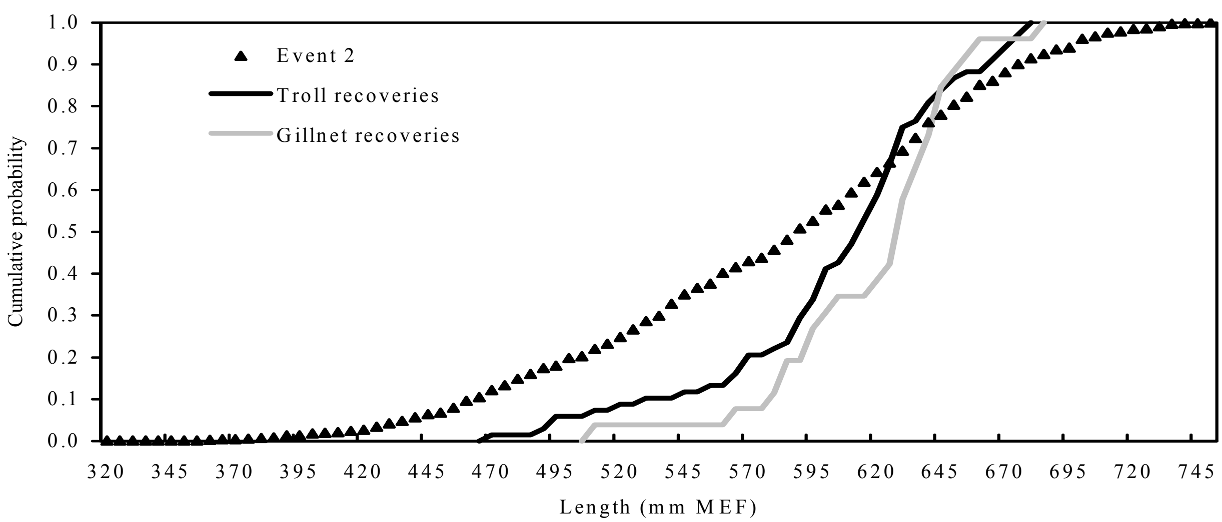


Figure 15.– Cumulative relative frequencies by length (MEF) of adult coho salmon sampled on the spawning grounds (Event 2) compared to adults with CWTs bound for the Unuk River and recovered from all sampled troll and gillnet fisheries, 2003.

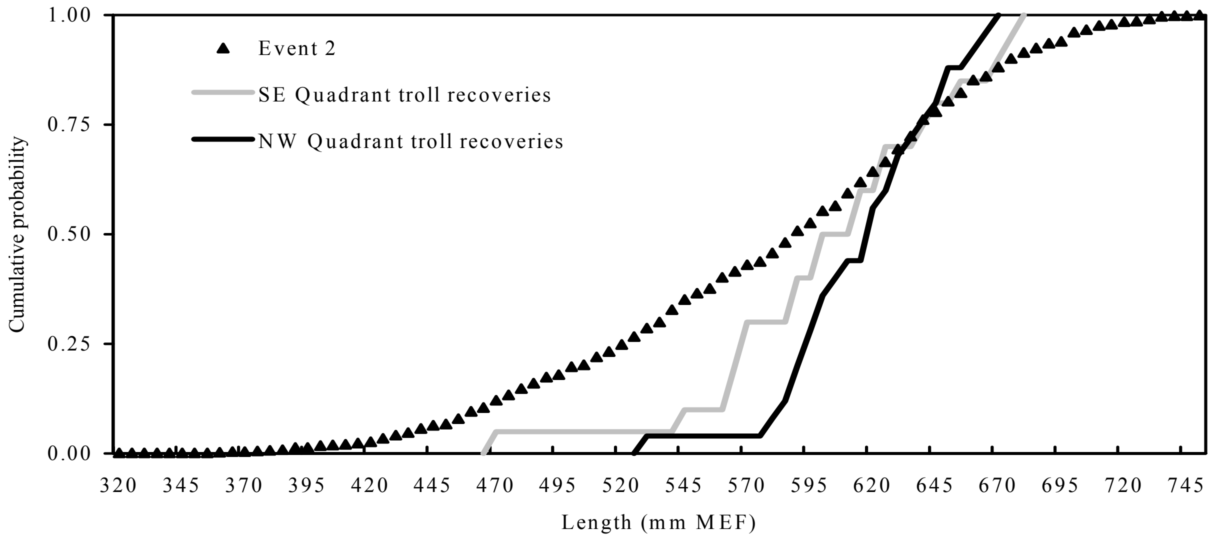


Figure 16.–Cumulative relative frequencies by length (MEF) of adult coho salmon sampled on the spawning grounds (Event 2) compared to adults with CWTs bound for the Unuk River and recovered from troll fisheries in the NW and SE quadrants, 2003.

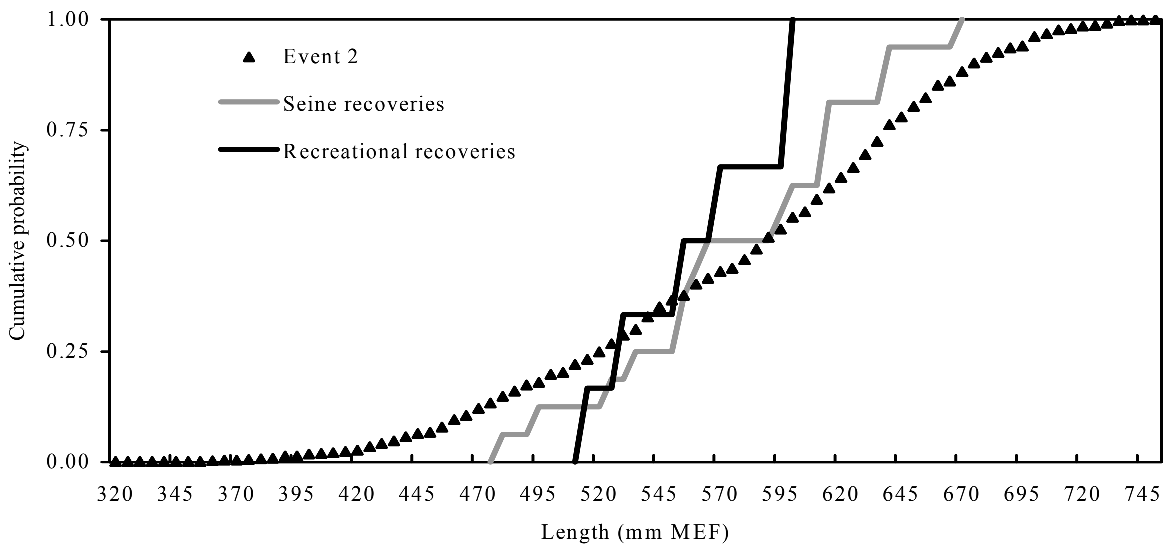


Figure 17.–Cumulative relative frequencies by length (MEF) of adult coho salmon sampled on the spawning grounds (Event 2) compared to adults with CWTs bound for the Unuk River and recovered from all sampled seine and recreational fisheries, 2003.

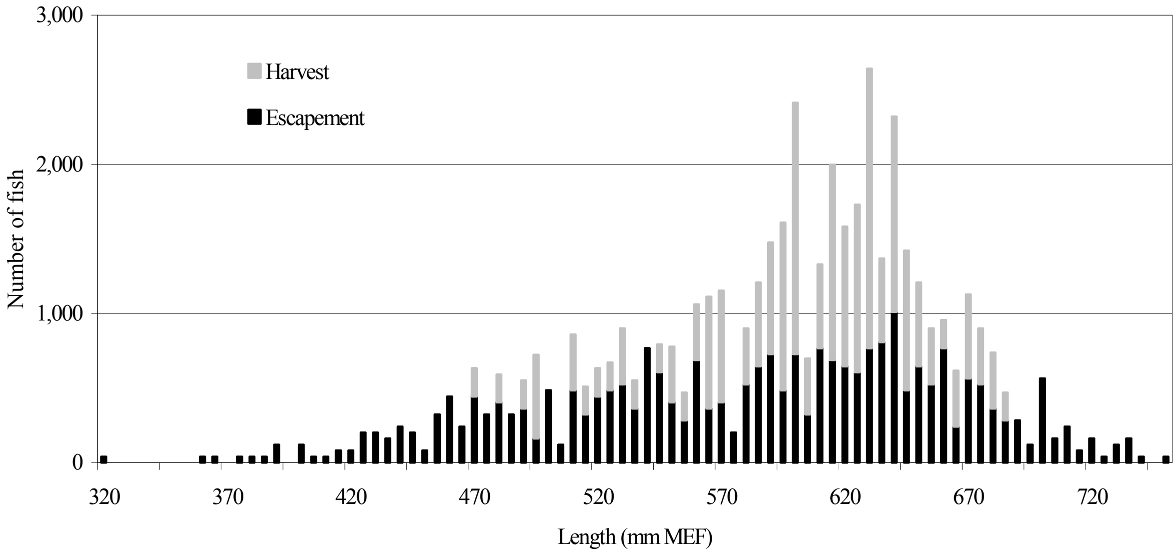


Figure 18.–Estimated escapement and harvest by length (MEF) for the Unuk River stock of coho salmon, 2003.

Table 7.–Estimated harvest and escapement of small (<541 mm MEF) and large (>540 mm MEF) Unuk River stock coho salmon, 2003.

	Coho salmon size		
	Small	Large	Total
Escapement	8,937	18,281	27,218
Harvest	2,623	19,111	21,735
Total	11,560	37,392	48,953

River in 2003, an estimated 51% were harvested in marine fisheries compared to 23% of small sized fish (Table 7).

Coho salmon from the Unuk River stock constituted an estimated 1.7% of the harvest of that species in the SE quadrant troll fishery, 3.7% and 4.0% of harvests in the District 101 and 106 seine fisheries, respectively, 2% of the Metlakatla Indian Community (MIC) drift gillnet fishery in District 101, and 2.1% and of recreational fishery harvest near Ketchikan and Sitka (Table 8; Appendix B8).

The estimated mean date of harvest in the troll fishery was 20 August, compared to 4 August, 10 August, and 1 September for the recreational, seine, and gillnet fisheries (Appendix B7). The overall mean date of harvest in 2003 was 18 August, similar to 2002 but almost two weeks later than the average mean date of harvest from 1998 to 2001 (Figure 16; Appendix B8) (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003).

The estimated exploitation rate in marine commercial and recreational fisheries was 44.4% (SE = 6.7%; Table 8). From 1998-2002, the exploitation rate averaged 50% with a range of 79% (1998) to 22% (2002). As in 2002, the troll fishery in the NW Quadrant accounted for only 20% of the estimated marine harvest in contrast to an average of 35% from 1998 to 2001 (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003).

The estimated marine survival rate was 6.5% (SE = 2.3%, Table 8), well below the previous five-year average of 8.4%.

DISCUSSION

In the previous five years of this study, approximately 50 radio tags were systematically placed in coho salmon from approximately mid-August through mid-September. Truncating the placement of radio tags to this period considerably reduced the effort required to verify immigration of the marked fish. Justification for truncating the application of radio tags to this portion of the run lies in the finding of no trend in tag loss as a function of tagging date. The radio telemetry

Table 8.– Estimated marine harvest, exploitation rate, run size, and marine survival rate of the Unuk River stock of coho salmon, 2003.

Fishery	Area	Estimated harvest	SE	Percent of marine harvest	Exploitation rate	SE
TROLL	SE Quadrant	3,155	1,173	14.5%	6.4%	1.6%
	SW Quadrant	765	370	3.5%	1.6%	0.5%
	NE Quadrant	1,467	2,166	6.8%	3.0%	2.5%
	NW Quadrant	4,095	1,367	18.8%	8.4%	1.9%
	Subtotal	9,482	1,429	43.6%	19.4%	3.0%
SEINE	District 101	1,682	1,515	7.7%	3.4%	1.8%
	District 102	2,339	2,338	10.8%	4.8%	2.7%
	District 104	636	457	2.9%	1.3%	0.5%
	District 106	1,392	733	6.4%	2.8%	0.9%
	District 109	395	284	1.8%	0.8%	0.3%
	District 112	469	469	2.2%	1.0%	0.5%
	Subtotal	6,913	2,223	31.8%	14.1%	3.1%
SPORT	Ketchikan	810	726	3.7%	1.7%	0.8%
	Sitka	157	156	0.7%	0.3%	0.2%
	Subtotal	966	405	4.4%	2.0%	0.5%
GILLNET	District 101	210	209	1.0%	0.4%	0.2%
	District 101 MIC	643	642	3.0%	1.3%	0.7%
	District 106-30	1,428	889	6.6%	2.9%	1.1%
	District 106-41	2,091	1,116	9.6%	4.3%	1.4%
	Subtotal	4,373	1,114	20.1%	8.9%	1.7%
	Total marine harvest	21,735	2,896	100.0%	44.4%	6.7%
	Mark-recapture tagging mortality	249	0		0.5%	
	Total escapement	26,934	6,495		55.1%	
	Total run	48,917	7,111		100.0%	
	Estimated marine survival	6.5%	2.3%			

results are then used to estimate the proportion of adults marked during the first event that suffered mortality or left the Unuk River prior to spawning. However, these results also provide valuable insights into the distribution and migratory timing of the various populations of coho salmon in the Unuk River. In August the run consists primarily of small-sized coho salmon (Weller et al. 2002; 2003). In previous years these fish were not fitted with radio tags either because they were captured prior to mid-August or because the radio tags were deemed too large to be placed without damaging the fish. Consequently the radio telemetry results are not representative of the distribution and migratory timing of the entire run. In 2003, therefore, radio tags were systematically placed in coho salmon throughout the duration of tagging operations at SN1. In addition, lighter, narrower radio tags were purchased for implantation in small sized coho salmon. This strategy proved successful; the proportion of radio tagged fish that survived to spawn was similar regardless of transmitter size, and the resulting tracking data provided information on run timing and spawning distribution.

Results from similar studies conducted from 1998 to 2002 (Jones III et al. 1999; 2001a; 2001b; Weller et al. 2002; 2003) and since 1997 with Chinook salmon (Jones III et al. 1998; Jones III and McPherson 1999, 2000; Weller and McPherson 2003a, b; 2004) suggest that fish bound for the various spawning tributaries of the Unuk River can be proportionately sampled using set gillnets operated at SN1. During three of the five previous years, operations at SN1 continued through the first week of October, after which time catches were deemed negligible and operations ceased. In 2003, the set gillnets were operated through 4 October, however high water and personnel shortages severely limited gillnet effort after 24 September. Recovery of CWTs in marine fisheries and CPUE at SN1 suggests that a proportionately small segment of the latter portion of the run was not sampled in 2003, as was also the case in 2001 and 2002. Nevertheless, as long as this portion of the run proportionately represented all spawning populations in the Unuk River, estimates of adult abundance are unbiased.

Using set gillnets to capture coho salmon remains the cause of size-selective sampling at SN1. In the first three years of this study, two 5¾" set gillnets were used to capture fish. Results from these studies suggest that these nets were likely size-selective for larger coho salmon (Jones III et al. 1999; 2001a; 2001b). From 2001-2003 a 4½" net was substituted for one of the larger mesh nets to correct this size-selectivity. Cumulative length frequencies of fish tagged at SN1 versus fish examined during the second event in these years indicate that SN1 was now size-selective for mid-sized coho salmon. As noted, operations at SN1 were terminated earlier than anticipated (~24 September versus 7 October) and prior to the end of the migration. The last, unsampled segment of the immigration was likely composed predominantly of larger fish (Figure 10), making early termination of operations one reason for the significant difference observed in the relative frequency distribution of fish sampled during both events.

Estimates of smolt abundance in the Unuk River for 1998–2000 are likely biased. Studies during those years lacked the means to detect size-specific differences in capture rates or marine survival rates of smolts. Existence of both differences in a single mark-recapture experiment implies estimates would be biased low. Smolt emigrating from the Eulachon River are less likely to be captured and marked as they tend to rear beyond the confines of our trapping area (Lava Falls to tidal influence on the main stem and its adjoining sloughs). In addition, some proportion of the juvenile coho salmon that were less than 70 mm FL in the spring of 2002 and consequently had no chance of being marked, undoubtedly migrated to sea that spring. The survival rate of larger marked smolt was roughly 1.9 times that of smaller marked smolt in 2003 (Appendix A.1), compared to an estimated rate of 2.5 in 2002 (Weller et al. 2003). The bias involved in the estimate of 2002 smolt abundance is 20%, compared to an estimated 14% bias in 2001. Speculation is that such bias, if present in statistics from 1997-2000, would be of similar magnitude.

CONCLUSION AND RECOMMENDATIONS

In 2004, fieldwork will be limited to operating the set gillnets, at a reduced level of effort, in order to capture enough coho salmon to determine the CWT marked fraction and to collect ASL and CPUE data. In order to maximize the usefulness of the information collected at the set gillnets in 2004, we recommend that the set gillnets be operated throughout the course of the return and that effort remain relatively constant throughout that period of time. In addition, all personnel should be given additional training in coho salmon gender identification, for small-sized fish in particular. Gender identification can be difficult at SN1 as secondary maturation characteristics may be absent or in early stages of development, particularly during the early stages of the inriver migration when small sized fish are predominate. Gender misidentification at SN1 may be a contributing factor to the observed difference in sex composition between events.

ACKNOWLEDGMENTS

We thank Dale Brandenburger, Roger Hayward, Jason Leavitt, and John Barton of ADF&G for their participation in the spring coded-wire-tagging study on coho salmon smolt in 2002; Nicole Zeiser, Chris S'gro, Roger Hayward, John Barton, Roger Wagner, Kristin Lyle, Mark Olsen, Steve Huffine, and Ricky Blanchard of ADF&G for their help with the fall mark-recapture study on coho salmon adults in 2003; Locke Hendry and Tim Baldy for their volunteer work during the coho salmon adult mark-recapture project; pilot Dave Doyon for his support during the aerial telemetry flights and pilots Jeff Carlin and Dave Doyon Jr. for their logistical support; Cathy Robinson, Ron Josephson, Detlef Buettner, Anna Sharp and the rest of the ADF&G Mark, Tag, and Age Laboratory in Juneau for dissecting and decoding heads and providing sampling supplies and data on CWT recoveries in a timely manner; Sue Millard for estimating the age (when possible) for each Unuk River coho salmon sampled for scales; Mike Wood for his assistance with the telemetry index map, and Judy Shuler for help with the final preparation of this manuscript.

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APPENDIX A

Abundance of smolt emigrating in 2002 was estimated with information gathered in that year and from returning adults in 2003. Petersen's model was used as the estimator under the conditions that every smolt (or adult) had an equal chance of being in the mark-recapture experiment and that the population was closed to recruitment. Fidelity of salmon to their natal watershed produces a de facto closure to recruitment from other populations, so long as sampling occurs in river, as is the case here. However, every smolt and adult did not have an equal chance of being included in the experiment because groups of smolts were marked and survived at different rates. Evidence for these differences and the means to counteract their effects are provided below.

When a population is divided into two groups labeled (1) and (2), Petersen's model of a mark-recapture experiment can be expressed as:

$$N_1 + N_2 = (N_1\alpha_1 + N_2\alpha_2)\frac{N_1\alpha_1 S_1\beta_1 + N_2\alpha_2 S_2\beta_2 + N_1(1-\alpha_1)S_1\beta_1 + N_2(1-\alpha_2)S_2\beta_2}{N_1\alpha_1 S_1\beta_1 + N_2\alpha_2 S_2\beta_2} \quad \text{(A.1)}$$

where N is abundance, α is the rate at which members of the group are marked (tagged), S the rate at which members survive to return as adults, and β the rate at which surviving members are captured. If all adults have an equal probability of being captured in the experiment regardless of group membership, and of their having or not having a mark, then $\beta_1 = \beta_2 = \beta$, and the equation above reduces to:

$$N_1 + N_2 = (N_1\alpha_1 + N_2\alpha_2)\frac{N_1\alpha_1 S_1 + N_2\alpha_2 S_2 + N_1(1-\alpha_1)S_1 + N_2(1-\alpha_2)S_2}{N_1\alpha_1 S_1 + N_2\alpha_2 S_2} \quad \text{(A.2)}$$

Relationships between capture rates and between survival rates by group can be expressed as $\alpha_2 = \alpha_1 A$ and $S_2 = S_1 B$, respectively. Plugging these relationships into the equation immediately above and simplifying produces:

$$N_1 + N_2 = \frac{(N_1 + AN_2)(N_1 + BN_2)}{N_1 + ABN_2} \quad \text{(A.3)}$$

Note that this result is false only when A ≠ 1 (i.e., $\alpha_1 \neq \alpha_2$) <u>and</u> B ≠ 1 (i.e., $S_1 \neq S_2$), that is, when groups of smolts are tagged at different rates and survive at different rates.

Evidence shows that larger smolts (group 2) in 2002 survived at better rates ($S_1 < S_2$) than did smaller smolt (group 1). In 2002 we established two groups of tagged smolt based on length: all < 85 mm long and all ≥ 85 mm. We did not tag smolt < 70 mm because experience has shown that many fish of this size hold over an extra year. We tagged 8,042 fish to represent smaller-smolt group and 5,303 to represent the larger-smolt group. A year later we recovered 65 tags from the smaller-smolt group and 83 from the larger in river and from marine fisheries. The rate of return is significantly different (χ^2 = 16.30, df = 1, P = 5.4E^{-05}) implying that the survival rate for larger smolt was 1.936 (= B) times the rate for smaller smolt.

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Evidence also shows that $\alpha_2 > \alpha_1$, that is, larger fish were marked at a higher rate. The table below contains information on tags recovered during the second sampling event of the experiment (at the setnet site) split into age of the fish tagged:

Set gillnet recoveries	Age 1.1	Age 2.1	Unknown	Total
Smaller smolt (1)	$9 = R_{1(1.1)}$	$0 = R_{1(2.1)}$	1	$10 = R_1$
Larger smolt (2)	$10 = R_{2(1.1)}$	$2 = R_{2(2.1)}$	4	$16 = R_2$
Unknown	$1 = R_{3(1.1)}$	$0 = R_{3(2.1)}$	0	$1 = R_3$
Total	20	2	5	27

Of the 1,268 salmon captured at the set gillnet site, age was determined for 1,065 with 93.3% (994) being age 1.1 (71 were judged as age 2.1). This relative age composition of adults can be expressed as:

$$0.827 = \frac{N_1S_1 + N_2\theta\ S_2}{N_1S_1 + N_2S_2} = \frac{N_1S_1 + N_2\theta BS_1}{N_1S_1 + N_2BS_1} = \frac{N_1 + N_2\theta B}{N_1 + N_2B}$$

where θ is the fraction of the larger-smolt group composed of fish age 1.1. An estimate of θ can be calculated from statistics in the second row of the table above plus recoveries on the spawning grounds:

Spawning ground recoveries	Age 1.1	Age 2.1	Unknown	Total
Smaller smolt (1)	2	0	1	3
Larger smolt (2)	$1 = r_{2(1.1)}$	$1 = r_{2(2.1)}$	2	4
Unknown	1	0	0	1
Total	4	1	3	8

The estimate $\hat{\theta}$ = 0.7857 = (10+1)/(10+1+2+1)]. Remembering that $\hat{B}$ = 1.936, the equation immediately above can be rearranged and simplified to show that $N_2 = 0.23N_1$. Plugging this relationship into α_2N_2 = 5,303 produces α_2N_1 = 22,739. Dividing this result by α_1N_1 = 8,042 produces the relationship $\alpha_2 = \alpha_1(2.83)$ where $\hat{A}$ = 2.83. This lower marking rate for the smaller-smolt group is consistent with some, but not necessarily all, young salmon < 70 mm smolting in 2002.

Fortunately, the same approach to detect problems with different marking and survival rates can be used to adjust Petersen's model to produce a relatively unbiased estimate of smolt abundance. Note that for an

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estimate using Chapman's modification of Petersen's model, $\hat{N} = (M_1 + M_2 + 1)(C + 1)/(R_1 + R_2 + 1)$ where M is the number marked by group, C the number inspected for marks, and R the number of marks recovered by group. Since A > 1 and S > 1, $N > \hat{N}$. However, if the smaller-smolt group had had the same marking rate as the larger-smolt group, AM_1 smolt would have been marked and AR_1 would have been recaptured as adults. Plugging these consequences into the model produces a rescaled estimate:

$$\hat{N}^* = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}R_1 + R_2 + 1} \tag{A.4}$$

The expected value of $\hat{N}^*$ is N because in the rescaled situation the two groups have the same effective marking rate.

Unfortunately, values for R must be estimated because not all recaptured adults can be assigned to a smolt group; tags are shed or heads are lost before tags can be retrieved and decoded. Of the 65 adults recaptured at the set gillnet site, 1 could not be assigned to a smolt-group. Of all tags recaptured and recovered from adults caught in fisheries and or sampled in the river, 43.92% [= 65/(65+83) x 100] were in the smaller-smolt group. Applying this fraction to the recaptured fish of unknown heritage apportions these fish into the two smolt groups. The resulting change in the calculation to estimate abundance is

$$\hat{N}^* = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}(R_1 + \hat{\pi}R_3) + R_2 + (1-\hat{\pi})R_3 + 1} \tag{A.5}$$

where π is the fraction of recaptured fish from the smaller-smolt group recaptured at the setnet site. In this instance

$$\hat{N}^* = \frac{[2.83(8{,}042) + 5{,}303 + 1](1{,}268 + 1)}{2.83[10 + 1(0.4392)] + 16 + (1 - 0.4392)(1) + 1} = 755{,}905$$

where C = 1,268 (the number of adults sampled in the second sampling event in the experiment. Contrast $\hat{N}^*$ to the biased $\hat{N}$ that equals 604,860, some 20% less.

Variance and relative statistical bias in the rescaled estimator were estimated through bootstrapping frequencies of capture histories as suggested in Buckland and Garthwaite (1991). As the mark-recapture experiment was designed, there are 20 capture histories for smolts (see Table A1). The model variable T corresponds to the number of all tags recovered and recaptured from adult salmon by group regardless of the how or where of the recovery or recapture. The model variable U corresponds to the number of unmarked fish by age in the second sampling event (the setnet site). Other model variables are defined in the text above. Values for model variables were used to calculate frequencies (n) for each capture history, and then these frequencies were summed to produce a cumulative density function. Each bootstrap sample began by randomly assigning $\hat{N}^*$ virtual fish to produce a series of virtual tallies

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$n'(1)$ ... $n'(20)$ according to the density function. In the next step these virtual tallies were used to back-calculate values for virtual model variables R′, r′, M′, T′, U′, and C′. Virtual model variables were then used to calculate π', θ', p', A', and finally $\hat{N}'$, as per these equations:

$$\pi' = \frac{T_1'}{T_1' + T_2'} \quad \text{(A.6)}$$

$$\theta' = \frac{R'_{2(1.1)} + r'_{2(1.1)}}{R'_{2(1.1)} + r'_{2(1.1)} + R'_{2(2.1)} + r'_{2(2.1)}} \quad \text{(A.7)}$$

$$p' = \frac{U'_{1.1} + \sum_{i=1}^{3} R'_{i(1.1)}}{U'_{1.1} + U'_{2.1} + \sum_{i=1}^{3}\sum_{j=1}^{2} R_{i(j.1)}} \quad \text{(A.8)}$$

$$A' = \frac{(p' - \theta')}{(1 - p')}\frac{T_2'}{T_1'} \quad \text{(A.9)}$$

$$\hat{N}' = \frac{(A'M_1' + M_2' + 1)(C' + 1)}{A'(R_1' + \pi' R_3') + R_2' + (1 - \pi')R_3' + 1} \quad \text{(A.10)}$$

Then the process was repeated a to create 1000 iterations and 1000 separate estimates $\hat{N}'$. At the end of the iterations, the following statistics were calculated:

$$\overline{N}' = \frac{\sum_{b=1}^{B} N'_{(b)}}{B} \quad \text{(A.11)}$$

$$v(\overline{N}') = \frac{\sum_{b=1}^{B} (N'_{(b)} - \overline{N}')^2}{B - 1} \quad \text{(A.12)}$$

$$\text{Relative Bias} = \frac{\overline{N}' - \hat{N}^*}{\hat{N}^*}(100) \quad \text{(A.13)}$$

The estimated SE for $\hat{N}^*$ is the square root of $v(\overline{N}')$ or 239,117 making the cv($\hat{N}^*$) = 0.316. The statistic $\overline{N}'$ equaled 736,700 for an estimated relative bias of 2.5%. Using the percentile method to estimate a 95% confidence interval about $\hat{N}^*$, the lower bound is 360,034 smolt and the upper 1,392,904 (see Figure A1). Implied in this analysis is the condition that differences in marking and survival rates between groups are “knife-edge.” Most likely they are not with changes in rates being smoother with changes in size of smolt. However, the stratification applied here should remove much of the systemic bias in the estimate of abundance (there’s demonstrably little statistical bias). What little systemic bias remains is probably negligible when compared to the estimated variance for estimated abundance.

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Table A1.–Relationships among history variables, capture histories, and model variables in bootstrap simulations.

History variable	Capture history	Model variables	Values
n(2)	Marked, not seen – Smaller smolt	$M_1 - T_1$	8,042 – 65 = 7,977
n(3)	" " – Larger smolt	$M_2 - T_2$	5,303 – 83 = 5,220
n(4)	Marked, recaptured – Smaller smolt – Age 1.1	$R_{1(1.1)}$	9
n(5)	" " " " – Age 2.1	$R_{1(2.1)}$	0
n(6)	" " " " – Unknown	$R_1 - \sum_{j=1}^{2} R_{1(j.1)}$	10 – (9 + 0) = 1
n(7)	" " – Larger smolt – Age 1.1	$R_{2(1.1)}$	10
n(8)	" " " " – Age 2.1	$R_{2(2.1)}$	2
n(9)	" " " " – Unknown	$R_2 - \sum_{j=1}^{2} R_{2(j.1)}$	16 – (10 + 2) = 4
n(10)	" " – Unknown – Age 1.1	$R_{3(1.1)}$	1
n(11)	" " " – Age 2.1	$R_{3(2.1)}$	0
n(12)	" " " " – Unknown	$R_3 - \sum_{j=1}^{2} R_{3(j.1)}$	1 – (1 + 0) = 0
n(13)	Marked, recovered, -Smaller smolt	$T_1 - R_1$	65 – 9 = 56
n(14)	" " – Larger Smolt – Age 1.1	$r_{2(1.1)}$	1
n(15)	" " " " – Age 2.1	$r_{2(2.1)}$	1
n(16)	" " " " – Unknown	$T_2 - R_2 - r_{2(1.1)} - r_{2(2.1)}$	83 – 16 – 1 – 1 = 65
n(17)	Not marked, captured – Age 1.1	$U_{1.1}$	974
n(18)	" " – Age 2.1	$U_{2.1}$	69
n(19)	" " – Unknown	$C - \sum_{j=1}^{2} U_{j.1} - \sum_{i=1}^{3}\sum_{j=1}^{2} R_{i(j.1)}$	1,268 – (974 + 60) – (20 + 2 + 5) = 198
n(1)	Not marked, not seen	$\hat{N}^* - M_1 - M2 - C + R_1 + R_2$	

Note that "captured" and "recaptured" refer to fish caught at the setnet sites. Note that relationships are predicated on the presumption that all adults recaptured from the smaller-smolt group are age 1.1.

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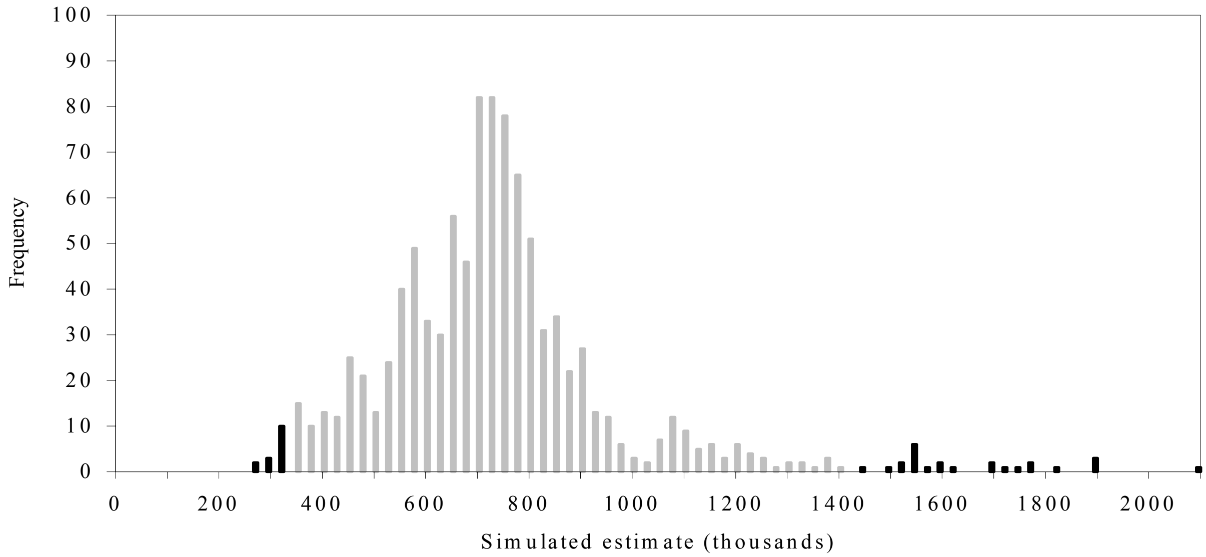

Figure A1.–Frequency of 1,000 simulated estimates from bootstrap simulations along with the 95% confidence interval (gray frequency bars) based on the percentile method of calculation.

APPENDIX B

Appendix B1.–Detection of size-selectivity in sampling and its effects on estimation of abundance and on age and size composition.

RESULTS OF HYPOTHESIS TESTS, K-S AND χ^2 on lengths of fish	
MARKED during the first sampling event and **RECAPTURED** during the second event	**MARKED** during the first sampling **INSPECTED** during the second event
Case I:	
Accept H_O	Accept H_O
There is no size-selectivity during either sampling event.	
Case II:	
Accept H_O	Reject H_O
There is no size-selectivity during the second event, but there is during the first.	
Case III:	
Reject H_O	Accept H_O
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_O	Reject H_O
There is size-selectivity during the second event; the status of size-selectivity during the first is unknown.	

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

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data (p. 17).

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

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

Appendix B2.–Random and select recoveries of coded-wire tags (CWTs) from the Unuk River stock of coho salmon, 2003.

Head number	Tag code	Gear	Recovery date	Stat. week	Quad.	Dist.	Length	Port survey site	Sample number
				RANDOM RECOVERIES					
516893	40536	Troll	7/6/2003	28	NE	109	537	Petersburg	3050261
160838	40536	Troll	7/19/2003	29	NE	109	685	Port Alexander	3080029
160905	40536	Troll	7/26/2003	30	NE	109	555	Port Alexander	3080042
521340	40536	Troll	8/3/2003	32	NE	109	734	Petersburg	3050604
163305	40536	Troll	8/7/2003	32	NE	109	663	Port Alexander	3080075
520798	40537	Troll	8/12/2003	33	NE	109	695	Wrangell	3120066
166400	40537	Troll	8/19/2003	34	NE	109	660	Port Alexander	3080108
166383	40537	Troll	8/19/2003	34	NE	109	684	Port Alexander	3080106
179062	40537	Troll	8/23/2003	34	NE	109	684	Port Alexander	3080118
518757	40537	Troll	8/25/2003	35	NE	109	685	Petersburg	3050844
55447	40537	Troll	7/22/2003	30	NW	114	660	Elfin Cove	3020050
220412	40536	Troll	7/25/2003	30	NW	113	674	Sitka	3030904
180571	40536	Troll	7/27/2003	31	NW	113	630	Sitka	3030923
223688	40536	Troll	7/31/2003	31	NW	113	577	Pelican	3010191
220497	40536	Troll	7/31/2003	31	NW	113	683	Sitka	3030940
220778	40536	Troll	8/13/2003	33	NW	113	635	Sitka	3031032
220790	40537	Troll	8/14/2003	33	NW	113	654	Sitka	3031042
225732	40537	Troll	8/19/2003	34	NW	114	658	Pelican	3010229
220819	40536	Troll	8/23/2003	34	NW	113	671	Sitka	3031087
220811	40537	Troll	8/23/2003	34	NW	113	706	Sitka	3031087
226101	40537	Troll	8/26/2003	35	NW	113	691	Pelican	3010244
220873	40537	Troll	8/26/2003	35	NW	113	647	Sitka	3031103
226125	40537	Troll	8/27/2003	35	NW	116	686	Pelican	3010247
235457	40536	Troll	8/29/2003	35	NW	113	645	Sitka	3031122
220679	40536	Troll	8/30/2003	35	NW	113	652	Sitka	3031130
226217	40537	Troll	9/1/2003	36	NW	113	678	Pelican	3010261
205515	40536	Troll	9/5/2003	36	NW	113	640	Port Alexander	3080165
235643	40537	Troll	9/6/2003	36	NW	113	675	Sitka	3031142
235680	40537	Troll	9/6/2003	36	NW	113	720	Sitka	3031146
235557	40536	Troll	9/8/2003	37	NW	113	641	Sitka	3031169
235767	40537	Troll	9/12/2003	37	NW	113	705	Sitka	3031188
235984	40537	Troll	9/13/2003	37	NW	113	693	Sitka	3031191
226504	40536	Troll	9/16/2003	38	NW	113	703	Pelican	3010300
248133	40537	Troll	9/18/2003	38	NW	113	730	Sitka	3031225
248294	40537	Troll	9/23/2003	39	NW	113	725	Sitka	3031241
526707	40537	Troll	8/1/2003	31	SE	101	613	Ketchikan	3060363
526652	40536	Troll	8/4/2003	32	SE	101	511	Ketchikan	3060393
526343	40537	Troll	8/5/2003	32	SE	101	679	Ketchikan	3060394
524420	40536	Troll	8/15/2003	33	SE	105	617	Craig	3070330
524412	40537	Troll	8/15/2003	33	SE		615	Craig	3070329
524704	40537	Troll	8/23/2003	34	SE	105	617	Craig	3070368
168949	40536	Troll	8/25/2003	35	SE	101	696	Metlakatla	3090207
526077	40537	Troll	8/25/2003	35	SE	101	702	Ketchikan	3060491
520851	40537	Troll	8/26/2003	35	SE	105	640	Wrangell	3120078
524635	40537	Troll	8/27/2003	35	SE	105	643	Craig	3070384
179183	40536	Troll	8/27/2003	35	SE	105	677	Port Alexander	3080137
518547	40537	Troll	9/7/2003	37	SE		741	Petersburg	3050926
524830	40536	Troll	9/8/2003	37	SE	105	730	Craig	3070435
525069	40537	Troll	9/9/2003	37	SE	102	735	Ketchikan	3060539
524920	40536	Troll	9/12/2003	37	SE	105	714	Craig	3070446

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Appendix B2.– Page 2 of 3.

Head number	Tag code	Gear	Recovery date	Stat. week	Quad.	Dist.	Length	Port survey site	Sample number
524913	40536	Troll	9/12/2003	37	SE	105	666	Craig	3070447
525423	40537	Troll	9/17/2003	38	SE	101	669	Ketchikan	3060561
525455	40536	Troll	9/18/2003	38	SE	101	654	Ketchikan	3060559
525468	40536	Troll	9/19/2003	38	SE	101	651	Ketchikan	3060554
526145	40537	Troll	9/30/2003	40	SE	101	590	Ketchikan	3060603
523815	40536	Troll	7/8/2003	28	SW	104	537	Craig	3070056
526684	40536	Troll	8/3/2003	32	SW	103	675	Ketchikan	3060386
523213	40536	Troll	8/5/2003	32	SW	103	645	Craig	3070267
524508	40536	Troll	8/21/2003	34	SW	103	600	Craig	3070353
524516	40537	Troll	8/21/2003	34	SW	103	566	Craig	3070353
524067	40536	Troll	8/22/2003	34	SW	103	667	Craig	3070370
524528	40536	Troll	8/26/2003	35	SW	152	650	Craig	3070380
524536	40537	Troll	8/26/2003	35	SW	152	740	Craig	3070380
523465	40537	Troll	9/8/2003	37	SW	104	680	Craig	3070433
523384	40536	Troll	9/11/2003	37	SW	103	532	Craig	3070441
163365	40537	Troll	8/13/2003	33			618	Port Alexander	3080086
521874	40537	Troll	8/16/2003	33			666	Petersburg	3050760
524223	40536	Troll	8/20/2003	34			678	Craig	3070347
513991	40536	Purse	7/11/2003	28	SE	101	603	Ketchikan	3060240
526118	40536	Purse	8/15/2003	33	SE	101	570	Ketchikan	3060431
526158	40536	Purse	8/18/2003	34	SE	101	537	Ketchikan	3060458
526153	40537	Purse	8/18/2003	34	SE	101	668	Ketchikan	3060458
521759	40537	Purse	8/15/2003	33	SE	102	520	Petersburg	3050757
525157	40536	Purse	8/29/2003	35	SE	102	665	Ketchikan	3060486
525259	40537	Purse	9/1/2003	36	SE	102	696	Ketchikan	3060513
526110	40536	Purse	8/15/2003	33	SW	104	696	Ketchikan	3060428
526112	40537	Purse	8/15/2003	33	SW	104	727	Ketchikan	3060428
521926	40536	Purse	8/20/2003	34	SE	106	605	Petersburg	3050787
521909	40537	Purse	8/20/2003	34	SE	106	580	Petersburg	3050789
521929	40537	Purse	8/20/2003	34	SE	106	667	Petersburg	3050795
518990	40537	Purse	8/22/2003	34	SE	106	646	Petersburg	3050833
521460	40536	Purse	8/11/2003	33	NE	109	615	Petersburg	3050694
521457	40537	Purse	8/11/2003	33	NE	109	606	Petersburg	3050694
519564	40537	Purse	7/14/2003	29	NE	112	651	Excursion Inlet	3100028
525522	40537	Drift	8/27/2003	35	SE	101	555	Ketchikan	3060475
525535	40536	Drift	8/27/2003	35	SE	106	681	Ketchikan	3060476
525528	40537	Drift	8/27/2003	35	SE	106	632	Ketchikan	3060476
525527	40537	Drift	8/27/2003	35	SE	106	683	Ketchikan	3060476
518778	40536	Drift	8/28/2003	35	SE	106	611	Petersburg	3050862
518708	40537	Drift	8/29/2003	35	SE	106	644	Petersburg	3050871
518738	40536	Drift	9/1/2003	36	SE	106	742	Petersburg	3050875
518737	40537	Drift	9/1/2003	36	SE	106	633	Petersburg	3050875
518720	40537	Drift	9/1/2003	36	SE	106	709	Petersburg	3050875
525220	40537	Drift	9/2/2003	36	SE	106	685	Ketchikan	3060507
521820	40536	Drift	9/3/2003	36	SE	106	659	Petersburg	3050896
521819	40537	Drift	9/3/2003	36	SE	106	635	Petersburg	3050895
518520	40537	Drift	9/4/2003	36	SE	106	644	Petersburg	3050915
518672	40536	Drift	9/8/2003	37	SE	106	702	Petersburg	3050927
518312	40289[a]	Drift	9/10/2003	37	SE	106	710	Petersburg	3050935
518307	40537	Drift	9/10/2003	37	SE	106	689	Petersburg	3050934
518152	40536	Drift	9/11/2003	37	SE	106	675	Petersburg	3050954
518190	40536	Drift	9/11/2003	37	SE	106	718	Petersburg	3050965
518569	40537	Drift	9/11/2003	37	SE	106	685	Petersburg	3050974
518193	40537	Drift	9/11/2003	37	SE	106	693	Petersburg	3050965
518279	40536	Drift	9/15/2003	38	SE	106	691	Petersburg	3050977

-continued-

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Head number	Tag code	Gear	Recovery date	Stat. week	Quad.	Dist.	Length	Port survey site	Sample number
518272	40537	Drift	9/15/2003	38	SE	106	696	Petersburg	3050977
518244	40537	Drift	9/15/2003	38	SE	106	699	Petersburg	3050977
78631	40537	Drift	9/15/2003	38	SE	101[b]	653	Metlakatla	3090274
78700	40537	Drift	9/23/2003	39	SE	101[b]	687	Metlakatla	3090307
534481	40536	Drift	9/23/2003	39	SE		702	Petersburg	3051027
241938	40537	Recreational	7/25/2003	30	SE	101	650	Ketchikan	3065240
241641	40537	Recreational	8/2/2003	31	SE	102	560	Ketchikan	3065248
241659	40536	Recreational	8/13/2003	33	SE	101	620	Ketchikan	3065285
241680	40537	Recreational	8/31/2003	36	SE	101	650	Ketchikan	3065300
241951	40536	Recreational	9/1/2003	36	SE	101	575	Ketchikan	3065320
242499	40536	Recreational	6/24/2003	26	NW	113	600	Sitka	3035228
234645	40536	Escapement	10/9/2003	41	SE	101	655	Cripple Creek	3938007
234632	40537	Escapement	8/20/2003	34	SE	101	465	Eulachon River	3932006
147642	40536	Escapement	9/18/2003	38	SE	101	470	Lake Creek	3934021
147640	40537	Escapement	9/18/2003	38	SE	101	490	Lake Creek	3934021
234643	40537	Escapement	9/22/2003	39	SE	101	440	Lake Creek	3934023
147643	40536	Escapement	9/23/2003	39	SE	101	630	Lake Creek	3934024
234644	40537	Escapement	10/5/2003	41	SE	101	660	Lake Creek	3934029
78495	40536	Escapement	8/7/2003	32	SE	101	510	Unuk River	3930053
78497	40536	Escapement	8/8/2003	32	SE	101	420	Unuk River	3930054
78496	40536	Escapement	8/8/2003	32	SE	101	540	Unuk River	3930054
78498	40536	Escapement	8/10/2003	33	SE	101	470	Unuk River	3930056
78499	40537	Escapement	8/15/2003	33	SE	101	400	Unuk River	3930061
147634	40536	Escapement	8/20/2003	34	SE	101	435	Unuk River	3930065
234639	40537	Escapement	8/23/2003	34	SE	101	555	Unuk River	3930067
147620	40536	Escapement	8/24/2003	35	SE	101	485	Unuk River	3930068
147633	40537	Escapement	8/26/2003	35	SE	101	535	Unuk River	3930098
234640	40537	Escapement	8/25/2003	35	SE	101	470	Unuk River	3930069
234641	40537	Escapement	8/27/2003	35	SE	101	545	Unuk River	3930071
234642	40537	Escapement	8/27/2003	35	SE	101	545	Unuk River	3930071
234652	40537	Escapement	9/1/2003	36	SE	101	570	Unuk River	3930075
234653	40536	Escapement	9/5/2003	36	SE	101	520	Unuk River	3930077
234654	40537	Escapement	9/7/2003	37	SE	101	565	Unuk River	3930079
234655	40537	Escapement	9/8/2003	37	SE	101	515	Unuk River	3930080
234656	40537	Escapement	9/9/2003	37	SE	101	585	Unuk River	3930081
234657	40536	Escapement	9/12/2003	37	SE	101	560	Unuk River	3930083
234658	40537	Escapement	9/13/2003	37	SE	101	515	Unuk River	3930084
234659	40537	Escapement	9/16/2003	38	SE	101	545	Unuk River	3930086
234661	40537	Escapement	9/18/2003	38	SE	101	645	Unuk River	3930088
234660	40537	Escapement	9/18/2003	38	SE	101	695	Unuk River	3930088
234662	40536	Escapement	9/19/2003	38	SE	101	630	Unuk River	3930089
234663	40537	Escapement	9/19/2003	38	SE	101	575	Unuk River	3930089
234664	40537	Escapement	9/23/2003	39	SE	101	545	Unuk River	3930093
223901	40536	Escapement	10/4/2003	40	SE	101	670	Unuk River	3930097

[a] Tag code 40289 from spring 2001 not included in marine harvest or smolt abundance estimations.
[b] District 101-28, M-I-C.

Appendix B3.–Fates and locations (km) of coho salmon fitted with radio transmitters as located during four aerial surveys or during spawning grounds sampling of the Unuk River, 2003.

	Transmitter			LOCATION BY TRACKING FLIGHT				Assumed
Date	Size	Frequency	Spawning grounds	16-Aug-03	15-Sep-03	30-Sep-03	6-Nov-03	Fate
22-Aug	F1845	151.013			not found	not found	not found	Lost
26-Aug	F1845	151.033			km11	km23		Spawned
8-Aug	F1845	151.044		km11	BL-km37	BL		Spawned
20-Aug	F1845	151.054	Lake Creek, 9/8		L5	L5		Spawned
25-Aug	F1845	151.063			E3 Fork	E3		Spawned
9-Aug	F1840	151.073		km3	Arthur Sl.	JS2	km2	Mortality
5-Aug	F1840	151.085	Lake Creek, 9/16	km11	L5	L5		Spawned
11-Aug	F1840	151.094		JS2	E2	km2	km2	Spawned
13-Aug	F1840	151.102		C2	C2	km6		Spawned
22-Aug	F1840	151.114			km35	km32		Spawned
12-Aug	F1840	151.124		km19	L2	L2		Spawned
7-Aug	F1840	151.134		E3	E5 Fork	E5 (S)		Spawned
2-Aug	F1840	151.144		km18	G2	G1		Spawned
19-Aug	F1840	151.153			km32	not found	not found	Spawned
14-Aug	F1840	151.165		km3	K2	not found	not found	Spawned
10-Aug	F1840	151.173		km13	km11	km37		Spawned
24-Aug	F1840	151.183			not found	not found	not found	Lost
8-Aug	F1840	151.193		E5	E6	E6		Spawned
5-Sep	F1845	151.204			not found	not found	km2	Mortality
7-Sep	F1845	151.223			km14	km32		Spawned
22-Aug	F1845	151.232			BL2	BL2		Spawned
1-Sep	F1845	151.244	SN1-8 Sept		km37	km37		Spawned
24-Sep	F1845	151.252				JS2	km3	Spawned
26-Aug	F1845	151.263			km11	not found	not found	Spawned
26-Aug	F1845	151.275			km34	km39		Spawned
12-Sep	F1845	151.284			km0	not found	not found	Lost
4-Sep	F1845	151.294			km21	km23		Spawned
18-Sep	F1845	151.302				E6		Spawned
23-Sep	F1845	151.314				C2		Spawned
29-Aug	F1845	151.323			km8	km21	km21	Spawned
13-Sep	F1845	151.344			E2	E3		Spawned
6-Sep	F1845	151.353			E3 Fork	E5 (S)		Spawned
30-Aug	F1845	151.382			not found	not found	not found	Lost
31-Aug	F1845	151.404			km0	not found	not found	Lost
23-Aug	F1845	151.414			km39	km19		Spawned
4-Oct	F1845	151.424					km29	Spawned
15-Sep	F1845	151.435				km27		Spawned
22-Sep	F1845	151.443				km3	E5	Spawned
21-Sep	F1845	151.469				not found	not found	Lost
29-Aug	F1845	151.474			not found	not found	not found	Lost
8-Sep	F1845	151.482	SN1-9 Sept		not found	not found	not found	Lost
19-Sep	F1845	151.492				km13	BL	Spawned
30-Sep	F1845	151.525					CR2	Spawned
16-Sep	F1845	151.535				km21	km19	Spawned
24-Aug	F1845	151.553	BL-6 Oct		km29	E2		Spawned
27-Aug	F1845	151.563			km0	km0	km1	Mortality
19-Sep	F1845	151.572				E6		Spawned
28-Sep	F1845	151.583				km39		Spawned
20-Sep	F1845	151.593				km19	km31	Spawned
10-Sep	F1845	151.602			km8	G2		Spawned
23-Sep	F1845	151.624				not found	Chickamin R	Chickamin River

K=Kerr Ck, E=Eulachon R., CR=Cripple Ck, BL=Boundary Lk, L=Lake Ck, G=Genes Lake, C=Clear Ck, JS=Johnson Slough.

Appendix B4.–Sulking time of adult coho salmon tagged at SN1 on the Unuk River, 2003.

					Sulk time		
Spaghetti tag #	Date released	Time released	Date recaptured	Time recaptured	Days	Hours	Minutes
4013	3-Aug	1216	8-Aug	1845	5	6	29
4037	6-Aug	1305	9-Aug	1313	3	0	8
4054	6-Aug	1800	22-Aug	1140	15	17	40
4213	13-Aug	1107	13-Aug	1230	0	1	23
4233	14-Aug	1110	19-Aug	1815	5	7	5
4250	15-Aug	1400	24-Aug	1147	8	21	47
4261	19-Aug	1125	1-Sep	1425	13	3	0
4270	19-Aug	1413	24-Aug	1000	4	19	47
4301	20-Aug	1240	22-Aug	1040	1	22	0
4337	22-Aug	1350	26-Aug	1306	3	23	16
4355	22-Aug	1728	22-Aug	1740	0	0	12
4355	22-Aug	1740	29-Aug	1700	6	23	20
4367	23-Aug	1120	23-Aug	1140	0	0	20
4401	23-Aug	1630	6-Sep	1140	13	19	10
4409	23-Aug	1810	5-Sep	1706	12	22	56
4418	24-Aug	0955	24-Aug	1006	0	0	11
4419	24-Aug	1005	31-Aug	1445	7	4	40
4421	24-Aug	1035	29-Aug	1121	5	0	46
4422	24-Aug	1045	24-Aug	1122	0	0	37
4426	24-Aug	1145	24-Aug	1325	0	1	40
4453	24-Aug	1622	23-Sep	1039	29	18	17
4466	25-Aug	1450	1-Sep	1605	7	1	15
4473	25-Aug	1549	27-Aug	1730	2	1	41
4502	25-Aug	1841	27-Aug	1310	1	18	29
4502	27-Aug	1310	4-Sep	1419	8	1	9
4528	26-Aug	1613	8-Sep	1621	13	0	8
4530	26-Aug	1618	30-Aug	1111	3	18	53
4583	27-Aug	1740	6-Sep	1615	9	22	35
4588	27-Aug	1800	1-Sep	1630	4	22	30
4664	1-Sep	1130	13-Sep	1530	12	4	0
4682	1-Sep	1530	9-Sep	1533	8	0	3
4688	1-Sep	1715	20-Sep	1310	18	19	55
4711	4-Sep	1319	12-Sep	1523	8	2	4
4795	8-Sep	1709	9-Sep	1532	0	22	23
4799	9-Sep	0957	10-Sep	1633	1	6	36
4829	9-Sep	1723	12-Sep	1733	3	0	10
4842	10-Sep	1533	15-Sep	1210	4	20	37
4843	10-Sep	1630	19-Sep	1605	8	23	35
4850	12-Sep	1228	19-Sep	1531	7	3	3
4901	13-Sep	1701	16-Sep	1600	2	22	59
4933	15-Sep	1730	20-Sep	1600	4	22	30
4939	16-Sep	1505	16-Sep	1715	0	2	10
14258	19-Sep	0920	4-Oct	1552	15	6	32
14284	19-Sep	1351	19-Sep	1416	0	0	25
14299	19-Sep	1622	21-Sep	1330	1	21	8
14322	20-Sep	1630	22-Sep	1332	1	21	2

Average sulking time equals 6 days, 6 hours, and 42 minutes.

Minimum sulking time equals 11 minutes.

Maximum sulking time equals 29 days, 18 hours, and 17 minutes.

Appendix B5.–Estimated age and sex composition of adult coho salmon sampled during the two-event mark-recapture experiment on the Unuk River, 2003.

		AGE				
		0.1	1.1	2.0	2.1	Total [a]
AGE COMPOSITION OF ADULT COHO SALMON						
PANEL A: EVENT 2-SAMPLING FOR MARKS						
TOTAL						
Female	n		186		24	210
	%		33.2		4.3	37.5
	SE of %		2.0		0.9	2.0
	Escapement		8,946		1,154	10,100
	SE of Esc.		2,219		357	2,494
	Avg. Length		621		634	617
	SE Length		4.48		9.38	2.22
Male	n	3	309	1	37	350
	%	0.5	55.2	0.2	6.6	62.5
	SE of %	0.3	2.1	0.2	1.1	2.0
	Escapement	144	14,862	48	1,780	16,833
	SE of Esc.	88	3,626	48	509	4,094
	Avg. Length	550	559	360	593	558
	SE Length	58.95	4.53		15.72	2.46
Total	n	3	495	1	61	560
	%	0.5	88.4	0.2	10.9	100.0
	SE of %	0.3	1.4	0.2	1.3	
	Escapement	144	23,807	48	2,934	26,934
	SE of Esc.	88	5,752	48	787	6,495
	Avg. Length	550	582	360	609	580
	SE Length	58.95	3.56		10.48	1.84
					Unique fish sampled	667
EULACHON RIVER						
Female	n		32		1	33
	%		29.1		0.9	30.0
	SE of %		4.4		0.9	4.4
	Avg. Length		584		615	570
	SE Length		11.88			11.93
Male	n	1	75		1	77
	%	0.9	68.2		0.9	70.0
	SE of %	0.9	4.5		0.9	4.4
	Avg. Length	435	527		455	524
	SE Length		7.02			7.01
Total	n	1	107		2	110
	%	0.9	97.3		1.8	100.0
	SE of %	0.9	1.6		1.3	
	Avg. Length		544		535	539
	SE Length		6.55		80.00	6.40
					Unique fish sampled	140

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		AGE				
		0.1	1.1	2.0	2.1	Total [a]
		LAKE CREEK				
Female	n		89		15	104
	%		37.1		6.3	43.3
	SE of %		3.1		1.6	3.2
	Avg. Length		626		628	623
	SE Length		6.74		10.72	6.15
Male	n	1	112	1	22	136
	%	0.4	46.7	0.4	9.2	56.7
	SE of %	0.4	3.2	0.4	1.9	3.2
	Avg. Length	585	558	360	592	559
	SE Length		8.35		23.41	7.93
Total	n	1	201	1	37	240
	%	0.4	83.8	0.4	15.4	100.0
	SE of %	0.4	2.4	0.4	2.3	
	Avg. Length		588		607	586
	SE Length		6.02		14.72	5.60
					Unique fish sampled	283
		BOUNDARY CREEK				
Female	n		26		3	29
	%		25.5		2.9	28.4
	SE of %		4.3		1.7	4.5
	Avg. Length		620		668	628
	SE Length		9.27		14.81	9.10
Male	n	1	64		8	73
	%	1.0	62.7		7.8	71.6
	SE of %	1.0	4.8		2.7	4.5
	Avg. Length	630	578		614	581
	SE Length		9.92		27.34	9.53
Total	n	1	90		11	102
	%	1.0	88.2		10.8	100.0
	SE of %	1.0	3.2		3.1	
	Avg. Length		588		629	593
	SE Length		8.12		21.22	7.61
					Unique fish sampled	118

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		AGE				
		0.1	1.1	2.0	2.1	Total [a]
			GENE'S LAKE CREEK			
Female	n		13		1	14
	%		39.4		3.0	42.4
	SE of %		8.6		3.0	8.7
	Avg. Length		629		685	631
	SE Length		13.44			0.00
Male	n		16		3	19
	%		48.5		9.1	57.6
	SE of %		8.8		5.1	8.7
	Avg. Length		585		575	575
	SE Length		12.37		18.93	12.01
Total	n		29		4	33
	%		87.9		12.1	100.0
	SE of %		5.8		5.8	
	Avg. Length		605		603	599
	SE Length		9.85		30.58	9.87
					Unique fish sampled	37
			CRIPPLE CREEK			
Female	n		12		1	13
	%		40.0		3.3	43.3
	SE of %		9.1		3.3	9.2
	Avg. Length		643		555	634
	SE Length		11.70			12.43
Male	n		16		1	17
	%		53.3		3.3	56.7
	SE of %		9.3		3.3	9.2
	Avg. Length		573		670	573
	SE Length		16.16			16.87
Total	n		28		2	30
	%		93.3		6.7	100.0
	SE of %		4.6		4.6	
	Avg. Length		603		613	601
	SE Length		12.33		57.50	12.08
					Unique fish sampled	35

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		AGE				
		0.1	1.1	2.0	2.1	Total [a]
			HELL ROARING CREEK			
Female	n		13		1	14
	%		39.4		3.0	42.4
	SE of %		8.6		3.0	8.7
	Avg. Length		643		585	638
	SE Length		13.02			11.98
Male	n		19			19
	%		57.6			57.6
	SE of %		8.7			8.7
	Avg. Length		606			584
	SE Length		14.58			19.08
Total	n		32		1	33
	%		97.0		3.0	100.0
	SE of %		3.0		3.0	
	Avg. Length		621		585	606
	SE Length		10.50			13.00
					Unique fish sampled	40
			CLEAR CREEK			
Female	n		1		2	3
	%		8.3		16.7	25.0
	SE of %		8.3		11.2	13.1
	Avg. Length		700		680	686
	SE Length				40.50	24.36
Male	n		7		2	9
	%		58.3		16.7	75.0
	SE of %		14.9		11.2	13.1
	Avg. Length		551		575	541
	SE Length		36.44		30.00	28.20
Total	n		8		4	12
	%		66.7		33.3	100.0
	SE of %		14.2		14.2	
	Avg. Length		570		625	572
	SE Length		36.62		36.34	28.27
					Unique fish sampled	14

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		AGE				
		0.1	1.1	2.0	2.1	Total [a]
PANEL B: EVENT 1-MARKING IN THE LOWER RIVER						
SN1						
Female	n		437		34	471
	%		41.0		3.2	44.2
	SE of %		1.5		0.5	1.5
	Avg. Length		564		605	565
	SE Length		3.47		12.07	3.39
Male	n		557		37	594
	%		52.3		3.5	55.8
	SE of %		1.5		0.6	1.5
	Avg. Length		535		561	536
	SE Length		3.01		15.69	2.92
Total	n		994		71	1,065
	%		93.3		6.7	100.0
	SE of %		0.8		0.8	
	Avg. Length		548		582	549
	SE Length		2.32		10.29	2.25
					Unique fish sampled	1,268
PANEL C: ALL SAMPLES COMBINED						
Female	n		623		58	681
	%		38.3		3.6	41.9
	SE of %		1.2		0.5	1.2
	Avg. Length		581		617	581
	SE Length		2.97		8.22	2.61
Male	n	3	866	1	74	944
	%	0.2	53.3	0.1	4.6	58.1
	SE of %	0.1	1.2	0.1	0.5	1.2
	Avg. Length	550	544	360	577	544
	SE Length	58.95	2.55		11.19	2.28
Total	n	3	1,489	1	132	1,625
	%	0.2	91.6	0.1	8.1	100.0
	SE of %	0.1	0.7	0.1	0.7	
	Avg. Length	550	559	360	595	560
	SE Length	58.95	1.99		7.42	1.77
					Unique fish sampled	1,935

[a] Length totals include fish sampled with known gender and location but without corresponding age data due to regenerated, inverted, or illegible scales. By location: SN1 (89F, 114M), Eulachon (12F, 18M), Lake (17F, 26M), Boundary (3F, 13M), Genes (2F, 2M), Cripple (3F, 2M), Hell Roaring (2F, 5M), and Clear (2M) where F=female and M=Male

Appendix B6.–Estimated mean date of migration of populations comprising the Unuk River stock of coho salmon past SN1 from 1998-2003 (Panel A) with the associated statistics of standard deviation (Panel B), skewness (Panel C), kurtosis (Panel D), and sample size (Panel E).

PANEL A: ESTIMATED MEAN DAY OF MIGRATION

		Tributary										
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Mainstem Unuk River	Cripple Creek	Grizzly Slough	Hell Roaring Creek	Boundary Creek	Tributaries combined
2003	31-Aug	13-Sep	17-Sep	2-Sep		31-Aug		23-Sep			6-Sep	5-Sep
2002	4-Sep	9-Sep		5-Sep	9-Sep	4-Sep		3-Sep			8-Sep	8-Sep
2001	1-Sep	26-Aug		26-Aug		26-Aug	8-Sep	20-Aug	4-Sep		28-Aug	26-Aug
2000	5-Sep	3-Sep		9-Sep						29-Aug	19-Sep	9-Sep
1999	5-Sep	1-Sep		8-Sep	3-Oct	2-Sep						8-Sep
1998	3-Sep	25-Sep	9-Sep	28-Aug	11-Sep		13-Sep					13-Sep
98-03 Mean	3-Sep	8-Sep	13-Sep	3-Sep	17-Sep	31-Aug	11-Sep	5-Sep	4-Sep	29-Aug	8-Sep	6-Sep

PANEL B: STANDARD DEVIATION (in days)

		Tributary										
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Mainstem Unuk River	Cripple Creek	Grizzly Slough	Hell Roaring Creek	Boundary Creek	Tributaries combined
2003	16			18							15	16
2002	14	7		11	3						12	9
2001	13	12		11		11		3			11	11
2000	11			11						2	7	11
1999	12	9		21								17
1998	16	2		16	3		5					11

PANEL C: SKEWNESS ESTIMATION

		Tributary										
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Mainstem Unuk River	Cripple Creek	Grizzly Slough	Hell Roaring Creek	Boundary Creek	Tributaries combined
2003	0.16			0.03							-0.67	-0.38
2002	-0.42	1.16		-0.40	0.01						-0.67	-0.07
2001	-0.20	-0.58		-0.63		-0.51		-0.64			0.62	-0.25
2000	0.67			0.28							-0.58	0.36
1999	0.58	-0.43		-0.18								0.17
1998	0.20	0.32		0.10	-0.51		0.10					-1.25

PANEL D: KURTOSIS ESTIMATION[a]

		Tributary										
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Mainstem Unuk River	Cripple Creek	Grizzly Slough	Hell Roaring Creek	Boundary Creek	Tributaries combined
2003	1.95			1.77							2.15	2.04
2002	2.48	3.84		2.06	1.00						2.39	3.20
2001	2.27	2.18		2.18		1.51		1.50			1.60	2.11
2000	3.36			1.29						1.00	1.51	1.42
1999	2.92	1.51		1.51								2.00
1998	2.29	2.02		1.50	1.50		1.75					5.47

PANEL E: NUMBER OF FISH MARKED AT SN1 AND RECAPTURED ON TRIBUTARIES

		Tributary										
Year	SN1	Eulachon River	Clear Creek	Lake Creek	Kerr Creek	Genes Lake Creek	Mainstem Unuk River	Cripple Creek	Grizzly Slough	Hell Roaring Creek	Boundary Creek	Tributaries combined
2003	1,222	1	1	12		1		1			6	22
2002	1,746	9		4	2	1		1			6	23
2001	1,602	6		6		3	1	3	1		5	25
2000	457	1		5						2	3	11
1999	915	3		3	1	1						8
1998	742	4	1	3	3		7					18

[a]Normal distributions have a kurtosis of 3.00.

Appendix B7.–Estimated harvests of the Unuk River stock of coho salmon in marine commercial and recreational fisheries by statistical week, 2003.

Stat Week	Week Begins	Troll NW	Troll NE	Troll SW	Troll SE	Troll Total	Gillnet SE	Seine SE	Seine SW	Seine NE	Seine Total	Recreational SE	Recreational NW	Recreational Total	Estimated weekly proportion by gear type: Troll	Gillnet	Seine	Sport	Total	Estimated cumulative harvest	Estimated cumulative proportion of harvest
26	23-Jun												158	158	0.00	0.00	0.00	0.16	0.01	158	0.01
27	29-Jun														0.00	0.00	0.00	0.00	0.00		0.01
28	6-Jul		149	98		247		229			229				0.03	0.00	0.03	0.00	0.02	476	0.03
29	13-Jul		149			149				474	474				0.02	0.00	0.07	0.00	0.03	1,099	0.06
30	20-Jul	339	149			488						162		162	0.05	0.00	0.00	0.17	0.03	1,749	0.09
31	27-Jul	508			155	663						162		162	0.07	0.00	0.00	0.17	0.04	2,574	0.12
32	3-Aug		298	197	310	804									0.08	0.00	0.00	0.00	0.04	3,378	0.16
33	10-Aug	339	149		310	797		2,501	643	399	3,543	132		132	0.08	0.00	0.51	0.14	0.20	7,850	0.36
34	17-Aug	493	443	205	169	1,309		2,005			2,005				0.14	0.00	0.29	0.00	0.15	11,164	0.52
35	24-Aug	821	148	137	724	1,828	2,070	550			550				0.19	0.47	0.08	0.00	0.20	15,612	0.72
36	31-Aug	657				657	694	188			188	362		362	0.07	0.16	0.03	0.37	0.09	17,513	0.80
37	7-Sep	493		137	846	1,475	658								0.15	0.15	0.00	0.00	0.10	19,646	0.90
38	14-Sep	328			507	836	581								0.09	0.13	0.00	0.00	0.06	21,063	0.97
39	21-Sep	164				164	419								0.02	0.09	0.00	0.00	0.03	21,646	0.99
40	28-Sep				169	169									0.02	0.00		0.00	0.01	21,815	1.00
Total		4,141	1,483	773	3,189	9,586	4,422	5,473	643	873	6,989	818	158	976	1.00	1.00	1.00	1.00	1.00		
Estimated mean date of harvest =		19-Aug	1-Aug	11-Aug	25-Aug	18-Aug	30-Aug	11-Aug	8-Aug	22-Jul	8-Aug	10-Aug	20-Jun	2-Aug					16-Aug		

Statistical week estimates for the troll and recreational fisheries were approximated by weighting catch by period or fortnight by the number of tags recovered in a statistical week.

Appendix B8.–Estimates of mean date of harvest, harvest, and percentage contribution in marine fisheries by statistical week for coho salmon bound for the Unuk River, 1998–2003.

Statistical week estimates for the troll and recreational fisheries were approximated by weighting catch by period or fortnight by the number of tags recovered in a statistical week.

PANEL A: TROLL[a]							
	Northwest Quadrant						
Statistical Week	1998	1999[b]	2000[c]	2001	2002	2003	Average 1998-2003
26							
27				1,668	181		308
28	2,896	1,037	658	1,026			936
29	724	1,186		1,411	91		568
30	2,534	1,037	987	1,026	272	335	1,032
31	2,896	1,186	658	770	91	503	1,017
32	2,172	1,334	987	257	272		837
33	362	1,334	562	187		335	463
34				469	221	487	196
35	2,430	2,440	240	281	442	812	1,107
36	810	861	240	1,031	662	649	709
37	1,620	861		187	552	487	618
38	810			281	221	325	273
39		287	127	94		162	112
40					110		18
41							
Total Unuk harvest	17,252	11,563	4,459	8,688	3,113	4,095	8,195
Total harvest	1,076,843	1,481,444	813,755	1,260,898	802,569	699,808	1,022,553
% Unuk	1.6	0.8	0.5	0.7	0.4	0.6	0.8
Mean harvest date	2-Aug	5-Aug	26-Jul	27-Jul	21-Aug	21-Aug	
	Northeast Quadrant						
Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27				146			24
28		216	426			147	131
29		108		437		147	115
30	409	216	426		260	147	243
31		323		146	174		107
32	819	108		146		294	228
33	588	323	282	95	94	147	255
34				95	187	438	120
35				95		146	40
36		105			94		33
37							
38							
39							
40							
41							
Total Unuk harvest	1,816	1,398	1,134	1,160	808	1,467	1,197
Total harvest	167,754	306,586	95,421	218,221	184,901	131,894	184,130
% Unuk	1.1	0.5	1.2	0.5	0.4	1.1	0.7
Mean harvest date	1-Aug	26-Jul	15-Jul	26-Jul	5-Aug	3-Aug	

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Statistical Week	Southwest Quadrant 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27		96		56			25
28	247	192		338	46	97	153
29	247	576	243	113			197
30	741	96	243	338			236
31	247	192		282	46		128
32	494	192	365	507	324	195	346
33	247	96	243	283			145
34			122	340	43	203	118
35	346			57	86	135	104
36		94			300		66
37						135	23
38							
39							
40							
41							
Total Unuk harvest	2,570	1,533	1,217	2,314	845	765	1,541
Total harvest	208,530	259,947	131,671	235,096	140,121	194,291	194,943
% Unuk	1.2	0.6	0.9	1.0	0.6	0.4	0.8
Mean harvest date	27-Jul	18-Jul	25-Jul	30-Jul	14-Aug	13-Aug	

Statistical Week	Southeast Quadrant 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28		70	270				57
29		70		71			23
30	713	209		71	80		179
31	178	348	539	71	160	153	242
32	1,426			214	561	306	418
33		278	280	223	66	306	192
34	361		140	298	329	167	216
35	541	508		149	527	669	399
36		610	419	149	263		240
37	361	610	280	595	263	836	491
38	722	610		298	263	502	399
39					66		11
40		203				167	62
41							
Total Unuk harvest	4,303	3,514	1,927	2,139	2,578	3,108	2,928
Total harvest	182,092	212,405	83,139	126,249	181,058	191,593	162,756
% Unuk	2.4	1.%	2.3	1.%	1.4	1.6	1.8
Mean harvest date	14-Aug	23-Aug	6-Aug	25-Aug	21-Aug	27-Aug	

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Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
	TROLL QUADRANTS COMBINED						
26							
27		96		1,870	181		358
28	3,143	1,514	1,354	1,364	46	245	1,278
29	971	1,938	243	2,032	91	147	904
30	4,398	1,557	1,657	1,435	612	482	1,690
31	3,321	2,048	1,198	1,269	471	656	1,494
32	4,911	1,633	1,352	1,124	1,157	795	1,829
33	1,197	2,031	1,367	788	159	789	1,055
34	361		261	1,202	780	1,295	650
35	3,317	2,948	240	582	1,054	1,762	1,650
36	810	1,670	659	1,180	1,319	649	1,048
37	1,981	1,471	280	782	815	1,459	1,131
38	1,532	610		579	484	827	672
39		287	127	94	66	162	123
40		203			110	167	80
41							
Total Unuk harvest	25,941	18,008	8,737	14,301	7,344	9,435	13,961
Total harvest	1,635,219	2,260,382	1,123,986	1,840,464	1,308,649	1,217,586	1,564,381
% Unuk	1.6	0.8	0.8	0.8	0.6	0.8	0.9
Mean harvest date	3-Aug	6-Aug	28-Jul	1-Aug	18-Aug	20-Aug	

PANEL B: DRIFT GILLNET

Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
	District 101[d]						
26							
27							
28							
29		123					21
30							
31				87	83		28
32							
33					69		12
34	406	195		135			123
35				314		210	87
36	2,205	317		63			431
37		133		353			81
38	412	186		367			161
39	304	96					67
40		139					23
41							
Total Unuk harvest	3,327	1,189		1,319	152	210	1,033
Total harvest	60,265	64,526	18,209	35,504	35,516	63,619	46,273
% Unuk	5.5	1.8		3.7	0.4	0.3	2.2
Mean harvest date	31-Aug	29-Aug		2-Sep	3-Aug	24-Aug	

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Statistical Week	District 101 MIC 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31							
32							
33				61			10
34							
35	268			86			59
36							
37		53			1,098		192
38						229	38
39		200	144			414	126
40							
41		62					10
Total Unuk harvest	268	315	144	147	1,098	643	436
Total harvest	29,012	42,662	14,173	43,642	55,071	33,059	36,270
% Unuk	0.9	0.7	1.0	0.3	2.0	2.0	1.2
Mean harvest date	23-Aug	19-Sep	17-Sep	20-Aug	8-Sep	18-Sep	

Statistical Week	District 106 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27		62					10
28		85					14
29		82		126			35
30							
31	264	199	182	136			130
32	278	73			147		83
33	487	196	515		124		220
34	1,262	198	182	463	136		374
35	549	107	281	208	91	1,838	512
36	291	444	1,006		443	686	478
37	567	817		765	620	651	570
38	328	954			229	345	309
39	575	531			411		253
40		180		196			63
41		67					11
Total Unuk harvest	4,601	3,995	2,166	1,894	2,201	3,520	3,063
Total harvest	273,197	203,262	96,207	188,465	226,560	212,057	199,958
% Unuk	1.7	2.0	2.3	1.0	1.0	1.7	1.5
Mean harvest date	23-Aug	31-Aug	16-Aug	28-Aug	4-Sep	30-Aug	

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Statistical Week	DRIFT GILLNET DISTRICTS COMBINED 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27		62					10
28		85					14
29		205		126			55
30							
31	264	199	182	223	83		159
32	278	73			147		83
33	487	196	515	61	193		242
34	1,668	393	182	598	136		496
35	817	107	281	608	91	2,048	659
36	2,496	761	1,006	63	443	686	909
37	567	1,003		1,118	1,718	651	843
38	740	1,140		367	229	574	508
39	879	827	144		411	414	446
40		319		196			86
41		129					22
Total Unuk harvest	8,196	5,499	2,310	3,360	3,451	4,373	4,532
Total harvest	362,474	310,450	128,589	267,611	317,147	308,735	282,501
% Unuk	2.3	1.8	1.8	1.3	1.1	1.4	1.6
Mean harvest date	27-Aug	31-Aug	25-Aug	31-Aug	3-Sep	1-Sep	

PANEL C: PURSE SEINE [c]

Statistical Week	District 101 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28						226	38
29							
30		254	288	301			141
31		153		813	115		180
32							
33		234				865	183
34		1,153		1,631	517	591	649
35		477			1,947		404
36							
37							
38							
39							
40							
41							
Total Unuk harvest		2,271	288	2,745	2,579	1,682	1,594
Total harvest	57,558	31,292	17,277	55,405	54,930	45,552	43,669
% Unuk		7.3	1.7	5.0	4.7	3.7	3.7
Mean harvest date		11-Aug	16-Jul	9-Aug	22-Aug	7-Aug	

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	District 102						
Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29				5,604			934
30							
31					396		66
32				884			147
33						1,609	268
34							
35						544	91
36					202	186	65
37							
38			204				34
39							
40							
41							
Total Unuk harvest			204	6,488	598	2,339	1,605
Total harvest	71,394	42,359	29,549	119,407	78,114	66,904	67,955
% Unuk			0.7	5.4	0.8	3.5	2.4
Mean harvest date			10-Sep	17-Jul	8-Aug	14-Aug	

	District 103						
Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31							
32							
33							
34				210			35
35				465			78
36							
37							
38							
39							
40							
41							
Total Unuk harvest				675			113
Total harvest	45,877	17,615	17,219	56,067	50,884	26,124	35,631
% Unuk				1.2			0.3
Mean harvest date				23-Aug			

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Statistical Week	District 104 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29	482						80
30			242				40
31	514			144			110
32		301		546	83		155
33	974		493	657		636	460
34		727					121
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest	1,970	1,028	735	1,347	83	636	967
Total harvest	102,671	68,448	72,056	134,203	15,719	74,120	77,870
% Unuk	1.9	1.5	1.0	1.0	0.5	0.9	1.2
Mean harvest date	29-Jul	10-Aug	30-Jul	7-Aug	4-Aug	13-Aug	

Statistical Week	District 105 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31							
32							
33				134			22
34							
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest				134			22
Total harvest	2,092	3,211	229	4,671	434	11,439	3,679
% Unuk				2.9			0.6
Mean harvest date				9-Aug			

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Statistical Week	District 106 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31							
32	444						74
33							
34			372			1,392	294
35		364		261			104
36	872						145
37				113			19
38							
39							
40							
41							
Total Unuk harvest	1,316	364	372	374		1,392	636
Total harvest	18,874	11,483	3,162	35,712	440	34,991	17,444
% Unuk	7.0	3.2	11.8	1.0		4.0	3.6
Mean harvest date	20-Aug	22-Aug	20-Aug	30-Aug		20-Aug	

Statistical Week	District 107 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31							
32							
33							
34				376			63
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest				376			63
Total harvest	3,030	8,968	3,625	20,189	6,175	22,805	10,799
% Unuk				1.9			0.6
Mean harvest date				19-Aug			

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Statistical Week	District 109 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29							
30							
31					237		40
32		267					45
33	553		346			395	216
34	761	245					168
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest	1,314	512	346		237	395	467
Total harvest	82,356	104,443	18,083	59,753	104,609	50,448	69,949
% Unuk	1.6	0.5	1.9		0.2	0.8	0.7
Mean harvest date	13-Aug	7-Aug	6-Aug		28-Jul	13-Aug	

Statistical Week	District 112 1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28							
29						469	78
30							
31							
32				45			8
33							
34							
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest				45		469	86
Total harvest	50,361	60,724	28,992	35,270	54,758	34,996	44,184
% Unuk				0.1		1.3%	0.2
Mean harvest date				5-Aug		16-Jul	

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	PURSE SEINE DISTRICTS COMBINED						
Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28						226	38
29	482			5,604		469	1,093
30		254	530	301			181
31	514	153		957	748		395
32	444	568		1,475	83		428
33	1,527	234	839	791		3,505	1,149
34	761	2,125	372	2,217	517	1,983	1,329
35		841		726	1,947	544	676
36	872				202	186	210
37				113			19
38			204				34
39							
40							
41							
Total Unuk harvest	4,600	4,175	1,945	12,184	3,497	6,913	5,552
Total harvest	434,213	348,543	190,192	520,677	366,063	367,379	371,178
% Unuk	1.1	1.2	1.0	2.3	1.0	1.9	1.5
Mean harvest date	8-Aug	11-Aug	5-Aug	29-Jul	17-Aug	10-Aug	

	PANEL D: RECREATIONAL						
	Sitka						
Statistical Week	1998	1999	2000	2001	2002	2003	Average 1998-2003
26		150				157	51
27		150		123			45
28							
29							
30							
31							
32	371	251					104
33	741	125		194			177
34			206	97	78		64
35		127	206				56
36							
37							
38							
39							
40							
41							
Total Unuk harvest	1,112	802	412	414	78	157	496
Total harvest	42,524	73,757	38,247	78,278	46,154	73,759	58,787
% Unuk	2.6	1.1	1.1	0.5	0.2	0.2	0.8
Mean harvest date	6-Aug	23-Jul	16-Aug	1-Aug	18-Aug	25-Jun	

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Statistical Week	Craig						
	1998	1999	2000	2001	2002	2003	Average 2000-2002
26							
27							
28							
29							
30				322			107
31				158			53
32			461				154
33				158			53
34							
35							
36							
37							
38							
39							
40							
41							
Total Unuk harvest	N/A	N/A	461	638		N/A	366
Total harvest	N/A	N/A	34,987	53,994	33,201	N/A	40,727
% Unuk			1.3	1.2			0.9
Mean harvest date			30-Jul	28-Jul			

Statistical Week	Ketchikan						
	1998	1999	2000	2001	2002	2003	Average 1998-2003
26							
27							
28					126		21
29				75			13
30		130		75		161	61
31						161	27
32	1,805	80		163	123		362
33				84		131	36
34	1,334	165		84			264
35		83		251	128		77
36		174		335	300	358	194
37	1,183	232		415	258		348
38	369	130		124			104
39					92		15
40					185		31
41							
Total Unuk harvest	4,691	994		1,605	1,211	810	1,552
Total harvest	24,059	20,719	38,247	26,693	33,889	38,499	30,351
% Unuk	19.5	4.8		6.0	3.6	2.1	5.1
Mean harvest date	18-Aug	21-Aug		25-Aug	29-Aug	12-Aug	

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Statistical Week	RECREATIONAL LOCATIONS COMBINED 1998	1999	2000	2001	2002	2003	Average 1998-2003
26		150				157	51
27		150		123			45
28					126		21
29				75			13
30		130		397		161	115
31				158		161	53
32	2,176	331	461	163	123		542
33	741	125		436		131	239
34	1,334	165	206	181	78		327
35		210	206	251	128		132
36		174		335	300	358	194
37	1,183	232		415	258		348
38	369	130		124			104
39					92		15
40					185		31
41							
Total Unuk harvest	5,803	1,796	873	2,657	1,289	967	2,231
Total harvest	66,583	94,476	111,481	158,965	113,244	112,258	109,501
% Unuk	8.7	1.9	0.8	1.7	1.1	0.9	2.0
Mean harvest date	15-Aug	8-Aug	7-Aug	15-Aug	29-Aug	4-Aug	

[a] Traditional troll harvest only.

[b] Unuk River harvest estimates for SE troll (weeks 35–40), NW troll (week 32), and SE recreational (weeks 37–38) revised from those previously published (Jones et al. 2001a).

[c] Unuk River harvest estimates for NW troll (weeks 28–32) revised from those previously published (Jones et al., 2001b).

[d] Traditional Tree Point fishery harvest only.

[e] Traditional purse seine harvest only.

Appendix B9.–Names of computer files containing data, statistics, and interim calculations concerning stock assessment of the Unuk River stock of coho salmon, 2002–2003.

File name	Description
03UNK43-R.XLS	Spreadsheet containing all the mark-recapture data, various pivot table results, Tables 1–7, Figures 5, 6, 8, and 9, Appendices A2–A6, harvest estimation calculations, abundance estimates, bootstrap results, Kolmogorov-Smirnov (K-S), various χ^2 hypothesis test results, and output from SPAS.EXE for the 2002 Unuk River coho salmon data.
SPAS1.EXE	Stratified Population Analysis (SPAS) program used to perform computer analysis of 2-sample mark-recovery data where each sample is from a geographically or temporally stratified population.
43Spas03.DAT	Data file containing the 2003 Unuk River coho salmon data for use in SPAS.exe.
43KSUNUK03_R.XLS	Kolmogorov-Smirnov (K-S) 2-sample tests, Figures 10 and 11.
43MVHarvest98-03.xls	Spreadsheet containing Appendix A7.