Fishery Data Series No. 24-13

Production of Chickamin River Chinook Salmon from the 2000–2005 Broods, Escapement from 2009–2012

by

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August 2024

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

The Alaska Department of Fish and Game, Division of Sport Fish implanted coded wire tags in juvenile Chinook Salmon *Oncorhynchus tshawytscha* from the Chickamin River from 2001 to 2007 (2000–2005 broods) as part of a production study. Adipose fins of coded-wire-tagged fish were excised during the first event of a 2-event mark–recapture study to estimate smolt abundance. Escapements from 2003 to 2012 were sampled annually for adipose clips, coded wire tags, and age/sex/length information in order to estimate the fraction of fish from each brood marked with adipose clips and tagged with coded wire tags. The fraction of fish marked with adipose clips was used to estimate smolt abundance, whereas the fraction of fish tagged with coded wire tags, in conjunction with catch sampling data and recoveries of coded wire tags in marine fisheries, was used to estimate marine harvest and exploitation. Estimated smolt abundance ranged from 170,013 (SE = 33,967) to 413,660 (SE = 74,026) and averaged 287,012. Estimated marine exploitation was estimated to be 3,243 (SE = 540), 3,112 (SE = 521), 2,810 (SE = 493), 1,874 (SE = 550), 983 (SE = 212), and 3,807 (SE = 939) from brood years 2000 to 2005, respectively.

Separate projects estimated spawner abundance from 2009 to 2012. The sum of annual peak survey counts of large (>660 mm METF) spawners on 8 index tributaries and an expansion factor of 4.75 (SE = 0.70) was used to estimate large spawner abundance. The abundance of small (<400 mm from mid eye to tail fork [METF]) and medium (≥400 and <660 mm METF) fish was estimated indirectly by expanding the estimates of large fish by the estimated size compositions. Size composition was estimated with age, sex, and length samples collected each year on the spawning grounds. Large spawning abundance was estimated to be 3,958 (SE = 591) in 2009, 7,080 (SE = 1,052) in 2010, 5,018 (SE = 761) in 2011, and 2,548 (SE = 384) in 2012. Total run was estimated in years where coded wire tag data for all major age classes were available. Estimates of the age ≥ 1.2 total run ranged from 6,690 (SE = 865) in 2009 to 10,741 (SE = 860) in 2006. The marine harvest rate of age ≥ 1.2 fish for the 2006–2009 run years averaged 33% (SE = 5%), which was significantly different than the Unuk River marine harvest rate for the same time period.

Keywords: coded wire tags, Chinook salmon, *Oncorhynchus tshawytscha*, Chickamin River, harvest, escapement, adipose clips, age, sex, length information, marked fraction, smolt abundance, standardized peak survey counts, expansion factor

INTRODUCTION

The Chickamin River originates in British Columbia, flows into the U.S. in the Misty Fjords National Monument Wilderness in southern Southeast Alaska (SEAK; Figure 1), and empties into upper East Behm Canal. The Chickamin River produces the second largest run of Chinook salmon *Oncorhynchus tshawytscha* in southern SEAK and is one of 4 Behm Canal index streams for the Chinook salmon escapement estimation program (Pahlke 1998). In response to depressed Chinook salmon stocks in many SEAK streams in the mid-1970s, a fisheries management program was implemented to rebuild stocks. Peak counts of large (≥660 mm from mid eye to tail fork [METF]) Chinook salmon serve as an index of abundance and have been collected annually by helicopter since 1975 using a standardized method (time and area; Kissner 1982). In SEAK, large Chinook salmon are generally fish that are saltwater age-3 or older. Aerial surveys cannot readily distinguish small and medium Chinook salmon (<660 mm METF) from other species of salmon, primarily chum salmon *O. keta* in southern SEAK. These index counts are used by the Alaska Department of Fish and Game (ADF&G) and the Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) to evaluate stock status and implement abundance-based management. Expansion factors for the peak counts obtained in 4 Behm Canal systems (Unuk, Chickamin, Blossom, and Keta Rivers) have been developed and provide drainagewide estimates of total escapement of large spawners. These drainagewide escapement estimates were used to establish a biological escapement goal for the Chickamin River stock, which is an expanded peak aerial survey count of 2,150 to 4,300 large spawners (McPherson and Carlile 1997; Heinl et al. 2017).

Peak counts of Chinook salmon in the Chickamin River have exhibited marked trends, ranging from lows of fewer than 450 Chinook salmon annually during the PSC base period (1975–1980) to highs of over 900 fish (with broad interannual fluctuations) during the 1980s, then a return to lower counts through the 1990s (Appendix A2). Peak counts increased again in 1999 and remained high through 2010. However, since 2011, peak counts have decreased averaging below 500 fish.

From 1981 to 1994, it was assumed that the sum of the peak counts on 8 index tributaries in the Chickamin River represented 62.5% of the total drainagewide escapement (Pahlke 1997, Figure 2). In order to validate the index, mark–recapture studies were performed to estimate the escapement of large Chinook salmon. In 1995 and 1996, estimated escapements of large Chinook salmon were 2,309 (SE = 723; Pahlke 1996) and 1,587 (SE = 199; Pahlke 1997). In addition, radio telemetry studies in 1996 showed that approximately 83% of all spawning occurred in the 8 index tributaries and that approximately 17% of all spawning occurred in small unnamed tributaries in the upper reaches of the drainage. No salmon were tracked into British Columbia (Pahlke 1997). Based on these 2 studies, a factor of 4.0 (Pahlke 1998) was developed to expand the peak aerial survey counts to a drainagewide estimate of total escapement of large fish.

As part of the State of Alaska's commitment to a coastwide rebuilding program, the ADF&G Division of Sport Fish obtained funding to conduct expanded research on the Chickamin River beginning in 2001 to estimate escapement and age, sex, and length composition of spawners. Funding for this program was approved by the PSC CTC using monies appropriated by the U.S. Congress to implement abundance-based management of Chinook salmon from Oregon to Alaska, as detailed in "The 1996 U.S. Letter of Agreement," as described in the 1999 Pacific Salmon Treaty Agreement.

The U.S. section of the PSC CTC (USCTC 1997) developed data standards for stock-specific assessments of escapement, terminal runs, and forecasts of total run. The standard for escapement was as follows:

> *Escapement. Annual age- and sex-specific estimates of total escapement should be available. Point estimates should be accompanied by variance estimates, and both should be based on annual sampling data. Factors used to expand the escapement from index areas (or counts of components of the escapement) should be initially verified a minimum of three times. Those expansion factors that have moderate to large amounts of inter-annual variability (a coefficient of variation of more than 20%) should be monitored annually.*

The PSC CTC concluded that the Chickamin River stock-assessment program needed improvements and recommended:

1) additional direct estimates of total escapement by sex and age, annually; and
2) continued evaluation of the expansion factor.

To meet PSC CTC data standards, ADF&G conducted a series of mark–recapture studies from 2001 to 2005. In 2001, the estimated escapement of large Chinook salmon was 5,177 (SE = 972), and the expansion factor for the peak aerial survey count was 5.13 (SE = 0.96; Freeman and McPherson 2003). The estimated escapements and expansion factors were 5,007 (SE = 738) and 4.94 (SE = 0.73) in 2002, 4,579 (SE = 592) and 4.75 (SE = 0.61) in 2003, 4,268 (SE = 893) and 5.35 (SE = 1.12) in 2004, and 4,257 (591) and 4.60 (SE = 0.64) in 2005 (Freeman and McPherson 2004, 2005; Freeman et al. 2007; Weller et al. 2007). A mean expansion factor of 4.75 (SE = 0.70) was estimated using data gathered in 1996 and from 2001 to 2005. The data from 1995 were not included in this estimate due to the small sample size and poor precision relative to the other estimates (Weller et al. 2007).

Juvenile Chinook salmon were injected with coded wire tags on the Chickamin River from 1983 to 1988 to estimate smolt abundance, adult migration routes, run timing, and contribution rates to commercial and recreational fisheries (Pahlke 1995). Overall harvest rates of Chickamin River Chinook salmon were estimated to range from 27% to 50%, although these estimates do not account for incidental fishing mortality. Smolt abundance in this study was estimated to range from 143,000 (SE = 69,000) to 320,000 (SE = 130,000).

Funding from the Alaska Sustainable Salmon Fund was used to re-implement a coded wire tagging program on juvenile Chinook salmon on the Chickamin River beginning in the fall of 2001 to better understand harvest, exploitation rate, marine survival, and smolt abundance, all of which are used as key tools for making informed management decisions. Tagging was continued each spring and fall through the spring of 2006. Funding from the PSC Northern Endowment Fund extended the coded wire tag project by 1 year, through spring of 2007. Recoveries in the various marine fisheries of Chinook salmon possessing coded wire tags germane to the Chickamin tagging program were used to estimate harvest and production of the Chickamin stock accordingly.

OBJECTIVES

Chinook salmon research on the Chickamin River had the following objectives:

1. Estimate the marine exploitation of Chickamin River Chinook salmon from the 2000–2005 brood years (via recovery of coded wire tagged smolt that emigrated in 2002–2007) such that the anticipated half-widths of the calculated 95% confidence intervals are 30% of the estimates. The estimates will be derived from tag recoveries in marine salmon fisheries and in the Chickamin River from 2003 through 2012.
2. Estimate the abundance of Chinook salmon smolt that emigrated from 2002 to 2007, such that the estimates are within 30% of the true value 90% of the time.
3. Estimate the age and sex composition of Chinook salmon spawning in the Chickamin River from 2009 to 2012 such that all estimated fractions are within ±5 percentage points of the true value 95% of the time.
4. Estimate the fraction of adults from each brood year that have adipose fin clips and possess coded wire tags and these fractions are used to estimate smolt abundance and harvest, respectively.
5. Estimate adult escapement in 2009, 2010, 2011, and 2012 by expanding the peak survey count such that the coefficient of variation of the expanded survey counts are <15%.

STUDY AREA

Field work occurred exclusively in the U.S. portions of the Chickamin River because no Chinook salmon spawning areas have ever been documented in Canada. Many of the Chickamin River's anadromous spawning tributaries flow clear; however, the mainstem is turbid from glacial influence, especially during summer. The lower river flows through a broad valley bordered by steep-sided mountains and is low gradient with braided channels that are relatively flat having fine sediments, exposed bars, and large bedrock-controlled pools. Moving upstream, the valley becomes more v-shaped, and the river is narrower having progressively coarser substrates, more bedrock, steeper gradient, and more logjams. Field crews were based out of the lower river and accessed upriver sampling locations using jet skiffs and helicopters.

METHODS

SPAWNING ABUNDANCE

Standardized, low-altitude helicopter and/or foot surveys have been used to count large Chinook salmon in index tributaries of the Chickamin River since 1975 (Pahlke 1998). The 8 index tributaries of the Chickamin River are South Fork, Barrier, Butler, Leduc, Indian, Humpy, Clear Falls, and King Creeks (Figure 2). In most years, multiple surveys were conducted on each tributary and the peak survey count was used as an index of the spawning abundance of large Chinook salmon. The sum of the 8 peak counts multiplied by the expansion factor (4.75) was used to estimate drainagewide spawning abundance of large Chinook from 2009 to 2012.

The abundance of small (<400 mm METF), $\hat{N}_S$, and medium (≥400 mm and <660 mm METF), $\hat{N}_M$, fish were estimated indirectly by expanding the estimated large fish abundance by the estimated spawning escapement size composition (McPherson et al. 1996):

$$\hat{N}_S = \hat{N}_L \frac{\hat{\phi}_S}{\hat{\phi}_L} \tag{1}$$

$$\hat{N}_M = \hat{N}_L \frac{\hat{\phi}_M}{\hat{\phi}_L} \tag{2}$$

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

$$\hat{\phi}_k = \frac{n_k}{n_{sp}} \tag{3}$$

where

n_{sp}	=	Number of fish sampled on the spawning grounds
n_k	=	Number of *k*-sized fish found in n_{sp},

with variance estimated as:

$$\text{var}(\hat{\phi}_k) = \frac{\hat{\phi}_k(1-\hat{\phi}_k)}{n_{sp}-1} \tag{4}$$

Repeated testing of spawning grounds samples collected from the Chickamin River in 1995–1996, 2001–2005 has found little evidence of size or gender selectivity (Pahlke 1996, 1997; Freeman and McPherson 2003–2005; Freeman et al. 2007; Weller et al. 2007). The variance of the abundance of small fish was estimated:

$$\text{var}(\hat{N}_S) = \hat{N}_L^{\,2}\,\text{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right) + \left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)^2 \text{var}(\hat{N}_L) - \text{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)\text{var}(\hat{N}_L) \tag{5}$$

where, by the delta method (Seber 1982, p. 8, noting that $Cov(\hat{\phi}_S, \hat{\phi}_L) = -\frac{\hat{\phi}_S \hat{\phi}_L}{n_{sp}}$),

$$\operatorname{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right) \approx \left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)^2 \left(\frac{\operatorname{var}(\hat{\phi}_S)}{\hat{\phi}_S^2} + \frac{\operatorname{var}(\hat{\phi}_L)}{\hat{\phi}_L^2} + \frac{2}{n_{sp}}\right) \tag{6}$$

Similarly,

$$\operatorname{var}(\hat{N}_M) = \hat{N}_L^{\ 2} \operatorname{var}\left(\frac{\hat{\phi}_M}{\hat{\phi}_L}\right) + \left(\frac{\hat{\phi}_M}{\hat{\phi}_L}\right)^2 \operatorname{var}(\hat{N}_L) - \operatorname{var}\left(\frac{\hat{\phi}_M}{\hat{\phi}_L}\right) \operatorname{var}(\hat{N}_L) \tag{7}$$

The abundance of all fish were estimated as:

$$\hat{N}_{ALL} = \frac{\hat{N}_L}{\hat{\phi}_L} \tag{8}$$

with variance estimated as:

$$\operatorname{var}(\hat{N}_{ALL}) = \operatorname{var}(\hat{N}_L)\left[\frac{1}{\hat{\phi}_L}\right]^2 + \hat{N}_L^{\ 2} \operatorname{var}\left[\frac{1}{\hat{\phi}}\right] - \operatorname{var}(\hat{N}_L) \operatorname{var}\left[\frac{1}{\hat{\phi}}\right] \tag{9}$$

where

$$\operatorname{var}\left(\frac{1}{\hat{\phi}_L}\right) \approx \left[\frac{1}{\hat{\phi}_L}\right]^4 \operatorname{var}(\hat{\phi}_L) \tag{10}$$

AGE, SEX, AND LENGTH COMPOSITION

The various spawning tributaries of the Chickamin River were sampled by a 2–5-person crew and each tributary often required multiple sampling trips to achieve desired sampling goals. For 2009–2012, it was recommended to increase the brood year adult sampling goal from 410 to 492 fish (Johnson et al. 2009).

Chinook salmon were captured on spawning grounds primarily using rod and reel gear, and at times dip nets, although carcasses were also sampled when encountered. Ideally, at least 5 scales were taken from each captured fish (Welander 1940) and scales were mounted onto gum cards; each gum card had the capacity to hold scales for 10 fish. The age of each fish was determined later from annual growth patterns of circuli (Olsen 1992) on images of scales impressed onto acetate magnified 70× (Clutter and Whitesel 1956). Each fish was measured to the nearest 5 mm from mid eye to tail fork (METF), sex was determined using external morphological characteristics, and all data were recorded on standardized forms. All carcasses were slashed along their left side and all live fish sampled were marked with a hole punch in their left operculum to prevent double sampling. All fish were examined for the absence of the adipose fin, and if missing, this was an indication that the fish may possess a coded wire tag. Heads were collected from fish without adipose fins that were carcasses, post-spawn, or ≤700 mm METF (due to fish of this size being predominantly male) and, along with pertinent data and forms, sent to the ADF&G Mark, Tag, and Age Laboratory for dissection and decoding of coded wire tags. Fish greater than 700 mm METF that were missing their adipose fins were recorded as such, sampled for all other information, and released.

Scales of known marine but unknown (regenerated) freshwater (FW) age were assumed to have a FW age of 1, as historically Chinook salmon from the Chickamin River are almost all from a single freshwater age, overwintering 1 year as parr and emigrating as age-1 (yearling) smolt. Also, less than 2% of scale samples have regenerated or otherwise unknown marine water age (Johnson et al. 2009) but it should be noted that scales from fish of marine age 1 have a significantly greater tendency to show regeneration than scales of fish of marine ages 2 and older.

The proportion of the spawning population composed of a given age *c* within a size class *k* (large, medium, and small) was estimated as a binomial variable:

$$\hat{p}_{kc} = \frac{n_{kc}}{n_k}, \tag{11}$$

$$\operatorname{var}(\hat{p}_{kc}) = \frac{\hat{p}_{kc}(1-\hat{p}_{kc})}{n_k - 1} \tag{12}$$

where n_{kc} is the number of Chinook salmon of age c in size group k, and n_k is the number of Chinook salmon in the sample of size group k. Numbers of spawning fish by age were estimated as the sum of the products of estimated age composition and estimated abundance within a size category:

$$\hat{N}_c = \sum_k (\hat{p}_{kc}\hat{N}_k) \tag{13}$$

because the $\hat{N}_k$ in Equation 3 are correlated ($\hat{N}_S$ and $\hat{N}_M$ are estimated from $\hat{N}_L$ by Equations 1 and 2), $\operatorname{var}(\hat{N}_c)$ was estimated by simulation. The stochastic components in the simulation were $\hat{N}_L \sim Normal(\hat{N}_L, \hat{\phi}_{\hat{N}_L})$, $\hat{\phi} \sim multinomial(n_{sp}, \hat{\phi})/n_{sp}$, and the vector of age-sex proportions for the *k*th size group as $\hat{p}_k \sim multinomial(n_k, \hat{p}_k)/n_k$. Notation for normal multinomial distribution parameters follows that of the R language[1] (version 4.2.2). The above equations were applied to each set of simulated values. The simulated variance of $\hat{N}_c$ was taken as the sample variance of the simulated $\hat{N}_c$ values.

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

$$\hat{p}_c = \frac{\hat{N}_c}{\hat{N}} \tag{14}$$

The $\operatorname{var}(\hat{p}_c)$ was estimated as the sample variance of the $\hat{p}_c$ generated in the simulation described above.

[1] R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.r-project.org/index.html.

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

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

JUVENILE CHINOOK SALMON CAPTURE, TAGGING, AND SAMPLING

All healthy Chinook salmon ≥55 mm FL were marked by removing the adipose fin as part of event 1 of the 2-event mark–recapture study to estimate smolt abundance and injected with a 1.1 mm section of uniquely coded wire for use in marine harvest estimates. Capture and tagging occurred each fall from 2001 to 2006 and each spring from 2002 to 2007. Nearly all Chinook salmon parr tagged in the fall of year $j+1$, and smolt tagged in the spring of year $j+2$, are from the same brood year j. After emigration, adults return to the river after rearing for 1 to 5 years at sea and these fish were sampled as they returned from 2003 to 2012 as part of event 2 of the 2-event mark–recapture study.

To obtain precision criteria in Objectives 2 and 4, coded wire tag sampling goals were based on procedures described in Bernard et al. (1998) and the following assumptions:

1. annual returns of 5,000 age-1.2 to age-1.5 fish, and smolt population averaging 225,000 fish (from Pahlke 1995);
2. 17,000 fingerlings are tagged each fall;
3. 75% of fingerlings survive to smolt (overwinter survival); i.e., 12,750 tagged fingerlings survive to smolt;
4. 10,000 smolt are tagged each spring, resulting in an anticipated marked fraction of approximately 0.1 (12,750+10,000/225,000) for each brood;
5. 40% exploitation rate, yielding adult harvests of 2,000 fish (5,000 x 0.4) and harvest sampling rates of 40% (Objective 4 only); and
6. at least 410 adults per brood are sampled for coded wire tags on the spawning grounds.

Historic patterns of tag recovery and total harvest among fishery strata were used to anticipate stratum specific tag recoveries, harvest (and its variance) of Chickamin River Chinook salmon.

Similar to the Unuk River, Chickamin River juvenile Chinook salmon rear in the mainstem of the river and not in their respective tributaries. In October each fall, from 2001 to 2006, 60 to 180 minnow traps baited with salmon eggs were fished daily in the mainstem of the Chickamin River and the lower Leduc River (Figure 2). Traps were divided between 2 trap lines, each of which was operated and checked by a 2-person crew. Each trap line was checked at least once per day. All fish ≥55 mm FL were transported to a tagging station, sorted by species, fin clipped, marked, tagged, held overnight to check for tag retention, and then released in the general area where originally captured. Minimum tagging lengths were used to ensure fish would emigrate as smolt the following spring and not remain an additional year. From early April to mid-May each spring, from 2002 to 2007, 60 to 180 baited minnow traps were fished daily in the mainstem of the Chickamin River from above the confluence of the Leduc River downstream (Figure 2), thus ensuring a representative sample from all Chinook salmon spawning tributaries. Two crews of 2 were employed to fish 2 trap lines. Methodology for capture and tagging of fish is as described above and unique codes were used for spring and fall tagging. Codes were ordered in spools of approximately 5,000 or 10,000 tags and were only changed when exhausted.

SMOLT ABUNDANCE

Experience has shown that estimates of the proportion of adults from a given brood year with adipose fin clips does not change appreciably over return years, and thus recovery data were pooled over the i years (maximum = 5, representing ages 1.1 through 1.5) in which fish from brood year j return (Weller and Evans 2012). Smolt abundance ($\hat{N}_{smolt,j}$) from brood year j was estimated using a version of the Chapman-modified Petersen formula:

$$\hat{N}_{smolt,j} = \frac{(\hat{M}_j + 1)(n_{\bullet j} + 1)}{(a_{\bullet j} + 1)} - 1, \tag{15}$$

where

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

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

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

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

$$\hat{M}_{f \to s,j} = M_{f,j} \hat{S}_j \tag{16}$$

and where

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

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

$$\hat{S}_j = \frac{\hat{M}_{s,valid,j} v_{\bullet,f,j}}{\hat{M}_{f,valid,j} v_{\bullet,s,j}} \tag{17}$$

and where

$\hat{M}_{s,valid,j}$ = estimated number of adipose-fin clipped smolt released with valid coded wire tags in the spring of year $j+2$;

$\hat{M}_{f,valid,j}$ = estimated number of adipose-fin clipped parr released with valid coded wire tags in the fall of year $j+1$;

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

$v_{\bullet,s,j}$ = $\sum_{i=1}^{L} v_{i,s,j}$, where $v_{i,s,j}$ is the total number of fish from brood year j implanted with valid coded wire tags in the spring of year $j+2$ that were subsequently recovered, regardless of recovery location or sample type. The variance of the smolt estimate was estimated as:

$$\text{var}\left(\hat{N}_{smolt,j}\right) = \left(n_{\bullet} + 1\right)^2 \text{var}\left[\left(\hat{M}_{f\to s,j} + M_{s,j} + 1\right)\frac{1}{\left(a_{\bullet} + 1\right)}\right] \tag{18}$$

where, by Goodman (1960) for independent variables,

$$\text{var}\left[\left(\hat{M}_{f\to s,j} + M_{s,j} + 1\right)\frac{1}{\left(a_{\bullet,j} + 1\right)}\right] = \left(M_{s,j} + \hat{M}_{f\to s,j} + 1\right)^2 \text{var}\left[\frac{1}{a_{\bullet,j} + 1}\right] + \left[\frac{1}{a_{\bullet,j} + 1}\right]^2 \text{var}\left(\hat{M}_{f\to}\right. \\ - \text{var}\left[\frac{1}{a_{\bullet,j} + 1}\right]\text{var}\left(\hat{M}_{f\to s,j}\right) \tag{19}$$

and $\text{var}\left(\hat{M}_{f\to s,j}\right)$ is obtained as described in Weller and McPherson (2003). By the delta method,

$$\text{var}\left[\frac{1}{a_{\bullet} + 1}\right] = \left[\frac{1}{a_{\bullet,j} + 1}\right]^4 n_{\bullet,j}\hat{p}_a\left(1 - \hat{p}_a\right) \tag{20}$$

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

The two components in Equation 19 are not entirely independent, but a simulation using data from studies on 7 brood years of Unuk River Chinook salmon to establish realistic population parameters showed the correlation to be negligible. The simulation showed the simulated variance of smolt abundance to be almost identical to that provided by the average of the Goodman (1960)-derived estimates (above) over the simulation.

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

$$\hat{N}_{f,j} = \hat{N}_{smolt,j} \frac{1}{\hat{S}_j}, \quad (21)$$

$$\text{var}(\hat{N}_{f,j}) \approx \hat{N}^2_{f,j} \left| cv^2\left(\hat{N}_{smolt,j}\right) + cv^2\left(\hat{S}_j\right) \right|, \quad (22)$$

FRACTION OF ADULTS BEARING CODED WIRE TAGS

The fraction of adults from brood year *i* that possess a coded wire tag was estimated as:

$$\hat{\theta}_j = \frac{\sum_{i=1}^{L} a_{ij} \rho_{ij}}{\sum_{i=1}^{L} n_{ij}} \quad (23)$$

where,

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

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

ρ_{ij} = $\frac{t_{ij}}{a^{'}_{ij}}$, the proportion of sacrificed adults from brood year j in year i that also possess a valid Chickamin coded wire tag; where

$a^{'}_{ij}$ = number of heads examined for coded wire tags from the a_{ij} fish with adipose fin clips;

t_{ij} = number of coded wire tags found in $a^{'}_{ij}$; and

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

The variances of $\hat{\theta}_j$ and $\hat{\theta}_j^{-1}$ were estimated using a parametric bootstrap simulation (e.g., Geiger 1990). For each year of recovery *i*, adipose clips were generated as $a^*_{ij} \sim \text{binomial}\left(n_{ij}, \frac{a_{ij}}{n_{ij}}\right)$, and then coded wire tags were generated as $t^*_{ij} \sim$ hypergeometric ($m = t_{ij} / a^{'}_{ij} a^*_{ij},\ n = a^*_{ij} - t_{ij} / a^{'}_{ij} a^*_{ij},\ k = a^{'}_{ij} / a_{ij} a^*_{ij}$). Notation for hypergeometric parameters follows that of the R language[1] (version 4.2.2); ρ^*_{ij} was then calculated as $t^*_{ij} / (a^*_{ij} a^{'}_{ij} / a_{ij})$, and $\hat{\theta}_j^*$ as:

$$\hat{\theta}_j^* = \frac{\sum_{i=1}^{L} a_i^* \rho_i^*}{\sum_{i=1}^{L} n_i} \quad (24)$$

Many values of $\hat{\theta}_j^{\,*}$ were simulated and the variance of $\hat{\theta}_j$ and of $\hat{\theta}_j^{-1}$ were estimated as the sample variance of the respective simulated values. Returning Chinook salmon were inspected for marks (missing adipose fins) and sampled for age (scale) data annually through 2012 (to complete recoveries of fish from brood year 2005) during mark–recapture operations.

HARVEST

Landed catch (hereafter referred to as harvest) and coded wire tag sampling data from Alaska and Canada fisheries were obtained from the Regional Mark Processing Center (RMPC, http://www.rmpc.org/), which maintains the centralized coastwide coded wire tag database (Regional Mark Information System or RMIS).

Fishery strata are defined as a combination of gear and harvest type with specific spatial and temporal characteristics. Commercial fishery harvest types in SEAK of relevance to this study were traditional fisheries, experimental area (troll) fisheries, terminal fisheries, and private nonprofit hatchery harvests in the Neets Bay terminal area. The traditional and experimental area fisheries are managed by ADF&G to achieve harvest targets (quotas) pursuant to the Pacific Salmon Treaty and as determined by the PSC CTC. Experimental area fisheries target Alaska hatchery returns of Chinook salmon in SEAK each spring (approximately May through June), although fish other than Alaskan hatchery fish (treaty fish) are also harvested. The proportion of treaty fish harvested in each experimental fishery determines the total catch limit for each fishery (See Lynch and Skannes 2009a and 2010 and Skannes and Hagerman [2011, 2012] for further details on these fisheries). Experimental area fisheries are spatially small (subdistrict specific; Figure 3) and harvest by fishery is tallied by statistical week.

The Neets Bay terminal area fishery is a fishery managed jointly by ADF&G and the Southern Southeast Aquaculture Association to harvest returns to the Neets Bay hatchery (Lynch and Skannes 2009c). Harvest is primarily for cost recovery and brood stock, but some common property terminal harvest does occur (Davidson, Thynes, et al. 2009). This fishery is confined to District 101-95 (Figure 3), harvest is tallied by statistical week, and gear is undefined.

The Hidden Falls terminal area fishery is a fishery managed jointly by ADF&G and the Northern Southeast Aquaculture Association to harvest returns to the Hidden Falls hatchery (Lynch and Skannes 2009c). This fishery is confined to District 112-22 (Figure 3) and is managed for cost recovery, brood stock, common property terminal harvest (Davidson, Thynes, et al. 2009), and common property experimental area troll harvest (Lynch and Skannes 2009a). Harvest is tallied by statistical week, harvest type, and gear.

Traditional fisheries are mixed stock interception fisheries; terminal area, subsistence, experimental area, and test fisheries are not considered traditional fisheries. Harvest from SEAK traditional purse seine (see Davidson, Thynes, et al. 2009 for details on these fisheries) and drift gillnet fisheries (see Davidson, Bachman, et al. 2009 for details on these fisheries) are tallied by statistical week and district fished (Figure 3). In SEAK the traditional troll fishery is composed of winter and summer components. The winter fishery begins 11 October and ends when 45,000 Chinook salmon have been harvested, or on 30 April, whichever occurs first (Lynch and Skannes 2009b). The summer troll fishery begins 1 July and ends 20 September unless the fishery is extended (Lynch and Skannes 2009c).

Traditional troll harvests in SEAK are tallied by quadrant and period. A quadrant is a group of combined contiguous districts that divides SEAK into 4 large troll reporting areas (NE, NW, SE, and SW; Figure 4). Period is a group of consecutive statistical weeks. Period 1 starts on 1 January (statistical week 1) and ends when the winter troll fishery closes. Period 2 encompasses the spring, or experimental area, fishery. Period 3 begins when the summer troll fishery opens, generally 1 July, and for traditional Chinook salmon harvest, effectively ends when an inseason assessment of harvest sampling data determines the summer allocation of Chinook salmon has been reached and the fishery is closed to Chinook salmon retention (note that the summer troll fishery generally remains open to retention of other salmon species and Period 3 extends throughout this time). If during the summer fishery the entire salmon troll fishery is closed and then reopened, or if Chinook salmon harvest during Period 3 was found to be substantially less than the allocation and management reopens the fishery to Chinook retention, an additional period or periods are used to define each additional fishery opening. Period 4 of each calendar year is from the 1 October start of the winter troll fishery to 31 December. Note that as Chickamin River Chinook salmon have completed spawning by 1 October, harvest contributions of Chickamin River Chinook salmon caught after August 1 of a calendar year are accredited to returns in the following calendar year. Canadian troll harvests are tallied by statistical week and management area (Figure 6).

Creel surveys and/or catch sampling of recreational fisheries were randomly conducted in SEAK at marine boat landing sites in Skagway, Haines, Petersburg, Wrangell, Sitka, Juneau, Craig, Ketchikan, Elfin Cove, and Gustavus during times of peak sport fishing activity, April through September (Figure 5). Information collected from individual fishers included harvest type, harvest date, harvest location, number of Chinook salmon inspected for missing adipose fins, and the number of Chinook salmon observed with missing adipose fins. Harvest types relevant to this study were marine boat (MB) and derby fishing in which the sampled fish was entered in a derby (DE). Each sample was classified as either random, select, or voluntary. Creel surveys were used to estimate recreational harvest by fortnight, harvest type, and port of landing (e.g., Wendt and Jaenicke 2011). Recoveries from Canadian recreational fisheries in northern British Columbia are strictly voluntary.

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

$$\hat{r}_{uj} = H_u \left[\frac{m_{uj}}{\lambda_u n_u} \right] \theta_j^{-1}; \qquad \lambda_u = \frac{a'_u t'_u}{a_u t_u} \tag{25}$$

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

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

INCIDENTAL FISHING MORTALITY

Incidental mortality (IM) is mortality caused by the act of fishing but not part of harvest and is defined as the difference between harvest (landed catch) and total fishing mortality (CTC 2021). IM includes mortality of large (≥28 in TL) fish in Chinook salmon nonretention (CNR) fisheries and mortality of small and medium (<28 in TL) fish in retention and CNR fisheries and is separated into multiple categories: shakers, sublegal CNR, legal CNR, and drop-off (see CTC 2021 for additional details).

IM estimates are generated by the PSC CTC and are by brood year and a reduced set of age classes. Due to methodological limitations, the CTC does not compute variances for IM estimates. Correspondingly, the analyses presented herein that reference CTC IM estimates also treat these IM estimates as known constants (i.e., variance 0). Computer program memory limitations in the CTC IM estimation algorithm resulted in the grouping of some fisheries. For example, traditional purse seine and drift gillnet fisheries have separate Chinook salmon harvest limits (allocations), management plans, and in the case of the purse seine fishery, size limits. The purse seine fishery has often been subject to periods of nonretention to avoid surpassing the annual harvest limit. Since 1995, the drift gillnet fishery has had no periods of nonretention or size limitations on catch. The CTC algorithm automatically estimates CNR mortality for both the drift gillnet fishery and purse seine fishery during periods of purse seine nonretention (Weller 2012). Hence, it was not possible to separate CNR mortality for the drift gillnet and purse seine fisheries. Due to these factors, IM estimates are only presented by age and brood year (i.e., not by fishery). The CTC program combines the 2 oldest age classes – age-1.4 and age-1.5 – into a plus group (≥age-1.4). Because of this results are occasionally summarized accordingly (age-1.1, age-1.2, age-1.3, and ≥age-1.4). Reporting results in this manner allows harvest rates with and without IM to be calculated and compared; however, it occasionally will lead to minor differences because the plus group is an aggregation of data from multiple brood years. See CTC (1997, 2004, 2021) for additional details about the CTC IM estimation methodology.

ADULT EQUIVALENTS

Adult equivalent (AEQ) denotes the probability a fish of a given age will return in the absence of fishing in current and all future years (Morishima 2004). AEQs reduce harvest and IM to account for the fact that some of the fish killed are not necessarily returning to the Chickamin

River that year (i.e., feeder fish). AEQs are stock, brood, and age class specific and were calculated by the PSC CTC (see CHM in CTC 2021). Similar to IM, the variance of the estimated AEQs were not available and thus considered constants.

PRODUCTION, EXPLOITATION, AND MARINE SURVIVAL

Production (total return) of adults from brood year j was estimated as:

$$\hat{T}_j = \sum_{i=1}^{L} \hat{N}_{ji} + \sum_{i=1}^{L} \hat{R}_{ji}(AEQ_{ji}) + \sum_{i=1}^{L} IM_{ji}(AEQ_{ji}) \tag{26}$$

where

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

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

$\hat{R}_{ji}$ = estimated exploitation in year i from brood year j,

IM_{ji} = incidental mortality in year i from brood year j,

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

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

$$var(\hat{T}_j) = \sum_{i=1}^{L} var(\hat{N}_{ji}) + \sum_{i=1}^{L} var(\hat{R}_{ji}) AEQ_{ji}^2 \tag{27}$$

The exploitation rate $\hat{U}_j$ of brood year j was estimated as:

$$\hat{U}_j = \frac{F\hat{M}_j}{\hat{T}_j} \tag{28}$$

where both production and fishing mortality are expressed in AEQs, and fishing mortality was $F\hat{M}_j = \sum_{i=1}^{L} \hat{R}_{ji}(AEQ_{ji})$. An approximation for the variance of $\hat{U}_j$ that incorporates the covariance between $F\hat{M}_j$ and $\hat{T}_j$ was calculated using the delta method (Seber 1982, p. 8):

$$var(\hat{U}_j) \approx \frac{F\hat{M}_j^2}{\hat{T}_j^2}\left[\frac{var(F\hat{M}_j)}{F\hat{M}_j^2} + \frac{var(\hat{T}_j)}{\hat{T}_j^2} - 2\frac{var(F\hat{M}_j)}{F\hat{M}_j\hat{T}_j}\right] \tag{29}$$

where

$$var(F\hat{M}_j) = var(\hat{R}_j + IM_j) = var(\hat{R}_j) \tag{30}$$

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

$$\hat{Q}_j = \frac{\hat{T}_j}{\hat{N}_{smolt,j}} \tag{31}$$

$$var(\hat{Q}_j) \approx \frac{\hat{T}_j^2}{\hat{N}_{smolt,j}^2}\left[\frac{var(\hat{T}_j)}{\hat{T}_j^2} + \frac{var(\hat{N}_{smolt,j})}{\hat{N}_{smolt,j}^2}\right] \tag{32}$$

Nominal estimates (i.e., not adjusted for AEQ) were calculated by removing the AEQ_{ji} variable from equations 26–31.

The total run of adults in year *i*, harvest, and harvest rates were calculated by substituting run year for return year in equations 26–30.

RESULTS

SPAWNING ABUNDANCE

2009

Standardized, low-altitude helicopter and/or foot surveys of the 8 index tributaries resulted in a peak index count of 611 large Chinook salmon. Using the long-term expansion factor (4.75) published in Weller et al. (2007), the index was expanded to a population estimate of 2,902 (SE = 428) large Chinook salmon (Table 1). Age, sex, and length sampling information was used to estimate the 1,017 (SE = 177) medium and 39 (SE = 17) small Chinook salmon (Table 2). Combined, this represents a total escapement estimate of 3,958 (SE = 591) Chinook salmon (all sizes).

2010

Standardized, low-altitude helicopter and/or foot surveys of the 8 index tributaries resulted in a peak index count of 1,156 large Chinook salmon. Using the long-term expansion factor published in Weller et al. (2007), the index was expanded to a population estimate of 5,491 (SE = 809) large Chinook salmon (Table 1). Age, sex, and length sampling information was used to estimate the 1,496 (SE = 257) medium and 93 (SE = 32) small Chinook salmon (Table 2). Combined, this represents a total escapement estimate of 7,080 (SE = 1,052) Chinook salmon (all sizes).

2011

Standardized, low-altitude helicopter and/or foot surveys of the 8 index tributaries resulted in a peak index count of 853 large Chinook salmon. Using the long-term expansion factor published in Weller et al. (2007), the index was expanded to a population estimate of 4,052 (SE = 597) large Chinook salmon (Table 1). Age, sex, and length sampling information was used to estimate the 966 (SE = 228) medium and no small Chinook salmon (Table 2). Combined, this represents a total escapement estimate of 5,018 (SE = 763) Chinook salmon (all sizes).

2012

Standardized, low-altitude helicopter and/or foot surveys of the 8 index tributaries resulted in a peak index count of 444 large Chinook salmon. Using the long-term expansion factor published in Weller et al. (2007), the index was expanded to a population estimate of 2,109 (SE 311) large Chinook salmon (Table 1). Age, sex, and length sampling information was used to estimate the 427 (SE = 100) medium and 12 (SE = 12) small Chinook salmon (Table 2). Combined, this represents a total escapement estimate of 2,548 (SE = 384) Chinook salmon (all sizes).

AGE, SEX, AND LENGTH COMPOSITION

2009

A total of 611 fish were captured on the spawning grounds and sampled for age, sex, and length information between 6 August and 15 September 2009. Scales from 6 of the samples were not used in the age composition analysis due to regeneration of the scale.

Age-1.1 fish, all male, made up 8.3% (SE = 2.2%) of medium-sized fish and 3.1% (SE = 0.7%) of the total escapement. Age-1.2 fish made up an estimated 82.1% (SE = 3.1%) of medium-sized fish, 24.8% (SE = 2.1%) of large fish, and 39.3% (SE = 2.0%) of the total escapement. Age-1.3 fish accounted for an estimated 7.1% (SE = 2.1%) of the medium fish, 52.4% (SE = 2.4%) of large fish, and 40.2% (SE = 2.0%) of the total escapement. Age-1.4 fish made up 15.4% (SE = 1.5%) of the escapement. Females accounted for 30.1% (SE = 1.9%) of the escapement (Table 3).

The average length of age-1.2 and age-1.3 males was 647 mm METF (SD = 57) and 776 mm METF (SD = 74), respectively (Table 4). On average, age-1.3 males were smaller than their female counterparts, 776 mm METF (SD = 74) compared to 807 mm METF (SD = 41).

2010

A total of 762 fish were captured on the spawning grounds and sampled for age, sex, and length information between 6 August and 30 August 2010. Scales from 21 of the samples were not used in the age composition analysis due to regeneration or inverted scales.

Age-1.1 fish, all male, made up 11.3% (SE = 2.5%) of medium-sized fish and 3.7% (SE = 0.7%) of the total escapement. Age-1.2 fish accounted for an estimated 85.0% (SE = 2.8%) of medium-sized fish, 13.0% (SE = 1.4%) of large fish, and 28.0% (SE = 1.6%) of the total escapement. Age-1.3 fish made up an estimated 3.8% (SE = 1.5%) of the medium fish, 63.9% (SE = 2.0%) of large fish, and 50.4% (SE = 1.8%) of the total escapement. Age-1.4 fish made up 17.8% (SE = 1.4%) of the escapement. Females accounted for 33.6% (SE = 1.7%) of the escapement (Table 5).

The average length of age-1.2 and age-1.3 males was 634 mm METF (SD = 56) and 799 mm METF (SD = 76), respectively (Table 6). On average, age-1.3 males were smaller than their female counterparts, 799 mm METF (SD = 76) compared to 825 mm METF (SD = 48).

2011

A total of 187 fish were captured on the spawning grounds and sampled for age, sex, and length information between 7 August and 15 September. Scales from 2 of the samples were not used in the age composition analysis due to regeneration or inverted scales.

Age-1.2 fish accounted for an estimated 94.4% (SE = 3.9%) of medium-sized fish, 4.7% (SE = 1.7%) of large fish, and 22.0% (SE = 3.0%) of the total escapement. Age-1.3 fish made up an estimated 5.6% (SE = 3.9%) of the medium fish, 68.5% (SE = 3.8%) of large fish, and 56.3% (SE = 3.6%) of the total escapement. Age-1.4 fish accounted for 20.1% (SE = 3.0%) of the escapement. Females, all large, accounted for 39.6% (SE = 3.6%) of the escapement (Table 7).

The average length of age-1.2 and age-1.3 males was 584 mm METF (SD = 82) and 771 mm METF (SD = 77), respectively (Table 8). On average, age-1.3 males were smaller than their female counterparts, 771 mm METF (SD = 77) compared to 815 mm METF (SD = 41).

2012

A total of 209 fish were captured on the spawning grounds and sampled for age, sex, and length information between 5 August and 3 September 2012. One fish escaped before scales could be taken.

Age-1.2 fish made up an estimated 85.3% (SE = 6.2%) of medium-sized fish, 6.9% (SE = 1.9%) of large fish, and 20.0% (SE = 2.8%) of the total escapement. Age-1.3 fish accounted for an estimated 2.9% (SE = 2.9%) of the medium fish, 73.4% (SE = 3.4%) of large fish, and 61.3% (SE = 3.4%) of the total escapement. Age-1.4 fish made up 16.3% (SE = 2.5%) of the escapement. Females, all large, accounted for 45.0% (SE = 3.5%) of the escapement (Table 9).

The average length of age-1.2 and age-1.3 males was 622 mm METF (SD = 53) and 791 mm METF (SD = 62), respectively (Table 10). On average, age-1.3 males were smaller than their female counterparts, 791 mm METF (SD = 62) compared to 810 mm METF (SD = 46).

SMOLT ABUNDANCE

For brood years 2000–2005, fall parr tagging efforts ranged from 18,057 in brood year 2000 to 28,979 coded wire tags applied in brood year 2001 with an average of 21,846 (Table 11) across all brood years. Overwinter survival of the parr ranged from 25% (SE = 6%) in brood year 2005 to 50% (SE = 10%) in brood year 2000 with an average of 38% across all brood years, which fell far below the assumed overwinter survival rate of 75% (Table 11). Smolt tagging efforts ranged from 6,819 in brood year 2005 to 11,039 coded wire tags applied in brood year 2002 with an average of 8,563 (Table 11) across all brood years. Thus, the estimated total number of adipose-fin clipped and coded wire tagged Chinook salmon smolt emigrating from the Chickamin River ranged from 12,165 in brood year 2005 to 19,904 in brood year 2003 with an average of 16,989 across all brood years (Table 11). Parr abundance estimates ranged from 438,453 (SE = 158,599) in brood year 2004 to 1,093,577 (SE = 338,753) in brood year 2002 averaging 765,351 across all brood years (Table 12). Smolt abundance estimates ranged from 170,013 (SE = 33,967) in brood year 2004 to 413,660 (SE = 74,026) in brood year 2002 averaging 287,012 across all brood years (Table 12).

FRACTION OF ADULTS BEARING CWTS

The estimated fraction of Chinook salmon possessing coded wire tags (θ) for the 2000–2005 brood years were 4.4%, 6.0%, 4.2%, 5.3%,7.1%, and 4.6%, respectively (Table 13). Five foreign (strays) coded wire tags were also sampled; 2 Unuk releases (one from the 2000 brood and another from the 2006 brood), 2 Neets Bay hatchery releases (both from the 2000 brood), and a Tamgas Hatchery release (from the 2001 brood).

HARVEST

The 2000–2005 brood years contributed 3,243 (SE = 540), 3,112 (SE = 521), 2,810 (SE = 493), 1,874 (SE = 550), 983 (SE = 212), and 3,807 (SE = 939) Chinook salmon to the commercial and sport fisheries from 2003 to 2011 (Table 14; see Appendix A1 for complete contribution by fishery). Tagged Chickamin River Chinook salmon were harvested in various SEAK commercial and sport fisheries (Figure 7) as well as in BC (Table 21). Harvest rates from 2006 to 2009 run years averaged 33% (range 15–43%; Table 15) and by fishery averaged 16% in the commercial troll, 4% in the commercial net, and 11% in the sport. During that same period, Chickamin River Chinook salmon were harvested at a higher rate (average of 33%) than the nearby Unuk River Chinook salmon run (average of 21%; Table 16). Two-sample Z tests were used to determine if the estimated Chickamin and Unuk River Chinook harvest rates were significantly different. Test results indicated that annual harvest rates were significantly different in 3 of the 4 run years (run year = 2006, $Z = -2.38$, $P < 0.01$; run year = 2007, $Z = -2.71$, $P < 0.01$; run year = 2008, $Z = 0.59$, $P > 0.05$; run year = 2009, $Z = -3.04$, $P < 0.01$) and that the average harvest rate was different (SE = 0.03; $Z = -2.06$, $P < 0.05$).

PRODUCTION, EXPLOITATION, AND MARINE SURVIVAL

Brood Year 2000

Brood year 2000 returns were completed in 2007 and an estimated 3,243 (SE = 540) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 17%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 3,058 (SE = 511) AEQs (Table 19). An estimated 2,022 (SE = 387) fish were exploited by commercial troll gear, approximately 62% of the total exploitation (Table 20). The drift gillnet, recreational, and purse seine fisheries exploited 83 (SE = 64), 1,014 (SE = 357), and 123 (SE = 103) fish representing approximately 3%, 31%, and 4% of the total estimated exploitation, respectively (Table 20). Exploitation primarily occurred in the Southeast (46%; 1,507 fish; SE = 376) and Northwest (37%; 1,202 fish; SE = 324) Quadrants of SEAK (Table 21). Approximately 5% of exploitation occurred in British Columbia (154 fish; SE = 113; Table 21). An estimated 971 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 673 AEQs (Table 23). Total fishing mortality was 4,215 (SE = 540, Table 22) fish or 3,731 (SE = 511, Table 23) AEQs. Based on an estimated spawning abundance of 7,434 (SE = 586) fish (Table 19 and 23), production was estimated to be 11,649 (SE = 797) fish or 11,165 AEQs (SE = 778). This equated to an exploitation rate of 36.2% (SE = 3.5%) or 33.4% (SE = 3.5%) for AEQs. Marine survival was 3.3% (SE = 0.5%) or 3.2% (SE = 0.5%) for AEQS.

Brood Year 2001

Brood year 2001 returns were completed in 2008 and an estimated 3,112 (SE = 521) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 17%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 2,980 (SE = 504) AEQs (Table 19). An estimated 1,641 (SE = 324) fish were exploited by commercial troll gear, approximately 53% of the total exploitation (Table 20). The drift gillnet, recreational, and purse seine fisheries exploited 20 (SE = 19), 1,309 (SE = 399), and 143 (SE = 83) fish representing approximately 1%, 42%, and 5% of the total estimated exploitation, respectively (Table 20). Exploitation primarily occurred in the Southeast (50%; 1,550 fish; SE = 365) and Northwest (28%; 875 fish; SE = 222) Quadrants of SEAK (Table 21). Approximately 9% of exploitation occurred in British Columbia (295 fish; SE = 199; Table 21). An estimated 927 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 636 AEQs (Table 23). Total fishing mortality was 4,039 (SE = 521; Table 22) fish or 3,616 (SE = 504; Table 23) AEQs. Based on an estimated spawning abundance of 5,274 (SE = 549) fish (Table 19 and 23), production was estimated to be 9,313 (SE = 757) fish or 8,890 (SE = 746) AEQs. This equated to an exploitation rate of 43.4% (SE = 4.1%) or 40.7% (SE = 4.2%) for AEQs. Marine survival was 3.3% (SE = 0.5%) or 3.1% (SE = 0.6%) for AEQs.

Brood Year 2002

Brood year 2002 returns were completed in 2009 and an estimated 2,810 (SE = 493) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 18%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 2,563 (SE = 445) AEQs (Table 19). An estimated 1,489 (SE = 309) fish were exploited by commercial troll gear, approximately 53% of the total exploitation (Table 20). The drift gillnet, recreational, and purse seine fisheries exploited 108 (SE = 64), 893 (SE = 325), and 320 (SE = 194) fish representing approximately 4%, 32%, and 11% of the total estimated exploitation, respectively (Table 20). Exploitation primarily occurred in the Southeast (59%; 1,653 fish; SE = 394) and Northwest (26%; 743 fish; SE = 251) Quadrants of SEAK (Table 21). Approximately 2% of exploitation occurred in British Columbia (45 fish; SE = 44; Table 21). An estimated 1,081 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 774 AEQs (Table 19 and 23). Total fishing mortality was 3,891 (SE = 493; Table 22) fish or 3,337 (SE = 445; Table 23) AEQs. Based on an estimated spawning abundance of 6,271 (SE = 560) fish (Table 19), production was estimated to be 10,162 (SE = 746) fish or 9,608 (SE = 715) AEQs. This equated to an exploitation rate of 38.3% (SE = 3.7%) or 34.7% (SE = 3.6%) for AEQs. Marine survival was 2.5% (SE = 0.5%) or 2.3% (SE = 0.5%) for AEQs.

Brood Year 2003

Brood year 2003 returns were completed in 2010 and an estimated 1,874 (SE = 550) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 29%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 1,749 (SE = 516) AEQs (Table 19). An estimated 886 (SE = 505) fish were exploited in the recreational fishery, approximately 47% of the total exploitation (Table 20). The drift gillnet and troll fisheries exploited 65 (SE = 46) and 813 (SE = 183) fish representing approximately 3% and 43% of the total estimated exploitation, respectively (Table 20). Exploitation primarily occurred in the Southeast (73%; 1,362 fish; SE = 529) and Northwest (19%; 365 fish; SE = 130) Quadrants of SEAK (Table 21). An estimated 793 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 539 AEQs (Table 19 and 23). Total fishing mortality was 2,667 (SE = 550; Table 22) fish or 2,288 (SE = 516; Table 23) AEQs. Based on an estimated spawning abundance of 5,271 (SE = 562) fish (Table 19 and 23), production was estimated to be 7,938 (SE = 786) fish or 7,559 (SE = 763) AEQs. This equated to an exploitation rate of 33.6% (SE = 5.2%) or 30.3% (SE = 5.3%; Table 20) for AEQs. Marine survival was 2.6% (SE = 0.6) or 2.5% (SE = 0.6%) for AEQs.

Brood Year 2004

Brood year 2004 returns were completed in 2011 and an estimated 983 (SE = 212) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 22%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 933 (SE = 204) AEQs (Table 19). An estimated 777 (SE = 174) fish were exploited by commercial troll gear, approximately 79% of the total exploitation (Table 20). The drift gillnet and purse seine fisheries exploited 22 (SE = 22) and 183 (SE = 119) fish, representing approximately 2% and 19% of the total estimated exploitation, respectively (Table 20). Although exploitation in the recreational fishery was estimated to be 0, this was likely the result of small sample sizes as evident by a non-random recovery in the Craig recreational fishery. Exploitation primarily occurred in the Northwest (44%; 433 fish; SE = 130) and Southeast (43%; 425 fish; SE = 157) Quadrants of SEAK (Table 21). An estimated 489 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 315

AEQs (Table 23). Total fishing mortality was 1,472 (SE = 212; Table 22) fish or 1,248 (SE = 204; Table 23) AEQs. Based on an estimated spawning abundance of 4,477 (SE = 393) fish (Table 19 and 23), production was estimated to be 5,948 (SE = 446) fish or 5,725 (SE = 442) AEQs. This equated to an exploitation rate of 24.7% (SE = 3.1%) or 21.8% (SE = 3.2%) for AEQs. Marine survival was 3.5% (SE = 0.7%) or 3.4% (SE = 0.7%) for AEQs.

Brood Year 2005

Brood year 2005 returns were completed in 2012 and an estimated 3,807 (SE = 939) fish were exploited (Table 14 and 17, Appendix A1) with an estimated CV of 25%. Use of AEQ conversion factors (Table 18) results in an estimated exploitation of 3,408 (SE = 852) AEQs (Table 19). An estimated 1,579 (SE = 298) fish were exploited by commercial troll gear, approximately 41% of the total exploitation (Table 20). The drift gillnet, recreational and purse seine fisheries exploited 678 (SE = 282), 833 (SE = 571), and 22 (SE = 21) fish representing approximately 18%, 22%, and 1% of the total estimated exploitation, respectively (Table 20). Terminal areas and cost-recovery fisheries exploited 696 (SE = 622) fish and accounted for 18% of the exploitation (Table 20). Exploitation primarily occurred in the Southeast (76%; 2,899 fish; SE = 902) Quadrants of SEAK (Table 21). An estimated 1,003 fish died as a result of IM (Table 22). Use of AEQ factors (Table 18) results in an estimated IM of 783 AEQs (Table 23). Total fishing mortality was 4,810 (SE = 939; Table 22) fish or 4,190 (SE = 852; Table 23) AEQs. Based on an estimated spawning abundance of 6,537 (SE = 636) fish (Table 19 and 23), production was estimated to be 11,347 (SE = 1,134) fish or 10,727 (SE = 1,063) AEQs. This equated to an exploitation rate of 42.4% (SE = 5.3%) or 39.1% (SE = 5.4%) for AEQs. Marine survival was 5.8% (SE = 1.2%) or 5.5% (SE = 1.1%; Table 18) for AEQs.

Estimates by Run Year

Only run years 2006–2009 had CWT data for the primary age classes (i.e. ≥age-1.2 and <age-1.5), which allowed for the estimation of total run and harvest rate. The 2006 total run does not include age-1.5 fish as the 1999 brood class were not CWT marked, but that contribution is assumed to be negligible based on the age-1.5 returners from the CWT marked years. Similarly, the 2009 total run does not include age-1.1 fish as the 2006 brood class were not CWT marked, but that contribution is both assumed to be negligible based on the age-1.1 returners from the CWT marked years and mitigated by limiting inference for certain statistics to ≥age-1.2 fish. Total nominal run averaged 9,095 fish from 2006 to 2009 and ranged from 7,356 (SE = 864) fish in 2009 to 12,092 (SE = 865) fish in 2006 (Table 24), where the estimated total nominal runs in 2006 and 2009 are likely biased low because age-1.5 and age-1.1 fish from brood years 1999 and 2006, respectively, were not tagged. In AEQs, total runs averaged 8,700 from 2006 to 2009 and ranged from 6,843 (SE = 770) in 2009 to 11,552 (SE = 836) in 2006 (Table 25), and again the 2006 and 2009 estimates are likely biased low. Total harvest in the gillnet, seine, recreational, and troll fisheries for the 2006–2009 run years were 738, 505, 4,009, 109, and 5,505, respectively (Table 26). The commercial troll and recreational fisheries accounted for 51% and 37% of the harvest during these harvest years. The Southeast Quadrant accounted for 56% of the harvest from 2006 to 2009 with the Northwest Quadrant accounting for 26% of the harvest (Table 27, Figure 4). During this period, harvest and IM of ≥age-1.2 fish averaged 2,717 and 470 (Table 28) or 2,508 and 391 AEQs (Table 29), respectively. Average total fishing mortality of ≥age-1.2 fish was estimated to be 3,187 (Table 28) or 2,900 AEQs (Table 29). During 2006–2009, the nominal harvest rate of ≥age-1.2 fish calculated with and without IM averaged 32.9% and 36.3%, respectively (Table 28), and the

AEQ harvest rate of ≥age-1.2 fish calculated with and without IM averaged 31.3% and 34.3%, respectively (Table 29).

DISCUSSION

The precision objective for the estimated marine harvest for brood years 2000–2005 (objective 1; half-width of the 95% confidence intervals ≤ 30% of the estimate) was not met throughout the duration of this project. Not meeting the stated objectives was a multi-faceted problem. The assumed overwinter survival rate of 75% was higher than reality (Table 11), which resulted in fewer coded wire tags than anticipated emigrating from the system each spring. Overwinter survival rates for Chinook salmon on the adjacent Unuk River were similar during this same time period. Harsh winter conditions with unusually cold weather and deep snowpacks resulted in low and very cold water during normal spring tagging periods and resulted in the spring smolt tagging sample size goals not being met in 4 of 6 years. Combined with poor overwinter survivals, the anticipated tagging fraction of 10% was never realized. The largest tagging fraction obtained was 7.1% for brood year 2004 (Table 13). Current research on the Unuk River shows overwinter survival from parr to smolt to be an average of 52%, and we assume the Chickamin River overwinter survival rate for Chinook salmon are similar. Although sample size goals of returning adults were met despite inclement weather, decreasing fish abundance, and a strained fiscal environment, the issues stemming from the low juvenile tagging fraction and lower-than-anticipated overwinter survival resulted in the harvest precision objective not being met.

The project met its precision objective for estimating smolt emigration in 4 of the 6 brood years (objective 2; estimates were within ±30% of the true value 90% of the time). The estimated smolt abundance for brood year 2003 had the largest error, with a CV of 21%. This was a result of having the lowest number of recoveries, a direct result of poor juvenile tagging fractions and poor weather conditions during spawning grounds sampling, especially in 2008 when age-1.3 fish were returning, typically the dominant age class in brood year returns for this stock (McPherson and Carlile 1997).

Annual sample size goals for estimating spawning age and sex composition conducted from 2009 to 2012 were met in 2 of the 4 years (objective 3; estimates were within ±5% of the true value 95% of the time). Sampling effort in 2009 and 2010 was boosted to meet the recommendation of Johnson et al. (2009); however, a combination of fiscal restraints and poor weather resulted in less spawning grounds samples being collected in 2011 and 2012.

In Johnson et al. (2009), it was recommended to increase the brood year adult sampling goal from 410 to 492 fish (20% increase), and that goal was obtained for each of the brood years (Table 12). Enough samples were gathered to estimate the fractions of adults possessing adipose fin clips and coded wire tags germane to juvenile tagging efforts on the 2000 to 2005 broods. Estimated mark fractions in all brood years had CVs ≤ 20% (objective 4; no objective criteria), with results indicating that the mark and tag rates were less than 10% for all brood years tagged. These results were obtained despite having lower than expected smolt tagging numbers and higher than anticipated overwinter mortality.

From 2009 to 2012, aerial surveys were conducted on all 8 of the spawning tributaries in the Chickamin River (Appendix A2). The concentrations of fish seen during these flights helped facilitate age, sex, length, and tag sampling efforts and increased overall sampling efficiency saving money over time. The BEG range for the Chickamin River is 2,150 to 4,300 large (≥660

METF) Chinook salmon, and 2009–2011 expanded aerial counts fell within the BEG whereas 2012 fell short of the BEG (Table 1).

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TABLES

Table 1.–Peak survey counts from index survey streams with spawning escapement estimates of large Chinook salmon (≥660 mm from mid eye to tail fork [METF]) in the Chickamin River, 2009–2012.

	Peak survey counts			
Year	2009	2010	2011	2012
South Fork Creek	74	243	158	90
Barrier Creek	7	43	3	26
Butler Creek	251	240	166	134
Leduc Creek	17	57	11	27
Indian Creek	55	123	79	20
Humpy Creek	30	80	17	26
King Creek	172	368	418	121
Clear Falls Creek	5	2	1	0
Total peak count	611	1,156	853	444
N_L[a]	2,902	5,491	4,052	2,109
$SE(N_L)$	428	809	597	311

[a] Expansion factor of 4.75 (SE 0.70) is used to calculate N_L (Weller et al. 2007).

Table 2.–Escapement of small (<400 mm mid eye to tail fork [METF]), medium (≥400 and <660 mm METF), and large (≥660 mm METF) Chinook salmon based on percentage of spawning ground samples taken, 2009–2012.

Year	Size	Sample Size	Percentage of fish in the sample (%)	Abundance Estimate	SE	CV (%)
2009	Small	6	0.1	39	17	43.3
	Medium	157	25.7	1,017	177	17.4
	Large	448	73.3	2,902	428	14.7
	Total	611	100.0	3,958	591	14.9
2010	Small	10	1.3	93	32	34.8
	Medium	161	21.1	1,496	257	17.2
	Large	591	77.6	5,491	809	14.7
	Total	762	100.0	7,080	1,052	14.9
2011	Small	0	0	0	0	0
	Medium	36	19.3	966	228	23.6
	Large	151	80.7	4,052	597	14.7
	Total	187	100.0	5,018	763	15.2
2012	Small	1	0.5	12	12	100
	Medium	35	16.7	427	100	23.5
	Large	173	82.8	2,109	311	14.7
	Total	209	100.0	2,548	384	15.1

Table 3.–Age and sex composition of the escapement of small (<400 mm mid eye to tail fork [METF]), medium (≥400 and <660 mm METF), and large (≥660 mm METF) Chinook salmon in the Chickamin River in 2009 as determined from spawning grounds samples.

		Brood year and age class									
		2006	2005	2006	2005	2004	2003	2002			
		0.2	0.3	1.1	1.2	1.3	1.4	1.5	Known Total	Unknown Age	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON											
Males	Sample size			6					6		6
	p_{ijk} x100			100.0							100.0
	SE(p_{ijk}) x100			0.0							0.0
	N_{ijk}			39							39
	SE(N_{ijk})			17							17
Females	Sample size										
	p_{ijk} x100										
	SE(p_{ijk}) x100			No small females encountered during spawning ground surveys							
	N_{ijk}										
	SE(N_{ijk})										
Sexes combined	Sample size			6					6		6
	p_{ij} x100			100.0							100.0
	SE(p_{ij}) x100			0.0							0.0
	N_{ij}			39							39
	SE(N_{ij})			17							17
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON											
Males	Sample size	3		13	124	11	1		152	1	153
	p_{ijk} x100	1.9		8.3	79.5	7.1	0.6				97.5
	SE(p_{ijk}) x100	1.1		2.2	3.2	2.1	0.6				1.3
	N_{ijk}	20		85	808	72	7				991
	SE(N_{ijk})	12		27	144	24	7				173
Females	Sample size				4				4		4
	p_{ijk} x100				2.6						2.5
	SE(p_{ijk}) x100				1.3						1.3
	N_{ijk}				26						26
	SE(N_{ijk})				14						13
Sexes combined	Sample size	3		13	128	11	1		156	1	157
	p_{ij} x100	1.9		8.3	82.1	7.1	0.6				100.0
	SE(p_{ij}) x100	1.1		2.2	3.1	2.1	0.6				0.0
	N_{ij}	20		85	835	72	7				1,017
	SE(N_{ij})	12		27	148	24	7				177

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Table 3.–Page 2 of 2.

		Brood year and age class									
		2006	2005	2006	2005	2004	2003	2002			
		0.2	0.3	1.1	1.2	1.3	1.4	1.5	Known Total	Unknown Age	Total
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON											
Males	Sample size	1			103	119	39	3	265	3	268
	p_{ijk} x100	0.2			23.3	26.9	8.8	0.7			59.8
	SE(p_{ijk}) x100	0.2			2.0	2.1	1.3	0.4			2.3
	N_{ijk}	7			675	780	256	20			1,736
	SE(N_{ijk})	7			115	130	54	12			264
Females	Sample size		1		7	113	53	4	178	2	180
	p_{ijk} x100		0.2		1.6	25.5	12.0	0.9			40.2
	SE(p_{ijk}) x100		0.2		0.6	2.1	1.5	0.4			2.3
	N_{ijk}		7		46	740	347	26			1,166
	SE(N_{ijk})		7		18	124	68	13			184
Sexes combined	Sample size	1	1		110	232	92	7	443	5	448
	p_{ij} x100	0.2	0.2		24.8	52.4	20.8	1.6			100.0
	SE(p_{ij}) x100	0.2	0.2		2.1	2.4	1.9	0.6			0.0
	N_{ij}	7	7		721	1,520	603	46			2,902
	SE(N_{ij})	7	7		121	234	105	18			428
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM AND LARGE CHINOOK SALMON COMBINED											
Males	Sample size	4		19	227	130	40	3	423	4	427
	p_{ik} x100	0.7		3.1	37.5	21.5	6.6	0.5			69.9
	SE(p_{ik}) x100	0.3		0.7	2.0	1.7	1.0	0.3			1.9
	N_{jk}	26		124	1,483	851	262	20			2,766
	SE(N_{jk})	14		35	241	141	56	12			425
Females	Sample size		1		11	113	53	4	182	2	184
	p_{ik} x100		0.2		1.8	18.7	8.8	0.7			30.1
	SE(p_{ik}) x100		0.2		0.5	1.6	1.2	0.3			1.9
	N_{jk}		7		72	740	347	26			1,192
	SE(N_{jk})		7		24	125	68	14			188
Sexes combined	Sample size	4	1	19	238	243	93	7	605	6	611
	p_j x100	0.7	0.2	3.1	39.3	40.2	15.4	1.2			100.0
	SE(p_j) x100	0.3	0.2	0.7	2.0	2.0	1.5	0.4			0.0
	N_j	26	7	124	1,555	1,592	609	46			3,958
	SE(N_j)	14	7	35	252	246	106	19			591

Note: Blank cells indicate no estimate is available or expected.

Table 4.–Average length (mm mid eye to tail fork [METF]) by age and sex of Chinook salmon sampled in the Chickamin River, 2009.

		Brood year and age class							
		2006	2005	2006	2005	2004	2003	2002	
		0.2	0.3	1.1	1.2	1.3	1.4	1.5	Total
Males	Sample size	4		19	227	130	40	3	423
	Avg. length	605		419	647	776	891	898	701
	SD	85		43	57	74	79	108	122
	SE	42		10	4	6	12	62	6
Females	Sample size		1		11	113	53	4	182
	Avg. length		810		675	807	872	916	820
	SD				63	41	47	58	66
	SE				19	4	7	29	5
Sexes	Sample size	4	1	19	238	243	93	7	605
combined	Avg. length	605	810	419	648	790	880	909	737
	SD	85		43	57	63	63	75	121
	SE	42		10	4	4	7	28	5

Note: Blank cells indicate no estimate is available or expected.

Table 5.–Age and sex composition of the escapement of small (<400 mm mid eye to tail fork [METF]), medium (≥400 and <660 METF) and large (≥660 mm METF) Chinook salmon in the Chickamin River in 2010 as determined from spawning grounds samples.

		Brood year and age class							
		2006	2007	2006	2005	2004			
		0.3	1.1	1.2	1.3	1.4	Known Total	Unknown Age	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON									
Males	Sample size		10				10		10
	p_{ijk} x100		100.0						100.0
	SE(p_{ijk}) x100		0.0						0.0
	N_{ijk}		93						93
	SE(N_{ijk})		32						32
Females	Sample size	No small females encountered during spawning ground surveys							
	p_{ijk} x100								
	SE(p_{ijk}) x100								
	N_{ijk}								
	SE(N_{ijk})								
Sexes combined	Sample size		10				10		10
	p_{ij} x100		100.0						100.0
	SE(p_{ij}) x100		0.0						0.0
	N_{ij}		93						93
	SE(N_{ij})		32						32
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON									
Males	Sample size		18	134	5		157	1	158
	p_{ijk} x100		11.3	83.8	3.1				98.1
	SE(p_{ijk}) x100		2.5	2.9	1.4				1.1
	N_{ijk}		168	1,253	47				1,468
	SE(N_{ijk})		47	220	22				253
Females	Sample size			2	1		3		3
	p_{ijk} x100			1.3	0.6				1.9
	SE(p_{ijk}) x100			0.9	0.6				1.1
	N_{ijk}			19	9				28
	SE(N_{ijk})			13	9				16
Sexes combined	Sample size		18	136	6		160	1	161
	p_{ij} x100		11.3	85.0	3.8				100.0
	SE(p_{ij}) x100		2.5	2.8	1.5				0.0
	N_{ij}		168	1,271	56				1,496
	SE(N_{ij})		47	222	24				257

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		Brood year and age class							
		2006	2007	2006	2005	2004			
		0.3	1.1	1.2	1.3	1.4	Known Total	Unknown Age	Total
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON									
Males	Sample size			70	200	50	320	18	338
	p_{ijk} x100			12.3	35	8.8			57.2
	SE(p_{ijk}) x100			1.4	2.0	1.2			2.0
	N_{ijk}			675	1,922	481			3,140
	SE(N_{ijk})			124	303	96			476
Females	Sample size	1		4	165	81	251	2	253
	p_{ijk} x100	0.2		0.7	28.9	14.2			42.8
	SE(p_{ijk}) x100	0.2		0.3	1.9	1.5			2.0
	N_{ijk}	10		38	1,587	779			2,351
	SE(N_{ijk})	10		20	256	140			364
Sexes	Sample size	1		74	365	131	571	20	591
combined	p_{ij} x100	0.2		13.0	63.9	22.9			100.0
	SE(p_{ij}) x100	0.2		1.4	2.0	1.8			0.0
	N_{ij}	10		712	3,510	1,260			5,491
	SE(N_{ij})	10		130	529	209			809
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM AND LARGE CHINOOK SALMON COMBINED									
Males	Sample size		28	204	205	50	487	19	506
	p_{ik} x100		3.7	27.2	27.8	6.8			66.4
	SE(p_{ik}) x100		0.7	1.6	1.6	0.9			1.7
	N_{jk}		261	1,928	1,969	481			4,701
	SE(N_{jk})		64	318	312	97			716
Females	Sample size	1		6	166	81	254	2	256
	p_{ik} x100	0.1		0.8	22.5	11.0			33.6
	SE(p_{ik}) x100	0.1		0.3	1.5	1.2			1.7
	N_{jk}	10		57	1,596	779			2,379
	SE(N_{jk})	10		25	257	140			368
Sexes	Sample size	1	28	210	371	131	741	21	762
combined	p_j x100	0.1	3.7	28.0	50.4	17.8			100.0
	SE(p_j) x100	0.1	0.7	1.6	1.8	1.4			0.0
	N_j	10	261	1,983	3,566	1,260			7,080
	SE(N_j)	10	64	326	538	210			1,052

Note: Blank cells indicate no estimate is available or expected.

Table 6.–Average length (mm mid eye to tail fork [METF]) by age and sex of Chinook salmon sampled in the Chickamin River, 2010.

		Brood year and age class					
		2006	2007	2006	2005	2004	
		0.3	1.1	1.2	1.3	1.4	Total
Males	Sample size		28	204	205	50	487
	Avg. length		420	634	799	922	720
	SD		41	56	76	76	140
	SE		8	4	5	11	6
Females	Sample size	1		6	166	81	254
	Avg. length	745		672	825	877	838
	SD			50	48	44	59
	SE			21	4	5	4
Sexes combined	Sample size	1	28	210	371	131	741
	Avg. length	745	420	635	810	894	761
	SD		41	56	67	62	131
	SE		8	4	3	5	5

Note: Blank cells indicate no estimate is available or expected.

Table 7.–Age and sex composition of the escapement of small (<400 mm mid eye to tail fork [METF]), medium (≥400 and <660 mm METF), and large (≥660 mm METF) Chinook salmon in the Chickamin River in 2011 as determined from spawning grounds samples.

		Brood year and age class							
		2007	2006	2005	2004	2006			
		1.2	1.3	1.4	1.5	0.4	Known Total	Unknown Age	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON									
Males	Sample size								
	p_{ijk} x100								
	SE(p_{ijk}) x100	No small fish encountered during spawning ground surveys							
	N_{ijk}								
	SE(N_{ijk})								
Females	Sample size								
	p_{ijk} x100								
	SE(p_{ijk}) x100	No small fish encountered during spawning ground surveys							
	N_{ijk}								
	SE(N_{ijk})								
Sexes combined	Sample size								
	p_{ij} x100								
	SE(p_{ij}) x100	No small fish encountered during spawning ground surveys							
	N_{ij}								
	SE(N_{ij})								
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON									
Males	Sample size	34	2				36		36
	p_{ijk} x100	94.4	5.6						100.0
	SE(p_{ijk}) x100	3.9	3.9						0.0
	N_{ijk}	912	54						966
	SE(N_{ijk})	218	38						228
Females	Sample size								
	p_{ijk} x100								
	SE(p_{ijk}) x100	No medium females encountered during spawning ground surveys							
	N_{ijk}								
	SE(N_{ijk})								
Sexes combined	Sample size	34	2				36		36
	p_{ij} x100	94.4	5.6						100.0
	SE(p_{ij}) x100	3.9	3.9						0.0
	N_{ij}	912	54						966
	SE(N_{ij})	218	38						228

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		Brood year and age class							
		2007	2006	2005	2004	2006			
		1.2	1.3	1.4	1.5	0.4	Known Total	Unknown Age	Total
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON									
Males	Sample size	7	56	12			75	2	77
	p_{ijk} x100	4.7	37.6	8.1					51.0
	SE(p_{ijk}) x100	1.7	4.0	2.2					4.1
	N_{ijk}	190	1,523	326					2,066
	SE(N_{ijk})	75	275	102					346
Females	Sample size		46	25	2	1	74		74
	p_{ijk} x100		30.9	16.8	1.3	0.7			49.0
	SE(p_{ijk}) x100		3.8	3.1	0.9	0.7			4.1
	N_{ijk}		1,251	680	54	27			1,986
	SE(N_{ijk})		239	159	39	27			335
Sexes combined	Sample size	7	102	37	2	1	149	2	151
	p_{ij} x100	4.7	68.5	24.8	1.3	0.7			100.0
	SE(p_{ij}) x100	1.7	3.8	3.6	0.9	0.7			0.0
	N_{ij}	190	2,774	1,006	54	27			4,052
	SE(N_{ij})	75	436	206	39	27			597
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM AND LARGE CHINOOK SALMON COMBINED									
Males	Sample size	41	58	12			111	2	113
	p_{ik} x100	22.0	31.4	6.5					60.4
	SE(p_{ik}) x100	3.0	3.4	1.8					3.6
	N_{jk}	1,103	1,576	326					3,032
	SE(N_{jk})	251	287	103					512
Females	Sample size		46	25	2	1	74	0	74
	p_{ik} x100		24.9	13.5	1.1	0.5			39.6
	SE(p_{ik}) x100		3.2	2.5	0.8	0.5			3.6
	N_{jk}		1,251	680	54	27			1,986
	SE(N_{jk})		242	160	39	28			337
Sexes combined	Sample size	41	104	37	2	1	185	2	187
	p_j x100	22.0	56.3	20.1	1.1	0.5			100.0
	SE(p_j) x100	3.0	3.6	2.9	0.8	0.5			0.0
	N_j	1,103	2,827	1,006	54	27			5,018
	SE(N_j)	251	448	207	39	28			763

Note: Blank cells indicate no estimate is available or expected.

Table 8.–Average length (mm mid eye to tail fork [METF]) by age and sex of Chinook salmon sampled in the Chickamin River, 2011.

		Brood year and age class					
		2006	2007	2006	2005	2004	
		0.4	1.2	1.3	1.4	1.5	Total
Males	Sample size		41	58	12		111
	Avg. length		584	771	919		718
	SD		82	77	75		137
	SE		13	10	22		13
Females	Sample size	1		46	25	2	74
	Avg. length	880		815	880	923	841
	SD			41	64	39	60
	SE			6	13	28	7
Sexes combined	Sample size	1	41	104	37	2	185
	Avg. length	880	584	790	893	923	767
	SD		82	67	69	39	127
	SE		13	7	11		9

Note: Blank cells indicate no estimate is available or expected.

Table 9.–Age and sex composition of the escapement of small (<400 mm mid eye to tail fork [METF]), medium (≥400 and <660 mm METF), and large (≥660 mm METF) Chinook salmon in the Chickamin River in 2012 as determined from spawning grounds samples.

		Brood year and age class						
		2009	2008	2007	2006			
		1.1	1.2	1.3	1.4	Known Total	Unknown Age	Total
PANEL A: AGE COMPOSITION OF SMALL CHINOOK SALMON								
Males	Sample size	1				1		1
	p_{ijk} x100	100.0						100.0
	SE(p_{ijk}) x100	0.0						0.0
	N_{ijk}	12						12
	SE(N_{ijk})	12						12
Females	Sample size							
	p_{ijk} x100							
	SE(p_{ijk}) x100	No small females encountered during spawning ground surveys						
	N_{ijk}							
	SE(N_{ijk})							
Sexes combined	Sample size	1				1		1
	p_{ij} x100	100.0						100.0
	SE(p_{ij}) x100	0.0						0.0
	N_{ij}	12						12
	SE(N_{ij})	12						12
PANEL B: AGE COMPOSITION OF MEDIUM CHINOOK SALMON								
Males	Sample size	4	29	1		34	1	35
	p_{ijk} x100	11.8	85.3	2.9				100.0
	SE(p_{ijk}) x100	5.6	6.2	2.9				0.0
	N_{ijk}	50	364	13				427
	SE(N_{ijk})	26	89	13				100
Females	Sample size							
	p_{ijk} x100							
	SE(p_{ijk}) x100	No medium females encountered during spawning ground surveys						
	N_{ijk}							
	SE(N_{ijk})							
Sexes combined	Sample size	4	29	1		34	1	35
	p_{ij} x100	11.8	85.3	2.9				100.0
	SE(p_{ij}) x100	5.6	6.2	2.9				0.0
	N_{ij}	50	364	13				427
	SE(N_{ij})	26	89	13				100

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		Brood year and age class						
		2009	2008	2007	2006			
		1.1	1.2	1.3	1.4	Known Total	Unknown Age	Total
PANEL C: AGE COMPOSITION OF LARGE CHINOOK SALMON								
Males	Sample size		12	53	14	79		79
	p_{ijk} x100		6.9	30.6	8.1			45.7
	SE(p_{ijk}) x100		1.9	3.5	2.1			3.8
	N_{ijk}		146	646	171			963
	SE(N_{ijk})		46	120	50			163
Females	Sample size			74	20	94		94
	p_{ijk} x100			42.8	11.6			54.3
	SE(p_{ijk}) x100			3.8	2.4			3.8
	N_{ijk}			902	244			1,146
	SE(N_{ijk})			154	62			187
Sexes combined	Sample size		12	127	34	173		173
	p_{ij} x100		6.9	73.4	19.7			100.0
	SE(p_{ij}) x100		1.9	3.4	3.0			0.0
	N_{ij}		146	1,548	414			2,109
	SE(N_{ij})		46	239	88			311
PANEL D: AGE COMPOSITION OF SMALL, MEDIUM AND LARGE CHINOOK SALMON COMBINED								
Males	Sample size	5	41	54	14	114	1	115
	p_{ik} x100	2.4	20.0	25.9	6.7			55.0
	SE(p_{ik}) x100	1.1	2.8	3.0	1.7			3.4
	N_{jk}	62	510	659	171			1,402
	SE(N_{jk})	31	113	123	51			236
Females	Sample size			74	20	94		94
	p_{ik} x100			35.4	9.6			45.0
	SE(p_{ik}) x100			3.3	2.0			3.4
	N_{jk}			902	244			1,146
	SE(N_{jk})			155	63			187
Sexes combined	Sample size	5	41	128	34	208	1	209
	p_j x100	2.4	20.0	61.3	16.3			100.0
	SE(p_j) x100	1.1	2.8	3.4	2.5			0.0
	N_j	62	510	1,561	414			2,548
	SE(N_j)	31	113	241	89			384

Note: Blank cells indicate no estimate is available or expected.

Table 10.–Average length (mm METF) by age and sex of Chinook salmon sampled in the Chickamin River, 2012.

		Brood year and age class					
		2009	2008	2007	2006		
		1.1	1.2	1.3	1.4	Unknown Age	Total
Males	Sample size	5	41	54	14	1	115
	Avg. length	409	622	791	921	610	728
	SD	13	53	62	52		135
	SE	6	8	8	14		13
Females	Sample size			74	20		94
	Avg. length			810	891		827
	SD			46	42		56
	SE			5	9		6
Sexes	Sample size	5	41	128	34	1	209
combined	Avg. length	409	622	802	904	610	773
	SD	13	53	54	48		117
	SE	6	8	5	8		8

Note: Blank cells indicate no estimate is available or expected.

Table 11.–Number of fall parr (M_f) and spring smolt (M_s) released with adipose fin clips, brood years 2000–2005.

Brood year	Life stage	M_f, M_s	$\hat{M}_{f,valid}$, $\hat{M}_{s,valid}$	$\hat{v}_{\bullet,f}$, $\hat{v}_{\bullet,s}$	Recovery years	$\hat{S}$	$SE(\hat{S})$	$\hat{M}_{f\to s}$	$SE(\hat{M}_{f\to s})$	$\hat{M}$
2000	Parr	18,091	18,057	53	2003–2007	0.495	0.101	8,961	1,820	
2000	Smolt	7,455	7,425	44	2003–2007					16,416
2001	Parr	29,154	28,979	45	2004–2008	0.376	0.087	10,961	2,516	
2001	Smolt	7,793	7,748	32	2004–2008					18,754
2002	Parr	21,979	21,296	27	2005–2009	0.378	0.096	8,314	2,037	
2002	Smolt	11,048	11,039	37	2005–2009					19,362
2003	Parr	24,872	23,733	20	2006-2010	0.380	0.116	9,448	2,755	
2003	Smolt	10,456	10,368	23	2006-2010					19,904
2004	Parr	18,875	18,781	21	2007-2011	0.388	0.117	7,319	2,196	
2004	Smolt	8,012	7,976	23	2007-2011					15,331
2005	Parr	20,675	20,230	28	2008-2012	0.248	0.062	5,135	1,249	
2005	Smolt	7,030	6,819	38	2008-2012					12,165

Note: $\hat{M}_{f,valid}$, $\hat{M}_{s,valid}$ = estimated number of fall parr and spring smolt that were released with valid coded wire tags by brood year (*j*);

$\hat{v}_{\bullet,f}$, $\hat{v}_{\bullet,s}$ = number of fish with valid coded wire tags that were subsequently recovered;

$\hat{S}$ = estimated proportion of coded wire tagged parr that survived to the following spring;

$\hat{M}_{f\to s}$ = estimated number of adipose-fin clipped parr that survived to smolt;

$\hat{M}$ = estimated total number of adipose-fin clipped smolt.

Table 12.–Sampling statistics and parameter estimates for Chickamin River Chinook salmon, brood years 2000–2005.

Brood year	Recovery years	$\hat{M}$	$n_{\bullet}$	$a_{\bullet}$	$\hat{N}_{smolt}$	$SE\left(\hat{N}_{smolt}\right)$	$\hat{N}_{parr}$	$SE\left(\hat{N}_{parr}\right)$	$\hat{\theta}_j$ (%)	$SE(\hat{\theta}_j)$(%)	$\hat{\theta}_j^{-1}$	$SE(\hat{\theta}_j^{-1})$
2000	2003–2007	16,416	1,898	87	354,262	53,584	715,237	181,348	4.41	0.47	22.67	2.51
2001	2004–2008	18,754	860	56	283,305	52,098	753,503	222,417	5.99	0.81	16.69	2.41
2002	2005–2009	19,362	939	43	413,660	74,026	1,093,577	338,753	4.16	0.68	24.02	4.23
2003	2006–2009	19,904	520	33	305,019	64,972	802,939	299,054	5.34	1.00	18.71	3.69
2004	2007–2011	15,331	498	44	170,013	33,967	438,453	158,599	7.07	1.20	14.15	2.61
2005	2008–2012	12,165	675	41	195,814	35,110	788,398	241,703	4.56	0.80	21.95	4.28

Note: Parameter definitions are as follows:
the estimated total number of smolt released with adipose fin clips ($\widehat{M}$)
the number of returning adults that were examined inriver for the presence of an adipose fin clip $n_{\bullet}$,
the number of fish examined that possessed an adipose fin clip $a_{\bullet}$,
the estimated abundance of smolt ($\widehat{N}_{smolt}$) and associated standard error of the estimate SE($\widehat{N}_{smolt}$),
the estimated abundance of parr ($\widehat{N}_{parr}$) and associated error of the estimate $SE\left(\widehat{N}_{parr}\right)$,
the estimated fraction of adults bearing CWTs ($\hat{\theta}_j$) and associated standard error of the estimate SE($\hat{\theta}_j$),
the estimated inverse of the fraction of adults bearing CWTs ($\hat{\theta}_j^{-1}$) and associated standard error of the estimate SE($\hat{\theta}_j^{-1}$), 2000–2005 brood years (*j*).

Table 13.–Numbers of adult Chinook salmon examined on the Chickamin River and found to be marked by brood year and sample type, 2000 brood year to 2012, recovered and marked as juveniles and smolt with coded wire tags (CWTs).

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags	Percent valid tags	Percent adipose clipped	Fraction bearing CWTs	Event
2000	1.1	2003	14	0	0	0	0.0	0.0	0.0	1
2000	1.1	2003	30	1	1	1	100.0	3.3	3.3	2
2000	1.2	2004	212	9	9	9	100.0	4.2	4.2	1
2000	1.2	2004	485	26	26	24	92.3	5.4	4.9	2
2000	1.3	2005	235	10	0	0	0.0	4.3	0.0	1
2000	1.3	2005	719	29	10	10	100.0	4.0	4.0	2
2000	1.4	2006	197	11	6	6	100.0	5.6	5.6	1
2000	1.5	2007	6	1	1	1	100.0	16.7	16.7	2
2000 Brood year total			1,898	87	53	51	96.2	4.6	4.4	1&2
2001	1.1	2004	8	1	1	1	100.0	12.5	12.5	1
2001	1.1	2004	56	3	3	3	100.0	5.4	5.4	2
2001	1.2	2005	83	4	4	4	100.0	4.8	4.8	1
2001	1.2	2005	214	9	8	8	100.0	4.2	4.2	2
2001	2.1	2005	2	0	0	0	0.0	0.0	0.0	1
2001	1.3	2006	352	27	4	3	75.0	7.7	5.8	2
2001	2.2	2006	2	0	0	0	0.0	0.0	0.0	2
2001	1.4	2007	142	12	5	4	80.0	8.5	6.8	2
2001	1.5	2008	1	0	0	0	0.0	0.0	0.0	2
2001 Brood year total			860	56	25	23	92.0	6.5	6.0	1&2
2002	1.1	2005	16	1	1	1	100.0	6.3	6.3	2
2002	1.1	2005	61	5	5	4	80.0	8.2	6.6	1
2002	1.2	2006	206	6	5	5	100.0	2.9	2.9	2
2002	1.3	2007	556	22	11	10	90.9	4.0	3.6	2
2002	1.4	2008	84	5	0	0	0.0	6.0	0.0	2
2002	1.5	2009	16	4	0	0	0.0	25.0	0.0	2
2002 Brood year total			939	43	22	20	90.9	4.6	4.2	1&2
2003	1.1	2006	14	0	0	0	0.0	0.0	0.0	2
2003	1.2	2007	169	15	13	11	84.6	8.9	7.5	2
2003	1.3	2008	244	11	2	2	100.0	4.5	4.5	2
2003	1.4	2009	93	7	4	3	75.0	7.5	5.6	1
2003 Brood year total			520	33	19	16	84.2	6.3	5.3	1&2

-continued-

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Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags	Percent valid tags	Percent adipose clipped	Fraction bearing CWTs	Event
2004	1.1	2007	24	2	2	2	100.0	8.3	8.3	2
2004	1.2	2008	98	8	5	3	60.0	8.2	4.9	1
2004	1.3	2009	243	16	9	7	77.8	6.6	5.1	2
2004	1.4	2010	131	18	4	4	100.0	13.7	13.7	1
2004	1.5	2011	2	0	0	0	0.0	0.0	0.0	2
2004 Brood year total			498	44	20	16	80.0	8.8	7.1	1&2
2005	1.1	2008	28	3	3	3	100.0	10.7	10.7	1
2005	1.2	2009	239	15	10	8	80.0	6.3	5.0	2
2005	1.3	2010	371	22	6	4	66.7	5.9	4.0	1
2005	1.4	2011	37	1	1	0	0.0	2.7	0.0	2
2005 Brood year total			675	41	20	15	75.0	6.1	4.6	1&2

Note: Return year 2012 not included because no age-1.5 fish from the 2005 brood year were recovered during sampling.

Table 14.–Exploitation of Chickamin Chinook salmon in all marine fisheries by brood and return year.

	Return year									
Brood year	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total return
2000	23	429	1,834	839	117					3,243
SE	22	191	419	269	82					540
2001			307	1,915	817	73				3,112
SE			120	415	283	73				521
2002			24	977	1,579	230				2,810
SE			24	331	339	134				493
2003					591	720	563			1,874
SE					322	192	403			550
2004						126	519	338		983
SE						68	143	142		212
2005							1,799	1,256	752	3,807
SE							655	257	621	939

Note: Return year 2012 not included because no age-1.5 fish from the 2005 brood year were recovered during sampling. Blank cells indicate no estimate is available or expected.

Table 15.–Chickamin River Chinook salmon escapement and harvest rate estimates by gear group of ≥age-1.2 fish, run years 2006–2009.

	Run year				2006–2009
	2006	2007	2008	2009	Average
Escapement[a,b]	7,009	4,854	6,292	3,808	5,491
Harvest	3,732	3,105	1,149	2,881	2,717
Total Run	10,741	7,959	7,441	6,690	8,208
Harvest Rate					
Troll Winter	0.05	0.05	0.04	0.03	0.04
Troll Spring	0.05	0.06	0.04	0.03	0.05
Troll Summer R1[c]	0.03	0.05	0.04	0.08	0.05
Troll Summer R2[c]	0.04	0.04	0.00	0.01	0.03
Troll All	0.17	0.21	0.12	0.15	0.16
Sport Early[D]	0.10	0.15	0.00	0.18	0.11
Sport Late[D]	0.01	0.01	0.00	0.00	0.00
Sport All	0.10	0.17	0.00	0.18	0.11
Net All	0.05	0.01	0.03	0.09	0.04
U.S. All	0.32	0.38	0.14	0.42	0.31
Canada All	0.03	0.01	0.01	0.01	0.02
Total	0.35	0.39	0.15	0.43	0.33

[a] The biological escapement goal (BEG) range for the Chickamin River is 2,150 to 4,300 large (≥660 mm mid eye to tail fork) Chinook salmon.

[b] Data from Johnson et al. 2009, reproduced in Appendix A3.

[c] Troll Summer R1 (retention period 1) occurs in July of the current year; Troll Summer R2 (retention period 2) occurs from August through September of the prior year.

[d] Sport Early period occurs April through July of the current year; Sport Late period occurs in August of the prior year.

Table 16.–Unuk and Chickamin River Chinook salmon calendar year harvest rate estimates of ≥age-1.2 fish, run years 2006–2009.

Stock	Statistic	Run Year 2006	2007	2008	2009	2006–2009 Average
Unuk River[a]	Est	0.23	0.24	0.18	0.19	0.21
	SE	0.03	0.03	0.03	0.03	0.03
Chickamin River	Est	0.35	0.39	0.15	0.43	0.33
	SE	0.04	0.05	0.03	0.07	0.05

[a] *Source*: Nathan Frost, Fishery Biologist, 2022, unpublished data; Division of Commercial Fisheries, Ketchikan.

Table 17.–Exploitation, incidental mortality, spawning abundance, and total return of Chickamin River Chinook salmon by age class, brood years 2000–2005.

Brood year	Exploitation: Age class 1.1	1.2	1.3	≥1.4	Total	Incidental mortality[a]: Age class 1.1	1.2	1.3	≥1.4	Total	Spawning abundance: Age class 1.1	1.2	1.3	≥1.4	Total	Total return: Age class 1.1	1.2	1.3	≥1.4	Total
2000	23	429	1,834	957	3,243	488	393	57	33	971	222	2,077	3,253	1,882	7,434	733	2,899	5,145	2,872	11,649
SE	22	191	419	281	540						64	220	452	294	586	68	291	616	407	797
2001	0	307	1,915	890	3,112	501	321	71	34	927	186	1,020	3,264	804	5,274	687	1,647	5,250	1,728	9,313
SE	0	120	415	292	521						43	204	491	132	549	43	237	643	320	757
2002	24	977	1,579	230	2,810	489	519	65	8	1,081		1,897	3,090	1,284	6,271	513	3,393	4,734	1,522	10,162
SE	24	331	339	134	493							242	456	218	560	24	410	568	256	746
2003	0	591	720	563	1,874	454	321	7	11	793	123	941	3,598	609	5,271	577	1,853	4,325	1,183	7,938
SE	0	322	192	403	550						38	125	536	106	562	38	345	569	416	786
2004	0	126	519	338	983	361	111	14	3	489	130	1,441	1,592	1,314	4,477	491	1,678	2,125	1,655	5,948
SE	0	68	143	142	212						34	217	246	213	393	34	227	284	256	446
2005	0	1,799	1,256	752	3,807	199	688	25	92	1,003	403	1,562	3,566	1,006	6,537	602	4,049	4,847	1,850	11,347
SE	0	655	257	621	939						99	252	538	207	636	99	702	596	655	1,134

[a] Incidental mortality values calculated by the PSC CTC (CTC 2021); SE not available.

Table 18.–Adult equivalent values for Chickamin River Chinook salmon by age class, brood years 2000–2005.

	Age class			
Brood year	1.1	1.2	1.3	≥1.4
2000	0.5604	0.7929	0.9531	1.0000
2001	0.5569	0.7955	0.9635	1.0000
2002	0.5715	0.8165	0.9632	1.0000
2003	0.5737	0.8124	0.9803	1.0000
2004	0.5765	0.8152	0.9492	1.0000
2005	0.5729	0.8046	0.9620	1.0000

Note: Adult equivalent values were calculated by the PSC CTC (CTC 2021).

Table 19.–Exploitation, incidental mortality, spawning abundance, and total return of Chickamin River Chinook salmon in adult equivalents by age class, brood years 2000–2005.

Brood year	Exploitation					Incidental mortality[a]					Spawning abundance					Total return				
	Age class					Age class					Age class					Age class				
	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total
2000	13	340	1,748	957	3,058	274	311	55	33	673	222	2,077	3,253	1,882	7,434	508	2,729	5,056	2,872	11,165
SE	12	151	399	281	511						64	220	452	294	586	65	267	603	407	778
2001	0	244	1,845	890	2,980	279	255	68	34	636	186	1,020	3,264	804	5,274	465	1,519	5,178	1,728	8,890
SE	0	95	400	292	504						43	204	491	132	549	43	225	633	320	746
2002	14	798	1,521	230	2,563	279	424	62	8	774	0	1,897	3,090	1,284	6,271	293	3,119	4,674	1,522	9,608
SE	13	270	327	134	445						0	242	456	218	560	13	363	561	256	715
2003	0	480	706	563	1,749	260	261	7	11	539	123	941	3,598	609	5,271	383	1,682	4,311	1,183	7,559
SE	0	261	188	403	516						38	125	536	106	562	38	290	568	416	763
2004	0	102	493	338	933	208	90	13	3	315	130	1,441	1,592	1,314	4,477	338	1,634	2,098	1,655	5,725
SE	0	55	136	142	204						34	217	246	213	393	34	224	281	256	442
2005	0	1,448	1,208	752	3,408	114	553	24	92	783	403	1,562	3,566	1,006	6,537	517	3,563	4,798	1,850	10,727
SE	0	527	247	621	852						99	252	538	207	636	99	584	592	655	1,063

[a] Incidental mortality values calculated by the PSC CTC (CTC 2021); SE not available.

Table 20.–Exploitation (PANEL A) and proportion of exploitation (PANEL B) by gear type of Chickamin River Chinook salmon, brood years 2000–2005.

PANEL A: EXPLOITATION

	Gear type					
Brood year	Gillnet	Seine	Recreational	Terminal/ PNP	Troll	Total
2000	83	123	1,014	0	2,022	3,243
SE	64	103	357	0	387	540
2001	20	143	1,309	0	1,641	3,112
SE	19	83	399	0	324	521
2002	108	320	893	0	1,489	2,810
SE	64	194	325	0	309	493
2003	65	0	886	109	813	1,874
SE	46	0	505	109	183	550
2004	22	183	0	0	777	983
SE	22	119	0	0	174	212
2005	678	22	833	696	1,579	3,807
SE	282	21	571	622	298	939
Total	977	791	4,936	805	8,321	15,829

PANEL B: PROPORTION OF EXPLOITATION

	Gear type					
Brood year	Gillnet	Seine	Recreational	Terminal/ PNP	Troll	Total
2000	0.03	0.04	0.31	0.00	0.62	1.00
2001	0.01	0.05	0.42	0.00	0.53	1.00
2002	0.04	0.11	0.32	0.00	0.53	1.00
2003	0.03	0.00	0.47	0.06	0.43	1.00
2004	0.02	0.19	0.00	0.00	0.79	1.00
2005	0.18	0.01	0.22	0.18	0.41	1.00
Total	0.06	0.05	0.31	0.05	0.53	1.00

Table 21.–Exploitation (PANEL A) and proportion of exploitation (PANEL B) by location of Chickamin River Chinook salmon, brood years 2000–2005.

PANEL A: EXPLOITATION

	Location					
Brood year	British Columbia	Northeast Quadrant	Northwest Quadrant	Southeast Quadrant	Southwest Quadrant	Total
2000	154	204	1,202	1,507	176	3,243
SE	113	125	324	376	130	540
2001	295	223	875	1,550	170	3,112
SE	199	182	222	365	129	521
2002	45	369	743	1,653	0	2,810
SE	44	153	251	394	0	493
2003	49	98	365	1,362	0	1,874
SE	49	56	130	529	0	550
2004	0	58	433	425	67	983
SE	0	33	130	157	49	212
2005	0	205	370	2,899	332	3,807
SE	0	84	150	902	198	939
Total	542	1,158	3,987	9,395	746	15,829

PANEL B: PROPORTION OF EXPLOITATION

	Location					
Brood year	British Columbia	Northeast Quadrant	Northwest Quadrant	Southeast Quadrant	Southwest Quadrant	Total
2000	0.05	0.06	0.37	0.46	0.05	1.00
2001	0.09	0.07	0.28	0.50	0.05	1.00
2002	0.02	0.13	0.26	0.59	0.00	1.00
2003	0.03	0.05	0.19	0.73	0.00	1.00
2004	0.00	0.06	0.44	0.43	0.07	1.00
2005	0.00	0.05	0.10	0.76	0.09	1.00
Total	0.03	0.07	0.25	0.59	0.05	1.00

Table 22.–Parameter estimates and standard error (SE) for Chickamin River Chinook salmon, brood years 2000–2005.

Brood year	$\hat{N}_{Smolt}$	$\hat{N}$	$\hat{R}$	IM	$\hat{FM}$	$\hat{T}$	$\hat{U}$ (%)	$\hat{Q}$ (%)
2000	354,262	7,434	3,243	971	4,215	11,649	36.2	3.3
SE	53,584	586	540		540	797	3.5	0.5
2001	283,305	5,274	3,112	927	4,039	9,313	43.4	3.3
SE	52,098	549	521		521	757	4.1	0.7
2002	413,660	6,271	2,810	1,081	3,891	10,162	38.3	2.5
SE	74,026	560	493		493	746	3.7	0.5
2003	305,019	5,271	1,874	793	2,667	7,938	33.6	2.6
SE	64,972	562	550		550	786	5.2	0.6
2004	170,013	4,477	983	489	1,472	5,948	24.7	3.5
SE	33,967	393	212		212	446	3.1	0.7
2005	195,814	6,537	3,807	1,003	4,810	11,347	42.4	5.8
SE	35,110	636	939		939	1,134	5.3	1.2

Note: Parameter definitions are as follows:

Smolt ($\hat{N}_{Smolt}$)

Spawning abundance ($\hat{N}$)

Exploitation ($\hat{R}$)

Incidental fishing mortality (IM), SE not available

Fishing mortality ($\widehat{FM}$)

Total return or production ($\hat{T}$), exploitation rate ($\hat{U}$), and marine survival rate ($\hat{Q}$).

Table 23.–Parameter estimates and standard error (SE) for Chickamin River Chinook salmon in adult equivalents, brood years 2000–2005.

Brood year	$\hat{N}_{Smolt}$	$\hat{N}$	$\hat{R}$	IM	$F\hat{M}$	$\hat{T}$	$\hat{U}$ (%)	$\hat{Q}$ (%)
2000	354,262	7,434	3,058	673	3,731	11,165	33.4	3.2
SE	53,584	586	511		511	778	3.5	0.5
2001	283,305	5,274	2,980	636	3,616	8,890	40.7	3.1
SE	52,098	549	504		504	746	4.2	0.6
2002	413,660	6,271	2,563	774	3,337	9,608	34.7	2.3
SE	74,026	560	445		445	715	3.6	0.5
2003	305,019	5,271	1,749	539	2,288	7,559	30.3	2.5
SE	64,972	562	516		516	763	5.3	0.6
2004	170,013	4,477	933	315	1,248	5,725	21.8	3.4
SE	33,967	393	204		204	442	3.2	0.7
2005	195,814	6,537	3,408	783	4,190	10,727	39.1	5.5
SE	35,110	636	852		852	1,063	5.4	1.1

Note: Parameter definitions are as follows:

Smolt ($\hat{N}_{Smolt}$)

Spawning abundance ($\hat{N}$)

Exploitation ($\hat{R}$)

Incidental fishing mortality (IM), SE not available

Fishing mortality ($\widehat{FM}$)

Total return or production ($\hat{T}$), exploitation rate ($\hat{U}$), and marine survival rate ($\hat{Q}$) in adult equivalents.

Table 24.–Harvest, incidental mortality, spawning abundance, and total run of Chickamin River Chinook salmon by age class, run years 2003–2011.

Run year	Harvest					Incidental mortality[a]					Spawning abundance					Total run				
	Age class					Age class					Age class					Age class				
	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total
2003	23				23	488				488	222				222	733				733
SE	22				22						64				64	68				68
2004	0	429			429	501	393			894	186	2,077			2,263	687	2,899			3,586
SE	0	191			191						43	220			224	43	291			294
2005	24	307	1,834		2,165	489	321	57		867	0	1,020	3,253		4,273	513	1,647	5,145		7,305
SE	24	120	419		436						0	204	452		496	24	237	616		660
2006	0	977	1,915	957	3,849	454	519	71	33	1,077	123	1,897	3,264	1,882	7,166	577	3,393	5,250	2,872	12,092
SE	0	331	415	281	601						38	242	491	294	623	38	410	643	407	865
2007	0	591	1,579	890	3,061	361	321	65	34	781	130	941	3,090	804	4,965	491	1,853	4,734	1,728	8,807
SE	0	322	339	292	551						34	125	456	132	492	34	345	568	320	739
2008	0	126	720	230	1,076	199	111	7	8	325	403	1,441	3,598	1,284	6,726	602	1,678	4,325	1,522	8,126
SE	0	68	192	134	244						99	217	536	218	626	99	227	569	256	672
2009		1,799	519	563	2,881		688	14	11	712		1,562	1,592	609	3,763		4,049	2,125	1,183	7,356
SE		655	143	403	782							252	246	106	367		702	284	416	864
2010			1,256	338	1,593			25	3	28			3,566	1,314	4,880			4,847	1,655	6,501
SE			257	142	294								538	213	579			596	256	649
2011				752	752				92	92				1,006	1,006				1,850	1,850
SE				621	621									207	207				655	655

Note: Blank cells indicate no estimate is available or expected.

[a] Incidental mortality values calculated by the PSC CTC (CTC 2021); SE not available.

Table 25.–Harvest, incidental mortality, spawning abundance, and total run of Chickamin River Chinook salmon in adult equivalents by age class, run years 2003–2011.

Run year	Harvest					Incidental mortality[a]					Spawning abundance					Total run				
	Age class					Age class					Age class					Age class				
	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total	1.1	1.2	1.3	≥1.4	Total
2003	13				13	274				274	222				222	508				508
SE	12				12						64				64	65				65
2004	0	340			340	279	311			590	186	2,077			2,263	465	2,729			3,194
SE	0	151			151						43	220			224	43	267			271
2005	14	244	1,748		2,006	279	255	55		589	0	1,020	3,253		4,273	293	1,519	5,056		6,868
SE	13	95	399		411						0	204	452		496	13	225	603		644
2006	0	798	1,845	957	3,600	260	424	68	33	786	123	1,897	3,264	1,882	7,166	383	3,119	5,178	2,872	11,552
SE	0	270	400	281	558						38	242	491	294	623	38	363	633	407	836
2007	0	480	1,521	890	2,892	208	261	62	34	566	130	941	3,090	804	4,965	338	1,682	4,674	1,728	8,422
SE	0	261	327	292	510						34	125	456	132	492	34	290	561	320	709
2008	0	102	706	230	1,038	114	90	7	8	219	403	1,441	3,598	1,284	6,726	517	1,634	4,311	1,522	7,983
SE	0	55	188	134	237						99	217	536	218	626	99	224	568	256	669
2009		1,448	493	563	2,503		553	13	11	577		1,562	1,592	609	3,763		3,563	2,098	1,183	6,843
SE		527	136	403	677							252	246	106	367		584	281	416	770
2010			1,208	338	1,546			24	3	27			3,566	1,314	4,880			4,798	1,655	6,453
SE			247	142	285								538	213	579			592	256	645
2011				752	752				92	92				1,006	1,006				1,850	1,850
SE				621	621									207	207				655	655

Note: Blank cells denote no estimate is available or expected.

[a] Incidental mortality values calculated by the PSC CTC (CTC 2021); SE not available.

Table 26.–Harvest (PANEL A) and proportion of harvest (PANEL B) by gear type of ≥age-1.2 Chickamin River Chinook salmon, run years 2006–2009.

PANEL A: HARVEST

	Gear type					
Run year	Gillnet	Seine	Recreational	Terminal/ PNP	Troll	Total
2006	84	403	1,376	0	1,868	3,732
SE	60	207	407	0	377	595
2007	49	0	1,314	0	1,742	3,105
SE	34	0	452	0	315	553
2008	62	24	73	109	880	1,149
SE	45	24	73	109	212	254
2009	542	77	1,246	0	1,016	2,881
SE	271	59	694	0	231	782
Total	738	505	4,009	109	5,505	10,867

PANEL B: PROPORTION OF HARVEST

	Gear type					
Run year	Gillnet	Seine	Recreational	Terminal/ PNP	Troll	Total
2006	0.02	0.11	0.37	0.00	0.50	1.00
2007	0.02	0.00	0.42	0.00	0.56	1.00
2008	0.05	0.02	0.06	0.10	0.77	1.00
2009	0.19	0.03	0.43	0.00	0.35	1.00
Total	0.07	0.05	0.37	0.01	0.51	1.00

Table 27.–Harvest (PANEL A) and proportion of harvest (PANEL B) by location of ≥age-1.2 Chickamin River Chinook salmon, run years 2006–2009.

PANEL A: HARVEST

Run year	Harvest location: British Columbia	Northeast Quadrant	Northwest Quadrant	Southeast Quadrant	Southwest Quadrant	Total
2006	320	355	1,092	1,915	49	3,732
SE	210	205	288	427	49	595
2007	101	309	855	1,720	120	3,105
SE	71	141	250	451	120	553
2008	73	70	540	442	24	1,149
SE	73	49	179	157	23	254
2009	49	66	385	2,006	376	2,881
SE	49	38	131	742	203	782
Total	542	800	2,872	6,083	570	10,867

PANEL B: PROPORTION OF HARVEST

Run year	Harvest location: British Columbia	Northeast Quadrant	Northwest Quadrant	Southeast Quadrant	Southwest Quadrant	Total
2006	0.09	0.10	0.29	0.51	0.01	1.00
2007	0.03	0.10	0.28	0.55	0.04	1.00
2008	0.06	0.06	0.47	0.38	0.02	1.00
2009	0.02	0.02	0.13	0.70	0.13	1.00
Total	0.05	0.07	0.26	0.56	0.05	1.00

Table 28.–Parameter estimates and standard error (SE) of age ≥1.2 Chickamin River Chinook salmon, run years 2006–2009.

				Without IM			With IM		
Run year	$\hat{N}$ [a]	$\hat{R}$	IM	$F\hat{M}$	$\hat{T}$	$\hat{U}$ (%)	$F\hat{M}$	$\hat{T}$	$\hat{U}$ (%)
2006	7,009	3,849	623	3,849	10,858	35.4	4,472	11,481	39.0
SE	621	601		601	864	4.1	601	864	3.8
2007	4,854	3,061	420	3,061	7,915	38.7	3,481	8,335	41.8
SE	491	551		551	738	4.9	551	738	4.6
2008	6,292	1,076	126	1,076	7,368	14.6	1,202	7,494	16.0
SE	618	244		244	664	3.1	244	664	3.0
2009	3,808	2,881	712	2,881	6,690	43.1	3,594	7,402	48.5
SE	368	782		782	865	7.1	782	865	5.9

[a] Data from Johnson et al. 2009.

Note: Parameter definitions are as follows:

Spawning abundance ($\hat{N}$)

Harvest ($\hat{R}$)

Incidental fishing mortality (IM), SE not available

Fishing mortality ($\widehat{FM}$)

Total run ($\hat{T}$) and harvest rate ($\hat{U}$)

Table 29.–Parameter estimates and standard error (SE) of age ≥1.2 Chickamin River Chinook salmon in adult equivalents, run years 2006–2009.

Run year	$\hat{N}$ [a]	$\hat{R}$	IM	Without IM $\hat{FM}$	Without IM $\hat{T}$	Without IM $\hat{U}$ (%)	With IM $\hat{FM}$	With IM $\hat{T}$	With IM $\hat{U}$ (%)
2006	7,009	3,600	526	3,600	10,609	33.9	4,125	11,134	37.1
SE	621	558		558	836	4.0	558	836	3.8
2007	4,854	2,892	357	2,892	7,746	37.3	3,249	8,103	40.1
SE	491	510		510	708	4.8	510	708	4.5
2008	6,292	1,038	105	1,038	7,330	14.2	1,144	7,436	15.4
SE	618	237		237	662	3.0	237	662	3.0
2009	3,808	2,503	577	2,503	6,312	39.7	3,080	6,889	44.7
SE	368	677		677	771	6.9	677	771	5.9

[a] Data from Johnson et al. 2009.

Note: Parameter definitions are as follows:

Spawning abundance ($\hat{N}$)

Harvest ($\hat{R}$),

incidental fishing mortality (IM), SE not available

fishing mortality ($\widehat{FM}$)

Total run ($\hat{T}$) and harvest rate ($\hat{U}$)

FIGURES

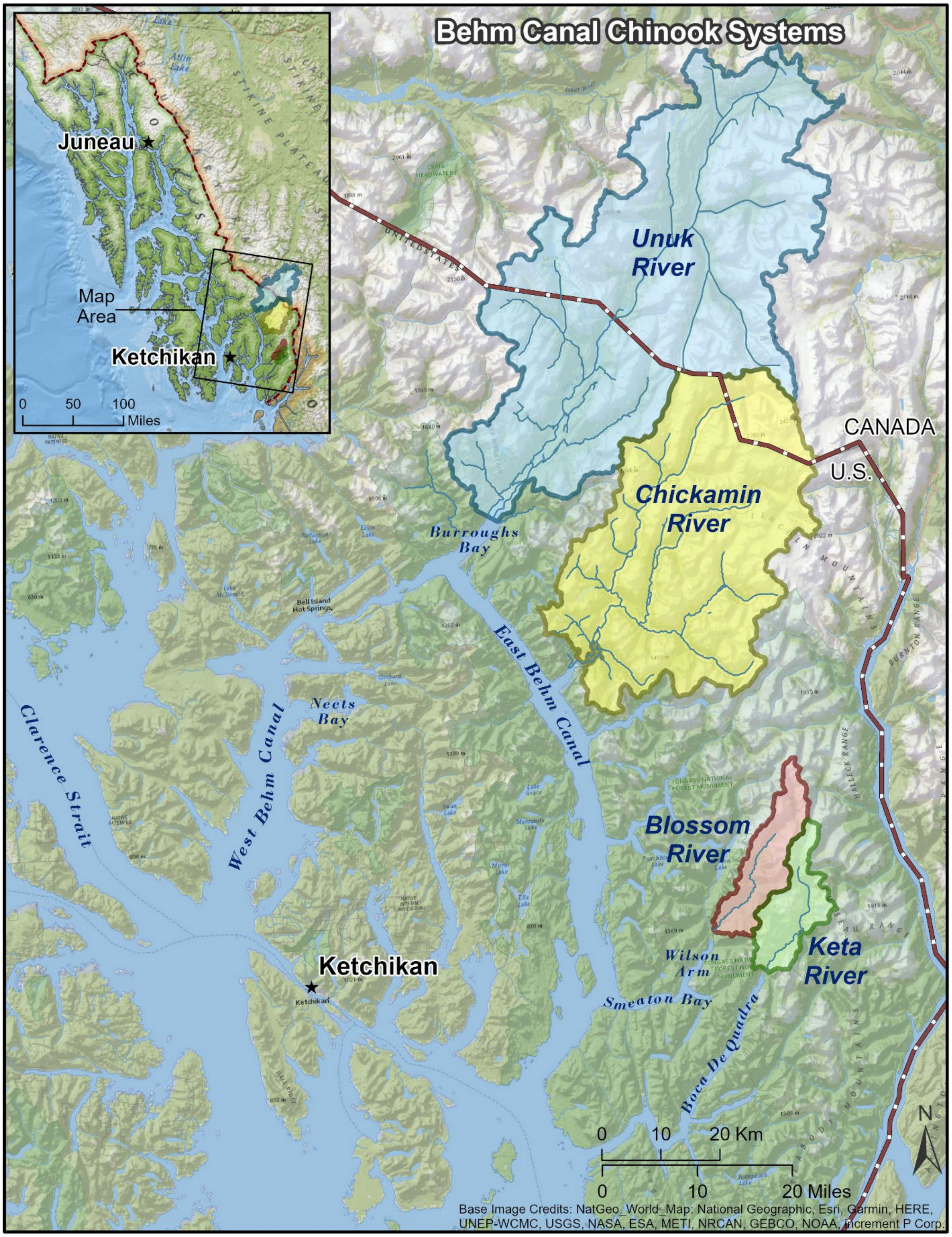

Figure 1.–Behm Canal area in Southern Southeast Alaska (inset), showing major Chinook salmon systems, including the Unuk, Chickamin, Blossom, and Keta Rivers.

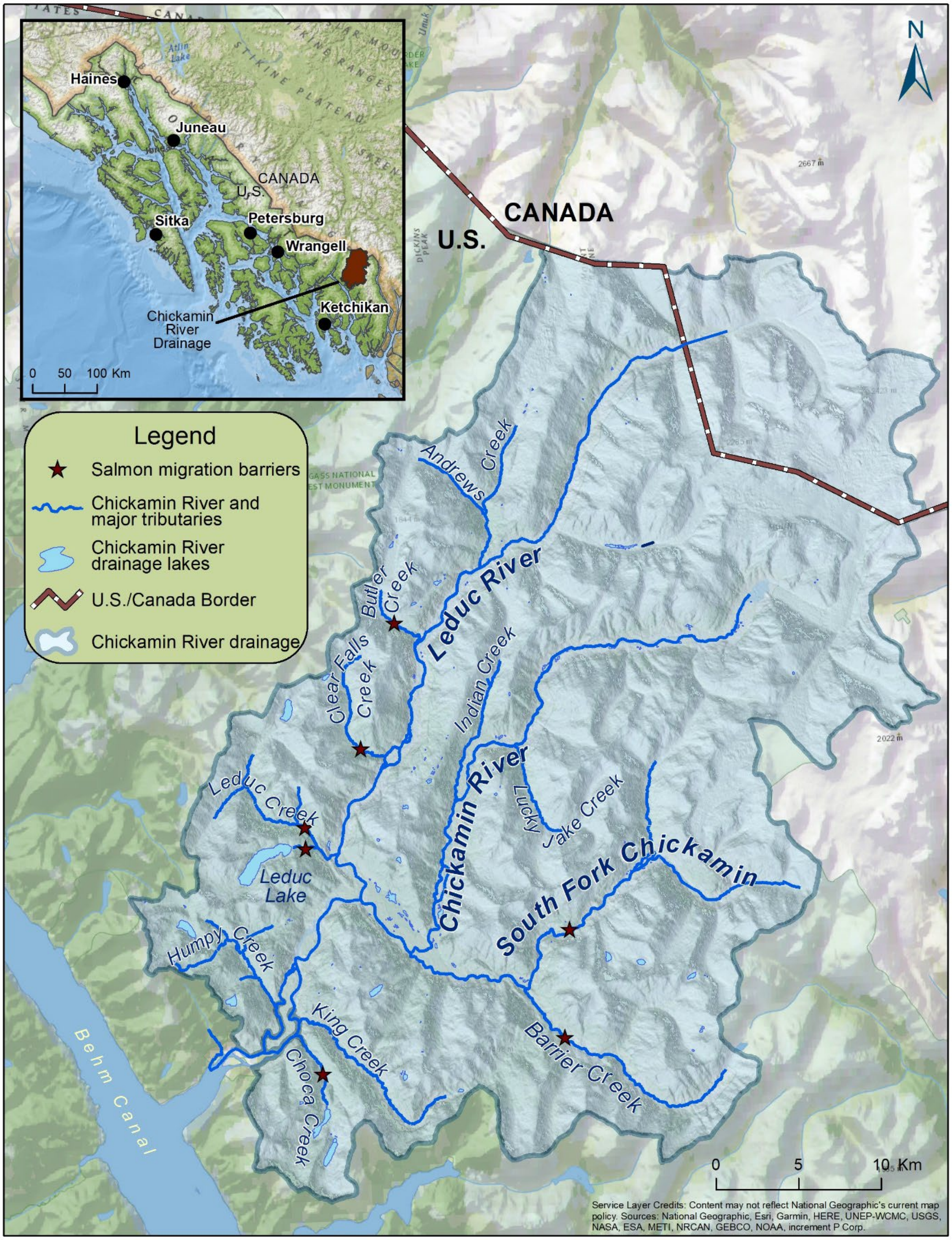

Figure 2.–The Chickamin River drainages in Southeast Alaska, showing location of major tributaries and barriers to fish migration.

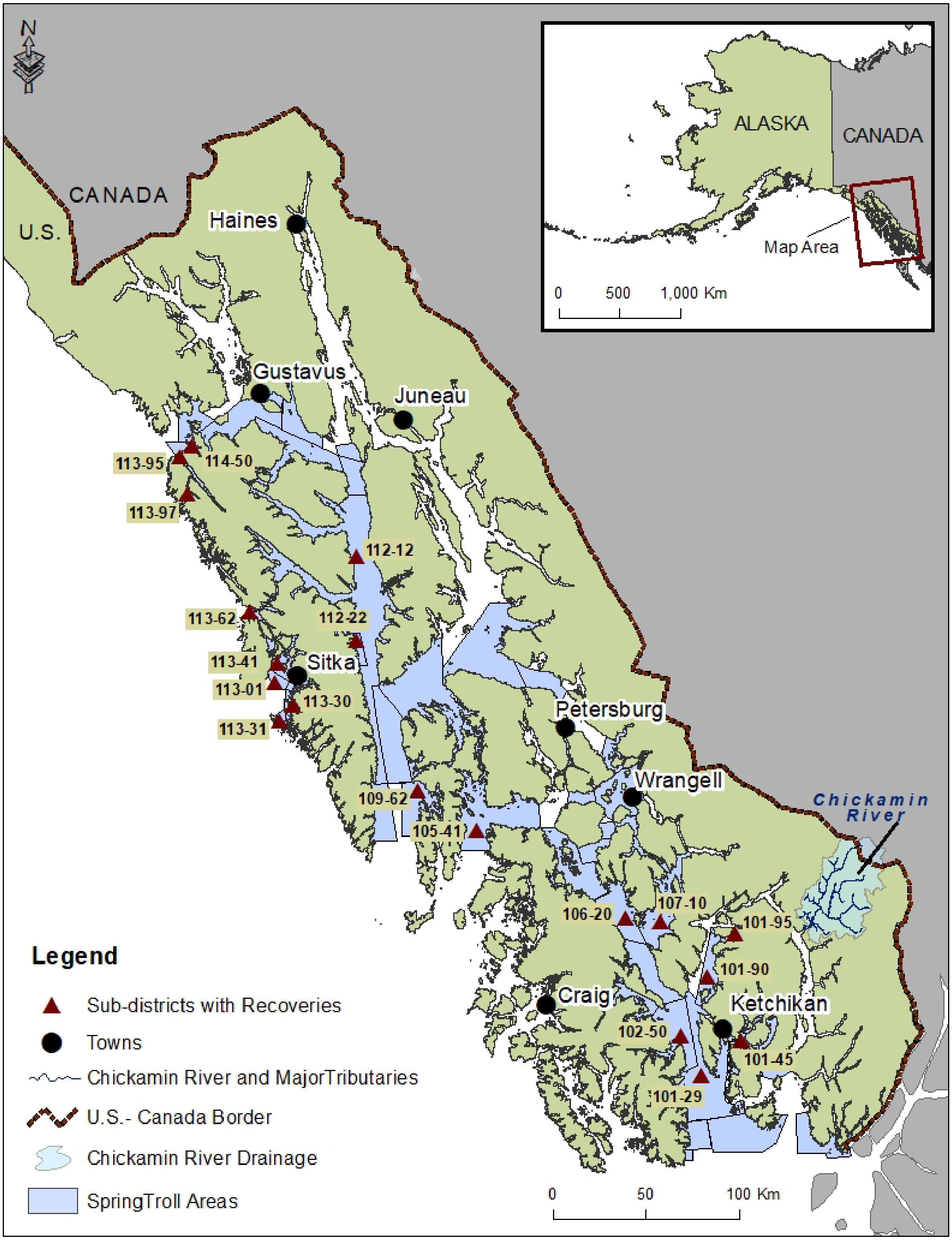

Figure 3.–Southeast Alaska experimental troll fishing areas as of 2012 (district/subdistrict) from which Chinook salmon with Chickamin river CWTs were recovered from 2003–2011.

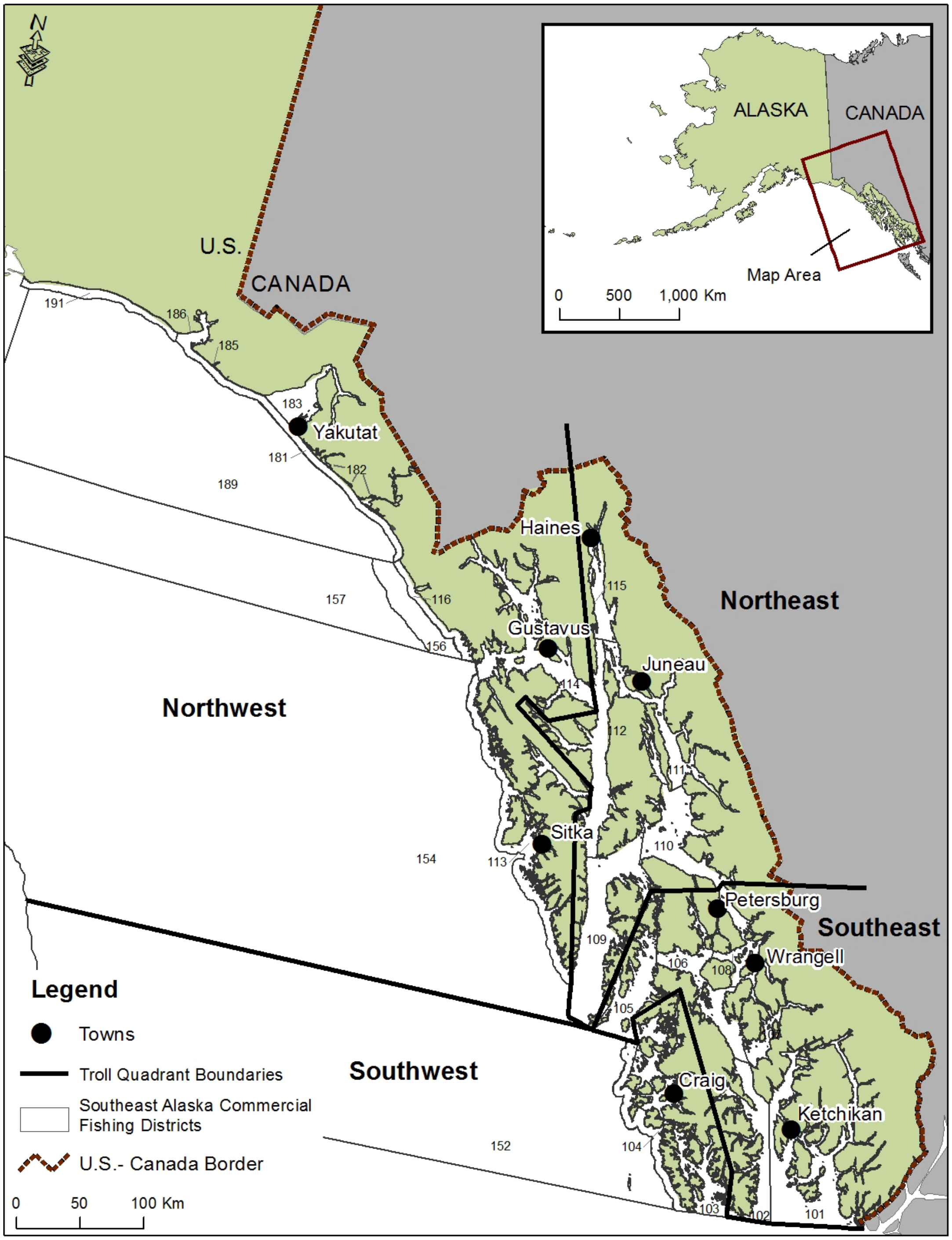

Figure 4.–Southeast Alaska troll fishery quadrants.

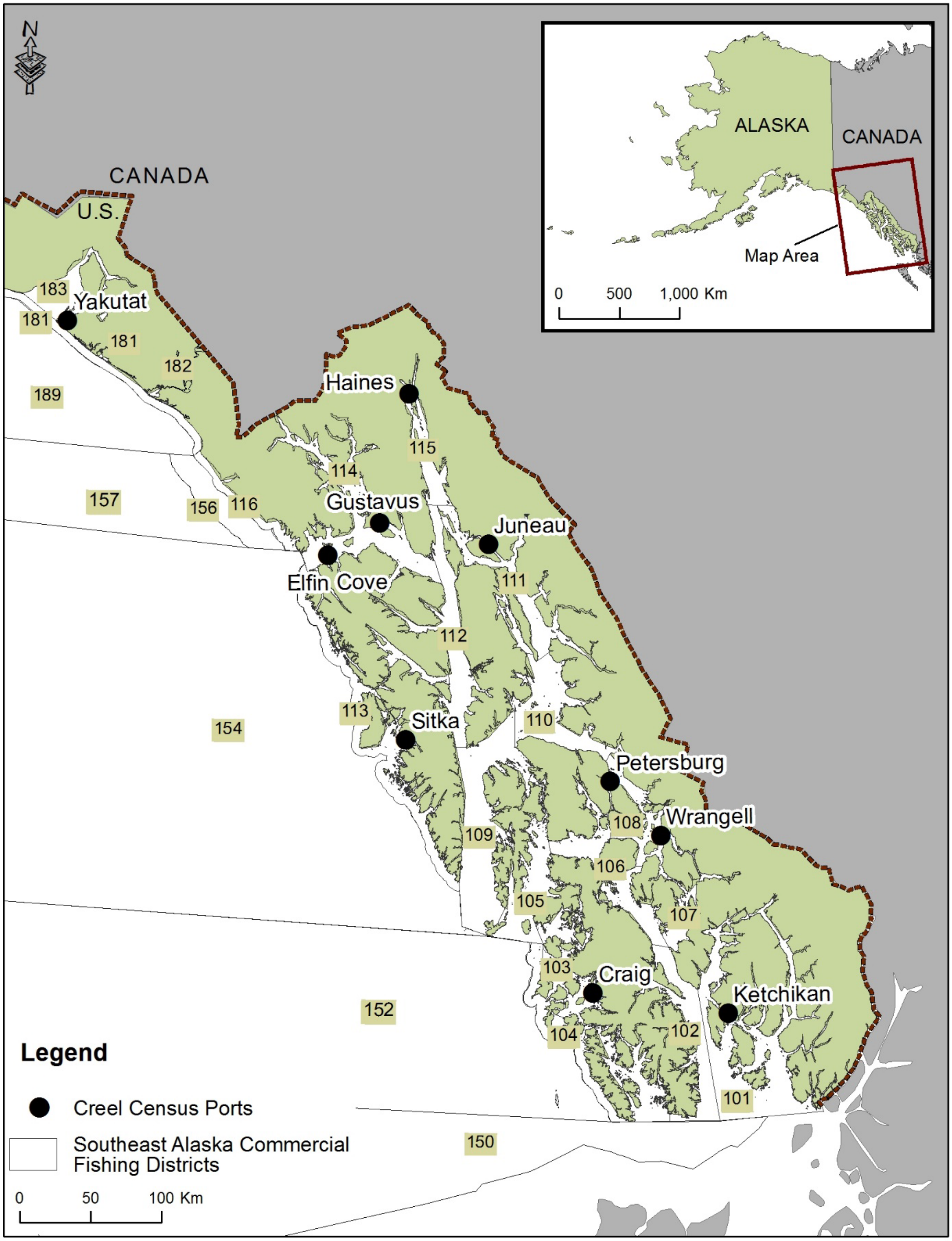

Figure 5.–Southeast Alaska commercial fishing districts and creel sampling ports as of 2012.

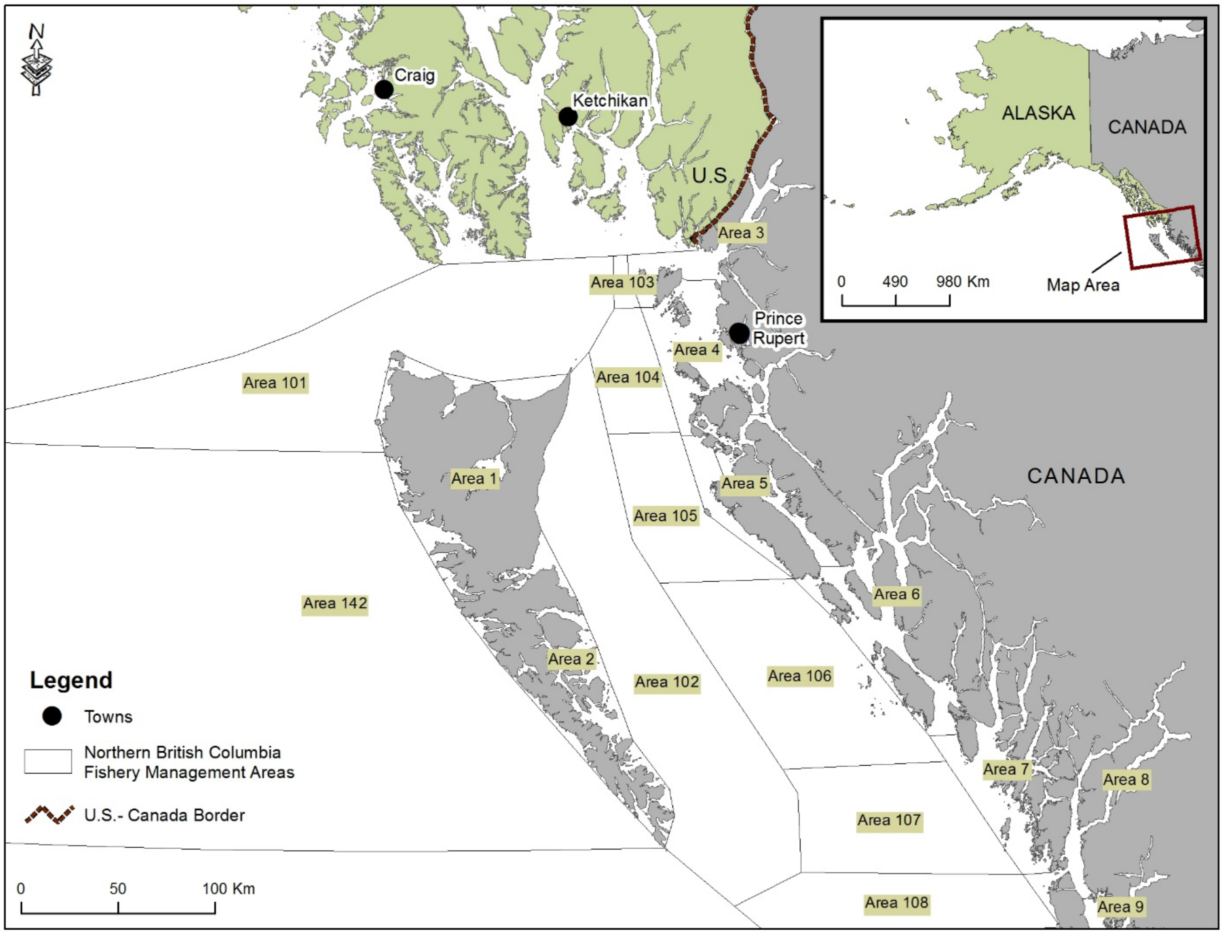

Figure 6.–Northern British Columbia fishery management areas as of 2012.

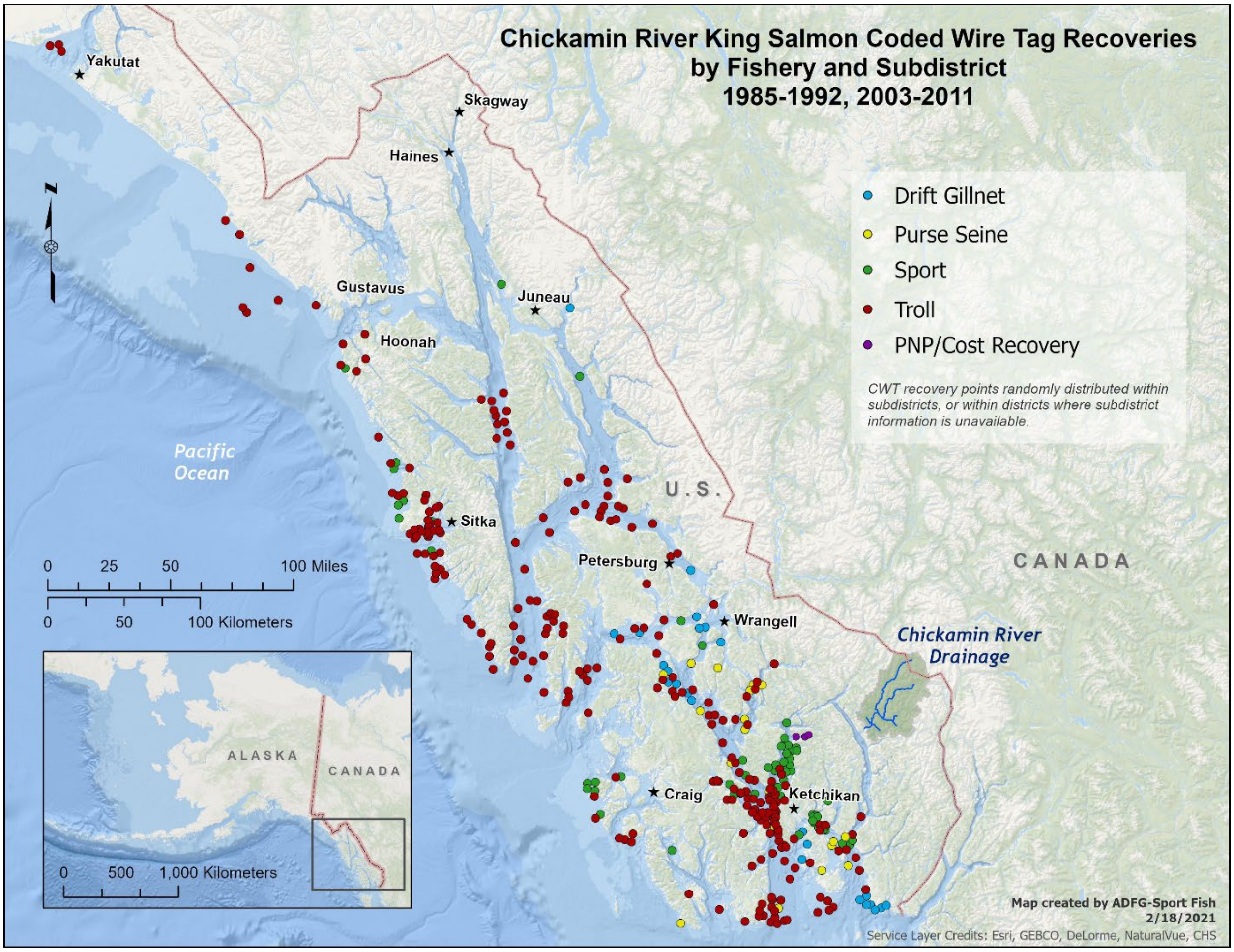

Figure 7.–Map of Chickamin River Chinook salmon coded-wire tag recoveries in SEAK fisheries from 1985 to 1992 and 2003 to 2011.

APPENDIX A: CHICKAMIN RIVER CWT RECOVERY, HARVEST, AND SPAWNING ESCAPEMENT DATA

Appendix A1.–Detailed Chickamin River coded wire tag (CWT) recovery and harvest data, brood years 2000–2005.

Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2003										
Purse	03	SE	NA	1.1	2000	37		1	23	22
Harvest Estimation 2004										
Troll	03	SE	101-45	1.2	2000	1,515		1	57	56
Troll	04	NW	113	1.2	2000	138,699		1	95	94
Troll	04	SE	101-21	1.2	2000	11,727		1	69	68
Drift	25	SE	106-41	1.2	2000	195		1	61	60
Drift	26	SE	101-11	1.2	2000	586		1	23	22
Sport	01	SE	101-90	1.2	2000	7,107	1,135,931	1	126	125
Harvest Estimation 2005										
Troll	01	NE	109-51	1.3	2000	2,184		1	96	96
Troll	01	NW	113-41	1.3	2000	28,349		1	112	112
Troll	01	SE	102-50	1.3	2000	3,933		1	81	80
Troll	02	SE	105-41	1.3	2000	1,214		1	35	35
Troll	03	SE	101-29	1.3	2000	5,309		3	108	106
Troll	03	SE	102-50	1.3	2000	1,964		4	119	117
Troll	04	NW	113	1.3	2000	95,209		1	78	77
Troll	04	NW	113-31	1.3	2000	95,209		1	78	77
Troll	04	NW	116-14	1.3	2000	95,209		1	78	77
Troll	04	SW	103-70	1.3	2000	23,066		1	62	61
Troll	05	NW		1.3	2000	38,603		1	78	78
Troll	06	NE	110-16	1.3	2000	1,513		1	36	35
Troll	06	SE		1.3	2000	1,413		1	54	53
Sport	01	NW	113-45	1.3	2000	13,138	689,567	1	71	71
Sport	01	SE	101-41	1.3	2000	8,553	519,590	1	107	106
Sport	01	SE	101-85	1.3	2000	8,553	519,590	1	107	106
Sport	01	SE	101-90	1.3	2000	8,553	519,590	1	107	106
Sport	02	SE	102-50	1.3	2000	10,315	1,156,758	1	213	212
Sport	02	SW	104-40	1.3	2000	5,654	204,714	1	115	114
Purse	02	SE		1.3	2000	355		1	101	100
Troll	03	SE	102-50	1.2	2001	1,964		3	66	64
Troll	04	SE	101-21	1.2	2001	10,208		1	67	66
Troll	04	SE	102-50	1.2	2001	10,208		1	67	66
Drift	21	SE	108-40	1.2	2001	3,089		1	20	19
Sport	01	NW	113-41	1.2	2001	13,138	689,567	1	52	52
Purse	04	SE		1.2	2001	17		1	35	35
Purse	03	SE		1.1	2002	83		1	24	24

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Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2006										
Troll	01	NW	113-41	1.4	2000	24,432		1	76	76
Troll	01	NW	183-10	1.4	2000	24,432		1	76	76
Troll	02	NW	113-31	1.4	2000	661		1	109	109
Troll	03	NW	113-30	1.4	2000	782		1	110	110
Troll	03	SE	101-29	1.4	2000	3,930		1	58	57
Troll	05	NW	113	1.4	2000	49,218		1	85	85
Troll	07	NW	113-41	1.4	2000	10,030		2	154	153
Sport	03	NE	111	1.4	2000	1,099	5,771	1	72	71
Sport	07	BC	Area 2	1.4	2000	Not available		1	98	98
Troll	01	NW	113-41	1.3	2001	24,432		2	112	111
Troll	01	SE	105	1.3	2001	4,891		1	33	33
Troll	02	SE	101-29	1.3	2001	1,297		1	27	27
Troll	03	SE	101-29	1.3	2001	3,930		2	85	84
Troll	03	SE	112-12	1.3	2001	4,396		1	42	41
Troll	04	NW	156	1.3	2001	96,526		1	62	62
Troll	04	NW	157	1.3	2001	96,526		1	62	62
Troll	04	NW	113-91	1.3	2001	96,526		1	62	62
Troll	04	NW	116-11	1.3	2001	96,526		1	62	62
Troll	05	SE	102-10	1.3	2001	2,076		1	54	53
Troll	05	SE	106-30	1.3	2001	2,076		3	162	160
Troll	06	NE	110-15	1.3	2001	233		1	177	176
Troll	07	NE	110-15	1.3	2001	1,802		1	46	46
Troll	07	SE	101-47	1.3	2001	1,962		1	51	51
Troll	27	BC	Area 101	1.3	2001	17,792		1	41	41

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Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2006										
Sport	01	NW	113-45	1.3	2001	13,502	808,274	1	45	44
Sport	01	SE	101-27	1.3	2001	5,151	213,240	1	78	78
Sport	01	SE	101-41	1.3	2001	5,151	213,240	1	78	78
Sport	01	SE	101-90	1.3	2001	5,151	213,240	1	78	78
Sport	01	SE	108-20	1.3	2001	3,324	508,568	1	147	146
Sport	02	SE	101-45	1.3	2001	5,557	316,913	1	123	123
Sport	05	BC	Area 1	1.3	2001	#N/A		1	181	181
Purse	02	SE		1.3	2001	706		1	58	57
Purse	02	SW		1.3	2001	1,087		1	49	49
Troll	03	NE	112-12	1.2	2002	4,396		1	60	60
Troll	04	SE	101-45	1.2	2002	4,100		1	60	59
Drift	21	SE	108-40	1.2	2002	3,205		1	35	35
Drift	26	SE	108-40	1.2	2002	701		1	49	49
Sport	01	SE	101-85	1.2	2002	5,151	213,240	2	225	224
Sport	02	NW	113-61	1.2	2002	13,818	871,474	1	75	74
Sport	02	SE	101-90	1.2	2002	5,557	316,913	1	177	177
Purse	02	SE		1.2	2002	702		1	140	139
Purse	03	SE		1.2	2002	852		1	132	132
Purse	05	SE		1.2	2002	141		1	24	24

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Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2007										
Troll	03	SE	101-29	1.5	2000	5,656		1	61	61
			Area							
Troll	32	BC	101	1.5	2000	8,316		1	56	56
Troll	03	NW	113-30	1.4	2001	764		1	33	33
Troll	03	NW	113-97	1.4	2001	11		1	23	22
Troll	04	NW	156	1.4	2001	103,464		1	57	56
Troll	05	SE	102-50	1.4	2001	5,651		1	50	50
Troll	06	NW	113-11	1.4	2001	3,123		1	56	56
Troll	06	NW	113-41	1.4	2001	3,123		2	112	111
Troll	06	SE	102-50	1.4	2001	2,458		1	32	31
Sport	01	NW	113	1.4	2001	14,018	627,754	1	68	67
Sport	01	NW	113-61	1.4	2001	14,018	627,754	1	68	67
Sport	02	SE	101-45	1.4	2001	8,596	647,183	1	198	198
Sport	02	SW	104-40	1.4	2001	5,100	198,702	1	120	120
Troll	01	NW	113-41	1.3	2002	29,540		1	73	73
Troll	01	SE	101-85	1.3	2002	4,307		1	46	46
Troll	01	SE		1.3	2002	4,307		1	46	46
Troll	02	NE	109-62	1.3	2002	3,424		1	40	39
Troll	03	NE	112-12	1.3	2002	4,176		1	54	54
Troll	03	NW	114-50	1.3	2002	1,519		1	70	70
Troll	03	SE	101-29	1.3	2002	5,656		3	195	193
Troll	03	SE	106-20	1.3	2002	277		1	38	38
Troll	04	NE	110-31	1.3	2002	4,921		1	61	60
Troll	04	NW	113	1.3	2002	103,464		1	82	81
Troll	04	SE	101-21	1.3	2002	7,357		1	52	52
Troll	05	NE	109-61	1.3	2002	4,273		1	73	73
Troll	05	SE	102-50	1.3	2002	5,651		1	72	72
Troll	05	SE	106-30	1.3	2002	5,651		1	72	72
Troll	05	SE	107-20	1.3	2002	5,651		1	72	72
Troll	06	SE	101-29	1.3	2002	2,458		1	46	46

-continued-

Appendix A1.–Page 5 of 7.

Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2007										
Troll	25	BC	Area 101	1.3	2002	18,076		1	45	44
Drift	25	SE	101-11	1.3	2002	545		1	24	24
Sport	01	NW	113-45	1.3	2002	14,018	627,754	1	97	97
Sport	01	NW	113-91	1.3	2002	721	93,542	1	115	115
Sport	01	SE	101-45	1.3	2002	4,179	117,166	1	123	122
Sport	03	NE	111	1.3	2002	1,649	23,067	1	81	80
Troll	04	SE	102-10	1.2	2003	7,357		2	81	80
Troll	04	SE	106-30	1.2	2003	7,357		1	41	40
Drift	26	SE	101-11	1.2	2003	374		1	25	25
Sport	02	SE	101-85	1.2	2003	8,596	647,183	1	222	221
Sport	02	SE	101-90	1.2	2003	8,596	647,183	1	222	221
Harvest Estimation 2008										
Sport	06	BC	Area 1	1.5	2001	Not available		1	73	73
Troll	02	NW	113-41	1.4	2002	2,486		2	171	170
Troll	02	NW	113-62	1.4	2002	705		1	59	58
Terminal	27	SE	101-95	1.3	2003	4,146		1	109	109
Troll	01	SE	105	1.3	2003	3,319		1	34	33
Troll	02	NW	113-95	1.3	2003	309		1	25	24
Troll	03	NW	113-01	1.3	2003	3,154		1	39	38
Troll	04	NW	113	1.3	2003	48,029		2	99	98
Troll	04	NW	113-21	1.3	2003	48,029		1	49	49
Troll	04	NW	113-61	1.3	2003	48,029		1	49	49
Troll	04	NW		1.3	2003	48,029		1	49	49
Troll	06	NE	110	1.3	2003	1,380		1	35	35
Troll	06	NE	110-16	1.3	2003	1,380		1	35	35
Troll	06	SE	102-60	1.3	2003	1,356		1	39	39
Troll	06	SE	107-10	1.3	2003	1,356		1	39	39
Troll	06	SE	107-20	1.3	2003	1,356		2	78	77
Drift	27	SE	106-30	1.3	2003	450		1	40	39
Troll	04	SE	101-29	1.2	2004	1,160		1	55	55
Troll	04	SW	104-30	1.2	2004	10,064		1	24	23
Drift	26	SE	101-11	1.2	2004	517		1	22	22
Purse	03	SE		1.2	2004	31		1	24	24

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Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
Harvest Estimation 2009										
Troll	03	NE	109-62	1.4	2003	4,538		1	28	27
Troll	04	NW	113-21	1.4	2003	75,088		1	55	55
Troll	06	SE	108-60	1.4	2003	1,028		1	37	37
Sport	07	BC	Area 1	1.4	2003	#N/A		1	49	49
Sport	11	SE	101-41	1.4	2003	5,256	493,979	1	394	393
Troll	01	NW	113-41	1.3	2004	15,584		1	39	38
Troll	01	NW	183-10	1.3	2004	15,584		1	39	38
Troll	02	NE	109-62	1.3	2004	845		1	17	16
Troll	03	NE	109-62	1.3	2004	4,538		1	21	21
Troll	03	NW	113-31	1.3	2004	1,704		1	22	22
Troll	03	SE	101-29	1.3	2004	5,274		1	38	37
Troll	04	NW		1.3	2004	75,088		1	42	41
Troll	04	SE	105-10	1.3	2004	3,162		1	52	51
Troll	04	SW	103-30	1.3	2004	5,375		1	44	43
Troll	05	NW	113-31	1.3	2004	24,386		1	40	39
Troll	06	NW	113-41	1.3	2004	2,800		1	42	42
Troll	06	NW	183-10	1.3	2004	2,800		1	42	42
Troll	06	SE	108-60	1.3	2004	1,028		1	28	28
Purse	02	SE		1.3	2004	966		1	55	55
Troll	03	SE	101-29	1.2	2005	5,274		1	59	58
Troll	04	NW		1.2	2005	75,088		1	65	64
Troll	04	SE	102-30	1.2	2005	3,162		1	80	80
Troll	04	SE	105-10	1.2	2005	3,162		2	160	159
Troll	04	SW		1.2	2005	5,375		1	68	67
Drift	27	SE	101-11	1.2	2005	284		1	22	21
Drift	27	SE	106-30	1.2	2005	333		1	66	65
Drift	28	SE	106-30	1.2	2005	326		2	311	310
Drift	28	SE	108-10	1.2	2005	948		1	144	143
Sport	12	SW	103-40	1.2	2005	1,217	38,271	1	130	129
Sport	13	SW	104-40	1.2	2005	2,943	223,662	1	135	134
Sport	15	SE	101-90	1.2	2005	9,005	1,364,280	1	539	539
Purse	04	SE		1.2	2005	65		1	22	21

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Gear	Sampling Period	Quadrant	District	Age	Brood Year	H	var[H]	mj	rj	SE[rj]
					Harvest Estimation 2010					
Troll	01	NW	113-41	1.4	2004	27,198		1	40	39
Troll	02	SE	101-90	1.4	2004	13		1	46	45
Troll	04	NW	113	1.4	2004	56,069		1	50	49
Troll	05	NW	113-31	1.4	2004	27,891		1	39	39
Troll	05	NW	113-71	1.4	2004	27,891		1	39	39
Troll	06	NE	110-16	1.4	2004	2,338		1	20	20
Purse	05	SE		1.4	2004	22		1	104	103
Terminal	28	SE	101-95	1.3	2005	4,551		1	78	77
Troll	01	NW	113	1.3	2005	27,198		1	61	61
Troll	01	NW	113-41	1.3	2005	27,198		2	123	122
Troll	01	SE	101-29	1.3	2005	3,216		1	35	35
Troll	01	SE	101-90	1.3	2005	3,216		1	35	35
Troll	01	SE	106-43	1.3	2005	3,216		1	35	35
Troll	02	NE	112-12	1.3	2005	817		1	43	43
Troll	03	NE	109-62	1.3	2005	3,867		1	31	30
Troll	03	SE	101-29	1.3	2005	6,158		4	227	225
Troll	05	NE	109-10	1.3	2005	913		1	38	38
Troll	05	NW	116-14	1.3	2005	27,891		1	61	60
Troll	05	NW		1.3	2005	27,891		1	61	60
Troll	05	SE	102-50	1.3	2005	883		1	44	43
Troll	06	NE	110-16	1.3	2005	2,338		1	32	31
Troll	06	NE	110-17	1.3	2005	2,338		1	32	31
Troll	06	SE	101-41	1.3	2005	1,293		1	61	61
Troll	06	SE	102-40	1.3	2005	1,293		1	61	61
Troll	06	SE	105-50	1.3	2005	1,293		1	61	61
Drift	26	SE	101-11	1.3	2005	540		1	34	34
Drift	29	SE	106-30	1.3	2005	296		1	43	42
Drift	30	SE	108	1.3	2005	125		1	58	58
					Harvest Estimation 2011					
Terminal	29	SE	107-35	1.4	2005	732		1	618	618
Troll	01	SE	101-90	1.4	2005	4,962		1	44	43
Troll	02	NE	112-12	1.4	2005	694		1	29	29
Troll	03	SE	107-10	1.4	2005	405		1	32	31
Sport	11	SE	108-30	1.4	2005	342		1	29	29

Note: Blank cells indicate no estimate is available or expected.

Appendix A2.–Estimated abundance of the spawning population of large (≥660 mm mid eye to tail fork [METF]) Chinook salmon in the Chickamin River, 1975–2012. Mean expansion factor is 4.75 (SE 0.70).

		Abundance estimated from expanded count		Abundance estimated from mark–recapture experiment		Preferred abundance estimate	
Year	Peak index count	N	SE (N)	M-R	SE (M-R)	Preferred	SE
1975	370	1,758	259			1,758	259
1976	157	746	110			746	110
1977	363	1,724	254			1,724	254
1978	308	1,463	216			1,463	216
1979	239	1,135	167			1,135	167
1980	445	2,114	312			2,114	312
1981	384	1,824	269			1,824	269
1982	571	2,712	400			2,712	400
1983	599	2,845	419			2,845	419
1984	1,102	5,235	771			5,235	771
1985	956	4,541	669			4,541	669
1986	1,745	8,289	1,222			8,289	1,222
1987	975	4,631	683			4,631	683
1988	786	3,734	550			3,734	550
1989	934	4,437	654			4,437	654
1990	564	2,679	395			2,679	395
1991	487	2,313	341			2,313	341
1992	346	1,644	242			1,644	242
1993	389	1,848	272			1,848	272
1994	388	1,843	272			1,843	272
1995	356	1,691	249	2,309	723	2,309	723
1996	422	2,005	295	1,587	199	1,587	199
1997	272	1,292	190			1,292	190
1998	391	1,857	274			1,857	274
1999	501	2,380	351			2,380	351
2000	801	3,805	561			3,805	561
2001	1,010	4,798	707	5,177	972	5,177	972
2002	1,013	4,812	709	5,007	738	5,007	738

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Year	Peak index count	Abundance estimated from expanded count		Abundance estimated from mark–recapture experiment		Preferred abundance estimate	
		N	SE (N)	M-R	SE (M-R)	Preferred	SE
2003	964	4,579	675	4,579	592	4,579	592
2004	798	3,791	559	4,268	893	4,268	893
2005	926	4,399	648	4,257	591	4,257	591
2006	1,330	6,318	931			6,318	931
2007	893	4,242	625			4,242	625
2008	1,111	5,277	778			5,277	778
2009	611	2,902	428			2,902	428
2010	1,156	5,491	809			5,491	809
2011	853	4,052	597			4,052	597
2012	444	2,109	311			2,109	311
Average 2003–2012	909	4,316				4,350	

Note: Blank cells indicate no estimate is available or expected.

Appendix A3.–Total Chickamin River Chinook salmon spawning abundance by brood and return year.

	Return year									
Brood year	2003[a]	2004[b]	2005[c]	2006[d]	2007[d]	2008[d]	2009	2010	2011	Total spawners
2000	222	2,077	3,253	1,848	34					7,434
SE	64	220	452	294	15					586
2001[e]		186	1,020	3,264	789	15				5,274[E]
SE		43	204	491	131	15				549
2002				1,897	3,090	1,238	46			6,271
SE				242	456	217	19			560
2003				123	941	3,598	609			5,271
SE				38	125	536	106			562
2004					130	1,441	1,592	1,260	54	4,477
SE					34	217	246	210	39	393
2005						403	1,562	3,566	1,006	6,537
SE						99	252	538	207	636

Note: Blank cells denote no estimate is available or expected.

[a] Data from Freeman and McPherson 2005, as summarized by Johnson et al. 2009.

[b] Data from Freeman et al. 2007, as summarized by Johnson et al. 2009.

[c] Data from Weller et al. 2007, as summarized by Johnson et al. 2009.

[d] Data from Johnson et al. 2009.

[e] Correction from Johnson et al. 2009 due to a spreadsheet error, estimate changed from 8,538 to 5,274.

APPENDIX B: ELECTRONIC DATA FILES

Appendix B1.–Names of computer files containing data, statistics and interim calculations and program code used in the preparation of this report.

File name	Description
Chickamin09to12.xlsx	2009–2012 ASL data, peak survey counts, and escapement estimates
asl_2009to2012.txt	2009–2012 ASL data formatted for use with R
nl_2009to2012.txt	2009–2012 large escapement estimates
aslboot_2009to2012.R	R code to compute the variance of escapement and ASL estimates
Chickamin Harvest Master.xlsx	Marine harvest data and estimates
theta.R	R code to compute variance of theta

Note: Files are available from the Division of Commercial Fisheries, Ketchikan.