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Spawning Abundance of Chinook Salmon in the Chickamin River in 2003

by

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and

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Alaska Department of Fish and Game

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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ABSTRACT

The escapement of Chinook salmon *Oncorhynchus tshawytscha* returning to the Chickamin River in 2003 was estimated as part of an effort to determine an expansion factor to apply to future and historical peak aerial survey counts. The escapement of spawning salmon, an expansion factor for peak aerial survey counts, and age, sex, and length composition of the population were estimated. Escapement was estimated using a two-event mark-recapture experiment. Fish were captured with set gillnets, marked with uniquely numbered spaghetti tags, and marked with two secondary marks. Later, spawning and pre-spawning fish were captured on the spawning grounds using rod-and-reel gear and dip nets, examined for marks, and sampled for age (scales), sex, and length. The escapement of large (≥660 mm MEF) Chinook salmon in 2003 was 4,579 (SE = 592) fish. This estimate was 4.75 (SE = 0.61) times the peak aerial survey count. The average of similar annual expansion factors for the Chickamin River (1996 and 2001-2003) is 4.64 (SE = 0.64; CV = 13.1%). We estimate the escapement of medium-sized (401–659 mm MEF) Chinook salmon was 735 (SE = 150) fish. The combined estimate for all Chinook salmon ≥401 mm (MEF) was 5,314 (SE = 611) fish, of which 2,550 (SE = 339) were large females. Age-1.3 fish from the 1998 year class composed an estimated 63% of the total escapement estimate, followed by age-1.4 fish (22%), and age-1.2 fish (10%). Brood years from 1996-2000 were represented, with all five age classes originating from age-1. (yearling) smolt.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, abundance, escapement, Chickamin River, mark-recapture, Darroch model, peak survey count, expansion factor, age, sex, length composition, Behm Canal, Southeast Alaska

INTRODUCTION

The Chickamin River flows into Behm Canal in the Misty Fjords National Monument Wilderness in southern Southeast Alaska (SEAK; Figure 1). The Chickamin River produces the second largest run of Chinook salmon *Oncorhynchus tshawytscha* in southern SEAK, and is one of four 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 MEF length) Chinook salmon serve as an index of abundance and have been collected annually by helicopter since 1975, using a standardized method (time and area). Large Chinook salmon are generally fish saltwater-age-.3 or older in 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 to implement abundance-based management. Expansion factors for the peak counts are being developed for the four Behm Canal systems and, after review, will provide estimates of total escapement of large spawners like the other seven Chinook systems in SEAK where Chinook escapement is estimated annually using expansions of aerial survey counts.

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 (Figure 2). Peak counts increased again in 1999 and continued this general trend through 2003.

From 1981 to 1994, it was assumed that the sum of index counts on eight tributaries represented 62.5% of the total annual escapement to the Chickamin River (Pahlke 1997). In order to validate the ongoing escapement index, studies were conducted to estimate the escapement of large Chinook salmon. In 1995 and 1996, respectively, estimated escapements were 2,309 (SE = 723; Pahlke 1996) and 1,587 (SE = 199; Pahlke 1997) large Chinook salmon. In addition, radiotelemetry studies in 1996 estimated that approximately 83% of all spawning occurred in the 8 index streams and no salmon were tracked into British Columbia. On the basis of these studies the expansion factor applied to peak aerial survey counts to estimate total escapement of large fish was revised to 4.0 (Pahlke 1998).

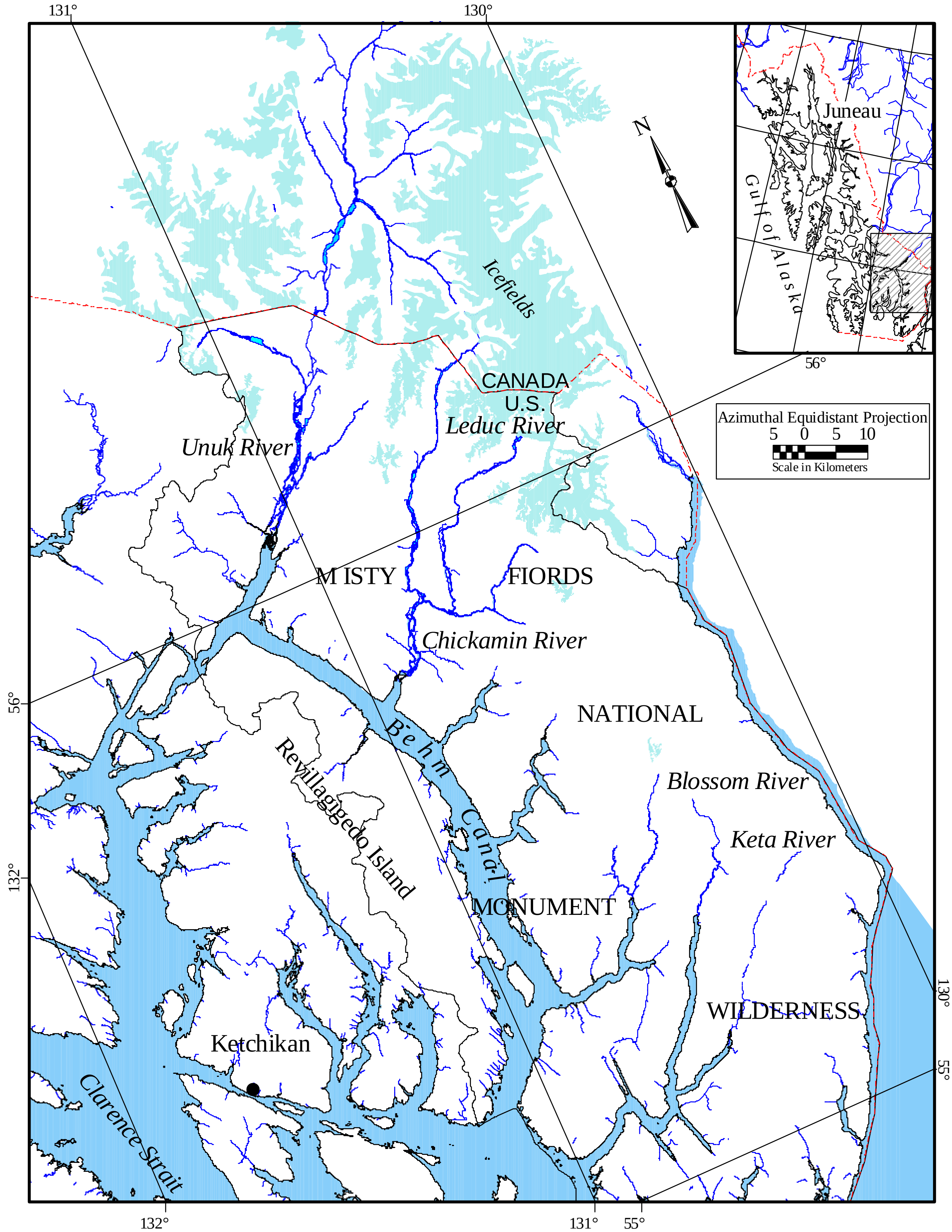

Figure 1.–Major Chinook salmon-producing river systems within the Misty Fjords National Monument that flow into Behm Canal in Southeast Alaska.

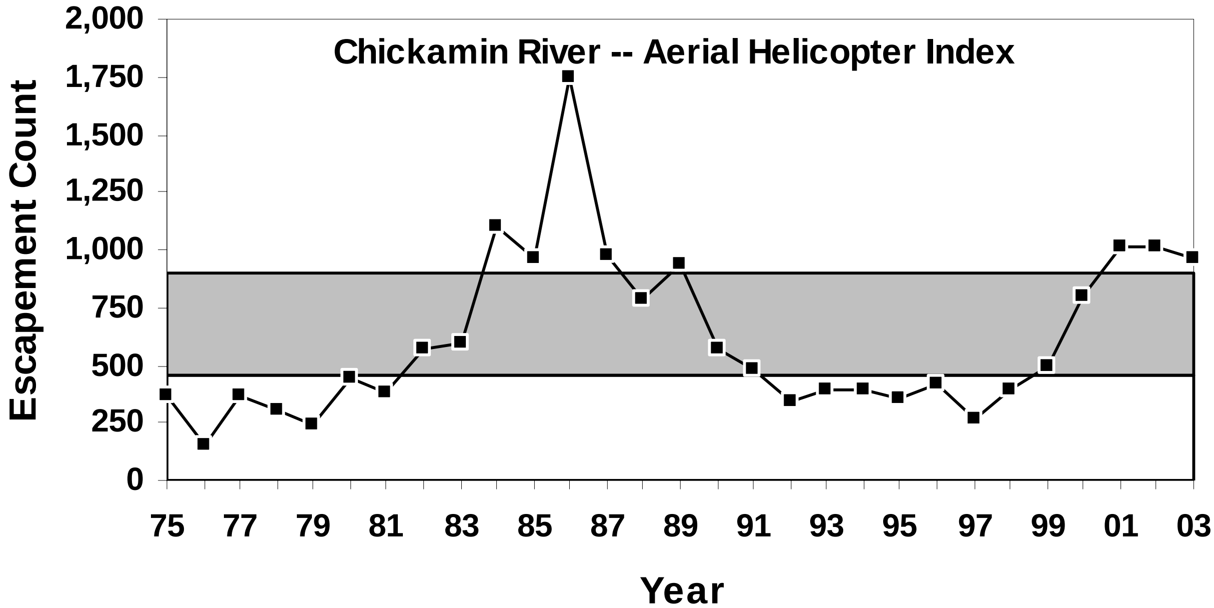

Figure 2.–Estimated escapements of large Chinook salmon spawners in the Chickamin River from 1975 to 2003, compared to 1997 survey biological escapement goal range (shaded area).

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 abundance and age, sex, and length composition of spawners. Funding for this program was approved by the Chinook Technical Committee (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*," signed by U. S. parties in the Pacific Salmon Treaty area, and as detailed in the 1999 Pacific Salmon Treaty Agreement.

The U. S. section of the CTC (PSC 1997) developed data standards for stock-specific assessments of escapement, terminal runs, and forecasts of total returns. The standard for escapement is 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 CTC concluded that the Chickamin River stock-assessment program needed improvements:

1) to estimate total escapement in additional years;
2) to estimate an expansion factor converting historical survey counts into estimates of total escapement; and
3) to estimate the escapement by sex and age annually.

In 2001, the estimated escapement was 5,177 (SE = 972) large Chinook salmon, and the expansion factor for the peak aerial survey count was 5.1 (SE = 199; Freeman and McPherson 2003). In 2002, the estimated escapement was 5,007 (SE = 738) and the expansion factor was estimated at 4.94 (SE = 0.73; Freeman and McPherson 2004).

An estimate of escapement in 2003 allows calculation of an expansion factor for a third consecutive year (and fifth overall), provides data to determine if U. S. CTC escapement data standards (PSC 1997) are met, and provides an additional data point to re-estimate total escapements from expanded aerial survey counts dating back to 1975. Peak counts of large fish for individual systems can be expanded to estimates of total escapement if a valid river specific expansion factor has been estimated for three or more years with a CV ≤20% (PSC 1997).

Research on the Chickamin River in 2003 (and in future years) will determine if the current expansion factor (4.0) for survey counts is indicative of the true spawning magnitude in the Chickamin River. In addition, funding from the Southeast Sustainable Salmon Fund was used to re-implement a coded-wire tagging program on juvenile Chinook and coho salmon on the Chickamin River beginning in the fall of 2001. The program was continued each spring and fall in 2002 and 2003, and is scheduled to operate going forward. Recoveries of the Chinook salmon tags will be used to revise estimates of harvest and production of Chinook salmon in the Chickamin River. Presently the biological escapement goal range for the Chickamin River stock is a survey index count of 450 to 900 large spawners (McPherson and Carlile 1997). Additional years of spawning escapement estimates will facilitate the ability of ADF&G to convert the escapement goal to a range of total escapement of large spawners.

ADF&G personnel returned to the Chickamin River in the summer of 2003. Research objectives in 2003 were to:

1. Estimate the total escapement of large (length ≥660 mm MEF) Chinook salmon in the Chickamin River in 2003, such that the estimate is within ±25% of the true value 95% of the time;
2. Estimate an expansion factor for converting peak aerial survey counts in the Chickamin River in 2003 to escapement, such that future estimates of escapement are within ±25% of the true value 80% of the time; and
3. Estimate the age and sex composition of large Chinook salmon spawning in the Chickamin River in 2003, such that all estimated fractions are within ±5% of the true values 95% of the time.

A secondary task of the research was to estimate abundance and mean length-at-age of medium-sized (length 401–659 mm MEF) Chinook salmon.

STUDY AREA

The Chickamin River is a transboundary river that originates in a heavily glaciated area of northern British Columbia and flows into Behm Canal in the Misty Fjords National Monument Wilderness approximately 65 km northeast of Ketchikan, Alaska. Although the Chickamin River is a transboundary river, no Chinook salmon spawning areas have been documented in Canada. Many of its anadromous spawning tributaries flow clear, however, the mainstem flows mostly turbid during summer from glacial influence. The lower river flows through a broad valley bordered by steep-sided mountains. The lower river channel has a relatively flat bottom, with fine riverbed sediments, exposed bars, low gradient with braided channels, and large, bedrock-controlled pools. Moving upstream, the river is narrower, with progressively coarser substrates, more bedrock, steeper gradient, and more log jams.

METHODS

OVERVIEW

A two-event mark-recapture (M-R) experiment for a closed population (CP; Seber 1982) was conducted on the Chickamin River in 2003. In the first event, set gillnets were used at two locations below the Leduc River to capture fish. Rod-and-reel snagging, dipnetting, and carcass recovery were employed on the spawning grounds for the second event. ADF&G studies in 1995 and 1996 (Pahlke 1996, 1997) and in 2001 and 2002 (Freeman and McPherson 2003, 2004) used similar sampling methods to estimate population parameters in the Chickamin River. The river was accessed from camp by boat downstream to the mouth and upstream to log jams or other impedance barriers located on the lower Leduc River, on the mainstem near Indian Creek, and on the South Fork to the Barrier Creek confluence (Figure 3).

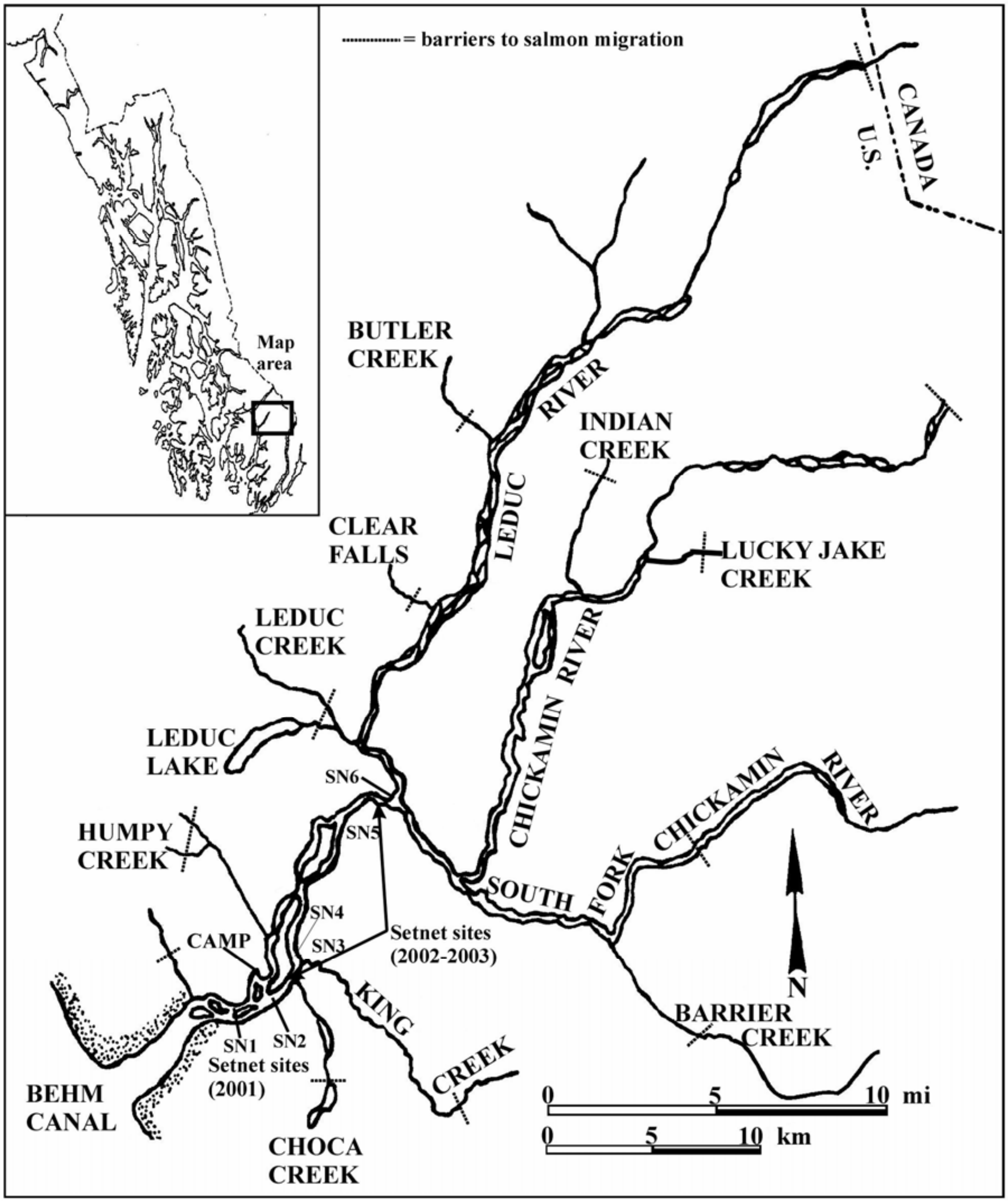

Figure 3.–Chickamin River drainage, showing major tributaries, ADF&G setnet (SN) sites, and barriers to salmon migration.

CAPTURE OF CHINOOK SALMON

Gillnet sampling during Event 1 (the marking event) occurred primarily at two sites: in the mainstem along the west bank at river km (RK) 5, just below the Choca Creek confluence (SN3) and in the mainstem along the east bank 0.5 km below the Leduc River confluence (SN5; RK16; Figure 3). At the west side mainstem confluence of Humpy Slough (SN1; RK3. 5) was a setnet site in the 1995, 1996, and 2001 studies, but it was discontinued in 2002 because of sediment aggradations, limitations from tidal influence, and low catches in 2001. Several other sites were fished in 2001-2002 but dropped because of snags or other physical factors that limited our ability to fish a site, hydrological changes, or low catches. These discontinued sites included those located: just above camp at RK4 (west bank); just upstream of the King Creek confluence at RK6 (east bank); and at the Leduc River confluence (SN6; RK17; west bank). A site across the river from SN5 (RK 16; west bank) was fished with unproductive results (low catches).

Setnets 120 ft (36.5 m) long, 18 ft (5.5 m) deep, of 7¼" (18.5 cm) stretch mesh, were fished throughout the day and tide stages in an effort to maximize Chinook catches while using roughly constant daily effort. Tides influenced setnetting at SN3 but ended well below SN5. Two crews of two persons each typically fished 12 shifts per week, with a target of 6 hours of setnet fishing time per shift. During each week, 5 days were spent fishing two shifts, and 2 non-consecutive days were spent fishing one shift. Often, during 2-shift days, one net was fished at SN3 and one at SN5. However, both crews did occasionally fish at opposite riverbanks at SN3 when conditions were favorable. Gillnets were watched continuously and a fish was removed from the net as soon as bobbing corks were observed. If fishing time was lost from entanglements, snags, cleaning the net, or tidal impacts, the lost time (processing time) was added on to the end of the shift to bring fishing time to 6 hours. For each Chinook salmon captured, 2 minutes of processing time was added to the shift.

MARKING AND SAMPLING

All fish captured in Event 1 were sampled for scales, length to the nearest 5 mm (MEF), sex, presence of the adipose fin (indicating the fish was marked with a coded wire tag), and coloration. Fish in good condition were marked with a uniquely numbered spaghetti tag. Five scales were taken from each captured fish and mounted onto gummed cards. The age of each fish was determined from annual growth patterns of circuli (Olsen 1992) on images of scales impressed onto acetate and magnified 70× (Clutter and Whitesel 1956). Spaghetti tags were inserted just below the posterior end of the dorsal fin. Each tag consisted of a 5.7-cm section of blue, laminated Floy™ tubing shrunk onto a 38-cm piece of 80 lb-test (36.3 kg) monofilament fishing line. The monofilament end of the tag was pushed into the hollow needle. The tag was then applied to the fish by first punching the tip portion of a hollow needle through the fish approximately 1.5 cm below the posterior end of the dorsal fin, so as to anchor it in front of the last two fin rays, and then withdrawing the needle. A metal leader sleeve was crimped with crimpers to secure the ends of the tag line across the fish, and the excess line was cut 0.5 cm above the crimp. Secondary marks applied (to control for primary loss) included a 0.6-cm punch in the left upper operculum (LUOP) and removal of the left axillary appendage (LAA).

SPAWNING GROUNDS SAMPLING

Rod-and-reel snagging, dipnetting, and carcass recovery were employed to capture fish on or near the spawning grounds during Event 2 of the M-R experiment. Fish were captured and sampled within tributaries and mainstem areas previously identified as key spawning areas, including all eight spawning areas that compose the aerial survey indices. All sampled fish were given a left lower operculum punch (LLOP), upon their first encounter, to prevent double sampling. Fish were closely examined for the presence of the primary tag, LUOP, LLOP, and LAA, for the absence of their adipose fin, stage of maturity, and sampled for length, sex, and age using the same techniques employed during Event 1. The tag number of each fish marked in Event 1 and recaptured in Event 2 was recorded.

ABUNDANCE ESTIMATION

Abundance of large and medium-sized Chinook salmon were estimated separately by design. This practice allows us to obtain comparable M-R estimates (within and across streams in SE Alaska) each year for large fish. The estimates for large fish were also compared to annual aerial survey counts of large fish to determine expansion factors. Escapements were estimated using the Petersen model if assumptions of the model were met. A stratified model (Arnason et al. 1996) was used otherwise.

Necessary conditions for accurate use of the Petersen CP estimator (Seber 1982) included:

(a) every fish had an equal probability of being marked in the first event, or that every fish has an equal probability of being captured in the second event, or that marked fish mix completely with unmarked fish;

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

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

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

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

(f) double sampling did not occur.

Results of two contingency tests were considered in determining if assumption (a) was met. The null hypotheses tested (α = 0.1 was used for all tests) were: 1) that the fractions of marked fish were constant across Event 2 spatial strata; and 2) that the probability of recovering a marked fish was independent of its initial time of marking (temporal strata). Failure to confirm one of these hypotheses was taken as evidence that a partially stratified estimator (spatial or temporal) of abundance was appropriate (Arnason et al. 1996); otherwise a Petersen model could be used.

Assumption (a) may also be violated if size- or sex-selective sampling occurs. Two Kolmogorov-Smirnov (K-S) two-sample tests were used to test the hypothesis that fish of different lengths were captured with equal probability (Appendix A1). The first test was used to investigate selectivity in the second sampling event, and the second test added information about selectivity in the first sampling event.

The experiment was assumed closed to recruitment because sampling spanned the entire immigration. Marking was assumed to have little effect on behavior of released fish or the catchability of fish on the spawning grounds because only fish in good condition were tagged and released, and because the 1996 Chickamin study and other radio telemetry studies in SEAK indicated minimal mortality from handling in the marking event for Chinook salmon (Pahlke 1997). The use of multiple marks during Event 1, careful inspection of all fish captured during Event 2, and additional marking of all fish inspected helped to ensure assumptions (d), (e), and (f) were met.

If a stratified abundance estimator was needed, temporal and/or geographical strata were pooled to find admissible (non-negative) estimates, reduce the number of parameters, and increase precision while finding no evidence of lack of fit (Arnason et al. 1996). Two main criteria were considered when pooling strata: the similarity of the fractions of fish marked (for recovery strata) and the similarity of recovery fractions (for marking strata). Pooling of neighboring strata (temporal periods, or adjoining or adjacent stream reaches) was also considered to remove redundancy and to develop an intuitive basis for pooling. Insufficient numbers of medium-sized Chinook salmon were sampled to attain an unbiased estimate using M-R techniques (Seber 1982). Consequently, the abundance of medium-sized fish was estimated by expanding the estimate for large fish by the estimated size composition of the spawning escapement:

$$\hat{N}_M = \hat{N}_L \left(\frac{1}{\hat{\phi}} - 1 \right) \quad (1)$$

where $\hat{N}_M$ is the estimated spawning escapement of medium-sized fish and $\hat{\phi}$ is the estimated fraction of large fish in the population of large- and medium-sized Chinook salmon captured in the lower river gillnets. Our use of gillnet data to estimate ϕ t may lead to some bias because the 7.25-in mesh should catch large fish better than medium fish. However, the proportion of medium-sized fish in gillnet catches in 2003 was higher than the proportion from samples collected on the spawning grounds, which suggests the true fraction is best estimated using the gillnet data. Similar findings occurred in previous years on the Chickamin River. Samples from the spawning grounds are not useful for estimating ϕ in this case because our angling methods (i.e., sight fishing on the spawning grounds in the Chickamin River drainage in 2001-2003 and in the Keta River in 1999 and 2000, (Freeman et al. 2000, 2001) are not effective at capturing medium-sized fish, especially the smaller ones.

Variance for $\hat{N}_M$ was estimated through simulation by treating the number of large-sized Chinook salmon sampled in the lower river gillnet sample as a binomial variable $n_L^* \sim$ binom ($\hat{\phi}$, n), where n is the number of lower river samples >400 mm MEF. One thousand such simulated samples were drawn for each $\hat{n}^* = n_L^* / n$, creating the empirical distribution $\hat{F}(\hat{\phi}^*)$ as an estimate of $F(\hat{\phi})$. Empirical distributions of $\hat{F}(\hat{\phi}^*)$ and $F(\hat{N}_L^*)$ were matched by sampling estimates of $\hat{N}_L$, from a normal distribution from its estimated variance, to produce the distribution $\hat{F}(\hat{N}_M^*)$ from which the estimate $v(\hat{N}_M^*)$ was produced with methods described above (McPherson et al. 1997).

EXPANSION FACTOR

Standardized, low altitude helicopter surveys have been used to count large Chinook salmon in index tributaries of the Chickamin River since 1975 (Pahlke 1998). During years when both M-R estimates and aerial counts were available (1995, 1996, and 2001-2003), an abundance-to-count annual expansion factor ($\hat{\pi}_t$) was calculated:

$$\hat{\pi}_i = \hat{N}_i / C_i \tag{2}$$

$$var(\hat{\pi}_t) = var(\hat{N}_i) / C_i^2 \tag{3}$$

where $\hat{N}_i$ is the mark-recapture estimate of large Chinook in year *i* and C_i is the peak aerial survey count in year *i*.

When M-R estimates were not available, a long-term expansion factor was used. The long-term observed expansion factor ($\hat{\pi}$) was estimated as:

$$\hat{\pi} = \sum_{i=1}^{k} \hat{\pi}_i \ / \ k \tag{4}$$

$$\text{var}(\hat{\pi}) = \sum_{i=1}^{k} \left(\hat{\pi}_i - \overline{\pi}\right)^2 / \ (k-1) \tag{5}$$

where k is the number of years with both counts and M-R estimates. Simulation studies suggest that measurement error in the M-R experiment does not need to be considered in this variance.

The estimator for expanding peak survey counts into estimates of spawning abundance in year *t* without a M-R estimate was then:

$$\hat{N}_t = \hat{\pi} \ C_t \tag{6}$$

$$\text{var}(\hat{N}_t) = C_t^2 \ \text{var}(\hat{\pi}) \tag{7}$$

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age *j* within each of the medium or large fish groups (*i*) was estimated as a binomial variable:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \tag{8}$$

$$\text{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_i - 1} \tag{9}$$

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

$$\hat{N}_j = \sum_i (\hat{p}_{ij} \hat{N}_i) \tag{10}$$

$$\text{var}(\hat{N}_j) = \sum_i \begin{pmatrix} \text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)\,\hat{p}_{ij}^2 \\ -\text{var}(\hat{p}_{ij})\,\text{var}(\hat{N}_i) \end{pmatrix} \tag{11}$$

where the variance is for a product of two independent variables (Goodman 1960).

The proportion of the spawning population (over a stated length) composed of a given age was estimated as the summed totals across size categories:

$$\hat{p}_j = \frac{\hat{N}_j}{\hat{N}} \quad (12)$$

$$\text{var}(\hat{p}_j) = \frac{\sum_i (\text{var}(\hat{p}_{ij})\hat{N}_i^2 + \text{var}(\hat{N}_i)(\hat{p}_{ij} - \hat{p}_j)^2)}{\hat{N}^2} \quad (13)$$

where variance is approximated by the delta method (Seber 1982):

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

RESULTS

MARKING, CAPTURE, RECAPTURE, AND ABUNDANCE ESTIMATION

From 14 June to 17 August 2003, 318 Chinook salmon were captured, sampled, and released with numbered tags and secondary marks. Catches were relatively low until July 8, after which most of the catch occurred (Figure 4). Peak daily catches of near 20 fish occurred on 31 July and on 7 August (Figure 4). One medium-sized fish was captured but not marked because it had an adipose fin clip and was sent to the ADF&G Tag and Otolith Laboratory in Juneau for processing. Of the 318 fish marked in Event 1, 44 were medium-sized and 274 were large (Table 1). At SN3, 32 medium and 170 large fish were tagged (below Choca Creek), and 12 medium and 104 large fish were captured at SN5 (below the Leduc River confluence) (Table 2; Appendix A2).

In Event 2, a total of 73 medium- and 1,003 large-sized fish were captured and inspected for marks (Table 3) on the spawning grounds from 1 to 30 August 2003. Two medium-sized fish and 66 of the large fish had been marked in Event 1 (2 of the marked large fish had lost their primary tag). The cumulative relative frequencies (CRFs) for lengths of *large* fish marked in Event 1 and those recaptured on the spawning grounds were not significantly different (K-S test, D-value = 0.128, P-value = 0.312; Figure 5). However, lengths of large marked fish were significantly different

Table 1.–Numbers of medium (401–659 mm MEF) and large (≥660 mm MEF) Chinook salmon marked in the lower Chickamin River and inspected for marks on the spawning grounds, 2003**.**

	401–659 mm	**≥660 mm**	**Total**
A. Event 1:			
Released with marks (*M*)	44	274	318
B. Event 2:			
Captured (C)	73	1,003	1,076
Recaptured (*R*)	2	66	68
R/C (%)	2. 7%	6. 6%	6. 3%

Table 2.–Catch of medium (401–659 mm MEF) and large (≥660 mm MEF) Chinook salmon marked with tags in Event 1, by setnet site, Chickamin River, 2003.

	Medium	Large	Total
Choca Creek site (SN3)			
Catch	33	170	203
Tagged	32	170	202
Mortalities[a]	1	0	1
Below Leduc River site (SN5)			
Catch	12	105	117
Tagged	12	104	116
Mortalities	0	1	1
Total, both sites			
Catch	45	275	320
Tagged	44	274	318
Mortalities	1	1	2

[a] One fish had a missing adipose fin and was dispatched for tag sampling at the ADF&G Tag & Otolith Laboratory.

Table 3.–Numbers of Chinook salmon ≥401 mm (MEF) sampled by size, location, and mark status during spawning ground surveys, Chickamin River, 2003.

	Captures		Recaptures		Marked rate	
Location	**Medium**	**Large**	**Medium**	**Large**	**Medium**	**Large**
Lower tributaries:						
Choca Creek	1					
Humpy Creek	15	119	1	5	0.067	0.042
King Creek	18	252	1	14	0.056	0.056
Subtotal Lower combined	34	371	2	19	0.059	0.051
Leduc River tributaries:						
Leduc Creek	7	59		5		0.085
Clear Falls Creek		20		1		0.050
Butler Creek	12	155		5		0.032
Subtotal Leduc combined	19	234		11		0.047
Middle-upper tributaries:						
Indian & Lucky Jake Cr.	9	62		9		0.145
South Fork Chickamin R.	11	336		27		0.080
Middle-upper combined	20	398		36		0.090
Total	73	1,003	2	66	0.027	0.066

from those captured on the spawning grounds (K-S test, P <0.001; Figure 5). These results indicate the setnets were size selective against the largest fish, while sampling gear on the spawning grounds was not selective for large fish. This selectivity led us to use just the spawning grounds samples to estimate age and sex composition of the escapement *within the large size group* (Appendix A1, Case II). K-S tests were not run for medium-sized fish as only two fish were recaptured, so the K-S tests would be meaningless.

Temporal and spatial stratification were required to estimate abundance of large fish. The estimated marked fraction was 0.051 in the lower tributaries (Choca, Humpy and King Creeks), 0.047 in the Leduc tributaries (Leduc, Clear Falls and Butler Creek) and 0.090 in the middle-upper tributaries (Indian, Lucky Jake, and South Fork; Table 3). Tests of the hypotheses of equal marked fractions across spatial recovery strata were rejected for large fish ($\chi^2 = 6.29$, df = 2, P = 0.043). Similarly, a test of the hypothesis that the recapture probability was independent of temporal marking strata was rejected for large fish ($\chi^2 = 8.75$, df = 1, P = 0.003), using data shown in Table 4 (Panel B).

A partially stratified model was used to estimate abundance of large fish. We tried several stratification schemes but only a model with two temporal marking strata and three geographic strata (Table 4, Panel B) satisfied fitting tests in Aranson et al. (1996). Other stratification did not meet fitting tests. For example, a simpler model of combined lower tributary and Leduc tributary catches, which had similar marked fractions, produced a similar abundance estimate (4,609 large fish) to the larger model (4,579 large fish), but did not fit well. The poor fit resulted primarily from almost all lower tributary spawning fish being tagged in the second temporal strata while the Leduc fish were tagged in both (see Table 4, Panel B). Both of these abundance estimates were about 11% above a Petersen model estimate of 4,120 large fish.

The abundance of large fish was estimated at 4,579 (SE = 592) using the stratification illustrated in Table 4, Panel B. Two of the 66 recovered large fish (3.0%) had lost their primary tag, one from King Creek assigned to the second marking strata and one from South Fork assigned to the first marking strata (Table 4).

Because few medium-sized fish were recaptured, the abundance of medium-sized fish was estimated using the M-R estimate for large Chinook salmon and the proportion of the estimated escapement comprised of large-sized fish (Equation 1). The caveats of this approach are explained in the methods. The proportion of medium-sized fish in setnets was 0.161 and the

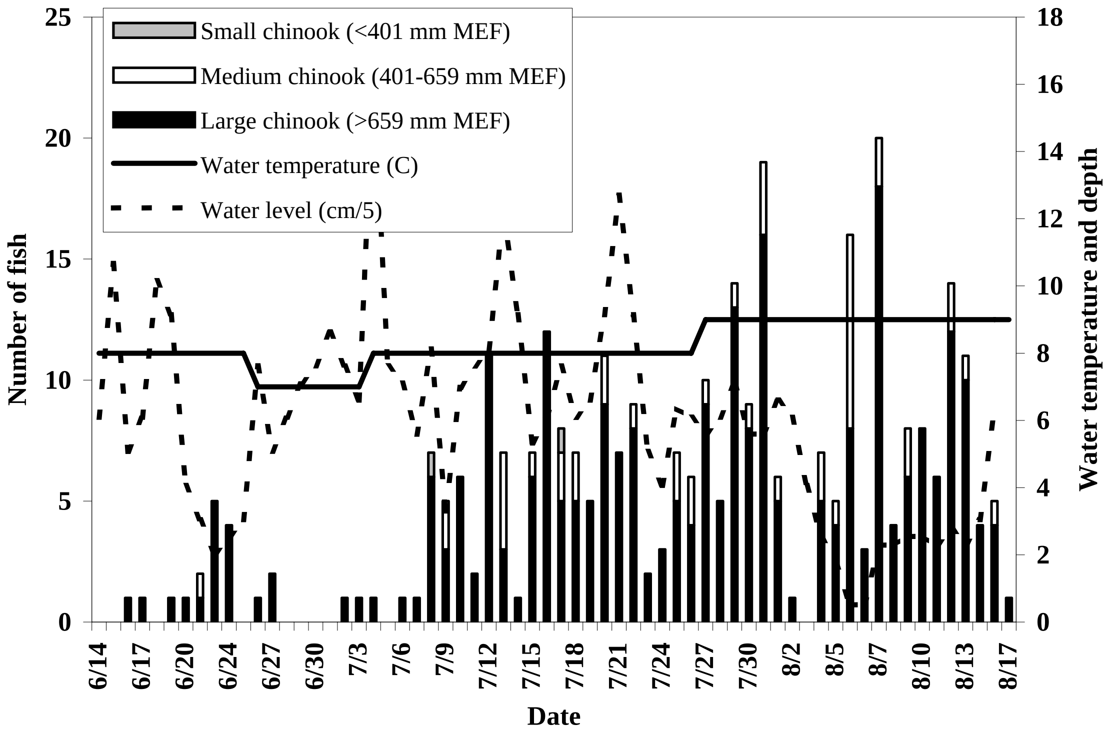

Figure 4.–Daily catches of Chinook salmon (by size class) captured in set gillnets and daily water temperature and depth in the lower Chickamin River, 2003.

proportion caught in the spawning grounds sample was 0.073. We concluded (as noted earlier) that sight fishing on the spawning grounds limits our ability to capture medium-sized fish, especially the smaller ones. The abundance of medium-sized fish was thus estimated as 735 (SE = 150). This estimate may be biased low because the 7.25-in mesh gillnet used should catch large fish better than medium fish.

The combined estimate for all Chinook salmon ≥401 mm is 5,314 (SE = 611) (Table 5). This estimate may be biased low because the 7.25-in mesh used in Event 1 should catch more large than medium fish, perhaps resulting in a low estimate of medium fish.

Estimates of Age, Sex, and Length Composition

The cumulative relative frequencies for lengths of large fish marked in Event 1 and those captured on the spawning grounds were significantly different (K-S test, D-value = 0.171, P-value <0.001; Figure 5). Since the second sampling event was determined to not be selective, the first appeared so (Appendix A1). In addition, 64 marked fish were recaptured and sexed in Event 2, and six of these fish (9%) had been assigned the opposite sex in Event 1. In half the cases, the original (more difficult) assignment was male and the final (spawning ground) assignment was female; the opposite was true in the other half of the cases. This infers greater imprecision in sex assignment of fish in Event 1, and a lack of confidence in comparing sex compositions in Event 1 and Event 2. As a result, only samples from Event 2 were used for estimating age and sex composition, and mean length at age and sex.

Similar to previous years, age-1.3 Chinook salmon from the 1998 brood year were dominant (63.4%, SE = 2.4%) on the Chickamin River in 2003 (Table 5). Males composed 52.0% (SE = 2.2%) of the escapement of fish ≥401 mm (MEF), but only 10.4% (SE = 2.1%) of the males ≥401 mm were age-1.2 fish from the 1999 brood. There were an estimated 2,550 (SE = 339) females (all

Table 4.–Number of large- and medium-sized Chinook salmon ≥401 mm MEF marked by period and sampled by recovery location in the lower Chickamin River, 2003.

Marking dates	Number marked	Fraction recovered	Recovery area [a] Lower tribs	Leduc tribs	S. Fork and Indian Cr.	Total
PANEL A. MEDIUM CHINOOK SALMON (401–659 MM MEF)						
6/16 to 7/28	20	0.00	0	0	0	0
7/29 to 8/17	24	0.08	2	0	0	2
Total	44		2	0	0	2
Number inspected			34	19	20	73
Fraction marked			0.06	0.00	0.00	0.03
PANEL B. LARGE CHINOOK SALMON (≥660 MM MEF)						
6/16 to 7/28	138	0.30	1	6	35	42
7/29 to 8/17	136	0.17	18	5	1	24
Total	274		19	11	36	66
Number inspected			371	234	398	1,003
Fraction marked			0.05	0.05	0.09	0.06
PANEL C. LARGE AND MEDIUM CHINOOK SALMON (≥401 MM MEF)						
6/16 to 7/28	158	0.26	1	6	35	41
7/29 to 8/17	160	0.14	20	5	1	27
Total	318		21	11	36	68

[a] A list of tributaries (tribs) contributing to each recovery area is included in Table 3.

large fish) in the spawning population, with age-1.3 fish the most abundant age class amongst females. Note that the escapement of age-1.1 and age-1.2 fish <401 mm MEF are not estimated because we could not effectively sample these fish, as only two were captured. All medium-sized fish sampled were males and about two-thirds (66.0%, SE = 6.6%) were age-1.2. All scale samples that were successfully aged were age-1. fish, from yearling smolt.

Average length-at-age generally increased with age for both male and female Chinook salmon sampled (Table 6; Figure 6). Within age-1.3 fish, females were on average 21 mm longer than males, whereas age-1.4 males averaged an estimated 41 mm longer than their female counterparts. Ages of small, medium, and large fish sampled in setnets and from the spawning grounds are shown in Appendix A3.

EXPANSION FACTOR

Two surveys were made to count spawning fish in each of the eight tributaries surveyed annually on the Chickamin River in 2003; the peak count was 964 large Chinook salmon, combined across them. The upper-middle tributaries were surveyed on 8 and 13 August, and the lower tributaries were surveyed on 13 and 22 August. The expansion factor for 2003 was estimated at 4.75 (SE = 0. 61), as compared with 6.49 in 1995, 3.76 in 1996, 5.13 in 2001, and 4.94 in 2002 (Table 7). The mean expansion factor to date is 4.64 (SE = 0. 61), using the latter four years (1996 and 2001-2003). We did not use the initial year (1995) because of the low sample size and poor precision of the mark-recapture estimate. The mean coefficient of variation (CV) of our estimate is 13.1%, well below the benchmark 20% precision guideline in USCTC (1997). Computer files of worksheets containing the data and analyses used for estimates in this document are reported in Appendix A4.

DISCUSSION

The estimated escapement of 4,579 large Chinook salmon in 2003 was slightly below the 2001 and 2002 estimates of 5,177 and 5,007 fish, though well above the 1995 and 1996 estimates of 2,309 and 1,587 large fish (Table 7). This year marked the fifth consecutive year (since 1998) that the peak index survey counts met or exceeded the

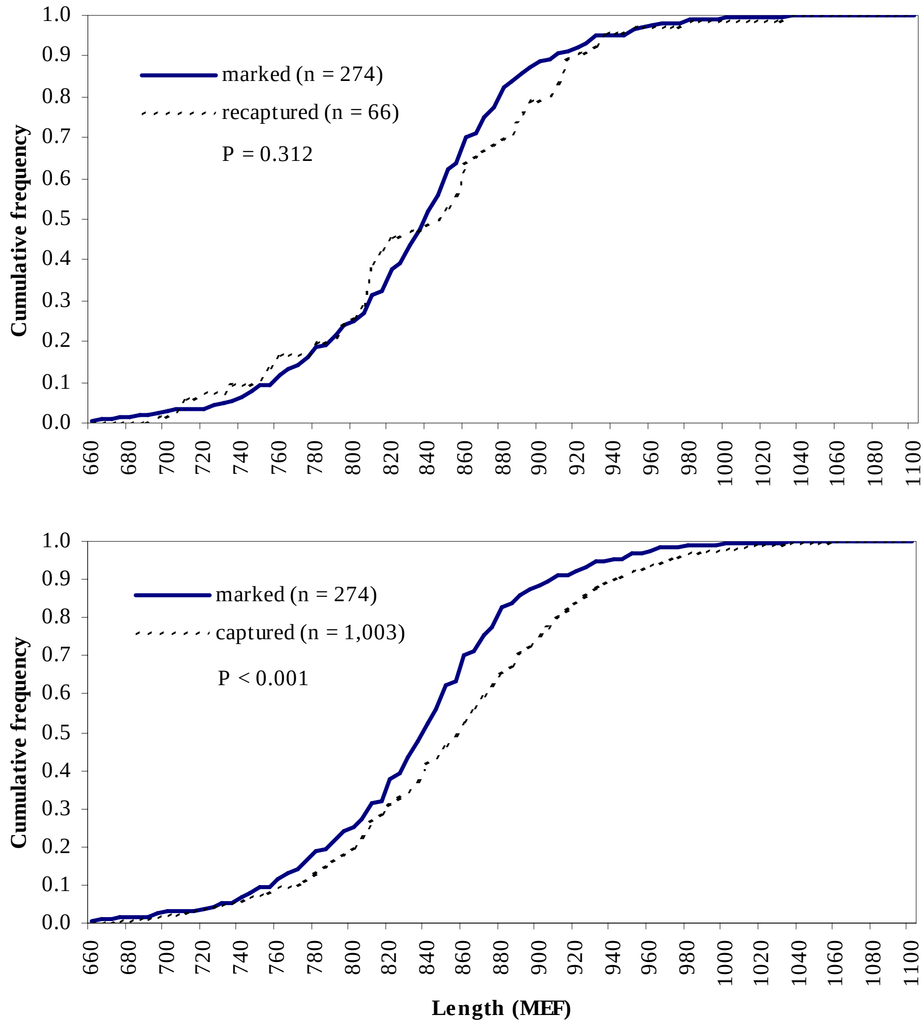

Figure 5.–Cumulative relative frequencies of large (≥660 mm MEF) Chinook salmon marked vs. recaptured (upper graph) and marked vs. captured in Event 2 (lower graph) in the Chickamin River, 2003.

present escapement goal (index count of 450–900 fish; McPherson and Carlile 1997).

The two primary setnet sites fished in 2002 (SN3 off Choca Creek and SN5 11 km upstream–below the Leduc River confluence, Figure 3) were again fishable and productive in 2003. This consistency allowed the crews more uninterrupted fishing time in proven waters.

Tagging goals were met and spawning ground sampling (Event 2) goals were exceeded in 2003. The crew's experience, extra effort, and efficiency coupled with mostly favorable weather and stream conditions in August yielded over 1,000 large fish sampled during the recovery event. This compares favorably to 883 large fish captured in 2001 utilizing more staffing and effort, and to the 623 large fish captured in 2002 using similar staffing and effort. The relative precision of the mark-recapture estimate was improved as a result.

Fish returning to the Leduc River tributaries were under-sampled (i.e. marked) as judged by the fractions marked/captured (M/C) in the lower tributaries and in the South Fork-Indian Creek

Table 5.–Estimated age and sex composition, and escapement of medium (401–659 mm MEF) and large (≥660 mm MEF) Chinook salmon in the Chickamin River, 2003. Estimates are from Chinook salmon sampled on the spawning grounds in Event 2.

PANEL A: MEDIUM CHINOOK SALMON (401–659 mm MEF)							
		Brood year and age class					
		2000	1999	1998	1997	1996	
		1.1	1.2	1.3	1.4	1.5	Total
Males	Sample size	16	35	2			53
	Percent	30.2%	66.0%	3.8%			100.0%
	SE of percent	6.4%	6.6%	2.6%			0.0%
	Escapement	222	485	28			735
	SE of esc.	64	110	20			150
Total	Sample size	16	35	2			53
	Percent	30.2%	66.0%	3.8%			100.0%
	SE of percent	6.4%	6.6%	2.6%			0.0%
	Escapement	222	485	28			735
	SE of esc.	64	110	20			150
PANEL B: LARGE CHINOOK SALMON (≥660 mm MEF)							
		Brood year and age class					
		2000	1999	1998	1997	1996	
		1.1	1.2	1.3	1.4	1.5	Total
Males	Sample size		13	305	61	2	381
	Percent		1.5%	35.5%	7.1%	0.2%	44.3%
	SE of percent		0.4%	1.6%	0.9%	0.2%	1.7%
	Escapement		69	1,624	325	11	2,029
	SE of esc.		21	223	58	8	273
Females	Sample size			323	154	2	479
	Percent			37.6%	17.9%	0.2%	55.7%
	SE of percent			1.7%	1.3%	0.2%	1.7%
	Escapement			1,720	820	11	2,550
	SE of esc.			235	122	8	339
Total	Sample size		13	628	215	4	860
	Percent		1.5%	73.0%	25.0%	0.5%	100.0%
	SE of percent		0.4%	1.5%	1.5%	0.2%	0.0%
	Escapement		69	3,344	1,145	21	4,579
	SE of esc.		21	438	162	11	592
PANEL C: MEDIUM AND LARGE CHINOOK SALMON COMBINED							
		Brood year and age class					
		2000	1999	1998	1997	1996	
		1.1	1.2	1.3	1.4	1.5	Total
Males	Sample size	16	48	307	61	2	434
	Percent	4.2%	10.4%	31.1%	6.1%	0.2%	52.0%
	SE of %	1.2%	2.1%	1.7%	0.8%	0.1%	2.2%
	Escapement	222	555	1,652	325	11	2,764
	SE of Esc.	64	112	224	58	8	312
Females	Sample size			323	154	2	479
	Percent			32.4%	15.4%	0.2%	48.0%
	SE of %			1.8%	1.2%	0.1%	2.2%
	Escapement			1,720	820	11	2,550
	SE of Esc.			235	122	8	339
Total	Sample size	16	48	630	215	4	913
	Percent	4.2%	10.4%	63.4%	21.5%	0.4%	100.0%
	SE of %	1.2%	2.1%	2.4%	1.5%	0.2%	0.0%
	Escapement	222	555	3,371	1,145	21	5,314
	SE of Esc.	64	112	438	162	11	611

areas in 2003, a trend we have seen in past years. In 2003, a higher (4.7%) rate of recapture, or marked fraction, of large fish was detected in the Leduc River tributaries, compared to the 2.8% (average) rate experienced here in 1995, 1996, 2001, and 2002, and the 6.3% and 6.4% average rates in the lower tributaries and South Fork, respectively (Freeman and McPherson 2004). The higher recapture rate at the Leduc tributaries was similar to the 5.1% rate in the lower tributaries but below the 9.0% rate in the South Fork and Indian Creek areas (mid-drainage, Table 3). A meta-analysis with pooled M/C data over the five years of the study yields a significant (P=0.002) chi-square test statistic, showing there are different marking rates for fish bound for the three Chickamin River areas referenced above. Efforts to mark more Leduc River-bound Chinook salmon in Event 1 in 2003 included setnetting across from SN5 (along the west bank of the mainstem) and at the Leduc River confluence. Both sites proved unproductive and fishing was discontinued. Additional efforts were also expended on the three Leduc River tributaries (Butler, Leduc, and Clear Falls creeks) in Event 2 to capture more fish. The resultant sample was 234 large fish, up from 128 fish in 2002 and likely more representative of the total run. A relatively higher percentage of all large fish marked were tagged at SN3 (mostly along the west bank) in 2003: 62% vs. 43% in 2002. This may have contributed to the higher rate of recapture seen in the Leduc tributaries in 2003, perhaps attributed in part to stream bank fidelity, as the Leduc River and its three sampled tributaries all enter along that stream bank.

The higher, combined 9.0% marked fraction measured for large Chinook salmon in the South Fork and Indian Creek areas in 2003 was the primary reason that the statistical test of the hypothesis of equal marked fractions across spatial recovery strata failed. Most of the fish recaptured in the South Fork were tagged at SN5, the same side of the mainstem that the South Fork enters. The highest marked fraction (14.5%) was measured at Lucky Jake Creek and nearby Indian Creek, which enter the mainstem from opposite sides higher in the drainage (Figure 3). Despite a small sample size (9 recaptures of 62 large fish captured), stream bank fidelity to the setnet sites was observed for 8 of the 9 recaptures, with 6 of 7 recaptures at Lucky Jake Creek marked at SN5

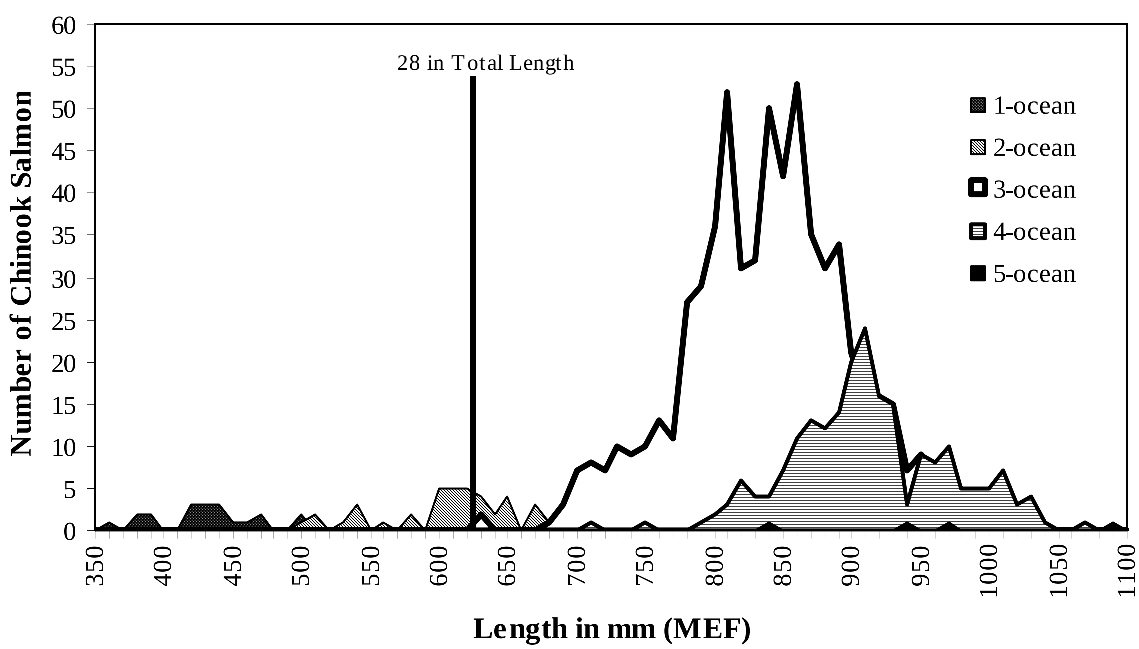

Figure 6.–Numbers of Chinook salmon by ocean age from samples taken in Event 2, Chickamin River, 2003. (Based on regulations for Southeast Alaska, 28 inches is the minimum total length of Chinook salmon permitted for harvest in the sport fishery.)

and both recaptured fish at Indian Creek marked at SN3. Alternatively, SN5 may be a staging or milling area for Chinook salmon bound for South Fork and Indian Creek.

Relative to the Unuk River and other Chinook salmon systems studied in SEAK, the lower Chickamin River lacks obvious holding areas or easily detected migration routes, and high bycatch of pink and chum salmon are inevitable. Finding effective setnet sites has proven challenging on this system. Despite some limitations (differential marking rates), the combination of the two primary sites fished in 2002 and 2003 seem to be our best options on the Chickamin River. Other sites have been tested and proven ineffective over the long term because of variable stream conditions, debris loading, or high bycatches.

Sampling appeared to be selective against very small to medium-sized (age-1.1 and some 1.2) fish in both events. The 7.25-in mesh net was better suited to catching large-sized fish, however, gillnets were hung loosely to help reduce bias towards larger fish. In 2003, the proportion of medium-sized Chinook salmon of the total (medium + large) gillnet catch was 0.138. In the four previous years of this study (1995, 1996, 2001, and 2002), the proportion of medium-sized fish caught in gillnets ranged from 0.164 to 0.189 with an average of 0.177. The estimate of 735 medium-sized fish in 2003 may be biased low, yet we are confident that the estimate falls within the 95% CI of 435 to 1,029 fish.

Catches on the spawning grounds matched our experience that small and medium-sized fish are consistently difficult to capture in Event 2. Perhaps this can be addressed somewhat in future sampling, by spending more effort trying to capture medium-sized fish.

Once the small and medium-sized fish were segregated, sampling size selectivity was less of an issue with large fish. We concluded (using our KS tests for large fish) that sampling was not size selective in Event 2 but that sampling in Event 1 was selective ($P<0.0001$) against the largest fish. This is to be expected given the 7.25-in mesh used to capture and mark fish in the lower river, in that the largest Chinook salmon (>860 mm MEF) are caught at a lower rate than on the spawning grounds. We note that over the medium and large size classes, effects of size-selective sampling are

Table 6.–Average length by sex and age of Chinook salmon sampled in the Chickamin River, 2003.

		Brood year and age class					
		2000	1999	1998	1997	1996	
		1.1	1.2	1.3	1.4	1.5	Total
Males	Sample size	21	48	307	61	2	439
	Average length	438	635	829	943	1033	
	SD	43	76	68	72	81	
	SE	9	11	4	9	57	
Females	Sample size			323	154	2	479
	Average length			850	902	890	
	SD			48	46	71	
	SE			3	4	50	
Sexes combined	Sample size	21	48	630	215	4	918
	Average length	438	635	844	916	936	
	SD	43	76	54	58	88	
	SE	9	11	2	4	44	

Note: Estimates include all Chinook salmon sampled and successfully aged from the spawning grounds.

Table 7.–Peak survey counts, mark-recapture estimates of escapement, and estimated expansion factors for large (≥660 mm MEF) Chinook salmon in the Chickamin River in 1995, 1996, 2001, 2002, and 2003.

	Year					1996-2003
Parameter	**1995**	**1996**	**2001**	**2002**	**2003**	**Average**
Survey count	356	422	1,010	1,013	964	852
Mark-recapture estimate (M-R)	2,309	1,587	5,177	5,007	4,579	4,088
M-R standard error	723	199	972	738	592	
M-R 95% relative precision	61.4%	24.6%	36.8%	28.9%	25.3%	28.9%
M-R lower 95% C. I.	1,388	1,279	3,780	3,892	3,481	
M-R upper 95% C. I.	4,650	2,089	7,573	6,742	5,134	
Survey count/(M-R)	15.4%	26.6%	19.5%	20.2%	21.1%	21.8%
Expansion factor	6.49	3.76	5.13	4.94	4.75	4.64
SE[expansion factor]	2.03	0.47	0.96	0.73	0.61	0.61
CV of expansion factor	31.3%	12.5%	18.8%	14.7%	12.9%	13.1%

substantially reduced within our size-stratified study design.

Direct evidence of handling or stress-related mortality of Chinook salmon was not observed in the gillnets. Low mortality using these methods was reported by Pahlke (1997), who observed that over 90% of gillnet-caught and radio-tagged Chinook salmon were tracked upstream to spawning areas in 1996. Some net mortality of pink and chum salmon was observed during the peak bycatch period in late July. Mortality was minimized because crews maintained a constant watch on the nets, and responded quickly to free entangled fish.

CONCLUSIONS AND RECOMMENDATIONS

We should continue to try to reduce the differences in the fractions of Chinook salmon bound for the three general spawning areas (lower, South Fork and Indian, and Leduc tributaries) that are marked. Further refinement of the timing of sampling at each location in each event may help in this endeavor, as will trying to catch more fish along the west bank near SN5 or SN6. If successful, similar marked fractions in the tributaries may make the experiment more robust.

We recommend that the previously established expansion factor (4.0) for aerial surveys conducted on the Chickamin River be revised to 4.64, based on the mean of the four estimates for 1996, 2001, 2002, and 2003. A continuation of this project will provide a better estimate of the expansion factor, and a more reliable base from which to estimate past and future escapements through aerial index surveys. We also recommend that the mark-recapture project or annual sampling of at least 400 adults on the spawning grounds be continued to permit us to recover enough coded-wire tagged fish sampled in future returns to more precisely estimate total return by age and brood year, adult production, exploitation rates, and smolt abundance.

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APPENDIX A

Appendix A1.–Detection of length-selectivity in sampling and its effects on estimation of length composition.

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

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

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

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

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

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

Appendix A2.–Setnet catch and effort records on the Chickamin River, 2003.

Date	Setnet Site	Start time	End time	Time fished (hrs)	No. large Chinook	No. medium Chinook	No. small Chinook	No. pink	No. chum	No. coho	Water level	Water temp (ºC)
6/14	3D	1022	1622	6.0							10	8
6/14	5	1200	1800	6.0							10	8
6/15	3D	925	1525	6.0							19	8
6/15	5	958	1558	6.0							19	8
6/16	3D	940	1543	6.0	1						8	8
6/16	5	825	1428	6.0							8	8
6/17	5	915	1517	6.0	1						10	8
6/17	3D	600	1435	8.5							10	8
6/18	3D	1040	1640	6.0							18	8
6/19	3D	1035	1537	5.0	1						16	8
6/19	5	900	1500	6.0							16	8
6/20	3D	1200	1800	6.0							6	8
6/20	5	1130	1732	6.0	1						6	8
6/21	3D	1050	1654	6.0	1	1					no data	8
6/23	3D	1215	1818	6.0	1				1		2	8
6/23	5	1150	1758	6.0	4						2	8
6/24	3D	1110	1716	6.0	3			1			3	8
6/24	5	1050	1652	6.0	1						3	8
6/25	3D	455	1055	6.0							4	8
6/26	3D	1115	1715	6.0							13	7
6/26	5	1155	1757	6.0	1				1		13	7
6/27	3D	930	1530	6.0					1		8	7
6/27	5	1115	1719	6.0	2				1		8	7
6/28	3D	1130	1730	6.0					1		no data	7
6/29	3D	1105	1703	6.0					2		12	7
6/29	5	1120	1720	6.0							12	7
6/30	3D	1600	1900	3.0					1		no data	7
7/01	3D	1450	1750	3.0					2		15	7
7/01	5	1135	1435	3.0							15	7
7/02	3D	1110	1712	6.0	1				1		13	7
7/03	5	710	1310	6.0					3		11	7
7/03	3D	1330	1932	6.0	1				2		11	7
7/04	5	1010	1612	6.0	1						30	8
7/05	3D	1045	1645	6.0				1	7		13	8
7/05	5	1110	1710	6.0				1	2		13	8
7/06	3D	1030	1632	6.0	1				6		12	8
7/06	5	1120	1720	6.0					1		12	8
7/07	3D	912	1512	6.0				4	5		9	8
7/07	5	1110	1712	6.0	1			2	5		9	8
7/08	3D	1210	1818	6.0	2		1	6	4		14	8
7/08	5	1305	1913	6.0	4				4		14	8
7/09	3D	1015	1625	6.0	3	2		6	8		4.5	8
7/10	3D	1130	1738	6.0	4			10	22		11.75	8
7/10	5	1050	1656	6.0	2			4	6		11.75	8
7/11	3D	1030	1632	6.0	1			10	13		13	8

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Date	Setnet Site	Start time	End time	Time fished (hrs)	No. large Chinook	No. medium Chinook	No. small Chinook	No. pink	No. chum	No. coho	Water level	Water temp (ºC)
7/11	5	1100	1600	5.0				4	15		13	8
7/11	3D	1805	1907	1.0	1			3	2		13	8
7/12	3D	1130	1734	6.0	2			11	14		14	8
7/12	5	1210	1828	6.0	9			3	1		14	8
7/13	3D	1130	1738	6.0	3	1		7	12		22	8
7/13	5	1215	1821	6.0		3		10	13		22	8
7/14	3D	1150	1152	6.0	1			21	12		no data	8
7/15	3D	1110	1720	6.0	4	1		142	20		8.5	8
7/15	5	1150	1754	6.0	2			6	4		8.5	8
7/16	3D	1115	1721	6.0	3			113	8		10	8
7/16	5	1230	1848	6.0	9			9	10		10	8
7/17	3D	1230	1836	6.0	2		1	39	4		13	8
7/17	5	1208	1818	6.0	3	2		11	9		13	8
7/18	3D	1145	1753	6.0	2	2		361	15		10	8
7/18	5	1200	1806	6.0	3			18	16		10	8
7/19	5	658	1304	6.0	3			60	4		11	8
7/19	5	1304	1908	6.0	2			61	13		11	8
7/20	5	705	1315	6.0	5			62	10		16	8
7/20	5	1315	1927	6.0	4	2		19	7		16	8
7/21	5	710	1314	6.0	2			48	9		23	8
7/21	5	1314	1924	6.0	5			44	15		23	8
7/22	5	725	1335	6.0	5	1		40	8		16	8
7/22	5	1335	1940	6.0	3			193	17		16	8
7/23	5	1135	1739	6.0	2			84	3		8	8
7/24	3D	1100	1704	6.0	2			735	18		6	8
7/24	5	1115	1717	6.0	1			118	8		6	8
7/25	5	704	1308	6.0	1	1		214	9		10.5	8
7/25	5	1308	1918	6.0	4	1		214	9		10.5	8
7/26	5	1225	1835	6.0	4	2		190	18		10	8
7/27	3A	1130	1738	6.0	3	1		461	4		9	9
7/27	5	1200	1812	6.0	6			173	21		9	9
7/28	3D	1100	1500	4.0	2			95	6	2	10	9
7/28	5	1115	1721	6.0	3			136	14		10	9
7/29	3D	1135	1751	6.0	7	1		193	32		12	9
7/29	5	1125	1737	6.0	6			208	19		12	9
7/30	3D	1115	1727	6.0	5	1		161	25		9	9
7/30	5	1145	1751	6.0	3			141	31		9	9
7/31	5	1130	1230	1.0	1			35	5		9	9
7/31	3C	1300	1814	5.0	8	2		65			9	9
7/31	3D	1130	1445	3.0	7	1		125	20	1	9	9
7/31	3D	1645	1945	3.0				106	13		9	9
8/01	3D	1050	1702	6.0	5	1		145	23		11	9
8/02	3D	1040	1642	6.0	1			93	8		10	9
8/03	3D	930	1330	4.0				75	11		6	9
8/03	3D	1715	1915	2.0							6	9

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Date	Setnet Site	Start time	End time	Time fished (hrs)	No. large Chinook	No. medium Chinook	No. small Chinook	No. pink	No. chum	No. coho	Water level	Water temp (ºC)
8/04	3D	1240	1854	6.0	5	2		210	7	1	3	9
8/05	3D	920	1530	6.0	4	1		138	8		1.5	9
8/06	3D	1200	1832	6.0	8	8		229	9	8	-1	9
8/06	3A	1145	1749	6.0	3			47	20	1	-1	9
8/07	3D	1323	2009	6.0	18	2		313	21	4	2.5	9
8/07	3D	715	1323	6.0	4			115	32		2.5	9
8/08	3D	1215	1831	6.0	6	2		231	43	8	no data	9
8/10	3D	1115	1731	6.0	8			130	22	2	no data	9
8/11	3D	1130	1742	6.0	6			158	22	8	2.5	9
8/12	3D	1230	1900	6.0	12	2		24	20	14	3.5	9
8/13	3D	1215	1839	6.0	10	1		56	14	1	2.5	9
8/14	3D	1320	1930	6.0	4			47	10	3	4	9
8/15	3D	1230	1840	6.0	4	1		38	12		10.5	9
8/17	3D	1230	1830	6.0	1			17	1	5	no data	9

Appendix A3.–Age by sex of unweighted large (≥660 mm MEF), medium (401–659 mm MEF), and small (≤400 mm MEF) Chinook salmon sampled in set gillnets and from spawning grounds, Chickamin River, 2003.

PANEL A. Chinook salmon sampled in Event 1 (set gillnets)

			Brood year and age class					
			2000	1999	1998	1997	1996	
			1.1	1.2	1.3	1.4	1.5	**Total**
Large fish	Males	Sample		7	90	5	1	**103**
		Percent		6.8%	87.4%	4.9%	1.0%	**45.8%**
	Females	Sample			96	26		**122**
		Percent			78.7%	21.3%		**54.2%**
	Total	Sample		7	186	31	1	**225**
		Percent		3.1%	82.7%	13.8%	0.4%	
Medium fish	Males	Sample	9	19	3			**31**
		Percent	29.0%	61.3%	9.7%			**100.0%**
	Total	Sample	9	19	3			**31**
		Percent	29.0%	61.3%	9.7%			
Set gillnets all Chinook	Males	Sample	9	26	93	5	1	**124**
		Percent	1.9%	63.3%	23.3%	11.2%		**65.5%**
	Females	Sample		13	44	55	1	**113**
		Percent		11.5%	38.9%	48.7%	0.9%	**34.5%**
	Total	Sample	4	149	94	79		**328**
		Percent	1.2%	45.4%	28.7%	24.1%		

PANEL B. Chinook salmon sampled in Event 2 (spawning grounds)

			Brood year and age class					
			2000	1999	1998	1997	1996	
			1.1	1.2	1.3	1.4	1.5	**Total**
Large fish	Males	Sample		12	278	55	2	**347**
		Percent		3.5%	80.1%	15.9%	0.6%	**43.2%**
	Females	Sample			306	149	2	**457**
		Percent			67.0%	32.6%	0.4%	**56.8%**
	Total	Sample		12	584	204	4	**804**
		Percent		1.5%	72.6%	25.4%	0.5%	
Medium fish	Males	Sample	16	33	2			**51**
		Percent	31.4%	64.7%	3.9%			**100.0%**
	Females	Sample						**0**
		Percent						**0.0%**
	Total	Sample	16	33	2			**51**
		Percent	31.4%	64.7%	3.9%			
Small fish	Males	Sample	5					**5**
		Percent	100.0%					**100.0%**
	Total	Sample	5					**5**
		Percent	100.0%					
Spawning grounds – all Chinook	Males	Sample	21	45	280	55	2	**403**
		Percent	5.2%	11.2%	69.5%	13.6%	0.5%	**59.9%**
	Females	Sample			306	149	2	**457**
		Percent			67.0%	32.6%	0.4%	**56.8%**
	Total	Sample	21	45	586	204	4	**860**
		Percent	2.4%	5.2%	68.1%	23.7%	0.5%	

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PANEL C. Chinook salmon sampled in Event 1 (set gillnets) and Event 2 (spawning grounds) combined

			Brood year and age class					
			2000	1999	1998	1997	1996	
			1.1	1.2	1.3	1.4	1.5	**Total**
Large fish	Males	Sample		19	368	60	3	**450**
		Percent		4.2%	81.8%	13.3%	0.7%	**43.7%**
	Female	Sample			402	175	2	**579**
		Percent			69.4%	30.2%	0.3%	**56.3%**
	Total	Sample		19	770	235	5	**1,029**
		Percent		25.8%	40.9%	32.8%	0.5%	
Medium fish	Males	Sample	25	52	5			**82**
		Percent	30.5%	63.4%	2.9%			**100.0%**
	Female	Sample						**0**
		Percent						**0%**
	Total	Sample	25	52	5			**82**
		Percent	30.5%	63.4%	6.1%			
Small fish	Males	Sample	5					**2**
		Percent	100%					**100.0%**
	Total	Sample	5					**2**
		Percent	100%					
Set gillnets & spawning grounds –all Chinook	Males	Sample	30	71	373	60	3	**537**
		Percent	1.0%	54.1%	31.1%	13.5%	0.2%	**48.1%**
	Female	Sample			402	175	2	**579**
		Percent			42.9%	51.9%	0.8%	**51.9%**
	Total	Sample	30	71	775	235	5	**1,116**
		Percent	2.7%	6.4%	69.4%	21.1%	0.4%	

Appendix A4.–Computer files used to estimate the spawning abundance and age, sex, and length data for Chinook salmon in the Chickamin River in 2003.

File name	**Description**
Chickamin King 2003 _FDS. xls	Spreadsheets containing mark-recapture data, summary tables, chi-square test results, Kolmogorov-Smirnov (K-S) 2-sample test results, abundance estimation, age, and sex composition data.
Chickamin03_T&F. xls	Spreadsheets used to develop selected report tables and figures.