Fishery Data Series No. 97-28

Abundance and Distribution of the Chinook Salmon Escapement on the Chickamin River, 1996

by

Keith A. Pahlke

November 1997

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 97-28

ABUNDANCE AND DISTRIBUTION OF THE CHINOOK SALMON ESCAPEMENT ON THE CHICKAMIN RIVER, 1996

by

Keith A. Pahlke
Division of Sport Fish, Douglas

Alaska Department of Fish and Game
Division of Sport Fish
P. O. Box 240020
Douglas, AK 99824-0020

November 1997

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-11, Job No. S-1-8.

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

Keith A. Pahlke
Alaska Department of Fish and Game, Division of Sport Fish
P. O. Box 240020, Douglas, AK 99824-0020, USA

This document should be cited as:
Pahlke, Keith A. 1997. Abundance and Distribution of the chinook salmon escapement on the Chickamin River, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-28, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

The distribution and abundance of large chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Chickamin River in 1996 was estimated by using radio telemetry and a mark-recapture experiment. Age, sex, and length compositions were estimated for the immigration. Set gillnets were used to capture 183 immigrant chinook salmon ≥660 mm in (mid-eye to fork) length during June, July, and August 1996; 174 fish were marked with spaghetti tags and opercle punches, and 112 of these also had radio transmitters inserted into their stomachs. One hundred and one (101) of the radio-tagged fish were tracked to spawning locations; 84 in survey index areas and 17 in unsurveyed streams. During August, 380 chinook salmon ≥660 mm long were captured at spawning sites and inspected for tags; 41 of these fish had been previously marked. A modified Petersen model (n1 = 174, n2 = 380, m2 = 41) estimated that 1,587 (SE = 199) chinook salmon ≥ 660 mm in length immigrated to the Chickamin River in 1996. Peak survey counts in August totaled 422 large chinook, about 27% of the estimated inriver run.

From immigrant age and length composition data collected in gillnet and spawning ground samples, it was estimated that 5.7% of the gillnet catch was age-1.1, 14.0% was age-1.2, 47.7% age-1.3, 25.4% age-1.4, and 3.1% age-1.5 (96 males and 97 females) and that 2.4% of the spawning ground samples were age-1.1, 7.7% age-1.2, 56.5% age-1.3, 30.4% age-1.4, and 2.7% age-1.5 (180 males and 195 females).

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, Chickamin River, mark-recapture, spawning distribution, radio telemetry, escapement, abundance, Behm Canal.

INTRODUCTION

In the mid- to late 1970s, it became apparent that some chinook salmon *Oncorhynchus tshawytscha* stocks in the Southeast Alaska region were depressed, relative to historical levels of production (Kissner 1982). The Alaska Department of Fish and Game (ADF&G) developed a structured rebuilding program in 1981 to rebuild Southeast chinook salmon stocks over a 15-year period (roughly three life cycles; ADF&G 1981). The rebuilding program has been evaluated, in part, by monitoring trends in indices of escapement for important stocks. Stocks in eleven river systems in Southeast Alaska are surveyed annually: the Situk, Alsek, Chilkat, Taku, King Salmon, Stikine, Unuk, Chickamin, Blossom, and Keta rivers, and Andrew Creek. Of the eleven index systems, total escapement has been estimated at the Situk, Chilkat, Taku, Unuk, Chickamin and King Salmon rivers and at Andrew Creek.

The Unuk, Chickamin, Blossom, and Keta rivers flow through the Misty Fiords National Monument/Wilderness into Behm Canal, a narrow saltwater passage east of Ketchikan (Figure 1). These rivers constitute the four index systems for the chinook salmon program in southern Southeast Alaska (Pahlke 1995) and are collectively referred to as the Behm Canal chinook systems. Since 1975 these four systems have been monitored with annual peak surveys to provide index escapement counts. Between 1986 and 1989, survey counts reached peak levels in the Behm Canal systems, then began a steady decline. By 1993, concern for the status and health of these stocks became a priority issue. The Unuk River (the largest system) was selected for a study to validate the ongoing index program in 1994 (Pahlke et al. 1996) and a similar project was implemented on the Chickamin River in 1995 (Pahlke 1996a). In 1996 the program on the Chickamin was expanded to include a radio telemetry project to estimate spawning distribution.

The objectives of the study were:

(1) to detect all spawning areas in the Chickamin River drainage which receive ≥5% of the large (≥660mm MEF length) immigrant chinook salmon;

(2) to estimate the abundance of large spawning chinook salmon in the Chickamin River; and

(3) to estimate age, sex, and length compositions of chinook salmon in the Chickamin River.

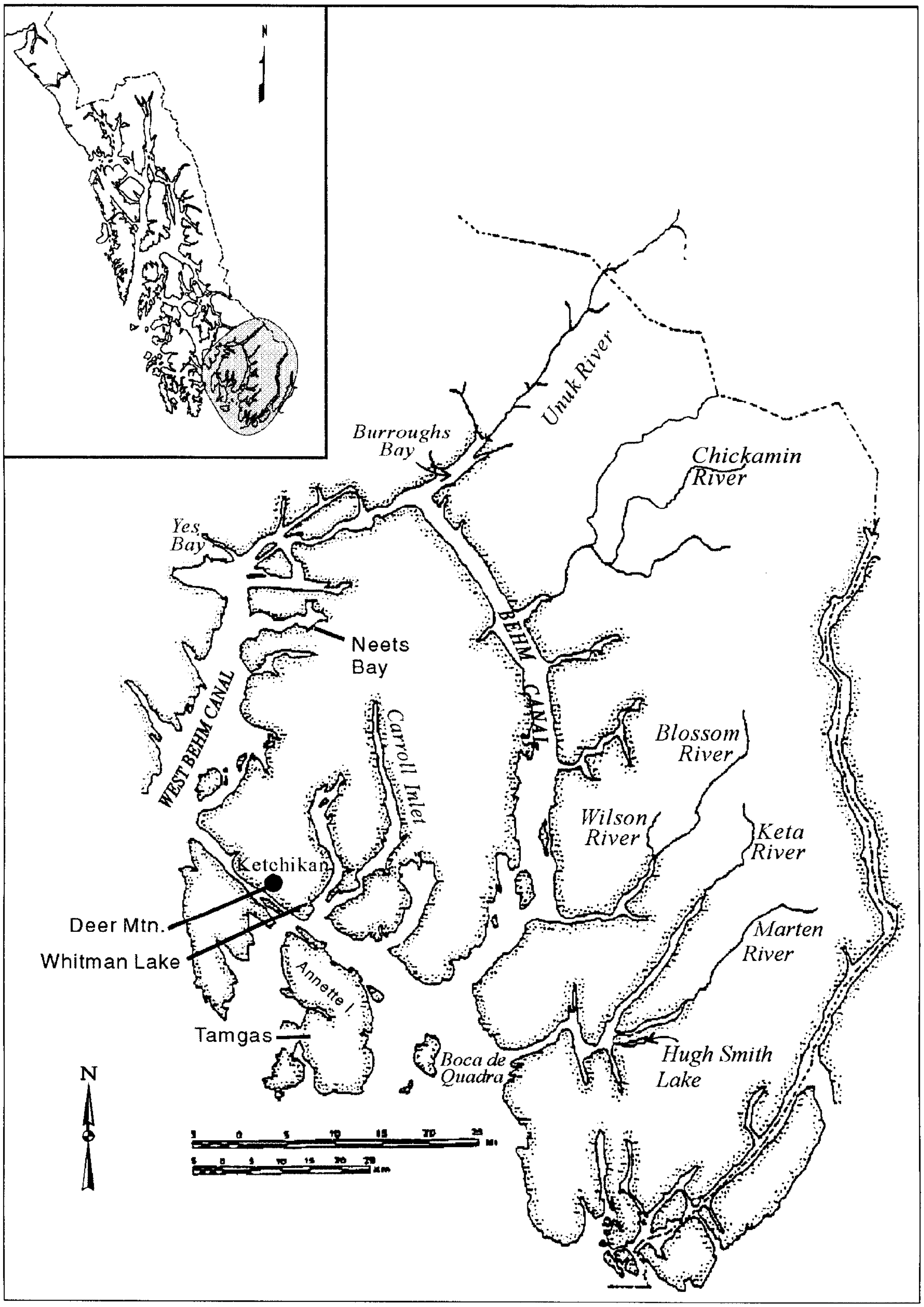


Figure 1.–Behm Canal area, showing major chinook systems and hatcheries.

Results from the study would help determine if current survey index areas represent the important spawning areas used in 1996, and permit a benchmark index survey-to-abundance expansion factor to be estimated; i.e., to estimate what fraction of total escapement is seen in the peak survey count.

STUDY AREA

The Chickamin River originates in a heavily glaciated area of northern British Columbia and flows into Behm Canal approximately 65 km northeast of Ketchikan, Alaska (Figure 2). Although the Chickamin River is a trans-boundary river, there are no chinook salmon spawning areas in Canada. Eight spawning areas (tributaries or stream reaches) in Alaska are included in the index survey. Aerial survey counts and distribution of spawning chinook salmon to the eight areas in 1981–1996 are shown in Table 1. Average spawning distributions include: Humpy Creek (4%), King Creek (31%), Leduc Creek (3%), Clear Falls Creek (6%), Butler Creek (13%), Indian Creek (8%), South Fork (22%), and Barrier Creek (13%). From 1981-1994, it was assumed that the sum of these index counts represented 62.5% of the total annual escapement to the Chickamin River (Pahlke 1995); in 1995 the expansion was revised to 25% (Pahlke 1996b).

The present index escapement goal for Chickamin River chinook salmon is 525 fish ≥660 mm MEF length. This goal was adopted in July 1994 on the basis of spawner recruit analysis in McPherson and Carlile (1997).

METHODS

The abundance estimate of immigrating chinook salmon relied on marking fish with uniquely numbered tags as they traversed the lower Chickamin River to upstream spawning sites. Sampling effort was held reasonably constant across the temporal span of the migration. As immigration waned, sampling for marks and age composition began at spawning sites.

Set gillnets 100 feet long and 18 feet deep, made of 7.25-inch stretch mesh, were fished at two sites on the lower Chickamin River between June 8 and August 15 to capture adult chinook salmon. One site was located near the mouth of Humpy Slough, and another site was located near the mouth of Choca Creek (Figure 2). Both sites were below all known spawning areas, with the exception of Humpy Creek, which flows through Humpy Slough into the Chickamin River below the Choca Creek site.

One net was fished approximately 7 hours per day at the Choca Creek site, and two nets were fished approximately 7 hours per day (each) at the Humpy Slough site. Nets were set between 0800 and 1000 hours. At the Choca Creek site, the net crossed about one third of the river, while at the Humpy Creek site the combined nets were fished in a 'V' shape that covered less than one fourth of the river. Both sites were fished daily unless high water or manpower shortages occurred. The nets were watched continuously and a fish was removed from the net as soon as it was observed. If fishing time was lost due to entanglements, snags, cleaning the net, or the like, the lost time (processing time) was added on to the end of the day to bring fishing time to 7 hours per net. For each chinook salmon captured 5 minutes of processing time was added and for each other salmon captured 1 minute was added to the process time up to a maximum of 2 additional hr/day.

Captured chinook salmon were placed in a box filled with water, quickly untangled or cut from the net, tagged, scale sampled, and their length and sex recorded during a visual examination (Johnson et al. 1993). Fish were classified as "large" if their mid-eye to fork length (MEF) was ≥ 660 mm, or "small" if their MEF was < 660mm (Pahlke 1995). Fish were judged to be "bright" or "dark" on the basis of external appearance, and the presence or absence of sea lice (*Lepeophtheirus* sp.)

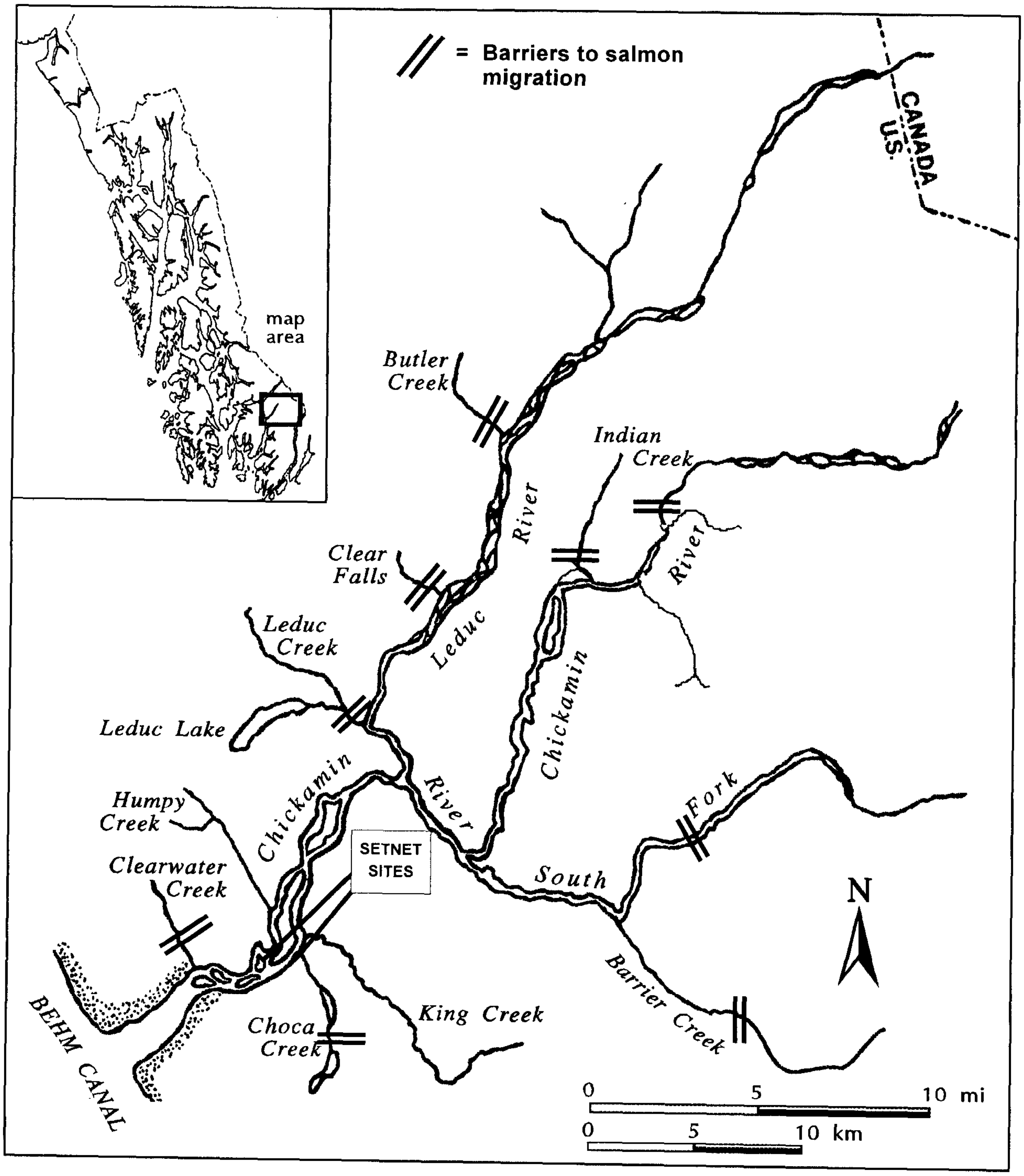


Figure 2.–Chickamin River drainage, showing major tributaries, barriers to fish migration and location of ADF&G research sites.

Table 1.–Distribution of spawning chinook salmon among index areas surveyed on the Chickamin River, 1981–1996.

Year	South Fork Creek	%	Barrier Creek	%	Butler Creek	%	Leduc Creek	%	Clear Falls Creek	%	Indian Creek	%	Humpy Creek	%	King Creek	%	Total
1981	51	13	105	27	51	13	25	7	31	8	12	3	4	1	105	27	384
1982	84	15	149	26	37	6	36	6	33	6	30	5	37	6	165	29	571
1983	28	5	138	24	91	16	30	5	30	5	47	8	–	–	212	37	576
1984	185	17	171	16	124	11	15	1	28	3	103	9	88	8	388	35	1,102
1985	136	14	156	16	93	10	8	0	12	1	125	13	50	5	377	39	957
1986	562	34	168	10	203	12	20	1	40	2	120	7	–	–	564	34	1,677
1987	261	27	76	8	120	12	19	2	48	5	115	12	26	3	310	32	975
1988	280	36	82	10	159	20	25	3	25	3	32	4	19	2	164	21	786
1989	226	24	90	10	137	15	57	6	94	10	84	9	22	2	224	24	934
1990	135	24	107	19	27	5	20	4	53	9	24	4	35	6	163	29	564
1991	125	26	18	4	49	10	14	3	45	9	38	8	13	3	185	38	487
1992	87	25	4	1	68	20	4	1	24	7	20	6	8	2	131	38	346
1993	67	17	46	12	68	17	11	3	75	19	29	7	13	3	80	21	389
1994	31	8	29	7	64	16	18	5	57	15	16	4	44	11	129	33	388
1995	87	24	12	3	59	17	60	17	27	8	36	10	13	4	62	17	356
Avg.	156	22	90	13	90	13	24	3	41	6	55	8	25	4	217	31	699
1996	72	17	13	3	74	18	23	6	56	13	48	11	30	7	106	25	422

was noted. General health and appearance of the fish was also recorded, including injuries due to handling or predators.

Initially, every large healthy chinook salmon had a 30-31 MHz Advanced Telemetry Systems (ATS) radio transmitter esophageally inserted into its stomach (Eiler 1990), and had a uniquely numbered spaghetti tag (Floy Tag Co.) attached just behind the dorsal fin. However, since capture rates were greater than expected, only one of every three chinook salmon captured during the latter half of the project were tagged with radio transmitters. The frequency of each radio transmitter was checked immediately after the fish was released to verify it was operating correctly and to note any deviations from the listed frequency. Each spaghetti tag was threaded over a solid core of 50 lb monofilament fishing line which was threaded through the dorsal musculature of the fish and then crimped to itself with metal leader sleeves (Johnson et al. 1993). The upper portion (dorsal side) of the left operculum on each fish was given a 1/4-inch-diameter paper punch as a secondary mark.

DISTRIBUTION OF SPAWNING

Assumptions of the experiment to estimate spawning distributions include: (a) fish were captured for radio-tracking in proportion to abundance during the immigration, (b) tagging did not change the destination (fate) of a fish; and (c) fates of radio-tracked fish are accurately determined. The first assumption will be true if fishing effort and catchability were constant for all "stocks" (fish spawning in the same area) in the immigration (stocks might be characterized by their age composition and immigration timing). Catchability would presumably vary with river conditions. Thus, sampling effort was held as constant as practically possible during the immigration. The river stage (height) was recorded for comparison to catch rates at the gillnet sites. Contingency table analysis was used to test the assumption of similar migratory timing for the stocks, as noted below.

Beginning June 20, an attempt was made to locate each radio transmitter at least once a week from boat or by airplane or helicopter as the size of the search area increased. The location of each tag was recorded by river mile from the mouth of the river or tributary. Transmitters used in this study were equipped with motion (mortality) sensors that doubled the pulse rate to 2 pulses per second following 3 to 4 h of inactivity. Subsequent movement reset the transmitter to the normal mode. Signals from radio-tagged fish were recorded as either normal or mortality mode (Eiler 1990, Bendock and Alexandersdottir 1992, Johnson et al. 1993).

At the conclusion of the tracking surveys, each radio-tagged fish was assigned one of four possible fates (Table 2; Johnson et al. 1993).

The proportion of the large chinook salmon spawning in each area was estimated:

$$P_a = \frac{\sum_{t=1}^{y}\left(\frac{N_t}{n_t}\right) r_{a,t}}{\sum_{a=1}^{x}\sum_{t=1}^{y}\left(\frac{N_t}{n_t}\right) r_{a,t}} \qquad (1)$$

where $r_{a,t}$ = the number of large fish tagged with radios in period t that were tracked to and assumed to spawn in area a,

N_t = the number of large fish captured in gillnets in period t, and

n_t = the number of large fish radio-tagged in period t.

Period (t) refers to distinct spans of time when the tagging fraction was constant. Transmitters assigned to fates not associated with successful spawning are ignored in computing P_a, so that the sum of the estimated proportions equals one.

The standard error of P_a was estimated using the bootstrap. In each period, n_t new samples were drawn from all assigned fates using the empirical distribution of the data, and new values of P_a computed. Confidence intervals for the estimated proportions were calculated using the bootstrap percentile method (Efron and Tibshirani 1993), because the assumption of normality was clearly inappropriate for the smaller estimated proportions.

Table 2.–Criteria to assign fates to radio tagged chinook salmon.

FATE CODE	FATE AND CRITERIA
1	**Probable spawning in a tributary:** a chinook salmon whose radio transmitter was tracked into a tributary, and remained in or was tracked downstream from that location. When a transmitter was tracked to more than one tributary, the last tributary was assumed to be the spawning location.
2	**Mortality or regurgitation:** a chinook salmon whose radio transmitter either did not advance upstream after tagging, or stopped in the mainstem Chickamin River and broadcast in the mortality mode (perhaps intermittently) over at least 4 weeks, and never tracked to a lower location in the river.
3	**Probable spawning in the mainstem:** a chinook salmon whose radio transmitter was tracked upstream (first observation, if the highest observed, was not in the mortality mode), observed in a mode other than the mortality mode near its highest observed location, then observed in a downstream location.
4	**Unknown:** a chinook salmon whose radio transmitter was rarely located (one or two weeks, never in a tributary), and/or does not fit into any of the other categories. These tracking histories were typically uninformative, or suggestive of more than one possible fate.

ABUNDANCE

The number of large chinook salmon in the Chickamin River escapement was estimated from a two-event mark-recapture experiment (Seber 1982). Fish captured by gillnet in the lower river and marked were included in event 1, and fish inspected for marks on the spawning grounds were included in event 2. During event 2, fish were captured with dip nets, seines, rod and reel gear and spears at eight spawning ground sites. The population was assumed to be closed during the study from July 26 through August 31.

Double-sampling on the spawning grounds was prevented by punching a hole in the lower (ventral) portion of the operculum of live fish and slashing sampled carcasses. The length and sex of each fish was recorded, along with the presence or absence of tags and opercle punches. Five scales were collected from each fish for age analysis.

The validity of this "closed" population experiment rests on several assumptions, including that: (a) every fish has an equal probability of being marked in event one, *or* that every fish has an equal probability of being captured in event 2, *or* that marked fish mix completely with unmarked fish; (b) recruitment and "death" (emigration) do not both occur between sampling events; (c) marking does not affect catchability (or mortality) of the fish; (d) fish do not lose their marks between sample events; (e) all recovered marks are reported; and (f) double sampling does not occur (Seber 1982).

Because of the duration of event 1 in this mark-recapture study, the first two assumptions must be carefully considered. Assumption (a) implies that tagging must occur in proportion to abundance during immigration, or if it does not, that there is no difference in age composition and immigration timing between stocks bound for different spawning locations, since mixing does not occur in time and between recovery areas. Assumption (a) also implies that sampling is not size-selective.

A 2x4 contingency table (chi-square statistic) was used to test the hypothesis ($\alpha = 0.05$) that fish radiotagged at the Choca Creek and Humpy Slough tagging sites were bound at equal rates for Leduc (Butler, Clear Falls, Leduc), Indian, South Fork/Barrier and lower (Humpy and King creeks) Chickamin River spawning sites. These sites were grouped based on their geography and similarities in observed run timing. A similar test was used to determine if fish tagged at the two sites were recovered at equal rates. If they were, data for both sites were combined to estimate abundance.

To provide evidence that assumption (a) was met, contingency table analysis was used to test the hypothesis ($\alpha = 0.05$) that fish sampled in the various spawning sites were marked at similar rates. If this hypothesis was accepted, a simple Petersen model was used to estimate abundance; otherwise a stratified estimator (Darroch 1961; Seber 1982, chapter 11) was employed. A program called SPAS (Stratified Population Analysis System) provided two tests to help determine if a stratified estimator was appropriate (Arnason et al. 1996). These are Chi-squared tests labeled "Equal Proportions" and "Complete Mixing" and if either test is low or insignificant it means that full or partial pooling is acceptable (Seber 1982). Variance, bias and confidence intervals for the point estimator were estimated with modifications of the bootstrap procedures in Buckland and Garthwaite (1991). Also, contingency table analysis was used to determine if fish marked early (prior to July 12) and late (July 12–August 12) in the immigration traveled to various spawning sites in the Chickamin River in similar proportions. If this hypothesis was rejected, migratory timing of the stocks differed, and rationale for stratifying the marking event by time was demonstrable.

Confidence intervals for the estimate were calculated using the bootstrap percentile method (Efron and Tibshirani 1993). The difference between the average of bootstrap estimates and the point estimator is an estimate of the statistical bias in the latter statistic (Efron and Tibshirani 1993).

The possibility of selective sampling was also investigated, since assumption (a) could be violated if sampling rate varied according to the size (or sex) of the fish. The hypothesis that fish of different sizes were captured with equal probability was tested with a Kolmogorov-Smirnov (K-S) 2-sample test. If size selective sampling occurred, rationale for stratifying the experiment by size was demonstrable (Appendix D1). Sex selection was tested using a 2 x 2 contingency table. If apparent, the abundance estimation procedures could be stratified by ages (age .3 versus age .4 and .5) and/or by sex.

Assumption (b) suggests tagging across the immigration, since deaths occur between sampling events. However, recruitment of untagged fish into the population was unlikely because gillnetting operations spanned the immigration and continued without large interruption. We assume tagged and untagged fish experience the same mortality (assumption c) from natural causes. Thus, estimates are germane to the time of tagging rather than recapture. To minimize effects of tag loss (assumption d), all marked fish received a dorsal opercle punch, providing secondary marks which cannot be lost. Similarly, we inspected all fish captured on the spawning grounds for marks (assumption e), and double sampling was prevented by placement of a ventral opercle punch (assumption f).

Age, Sex, and Length Composition of Escapement

All fish captured in the gillnet and spawning ground surveys were sampled for scales to enable age determination (Olsen 1995). Proportions by age or by sex in gillnet and spawning grounds samples were estimated by

$$\hat{p}_i = \frac{n_i}{n} \qquad (2)$$

$$V[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1} \qquad (3)$$

where p_i = proportion in the age, sex, or length group i, n_i = the number in the sample of group i, and n = sample size.

The age composition of chinook captured in the two lower river gillnets was compared using a chi-square test, prior to combining these samples. The test was also conducted for the different spawning areas. If size selective sampling occurred, procedures were taken to adjust the age and length compositions (Appendix D). In the absence of size selective sampling at the gillnet site, the age composition of the combined gillnet samples was compared with the age composition from the pooled spawning grounds using another chi-square test.

Estimates of mean length at age and its variance was calculated by standard normal procedures.

RESULTS

One hundred eighty-three (183) large (≥660 mm MEF) and 41 small chinook salmon were captured in the lower Chickamin River between June 7 and August 15, 1996 (Table 3; Appendices A1, A2). The majority of the fish (145) were caught at the Humpy Slough site; 89 fish were captured prior to July 12 (Period 1) and 94 from July 12 on (Period 2; Table 4). Setnet effort was typically 7 hours per day, with two nets at the Humpy Slough site and one net at the Choca Creek site, although many days were not sampled at the Choca Creek site (Figure 3c; Appendices B1, B2).

Catch rates ranged from 0 to 1.2 fish/net/hour, with peak catches on July 6 and August 2, when 12 large chinook were captured (Figure 3a). The date of 50% cumulative catch was July 17 at the Choca Creek site and July 12 at the Humpy Slough site. Nine large chinook salmon died in the nets, the remaining 174 fish were marked with spaghetti tags and upper opercle punches and of these, 112 had radio tags inserted into their stomachs. The sex ratio of large chinook salmon caught in the gillnets was equal (97 females, 96 males). Thirty-six small chinook were also marked with spaghetti tags and opercle punches. In addition, 5,702 chum *O. keta*, 24 sockeye *O. nerka*, and 5,081 pink *O. gorbuscha* and 88 coho *salmon O. kisutch* were captured and released (Appendix B). The "incidental" catches of pink and chum salmon occurred during the middle of the chinook return (Figure 3) and could have resulted in the bimodal shape of the chinook catch curve, since effective effort during this time was certainly lowered substantially.

Distribution of Spawning

Of the 112 fish marked with radio transmitters, 101 (90%) were successfully tracked to upstream spawning areas (Table 5). The 11 remaining transmitters were either regurgitated, lost because a fish died before spawning, never found or tracked in a way that defied assign-

Table 3.–Catch of large chinook salmon, number marked with tags and mortalities, by tagging site and sex, Chickamin River, 1996.

	Choca Creek site		
	Males	Females	Total
Catch	14	24	38
Tagged	14	24	38
Radio tags	10	14	24
Mortalities	0	0	0
	Humpy Slough site		
Catch	59	86	145
Tagged	52	84	136
Radio tags	30	58	88
Mortalities	7	2	9
	Total both sites		
Catch	73	110	183
Tagged	66	108	174
Radio tags	40	72	112
Mortalities	7	2	9

Table 4.–Catch of large chinook salmon, number marked with tags and mortalities, by tagging site and period, Chickamin River, 1996.

	Choca Creek site		
	Period 1	Period 2	Total
Catch	17	21	38
Radio Tags	17	7	24
Spaghetti Tags	0	14	14
Mortalities	0	0	0
	Humpy Slough site		
Catch	72	73	145
Radio Tags	66	22	88
Spaghetti Tags	3	45	48
Mortalities	3	6	9
	Total both sites		
Catch	89	94	183
Radio Tags	83	29	112
Spaghetti Tags	3	59	62
Mortalities	3	6	9

ment of a fate (Appendix C). Eighty-four of the radio tags were tracked to Index spawning areas, and 17 were tracked to two small unnamed tributaries of the upper Chickamin River, near Indian Creek. We named them Lucky Jake and Ranger Paige Creeks, simplified to Indian Tribs in the distribution analysis. No fish were tracked above the border with British Columbia.

Based on the radio-tracking results, the estimated proportions of large chinook salmon spawning in each area of the Chickamin River were: Butler Creek 6.4% (SE = 2.9), Clear Falls 9.5% (SE = 3.2), Leduc Creek 5.1% (SE = 2.3), Indian Creek 4.4% (SE = 1.6), Indian Tribs 13.4% (SE = 3.4), South Fork/Barrier Creek 29.9% (SE = 5.2), Humpy Creek 14.7% (SE = 4.3) and King Creek 16.6% (SE = 4.6). Bootstrap confidence intervals for the proportions spawning in each area were asymmetric for the areas with small contributions (Table 5).

ABUNDANCE

Three hundred eighty (380) large chinook salmon were examined for marks on the spawning grounds, and 41 marked fish were recovered (Table 6). Five of the recovered fish were missing the numbered tag; three of those carried radio tags, and the remaining two fish could not be identified as to tagging site or date. The probability of recapturing spaghetti and radio-tagged fish was not significantly different (χ^2 = 1.76, df = 1, P = 0.185; Table 7) The distribution of fish radio-tagged at the Humpy Slough site was not significantly different from that of fish tagged at the Choca Creek site (χ^2 = 7.10, df = 3, P = 0.069; Table 8), so tags from each site were pooled. Although 5 of 41 fish sampled in spawning ground surveys had lost their primary (numbered) tag, tag loss is not a factor in an unstratified experiment, because fish did not lose their secondary or tertiary marks.

There was a significant difference between the distribution of fish tagged in period 1 (prior to July 12) and period 2 (from July 12 to August 12) (χ^2 = 14.49, df = 3, P = 0.002; Table 9), which indicated different migratory timing for the stocks.

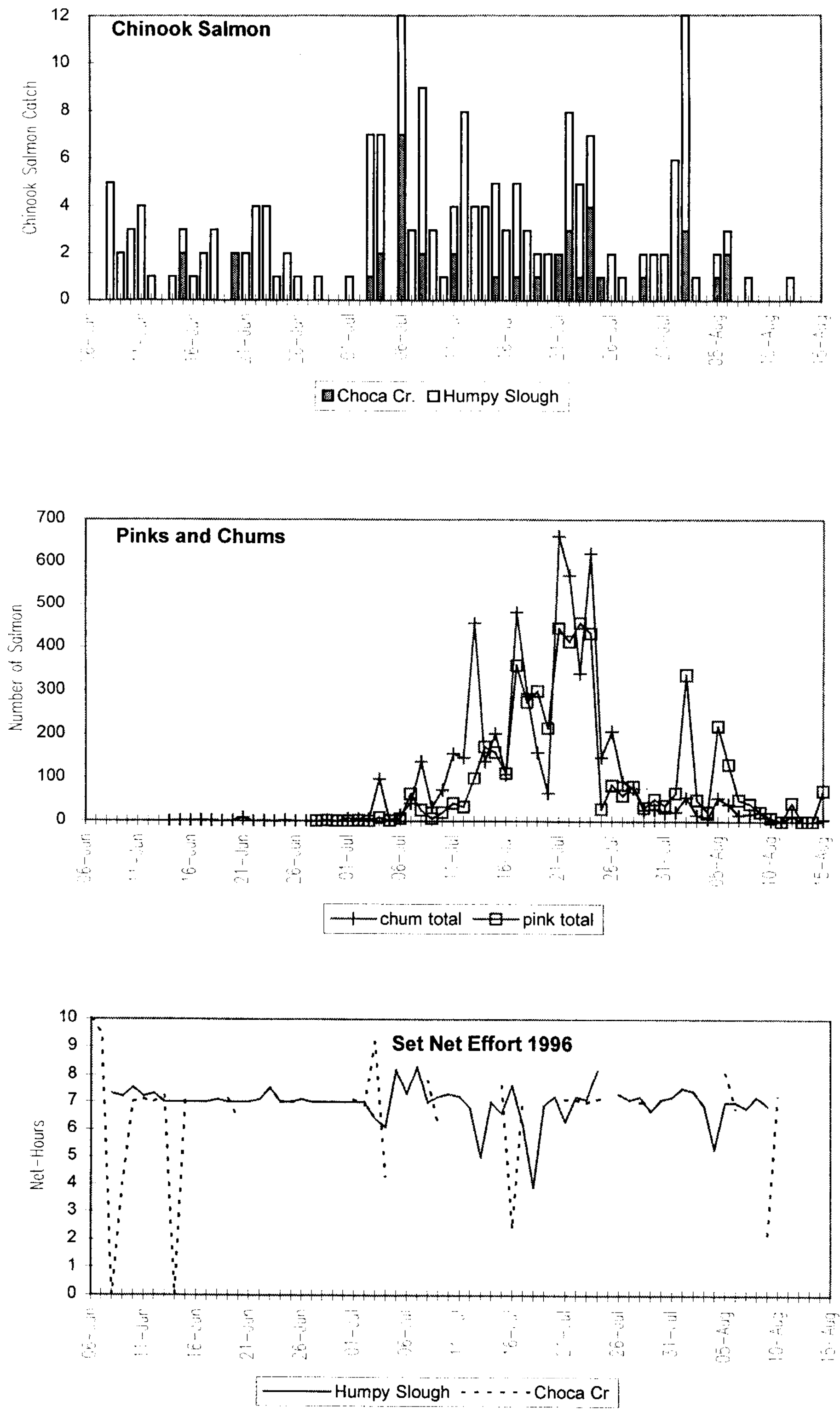


Figure 3.–Daily catch of large chinook salmon, daily catch of chum and pink salmon, and setnet effort (net-hours), by date and location, Chickamin River, 1996.

Table 5.–Summary of fates assigned to radio transmitters Chickamin River, 1996. Tags assigned to fates by period tagged and tagging site, estimated proportions spawning in each tributary with SE and upper and lower confidence intervals, compared with 1996 and 1981-95 average aerial survey proportions.

Assigned fate	Radio-tracking Period 1 Humpy	Period 1 Choca	Period 2 Humpy	Period 2 Choca	Total	Estimated proportion spawning	Bootstrap (%) SE	LCI	UCI	Aerial surveys 1996	81-95 Avg.
Tributary:											
Butler	3	1	2	0	6	6.4	2.9	1.3	13.1	17.5 (15.2)	12.9 (11.2)
Clear Falls	7	2	1	1	11	9.5	3.2	3.9	17.1	13.3 (11.5)	5.9 (5.1)
Leduc Cr.	3	2	0	1	6	5.1	2.3	1.3	10.8	5.5 (4.8)	3.5 (3.0)
Indian Cr.	6	1	0	0	7	4.4	1.6	1.8	7.8	11.4 (9.9)	7.9 (6.8)
Indian Tribs	9	6	1	1	17	13.4	3.4	7.0	21.1	NS	NS
S.F./Barrier	20	3	5	3	31	29.9	5.2	20.4	41.3	20.2 (17.5)	35.2 (30.5)
Humpy	5	0	6	0	11	14.7	4.3	6.9	24.1	7.1 (6.1)	3.5 (3.0)
King	5	0	6	1	12	16.6	4.6	7.8	26.7	25.1 (21.7)	31.1 (26.9)
Subtotal	58	15	21	7	101	100.0				100 (86.7)	100 (86.6)
Mortality/ Regurgitation	4	0	1	0	5						
Unknown	4	2	0	0	6						
Total	66	17	22	7	112						

Proportions in ( ) discounted by 0.867, the estimated proportion of radio-tagged fish that spawned in index areas in 1996.
LCI = lower 95% confidence interval, UCI = upper 95% confidence interval.

Table 6.–Numbers of marked and unmarked chinook salmon sampled during spawning ground surveys, by size and location, Chickamin River, 1996.

Location	Captures[a] Large	Captures[a] Small	Recaptures Large Radio	Large Spag. only	Small Spaghetti
Humpy Creek	24	2	2	5	0
King Creek	44	13	2	5	0
Leduc Creek	7	0	2	1	0
Clear Falls Creek	66	4	2	0	0
Butler Creek	43	0	1	0	0
Indian Creek	6	0	1	0	0
South Fork/Barrier	165	13	10	6	1
Indian Tribs	25	1	3	1	0
Total	380	33	23	18	1

[a] Includes recaptures.

Total of 5 missing spaghetti tags, 3 of which were radio tagged.

Finally, the probability of recovering a marked fish in the lower (Humpy and King; 0.205), Leduc (Leduc, Clear Falls, Butler; 0.052), Indian (Indian and Indian Tribs; 0.161), and South Fork/Barrier, (0.097) was significantly different ($\chi^2 = 11.71$ df = 3, P = 0.008; Table 10).

The sex ratio of large chinook salmon sampled on the spawning grounds (210 females, 170 males) was not significantly different from that of the gillnet sample ($\chi^2 = 0.93$, df = 1, P = 0.335).

Length distributions of fish marked in event 1 and recovered in event 2 were not significantly different (KS tests, P = 0.710; Figure 4a). Also, length distributions of fish captured in event 1 and event 2 were not significantly different (KS test, P < 0.240; Figure 4b). These tests indicate no size selectivity during event 1 or 2, and that the age,

Table 7.–Number of fish marked with spaghetti tags and radio tags that were recovered, and not recovered, in spawning ground surveys, Chickamin River, 1996.

	Radio & spaghetti tag	Spaghetti only	Total
Recovered	23	18	41
Not recovered	89	44	133
Total released	112	61	174
Recovery rate	0.205	0.295	0.236

$\chi^2 = 1.76$, P = 0.185, df = 1

H_0: Recovery rate of radio tags = recovery rate of spaghetti tags.

Accept H_0:

Table 8.–Distribution of radio-tagged fish into spawning areas of the Chickamin River by tagging site, 1996.

	Lower[a]	Leduc	S. Fork	Indian
Choca Creek	1	7	6	8
Humpy Slough	22	16	25	16

$\chi^2 = 7.10$, P = 0.069, df = 3

Accept H_0: Distributions are equal.

[a] Lower area = Humpy and King creeks.
Leduc area = Leduc, Clear Falls, and Butler creeks.
S. Fork area = South Fork of Chickamin and Butler Creek.
Indian = Indian, Lucky Jake, Ranger Paige creeks (Indian Tribs).

Table 9.–Distribution of radio-tagged fish into spawning areas of the Chickamin River by tagging period, 1996.

	Lower	Leduc	S. Fork	Indian
Period 1: June 8–July 11	10	18	23	10
Period 2: July 12–Aug 12	13	5	8	13

$\chi^2 = 14.49$, P = 0.0023, df = 3

Reject H_0: Distributions are not equal.

sex and lengths from both sampling events should be pooled to improve precision of proportions in estimates of composition. (Appendix D). The power of these tests to detect violations of the mark-recapture experiment assumptions was low because of small sample sizes.

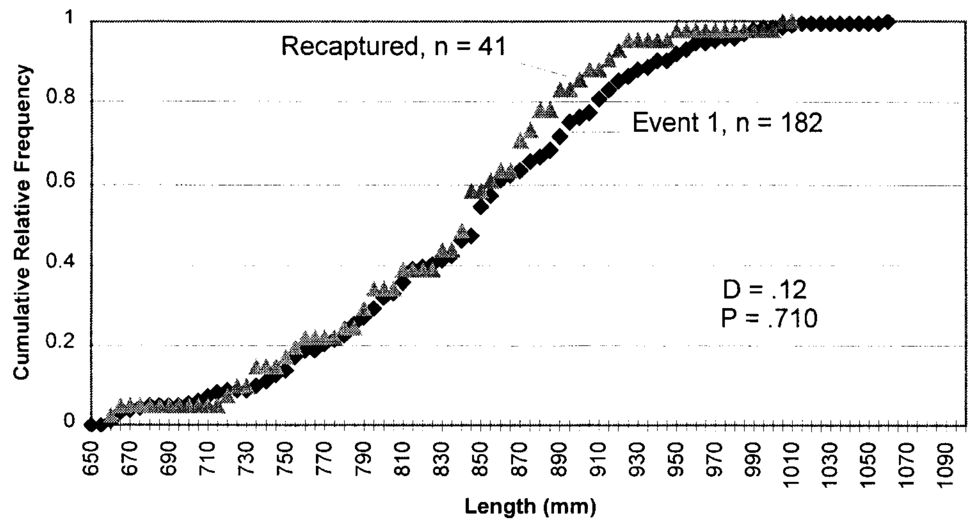
The differences in probability of recovering a marked fish in the 4 recovery strata (Table 10) indicated a probable failure of assumption (a): that every fish had a equal probability of being marked in event one, or that every fish had an equal probability of being captured in event 2. This failure indicated that a stratified or Darroch model might be the appropriate abundance estimator in this case. Several stratified models were examined with the tagging period stratified by time into 2, 3 or 4 periods and the recovery event stratified into 2, 3, or 4 strata geographically or 2 periods by time. The best model appeared to be a 2×2 matrix of temporal tagging and recovery strata. The abundance estimate from this model is 1,818 large chinook (SE = 350). Arnason et al. (1996) in a program called SPAS (Stratified Population Analysis System) provide two tests to help determine if a stratified estimator is appropriate. If these chi-squared tests, labeled "Equal Proportions" and "Complete Mixing," are either low or not significant, full or partial pooling is acceptable (Seber 1982, page 438). In this case the test of equal proportions was significant (Table 10) but the test of complete mixing was not significant ($\chi^2 = 1.36$, 1df, P = 0.24) indicating it should be safe to use the Petersen model (Arnason et al. 1996).

Table 10.–Numbers of large chinook salmon captured in surveys of spawning areas of the Chickamin River, by marking status, 1996.

	Lower	Leduc	S. Fork	Indian
Marked	14	6	16	5
Unmarked	54	110	149	26
Proportion marked	0.21	0.052	0.097	0.16

$\chi^2 = 11.71$, P = 0.00845, df = 3

Reject H_0: Distributions are not equal.



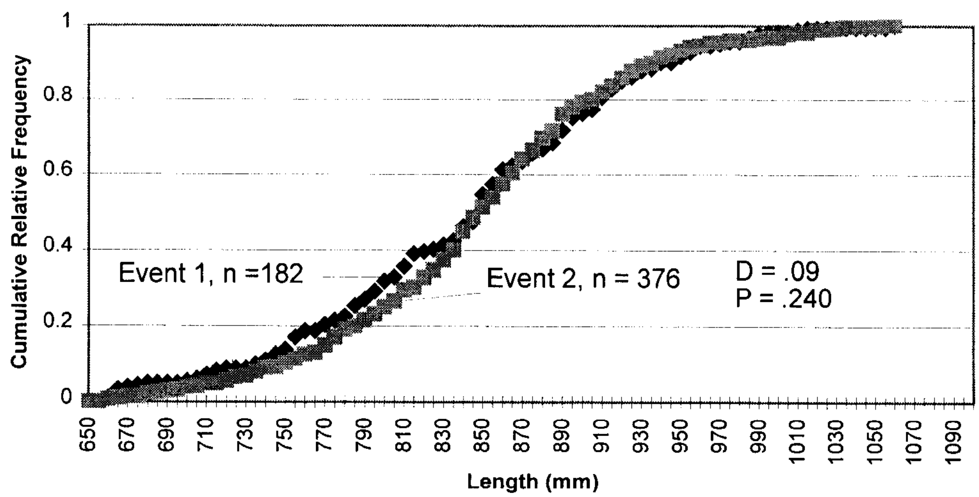


Figure 4.–Cumulative relative frequency of large chinook salmon captured in event 1 (lower river gillnet) and marked chinook recovered in event 2 (spawning ground sampling) and cumulative relative frequency of chinook captured in event 1 and all chinook salmon sampled in event 2.

With this caveat, Chapman's modified Petersen model (n1 = 174, n2 = 380, m2 = 41) could be used to estimate the number of large chinook salmon in the escapement to the Chickamin River. This model results in an abundance estimate of 1,587 large chinook salmon (SE = 199). The 95% bootstrap confidence limits were 1,279 and 2,089, and the estimated relative bias was 1.9%.

AGE, SEX, AND LENGTH COMPOSITIONS

Sex, length and scale samples were collected from 223 chinook salmon during gillnetting in the lower river. Complete ages could be determined for 193 fish. The dominant age classes were 1.3 and 1.4 (Table 11). With the exception of four fish age -0. and three fish age -2., all sampled fish spent 1 year in fresh water. The gillnet sample was 50% male

Table 11.–Estimated age composition of chinook salmon in the Chickamin River set gillnet catch, by sex, age class and fishing period, 1996.

	BROOD YEAR AND AGE CLASS								
	1993	1992	1991		1990			1989	
	1.1	1.2	0.4	1.3	0.5	1.4	2.3	1.5	**Total**
Period 1: June 8 through July 11									
Male									
Sample size	3	4	1	18	0	8	0	2	36
Percent	3.5%	4.7%	1.2%	20.9%		9.3%		2.3%	41.9%
SE	2.0%	2.3%	1.2%	4.4%		3.2%		1.6%	5.4%
Female									
Sample size	0	1	1	24	0	23	0	1	50
Percent		1.2%	1.2%	27.9%		26.7%		1.2%	58.1%
SE		1.2%	1.2%	4.9%		4.8%		1.2%	5.4%
All fish									
Sample size	3	5	2	42	0	31	0	3	86
Percent	3.5%	5.8%	2.3%	48.8%		36.0%		3.5%	100.0%
SE	2.0%	2.5%	1.6%	5.4%		5.2%		2.0%	0.0%
Period 2: July 12 through August 12									
Male									
Sample size	8	21	0	25	0	5	0	1	60
Percent	7.5%	19.6%		23.4%		4.7%		0.9%	56.1%
SE	2.6%	3.9%		4.1%		2.0%		0.9%	4.8%
Female									
Sample size	0	1	2	25	1	13	3	2	47
Percent		0.9%	1.9%	23.4%	0.9%	12.1%	2.8%	1.9%	43.9%
SE		0.9%	1.3%	4.1%	0.9%	3.2%	1.6%	1.3%	4.8%
All fish									
Sample size	8	22	2	50	1	18	3	3	107
Percent	7.5%	20.6%	1.9%	46.7%	0.9%	16.8%	2.8%	2.8%	100.0%
SE	2.6%	3.9%	1.3%	4.8%	0.9%	3.6%	1.6%	1.6%	0.0%
Combined periods (unweighted)									
Male									
Sample size	11	25	1	43	0	13	0	3	96
Percent	5.7%	13.0%	0.5%	22.3%		6.7%		1.6%	49.7%
SE	1.7%	2.4%	0.5%	3.0%		1.8%		0.9%	3.6%
Female									
Sample size	0	2	3	49	1	36	3	3	97
Percent		1.0%	1.6%	25.4%	0.5%	18.7%	1.6%	1.6%	50.3%
SE		0.7%	0.9%	3.1%	0.5%	2.8%	0.9%	0.9%	3.6%
All fish									
Sample size	11	27	4	92	1	49	3	6	193
Percent	5.7%	14.0%	2.1%	47.7%	0.5%	25.4%	1.6%	3.1%	100.0%
SE	1.7%	2.5%	1.0%	3.6%	0.5%	3.1%	0.9%	1.3%	0.0%

and 50% female. Length and sex was recorded for every fish but is reported only for fish of known age (Table 12). Lengths from all fish were used in analysis of length distributions. Lengths ranged from 365 to 1,125 mm.

Four hundred-thirteen (413) fish were examined during spawning ground sampling, and scale samples were obtained from 412 individuals. Complete ages could be determined for 375 fish, sex was estimated for 413 fish, and length was recorded for 409 fish. All sampled fish spent 1 year in fresh water, and the dominant ages were 1.3 and 1.4 for females and 1.3 for males (Table 13). The sample was 52% female and 48% male. Length ranged from 340 to 1,055 mm (Table 14). Because there was no size selectivity (Figure 4) and no difference in age composition between the two samples ($\chi^2 = 0.39$, $P = 0.82$, 2df), pooled gillnet and spawning ground samples were used to estimate age and sex composition of the escapement (Table 15).

Two chinook salmon with possible adipose fin clips were recovered from the Chickamin River spawning grounds in 1996. No coded wire tags were found in either fish.

DISCUSSION

Conservation concerns for Behm Canal chinook stocks stem almost entirely from the decline in observed escapements. Since 1994, we have conducted experiments to estimate the escapement and distribution of chinook salmon to the Unuk and Chickamin rivers and revised the escapement goals for all four Behm Canal systems. The information derived from these studies has alleviated some of the conservation concerns for these stocks; however, low escapement counts continue to be a problem.

Similar concerns over low observed peak escapements in the Chilkat River had resulted in fishery restrictions and an adult mark-recapture and radio tagging study in 1991 and 1992 (Johnson et al. 1992, 1993). The radio tags showed that <5% of spawning occurred in the surveyed index areas, and the mark-recapture estimate was an order of magnitude higher than the observed counts. In that case, the index areas proved not to be representative of the actual escapement, and the surveys were discontinued. The Chilkat study cast some doubt on other chinook index surveys that haven't been validated by weir counts or mark-recapture studies.

This study does not address the conservation issue directly, but shows that escapement to the Chickamin River in 1996 was greater than previously assumed expansion factors would have indicated (see Pahlke 1995); prior to 1996, Chickamin River index counts were expanded by 1.6 to estimate escapement. The 1996 peak aerial survey count of 422 large chinook salmon in the Chickamin River was about 27% of the Petersen estimate of 1,587 or about 23% of the Darroch estimate of 1,818. This is somewhat more than the 15% proportion of the estimated escapement observed on the Chickamin in 1995 and the Unuk River in 1994 (Pahlke 1996a, Pahlke et al. 1996) but agrees closely with the latest index expansion factor for the Unuk and Chickamin Rivers which was revised in 1996 to 25% or 4 times the peak index counts (Pahlke 1996b).

The distribution of radio-tagged fish in 1996 suggest that index streams receive: (a) the majority (86.7%) of the escapement (Table 5), and (b) escapements in proportions roughly similar to those obtained in average historical index surveys. An exception was Humpy Creek which received almost 15% of the radio-tagged fish while the survey average is 4% and has never exceeded 11%. Humpy Creek is difficult to survey from the air because of the high numbers of pink or humpy salmon which spawn concurrently with the chinook salmon. Foot surveys may be more effective at counting chinook salmon under those conditions, but a lower than usual proportion is likely to be counted with any method.

The Choca Creek set gillnet site was upriver about 0.5 mile from the mouth of Humpy Creek Slough. None of the 24 radio-tagged fish and only 1 spaghetti tagged fish from the Choca Creek site were tracked to or recovered in Humpy

Table 12.–Estimated length composition of chinook salmon in the Chickamin River set gillnet catch by sex, age class, and fishing period, 1996.

		AGE							
SEX		1.1	1.2	0.4	1.3	0.5	1.4	1.5	2.3
	Period 1: June 8 through July 11								
Male									
	Sample size	3	4	1	18	0	8	2	0
	Average length	403	640	895	792		923	1,000	
	SD	49	18		95		85	85	
Female									
	Sample size	0	1	1	24	0	23	1	0
	Average length		580	920	822		907	950	
	SD				50		57		
All fish									
	Sample size	3	5	2	42	0	31	3	0
	Average length	403	628	908	809		911	983	
	SD	49	31	18	73		64	67	
	Period 2: July 12 through August 12								
Male									
	Sample size	8	21	0	25	0	5	1	0
	Average length	428	598		813		825	990	
	SD	55	75		72		87		
Female									
	Sample size	0	1	2	25	1	13	2	3
	Average length		750	843	817	840	892	835	848
	SD			18	33		53	113	53
All fish									
	Sample size	8	22	2	50	1	18	3	3
	Average length	428	605	843	815	840	873	887	848
	SD	55	80	18	56		69	120	53
	Combined periods (unweighted)								
Male									
	Sample size	11	25	1	43	0	13	3	0
	Average length	421	604	895	805		885	997	
	SD	52	71		82		96	60	
Female									
	Sample size	0	2	3	49	1	36	3	3
	Average length		665	868	819	840	901	873	848
	SD		120	46	42		55	104	53
All fish									
	Sample size	11	27	4	92	1	49	6	3
	Average length	421	609	875	812	840	897	935	848
	SD	52	74	40	64		68	102	53

Table 13.–Estimated age composition of chinook salmon in the combined spawning ground samples, by sex, Chickamin River, 1996.

	BROOD YEAR AND AGE CLASS						
	1993	1992	1991	1990	1989	1989	
	1.1	1.2	1.3	1.4	1.5	2.4	TOTAL
Males							
Sample Size	9	27	105	33	6	0	180
Percent	2.4%	7.2%	28.0%	8.8%	1.6%	0.0%	48.0%
SE	0.8%	1.3%	2.3%	1.5%	0.6%	0.0%	2.6%
Females							
Sample Size	0	2	107	81	4	1	195
Percent	0.0%	0.5%	28.5%	21.6%	1.1%	0.3%	52.0%
SE	0.0%	0.4%	2.3%	2.1%	0.5%	0.3%	2.6%
All fish							
Sample Size	9	29	212	114	10	1	375
Percent	2.4%	7.7%	56.5%	30.4%	2.7%	0.3%	100.0%
SE	0.8%	1.4%	2.6%	2.4%	0.8%	0.3%	0.0%

Creek. This contrasts with the 1994 Unuk River study, where fish were marked upriver 2 miles and several were tracked to spawning areas on the Eulachon River, downriver near the mouth of the Unuk.

When spawning recoveries were pooled into four geographic strata there was no statistical difference between recovery rates of fish marked at each gillnet site on the Chickamin River. Marked fish were recovered in all of the seven known spawning areas and in the previously unsampled Indian Tribs. Thus, some concern regarding capture locations in the lower Chickamin River was relieved following the sampling.

A concern in planning this study was that the mouths of Humpy Creek and King Creek, known chinook spawning areas, are very low in the Chickamin River and subject to tidal influence. Both gillnet sites were also located in intertidal areas which presented two potential problems.

Table 14.–Length composition of chinook salmon in the combined spawning ground samples, by sex and age, Chickamin River, 1996.

	BROOD YEAR AND AGE CLASS						
	1993	1992	1991	1990	1989	1989	
	1.1	1.2	1.3	1.4	1.5	2.4	TOTAL
Males							
Sample Size	9	27	105	33	6	0	180
Average Length	418	642	810	909	944		
SD	34.5	48.0	67.0	82.4	111.2		
Females							
Sample Size	0	2	107	81	4	1	195
Average Length		673	836	883	926	1,035	
SD		88.4	41.9	52.9	56.5		
All fish							
Sample Size	9	29	212	114	10	1	375
Average Length	418	644	823	891	937	1,035	
SD	34.5	49.8	57.3	63.5	89.5		

Table 15.–Estimated age composition of chinook salmon in the Chickamin River combined set gillnet and spawning ground samples, 1996. The proportion of age -1.1 fish is probably underestimated because none of the gear used is effective on small fish.

	BROOD YEAR AND AGE CLASS									
	1993	1992	1991		1990			1989		
	1.1	1.2	1.3	0.4	1.4	0.5	2.3	1.5	2.4	TOTAL
Males										
Sample Size	20	52	148	1	46	0	0	9	0	276
Percent	3.5%	9.1%	26.0%	0.2%	8.1%	0.0%	0.0%	1.6%	0.0%	48.5%
SE	0.8%	1.2%	1.8%	0.2%	1.1%			0.5%		2.1%
Females										
Sample Size	0	4	156	3	117	1	3	7	1	292
Percent	0.0%	0.7%	27.4%	0.5%	20.6%	0.2%	0.5%	1.2%	0.2%	51.3%
SE		0.4%	1.9%	0.3%	1.7%	0.2%	0.3%	0.5%	0.2%	2.1%
All fish										
Sample Size	20	56	304	4	163	1	3	16	1	568
Percent	3.5%	9.8%	53.4%	0.7%	28.6%	0.2%	0.5%	2.8%	0.2%	100.0%
SE	0.8%	1.3%	2.1%	0.4%	1.9%	0.2%	0.3%	0.7%	0.2%	

First, the effectiveness of the gillnets in capturing fish will be affected by the changing tides, and behavior of migrating fish may also be linked to tides. Second, fish that have just entered fresh water may be more susceptible to stress-related mortality than fish that are acclimated to fresh water (Vincent-Lang et al. 1993).

There did not appear to be any relationship between chinook salmon catches and tide stage. Chinook were captured in small numbers at all stages of tide and river depth (Appendix B). However, during some of the highest tide stages there were complete flow reversals at the Humpy Creek site and the gillnets were ineffective. There did seem to be an increase in chinook catch following the highest tides of a series. Both sites were effective at catching fish of the targeted size range, as indicated by the catches of chinook and also by the large catches of similar sized chum salmon throughout the duration of the study.

Chum and pink salmon catches were so high during the middle of the chinook return (7/13–7/24) (peak daily catch 661 chum, 445 pink) that the effectiveness of the nets may have been affected by gear saturation (Rothschild 1978). We tried to address this problem by adding fishing time to make up for the time we spent handling chum salmon, but during the peak of the chum run it was impossible to compensate for the chum catch because more chums were caught in the additional fishing time than could be corrected for. The highest chum catches during mid-July corresponded with a drop in chinook catches, which increased again in late July as the chum catches dropped (Figure 3b). This same trend occurred in 1994 (Pahlke 1996a). Chum salmon were unusually abundant throughout Southeast Alaska in 1996.

We saw “bright” chinook salmon with sea lice (indicating recent entry into fresh water, McLean et al. 1990) in our gillnets as late as August 2, and “dark” fish without lice were caught as early as June 8 (Appendix A). Whether there is actually a bimodal pattern in chinook immigration timing or the decrease in chinook catches in July was a result of high chum catches cannot be determined from this study, due to the small number of tag recoveries. However, because the highest proportions of marked fish recovered on the spawning grounds were in Indian Creek and the Indian Tribs, which tended to be early runs, and King and Humpy Creeks, which tended to be late runs (Table 10), it appears the middle portion of the run was marked at a lower rate due to gear saturation by chum and pink salmon.

Increased mortality due to handling was a concern after the first year of this study in 1995 (Pahlke 1996a). The number of tags recovered was small, and no fish were radio-tagged to provide an estimate of mortality. Vincent-Lang et al. (1993) documented much higher mortality rates in sport caught coho salmon captured in estuary waters than in fish captured above the estuary. However, chinook salmon captured with sport gear in estuary waters of the Kenai River experienced handling mortalities of less than 10% (Bendock and Alexandersdottir 1992). In a mark-recapture study on the Unuk River in 1994, chinook salmon were captured and handled similar to the fish in this study, except that capture sites were upriver from major tidal influence and a different external tag was used. A portion of those fish were also marked with radio transmitters, and 86% of the radio-tagged fish were successfully tracked to spawning grounds, indicating low mortality due to capture by set gillnets and tagging procedures (Pahlke et al. 1996). On the Chickamin River in 1996, we radio-tagged 112 large chinook, and 101 (90%) were tracked upstream to spawning areas, indicating that handling induced mortality was not significant.

Loss of the spaghetti tags used in 1996 was significant (5 of 41); however, the secondary marks were effective at identifying marked fish.

The two methods used to estimate the abundance of spawning chinook salmon in this study deserve additional discussion.

The 95% confidence limits on the two abundance estimates overlap considerably (Darroch: 1,132–2,503; Petersen: 1,279–2,089). The SE of the Petersen estimate (199) is less than that of the Darroch (350). The Petersen estimate is usually more precise than the Darroch, although more prone to bias (Arnason et al. 1996). The user must trade off risk of introducing bias against gains in precision. In this case the Petersen estimate likely has bias introduced due to heterogeneity in capture rates during the tagging operation. However, the test of the hypothesis that the probability of recapturing a tagged fish is independent of its tagging strata is not significant, indicating it should be safe to use the Petersen estimate (Arnason et al, 1996). There is not a clear choice between the methods and it is likely the actual abundance falls somewhere within the two estimates.

We take some comfort from a belief the experimental design is generally sound and that significant departures from the assumptions have not been identified in similar, previous studies (Johnson et al. 1992, 1993; Pahlke et al. 1996).

Length and sex composition data in this study indicate that size selective sampling did not occur in the spawning surveys and during gillnet fishing. Gillnets are well documented to be size selective, but for the fish of interest in this experiment (length ≥660 mm MEF), gillnets do not show strong selectivity. In addition, the age composition of the large fish captured in the gillnets was similar to that of the spawning ground escapement sample and the large mesh gillnet samples actually had a slightly higher percentage of small fish than the spawning ground samples (Table 11, 13). This was a significant change from the results in 1995 on the Chickamin and in 1994 on the Unuk River, where the spawning ground samples were significantly different from the gillnet samples in both size and sex.

Spearing dead and dying fish was our primary method of collecting fish on the spawning grounds in 1995, when size selective sampling appeared to be a problem. In 1996, we added angling, beach seining and dip netting to our sampling methods in an attempt to collect a more representative sample of the escapement.

Spawning ground sampling was hampered by a logjam in the Leduc River, which prevented access by boat to Leduc, Clear Falls and Butler creeks. Also, the observed escapement to King Creek in 1996 was only 106 fish, down from the 1981–1994 average of 228. King Creek has the latest spawning timing in the Chickamin and usually accounts for almost a third of the chinook counted (Table 1). In 1995, only 17% of the observed escapement was in King Creek, and only 25% in 1996. The Indian Tribs are difficult to access by boat but can be quickly surveyed by helicopter in conjunction with ongoing surveys of Indian Creek.

CONCLUSIONS AND RECOMMENDATIONS

This was the second attempt at estimating the total escapement of chinook salmon to the Chickamin River. Spawning abundance was estimated with acceptable results using methods developed in 1995. With 101 radio tags successfully tracked to spawning areas, the objective of determining the location of all the major spawning areas in the Chickamin River was met. Operation of set gillnets is an effective method of capturing large chinook salmon migrating up the Chickamin River, however large returns of chum salmon interfere with the capture of chinook during the middle portion of the migration. Index area counts underestimate the magnitude of the escapement, but distribution of radio-tagged fish in 1996 suggests that index streams receive the majority (86.7%) of the escapement The Indian Tribs should be surveyed regularly for possible inclusion into the index program.

ACKNOWLEDGMENTS

Dave Magnus, Dave Dreyer, Tim Shantz, Paul Overturf, Ardath Guatney, and Ron Hulse conducted field work and data collection. Amy Holm was the logistics coordinator in Ketchikan. Phil Doherty, Glenn Freeman, Scott Walker, Marlene Campbell, Steve Huffine, Red Weller, Don House, Heather Swearington, Mary Urquhart, John Joyce and others helped with many aspects of the project. Mike Wallendorf, Bob Marshall, and Scott McPherson provided assistance with operational planning and data analysis. Scott McPherson and Steve Elliott, provided editorial comments. Sue Millard and Scott McPherson aged the scale samples. The residents of the Chickamin River, especially Mike, Lois and Pat Bethel provided assistance to the field crew. The staff of the Misty Fiords National Monument was helpful in the operation of the project.

LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1981. Proposed management plan for Southeast Alaska chinook salmon runs in 1981. Regional unpublished report 1J81-3. Juneau.

Arnason, A.N. , C.W. Kirby, C.J. Schwarz, and J.R. Irvine. 1996 Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapement and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106. Naniamo, British Columbia.

Bendock, T. and M. Alexandersdottir. 1992. Mortality and movement behavior of hooked-and-released chinook salmon in the Kenai River recreational fishery, 1989-1991. Alaska Department of Fish and Game, Fishery Manuscript No. 92-2. Anchorage.

Buckland, S. T. and P. H. Garthwaite. 1991. Quantifying precision of mark-recapture estimates using the bootstrap and related methods. Biometrics 47:255-268.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-60.

Eiler, J. H. 1990. Radio transmitters used to study salmon in glacial rivers. American Fisheries Society Symposium 7:364-369.

Efron, B. I. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Monographs on statistics and applied probability 57. Chapman and Hall, New York.

Goodman, L. G. 1960. On the exact variance of a product. Journal of the American Statistical Association 66:708-713.

Johnson, R. E., R. P. Marshall, and S. T. Elliott. 1992. Chilkat River chinook salmon studies, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-43, Anchorage.

Johnson, R. E., R. P. Marshall, and S. T. Elliott. 1993. Chilkat River chinook salmon studies, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-50, Anchorage.

Kissner, Paul D. 1982. A study of chinook salmon in southeast Alaska. Alaska Department of Fish and Game. Annual report 1981–1982, Project F-9-14, 24 (AFS-41).

McLean, P. H., G. W. Smith, and M. J. Wilson. 1990. Residence time of the sea louse *Lepeoptheirus salmonis K.* on Atlantic salmon *Salmo salar L.* after immersion in fresh water. Journal of Fish Biology (1990)37, 311–314.

McPherson, S. A. and J. K. Carlile. 1997. Spawner-recruit analysis of Behm Canal chinook salmon stocks. Alaska Department of Fish and Game. Division of Commercial Fisheries Management and Development, Regional Information Report Series 1J97-06. Douglas.

Olsen, M. A. 1995. Abundance, age, sex, and size of chinook salmon catches and escapements in Southeast Alaska in 1988. Alaska Department of Fish and Game, Technical Fishery Report 95-02. Juneau.

Pahlke, K. P. 1995. Escapements of chinook salmon in Southeast Alaska and transboundary rivers in 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-35, Anchorage.

Pahlke, K. P. 1996a. Abundance of chinook salmon escapement on the Chickamin River, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-37, Anchorage.

Pahlke, K. P. 1996b. Escapements of chinook salmon in Southeast Alaska and transboundary rivers in 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-35, Anchorage.

Pahlke, K. P., S. A. McPherson and R. P. Marshall. 1996. Chinook salmon research on the Unuk River, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-14. Anchorage.

Rothschild, B. J. 1978. Fishing Effort. *In* J. A. Gulland, editor. Fish Population Dynamics. John Wiley and Sons, New York.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, second edition. Griffin and Company, Ltd., London.

Vincent-Lang, D., M. Alexandersdottir and D. McBride. 1993. Mortality of coho salmon caught and released using sport tackle in the Little Susitna River, Alaska. Fisheries Research 15:339-356.

APPENDIX

Appendix A1.–Fish number, date captured, sex, length, tag number, age and comments on fish captured on the Chickamin River, Humpy Slough site, 1996.

Fish #	Date	Period	Time	Sex	MEF	Tag #	Radio	Lice	Age	AEC	Condition	Recovered	Date
101	8-Jun	1	10:44	1	800	104		n	1.3		bright		
102	8-Jun	1	12:06	1	860	101		n		R	bright		
103	8-Jun	1	13:56	1	930	102	30.180	n	1.4		dark		
104	8-Jun	1	14:56	2	920	103	30.150	y	1.4		bright		
105	8-Jun	1	16:01	2	840	105	30.962	n	1.4		bright		
106	9-Jun	1	12:55	1	895	107	30.992	n	0.4		bright		
107	9-Jun	1	14:14	2	785	108	30.972	n		chum	bright		
108	9-Jun	1	15:48	1	880	109	30.160	n	1.3		dark		
109	10-Jun	1	12:49	1	890	110	30.922	n	1.3		bright		
110	10-Jun	1	12:58	2	885	111	30.932	n	1.3		bright		
111	10-Jun	1	15:37	2	745	112	30.140	n		chum	chum?		
112	10-Jun	1	16:34	2	1010	113	30.982	n	1.4		bright		
113	11-Jun	1	10:01	2	920	114	30.872	n	0.4		bright		
114	11-Jun	1	12:09	1	895	115	30.882	n	1.4		bright		
115	11-Jun	1	16:07	2	825	116	30.943	n	1.3		bright		
	11-Jun	1	16:15	1	750			n	1.3		net mortality		
116	12-Jun	1	10:30	2	855	117	30.633	n	1.3		bright		
117	14-Jun	1	12:46	2	850	118	30.892	n	1.3		bright	South Fork2	20-Aug
118	15-Jun	1	13:41	2	840	119	30.592	n		R	dark		
119	16-Jun	1	12:28	2	955	120	30.643	n	1.4		turning	Indian Trib.	28-Aug
120	17-Jun	1	12:37	2	935	121	30.652	n	1.4		bright		
121	17-Jun	1	15:27	1	1125	122	30.603	n		R	bright		
122	18-Jun	1	14:00	2	760	123	30.902	n		R	bright		
123	18-Jun	1	18:10	2	850	124	30.612	n	1.4		bright		
124	18-Jun	1	18:10	2	905	125	30.702	n	1.3		bright		
125	21-Jun	1	1110	1	755	126	30.712	n	1.4		bright		
126	21-Jun	1	14:45	2	795	127	30.722	n	1.3		tired, bright		
127	22-Jun	1	10:06	2	890	128	30.732	n	1.3		bright	Clear Falls	17-Aug
128	22-Jun	1	12:03	2	850	129	30.742	n	1.3		tired, bright		
129	22-Jun	1	12:15	1	930	130	30.752	y	1.3		bright		
130	22-Jun	1	13:02	1	960	131	30.773	n	1.3		bright		
131	23-Jun	1	10:00	2	940	132	30.783	n	1.4		bright		
132	23-Jun	1	10:05	2	885	133	30.822	n	1.4		bright		
133	23-Jun	1	15:40	2	895	134	30.792	n	1.4		seal bites, bright		
134	23-Jun	1	16:20	2	985	135	30.802	y	1.4		bright		
135	24-Jun	1	8:30	2	850	136	30.810	n	1.3		bright	South Fork	11-Aug
136	25-Jun	1	12:45	1	1060	137	30.832	n	1.5		turning		
137	25-Jun	1	15:00	2	780	138	30.852	n		R	bright		
138	26-Jun	1	13:59	2	755	139	30.313	n	1.4		bright		
	28-Jun	1	13:00	1	960			n	1.4		net mortality		
139	1-Jul	1	8:50	1	755	140	30.290	n	1.3		bright		
	2-Jul	1	11:10	1	625			y	1.2		bright		
140	3-Jul	1	6:30	1	850	141	30.300	y	1.3		turning	Leduc Cr.	23-Aug
141	3-Jul	1	8:15	1	740	142	30.322	y	1.3		gray		
142	3-Jul	1	8:20	1	785	143	30.333	y	1.3		bright	King Cr.	27-Aug
143	3-Jul	1	9:45	2	890	144	30.840	y	1.4		bright,tired	Indian Cr.	31-Jul
144	3-Jul	1	11:35	2	810	145		n	1.3		bright		
145	3-Jul	1	11:35	2	950	146	30.672	y	1.5		bright		
	3-Jul	1	13:05	1	375			n	1.1		bright		
146	4-Jul	1	7:30	1	975	147	30.353	y	1.4		turning		
147	4-Jul	1	7:45	2	710	148	30.362	n	1.3		bright,tired		

-continued

Fish #	Date	Period	Time	Sex	MEF	Tag #	Radio	Lice	Age	AEC	Condition	Recovered	Date
148	4-Jul	1	8:40	2	800	149	30.682	y	1.3		bright		
149	4-Jul	1	11:25	2	745	150	30.693	n	1.3		bright		
150	4-Jul	1	13:35	1	650	151		n	1.2		bright		
151	4-Jul	1	14:15	1	770	152	30.863	y	1.3		bright		
152	6-Jul	1	9:02	2	910	153	30.392	y	1.4		bright		
153	6-Jul	1	10:23	1	940	154	30.400	n	1.5		dark		
154	6-Jul	1	12:14	2	790	155	30.420	n	1.3		dark		
155	6-Jul	1	13:51	1	800	156	30.442	n	1.3		bright		
156	6-Jul	1	13:53	1	900	157	30.452	n		R	dark		
157	6-Jul	1	14:47	2	580	158		n	1.2		bright		
	6-Jul	1	15:10	2	895			n	1.3		net mortality		
158	7-Jul	1	8:30	1	375	159		n	1.1		bright		
159	7-Jul	1	8:50	2	950	160	30.952	y	1.4		bright		
160	7-Jul	1	10:45	1	860	161	30.532	y	1.3		gray		
161	7-Jul	1	11:05	1	625	162		y	1.2		gray		
162	7-Jul	1	16:52	2	970	164	30.562	n		R	bright		
163	8-Jul	1	8:40	1	760	166	30.721	y	1.3		gray,tired	Humpy Cr.	25-Aug
164	8-Jul	1	8:59	2	955	163	30.200	y	1.4		bright		
165	8-Jul	1	11:17	2	890	167	30.821	n	1.4		bright	South Fork	11-Aug
166	8-Jul	1	11:30	2	850	165	30.970	n	1.4		bright		
167	8-Jul	1	11:40	2	915	169	31.302	n	1.4		bright	Humpy Cr.	25-Aug
168	8-Jul	1	13:40	2	875	172	30.992	y		R	bright		
169	8-Jul	1	13:55	1	460	171		n	1.1		bright		
170	8-Jul	1	15:40	1	995	170	30.010	n	1.4		turning		
171	9-Jul	1	8:20	2	860	173	30.020	y		R	bright		
172	9-Jul	1	11:25	2	960	174	30.030	y	1.4		bright		
173	9-Jul	1	14:35	2	755	175	30.040	n	1.3		bright		
174	10-Jul	1	8:53	2	815	176	30.050	y	1.3		bright	South Fork2	26-Aug
175	11-Jul	1	10:15	2	780	177	30.060	y	1.3		gray,tired		
176	11-Jul	1	11:15	2	855	178	30.070	n	1.3		gray		
177	12-Jul	2	9:25	2	755	179		y	1.5		bright, bleeder		
178	12-Jul	2	9:55	1	650	180		n		R	bright		
179	12-Jul	2	10:45	2	815	181	30.080	y	1.3		dark		
180	12-Jul	2	12:10	2	860	182		y	1.3		bright		
181	12-Jul	2	13:00	2	910	183		y	2.3		bright		
182	12-Jul	2	13:30	2	820	184	30.090	n	2.3		bright		
183	12-Jul	2	14:45	1	840	185		y		R	dark		
184	12-Jul	2	15:35	2	8??	186		n	1.3		bright		
	12-Jul	2	17:30	1	830			n		R	net mortality		
185	13-Jul	2	11:00	1	530	187		n	1.2		bright,hook scar		
186	13-Jul	2	12:20	1	410	188		n	1.1		bright	South Fork2	28-Aug
187	13-Jul	2	15:30	1	390	189		n	1.1		bright		
188	13-Jul	2	17:15	1	665	190		y	1.2		turning		
189	13-Jul	2	18:00	2	930	191	30.110	n		R	bright		
190	13-Jul	2	18:30	1	900	192	30.170	n	1.3		dark		
191	13-Jul	2	19:05	2	790	193		n	1.3		gray		
192	13-Jul	2	19:05	1	570	194		n	1.2		bright		
193	14-Jul	2	8:54	1	895	195		n	1.3		bright		
194	14-Jul	2	9:20	2	910	196		n	1.4		dark,tired		
195	14-Jul	2	10:00	2	795	197	30.240	y	1.3		bright		
196	14-Jul	2	14:00	1	420	198		n	1.1		bright		
197	14-Jul	2	14:25	1	365	199		n	1.1		bright		

-continued

Fish #	Date	Period	Time	Sex	MEF	Tag #	Radio	Lice	Age	AEC	Condition	Recovered	Date
198	14-Jul	2	16:40	2	835	200		n	1.3		gray		
199	15-Jul	2	9:00	1	890	201	30.220	y	1.3		turning	South Fork2	20-Aug
200	15-Jul	2	10:00	1	915	202		n	1.3		gray	South Fork4	26-Aug
201	15-Jul	2	10:15	1	560	203		n	1.2		bright,bleeder		
202	15-Jul	2	11:20	2	870	204		y	1.4		bright	Humpy Cr.	25-Aug
	15-Jul	2	12:00	1	735			n	1.4		net mortality		
203	16-Jul	2	10:02	1	620	205		n		R	bright		
204	16-Jul	2	10:21	2	815	206	30.280	n	1.3		dark	Indian Trib.	16-Aug
205	16-Jul	2	13:30	2	840	207		y	1.4		bright,tired		
206	16-Jul	2	16:20	2	925	208		y		R	gray		
207	17-Jul	2	7:15	2	785	209	30.100	y	1.3		bright		
208	17-Jul	2	7:35	2	920	210		y	1.4		bright	King Cr.	27-Aug
209	17-Jul	2	7:55	1	605	211		y	1.2		gray,tired		
210	17-Jul	2	10:20	2	815	212	30.270	n	2.3		bright		
211	17-Jul	2	12:30	1	410	215		n		coho	bright-COHO		
212	17-Jul	2	15:35	1	665	213		y	1.2		turning		
	18-Jul	2	10:00	1	865			y	1.3		net mortality		
213	18-Jul	2	13:40	1	775	214		n	1.3		turning		
214	18-Jul	2	13:40	1	665	216		n	1.2		gray	South Fork2	28-Aug
215	18-Jul	2	15:24	1	625	217		n	1.2		turning		
	19-Jul	2	14:30	1	790			n	1.3		gray, prob. died		
	20-Jul	2	8:35	1	455			n	1.2		bright		
216	20-Jul	2	10:00	1	590	218		n		R	bright		
217	20-Jul	2	12:15	2	850	219		n	1.3		dark	King Cr.	27-Aug
218	20-Jul	2	14:58	2	805	220	30.230	n	1.3		gray	King Cr. 3	29-Aug
219	22-Jul	2	8:33	2	815	221		y	1.3		gray		
220	22-Jul	2	9:20	1	630	222		y		R	turning		
221	22-Jul	2	927	1	715	223		y	1.3		dark	Humpy Cr.	25-Aug
222	22-Jul	2	10:05	1	715	224	30.130	n	1.3		gray		
223	22-Jul	2	12:00	2	850	225		n	1.3		gray,tired		
224	22-Jul	2	12:49	1	625	226		n	1.2		bright		
225	22-Jul	2	14:45	1	745	227		n	1.3		dark		
226	23-Jul	2	9:20	2	850	228	30.260	y	1.3		gray		
227	23-Jul	2	14:43	2	845	229		n	1.3		gray		
228	23-Jul	2	16:19	1	705	230			1.2		turning		
229	23-Jul	2	16:34	2	785	231	31.102		1.3		gray,gill net scar		
230	24-Jul	2	8:45	1	735	232		n	1.3		gray		
231	24-Jul	2	9:35	1	595	233		n		coho	bright-COHO		
	24-Jul	2	9:35	1	505			n		R	net mortality		
232	24-Jul	2	14:35	2	875	234		y	1.4		dark,tired	South Fork	11-Aug
	24-Jul	2	16:30	1	840			n	1.3		possible mortality		
	26-Jul	2	10:15	2	835			y	1.3		net mortality		
234	26-Jul	2	14:14	2	920	235		n	1.4		dark,tired		
235	27-Jul	2	9:32	2	830	236	31.062	n	0.4		bright		
236	27-Jul	2	10:42	1	470	237		y	1.2		bright		
237	28-Jul	2	10:17	1	600	238		n		R	gray		
238	29-Jul	2	12:00	1	630	239		n	1.2		turning		
239	29-Jul	2	12:26	2	875	240		n	1.3		dark		
240	30-Jul	2	8:50	1	550	241		n	1.2		dark		
241	30-Jul	2	9:30	1	905	242	31.172	n	1.3		dark		
242	30-Jul	2	14:20	1	940	243		n	1.4		red		
243	31-Jul	2	8:30	1	860	244		y	1.4		turning		

-continued

Appendix A1.–Page 4 of 4.

Fish #	Date	Period	Time	Sex	MEF	Tag #	Radio	Lice	Age	AEC	Condition	Recovered	Date
	31-Jul	2	9:50	1	450			n	1.2		bright,net mortality		
244	31-Jul	2	12:20	2	840	245		n	0.5		bright, bleeder		
245	1-Aug	2	8:17	1	990	246	31.531	y		R	turning		
246	1-Aug	2	10:36	1	740	247		n	1.4		turning		
247	1-Aug	2	11:13	1	810	248		n	1.3		bright		
248	1-Aug	2	11:20	1	720	249	31.582	y	1.3		turning	Humpy Cr.	29-Aug
249	1-Aug	2	12:08	2	760	250		n	1.4		bright	King Cr.	27-Aug
250	1-Aug	2	12:30	1	700	251		y	1.3		turning		
251	2-Aug	2	7:08	1	670	252	31.852	n	1.2		gray		
252	2-Aug	2	7:23	1	885	253		n	1.3		turning		
253	2-Aug	2	7:46	1	815	254		n	1.3		turning		
254	2-Aug	2	8:17	2	925	255	31.222	n	1.4		turning		
255	2-Aug	2	8:33	2	855	256		n	0.4		bright		
256	2-Aug	2	10:17	1	805	257		n	1.3		turning		
257	2-Aug	2	10:53	2	800	258	31.612	y	1.3		gray		
258	2-Aug	2	11:14	1	605	259		n	1.2		bright		
259	2-Aug	2	13:15	1	535	260		n	1.1		bright		
260	2-Aug	2	13:40	2	800	261		y		R	bright		
261	2-Aug	2	14:45	2	855	262		y	1.3		bright	King Cr. 2	29-Aug
262	3-Aug	2	8:36	2	915	263	31.552	n	1.4		bright		
263	3-Aug	2	12:40	1	385	264		n	1.1		bright		
264	5-Aug	2	10:08	1	710	265		n	1.3		dark		
265	6-Aug	2	8:30	1	850	266		n	1.4		dark	King Cr. 2	29-Aug
266	8-Aug	2	10:13	2	785	267		n		R	bright		
267	12-Aug	2	10:14	1	755	268	31.542	n	1.3		dark		

Sex: 1= MALE, 2 = FEMALE; AEC = AGE ERROR CODE; R = REGENERATED.

Appendix A2.–Fish number, date captured, sex, length, tag number, age and comments on fish captured on the Chickamin River, Choca Creek site, 1996.

Fish #	Date	Period	Time	Sex	MEF	Tag #	Radio	Lice	Age	AEC	Comments	Recovered	Date
1	15-Jun	1	14:42	2	795	1	30.912	n	1.3		bright		
2	20-Jun	1	12:45	2	950	2	30.573	n	1.4		bright		
3	20-Jun	1	15:30	2	890	3	30.582	n		R	bright, scarred		
4	3-Jul	1	14:38	2	910	4	30.662	y		R	bright		
5	4-Jul	1	13:32	2	850	5	30.342	y	1.3		bright		
6	4-Jul	1	13:40	2	910	6	30.372	y	1.4		bright	Clear Falls	21-Aug
7	6-Jul	1	8:40	2	845	7	30.383	y	1.4		bright		
8	6-Jul	1	8:55	2	855	8	30.412	n	1.4		gray,anal fin scar	Leduc Cr.	7-Aug
9	6-Jul	1	11:30	2	795	9	30.432	y	1.3		bright	changed freq from .422	
10	6-Jul	1	11:50	1	675	10	30.460	y	1.3		turning		
11	6-Jul	1	12:00	1	1015	11	30.472	y	1.4		bright	South Fork2	20-Aug
12	6-Jul	1	13:10	1	660	12	30.482	y	1.2		bright,bleeder		
13	6-Jul	1	13:20	1	655	13		y	1.3		bright,bleeder		
14	6-Jul	1	15:30	1	785	14	30.492	n		R	gray		
15	6-Jul	1	15:30	1	590	15		n	1.3		bright		
16	8-Jul	1	9:40	2	775	16	30.542	y	1.3		bright,tired	South Fork2	26-Aug
17	8-Jul	1	16:30	2	850	17	30.250	y	1.3		bright		
18	11-Jul	1	12:45	1	625	18		n		R	bright		
19	11-Jul	1	13:20	1	860	19	30.522	n	1.4		turning	Butler Cr.	17-Aug
20	11-Jul	1	15:30	1	810	20	30.762	n	1.3		turning		
21	15-Jul	2	10:05	1	445	21		n	1.1		bright		
22	15-Jul	2	11:00	1	990	22	30.512	y	1.5		turning		
23	15-Jul	2	13:50	1	635	23		n	1.2		bright		
24	17-Jul	2	8:45	1	470	24		y	1.1		bright		
25	17-Jul	2	12:40	1	665	25		y	1.2		turning		
26	19-Jul	2	9:50	1	545	26		n	1.2		bright,bleeder		
27	19-Jul	2	10:17	2	915	27		n	1.5		turning	Leduc Cr.	14-Aug
28	21-Jul	2	9:40	2	750	28	30.210	y	1.2		bright	South Fork4	26-Aug
29	21-Jul	2	13:50	2	985	29		n	1.4		dark,tired	South Fork3	20-Aug
30	22-Jul	2	9:30	2	895	30		n	1.4		bright		
31	22-Jul	2	15:50	1	875	31	30.552	n	1.3		dark		
32	22-Jul	2	15:50	1	680	32		n		R	dark		
33	22-Jul	2	18:30	1	610	33		n		R	bright		
34	23-Jul	2	13:45	2	770	34		y	1.3		bright		
35	24-Jul	2	9:37	1	865	35	30.120	n	1.3		turning,tired	South Fork4	24-Aug
36	24-Jul	2	12:17	2	870	36		y	1.4		bright	South Fork2	26-Aug
37	24-Jul	2	14:23	2	745	37		n	1.3		bright		
38	24-Jul	2	14:50	1	660	38		y	1.2		gray		
39	25-Jul	2	15:25	2	880	39	31.121	n		R	turning		
40	29-Jul	2	16:27	2	910	40		y	1.4		gray	South Fork2	28-Aug
41	2-Aug	2	13:04	2	840	41		n	1.3		bright		
42	2-Aug	2	13:55	1	860	42	31.990	y	1.3		red	South Fork2	26-Aug
43	2-Aug	2	15:10	2	770	43		y	1.3		dark	Humpy Cr.	25-Aug
44	5-Aug	2	15:35	1	850	44		y	1.3		dark		
45	6-Aug	2	8:46	2	810	45	31.382	n	1.3		turning,tired		
46	6-Aug	2	9:42	2	810	46		n	1.3		turning		

Appendix B1.–Setnet catch and effort records, Chickamin River, 1996, Humpy Slough site. Effort recorded is for each net; total of two at this site.

Date	Start time	Stop time	Total time	Process Time	Process Effort	Net/ hours	Large chin	Cum. total	%	Small chin	Chum	Pink	Sock	Coho	Tide Time	Tide Height	Crew	Comments
06-Jun																		
07-Jun																		
08-Jun	10:25	18:20	07:55	00:25	07:30	7.3	5	5	3%						19:35	14.6	KP/AG/TS	two nets, all fish at low tide
09-Jun	08:40	16:10	07:30	00:15	07:15	7.2	2	7	5%		1				07:52	12.5	AG/TS	two nets, all fish at low tide
10-Jun	08:50	16:57	08:07	00:20	07:47	7.5	3	10	7%		1				09:09	12.2	AG/TS	two nets, all fish at low tide
11-Jun	09:35	17:15	07:40	00:20	07:20	7.2	4	14	10%						10:20	12.3	AG/TS	1 mort
12-Jun	10:00	17:30	07:30	00:05	07:25	7.3	1	15	10%						11:21	12.7	AG/TS	fish in cross net
13-Jun	09:15	16:15	07:00	00:00	07:00	7	0	15	10%						12:12	13.2	AG/TS	
14-Jun	09:00	16:05	07:05	00:05	07:00	7.0	1	16	11%						12:56	13.6	DD/TS	fish in cross net
15-Jun	09:45	16:45	07:00	00:05	06:55	7.0	1	17	12%						13:36	13.9	AG/TS	fish in downstream net
16-Jun	10:30	17:35	07:05	00:05	07:00	7.0	1	18	13%		1				14:14	14.1	AG/PO	fish in cross net
17-Jun	11:00	18:15	07:15	00:12	07:03	7.0	2	20	14%		2				14:50	14.1	AG/TS	one fish in each net
18-Jun	11:00	18:25	07:25	00:16	07:09	7.1	3	23	16%		1				15:25	14	AG/TS	
19-Jun	12:00	19:00	07:00	00:00	07:00	7.0	0	23	16%						16:01	13.8	AG/DM	
20-Jun	09:05	16:10	07:05	00:05	07:00	7.0	0	23	16%		1				16:37	13.5	DD/AG/PO	
21-Jun	08:35	15:45	07:10	00:10	07:00	7.0	2	25	17%		8				17:16	13.3	DM/PO	all fish on incoming tide
22-Jun	09:00	16:25	07:25	00:20	07:05	7.1	4	29	20%						17:58	13.2	AG/PO	two fish in each net
23-Jun	09:30	17:35	08:05	00:20	07:45	7.5	4	33	23%		1				18:35	13.1	AG/TS	all in downstream net
24-Jun	08:30	15:30	07:00	00:05	06:55	7.0	1	34	24%						06:58	11	AG/DM	
25-Jun	08:30	15:35	07:05	00:10	06:55	7.0	2	36	25%		2				08:30	10.8	DM/TS	both in downstream net on tide
26-Jun	08:48	16:00	07:12	00:05	07:07	7.1	1	37	26%						09:29	11	AG/TS	fish in crossnet
27-Jun	06:23	13:25	07:02	00:00	07:02	7.0	0	37	26%						10:37	11.8	DM/TS	
28-Jun	10:45	17:50	07:05	00:05	07:00	7.0	1	38	26%						11:19	16.5	AG/TS	net mortality
29-Jun	08:30	15:30	07:00	00:00	07:00	7.0	0	38	26%						12:27	14	PO/TS	downstream net in 1 hour longer
30-Jun	08:30	15:45	07:15	00:15	07:00	7.0	0	38	26%						13:15	15	AG/PO	fished downstream net only
01-Jul	08:35	15:40	07:05	00:05	07:00	7.0	1	39	27%		3				14:02	15.8	DM/PO	
02-Jul	05:50	12:50	07:00	00:00	07:00	7.0	0	39	27%	1					14:48	16.3	DM/TS	
03-Jul	05:55	13:05	07:10	00:35	06:35	6.4	6	45	31%	1					15:34	16.5	DM/PO	
04-Jul	06:40	14:40	08:00	01:55	06:05	6.1	5	50	35%	1	90	7			16:21	16.4	PO/TS	
05-Jul	07:10	15:30	08:20	00:02	08:18	8.2	0	50	35%		2	1			17:10	16	AG/DM	crossnet not in until 09:30
06-Jul	07:15	15:25	08:10	00:37	07:33	7.3	5	55	38%	1	7	6			18:03	15.5	AG/PO	1 net mort, 1 recap #0008
07-Jul	07:50	17:25	09:35	01:06	08:29	8.3	3	58	40%	1	41	63			18:59	15	PO/TS	
08-Jul	08:22	17:30	09:08	02:06	07:02	7.0	7	65	45%	1	93	20			07:25	12.1	DM/PO	recap #0169
10-Jul	08:10	16:50	08:40	01:17	07:23	7.3	1	69	48%		72	20			10:00	11.3	AG/PO	
11-Jul	08:00	17:20	09:20	02:01	07:19	7.2	2	71	49%		111	36			11:06	11.8	DM/AG	
12-Jul	08:18	18:15	09:57	03:07	06:50	6.8	8	79	55%	1	147	34			11:58	12.3	DM/PO	
13-Jul	08:15	19:30	11:15	06:17	04:58	5.0	4	83	58%	4	357	94	3		12:42	12.9	DM/TS	

-continued-

Appendix B1.–Page 2 of 2.

Date	Start time	Stop time	Total time	Process Time	Process Effort	Net/ hours	Large chin	Cum. total	%	Small chin	Chum	Pink	Sock	Coho	Tide Time	Tide Height	Crew	Comments
14-Jul	08:20	18:00	09:40	02:38	07:02	7.0	4	87	60%	2	138	172			13:20	13.5	AG/TS	
15-Jul	08:40	18:05	09:25	02:46	06:39	6.6	4	91	63%	1	146	121	1		13:54	13.9	AG/DM	
16-Jul	07:25	16:40	09:15	01:36	07:39	7.6	3	94	65%	1	81	95			14:55	15.1	AG/TS	
17-Jul	07:05	16:40	09:35	03:24	06:11	6.2	4	98	68%	1	184	140	1	1	14:58	14.3	PO/TS	
18-Jul	07:30	16:35	09:05	05:14	03:51	3.9	3	101	70%	1	294	275		1	15:30	14.4	DD/PO	ds out 11:00
19-Jul	07:35	16:05	08:30	01:35	06:55	6.9	1	102	71%		90	202	3		16:02	14.3	DD/DM	king near dead, recap #0026
20-Jul	07:35	16:15	08:40	01:25	07:15	7.2	2	104	72%	2	65	215	1		16:36	14.1	DD/AH	
21-Jul	07:10	15:30	08:20	02:00	06:20	6.3	0	104	72%		386	291	2		17:12	14	AH/DM	ds out 14:30,120max cs enacted
22-Jul	08:00	17:35	09:35	02:25	07:10	7.2	5	109	76%	2	310	267			17:55	13.8	PO/TS	ds out 15:50
23-Jul	08:19	17:45	09:26	02:20	07:06	7.1	4	113	78%		189	322	1		18:45	13.7	DD/AH/TS	
24-Jul	07:45	18:10	10:25	02:15	08:10	8.2	3	116	81%	2	325	311		3	07:30	10.7	DD/PO	1 net mort jack,recap #0232
25-Jul			00:00		00:00			116	81%									
26-Jul	07:30	17:00	09:30	02:10	07:20	7.3	2	118	82%		208	84	1		15:43	3.9	AG/PO	1 net mort
27-Jul	07:45	16:30	08:45	01:37	07:08	7.1	1	119	83%	1	92	60			11:16	12.6	DD/AG/PO	
28-Jul	07:25	15:25	08:00	00:48	07:12	7.2	0	119	83%	1	48	70			12:09	14	PO/TS	
29-Jul	08:30	15:30	07:00	00:15	06:45	6.7	1	120	83%		10	14		1	12:57	15.3	DD/AG	
30-Jul	08:00	15:45	07:45	00:39	07:06	7.1	2	122	85%	1	29	51		1	13:42	16.3	DD/PO	
31-Jul	08:03	15:48	07:45	00:30	07:15	7.2	2	124	86%	1	20	37		1	14:26	17	DM/PO	ds out 12:45
01-Aug	07:15	15:35	08:20	00:52	07:28	7.5	6	130	90%		22	65		6	15:09	17.3	AG/PO/TS	ds out 13:15
02-Aug	06:30	15:20	08:50	01:25	07:25	7.4	9	139	97%	2	40	228	1	6	15:53	17.1	DD/TS	2 recaps #0231,#0249
03-Aug	07:15	14:30	07:15	00:20	06:55	6.9	1	140	97%	1	15	50		4	16:38	16.6	DD/AG	recap #0191
04-Aug	06:35	12:05	05:30	00:07	05:23	5.3	0	140	97%		7	22		2	04:53	14.8	AG/TS	
05-Aug	08:35	16:00	07:25	00:25	07:00	7.0	1	141	98%		20	131	3	10	17:50	13.2	DD/AG	
06-Aug	07:55	15:15	07:20	00:20	07:00	7.0	1	142	99%		15	82	2	13	06:56	11.8	AG/PO/TS	
07-Aug	08:40	15:45	07:05	00:15	06:50	6.8	0	142	99%		15	50	1	3	08:14	10.9	DD/AG	
08-Aug	08:45	16:18	07:33	00:22	07:11	7.2	1	143	99%		17	41		8	09:37	10.8	KP/TS	
09-Aug	08:30	15:45	07:15	00:19	06:56	6.9	0	143	99%		16	10		3	10:46	11.3	AG/JJ/KP	
10-Aug			00:00		00:00			143	99%									
11-Aug			00:00		00:00			143	99%									
12-Aug	08:20	15:40	07:20	00:18	07:02	7.0	1	144	100		13	43		5	12:55	13.5	AG/TS	
13-Aug			00:00		00:00			144	100									
14-Aug			00:00		00:00			144	100									
15-Aug	09:30	16:40	07:10	00:16	06:54	6.9	0	144	100		5	71		11	14:26	14.9	AG/KP	
TOTALS							144			30	3771	3806	20	79				

Appendix B2.–Setnet catch and effort records, Chickamin River, 1996, Choca Creek site.

	Start	Stop	Total	Process		Net/	Large	Cum.		Small					Water		Tide			
Date	time	time	time	Time	Effort	hours	chin	total	%	chin	Chum	Pink	Sock	Coho	Temp	Depth	Time	Height	Crew	Comments
06-Jun	14:15	09:45	19:50	00:00	19:50	10.0	0	0	0							3.3	17:36	15	kp/dm	overnight set
07-Jun			00:00		00:00	9.5		0	0											
08-Jun			00:00		00:00	0		0	0											
09-Jun	14:20	18:20	04:00	00:00	04:00	4		0	0						7	3.3	20:58	14.7	po/kp	new 20 fathom net
10-Jun	11:15	18:15	07:00	00:00	07:00	7		0	0						8	2.6	21:37	15	po/dd	
11-Jun	09:40	17:22	07:42	00:35	07:07	7.1		0	0						8	2	10:20	12.3	po/dd	
12-Jun	10:15	17:15	07:00	00:00	07:00	7.0	0	0	0						9	2.4	11:21	12.7	dd/po	king creek
13-Jun	09:00	16:10	07:10	00:00	07:10	7.2	0	0	0						8	1.10	12:12	13.2	dd/po	king creek
14-Jun			00:00		00:00	0.0		0	0											
15-Jun	09:00	16:30	07:30	00:05	07:25	7.3	2	2	5		1				9	0.1	13:36	13.9	po/dd	lost 1 king
16-Jun			00:00		00:00			2	5											
17-Jun	10:30	18:00	07:30	00:00	07:30	7.3		2	5						10	0	14:50	14.1	po/dd	
18-Jun			00:00		00:00			2	5											
19-Jun	10:45	18:10	07:25	00:15	07:10	7.1		2	5						9	0	16:01	13.8	po/ts	
20-Jun	12:23	19:05	06:42	00:05	06:37	6.4	2	4	10							0.3	16:37	13.5	po/ts	
21-Jun			00:00		00:00			4	10											
22-Jun	08:57	16:00	07:03	00:00	07:03	7.0	0	4	10						8	2.7	17:58	13.2	dm/ts	king creek set, 1 net
23-Jun			00:00		00:00			4	10											
24-Jun	08:50	15:50	07:00	00:00	07:00	7.0	0	4	10						7	3.7	19:38	13.3	po/ts	
25-Jun	08:05	15:05	07:00	00:02	06:58	7.0	0	4	10						7.5	3.9	08:13	10.8	ag/po	
26-Jun	08:35	15:35	07:00	00:00	07:00	7.0	0	4	10						7	3.8	09:29	10.8	dm/po	
27-Jun			00:00		00:00			4	10											
28-Jun			00:00		00:00			4	10											
29-Jun	08:40	15:55	07:15	00:02	07:13	7.2	0	4	10		2	1			6.5	3.8	12:27	14	ag/dm	king creek
30-Jun			00:00		00:00			4	10											
01-Jul	08:40	15:50	07:10	00:03	07:07	7.1	0	4	10		3				6	3.1	14:02	15.8	ag/ts	king creek
02-Jul	09:40	16:40	07:00	00:06	06:54	6.9	0	4	10		6	1			8	1.9	14:48	16.3	ag/po	
03-Jul	08:40	18:00	09:20	00:10	09:10	9.2	1	5	13		5				7	1.6	15:34	16.5	ag/ts	
04-Jul	11:57	16:35	04:38	00:18	04:20	4.3	2	7	18		8	1			8	1.9	16:21	16.4	ag/dm	
05-Jul			00:00		00:00			7	18											
06-Jul	08:30	17:10	08:40	00:53	07:47	7.8	7	14	36	2	8				6	3	18:03	15.5	dm/ts	
07-Jul			00:00		00:00			14	36											
08-Jul	08:20	17:05	08:45	00:55	07:50	7.8	2	16	41		45	6			8	3.7	07:25	12.1	ag/ts	recap jack #015
09-Jul	09:12	15:25	06:13	00:02	06:11	6.2	0	16	41		2	1			8	4.1	08:43	11.4	dm/kp	1 lg king hit net & escaped
10-Jul			00:00		00:00			16	41											

-continued-

Date	Start time	Stop time	Total time	Process Time	Process Effort	Net/ hours	Large chin	Cum. total	Cum. %	Small chin	Chum	Pink	Sock	Coho	Water Temp	Water Depth	Tide Time	Tide Height	Crew	Comments
11-Jul	07:50	16:10	08:20	01:00	07:20	7.3	2	18	46	1	45	6			7	2.5	11:06	11.8	po/ts	
12-Jul			00:00		00:00			18	46											
13-Jul	08:30	17:35	09:05	01:40	07:25	7.4	0	18	46		100	5				2.5	12:42	12.9	ag/po	
14-Jul			00:00		00:00			18	46											
15-Jul	08:50	17:25	08:35	01:01	07:34	7.6	1	19	49	2	56	38			7	2.4	13:54	13.9	po/ts	
16-Jul	14:40	17:30	02:50	00:27	02:23	2.4	0	19	49		27	16			8	1.7	14:55	15.1	dm/po	
17-Jul	08:25	17:35	09:10	02:05	07:05	7.1	1	20	51	1	298	218			7	1.8	15:30	14.4	dm/ts	
18-Jul			00:00		00:00			20	51											
19-Jul	08:20	15:05	06:45	01:14	05:31	5.5	1	21	54	1	69	97			8	1.11	16:02	14.3	po/ts	
20-Jul			00:00		00:00			21	54											
21-Jul	08:10	17:25	09:15	02:10	07:05	7.1	2	23	59		275	154			8	1.4	17:12	14	dd/po	
22-Jul	09:20	18:40	09:20	02:15	07:05	7.1	3	26	67	1	260	147			8	1.3	17:12	14	dd/ah	
23-Jul	07:50	16:55	09:05	02:05	07:00	7.0	1	27	69		151	136			8	1.6	18:45	13.7	sh/dm/po	
24-Jul	08:05	17:30	09:25	02:20	07:05	7.1	4	31	79		295	122			7	1.10	07:30	10.7	ag/ts	
25-Jul	07:48	17:08	09:20	02:05	07:15	7.2	1	32	82		148	29			7		08:54	10.7	ag/ts	
26-Jul			00:00		00:00			32	82											
27-Jul			00:00		00:00			32	82											
28-Jul	07:57	15:30	07:33	00:29	07:04	7.0	0	32	82		29	11			8	3.6	12:09	14	dd/ag	
29-Jul	08:40	17:10	08:30	01:28	07:02	7.0	1	33	85		17	18			8	4.1	12:57	15.3	po/ts	66min pt to replace net
30-Jul			00:00		00:00			33	85											
31-Jul			00:00		00:00			33	85											
01-Aug			00:00		00:00			33	85											
02-Aug	07:35	15:30	07:55	00:33	07:22	7.4	3	36	92		16	109			8	1.6	15:53	17.1	ag/dm/po	
03-Aug			00:00		00:00			36	92											
04-Aug			00:00		00:00			36	92											
05-Aug	08:00	16:45	08:45	00:42	08:03	8.1	1	37	95		35	89		2	6	1.7	05:50	13.2	po/ts	
06-Aug	08:15	15:40	07:25	00:35	06:50	6.8	2	39	100		25	50	4	4		1.6	06:56	11.8	dd/ts	recap #0033
07-Aug			00:00		00:00			39	100											
08-Aug			00:00		00:00			39	100											
09-Aug	14:00	16:15	02:15	00:06	02:09	2.2	0	39	100	1	5	12		1		3	10:46	11.3	ag/ej	
10-Aug	08:00	15:20	07:20	00:10	07:10	7.2	0	39	100		2	8		2	8	3	11:39	12	ag/ej/ts	
11-Aug																				
12-Aug																				
13-Aug																				
TOTALS							39			9	1933	1275	4	9						

Appendix C1.–Locations of radio transmitters implanted in large chinook salmon on the Chickamin River, in 1996, by radio frequency, date tagged, tributary/river mile where located (see system codes) and survey type and date.

Fish no.	Count no.	Tag date	Sheet freq.	SURVEY TYPE AND DATE (A = fixed wing aerial, H = helicopter, B = boat)											Fate/ Destination
				A 6/20	B&A 6/27,6/28	B&A 7/04,7/05	A 7/09	B & A 7/16,7/17	B & A 7/22,7/23	B&A 7/30	B & H 8/08,8/13	A 8/19	A 8/25	A 8/30	
104	1	6/08	30.150	Leduc forks	C9(B)	L7	L2	L5	L5	L5		L6 mort	L6 mort		Clear Falls
103	2	6/08	30.180	C7	C12(B)	C12(B) mort	SF1 mort	C11(B) mort	C11(B) mort	C11(B) mort	C11(B) mort	C11 mort	C11 mort		South Fork
105	3	6/08	30.962	L4	L4	L10	L10	L11	L10	L11 mort			L11 mort		Butler
108	4	6/09	30.160	C10	C15 mort	C14 mort	C15 mort	C15 mort	C14 mort	C14 mort		C14 mort	C14 mort		Mort\Regurg
	5	6/09	30.972	C5				C4(B) mort		SF1					Chum salmon
106	6	6/09	30.992	L3	C6	C8(B)	L6	L6	L6	L6		L6	L6 mort		Clear Falls
	7	6/10	30.140	C3	K1 mort	K1(B) (A)mort	K1 mort	C5(B) mort	C4(B) mort	C4(B) normal	C4(B)	K1 mort	K1 mort	C4 mort	Chum salmon
109	8	6/10	30.922	C9@forks	SF2	C12	SF3	SF2(B)	SF2(B)						South Fork
110	9	6/10	30.932	C5(K2)	C7	C10(B)	C7	C9(B)	C9	L2		L2	C9 mort	C9 mort	LeDuc
112	10	6/10	30.982	C12	SF1 mort	SF3	C12	SF4	SF5(B)	SF3(B) mort	SF3(B) mort	SF3 mort	C8 mort		South Fork
113	11	6/11	30.872	C9	C7	C10(B)	C10	C19	C23	I2		I2 mort	I2 mort		Indian
114	12	6/11	30.882										SF2 rec8/20		South Fork
115	13	6/11	30.943		C9(B)	C9(B)	L5	L4	L5	L2		L6	L2 mort	L2 mort	Leduc
116	14	6/12	30.633	C10	C10 mort	L1 mort	C10 mort	C10 mort	C9 mort	L2 mort		L2 mort	L1 mort		Mort\Regurg
117	15	6/14	30.892	C6(K1)	C9(B)	C10(B)	C10	C9(B)	C9(B)	SF4(B)	SF4(B)	SF2	C9 mort	C2 mort	South Fork
118	16	6/15	30.592	C21	C22	C20	C15 mort	C20	C19	C16 mort	I1	C21 mort	C20 mort	C20 mort	Indian
1	17	6/15	30.912												Unknown
119	18	6/16	30.643	C8	C13	C11(B)	C10	SF1(B)	SF1(B)	C12(B)	C24	C22 or I	C24 mort		Indian Trib
121	19	6/17	30.603												Unknown
120	20	6/17	30.652	C2	C8	SF4	SF2	SF3	SF5(B)	SF3(B)	SF4(B)	SF3 mort	SF3 mort		South Fork
123	21	6/18	30.612				C10	C9(B)	C9	L2			L8 mort	L8 mort	Butler
124	22	6/18	30.702		C7(B)	C9(B)	C16	C24	C26	C26 mort	C26 mort	C26 mort	C26 mort		Indian Trib
122	23	6/18	30.902	C11	C13	C12(B)	SF3	SF4	SF5(B)	SF5(B)	SF4(B)	C9 mort			South Fork
2	24	6/20	30.573		C1	C3(B)	L6								Unknown
3	25	6/20	30.582		L5	L8	L6 mort		L6 mort	L6 mort		L6 mort	L6 mort		Clear Falls
125	26	6/21	30.712					C5(B)		H1(B)		H2			Humpy
126	27	6/21	30.722		C9	C18	C21		C21 mort	I1,C21 mort	I1 mort	I1 mort	I1 mort		Indian
127	28	6/22	30.732			C8(B)	C8	C8	L2	L2		CF rec.8/17	recovered 8/17		Clear Falls
128	29	6/22	30.742			C2(B)	L6	L6	L5	L6	L4	L2 mort	L2 mort	L2 mort	Clear Falls
129	30	6/22	30.752												Unknown
130	31	6/22	30.773		C9(B)	C13(B)	C12	SF4	SF2(B)	SF4(B)	B2	SF5	SF3 mort		South Fork/Barrier
131	32	6/23	30.783			C1(B) mort									Mort\Regurg
133	33	6/23	30.792		C1	C2(B)	L1	SF2(B)	SF2(B)	SF2(B)		C12 mort	SF1 mort		South Fork
134	34	6/23	30.802				C1	Bay mort							Mort\Regurg

-continued-

Appendix C1.–Page 2 of 4.

Fish no.	Count no.	Tag date	Sheet freq.	SURVEY TYPE AND DATE (A = fixed wing aerial, H = helicopter, B = boat) A 6/20	B&A 6/27,6/28	B&A 7/04,7/05	A 7/09	B & A 7/16,7/17	B & A 7/22,7/23	B&A 7/30	B & H 8/08,8/13	A 8/19	A 8/25	A 8/30	Fate/ Destination
132	35	6/23	30.822			C1(B)	L3	C12	C26	C26		C23 mort	C24 mort		Indian Trib
135	36	6/24	30.810		L1	C9	L1	SF4	SF5(B)	SF4	SF4 rec.8/11	Sfrec. 8/11	recovered 8/11		South Fork
136	37	6/25	30.832		C2	C10(B)	C11	C9(B)	SF4(B)	SF4(B)	SF4(B)	SF3 mort	SF3 mort		South Fork
137	38	6/25	30.852		C5(B)	SF junction	C21	C22	C23	C24	C24	C24 mort	C24 mort		Indian Trib
138	39	6/26	30.313			C19	I2(main river?)		C23	I2	I2 mort	I mort	I mort		Indian
139	40	7/01	30.290			L2		L6	L6	L6	L6 Clear Falls	L6 mort			Clear Falls
140	41	7/03	30.300				L1	C9	L2	L2	LC1	L2	LC1 rec 8/23		LeDuc
141	42	7/03	30.322				C10	C21	C23	C22	I2 mort	I mort	I mort		Indian
142	43	7/03	30.333						C4(B)	C4(B)	C4(B)	K4	K4	K4 rec8/27	King
4	44	7/03	30.662			C8(B)	C7	C9(B)	SF3(B)	SF2(B)	SF2(B) mort	C12 mort			South Fork
145	45	7/03	30.672			C3(B)	C5	C8(B)	C9	L1		L6	L6	L4 mort	Clear Falls
143	46	7/03	30.840				C10				I2 rec.7/31	I rec. 7/31	recovered 7/31		Indian
5	47	7/04	30.342					C21	C22	C24	C24	C24 mort	C24 mort		Indian
146	48	7/04	30.353				L2	L6	L6	L6	CF1	L6 mort	L6 mort		Clear Falls
147	49	7/04	30.362					C7(B)	SF1(B)	SF1(B)	SF2(B)	C26	C26	C26	Indian Trib
6	50	7/04	30.372				L1	L2	L2	L2	LC1	L6	CF rec8/21		Clear Falls
148	51	7/04	30.682					C24	C23	C24	C25	C24 mort	C24 mort		Indian Trib
149	52	7/04	30.693				C7	C9(B)	C9	C26		C26 mort	C26 mort		Indian Trib
151	53	7/04	30.863				C9	C8(B)	C9(B)		SF2(B)	C12	SF2	SF2	South Fork
7	54	7/06	30.383				C8	C9	L2	L2		L2 mort	L2 mort	L2 mort	LeDuc
152	55	7/06	30.392				C6	C9(B)	C9(B)	C9(B)	BT1 mort	L11 mort	L11		Butler
153	56	7/06	30.400					C8(B)	C8(B)	C5(B)	H1(B)	C3			Unknown
8	57	7/06	30.412				L1	L2	L2	L2	LC1 rec.8/07	LC rec. 8/07	recovered 8/07		LeDuc
154	58	7/06	30.420				C8 mort	SF1(B)	C23	C24		C24	C24	C22 mort	Indian Trib
9	59	7/06	30.432	never tracked, recovered at Lucky Jake			X	X	X	X	X	X	X	X	Indian Trib
155	60	7/06	30.442						C4(B)	C4(B)	C4(B)	C5	K4	K4	King
156	61	7/06	30.452				L1								Unknown
10	62	7/06	30.460				C6	C21	C24 mort	C24 mort		C24 mort	C24 mort		Indian Trib
11	63	7/06	30.472				C7	C9(B)	SF2(B)	SF2(B)	SF1(B) forks		SF2 rec8/20		South Fork
12	64	7/06	30.482					C23	C23	C24	Jake Creek	C24 mort	C24 mort		Indian Trib
14	65	7/06	30.492				C7 mort	C23	C23	C21		C14 mort	C14 mort		Indian Trib
160	66	7/07	30.532						C9(B)	C12(B)	SF1(B) forks	C12	SF2	SF2	South Fork
162	67	7/07	30.562				C2	C4		H1(B)		H2	H1 mort	H1 mort	Humpy
159	68	7/07	30.952				C1	C8(B)	SF1(B)	SF1(B)	SF1(B) forks	SF1	SF1	SF1	South Fork
170	69	7/08	30.010				C1		SF5(B)	SF5(B)		SF1 mort	SF1 mort	SF1 mort	South Fork
164	70	7/08	30.200						K3	K2		K4	K2 mort		King
17	71	7/08	30.250				C7	C23	C23	C25	C23	C24	C24 mort		Indian Trib
16	72	7/08	30.542						SF1(B)	SF1(B)	SF1(B)	SF3	SF1	SF3 rec8/26	South Fork
163	73	7/08	30.721				I3(main river)	C21 mort		H2 mort		H2 mort	H2 mort	H2 mort	Humpy

-continued-

Appendix C1.–Page 3 of 4.

Fish no.	Count no.	Tag date	Sheet freq.	SURVEY TYPE AND DATE (A = fixed wing aerial, H = helicopter, B = boat)											Fate/ Destination
				A 6/20	B&A 6/27,6/28	B&A 7/04,7/05	A 7/09	B & A 7/16,7/17	B & A 7/22,7/23	B&A 7/30	B & H 8/08,8/13	A 8/19	A 8/25	A 8/30	
165	74	7/08	30.821				L1	L2	L1	L5	SF2 rec.8/11	SF2 rec. 8/11	recovered 8/11		South Fork
166	75	7/08	30.970							SF1(B)	SF1(B)		SF4	SF4 mort	South Fork
168	76	7/08	30.992						K3	K4	K5	K4	K4	K4	King
167	77	7/08	31.302				C2			H1(B)	H1(B)	H1	H1 rec8/25		Humpy
171	78	7/09	30.020						C8	C12(B)	SF2(B)	SF3	SF5	SF5	South Fork
172	79	7/09	30.030					C8(B)	SF5(B)	H1(B)	LC1	H2	H2	H2	Humpy
173	80	7/09	30.040						C9(B)	C9(B)		C24	C24	C24	Indian Trib
174	81	7/10	30.050					C1	C9	SF3(B)	SF2(B)	SF3	SF3	SF3 rec8/26	South fork
175	82	7/11	30.060					SF2(B)	SF5(B)	SF5(B)		SF4 mort	SF5 mort		South Fork
176	83	7/11	30.070						C9	C9(B)		K1	K2	K1	King
19	84	7/11	30.522					C9(B)	C9	L8	BT1	BT rec.8/17	recovered 8/17		Butler
20	85	7/11	30.762					C9(B)	C22	C24	Jake Creek	C26	C26 mort		Indian Trib
179	86	7/12	30.080					L5	L5	L6			C9 mort		Clear Falls
182	87	7/12	30.090					C5(B)	C4(B)	K2	K2	K3	K3	K4	King
189	88	7/13	30.110					C2(B)	C2(B) mort	C1 mort	C2(B) mort	C1	C1	C1	Mort\Regurg
190	89	7/13	30.170							C12(B)		SF1	SF2	SF2	South Fork
195	90	7/14	30.240					L4	L10	L11	BT1	L11	L11 mort	L11 mort	Butler
199	91	7/15	30.220					C10	SF1(B)	SF2(B)	SF3(B)	SF2	SF2 rec8/20		South Fork
22	92	7/15	30.512					C6(B)	L2	L2		L2	L2	L2	LeDuc
204	93	7/16	30.280					X	X	X	X	Jake rec 8/07	recovered 8/07		Indian Trib
207	94	7/17	30.100							SF1(B)	SF1(B) forks	SF5, B1	SF5	SF5	South Fork
210	95	7/17	30.270										H1	H2	Humpy
218	96	7/20	30.230						C4	C4		C4	K2	K3 rec8/29	King
28	97	7/21	30.210						C4	SF3(B)	SF2(B)	SF4	SF4	SF4 rec8/26	South Fork
222	98	7/22	30.130									L2	L8	L8	Butler
31	99	7/22	30.552							L6	L6	L6	L4 mort	L4 mort	Clear Falls
226	100	7/23	30.260								SF1(B)	C12	SF2	SF2	South Fork
229	101	7/23	31.102							C2(B)				K2-3	King
35	102	7/24	30.120							C1	SF1(B) forks	SF5, B1	SF4 rec.		South Fork
39	103	7/25	31.121							C12(B)		C24	C24	C24	Indian Trib
235	104	7/27	31.062										K2	K2	King
241	105	7/30	31.172									K4	K4	K4	King
254	106	8/01	31.222									H2	H2	H2 mort	Humpy
245	107	8/01	31.531									C5	H2	H2	Humpy
248	108	8/01	31.582								H1(B)	K1	H1	H2 rec8/29	Humpy
257	109	8/02	31.612(M)									C5	H2	H1	Humpy
251	110	8/02	31.852									SF1	SF2	SF2	South Fork
42	111	8/02	31.990								SF1(B) forks	SF2	SF2	SF2-3rec8/26	South Fork
262	112	8/03	31.552(M)									C5	H2	H2	Humpy

-continued-

Appendix C1.–Page 4 of 4.

Fish no.	Count no.	Tag date	Sheet freq.	SURVEY TYPE AND DATE (A = fixed wing aerial, H = helicopter, B = boat)											Fate/ Destination
				A 6/20	B&A 6/27,6/28	B&A 7/04,7/05	A 7/09	B & A 7/16,7/17	B & A 7/22,7/23	B&A 7/30	B & H 8/08,8/13	A 8/19	A 8/25	A 8/30	
45	113	8/06	31.382								C3(B) mort	C2 mort	C4 mort	K1 live	King
267	114	8/12	31.542(M)									K3	K3	K3	King

M = mortality signal; X = frequency not looked for during that survey.

SYSTEM CODES— Letter code denotes tributary name; numbers indicate river mile: Chickamin mainstem (C1–C33), South Fork (SF1–SF11), Leduc River (L1–L18), Leduc Cr (LC1), Clear Falls (CF1), Clear CR (CL1–CL3), Choca Cr (CD1–CD3), Barrier Cr (B1–B7), Butler Cr (BT1), Indian Cr (I1–I3), King Cr (K1–K7), Humpy Cr (H1–H4).

Appendix D1.–Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of Hypothesis Tests (K-S and χ^2) on lengths of fish MARKED during the First Event and RECAPTURED during the Second Event	Results of Hypothesis Tests (K-S and χ^2) on lengths of fish CAPTURED during the First Event and CAPTURED during the Second Event

Case I:

"Accept" H_O "Accept" H_O

There is no size-selectivity during either sampling event.

Case II:

"Accept" H_O Reject H_O

There is no size-selectivity during the second sampling event but there is during the first.

Case III:

Reject H_O "Accept" H_O

There is size-selectivity during both sampling events.

Case IV:

Reject H_O Reject H_O

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

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

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

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

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

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for

-continued-

Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Size/age-selectivity in sampling (assumptions 1 and 2) will be investigated according to protocols inThe fraction p_{ij} of the fish in age (or sex or length) group j in stratum i (large or small fish). will be calculated as:

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

where n_i = the number of large (or small) fish sampled at Canyon and n_{ij} = the number from this sample that belong to age (or sex or length) group j. Note that $\sum_j p_{ij} = 1$. The variance for $\hat{p}_{ij}$ is:

$$Var(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_i - 1}$$

The estimated abundance of group j in the population ($\hat{N}_j$) is:

$$\hat{N}_j = \sum_i \hat{p}_{ij}\hat{N}_i$$

where $\hat{N}_i$ = the estimated abundance in stratum i of the mark-recapture experiment. From Goodman (1960), $Var(\hat{N}_j)$ is a sum of the products of the exact variance for $\hat{N}_i$ and the sample variance of $\hat{p}_{ij}$:

$$Var(\hat{N}_j) = \sum_i \left[Var(\hat{p}_{ij})\hat{N}_i^2 + Var(\hat{N}_i)\hat{p}_{ij}^2 \right]$$

The estimated fraction of the population that belongs to group j ($\hat{p}_j$) is:

$$\hat{p}_j = \frac{\hat{N}_j}{\sum_i \hat{N}_i}$$

The variance of the estimated fraction can be approximated with the delta method (see Seber 1982):

$$Var(\hat{p}_j) \cong \hat{N}^{-2}\sum_i \left[\hat{N}_i^2 Var(\hat{p}_{ij})\right] + \hat{N}^{-2}\sum_i \left[Var(\hat{N}_i)(\hat{p}_{ij} - \hat{p}_j)^2\right]$$

where $\hat{N} = \sum_i \hat{N}_i$. If size/age/sex-selectivity can not be excluded with the protocols in Appendix B, large and small fish will be subdivided further into smaller strata and Equations 3-8 will be applied to achieve unbiased estimates.

Appendix D2.–Computer files used to estimate the distribution and spawning abundance of chinook salmon in the Chickamin River in 1996.

File name	Description
SETNETC.xls	EXCEL spreadsheet with setnet tagging data--daily effort, catch by species, and water depth by site; setnet charts.
CHKESC96.xls	EXCEL spreadsheet with recovery data for chinook salmon in the Chickamin River in 1996. Includes recovery data by tributary (date, length (MEF), sex, age and any marks); length frequencies; length at age; age composition of setnet and tributary samples; KS test data; charts.
41CHKM96.xls	EXCEL spreadsheet with setnet tagging data for each fish tagged—site, date, sex, length (MEF), age, tag numbers and comments.
Chick96.doc	WORD 6.0 (Windows) file of this FDS report.