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Spawning Abundance of Chinook Salmon in the Taku River in 1995

by

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Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

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

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ABSTRACT

A cooperative study between the Alaska Department of Fish and Game, the Taku River Tlingit First Nation, and the Canadian Department of Fisheries and Oceans was conducted to estimate abundance of spawning of chinook salmon *Oncorhynchus tshawytscha* in the Taku River in 1995 with a mark-recapture experiment. Fish were captured at Canyon Island on the lower Taku river with fish wheels from May through August and were individually marked with metal jaw tags or back-sewn spaghetti tags and were batch marked as well with an opercle punch plus removal of the left axillary appendage. Sampling on the spawning grounds in tributaries was used to estimate the fraction of the population that had been marked. Abundance of chinook salmon 401–659 mm long (mid-eye to fork of tail) was estimated directly from the mark-recapture experiment to be 32,246 (SE = 3,751). Abundance of fish larger than 659 mm was estimated by expanding the estimate for smaller fish by size composition of fish sampled on the spawning grounds. Estimated abundance of larger fish (≥ 660 mm) in 1995 was 33,805 (SE = 5,060). Estimated abundance of these larger fish from aerial surveys of parts of the Taku River was considerably smaller than estimates expanded from the mark-recapture experiment in 1995, a trend repeated from similar studies in 1989 and 1990. The 1991 brood year (mostly age 1.2) constituted 47% of the spawning population, followed by the 1989 brood year (mostly age 1.4), which constituted 31% of the population.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, Taku River, spawning abundance, mark-recapture, age and sex composition.

INTRODUCTION

The Taku River has one of the largest populations of chinook salmon *Oncorhynchus tshawytscha* in Southeast Alaska (Figure 1; Pahlke 1995). Prior to the mid-1970s these fish were exploited in directed commercial and recreational fisheries, with annual commercial harvests reaching 15,000 fish (Kissner 1976). Various restrictions were placed on all intercepting fisheries (troll, gillnet and recreational), beginning in 1976, as part of a program to rebuild stocks of chinook salmon in Southeast Alaska. This rebuilding effort has been combined with a coastwide rebuilding program for chinook salmon in conjunction with the Pacific Salmon Treaty, since 1985.

Presently, migrating chinook salmon from the Taku River are caught incidentally in a commercial gillnet fishery located in U.S. waters near the river, and in an inriver Canadian gillnet fishery. Chinook salmon from the Taku River also constitute an unknown, but thought to be large, component of the spring catch in the recreational fishery in marine waters near Juneau and are caught in recreational fisheries in Canadian reaches of the drainage. Exploitation of this population is jointly managed by the U.S. and Canada through a subcommittee of the Pacific Salmon Commission (PSC).

Since 1975, escapements to the Taku River have been assessed by counting chinook salmon on the spawning grounds in some clearwater tributaries from helicopters (Pahlke 1995). Only large (typically 3-ocean age [age -.3] and older or fish approximately larger than 660 mm mid-eye to fork of tail [MEF]) chinook salmon are counted in these surveys. Fish age -.1 and age -.2 (1- and 2-ocean age) are not counted because of the difficulty of distinguishing these fish from other species from the air. Survey counts of large chinook salmon have been expanded to account for fish not present or observed during surveys and for unsurveyed tributaries (Mecum and Kissner 1989; PSC 1993).

Expansions were established in 1981 and were revised in 1991. In 1988, a study demonstrated that it was possible to mark and recapture enough large chinook salmon in the Taku River to estimate escapement (McGregor and Clark 1989).

In 1989 and 1990, the Commercial Fisheries Division (now the Commercial Fisheries Management and Development Division [CFMDD]), the Canadian Department of Fisheries and Oceans

(DFO), and the U.S. National Marine Fisheries Service (NMFS) estimated abundance of large chinook salmon in the Taku River from a mark-recapture and radio telemetry study (Pahlke and Bernard 1996; Eiler et al. *In prep.*). Results from those studies estimated the abundance of large chinook at 40,329 (SE = 5,646) in 1989 and 52,142 (SE = 9,326) in 1990. Chinook salmon were captured in fish wheels at Canyon Island, a location which is well below the spawning grounds in tributaries upriver where chinook salmon were inspected for marks.

Chinook salmon from the Taku River are a "spring run" of fish; returning fish are present in terminal marine areas from late April through early July. Spawning occurs from late July to mid-September. Almost all juveniles rear for one year in fresh water after emergence and smolt to sea at age 1.- (Kissner and Hubartt 1986).

This stock rears offshore out of reach of fisheries in Southeast Alaska until they reach maturity and migrate to their spawning grounds. These fish mature after one to five years at sea, age -.1 and -.2 fish being mostly males, and age -.3, -.4, and -.5 fish being of both sexes but mostly females. Ages -.2, -3, and -.4 dominate the annual spawning population; age-.5 fish are uncommon (<5% of the run).

The objectives of this study were to estimate abundance of large chinook salmon spawning in the Taku River in 1995 and the age and sex composition of these fish.

METHODS

STUDY AREA

The Taku River originates in the Stikine Plateau of northwestern British Columbia, Canada (Figure 1), and flows approximately 300 km downstream, emptying into Taku Inlet about 30 km east of Juneau, Alaska, through a drainage of approximately 17,094 km^2 (Bigelow et al. 1995). Two principal tributaries, the Inklin and the Nakina rivers, merge about 55 km above the U.S./Canada border to form the main body of the lower river. Discharge past Canyon Island (Figure 1) increases from a winter low on average of 60 m^3/sec in February to 1,097 m^3/sec in June (Bigelow et al. 1995). The Taku River mainstem is turbid, with a large volume of discharge from glacial melt in Alaska and Canada; however, the tributaries where most chinook salmon spawn have relatively clear waters, notably the Nakina, King Salmon, Kowatua, Hackett and Nahlin rivers.

CANYON ISLAND

Chinook salmon returning to the Taku River and migrating upstream were captured with two fish wheels placed on opposite banks of the Taku River approximately 200 m apart at Canyon Island, about 4 km downstream from the International border (Figure 1). The sites for the two fish wheels were the same ones used since 1984. The Taku River narrows significantly at Canyon Island, and much of the river, under low to medium water levels, is forced between a deep channel with bedrock on both banks, making it an ideal location for fish wheel operation. Fish wheels were operated continuously from 4 May through 27 September except during extreme high or low water levels and during maintenance or sampling.

Fish wheel configurations and fish wheel operations are discussed in detail in Kelley et al. (*In prep.*). In brief, each fish wheel consisted of a framework with two aluminum pontoons and wooden collection baskets (two, three, or four) mounted on an axle, which turned from water force acting on the baskets and/or wooden paddles. Fish that were scooped up by the baskets were guided by V-shaped slides into wooden live boxes bolted to the outer edge of each pontoon.

A scale sample was taken from each chinook salmon captured at Canyon Island, the length of each captive measured, and its sex noted. Individual fish were dipnetted from live boxes, elevated, and transferred to a trough partially filled with river water. Fish were handled with bare hands to prevent injury. While one person held the fish, another sampled and a third recorded data. Measurements of length were recorded as distance from mid-eye to fork of tail (MEF) and post-orbit to hypural plate (POH). Gender of each sampled fish was determined from inspection of its external characteristics. Four scales from each fish were

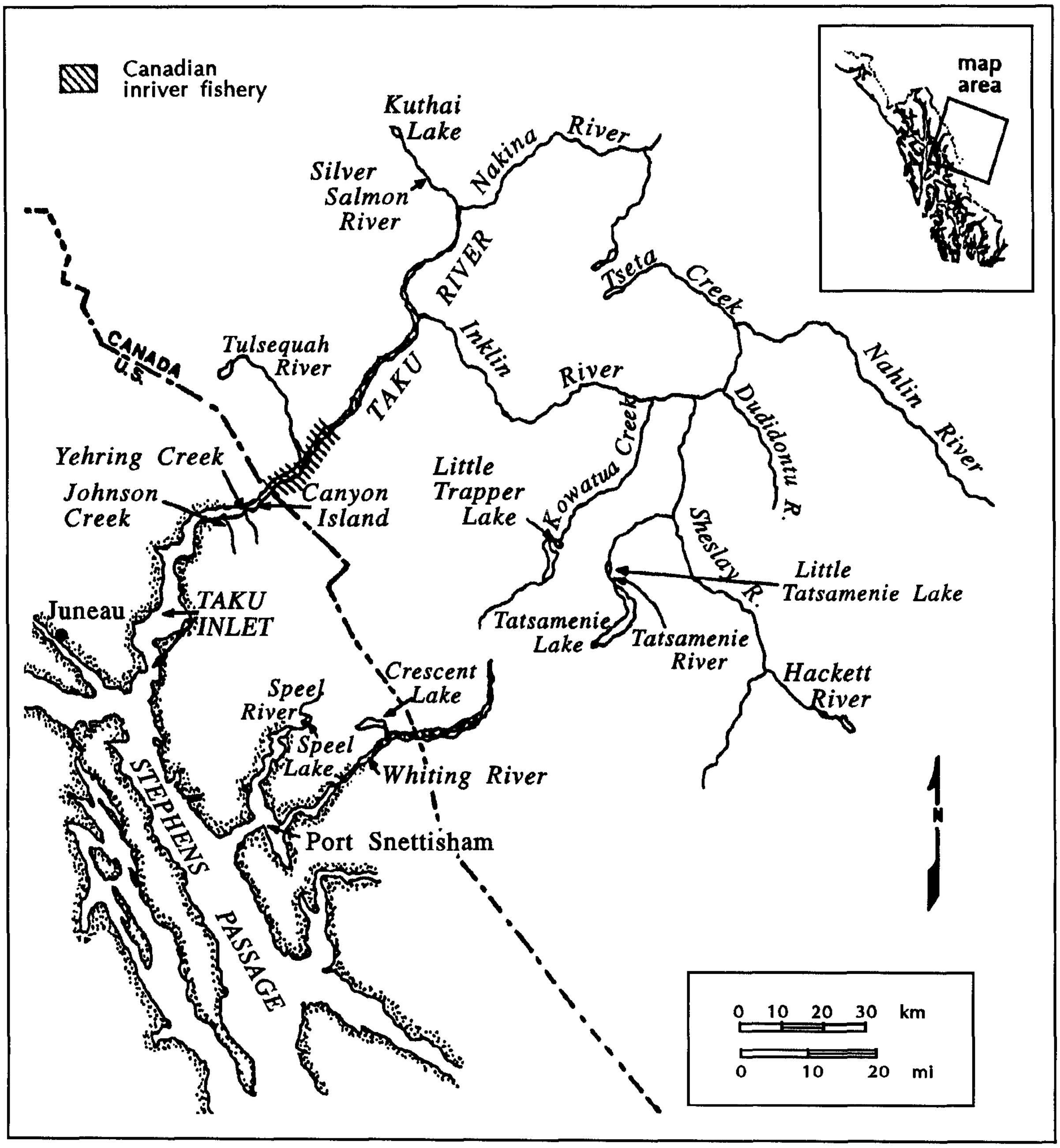

Figure 1.–Taku Inlet and Taku River drainage.

taken from the "preferred area" two rows above the lateral line on the left side of the fish across a diagonal running from the posterior terminus of the dorsal fin to the anterior margin of the anal fin.

Scales were mounted onto gummed cards which held scales from 10 fish. Age of each fish was determined later from the pattern of circuli (Olsen 1992) on images of scales impressed onto acetate magnified 70×. (Clutter and Whitesel 1956). In cooperation with another project, presence or absence of an adipose fin was noted for each sampled fish.

All captured chinook salmon judged uninjured were also tagged and marked for the first-event of a mark-recapture experiment to estimate abundance. Initially, we tagged each subject with a stainless steel, individually numbered, self-piercing band (jaw tags) strapped around the left jaw of the fish with the ends crimped and locked together. Because chinook salmon vary greatly in size (from 250 to 1,000 mm or more MEF), three sizes of jaw tags from National Band and Tag Co. (NBT) were used initially: 18-mm jaw tags (NBT#1005-4)—mostly on age -.1 fish; 25-mm tags (NBT#1005-681)—mostly on age -.2 fish; and 38-mm tags (NBT#1005-49)—on age -.3 and older fish.

However, the locking device on the 25-mm tags failed often, and the 38-mm tags were too small for chinook salmon over 800 mm MEF. Partway through the season, we changed the tagging protocol thus:

(1) 18-mm tags were strapped around jaws of fish 250–400 mm MEF;

(2) fish 401–545 mm MEF were not strapped with jaw tags but tagged with individually numbered, hollow-core, plastic spaghetti tags sewn through the back below the posterior end of the dorsal fin and knotted;

(3) 38-mm tags were strapped around the jaws of fish 550–795 mm MEF; and

(4) fish >795 mm MEF were marked with 18-mm jaw tags clamped and locked on the posterior edge of the operculum.

Besides the individually numbered tag (the primary mark), each fish was also batch marked by a 5/16″ hole punched in the upper one-third of their left operculum (UOP) and by excision of the left axillary appendage (LAA) with a canine nail clipper.

SAMPLING ON THE SPAWNING GROUNDS

Chinook salmon were sampled on the Nahlin, Nakina, Kowatua and Tatsatua (Tatsamenie) rivers in 1995 as representative stocks of early, mid-season, and late-season migrants (ADF 1951; Eiler et al. *In prep*; Pahlke and Bernard 1996).

All fish captured live at a weir situated below most spawning areas on the Nahlin River from 7 June to 10 August were inspected for marks. A carcass weir was used to inspect fish on the Nakina River from 2 to 25 August. Carcass surveys of spawned-out fish were conducted periodically from 3 August to 8 September on the Kowatua River, from 26 August to 24 September on the upper Tatsamenie River (Tatsatua system) and from 3 to 6 September on the lower Tatsamenie River (Tatsatua system). Sampled carcasses were marked to prevent their being resampled at a later date.

All inspected fish were closely examined for the presence of the primary tag, the UOP and the LAA, for the absence of their adipose fin, and were measured to the nearest mm MEF and POH. Scale samples were taken from a systematically drawn subset of inspected fish at each tributary according to procedures described for similar sampling at Canyon Island.

ABUNDANCE BY SIZE

Abundance on the spawning grounds of "medium-sized" (401–659 mm MEF) chinook salmon was estimated with Chapman's modified Petersen mark-recapture estimator (Seber 1982, p.60). The population was divided into size groups because fish wheels are selective for smaller fish (Meehan 1961; Pahlke and Bernard 1996). "Small" chinook salmon were < 401 mm MEF; "large" were ≥ 660 mm MEF. Estimated abundance ($\hat{N}_{ms}$) of medium-sized fish on the spawning grounds was calculated as

$$\hat{N}_{ms} = \frac{(\hat{M}_{ms} + 1)(C_{ms} + 1)}{(R_{ms} + 1)} - 1 \qquad (1)$$

where $\hat{M}_{ms}$ is the estimated number of marked fish that survived to spawn, C_{ms} is the number of fish inspected for marks on spawning grounds, and R_{ms} is the number of these inspected fish with marks.

The estimated number of marked medium-sized fish on the spawning grounds was $\hat{M}_{ms} = T_{ms} - \hat{H}_{ms}$, where T_{ms} is the number of tagged fish released at Canyon Island and $\hat{H}_{ms}$ is the estimated number of tagged fish removed by fishing (censored from the experiment). Fractions of samples composed of recaptured fish (R_{ms}/C_{ms}) were compared across tributaries to determine if the estimator was consistent (Seber 1982, p. 439). The length distribution of medium-sized fish tagged and released at Canyon Island was also compared with the length distribution of medium-sized fish recaptured in all tributaries to detect size-selective sampling on the spawning grounds.

Estimated numbers of tagged medium-sized fish censored from the experiment ($\hat{H}_{ms}$) are tallies of returned tags and expanded samples from fisheries downstream and upstream of Canyon Island. The number of tagged chinook salmon recovered through sampling by CFMADD of catches from the Alaska gillnet fisheries for sockeye salmon *O. nerka* in Taku Inlet/Stephens Passage was expanded by the fraction of the catch of chinook salmon sampled (44.25% for 1995). Only catches sampled before 15 July were included in the expansion, because no tags were recovered beyond that date. Historically, 80–90% of chinook salmon incidentally harvested in this fishery have been taken before mid-July.

No tags were recovered from a creel survey of the U.S. recreational fishery near Juneau; however, participants in this fishery voluntarily returned one tag. Another tag was voluntarily returned from the inriver recreational fishery in Canada. Because of a reward (US$2) for each tag returned from the inriver Canadian gillnet fishery, tags from all marked fish censored in this fishery were probably recovered.

Variance (mean square error), bias, and confidence intervals for $\hat{N}_{ms}$ were estimated with modifications of bootstrap procedures in Buckland and Garthwaite (1991). Medium-sized chinook salmon passing by Canyon Island were divided into seven capture histories (Table 1). The estimated number of fish past Canyon Island $\hat{N}^{+}_{ms}$ is greater than the estimate of abundance on the spawning grounds $\hat{N}_{ms}$ by the number of marked fish censored in fisheries $\hat{H}_{ms}$.

A bootstrap sample was built by drawing with replacement a sample of size $\hat{N}^{+}_{ms}$ from the empirical distribution defined by the capture histories. A new set of statistics from each bootstrap sample $\{\hat{M}^{*}_{ms}, C^{*}_{ms}, R^{*}_{ms}, \hat{H}^{*}_{ms}, T^{*}_{ms}\}$ was generated, along with a new estimate $\hat{N}^{*}_{ms}$ for abundance on the spawning grounds, and 1,000

Table 1.–Capture histories for medium-sized chinook salmon in the population spawning in the Taku River in 1995. Notation is in text.

Capture history	Medium-sized (401–659 mm)	Source of statistics
Marked, but censored in recreational fisheries	2	Returned
Marked, but censored in the marine commercial fishery	23	Observed/0.4425
Marked, but censored in the inriver commercial fishery	121	Returned
Marked and not sampled in tributaries	735	$\hat{M}_i - R_i$
Marked and recaptured in tributaries	63	R_i
Not marked but and captured in tributaries	2,519	$C_i - R_i$
Not marked and not sampled in tributaries	28,929	$\hat{N}_i - \hat{M}_i - C_i + R_i$
Effective population for simulations	32,392	$\hat{N}^{+}_{i}$

such bootstrap samples were drawn creating the empirical distribution $\hat{F}(\hat{N}^{*}_{ms})$, which is an estimate of $F(\hat{N}_{ms})$. The difference between the average $\bar{\hat{N}}^{*}_{ms}$ of bootstrap estimates and $\hat{N}_{ms}$ is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Confidence intervals were estimated from $\hat{F}(\hat{N}^{*}_{ms})$ with the percentile method (Efron and Tibshirani 1993, Section 13.3).

Variance was estimated as

$$v(\hat{N}^{*}_{ms}) = (B-1)^{-1}\sum_{b=1}^{B}(\hat{N}^{*}_{ms(b)} - \bar{\hat{N}}^{*}_{ms})^2$$

where B is the number of bootstrap samples.

Abundance of large chinook salmon was estimated by expanding the estimate for medium-sized fish by the estimated size composition of the spawning population. Because unusually low flows in May hampered efficacy of fish wheels, too few large fish were captured at Canyon Island to estimate their abundance directly with a mark-recapture experiment. Expansion was by the estimated fraction of medium-sized fish $\hat{\pi}$ in the population of large and medium-sized chinook salmon spawning in the Nahlin River:

$$\hat{N}_L = \hat{N}_{ms}\left(\frac{1}{\hat{\pi}} - 1\right) \qquad (2)$$

where $\hat{N}_L$ is the estimated abundance of all large chinook salmon on spawning grounds in the Taku drainage. Past sampling on the spawning grounds in several tributaries has not been demonstrably size-, age-, or sex-selective (Pahlke and Bernard 1996). In the past, differences in size composition among tributaries could be attributed to methods of capture, carcass weirs being selective for males (generally smaller, younger fish) and carcass surveys selective for females (generally larger, older fish) (Pahlke and Bernard 1996). Chinook salmon sampled in the Nahlin River were captured with a weir in 1995 as live fish moving upstream to spawn, a method without the sampling problems of a carcass weir or a carcass survey.

Variance and confidence intervals for $\hat{N}_L$ were also estimated through simulation by treating the number of medium-sized chinook salmon sampled in the Nahlin River as a binomial variable $n^*_{ms} \sim \text{binom}(\hat{\ },n)$, where n is the number of sampled fish > 400 mm MEF in that river. A thousand such simulated samples were drawn for each $\hat{\pi}^* = n^*_{ms}/n$, creating the empirical distribution $\hat{F}(\hat{\pi}^*)$ as an estimate of $F(\hat{\pi})$. Empirical distributions $\hat{F}(\hat{\pi}^*)$ and $\hat{F}(\hat{N}^*_{ms})$ were matched through equation (2) to produce the distribution $\hat{F}(\hat{N}^*_L)$ from which the estimate $v(\hat{N}^*_L)$ and confidence intervals for $\hat{N}_L$ were produced with methods described above.

Abundance of spawning chinook salmon of both large and medium-sized chinook salmon was estimated as $\hat{N} = \hat{N}_{ms}/\hat{\pi}$. Confidence intervals for $\hat{N}$ and $v(\hat{N})$ were estimated as per procedures described above. Because few small fish were recaptured on the spawning grounds, we did not estimate their abundance directly. Nor did we estimate their abundance indirectly through expansion, because sampling on the spawning grounds was not designed to produce a representative sample of small fish.

AGE AND SEX COMPOSITION

The proportion of the spawning population > 400 mm MEF composed of a given age was estimated as a binomial variable from fish sampled at Nahlin, Nakina, Kowatua, and Tatsatua rivers:

$$\hat{p}_j = \frac{m_j}{m} \qquad (3)$$

where $\hat{p}_j$ is the estimated proportion of the population of age j and m_j is the number of chinook salmon in the sample of size m taken on the spawning grounds. Note $\sum_j \hat{p}_j = 1$.

Information taken at Canyon Island was not used to estimate age or sex composition of the spawning population, because fish wheels are size-selective for smaller salmon (Meehan 1961). Samples taken at the Nahlin, Nakina, Kowatua, and Tatsatua rivers were pooled, because the proportion of age-.2 fish seen at the Nahlin River (0.4882) was similar to the proportion in the pooled sample (0.4676) (Z-statistic = 0.7455, P ≈ 0.46; Zar 1984); and the proportion across the large-fish ocean ages (.3, .4 and .5) in the pooled sample was similar to the distribution in the Canyon Island samples ($\chi 2$ = 0.141, df = 2, P = 0.932). Sample variance was calculated as

$$v(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{m-1} \qquad (4)$$

Numbers of spawning fish by age were estimated as products of estimated age composition and estimated abundance:

$$\hat{N}_j = \hat{p}_j \hat{N} \qquad (5)$$

with a sample variance calculated according to procedures in Goodman (1960):

$$v(\hat{N}_j) = v(\hat{p}_j)\hat{N}^2 + v(\hat{N})\hat{p}_j^2 - v(\hat{p}_j)v(\hat{N}) \quad (6)$$

Although there was some overlap between samples used to estimate $\{\hat{p}_j\}$ and $\hat{\pi}$, $\hat{p}_j$ and $\hat{N}$ were considered to be estimated independently, because all of n samples for $\hat{\pi}$ came from the Nahlin River, whereas m samples to determine age composition contained a subset of these n samples plus others drawn independently at the Nakina, Kowatua and Tatsatua rivers.

Sex composition and age-sex composition for the entire spawning population and its associated variances were also estimated with the equations above by first redefining the binomial variables in samples to produce estimated proportions by sex $\hat{p}_k$, where k denotes gender (male or female), such that $\sum_k \hat{p}_k = 1$, and by age-sex $\hat{p}_{jk}$, such that $\sum_{jk} \hat{p}_{jk} = 1$. Estimated sex composition for stocks in the Nahlin, Nakina, Kowatua, and Tatsatua rivers were again combined, and estimates from the Canyon Island fish wheels were excluded because of difficulty in accurately sexing fish (most are ocean-bright and have not developed secondary maturation characteristics).

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

Of a total 1,535 chinook salmon caught at Canyon Island (Appendix A1), 1,436 were tagged and released (Table 2). Ninety-five percent (95%) of catches occurred between 2 May and 1 July. Of the fish tagged, 158 were small (< 400 mm MEF), 944 were medium-sized (401–659 mm MEF) and 334 were large (≥ 660 mm MEF). Fisheries censored an estimated 182 tagged fish (12.6%) of all sizes (Table 2).

Although changes in water velocity can adversely affect catchability of migrating salmon in fish wheels, especially during periodic flooding from sudden releases of glacially retained water from the Tulsequah River (Kerr 1948; Marcus 1960), water levels and flows remained lower than average and relatively stable throughout the project in 1995 (Kelley et al. *In prep.*).

Estimated abundance of medium-sized chinook salmon $\hat{N}_{ms}$ on the spawning grounds in 1995 was 32,246 (SE = 3,751), based on 2,582 fish inspected for marks ($=C_{ms}$) at four tributaries, 63 of which were recaptured fish ($=R_{ms}$) (Table 2). Thirteen (21%) of the 63 recovered medium-sized fish had lost their primary tag, but were detected as marked fish from the upper opercle punch (UOP) and/or a missing left axillary appendage (LAA). All medium-sized fish that had shed their primary tags were inspected as carcasses on the Nakina (9), Kowatua (1), and Tatsatua/Tatsamenie (3) rivers. Fisheries censored an estimated 146 (15.5%) tagged fish ($=\hat{H}_{ms}$) making the estimated number of medium-sized tagged fish that survived to spawn 798 ($=\hat{M}_{ms}$). Similarities in the fraction marked among fish inspected in different tributaries (Nahlin River: 0.0247; Nakina River: 0.0236; and Kowatua/ Tatsatua rivers pooled: 0.0278) indicate that the Petersen estimator based on data pooled across tributaries is a consistent estimator for the mark-recapture experiment. ($\chi^2 = 0.12$, df = 2, P = 0.94). Lengths of fish recaptured in the tributaries were similar (Kolmogorov-Smirnof Two Sample Test, P = 0.12; Figure 2) to lengths of fish released with tags at Canyon Island (minus those fish known to have been censored) indicating that sampling in tributaries was not size-selective among medium-sized fish. Estimated abundance of medium-sized fish has a 95% confidence interval of 26,317 to 40,945, and an estimated relative bias of 1.14%.

Estimated abundance of large chinook salmon $\hat{N}_L$ on the spawning grounds for 1995 was 33,805 (SE = 5,060), making the estimated abundance of all chinook salmon > 400 mm MEF 66,051

Table 2.–Numbers of chinook salmon marked at Canyon Island, removed by fisheries and inspected for marks in tributaries in 1995 by length group.

	0–400 mm	401–659 mm	≥660 mm	Total
A. Released at Canyon Island with marks	158	944	334	1,436
B. Removed by:				
1. Sport fisheries [a]	0	2	1	3
2. U.S. gillnet [b]	0	23	9	32
3. Canadian gillnet	3	121	23	147
Total removals	3	146	33	182
C. Estimated $\hat{M}$	155	798	301	1,254
D. Inspected at:				
1. Nakina River				
Inspected	122	1,230	659	2,011
Recaptured	6	29	3	38
Recaptured/captured	0.0492	0.0236	0.0046	0.0189
2. Nahlin River				
Inspected	14	1,172	1,182	2,368
Recaptured	0	29	4	33
Recaptured/captured	0.0000	0.0247	0.0034	0.0139
3. Kowatua/Tatsatua rivers				
Inspected	7	180	248	435
Recaptured	0	5	1	6
Recaptured/captured	0.0000	0.0278	0.0040	0.0138
Total inspected				
Inspected	143	2,582	2,089	4,814
Recaptured	6	63	8	77
Recaptured/captured	0.0420	0.0244	0.0038	0.0160

[a] Includes voluntary recoveries, two from U.S. and one from Canadian sport fisheries.

[b] Estimated by expanding random recoveries in the U.S. gillnet fishery District 111 (Taku Inlet/Stephens Passage); 44.25% of chinook salmon harvested in this fishery were sampled through 22 July, yielding 10 medium and 4 large tagged chinook salmon.

(SE = 8,325). The estimated proportion of medium-sized fish $\hat{\pi}$ in samples at the Nahlin River was 0.4882 (Table 3). Estimated abundance of large fish had a 95% confidence interval of 25,455 to 45,216, and the estimated 95% confidence interval for $\hat{N}$ (medium + large fish) was 52,410 to 84,410.

ESTIMATES OF AGE AND SEX COMPOSITION

Age-.2 and consequently males dominated the age and sex compositions of chinook salmon > 400 mm MEF on the spawning grounds of the Taku River in 1995. Age -.2 fish constituted 47% of samples pooled across the Nakina, Nahlin, Kowatua, and Tatsatua rivers (Table 4). Age -.4 fish constituted 30%, and age -.3 fish constituted 22% of these samples; 70% of the pooled samples were males. Determination of gender in catches at Canyon Island was deemed unreliable; some age -.2 fish tagged at Canyon Island were recorded as females, yet were obviously males when recaptured on the spawning grounds.

Of the fish > 400 mm MEF sampled at Canyon Island, 74% were age -.2 fish, 11% age -.3 fish, and 15% age -.4 fish (Table 5). Age 1.1 fish were excluded from estimates of age and sex composition because of difficulties in obtaining a representative sample of these small fish on the spawning grounds to estimate abundance.

Estimated size composition and estimated age composition of chinook salmon were similar,

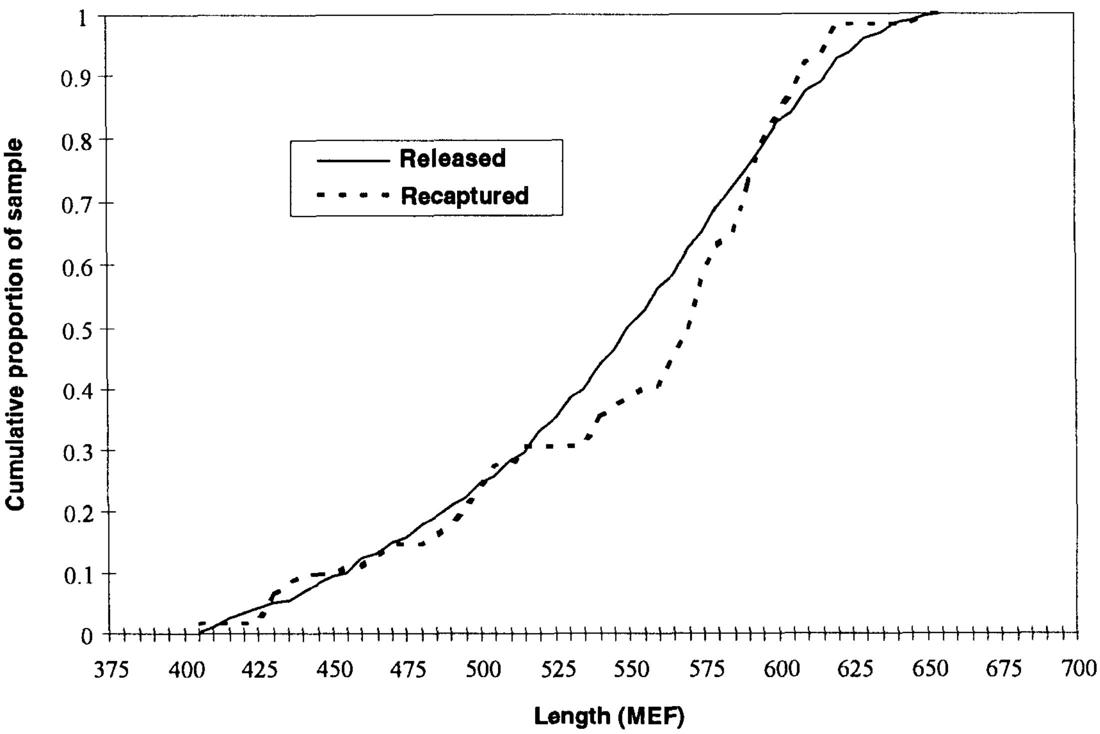

Figure 2.–Cumulative relative frequencies of medium size (401–659 mm MEF) chinook salmon marked at Canyon Island in 1995 versus those subsequently recaptured in sampling at Nakina, Nahlin, and Tatsatua/Kowatua rivers.

small fish being mostly age 1.1 fish, medium-sized fish being mostly age -.2, and large fish being older individuals (Figure 3). For example, of the fish sampled at Nakina River, 87% of small fish were age -.1 with the balance being fish age -.2 and the overlap being compensating. Of medium fish sampled, 97% of medium-sized fish were age -.2, and the balance age - .1 (1%) and -.3 (2%). Large fish in this sample were 97% age - .3, -.4 or -.5, and the balance age - .2 (3%). The same trends were seen in fish sampled at Canyon Island and other tributaries.

DISCUSSION

Our censoring of tagged fish caught in fisheries reduced bias in estimated abundance and its variance, but did not eliminate it completely. If there is mortality between sampling events in a mark-recapture experiment such as ours, estimated abundance will still be unbiased so long as marked and unmarked fish die at the same rate (Seber 1982, p. 71). However, at least some of the fish tagged and released at Canyon Island "backed down" to be caught in fisheries downstream. This "backing-down" phenomenon of tagged chinook salmon has been observed in other studies (Milligan et al. 1984; Johnson et al. 1992, 1993; Bendock and Alexandersdottir 1993; Eiler et al. *In prep*). If this phenomenon occurs only with handled fish, tagged fish caught in fisheries downstream of Canyon Island represent a source of inflationary bias in estimated abundance. Although the inriver commercial fishery is upstream of Canyon Island, incidental catches of delayed chinook salmon in this fishery would also inflate estimated abundance, because the fishery opened 18 June, well after most unmarked fish would have passed upstream. Our censoring of these intercepted fish was incomplete, because we had only minimal estimates of the number caught in recreational fisheries. However, considering that no tags were found when 17% of the harvest of the U.S. recreational fishery was inspected

Table 3.–Age composition of chinook salmon inspected for tags and passed at Nahlin River weir in 1995 by sex and size group (age-.2 fish were 48.82% of the total 2–5 ocean-age fish at the weir).

PANEL A: FISH INSPECTED FOR TAG RECOVERY ONLY

		Age class							
		1.1	1.2	1.3	2.2	1.4	1.5	2.4	Total
Females	n		5	66		88			159
	%		3.1	41.5		55.3			100.0
	SE% [a]		1.2	3.4		3.4			0.0
	Inspected for tags		19	250		334			603
Males <650 POH	n	2	147	42	13	2			206
	%	1.0	71.4	20.4	6.3	1.0			100.0
	SE%	0.6	2.9	2.6	1.6	0.6			0.0
	Inspected for tags	14	1,059	303	94	14			1,484
Males >649 POH	n			14		27	1	1	43
	%			32.6		62.8	2.3	2.3	100.0
	SE%			6.7		6.9	2.1	2.1	0.0
	Inspected for tags			91		176	7	7	281
Sexes combined	n	2	152	122	13	117	1	1	408
	%	0.6	45.5	27.2	4.0	22.2	0.3	0.3	100.0
	SE%	0.4	1.9	2.0	1.0	1.3	0.3	0.3	0.0
	Inspected for tags	14	1,078	644	94	525	7	7	2,368

PANEL B: ALL FISH PASSED AT THE WEIR

		Age class							
		1.1	1.2	1.3	2.2	1.4	1.5	2.4	Total
Females	n		5	66		88			159
	%		3.1	41.5		55.3			100.0
	SE%		1.3	3.5		3.6			0.0
	Weir count		28	364		485			876
Males <650 POH	n	2	147	42	13	2			206
	%	1.0	71.4	20.4	6.3	1.0			100.0
	SE%	0.7	3.0	2.7	1.6	0.7			0.0
	Weir count	20	1,494	427	132	20			2,094
Males >649 POH	n			14		27	1	1	43
	%			32.6		62.8	2.3	2.3	100.0
	SE%			6.9		7.1	2.2	2.2	0.0
	Weir count			143		276	10	10	440
Sexes combined	n	2	152	122	13	117	1	1	408
	%	0.6	44.6	27.4	3.9	22.9	0.3	0.3	100.0
	SE%	0.4	1.9	2.1	1.0	1.4	0.3	0.3	0.0
	Weir count	20	1,523	934	132	781	10	10	3,410

[a] Standard error of % (SE%) adjusted for finite population correction.

(Hubartt et al. 1996), and considering the size of the Canadian recreational harvest (<100 chinook salmon of all sizes), this bias from partial censoring should be negligible. Uncertainty from sampling to estimate the number of censored fish was included in the sample variance for estimated abundance through bootstrapping.

One capture history was excluded from the simulations: fish not captured at Canyon Island but caught in the inriver commercial fishery. Since we had no estimates of size composition of unmarked chinook salmon caught in this fishery, these fish were not represented in the simulations. Because so few fish shared this history

Table 4.–Estimated abundance and composition by age and sex of the escapement in the Taku River in 1995 for chinook salmon 2- to 5-ocean age.

PANEL A: AGE AND SEX COMPOSITION OF TOTAL

		Age class							2-5 ocean
		1.2	2.2	1.3	2.3	1.4	2.4	1.5	total
Males	n	721	26	200	1	167	3	8	1,126
	%	44.5	1.6	12.4	0.1	10.3	0.2	0.5	69.5
	SE of %	1.2	0.3	0.8	0.1	0.8	0.1	0.2	1.1
	Escapement	29,415	1,061	8,159	41	6,813	122	326	45,938
	SE of esc.	3,795	245	1,160	41	991	72	121	5,838
Females	n	9	1	156	1	317	2	7	493
	%	0.6	0.1	9.6	0.1	19.6	0.1	0.4	30.5
	SE of %	0.2	0.1	0.7	0.1	1.0	0.1	0.2	1.1
	Escapement	367	41	6,364	41	12,933	82	286	20,113
	SE of esc.	130	41	935	41	1,754	58	113	2,644
Combined	n	730	27	356	2	484	5	15	1,619
	%	45.1	1.7	22.0	0.1	29.9	0.3	0.9	100.0
	SE of %	1.2	0.3	1.0	0.1	1.1	0.1	0.2	0.0
	Escapement	29,782	1,102	14,524	82	19,746	204	612	66,051
	SE of esc.	3,840	251	1,951	58	2,598	94	174	8,325

PANEL B: PERCENTAGE AGE COMPOSITION BY SEX

		Age class							2-5 ocean
		1.2	2.2	1.3	2.3	1.4	2.4	1.5	total
Males	%	64.0	2.3	17.8	0.1	14.8	0.3	0.7	100.0
	SE of %	1.4	0.4	1.1	0.1	1.1	0.2	0.3	0.0
Females	%	1.8	0.2	31.6	0.2	64.3	0.4	1.4	100.0
	SE of %	0.6	0.2	2.1	0.2	2.2	0.3	0.5	0.0

(1,693 all sizes), their exclusion probably did not meaningfully bias statistics. While the loss rate of primary tags was unsettling, it did not bias estimates of abundance. Metal jaw tags of three sizes strapped around lower jaws and across opercular flaps of chinook salmon of all sizes were shed, as were hollow core plastic tags sewn through backs of chinook salmon. Highest rates of tag loss were recorded from carcasses at the Nakina and Kowatua/Tatsatua rivers. No live fish recaptured at the Nahlin River had shed its primary tag. Recognition of secondary marks proved sufficient insurance to avoid bias in estimates of abundance from tag loss.

Success of the mark-recapture experiment in 1995 depended heavily on marking chinook salmon at Canyon Island in proportion, or nearly in proportion, to their passing abundance. For our estimates of abundance to be unbiased (consistent), every fish must have had an equal chance of being marked at Canyon Island, or every fish on the spawning grounds must have had an equal chance of being inspected, or marked and unmarked fish must have mixed completely between Canyon Island and tributaries (from Seber 1982, pp. 437–9).

Fish in tributaries other than the Nakina, Nahlin, Kowatua, and Tatsatua rivers had no chance of being inspected, and differences in migratory timing of fish bound for different tributaries precludes complete mixing of marked and unmarked fish. Only by marking fish in proportion to their abundance at Canyon Island could we meet the assumption of proportionally tagging all stocks in the river. Changes in flow

Table 5.–Age composition samples collected from chinook salmon in the Taku River in 1995 by sex and age.

			1-ocean		2-ocean		3-5 ocean-age (large) fish					
			1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5	**Total**
Nakina	Male	n	39	2	426	8	98	1	112	1	7	694
		%	5.6	0.3	61.4	1.2	14.1	0.1	16.1	0.1	1.0	77.9
	Female	n					40		149	2	6	197
		%					20.3		75.6	1.0	3.0	22.1
	Total	n	39	2	426	8	138	1	261	3	13	891
		%	4.4	0.2	47.8	0.9	15.5	0.1	29.3	0.3	1.5	
Nahlin	Male	n	2		147	13	56		29	1	1	249
		%	0.8		59.0	5.2	22.5		11.6	0.4	0.4	61.0
	Female	n			5		66		88			159
		%			3.1		41.5		55.3			39.0
	Total	n	2		152	13	122		117	1	1	408
		%	0.5		37.3	3.2	29.9		28.7	0.2	0.2	
Kowatua/ Tatsatua	Male	n	5		148	5	46		26	1		231
		%	2.2		64.1	2.2	19.9		11.3	0.4		62.8
	Female	n			4	1	50	1	80		1	137
		%			2.9	0.7	36.5	0.7	58.4		0.7	37.2
	Total	n	5		152	6	96	1	106	1	1	368
		%	1.4		41.3	1.6	26.1	0.3	28.8	0.3	0.3	
Subtotal all three tributaries	Male	n	46	2	721	26	200	1	167	3	8	1,174
		%	3.9	0.2	61.4	2.2	17.0	0.1	14.2	0.3	0.7	70.4
	Female	n	0	0	9	1	156	1	317	2	7	493
		%			1.8	0.2	31.6	0.2	64.3		1.4	29.6
	Total	n	46	2	730	27	356	2	484	5	15	1,667
		%	2.8	0.1	43.8	1.6	21.4	0.1	29.0	0.3	0.9	
Canyon Is. fish wheels	Male	n	117	21	747	18	54	2	67	2	3	1031
		%	11.3		72.5	1.7	5.2		6.5	0.2		78.2
	Female	n			104	5	66	2	104	3	3	287
		%			36.2	1.7	23.0	0.7	36.2		1.0	21.8
	Total	n	117	21	851	23	120	4	171	5	6	1318
		%	8.9	1.6	64.6	1.7	9.1	0.3	13.0	0.4	0.5	

NOTE: 1 age 0.2 male for Canyon Island not included; sexing not accurate at Canyon Island (biased high for females).

rates and censoring of marked fish removed by fisheries could have affected our ability to proportionally mark chinook salmon. Still, our data for medium-sized fish easily passed the test of consistency (Seber 1982, p. 439), indicating that our marking had been proportional (or nearly so) for these fish, similar to mark-recapture studies of chinook salmon on the Taku River in 1989 and 1990 (Pahlke and Bernard 1996). Because our samples came from populations that represented the earliest through the latest fish to pass by Canyon Island (ADF 1951; Eiler et al. *In prep.*), our estimates of abundance pertain to all chinook salmon spawning in the Taku River watershed.

In estimating abundance and age and sex composition for the watershed we presumed that all stocks in the Taku River shared the same age, sex, and size compositions. Similarities across tributaries over the years of this project have been striking: the same strong and weak year classes have been evident across sampled stocks (Appendices A2 and A3). What differences there have been could be attributed to different methods of capturing chinook salmon employed in different tributaries. Because males tend to drift downstream in a moribund condition after spawning, while females tend to die near their redds (Kissner and Hubartt 1986), estimates of

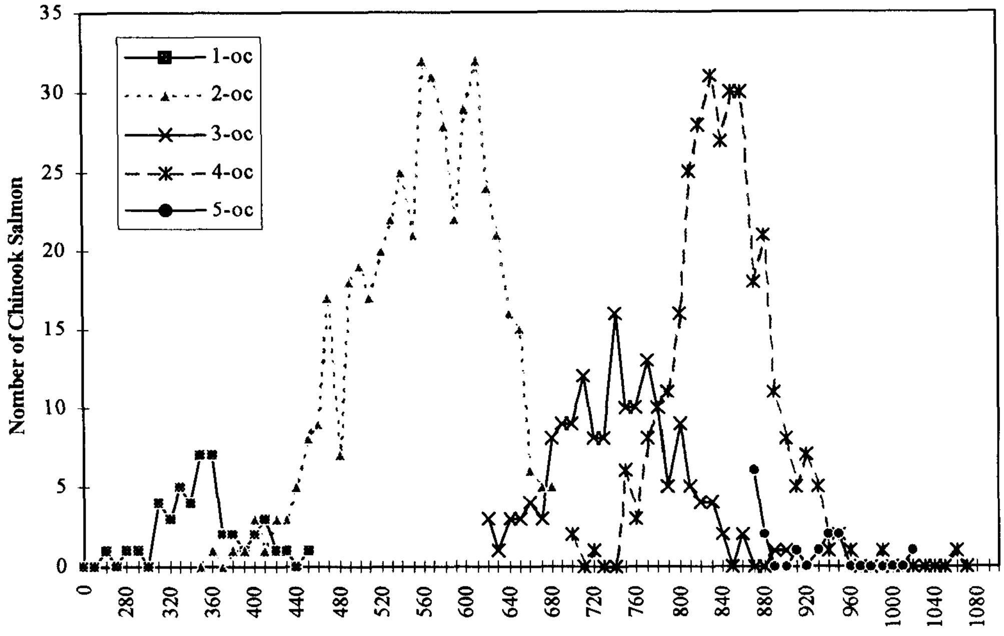

Figure 3.–Numbers of chinook salmon by ocean-age from chinook salmon sampled at Nakina River carcass weir in 1995.

age/sex/size composition for fish "caught" at carcass weirs tend to be biased towards males which tend to be younger, smaller chinook salmon, whereas estimates from carcass surveys tend to be biased towards females which are larger fish. Chinook salmon encountered at weirs passing live fish prior to their spawning are more likely to be of a representative size, age, and sex. This reasoning was used in 1995 to base expansion of abundance estimates on samples taken at the only live weir in the watershed, the weir on the Nahlin River. Hypothesis tests showed the pooled sample from all three sampled locations to be representative, probably because of compensating differences.

Estimated abundance of large chinook salmon on the spawning grounds of the Taku River was considerably greater in 1995 than the corresponding estimate from the aerial survey, a pattern seen on the Taku River in 1989 and 1990 (Table 6; Pahlke and Bernard 1996) and in other studies of chinook salmon in Southeast Alaska and in northern British Columbia (Johnson et al. 1992; Pahlke et al. 1996). Peak abundance of large chinook salmon in the Taku River has been estimated annually by flying slowly over spawning grounds in a helicopter and counting large fish below (Pahlke 1995). These counts have been expanded for fish missed in the survey of each tributary (Nakina, Nahlin, Dudidontu, Tseta, Tatsamenie and Kowatua rivers) and for fish in tributaries not surveyed. Factors used in the expansion have been based mostly on professional opinions of the ability to see fish during surveys and the distribution of spawners in the watershed.

Expanded survey counts, 25,481 for 1989, 32,622 for 1990 (Pahlke 1995) and 23,861 for 1995, represent 63.2% (1989), 62.6% (1990) and 70.6% (1995) of the abundance estimates of large fish from mark-recapture estimates. The unexpanded survey counts, 9,480 for 1989, 12,249 for 1990 (Pahlke 1995) and 8,757 for 1995, represent 23.5% (1989), 23.5% (1990) and 25.9% (1995) of the abundance estimates from mark-recapture experiments. In light of these comparisons, expansions used in aerial stock assessment should be changed. As past estimates of escapements to these rivers are

Table 6.–Comparison of estimated abundance of large chinook (>660 mm MEF) in the Taku River in 1989, 1990, and 1995 between estimates from expanding aerial surveys and through mark-recapture experiments. Methods of expansions of counts from aerial surveys are described in Pahlke (1995). Confidence intervals for 1989 and 1990 are described in Pahlke and Bernard (1996), those for 1995 are from this document and are similar to methodology for 1989 and 1990.

	1989	1990	1995	Average
Raw aerial survey counts summed across 6 tributaries: (Nakina, Nahlin, Tseta, Kowatua, Dudidontu and Tatsamenie)	9,480	12,249	8,757	10,162
Mark-recapture estimate(M-R)	40,329	52,142	33,805	42,092
M-R/aerial survey counts	23.507 %	23.492 %	25.904 %	24.301 %
Previous expansions	25,481	32,622	23,861	27,321
Previous expansion/M-R	63.183 %	62.564 %	70.584 %	65.444 %
M-R standard error	5,646	9,326	5,060	6,677
M-R lower 95% CI	30,936	37,072	25,455	31,154
M-R upper 95% CI	56,995	80,784	45,216	60,998

changed to higher, more realistic levels, associated estimates of exploitation rates will be lowered, which will then need to be included in re-evaluation of escapement goals and overall stock status.

CONCLUSION AND RECOMMENDATIONS

Since this project is to continue, we recommend some strategies to improve the precision of estimates. First, a greater number of large chinook salmon should be tagged. Fish wheels of an improved design will be used in 1996 to increase catches during low-water conditions which often prevail in May. Additionally, net gear at Canyon Island may increase catches. Gillnets have been used successfully to capture chinook salmon without harm in projects on the Chilkat, Unuk, Chickamin, and Kenai rivers.

Second, an improved primary tag is needed. Next year the primary mark will be a solid-core spaghetti tag sewn through the back of chinook salmon. The design is an improvement over the one used successfully on the Chilkat River by Johnson et al. (1992). The same tag type and secondary and tertiary marks will be used on all sizes of fish.

Third, precision can be improved by examining more fish on the Kowatua and Tatsatua (Tatsamenie) rivers.

We also recommend abundance of large (≥ 660 mm MEF) chinook salmon as estimated from aerial surveys in past years be adjusted upward in line with information gathered with mark-recapture experiments in 1989, 1990, and 1995. We recommend that aerial survey counts for other years be summed across all six index tributaries and that the total escapement of large chinook be estimated by dividing the sum of the aerial counts by 0.243 (the average fraction counted in 1989, 1990 and 1995). We also recommend escapement goals for Taku River chinook salmon be examined by 1997 to reflect the knowledge gained from mark-recapture studies.

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APPENDIX A

Appendix A1.–Fish wheel effort, catch and CPUE for chinook salmon at Canyon Island in 1995.

	Fishwheel #1		Fishwheel #2			Fishwheels combined							
Date	Hours fished	RPM	Hours fished	RPM	Water level (in)	Tagged daily	Tagged cum.	Catch daily	Catch cum.	CPUE daily	CPUE cum.	Daily prop.	Cum. prop.
27-Apr					6								
28-Apr					16								
29-Apr					24								
30-Apr					31								
1-May					35								
2-May					34								
3-May	5.67	2.00			35								
4-May	23.25	2.00			35	3	3	4	4	0.057	0.057	0.004	0.004
5-May	23.16	2.00			37	6	9	6	10	0.086	0.144	0.006	0.010
6-May	23.42	2.20			42	12	21	12	22	0.171	0.314	0.011	0.021
7-May	23.67	2.20			42	8	29	8	30	0.113	0.427	0.008	0.029
8-May	23.67	2.10			40	4	33	5	35	0.070	0.498	0.005	0.033
9-May	23.08	2.25	7.16	2.75	45	17	50	18	53	0.306	0.803	0.020	0.054
10-May	14.16	2.60	18.55	2.70	57	23	73	24	77	0.224	1.028	0.015	0.069
11-May			21.50	2.80	73	3	76	3	80	0.070	1.098	0.005	0.073
12-May			9.33	3.10	87	2	78	2	82	0.107	1.205	0.007	0.080
13-May					106	0	78	0	82		1.205	0.000	0.080
14-May					114	0	78	0	82		1.205	0.000	0.080
15-May			14.83	3.10	109	6	84	6	88	0.202	1.407	0.014	0.094
16-May	11.42	2.70	23.33	2.70	91	17	101	17	105	0.162	1.569	0.011	0.105
17-May	23.33	2.60	22.33	2.70	78	47	148	51	156	0.453	2.022	0.030	0.135
18-May	23.16	2.10	22.25	2.40	60	43	191	46	202	0.410	2.432	0.027	0.162
19-May	16.42	2.00	22.25	2.20	49	45	236	53	255	0.503	2.935	0.034	0.196
20-May	10.00	2.00	23.33	2.10	44	12	248	14	269	0.136	3.070	0.009	0.205
21-May	16.67	1.90	23.25	1.90	43	39	287	43	312	0.392	3.463	0.026	0.231
22-May			23.42	1.90	38	17	304	20	332	0.427	3.889	0.029	0.260
23-May			23.33	2.00	38	37	341	28	360	0.600	4.490	0.040	0.300
24-May	14.83	2.10	23.58	2.40	42	5	346	20	380	0.183	4.673	0.012	0.312
25-May	22.92	2.30	23.00	2.20	46	38	384	36	416	0.313	4.986	0.021	0.333
26-May	23.16	2.20	23.00	2.10	55	46	430	55	471	0.478	5.464	0.032	0.365
27-May	22.58	2.30	23.67	2.20	66	33	463	36	507	0.307	5.771	0.021	0.385
28-May	23.25	2.40	23.16	2.40	72	77	540	55	562	0.475	6.245	0.032	0.417
29-May	23.42	2.60	23.25	2.30	70	19	559	44	606	0.378	6.623	0.025	0.442
30-May	23.25	2.30	23.00	2.50	62	45	604	48	654	0.416	7.040	0.028	0.470
31-May	20.33	2.30	23.00	2.60	50	53	657	54	708	0.481	7.520	0.032	0.502
1-Jun	23.58	2.00	22.92	2.50	46	40	697	42	750	0.364	7.885	0.024	0.527
2-Jun	23.50	2.30	23.25	2.30	40	32	729	33	783	0.283	8.168	0.019	0.545
3-Jun	23.67	2.30	23.08	1.80	36	24	753	25	808	0.216	8.384	0.014	0.560
4-Jun	23.83	1.90			31	10	763	11	819	0.231	8.614	0.015	0.575
5-Jun	23.75	2.20	23.75	2.10	34	10	773	10	829	0.084	8.699	0.006	0.581

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Appendix A1.–(Page 2 of 3).

	Fishwheel #1		Fishwheel #2			Fishwheels combined							
Date	Hours fished	RPM	Hours fished	RPM	Water level (in)	Tagged daily	Tagged cum.	Catch daily	Catch cum.	CPUE daily	CPUE cum.	Daily prop.	Cum. prop.
6-Jun	23.58	2.40	23.50	2.30	36	15	788	16	845	0.136	8.835	0.009	0.590
7-Jun	23.75	2.30	23.42	2.20	34	17	805	17	862	0.145	8.979	0.010	0.600
8-Jun	23.67	2.30	23.50	2.40	37	13	818	13	875	0.110	9.090	0.007	0.607
9-Jun	22.83	2.50	21.50	2.20	51	26	844	27	902	0.248	9.338	0.017	0.624
10-Jun	22.75	3.10	23.58	2.60	65	28	872	28	930	0.239	9.577	0.016	0.640
11-Jun	22.75	3.20	23.67	2.70	84	26	898	26	956	0.221	9.799	0.015	0.654
12-Jun	22.75	2.70	23.00	2.90	94	43	941	45	1,001	0.392	10.191	0.026	0.681
13-Jun	20.00	2.90	23.00	2.70	90	33	974	34	1,035	0.304	10.494	0.020	0.701
14-Jun	22.83	2.60	22.92	2.60	90	23	997	24	1,059	0.210	10.704	0.014	0.715
15-Jun	23.00	2.10	23.00	2.50	73	22	1,019	24	1,083	0.209	10.913	0.014	0.729
16-Jun	23.08	2.20	22.00	2.80	64	52	1,071	57	1,140	0.513	11.426	0.034	0.763
17-Jun	22.52	2.30	21.50	2.50	58	37	1,108	41	1,181	0.378	11.804	0.025	0.788
18-Jun	23.08	2.90	23.00	3.00	62	20	1,128	21	1,202	0.182	11.986	0.012	0.800
19-Jun	19.58	2.60	22.16	2.60	65	40	1,168	45	1,247	0.416	12.402	0.028	0.828
20-Jun	22.83	2.70	22.16	2.50	70	72	1,240	49	1,296	0.440	12.841	0.029	0.858
21-Jun	22.50	2.80	23.50	2.50	68	0	1,240	30	1,326	0.258	13.099	0.017	0.875
22-Jun	22.75	2.80	23.50	2.70	67	25	1,265	25	1,351	0.214	13.313	0.014	0.889
23-Jun	23.25	2.70	23.50	2.50	67	10	1,275	11	1,362	0.094	13.407	0.006	0.895
24-Jun	22.75	2.40	23.33	2.50	62	6	1,281	6	1,368	0.052	13.459	0.003	0.899
25-Jun	20.25	3.00	22.08	2.50	53	9	1,290	9	1,377	0.083	13.542	0.006	0.904
26-Jun	20.75	2.70	22.83	2.50	47	13	1,303	14	1,391	0.125	13.666	0.008	0.913
27-Jun	23.08	2.60	22.75	2.50	48	14	1,317	14	1,405	0.123	13.789	0.008	0.921
28-Jun	23.08	2.60	23.42	2.60	50	8	1,325	10	1,415	0.086	13.875	0.006	0.927
29-Jun	22.83	2.50	22.33	2.80	65	19	1,344	20	1,435	0.178	14.053	0.012	0.938
30-Jun	23.16	2.50	23.16	2.70	67	7	1,351	7	1,442	0.060	14.114	0.004	0.942
1-Jul	21.50	2.60	22.42	2.70	79	15	1,366	15	1,457	0.135	14.249	0.009	0.951
2-Jul	21.83	2.50	22.92	2.60	75	6	1,372	7	1,464	0.062	14.310	0.004	0.956
3-Jul	21.50	2.60	22.58	2.50	71	8	1,380	8	1,472	0.072	14.382	0.005	0.960
4-Jul	21.16	2.50	22.00	2.60	72	7	1,387	8	1,480	0.073	14.455	0.005	0.965
5-Jul	22.83	2.60	23.33	2.60	66	6	1,393	6	1,486	0.052	14.507	0.003	0.969
6-Jul	22.92	2.50	23.33	2.80	70	2	1,395	2	1,488	0.017	14.524	0.001	0.970
7-Jul	9.92	3.30	9.67	3.00	92	2	1,397	2	1,490	0.041	14.565	0.003	0.973
8-Jul	13.33	2.70	14.25	2.70	78	1	1,398	1	1,491	0.014	14.579	0.001	0.974
9-Jul	22.58	2.70	22.83	2.50	73	2	1,400	3	1,494	0.026	14.606	0.002	0.975
10-Jul	22.50	2.80	22.83	2.50	73	3	1,403	4	1,498	0.035	14.641	0.002	0.978
11-Jul	20.50	2.80	23.08	2.90	78	2	1,405	2	1,500	0.018	14.658	0.001	0.979
12-Jul	22.75	2.80	22.42	2.70	76	4	1,409	4	1,504	0.036	14.694	0.002	0.981
13-Jul	22.95	2.60	22.67	2.60	80	3	1,412	4	1,508	0.035	14.729	0.002	0.984
14-Jul	22.67	2.60	23.33	2.50	70	4	1,416	4	1,512	0.034	14.764	0.002	0.986
15-Jul	22.50	2.40	23.42	2.50	65	0	1,416	0	1,512	0.000	14.764	0.000	0.986

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Appendix A1.–(Page 3 of 3).

Date	Fishwheel #1 Hours fished	Fishwheel #1 RPM	Fishwheel #2 Hours fished	Fishwheel #2 RPM	Water level (in)	Fishwheels combined Tagged daily	Tagged cum.	Catch daily	Catch cum.	CPUE daily	CPUE cum.	Daily prop.	Cum. prop.
16-Jul	22.25	2.40	23.33	2.50	60	0	1,416	0	1,512	0.000	14.764	0.000	0.986
17-Jul	23.08	2.50	23.50	2.70	58	2	1,418	2	1,514	0.017	14.781	0.001	0.987
18-Jul	22.42	2.80	22.67	2.90	62	2	1,420	2	1,516	0.018	14.798	0.001	0.988
19-Jul	22.92	2.60	23.00	2.80	75	0	1,420	0	1,516	0.000	14.798	0.000	0.988
20-Jul	22.67	2.50	22.58	2.70	72	1	1,421	1	1,517	0.009	14.807	0.001	0.989
21-Jul	22.83	2.60	23.08	2.90	72	0	1,421	1	1,518	0.009	14.816	0.001	0.989
22-Jul	20.50	2.80	22.67	2.90	81	5	1,426	5	1,523	0.045	14.861	0.003	0.992
23-Jul	20.83	2.80	22.34	2.50	88	3	1,429	4	1,527	0.036	14.897	0.002	0.995
24-Jul	11.42	3.40	11.92	3.00	96	1	1,430	1	1,528	0.017	14.914	0.001	0.996
25-Jul					120	0	1,430	0	1,528		14.914	0.000	0.996
26-Jul					180	0	1,430	0	1,528		14.914	0.000	0.996
27-Jul	11.92	2.40	9.50	2.60	77	0	1,430	0	1,528	0.000	14.914	0.000	0.996
28-Jul	22.67	2.25	22.67	2.30	58	1	1,431	1	1,529	0.009	14.923	0.001	0.997
29-Jul			23.25	1.90	48	0	1,431	0	1,529	0.000	14.923	0.000	0.997
30-Jul			23.25	1.90	48	0	1,431	0	1,529	0.000	14.923	0.000	0.997
31-Jul			21.83	2.20	50	0	1,431	0	1,529	0.000	14.923	0.000	0.997
1-Aug	6.50	2.00	22.83	1.80	48	0	1,431	0	1,529	0.000	14.923	0.000	0.997
2-Aug	22.92	1.00	23.16	1.00	42	0	1,431	0	1,529	0.000	14.923	0.000	0.997
3-Aug	23.08	2.20	23.42	2.20	42	0	1,431	0	1,529	0.000	14.923	0.000	0.997
4-Aug	22.00	2.50	23.08	2.50	66	0	1,431	0	1,529	0.000	14.923	0.000	0.997
5-Aug	22.58	2.20	22.67	2.40	66	1	1,432	1	1,530	0.009	14.932	0.001	0.997
6-Aug	23.75	2.70	23.08	2.50	52	0	1,432	0	1,530	0.000	14.932	0.000	0.997
7-Aug	23.00	2.30	22.83	2.10	46	0	1,432	0	1,530	0.000	14.932	0.000	0.997
8-Aug	19.58	2.40	22.83	2.40	48	0	1,432	0	1,530	0.000	14.932	0.000	0.997
9-Aug	22.92	2.50	22.67	2.40	45	0	1,432	0	1,530	0.000	14.932	0.000	0.997
10-Aug	23.17	2.60	23.42	2.40	45	1	1,433	1	1,531	0.009	14.940	0.001	0.998
11-Aug	22.75	2.60	23.16	2.20	50	0	1,433	0	1,531	0.000	14.940	0.000	0.998
12-Aug	22.75	2.50	22.83	2.40	52	1	1,434	1	1,532	0.009	14.949	0.001	0.998
13-Aug	23.25	2.60	23.16	2.50	52	1	1,435	1	1,533	0.009	14.958	0.001	0.999
14-Aug	22.66	2.70	23.58	2.50	58	0	1,435	0	1,533	0.000	14.958	0.000	0.999
15-Aug	22.50	2.80	23.50	2.40	51	1	1,436	1	1,534	0.009	14.966	0.001	0.999
16-Aug	22.83	2.50	23.25	2.40	46	0	1,436	0	1,534	0.000	14.966	0.000	0.999
17-Aug	23.00	2.50	23.25	2.20	47	0	1,436	0	1,534	0.000	14.966	0.000	0.999
18-Aug	23.08	2.40	23.33	2.20	41	0	1,436	0	1,534	0.000	14.966	0.000	0.999
19-Aug	21.58	2.50	23.08	2.40	43	0	1,436	0	1,534	0.000	14.966	0.000	0.999
20-Aug	22.67	2.70	22.83	2.40	44	0	1,436	0	1,534	0.000	14.966	0.000	0.999
21-Aug	22.67	2.40	22.66	2.50	44	0	1,436	0	1,534	0.000	14.966	0.000	0.999
22-Aug	22.42	2.60	22.92	2.70	50	0	1,436	0	1,534	0.000	14.966	0.000	0.999
23-Aug	22.25	2.70	22.58	2.60	48	0	1,436	0	1,534	0.000	14.966	0.000	0.999
24-Aug	22.75	2.80	22.75	2.70	47	0	1,436	0	1,534	0.000	14.966	0.000	0.999
25-Aug	22.75	2.70	22.33	2.60	47	0	1,436	1	1,535	0.009	14.975	0.001	1.000
Total	2,224		2,321			1,436		1,535		14.975		1.000	
Avg.	21.38	2.5	22.10	2.5	59	12		13		0.135		0.009	

Appendix A2.–Age composition of chinook salmon sampled at Nakina River carcass weir by sex and age, 1956–1995. Estimates are summed across size groups from samples within size groups, 25-mm increments for 1956–1992 and 100-mm increments for 1993–1995.

PANEL A: NUMBERS OF FISH

	Male						Female				Combined					
Year	1.1	1.2	1.3	1.4	1.5	Total	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1956	958	1,118	242	35	0	2,353	270	154	0	424	958	1,118	512	189	0	2,777
1957	789	1,245	270	39	0	2,343	244	159	0	403	789	1,245	514	198	0	2,746
1958	1,716	2,106	513	88	0	4,423	413	231	0	644	1,716	2,106	926	319	0	5,067
1959	950	1,090	615	224	0	2,879	665	526	0	1,191	950	1,090	1,280	750	0	4,070
1973	446	772	283	203	7	1,711	167	447	0	614	446	772	450	650	7	2,325
1974	845	636	260	99	3	1,843	163	257	0	420	845	636	423	356	3	2,263
1975	297	445	94	50	1	887	14	55	0	69	297	445	108	105	1	956
1976	85	419	226	77	4	811	151	234	0	385	85	419	377	311	4	1,196
1977	1,269	306	327	330	7	2,239	182	950	11	1,143	1,269	306	509	1,280	18	3,382
1978	2,192	930	140	74	8	3,344	41	159	7	207	2,192	930	181	233	15	3,551
1979	675	1,352	375	59	2	2,463	185	82	4	271	675	1,352	560	141	6	2,734
1980	486	542	388	172	0	1,588	258	396	0	654	486	542	646	568	0	2,242
1981	178	401	365	322	0	1,266	198	862	6	1,066	178	401	563	1,184	6	2,332
1982	856	248	263	274	8	1,649	90	537	15	642	856	248	353	811	23	2,291
1983	752	1,134	126	163	2	2,177	50	225	1	276	752	1,134	176	388	3	2,453
1984	226	438	357	31	0	1,052	133	89	5	227	226	438	490	120	5	1,279
1985	670	359	491	182	0	1,702	320	575	2	897	670	359	811	757	2	2,599
1986	305	836	230	195	2	1,568	87	339	6	432	305	836	317	534	8	2,000
1987	1,720	866	752	324	8	3,670	198	437	17	652	1,720	866	950	761	25	4,322
1988	467	1,798	347	568	16	3,196	88	1,009	22	1,119	467	1,798	435	1,577	38	4,315
1989	321	768	1,833	282	18	3,222	816	648	81	1,545	321	768	2,649	930	99	4,767
1990	757	393	408	499	8	2,065	151	1,057	22	1,230	757	393	559	1,556	30	3,295
1991	334	842	311	95	0	1,582	85	309	24	418	334	842	396	404	24	2,000
1992	98	1,086	1,138	402	12	2,736	157	728	14	899	98	1,086	1,295	1,130	26	3,635
1993	68	582	1,152	730	19	2,551	323	1,382	34	1,739	68	582	1,475	2,112	53	4,290
1994	355	179	418	319	15	1,286	358	579	22	959	355	179	776	898	37	2,245
1995	115	1,224	182	174	13	1,708	64	227	12	303	115	1,224	246	401	25	2,011
Avg	664	819	448	223	6	2,160	217	469	11	697	664	819	666	691	17	2,857

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Appendix A2.–(Page 2 of 2).

	PANEL B: PERCENTAGES																
	Male						Female				Combined						
Year	1.1	1.2	1.3	1.4	1.5	Total	1.3	1.4	1.5	Total	1.1	1.2	1.3	1.4	1.5	Total
1956	41%	48%	10%	1%	0%	100%	64%	36%	0%	100%	34%	40%	18%	7%	0%	100%
1957	34%	53%	12%	2%	0%	100%	61%	39%	0%	100%	29%	45%	19%	7%	0%	100%
1958	39%	48%	12%	2%	0%	100%	64%	36%	0%	100%	34%	42%	18%	6%	0%	100%
1959	33%	38%	21%	8%	0%	100%	56%	44%	0%	100%	23%	27%	31%	18%	0%	100%
1973	26%	45%	17%	12%	0%	100%	27%	73%	0%	100%	19%	33%	19%	28%	0%	100%
1974	46%	35%	14%	5%	0%	100%	39%	61%	0%	100%	37%	28%	19%	16%	0%	100%
1975	33%	50%	11%	6%	0%	100%	20%	80%	0%	100%	31%	47%	11%	11%	0%	100%
1976	10%	52%	28%	9%	0%	100%	39%	61%	0%	100%	7%	35%	32%	26%	0%	100%
1977	57%	14%	15%	15%	0%	100%	16%	83%	1%	100%	38%	9%	15%	38%	1%	100%
1978	66%	28%	4%	2%	0%	100%	20%	77%	3%	100%	62%	26%	5%	7%	0%	100%
1979	27%	55%	15%	2%	0%	100%	68%	30%	1%	100%	25%	49%	20%	5%	0%	100%
1980	31%	34%	24%	11%	0%	100%	39%	61%	0%	100%	22%	24%	29%	25%	0%	100%
1981	14%	32%	29%	25%	0%	100%	19%	81%	1%	100%	8%	17%	24%	51%	0%	100%
1982	52%	15%	16%	17%	0%	100%	14%	84%	2%	100%	37%	11%	15%	35%	1%	100%
1983	35%	52%	6%	7%	0%	100%	18%	82%	0%	100%	31%	46%	7%	16%	0%	100%
1984	21%	42%	34%	3%	0%	100%	59%	39%	2%	100%	18%	34%	38%	9%	0%	100%
1985	39%	21%	29%	11%	0%	100%	36%	64%	0%	100%	26%	14%	31%	29%	0%	100%
1986	19%	53%	15%	12%	0%	100%	20%	78%	1%	100%	15%	42%	16%	27%	1%	100%
1987	47%	24%	20%	9%	0%	100%	30%	67%	3%	100%	40%	20%	22%	18%	1%	100%
1988	15%	56%	11%	18%	1%	100%	8%	90%	2%	100%	11%	42%	10%	37%	1%	100%
1989	10%	24%	57%	9%	1%	100%	53%	42%	5%	100%	7%	16%	56%	20%	3%	101%
1990	37%	19%	20%	24%	0%	100%	12%	86%	2%	100%	23%	12%	17%	47%	1%	101%
1991	21%	53%	20%	6%	0%	100%	20%	74%	6%	100%	17%	42%	20%	20%	2%	100%
1992	4%	40%	42%	15%	0%	100%	17%	81%	2%	100%	3%	30%	36%	31%	1%	100%
1993	3%	23%	45%	29%	1%	100%	19%	79%	2%	100%	2%	14%	34%	49%	2%	101%
1994	28%	14%	33%	25%	1%	100%	37%	60%	2%	100%	16%	8%	35%	40%	3%	101%
1995	7%	72%	11%	10%	1%	100%	21%	75%	4%	100%	6%	61%	12%	20%	1%	100%
Avg	29%	38%	21%	11%	0%	100%	33%	65%	1%	100%	23%	30%	23%	24%	1%	100%

Appendix A3.–Age composition of chinook salmon at Nahlin live weir, 1993–1995.

PANEL A: 1993

		1.1	1.2	2.1	1.3	2.2	1.4	2.3	1.5	2.4	Total	Sex
Females	n	0	3	0	37	0	78	0	3	1	122	
	%	0.0%	2.5%	0.0%	30.3%	0.0%	63.9%	0.0%	2.5%	0.8%	100.0%	43.5%
	SE %	0.0%	1.3%	0.0%	4.0%	0.0%	4.1%	0.0%	1.3%	0.8%	0.0%	2.9%
	Esc	0	30	0	372	0	784	0	30	10	1227	
Males	n	0	45	0	45	0	55	0	4	0	149	
	%	0.0%	30.2%	0.0%	30.2%	0.0%	36.9%	0.0%	2.7%	0.0%	100.0%	56.5%
	SE %	0.0%	3.6%	0.0%	3.6%	0.0%	3.8%	0.0%	1.3%	0.0%	0.0%	2.9%
	Esc	0	481	0	481	0	587	0	43	0	1591	
All fish	n	0	48	0	82	0	133	0	7	1	271	
	%	0.0%	18.1%	0.0%	30.3%	0.0%	48.7%	0.0%	2.6%	0.4%	100.0%	
	SE %	0.0%	2.1%	0.0%	2.7%	0.0%	2.8%	0.0%	0.9%	0.3%	0.0%	
	Esc	0	511	0	853	0	1372	0	73	10	2818	

PANEL B: 1994

		1.1	1.2	2.1	1.3	2.2	1.4	2.3	1.5	2.4	Total	Sex
Females	n	0	0	0	99	0	141	3	1	0	244	
	%	0.0%	0.0%	0.0%	40.6%	0.0%	57.8%	1.2%	0.4%	0.0%	100.0%	52.5%
	SE %	0.0%	0.0%	0.0%	2.8%	0.0%	2.9%	0.6%	0.4%	0.0%	0.0%	2.4%
	Esc	0	0	0	542	0	772	16	5	0	1336	
Males	n	6	12	1	124	0	79	2	3	0	227	
	%	2.6%	5.3%	0.4%	54.6%	0.0%	34.8%	0.9%	1.3%	0.0%	100.0%	47.5%
	SE %	1.0%	1.3%	0.4%	3.0%	0.0%	2.9%	0.6%	0.7%	0.0%	0.0%	2.4%
	Esc	32	64	5	659	0	420	11	16	0	1207	
All fish	n	6	12	1	223	0	220	5	4	0	471	
	%	1.3%	2.5%	0.2%	47.2%	0.0%	46.9%	1.1%	0.8%	0.0%	100.0%	
	SE %	0.5%	0.6%	0.2%	2.1%	0.0%	2.0%	0.4%	0.4%	0.0%	0.0%	
	Esc	32	64	5	1201	0	1192	27	21	0	2543	

PANEL C: 1995

		1.1	1.2	2.1	1.3	2.2	1.4	2.3	1.5	2.4	Total	Sex
Females	n	0	5	0	66	0	88	0	0	0	159	
	%	0.0%	3.1%	0.0%	41.5%	0.0%	55.3%	0.0%	0.0%	0.0%	100.0%	25.7%
	SE %	0.0%	1.3%	0.0%	3.5%	0.0%	3.6%	0.0%	0.0%	0.0%	0.0%	2.4%
	Esc	0	28	0	364	0	485	0	0	0	876	
Males	n	2	147	0	56	13	29	0	1	1	249	
	%	0.8%	59.0%	0.0%	22.5%	5.2%	11.7%	0.0%	0.4%	0.4%	100.0%	74.3%
	SE %	0.6%	2.5%	0.0%	2.5%	1.3%	1.4%	0.0%	0.4%	0.4%	0.0%	2.4%
	Esc	20	1496	0	570	132	296	0	10	10	2534	
All fish	n	2	152	0	122	13	117	0	1	1	408	
	%	0.6%	44.7%	0.0%	27.4%	3.9%	22.9%	0.0%	0.3%	0.3%	100.0%	
	SE %	0.4%	1.9%	0.0%	2.1%	1.0%	1.4%	0.0%	0.3%	0.3%	0.0%	
	Esc	20	1524	0	934	132	781	0	10	10	3410	3410

Note: Males were stratified by jacks and large.

Appendix A4.–Computer files used to estimate the spawning abundance of chinook salmon in the Taku River in 1995.

File Name	Description
TAKUKI95.xls	Spreadsheet of data and background for Tables 1,2, 4, 5 and 6; chi-square and KS tests, bootstrap setup and results and Appendix A1 (fish wheel catch and effort, etc.).
41CI95EJ.xls	Spreadsheet of chinook salmon caught and tagged at Canyon Island: tagging data; recovery data; age, sex and length data.
KOWTAT.xls	Spreadsheet of chinook salmon sampled on the Tatsatua (Tatsamenie) and Kowatua Rivers: fish inspected; tag recoveries; age, sex and length data; CWT recovery data
NAHC95.xls	Spreadsheet of chinook salmon sampled at the Nahlin River live weir: fish inspected; tag recoveries; age, sex and length data; CWT recovery data
NAKC95EJ.xls	Spreadsheet of chinook salmon sampled at the Nakina River carcass weir: fish inspected; tag recoveries; age, sex and length data; CWT recovery data.
TAKUKI95.doc	WORD 6.0 (Windows) file of this FDS report.