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Spawning Abundance of Chinook Salmon in the Taku River in 1998

by

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and

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October 1999

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 mark-recapture study involving the Alaska Department of Fish and Game, the Taku River Tlingit First Nation, and the Department of Fisheries and Oceans Canada was conducted to estimate the number of spawning chinook salmon *Oncorhynchus tshawytscha* in the Taku River in 1998. Fish were captured at Canyon Island on the lower Taku River with fish wheels from May through August. The fish were individually marked with back-sewn, solid-core 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. Spawning abundance of small and medium-size chinook salmon (270–659 mm in length from mid eye to tail fork) was estimated to be 11,775 (SE = 3,237), estimated from the mark-recapture experiment. Estimated spawning abundance of large-size fish (≥660 mm) was 31,039 (SE = 12,720); this estimate was derived by expanding aerial survey counts because of low tagging and recovery rates for large chinook salmon. The estimated total spawning population of chinook salmon was 42,814 (SE = 13,125). The 1992 brood year (primarily age 1.4) constituted 49% of the estimated spawning population.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, Taku River, spawning abundance, mark-recapture; age, sex and length composition, aerial survey expansion.

INTRODUCTION

The Taku River, which originates in northwestern British Columbia, produces the largest population of chinook salmon *Oncorhynchus tshawytscha* in Southeast Alaska (Pahlke and Bernard 1996; McPherson et al. 1998; Pahlke 1998). Prior to the mid 1970s, these fish were exploited in directed commercial and recreational fisheries, with annual commercial harvests estimated to have reached approximately 15,000 or more 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 commercial and aboriginal gillnet fishery in Canada (Figure 1). Chinook salmon from the Taku River are also caught in directed recreational fisheries in Alaska and in northwestern British Columbia and constitute a large portion of the chinook harvest during spring near Juneau (McPherson et al. *In press*). Exploitation of this population is jointly managed by the U.S. and Canada through the Transboundary Technical Committee 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 six clearwater tributaries from helicopters (Pahlke 1998). Only large chinook salmon (typically 3-ocean age [age-.3] and older or larger than approximately 660 mm mid eye to tail fork [MEF]) 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). Expansion factors were established in 1981 and were revised in 1991, which were based on professional opinions of the ability to see fish during surveys and the distribution of spawners in the watershed from radiotelemetry. Expansion factors were revised in 1999 utilizing five estimates of total escapement (1989, 1990 and 1995–1997; Pahlke and Bernard 1996; McPherson et al. 1996, 1997, 1998) coupled with concurrent survey counts (McPherson et al. *In press*).

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). Information from tagging and radiotelemetry studies in 1989 and 1990 by the Commercial Fisheries Division (CFD), the Department of Fisheries and Oceans Canada (DFO), and the U.S. National Marine Fisheries Service (NMFS) was used to estimate the abundance of large chinook salmon in the Taku River: 40,329 (SE = 5,646) in 1989 and 52,142 (SE = 9,326) in 1990 (Pahlke and Bernard 1996; Eiler et al. *In prep.*). Chinook salmon were captured in fish wheels, tagged, inspected for marks, and released at Canyon Island, a location well below the spawning grounds in upriver tributaries where recoveries were made.

Chinook salmon from the Taku River are a "spring run" of salmon, in that returning adults 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, smolt at age 1 (Kissner and Hubartt 1986), then rear offshore out of reach of fisheries in Southeast Alaska and British Columbia. When they reach maturity and migrate to their spawning grounds, these salmon have spent 1–5 years at sea, the ones maturing at a younger age (age-.1 and -.2) being mostly males, age-.3 being of both sexes, and age-.4 being 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 1998 and to estimate the age, sex and length composition of these fish.

METHODS

STUDY AREA

The Taku River originates in the Stikine Plateau of northwestern British Columbia, Canada (Figure 1), and flows nearly 300 km downstream, emptying into the 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 approximately 55 km upstream from 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 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, Tatsatua (Tatsamenie), 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 through a deep channel with bedrock on both banks, making it an ideal location for fish wheel operation. Fish wheels were operated continuously from 3 May through September except during extreme high or low water levels and during maintenance or sampling and tagging.

Fish wheel configurations and fish wheel operations are discussed in detail in Kelley and Milligan (1997, 1999). In brief, each fish wheel consisted of a framework with two aluminum pontoons and aluminum collection baskets (two, three, or four) mounted on an axle, which turned from water force acting on the baskets and polycarbonate paddles. Fish were scooped up by the baskets and guided by V-shaped slides into aluminum live boxes bolted to the outer edge of each pontoon.

Individual fish were dipnetted from live boxes, elevated, and transferred to a trough partially filled with river water where they were sampled and tagged. Fish were handled with bare hands to prevent injury. While one person held the fish, another took samples and measurements, and a third recorded data. Length was measured to the

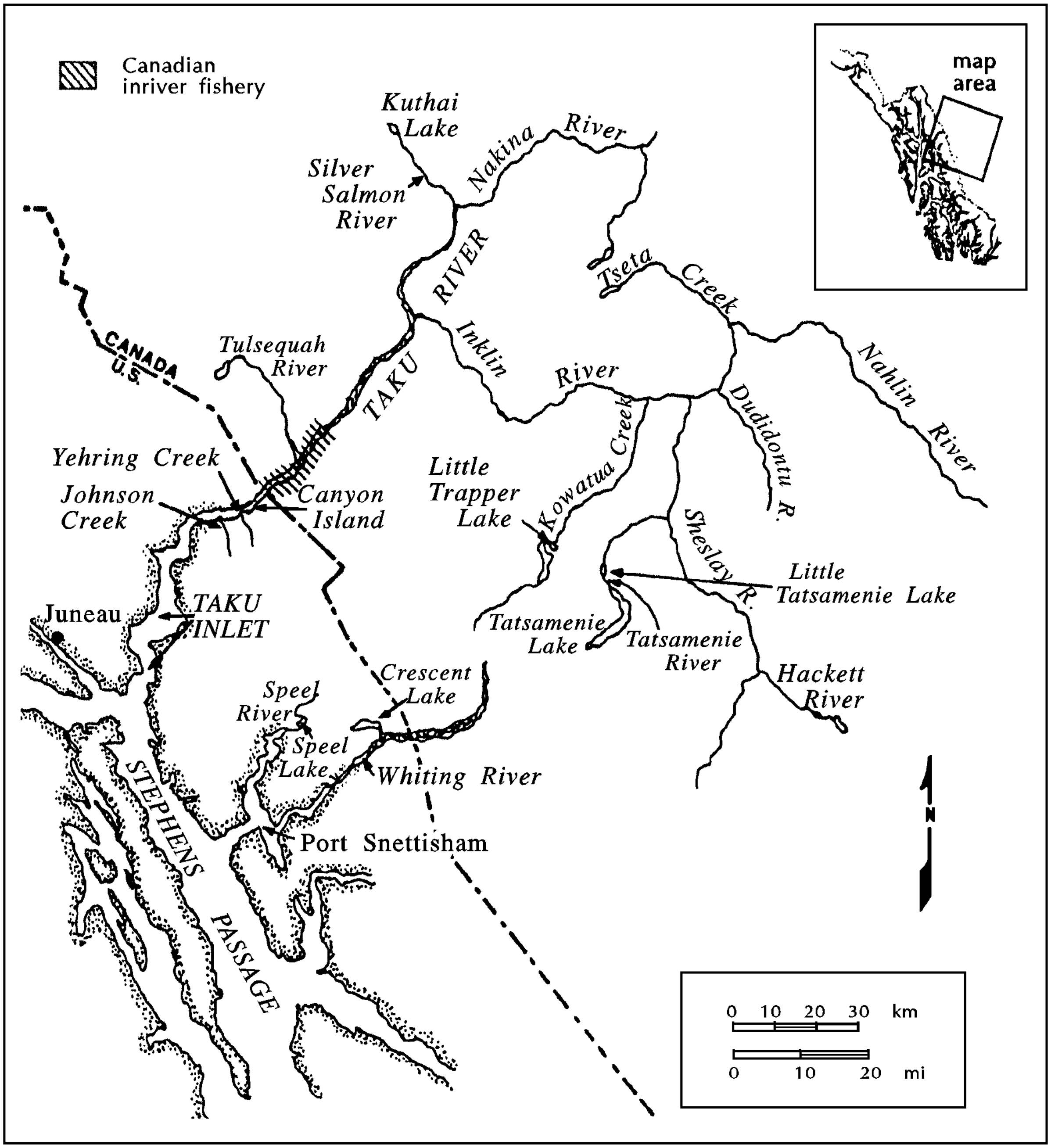

Figure 1.–Taku Inlet and Taku River drainage.

nearest mm MEF, and gender determined from inspection of external characteristics of each fish. Four scales from every fourth fish handled were 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 (Welander 1940).

Scales were mounted onto gummed cards which held scales from 10 fish. The 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. We tagged each subject with a "solid-core" spaghetti tag, which consisted of a 2 1/4″ (5.72 cm) section of laminated plastic tubing shrunk onto a 15″ (38.1 cm) piece of 80-lb-test (36.4 kg) monofilament fishing line—an improved design over that used by Johnson on the Chilkat River in 1991 (Johnson et al. 1992). The monofilament was back-sewn at the posterior end of the dorsal fin, so as to catch the last fin rays, and secured by crimping both ends of the monofilament in a line crimp. Excess monofilament was trimmed. Each tag was individually numbered and stamped with a contact phone number.

Besides the individually numbered tag (the primary mark), each fish was also batch marked by a 5/16″ (4.8 mm) 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 Nakina, Kowatua and Tatsatua (Tatsamenie) rivers in 1998; these rivers represent mid-season and late-season migrants (ADF 1951; Eiler et al. *In prep*; Pahlke and Bernard 1996). Fish on the Nahlin River, which represent the early component of the run, were not sampled 1998. A carcass weir was used to inspect fish on the Nakina River from 4 to 26 August. Spawned-out fish and live fish were sampled from 1 to 18 September on the upper Tatsamenie River (Tatsatua system). Carcasses and spent live fish were sampled from 27 August to 8 September on the lower Tatsamenie and Kowatua rivers using partial carcass weirs and sampling of spent fish. All sampled fish were marked with a lower opercle punch 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 5 mm MEF. 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

Abundances of "small" (270–400 mm MEF) and "medium" (401–659 mm MEF) chinook salmon on the spawning grounds were estimated with Chapman's modified Petersen mark-recapture estimator (Seber 1982, p. 60). Estimated abundance ($\hat{N}_i$) of small and medium fish on the spawning grounds was calculated as

$$\hat{N}_i = \frac{\left(\hat{M}_i + 1\right)\left(C_i + 1\right)}{\left(R_i + 1\right)} - 1 \qquad (1)$$

where $\hat{M}_i$ is the estimated number of marked fish that survived to spawn of size *i*, C_i is the number of fish of size *i* inspected for marks on spawning grounds, and R_i is the number of these inspected fish with marks.

The estimated number of marked fish on the spawning grounds was $\hat{M}_i = T_i - \hat{H}_i$, where T_i is the number of tagged fish released at Canyon Island and $\hat{H}_i$ is the estimated number of tagged fish removed by fishing (censored from the experiment). The proportions of recaptured marked fish in tributary samples (R_i / C_i) were compared across tributaries to determine if the estimator or tagging event was consistent (Seber 1982, p. 439). Length distributions of small and medium fish tagged and released at Canyon Island were also compared with the length distributions of small and medium fish recaptured in all tributaries to detect size-selective sampling on the spawning grounds.

Estimated numbers of tagged small and medium fish censored from the experiment ($\hat{H}_i$) were tallies of returned tags and expanded samples from fisheries downstream and upstream of Canyon Island. No tagged chinook salmon of these two size classes were recovered through sampling by CFD of catches from the Alaska gillnet fisheries directed at sockeye salmon *O. nerka* in Taku Inlet/Stephens Passage. Likewise, no tags were recovered from a creel survey of the U.S. recreational fishery near Juneau. Sampling rates were 18% for the gillnet fishery and 19% for the recreational fishery.

One tag was voluntarily returned from the Alaskan inriver personal-use fishery in the lower river, and three tags were voluntarily returned from the recreational fishery in Canada. Because of a reward (US$2) for each tag returned from the inriver Canadian gillnet fishery, tags recovered from 38 small and medium fish probably represented all marked fish caught in this fishery.

Variance, bias, and confidence intervals for $\hat{N}_i$ were estimated with modifications of bootstrap procedures in Buckland and Garthwaite (1991). Small and medium chinook salmon passing by Canyon Island were divided into seven capture histories (Table 1). The estimated number of fish past Canyon Island $\hat{N}_i^+$ was greater than the estimate of abundance on the spawning grounds $\hat{N}_i$ by the number of fish harvested in fisheries.

A bootstrap sample was built by drawing with replacement a sample of size $\hat{N}_i^+$ from the empirical distribution defined by the capture histories. A new set of statistics from each bootstrap sample { $\hat{M}_i^*, C_i^*, R_i^*, \hat{H}_i^*, T_i^*$ } was generated, along with a new estimate $\hat{N}_i^*$ for abundance on the spawning grounds, and 1,000 such bootstrap samples were drawn, creating the empirical distribution $\hat{F}(\hat{N}_i^*)$, which is an estimate of F($\hat{N}_i$). The difference between the average $\overline{\hat{N}}_i^*$ of bootstrap estimates and $\hat{N}_i$ is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Confidence intervals were estimated from $\hat{F}(\hat{N}_i^*)$ with the percentile method (Efron and Tibshirani 1993, Section 13.3).

Variance was estimated as

$$v(\hat{N}_i^*) = (B-1)^{-1}\sum_{b=1}^{B}(\hat{N}_{i(b)}^* - \overline{\hat{N}}_i^*)^2 \qquad (2)$$

where B is the number of bootstrap samples.

Table 1.–Capture histories for small/medium and large chinook salmon in the population spawning in the Taku River in 1998. Notation is explained in text.

Capture history	Small and medium	Large	Source of statistics
Marked, but censored in recreational fisheries	4	1	Returned
Marked, but censored in the U.S. marine commercial fishery	0	1	Returned
Marked, but censored in the Canadian inriver commercial fishery	38	24	Returned
Marked and not sampled in tributaries	452	309	$\hat{M}_i - R_i$
Marked and recaptured in tributaries	17	2	R_i
Not marked, but captured in tributaries	433	721	$C_i - R_i$
Not marked and not sampled in tributaries	10,873	NA	$\hat{N}_i - \hat{M}_i - C_i + R_i$
Effective population for simulations	11,817	NA	$\hat{N}_i^+$

Abundance of spawning chinook salmon of both small and medium chinook was estimated by combining statistics for both size groups. Confidence intervals for $\hat{N}$ and $v(\hat{N})$ were estimated as described above.

Because almost no large fish were recaptured on the spawning grounds, we did not estimate their abundance directly from the mark-recapture experiment. Rather, we estimated the abundance of large chinook by expanding aerial survey counts using the methodology in McPherson et al. (*In press*). These methods are detailed in Appendix A.

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age within small/medium-sized or large fish was estimated as a binomial variable from fish sampled at the Nakina, Kowatua and Tatsamenie rivers:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \quad (3)$$

where $\hat{p}_{ij}$ is the estimated proportion of the population of age j in size group i, n_{ij} is the number of chinook salmon of age j of size group i, and n_i is the number of chinook salmon in the sample n of size group i taken on the spawning grounds. 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 Nakina, Kowatua and Tatsamenie rivers were pooled, because investigations showed sampling on the spawning grounds had not been size-selective within a size group (Pahlke and Bernard 1996, McPherson et al. 1996, 1997, 1998). Sample variance was calculated as:

$$v(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_i - 1} \quad (4)$$

Numbers of spawning fish by age were estimated as the summation of products of estimated age composition and estimated abundance within a size category:

$$\hat{N}_j = \sum_i \left(\hat{p}_{ij}\hat{N}_i\right) \quad (5)$$

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

$$v(\hat{N}_j) = \sum_i \begin{pmatrix} v(\hat{p}_{ij})\hat{N}_i^2 + v(\hat{N}_i)\hat{p}_{ij}^2 \\ - v(\hat{p}_{ij})v(\hat{N}_i) \end{pmatrix} \quad (6)$$

The proportion of the spawning population >270 mm MEF composed of a given age was estimated as the summed totals across size categories:

$$\hat{p}_j = \frac{\hat{N}_j}{\hat{N}} \quad (7)$$

with a variance approximated according to procedures in Seber (1982, p. 8-9):

$$v(\hat{p}_j) = \frac{\sum_i \left(v(\hat{p}_{ij})\hat{N}_i^2 + v(\hat{N}_i)(\hat{p}_{ij} - \hat{p}_j)^2 \right)}{\hat{N}^2} \quad (8)$$

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 Nakina, Kowatua and Tatsamenie 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 889 chinook salmon caught at Canyon Island (Appendix B1), 848 were tagged and released (Table 2). Ninety-five percent (95%) of catches occurred between 6 May and 2 July. Of the fish tagged, 202 were small (≤400 mm MEF), 309 were medium-sized (401–659 mm MEF) and 337 were large (≥660 mm MEF). All fisheries, recreational and commercial, removed an estimated 68 tagged fish (8% of all tagged) of all sizes (Table 2). Of the 511 small and medium-sized chinook salmon tagged, 42 (8%) were removed by fisheries.

Table 2.–Numbers of chinook salmon marked at Canyon Island, removed by fisheries and inspected for marks in tributaries in 1998 by size group.

	0–400 mm MEF	401–659 mm MEF	≥660 mm MEF	Total
A. Released at Canyon Island with marks	202	309	337	848
B. Removed by:				
1. Sport fisheries [a]	3	1	1	5
2. U.S. gillnet [b]	0	0	1	1
3. Canadian gillnet	3	35	24	62
Total removals	6	36	26	68
C. Estimated $\hat{M}$	196	273	311	780
D. Inspected at:				
1. Nakina River				
Inspected	112	226	318	656
Recaptured	5	7	0	12
Recaptured/captured	0.045	0.031		
2. Nahlin River				
Inspected				
Recaptured				
Recaptured/captured				
3. Kowatua/Tatsatua (Tatsamenie)				
Inspected	17	95	405	517
Recaptured	1	4	2	7
Recaptured/captured	0.059	0.042	0.005	
Total inspected				
Inspected	129	321	723	1,173
Recaptured	6	11	2	19
Recaptured/captured	0.047	0.034	0.003	

[a] Includes 1 fish from U.S. personal-use fishery and 4 fish (3 small; 1 large) from Canadian sport fishery.

[b] Includes 1 large chinook salmon voluntarily returned from the U.S. gillnet fishery District 111 (Taku Inlet/Stephens Passage).

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). However, water levels and flows remained well below average, but relatively stable throughout the project in 1998, except in late May and early June (Appendix B1). Sampling on the spawning grounds was not size selective within the small/medium size group. Cumulative density functions for censored, marked fish >270 mm MEF were essentially the same as the corresponding function for fish recaptured on the spawning grounds (P = 0.63; Figure 2).

Estimated abundance of small and medium chinook salmon $\hat{N}_{ms}$ on the spawning grounds in 1998 was 11,775 (SE = 3,237), based on 450 (129 small and 321 medium) fish inspected for marks ($=C_{ms}$) in tributaries, 17 of which were recaptured fish ($=R_{ms}$) (Tables 2 and 3). Five (29%) of the 17 recovered small/medium fish had lost the primary tag, but were detected as marked fish from the upper opercle punch (UOP) and/or a missing left axillary appendage (LAA). All of these fish with shed tags were inspected at the Taku River Tlingit Nakina carcass weir. Fisheries censored an estimated 42 (8%) tagged fish ($=\hat{H}_{ms}$), making the estimated number of medium-sized tagged fish that survived to spawn 469 ($=\hat{M}_{ms}$). Similarities in the proportions marked among fish inspected in different tributaries (Nakina River: 0.036; Tatsamenie/Kowatua rivers: 0.045) indicate that the Petersen estimator

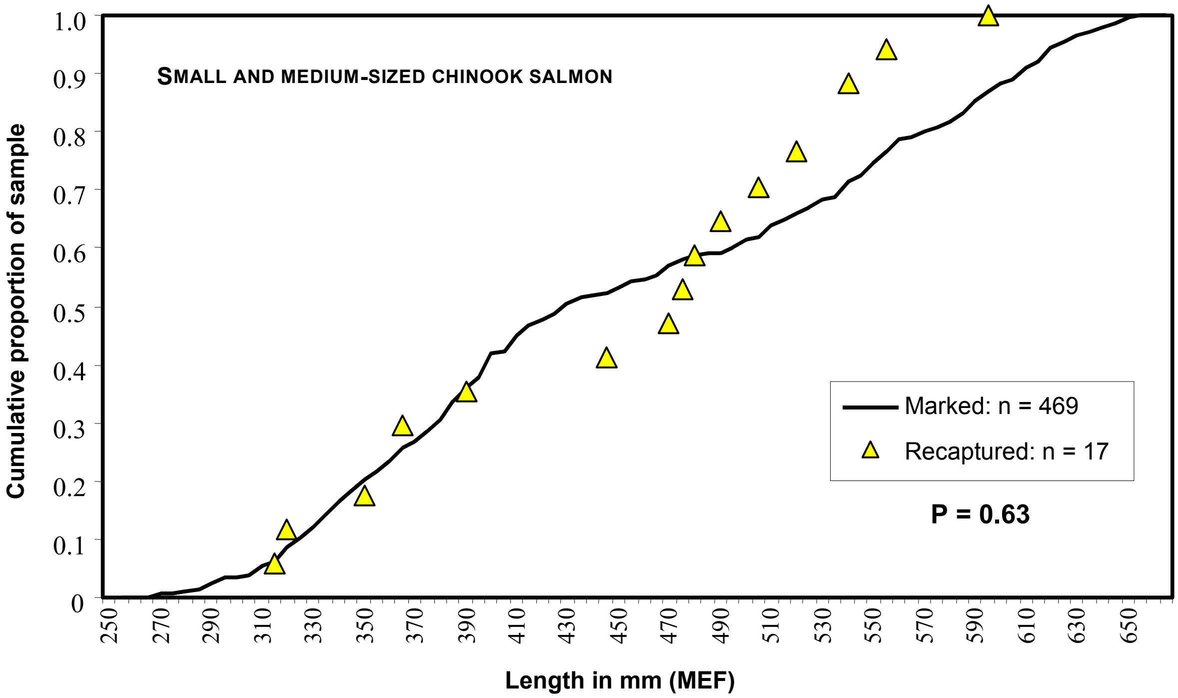

Figure 2.–Cumulative relative frequencies of small and medium-sized chinook salmon (combined) marked at Canyon Island in 1998 versus those subsequently recaptured in sampling at tributaries.

based on data pooled across tributaries is a consistent estimator for the mark-recapture experiment ($\chi^2 = 0.19$, df = 1, P = 0.66). Estimated abundance of small and medium-sized fish has a 95% confidence interval of 8,123 to 20,322, and an estimated relative bias of 5.3%.

Estimated abundance of large chinook salmon $\hat{N}_{ls}$ on the spawning grounds in 1998 was 31,039 (SE = 12,720), based on 5,969 fish counted in peak aerial surveys on five tributaries (Nakina, Nahlin, Kowatua, Tatsamenie and Dudidontu rivers) and an expansion factor of 5.20 (Appendix A; Table 3). The estimated abundance of all chinook salmon >270 mm MEF ($\hat{N} = \hat{N}_{ms} + \hat{N}_{ls}$) on the spawning grounds for 1998 was 42,814 (SE = 13,125).

ESTIMATES OF AGE AND SEX COMPOSITION

Age-1.4 chinook salmon dominated the age and sex compositions of chinook salmon >270 mm MEF on the spawning grounds of the Taku River in 1998. Age-1.4 fish constituted 49% (SE = 6.7%) of the estimated escapement (Table 3), age-1.3 fish constituted 20% (SE = 2.7%), and age-1.2 fish constituted 19% (SE = 5.7%); 60% (SE = 5.5%) were males. Age-1.2 fish constituted 60% of small/medium fish, and males accounted for 99% of all small/medium fish. Age-1.4 fish accounted for 67% of all large fish and females constituted 55% of large fish. An estimated 17,240 (SE = 7,038) females spawned in 1998.

Of the large fish sampled at Canyon Island, 59% were age-1.4 fish and 31% were age-1.3 fish (Appendix B2); among small/medium fish sampled, 50% were age-1.1 and 43% were age-1.2

Table 3.–Estimated abundance and composition by age and sex of the spawning population in the Taku River in 1998 for small, medium and large chinook salmon.

		Brood year and age class									
		1995	1994	1994	1993	1993	1992	1992	1991	1991	
		1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5	Total
PANEL A: AGE AND SEX COMPOSITION OF SMALL AND MEDIUM CHINOOK SALMON											
Males	n	136	4	235	1	12		1			**389**
	%	34.6	1.0	59.8	0.3	3.1		0.3			**99.0**
	SE of %	2.4	0.5	2.5	0.3	0.9		0.3			**0.5**
	Escapement	4,075	120	7,041	30	360		30			**11,655**
	SE of esc.	1,153	66	1,956	30	139		30			**3,205**
Females	n			2	1	1					**4**
	%			0.5	0.3	0.3					**1.0**
	SE of %			0.4	0.3	0.3					**0.5**
	Escapement			60	30	30					**120**
	SE of esc.			44	30	30					**66**
Sexes combined	n	136	4	237	2	13		1			**393**
	%	34.6	1.0	60.3	0.5	3.3		0.3			**100.0**
	SE of %	2.4	0.5	2.5	0.4	0.9		0.3			**0.0**
	Escapement	4,075	120	7,101	60	390		30			**11,775**
	SE of esc.	1,153	66	1,972	44	148		30			**3,237**
PANEL B: AGE AND SEX COMPOSITION OF LARGE CHINOOK SALMON											
Males	n			15		101	4	162	1	4	**287**
	%			2.3		15.8	0.6	25.3	0.2	0.6	**44.8**
	SE of %			0.6		1.4	0.3	1.7	0.2	0.3	**2.0**
	Escapement			727		4,898	194	7,857	48	194	**13,919**
	SE of esc.			343		2,048	119	3,256	48	119	**5,731**
Females	n			3		71	1	267	4	7	**353**
	%			0.5		11.1	0.2	41.7	0.6	1.1	**55.2**
	SE of %			0.3		1.2	0.2	2.0	0.3	0.4	**2.0**
	Escapement			145		3,443	48	12,949	194	339	**17,120**
	SE of esc.			97		1,454	48	5,335	119	181	**7,038**
Sexes combined	n			18		172	5	429	5	11	**640**
	%			2.8		26.9	0.8	67.0	0.8	1.7	**100.0**
	SE of %			0.7		1.8	0.3	1.9	0.3	0.5	**0.0**
	Escapement			873		8,342	242	20,806	242	533	**31,039**
	SE of esc.			403		3,454	140	8,543	140	263	**12,720**
PANEL C: AGE AND SEX COMPOSITION OF ALL SPAWNING CHINOOK SALMON											
Males	n	136	4	250	1	113	4	163	1	4	**676**
	%	9.5	0.3	18.1	0.1	12.3	0.5	18.4	0.1	0.5	**59.7**
	SE of %	3.5	0.2	5.7	0.1	1.6	0.2	2.8	0.1	0.2	**5.5**
	Escapement	4,075	120	7,769	30	5,258	194	7,887	48	194	**25,574**
	SE of esc.	1,153	66	1,986	30	2,053	119	3,257	48	119	**6,566**
Females	n			5	1	72	1	267	4	7	**357**
	%			0.5	0.1	8.1	0.1	30.2	0.5	0.8	**40.3**
	SE of %			0.2	0.1	1.4	0.1	4.3	0.2	0.3	**5.5**
	Escapement			205	30	3,473	48	12,949	194	339	**17,240**
	SE of esc.			106	30	1,455	48	5,335	119	181	**7,038**
Sexes combined	n	136	4	255	2	185	5	430	5	11	**1,033**
	%	9.5	0.3	18.6	0.1	20.4	0.6	48.7	0.6	1.2	**100.0**
	SE of %	3.5	0.2	5.7	0.1	2.7	0.3	6.7	0.3	0.4	**0.0**
	Escapement	4,075	120	7,974	60	8,731	242	20,836	242	533	**42,814**
	SE of esc.	1,153	66	2,013	44	3,458	140	8,543	140	263	**13,125**

fish. These percentages show that within size groups, the age proportions from samples taken at Canyon Island are similar to those from the combined tributary samples. Average length by age of all fish sampled for length and successfully aged on the spawning grounds are listed in Table 4.

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). 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*; Bernard et al. *In press*). 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. In 1999, we observed minimal recovery of tagged chinook that "backed down." One tag was voluntarily returned from the U.S. personal use fishery in the Taku River. One tag was voluntarily returned from the Juneau recreational fishery; no tags were observed in sampling 19% of the chinook harvested in this fishery (Hubartt et al. 1999). Additionally, one tag was voluntarily returned from the Taku Inlet commercial gillnet fishery; no tags were observed when 18% of the chinook harvest was sampled.

Tagged fish harvested in upriver fisheries would also be a source of inflationary bias if not censored. The inriver commercial and aboriginal fishery is upstream of Canyon Island and opened 15 June, well after most unmarked fish would have passed upstream. Our censoring of these intercepted fish (62 fish of all size groups) was considered complete because of a tag-reward program which has been in place since 1982. Four tags were voluntarily returned from the Canadian recreational fishery. Considering the size of the Canadian recreational harvest (assumed to be <200 chinook salmon of all sizes), the bias from partial censoring should be negligible.

Our simulations to estimate precision in the abundance of small and medium-sized fish did not include one capture history—fish not captured at Canyon Island but caught in the inriver commercial fishery. Because 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 (1,272 all sizes; total catch minus 62 recoveries), their exclusion probably did not meaningfully bias statistics.

While the loss rate of primary tags was unsettling, it did not bias estimates of abundance. Solid-core spaghetti tags were shed on 29% of small/medium recoveries (5/17), which were all males. All lost primary tags were recorded from carcasses at the Nakina River. Recognition of secondary marks proved sufficient insurance to avoid bias in estimates of abundance from tag loss. No recaptured fish with a primary mark was observed to be missing both the secondary or tertiary mark.

Success of the mark-recapture experiment for estimating small/medium abundance in 1998 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, Kowatua and Tatsatua (Tatsamenie) rivers were not 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 rates and censoring of marked fish removed by

Table 4.–Estimated average length by age and sex on the spawning grounds in the Taku River in 1998.

SPAWNING GROUNDS										
		Brood year and age class								
		1995	1994	1994	1993	1993	1992	1992	1991	1991
		1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5
Males	n	136	4	250	1	113	4	163	1	4
	Average length	373	401	561	610	746	760	879	820	974
	SD	40	23	65		75	41	72		73
	SE	3	12	4		7	21	6		37
Females	n			6	1	71	1	267	4	7
	Average length			659	568	807	765	844	861	853
	SD			46		47		40	47	39
	SE			19		6		2	24	15
All fish	n	136	4	256	2	184	5	430	5	11
	Average length	373	401	564	589	769	761	857	853	897
	SD	40	23	66	30	72	35	57	45	72
	SE	3	12	4	21	5	16	3	20	22

fisheries could have affected our ability to proportionally mark chinook salmon.

Nevertheless, our data for small/medium fish easily passed the test of consistency (Seber 1982, p. 439; see Figure 2), 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, 1990 and 1995–1997 (McPherson et al. 1996, 1997, 1998; Pahlke and Bernard 1996).

In estimating abundance and age and sex composition of chinook salmon for the watershed, we presumed that our combined tributary samples within the two size groups (small/medium and large) were representative of the total population (see Figures 2 and 3). What differences there may 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 state after spawning, whereas females tend to die near their redds (Kissner and Hubartt 1986), estimates of 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-only surveys tend to be biased towards females, which are larger fish. Chinook salmon encountered at weirs passing live fish prior to spawning are generally more likely to be of a representative size, age, and sex, than are chinook salmon encountered during spawning grounds surveys which employ gear to capture carcasses and live fish—i.e., collection of carcasses combined with netting of live fish.

We found that the pooled tributary samples were appropriate for estimating age and sex composition within the small/medium size group and indications are that the same is true for large fish. Hypothesis testing of marked vs. recaptured and marked vs. inspected for small/medium chinook indicated that the tagging event was size selective ($P < 0.001$) for this size group, but that the recapture event was not ($P = 0.63$). Hence, we used the pooled tributary sample to estimate age and sex composition for this group.

We could not perform companion tests for large fish, but past sampling has indicated that the pooled tributary sample was not size selective in 1995, 1996 and 1997 (McPherson et al. 1996, 1997, 1998). We did test for differences in age composition between large fish sampled on the Nakina River versus those sampled in the combined Tatsamenie/Kowatua samples (see

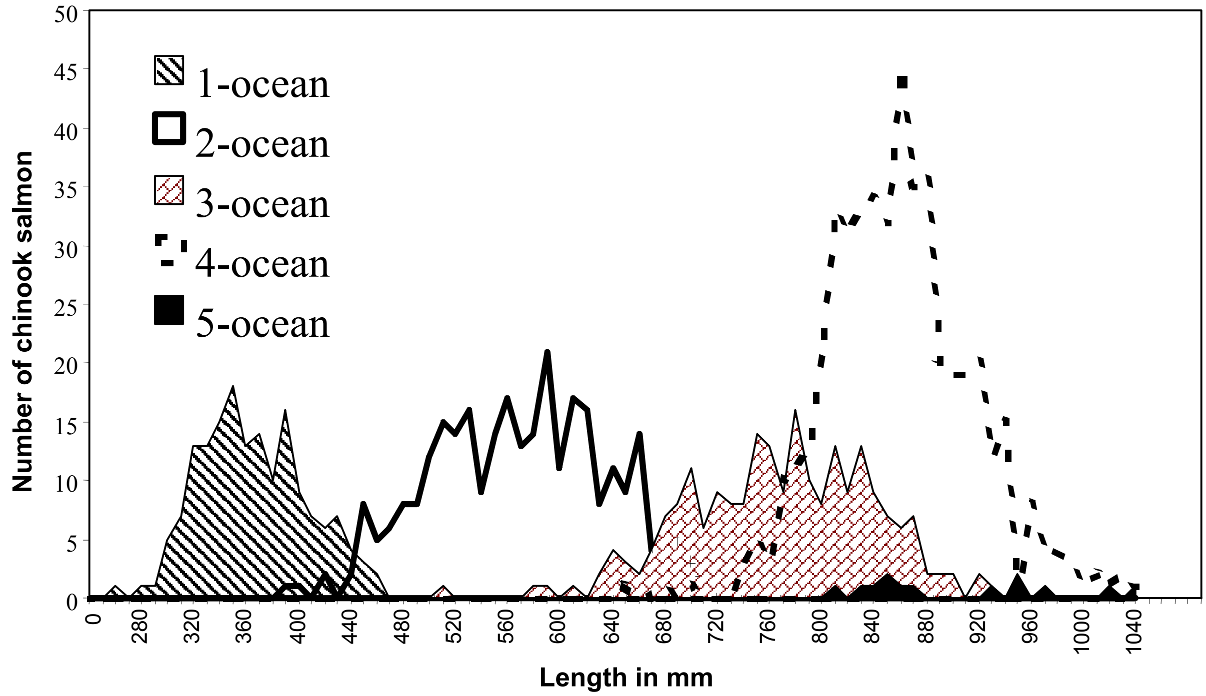

Figure 3.–Numbers of chinook salmon by ocean-age from spawning grounds samples in 1998.

Appendix B2). We found no differences in age composition between the two samples ($\chi^2 = 0.22$, df = 2, P = 0.89). Males were more prevalent in samples from large fish on the Nakina River (P <0.001). We attribute this to the gear type (carcass weir) versus a combination of gear used on Kowatua and upper and lower Tatsamenie rivers—carcass collection by foot, collection of live spent fish and carcass weirs.

Estimated abundance of large chinook salmon on the spawning grounds of the Taku River directly from the mark-recapture experiment was not possible because of low abundance and low water levels which led to low tagging rates and considerably hampered our abilities to inspect enough large chinook salmon upstream. Left with no other option, we expanded the aerial survey counts in the five tributaries mentioned above to estimate the spawning abundance of large fish. The precision of this estimate is poor due to the unusually low fraction counted in aerial surveys in one (1997) of the 5 years in which mark-recapture experiments were operated (Table 5 and Appendix A). However, this is consistent with the methods used to estimate escapements of large spawners in earlier years (1973–1988 and 1991–1994) in a recent analysis to estimate optimal spawning requirements for the Taku River chinook salmon stock (McPherson et al. *In press*). That analysis recommended an escapement goal range of 30,000 to 55,000 large spawners; this range and the analysis supporting it have been reviewed and accepted by internal ADF&G and DFO review teams, as well as by the Transboundary Technical and Chinook Technical committees of the Pacific Salmon Commission. Our estimate in 1998 of 31,039 large spawners slightly exceeded the lower end of the recommended range.

CONCLUSIONS AND RECOMMENDATIONS

Since this project is to continue, we recommend some strategies to improve the precision of estimates. First, it has become apparent that a minimum of 700 to 1,000 large chinook need to be tagged (and survive fisheries) in order to produce a relatively precise and unbiased estimate of spawning abundance. Fish wheel

Table 5.–Comparison of estimated abundance of large chinook (≥660 mm MEF) in the Taku River in 1989, 1990, and 1995–1997 between aerial surveys and through mark-recapture experiments. Confidence intervals for 1989 and 1990 are described in Pahlke and Bernard (1996); those for 1995–1997 are described in this document.

	1989	1990	1995	1996	1997	Average	SD	CV
Raw aerial survey counts	9,480	12,249	8,757	19,777	13,849	12,822	4,400	34.3%
(summed across 6 tribs: Nakina, Nahlin, Tseta, Kowatua, Dudidontu and Tatsamenie)								
Mark-recapture estimate(M-R)	40,329	52,142	33,805	79,019	114,938	64,047	33,290	52.0%
Aerial survey counts/(M-R)	**23.5%**	**23.5%**	**25.9%**	**25.0%**	**12.0%**	**22.0%**	**5.7%**	**25.7%**
M-R Standard Error	5,646	9,326	5,060	9,048	17,888			
M-R lower 95% CI	30,936	37,072	25,455	64,388	88,593			
M-R upper 95% CI	56,995	80,784	45,216	99,866	157,717			

catches need to be supplemented with seine or gillnet gear during periods of low abundance or low water levels. Second, too few chinook salmon were sampled upriver during the recovery event. Recovery efforts can be improved by intensifying tributary sampling and/or examining chinook salmon in the lower river in a test fishery beginning in early May. We also recommend that a method of estimating inseason escapement be formulated and, if necessary, that monies be requested to support such a program.

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LITERATURE CITED

ADF (Alaska Department of Fisheries). 1951. Annual report for 1951. Report No. 3, Juneau.

Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management 13:540-549.

Bernard, D. R., J. J. Hasbrouck, and S. J. Fleischman. *In press*. Handling-induced delay and downstream movement of adult chinook salmon in rivers. Fisheries Research.

Bigelow, B. B., B. J. Bailey, M. M. Hiner, M. F. Schellekens, and K. R. Linn. 1995. Water resources data Alaska water year 1994. U.S. Geological Survey Water Data Report AK-94-1, 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.

Clutter R. and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, New Westminster, British Columbia.

Efron, B. and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York.

Eiler, J., M. M. Masuda, J. Pella, H. R. Carlson, R. F. Bradshaw, and B. D. Nelson. *In prep.* Stock composition, escapement estimate, and timing of chinook salmon returns in the Taku River, Alaska and British Columbia.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hubartt, D. J., A. E. Bingham, and P. M. Suchanek. 1999. Harvest estimates for selected marine sport fisheries in Southeast Alaska during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-15, Anchorage.

Johnson, R. E., R. P. Marshall, and S. T. Elliott. 1992. Chilkat River chinook salmon studies, 1991. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 92-49, Anchorage.

Johnson, R. E., R. P. Marshall, and S. T. Elliott. 1993. Chilkat River chinook salmon studies, 1992. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 93-50, Anchorage.

Kelley, M. S., and P. A. Milligan. 1997. Adult mark-recapture studies of Taku River salmon stocks in 1996. Alaska Department of Fish and Game, Commercial Fisheries Management Division, Regional Information Report 1J97-22, Douglas.

Kelley, M. S., and P. A. Milligan. 1999. Mark-recapture studies of Taku River adult salmon stocks in 1997. Alaska Department of Fish and Game, Commercial Fisheries Management Division, Regional Information Report 1J99-21, Douglas.

Kerr, F. A. 1948. Taku River map area, British Columbia. Canadian Department of Mines and Resources, Geological Survey Memoir 248, Ottawa.

Kissner, P. D., Jr. 1976. A study of chinook salmon in southeast Alaska. Alaska Department of Fish and Game, Annual Report 1975–1976, Project F-9-8, 17 (AFS-41).

Kissner, P. D., Jr., and D. J. Hubartt. 1986. A study of chinook salmon in Southeast Alaska. Alaska Department of Fish and Game, Annual Report 1985-1986, Project F-10-1, 27 (AS-41).

Marcus, M. B. 1960. Periodic drainage of glacier-dammed Tulsequah Lake, British Columbia. Geographical Review 1:89–106.

McGregor, A. J. and J. E. Clark. 1989. Migratory timing and escapement of Taku River salmon stocks in 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 1J89-40, Juneau.

McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1996. Spawning abundance of chinook salmon in the Taku River in 1995. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 96-36, Anchorage.

McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1997. Spawning abundance of chinook salmon in the Taku River in 1996. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 97-14, Anchorage.

McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1998. Spawning abundance of chinook salmon in the Taku River in 1997. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 98-41, Anchorage.

McPherson, S. A., D. R. Bernard and J. H. Clark. *In press*. Optimal production of chinook salmon from the Taku River. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Manuscript, Anchorage.

Mecum, R. D. and P. D. Kissner, Jr. 1989. A study of chinook salmon in Southeast Alaska. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 117, Anchorage.

Meehan, W. R. 1961. Use of a fish wheel in salmon research and management. Transactions of the American Fisheries Society 90(4):490-494.

Milligan, P. A., W. O. Rublee, D. D. Cornett, and R. A. C. Johnston. 1984. The distribution and abundance of chinook salmon in the upper Yukon River basin as determined by a radiotagging and spaghetti tagging program: 1982–1983. Department of Fisheries and Oceans, Yukon River Basin Study, Technical Report 35. Whitehorse, Yukon Territory.

Olsen, M. A. 1992. Abundance, age, sex and size of chinook salmon catches and escapements in Southeast Alaska in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-07, Juneau.

PSC (Pacific Salmon Commission). 1993. Transboundary river salmon production, harvest, and escapement estimates, 1992. Transboundary Technical Committee Report (93-3).

Pahlke, K. A. 1998. Escapements of chinook salmon in Southeast Alaska and transboundary rivers in 1997. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series 98-33, Anchorage.

Pahlke, K. A. and D. R. Bernard. 1996. Abundance of the chinook salmon escapement in the Taku River, 1989 and 1990. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Alaska Fishery Research Bulletin 3(1):8–19, Juneau.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, second edition. MacMillan and Company, New York.

Welander, A. D. 1940. A study of the development of the scale of the chinook salmon (*Oncorhynchus* tshawytscha). Master's thesis, University of Washington, Seattle.

APPENDICES

APPENDIX A:

ESTIMATING NUMBERS OF LARGE SPAWNING CHINOOK SALMON BY EXPANDING AERIAL SURVEY COUNTS

Spawning Abundance

This appendix describes methods use to expand aerial survey counts into estimates of large spawners as detailed in McPherson et al. (*In press*). Since 1973, escapements to the Taku River have been assessed with aerial surveys from helicopters. Only "large" chinook salmon, typically 3-ocean age [age-.3 fish] and older (most ≥660 mm mid-eye to tail fork [MEF]) were counted annually by flying over stretches of the Nakina, Nahlin, Kowatua, Tatsamenie, and Dudidontu rivers, and, after 1981, Tseta Creek, according to fixed schedules and protocols (Pahlke 1998). Fish age-1.1 and age-1.2 (1- and 2-ocean age) were not counted because of the difficulty of distinguishing these fish from other species. Large chinook salmon could be distinguished from smaller fish because there was little overlap in age distributions (Figure A1). Counts were highly correlated across tributaries (Table A1), indicating the relative strengths of year classes were the same throughout the Taku River. For this reason,

Table A1.–Pearson correlation coefficients among counts of large chinook salmon in five tributaries to the Taku River from 1973 to 1997. All P <0.01 with 20 ≤df ≤ 23.

	Nakina	Kowatua	Tatsamenie	Dudidontu
Nahlin	0.74	0.76	0.75	0.80
Nakina		0.73	0.85	0.77
Kowatua			0.82	0.78
Tatsamenie				0.77

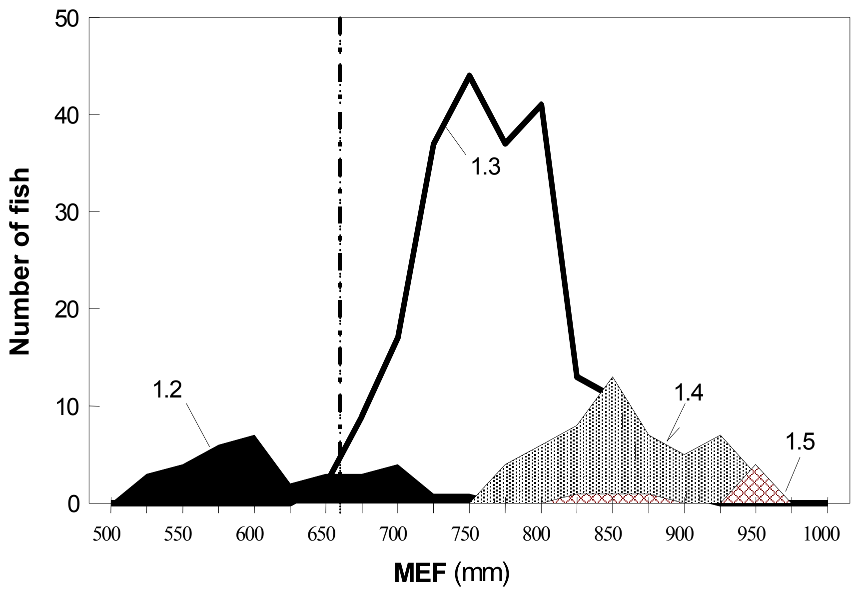

Figure A1.–Length-frequency polygons of age groups of chinook salmon sampled in fish wheels at Canyon Island on the Taku River in 1988. Dashed vertical line marks boundary segregating "large" fish (≥ 660 mm MEF).

Table A2.–Survey counts, estimated abundance $\hat{N}$ along with its estimated standard error and approximate 95% confidence intervals for large (≥660 mm FL) chinook salmon spawning in the Taku River from 1973 through 1998. Statistics in bold face come directly from mark-recapture experiments in 1989, 1990, and 1995–1997; all other statistics are expanded from counts based on the estimated relationship between survey counts and estimates during years with mark-recapture experiments.

Year	Survey counts	$\hat{N}$	SE ($\hat{N}$)	$\hat{N}$ - 1.96 SE ($\hat{N}$)	$\hat{N}$ + 1.96 SE ($\hat{N}$)
1973	2,800	14,564	5,968	2,867	26,261
1974	3,079	16,015	6,563	3,152	28,878
1975	2,484	12,920	5,294	2,543	23,297
1976	4,726	24,582	10,073	4,838	44,325
1977	5,671	29,497	12,087	5,806	53,188
1978	3,292	17,124	7,017	3,371	30,878
1979	4,156	21,617	8,858	4,255	38,979
1980	7,544	39,239	16,080	7,723	70,755
1981	9,528	49,559	20,308	9,755	89,363
1982	4,585	23,848	9,773	4,694	43,003
1983	1,883	9,794	4,014	1,928	17,661
1984	3,995	20,778	8,514	4,090	37,466
1985	6,905	35,916	14,718	7,069	64,762
1986	7,327	38,111	15,617	7,501	68,720
1987	5,563	28,935	11,857	5,695	52,176
1988	8,560	44,524	18,245	8,764	80,284
1989	8,986	**40,329**	**5,646**	**29,263**	**51,395**
1990	12,077	**52,142**	**9,326**	**33,863**	**70,421**
1991	9,929	51,645	21,163	10,165	93,124
1992	10,745	55,889	22,902	11,001	100,778
1993	12,713	66,125	27,097	13,015	119,236
1994	9,299	48,368	19,820	9,520	87,216
1995	7,971	**33,805**	**5,060**	**23,887**	**43,723**
1996	18,576	**79,019**	**9,048**	**61,285**	**96,753**
1997	13,201	**114,938**	**17,888**	**79,878**	**149,998**
1998	5,969	31,039	12,720	6,108	55,970

counts within a year were summed across tributaries to produce a single count representing the entire population of large chinook salmon spawning in the Taku River.[1]

[1] Because of cancelled flights, no counts are available for Tatsamenie and Kowatua rivers in 1975 or for the Dudidontu River in 1978 and 1984. For those years, sums of counts across surveyed watersheds were expanded by complements of interpolated fractions for watersheds not surveyed. For instance, 2,089 large chinook salmon were counted in 1975. Counts for the Tatsamenie River represented 7.6% of all counts in 1974 and 7.2% in 1976, making the interpolated fraction 0.074 for 1975. Together with the interpolated value of 0.085 for the Kowatua River, the expanded count is 2,484 [=2,089/(1-0.074-0.085)] for 1975.

Because surveys over Tseta Creek began in 1981, eight years after the start of surveys elsewhere, counts from Tseta Creek were not used in subsequent analyses. Counts from Tseta Creek were highly correlated with those from other watersheds ($P < 0.01$). Summed counts C_t for the Taku River are listed in Table A2.

Abundance of large spawners in the Taku River was estimated with mark-recapture experiments based on tagging and radiotelemetry studies in 1989 and 1990 by the Commercial Fisheries Division [CFD] of the Alaska Department of Fish and Game (ADF&G), the Department of Fisheries and Oceans Canada (DFO), and the U.S. National Marine Fisheries Service (NMFS)

Table A3.–Equations used to expand counts C_t into estimates of abundance N_t of large (≥660 mm MEF) chinook salmon spawning in the Taku River where t is year, k is the number of years with mark-recapture experiments, π is the ratio (expansion factor) N_i/C_i where i denotes years with mark-recapture experiments.

	Statistic	Estimated variance
Expansion	$\hat{N}_t = C_t \bar{\pi}$	$v(\hat{N}_t) = C_t^2 v(\pi)$
Mean expansion factor	$\bar{\pi} = \frac{\sum_{i=1}^{k} \hat{\pi}_i}{k}$	$v(\pi) = \frac{\sum_{i=1}^{k}(\hat{\pi}_i - \bar{\pi})^2}{k-1} + \frac{\sum_{i=1}^{k} v(\hat{\pi}_i)}{k}$
Estimated expansion factor	$\hat{\pi}_i = \hat{N}_i C_i^{-1}$	$v(\hat{\pi}_i) = v(\hat{N}_i) C_i^{-2}$

(Pahlke and Bernard 1996; Eiler et al. *In prep.*) and from cooperative tagging studies by CFD, DFO, and the Division of Sport Fish (DSF) of ADF&G from 1995 through 1997 (McPherson et al. 1996, 1997, 1998). Adults were captured in fish wheels at Canyon Island (the first sampling event) and on the spawning grounds in the Nakina, Nahlin, Tatsamenie, and Kowatua rivers (the second sampling event). Marked chinook salmon subsequently captured in commercial or recreational fisheries were censored from the marked population, making the estimate germane to all chinook salmon spawning in the Taku River. No spawning has been detected downstream or in the vicinity of Canyon Island (Eiler *In prep.*). Estimated abundance was stratified into fish age 1.2 and fish age 1.3 and older. Estimated abundance $\hat{N}_t$ for the latter group in year t is in Table A2.

Abundance of spawners age 1.3 and older in years without mark-recapture experiments was estimated indirectly from expansions of counts C_t of large fish (≥660 mm MEF); an expansion factor was derived in the five years with both survey counts and mark-recapture experiments (Table A3).

Expansion factors π for individual years with experiments are 4.49 (SE = 0.63), 4.43 (SE = 0.77), 4.24 (SE = 0.63), 4.25 (SE = 0.49), and 8.71 (SE = 1.36), making the mean expansion factor $\bar{\pi} = 5.20$[2] and the estimated variance $v(\pi) = 4.54$. Note that $v(\pi)$ instead of $v(\bar{\pi})$ was used in calculations to capture measurement error from mark-recapture experiments and from uncertainty of individual aerial surveys across years.

[2] The unusually high factor of 8.71 represents 1997, a year when estimated spawning abundance was exceptionally large. Excluding information from 1997, the expansion factor drops to 4.33 and has an estimated variance of 0.42. If 1997 does represent an anomaly in the survey, information from future years should greatly improve precision of expansions.

Appendix B1.–Fish wheel effort for chinook salmon, including water level, catches, numbers tagged, CPUE, and daily proportions in 1998.

	Fish wheel #1		Fish wheel #2			Fish wheels combined													
Date	Hours fished	RPM	Hours fished	RPM	Water level (ft)	Tagged small daily	Tagged small cum.	Tagged medium daily	Tagged medium cum.	Tagged large daily	Tagged large cum.	Total tagged daily [a]	Tagged cum.	Total catch daily	Total catch cum.	CPUE daily	CPUE cum.	Daily prop.	Cum. prop.
27-Apr																			
28-Apr					-0.7														
29-Apr					-0.3														
30-Apr					-0.3														
1-May					0.0														
2-May	14.00	1			0.6														
3-May	24.00	1.7			1.5	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.000	0.000
4-May	24.00	1.6			1.5	0	0	1	1	0	0	1	1	1	1	0.04	0.04	0.002	0.002
5-May	24.00	1.8			2.0	0	0	1	2	4	4	5	6	5	6	0.21	0.25	0.010	0.012
6-May	23.92	1.6			1.1	0	0	0	2	6	10	6	12	6	12	0.25	0.50	0.012	0.024
7-May	23.83	1.6			1.1	0	0	0	2	4	14	4	16	4	16	0.17	0.67	0.008	0.031
8-May	24.00	1.2			1.5	0	0	1	3	5	19	6	22	6	22	0.25	0.92	0.012	0.043
9-May	9.00				1.3		0		3		19		22		22	0.00	0.92	0.000	0.043
10-May	0.00				1.0		0		3		19		22		22		0.92	0.000	0.043
11-May	0.00		4.25	1.6	1.1		0		3		19		22		22	0.00	0.92	0.000	0.043
12-May	0.00		23.75	1.5	1.2	0	0	1	4	8	27	9	31	9	31	0.38	1.30	0.018	0.061
13-May	0.00		21.33	1.6	1.3	0	0	2	6	8	35	10	41	10	41	0.47	1.77	0.022	0.083
14-May	0.00		24.00	1.6	1.3	0	0	5	11	15	50	20	61	21	62	0.88	2.64	0.041	0.124
15-May	0.00		24.00	1.6	1.2	0	0	6	17	14	64	20	81	21	83	0.88	3.52	0.041	0.165
16-May	8.00	1.8	23.58	2	1.6	3	3	1	18	1	65	5	86	5	88	0.16	3.67	0.007	0.173
17-May	22.75	2	23.58	2	2.6	6	9	2	20	3	68	11	97	11	99	0.24	3.91	0.011	0.184
18-May	23.50	2.1	23.25	2.2	3.2	6	15	10	30	7	75	23	120	24	123	0.51	4.43	0.024	0.208
19-May	22.58	2.3	22.58	2.4	3.6	15	30	14	44	17	92	46	166	47	170	1.04	5.47	0.049	0.257
20-May	23.33	1.9	23.16	2.4	3.5	5	35	12	56	12	104	29	195	31	201	0.67	6.13	0.031	0.288
21-May	23.58	2.1	23.08	2.4	3.3	15	50	7	63	9	113	31	226	31	232	0.66	6.80	0.031	0.320
22-May	23.67	2	22.92	2.6	3.4	5	55	7	70	10	123	22	248	22	254	0.47	7.27	0.022	0.342
23-May	23.50	2	22.50	2.1	4.1	3	58	9	79	15	138	27	275	29	283	0.63	7.90	0.030	0.372
24-May	23.50	2.4	23.25	2.2	4.1	6	64	13	92	9	147	29	304	29	312	0.62	8.52	0.029	0.401
25-May	22.75	2.8	23.08	2.9	5.9	5	69	6	98	8	155	19	323	20	332	0.44	8.96	0.021	0.421
26-May	13.50	3.4	16.16	3.3	7.9	0	69	1	99	1	156	2	325	2	334	0.07	9.02	0.003	0.424
27-May	0.00		0.00		10.0		69		99		156		325		334		9.02	0.000	0.424
28-May	0.00		0.00		10.5		69		99		156		325		334		9.02	0.000	0.424
29-May	0.00		0.00		10.9		69		99		156		325		334		9.02	0.000	0.424
30-May	0.00		0.00		10.7		69		99		156		325		334		9.02	0.000	0.424
31-May	0.00		0.00		10.3		69		99		156		325		334		9.02	0.000	0.424
1-Jun	11.83	3.1	12.75	2.9	9.7	1	70	0	99	1	157	2	327	3	337	0.12	9.15	0.006	0.430
2-Jun	23.50	2.8	23.08	2.9	8.3	3	73	3	102	11	168	17	344	18	355	0.39	9.53	0.018	0.448
3-Jun	23.50	2.5	23.16	2.9	7.7	6	79	10	112	9	177	25	369	28	383	0.60	10.13	0.028	0.476
4-Jun	23.08	2.6	23.67	2.8	7.5	3	82	6	118	4	181	13	382	14	397	0.30	10.43	0.014	0.491
5-Jun	23.75	2.9	23.33	2.7	8.2	6	88	7	125	4	185	17	399	19	416	0.40	10.84	0.019	0.510
6-Jun	23.75	3	23.00	3.1	8.6	1	89	4	129	15	200	20	419	21	437	0.45	11.29	0.021	0.531
7-Jun	23.67	2.8	22.92	2.8	8.2	1	90	13	142	10	210	25	444	26	463	0.56	11.84	0.026	0.557
8-Jun	23.75	2.8	23.08	3	8.2	13	103	6	148	6	216	25	469	26	489	0.56	12.40	0.026	0.583
9-Jun	23.75	3.1	23.00	3	8.9	1	104	5	153	6	222	12	481	13	502	0.28	12.68	0.013	0.596

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	Fish wheel #1		Fish wheel #2			Fish wheels combined													
Date	Hours fished	RPM	Hours fished	RPM	Water level (ft)	Tagged small daily	Tagged small cum.	Tagged medium daily	Tagged medium cum.	Tagged large daily	Tagged large cum.	Total tagged daily [a]	Tagged cum.	Total catch daily	Total catch cum.	CPUE daily	CPUE cum.	Daily prop.	Cum. prop.
10-Jun	23.67	2.8	23.06	2.9	8.6	1	105	3	156	5	227	9	490	9	511	0.19	12.87	0.009	0.605
11-Jun	23.75	2.6	23.25	2.6	6.9	5	110	7	163	6	233	18	508	19	530	0.40	13.27	0.019	0.624
12-Jun	23.25	2.4	23.16	2.2	5.9	4	114	6	169	8	241	18	526	18	548	0.39	13.66	0.018	0.642
13-Jun	23.08	2.2	22.50	2.3	5.3	6	120	11	180	8	249	25	551	28	576	0.61	14.28	0.029	0.671
14-Jun	22.92	2.3	23.25	2.4	4.8	5	125	9	189	6	255	20	571	22	598	0.48	14.75	0.022	0.694
15-Jun	23.42	2.4	22.67	2.3	4.8	3	128	7	196	10	265	20	591	21	619	0.46	15.21	0.021	0.715
16-Jun	22.67	2.4	23.25	2.2	4.4	8	136	5	201	9	274	22	613	22	641	0.48	15.69	0.023	0.738
17-Jun	23.08	2.1	22.67	2	4.3	6	142	8	209	2	276	16	629	17	658	0.37	16.06	0.017	0.755
18-Jun	23.16	2.5	22.42	2.2	4.5	6	148	12	221	3	279	21	650	21	679	0.46	16.52	0.022	0.777
19-Jun	22.92	2.7	22.75	2.3	5.3	12	160	9	230	3	282	24	674	25	704	0.55	17.07	0.026	0.803
20-Jun	22.50	2.9	21.58	2.6	5.7	11	171	13	243	10	292	34	708	36	740	0.82	17.88	0.038	0.841
21-Jun	23.00	2.9	22.50	2.6	6.0	4	175	9	252	7	299	20	728	21	761	0.46	18.34	0.022	0.863
22-Jun	23.75	2.7	22.25	2.5	5.3	6	181	10	262	4	303	20	748	20	781	0.43	18.78	0.020	0.883
23-Jun	23.00	2.5	22.42	2.5	5.3	3	184	3	265	2	305	8	756	8	789	0.18	18.96	0.008	0.891
24-Jun	23.42	2.2	23.25	2.2	4.6	1	185	4	269	4	309	9	765	11	800	0.24	19.19	0.011	0.902
25-Jun	23.50	2.1	23.00	2	4.1	2	187	3	272	5	314	10	775	10	810	0.22	19.41	0.010	0.913
26-Jun	23.08	2.3	22.75	2.5	4.7	1	188	8	280	1	315	10	785	10	820	0.22	19.62	0.010	0.923
27-Jun	22.83	3	22.92	2.8	5.3	4	192	4	284	4	319	12	797	12	832	0.26	19.89	0.012	0.935
28-Jun	22.16	2.6	22.83	2.8	5.3	3	195	7	291	3	322	13	810	13	845	0.29	20.18	0.014	0.949
29-Jun	22.58	2.5	21.58	2.7	5.3	5	200	4	295	5	327	14	824	15	860	0.34	20.52	0.016	0.965
30-Jun	22.33	2.7	21.92	2.7	5.7	0	200	2	297	2	329	4	828	5	865	0.11	20.63	0.005	0.970
1-Jul	22.92	2.7	18.58	3.1	6.9	0	200	3	300	0	329	3	831	3	868	0.07	20.70	0.003	0.973
2-Jul	23.42	2.5	23.25	2.5	7.0	1	201	2	302	0	329	3	834	3	871	0.06	20.76	0.003	0.976
3-Jul	23.75	2.4	23.33	2.6	6.8	0	201	0	302	2	331	2	836	3	874	0.06	20.83	0.003	0.979
4-Jul	23.75	2.9	22.83	2.7	7.3		201		302		331		836		874	0.00	20.83	0.000	0.979
5-Jul	17.67	2.9	22.83	2.6	7.8	0	201	0	302	1	332	1	837	1	875	0.02	20.85	0.001	0.981
6-Jul	0.00		21.92	2.6	7.4	0	201	0	302	1	333	1	838	1	876	0.05	20.90	0.002	0.983
7-Jul	0.00		22.25	2.3	6.8	0	201	1	303	1	334	2	840	3	879	0.13	21.03	0.006	0.989
8-Jul	9.67	2.6	23.00	2.1	5.6	0	201	1	304	0	334	1	841	1	880	0.03	21.06	0.001	0.991
9-Jul	23.16	2.5	22.92	2.3	5.1	0	201	1	305	0	334	1	842	1	881	0.02	21.09	0.001	0.992
10-Jul	23.16	2.6	23.50	2.3	5.1		201		305		334		842		881	0.00	21.09	0.000	0.992
11-Jul	23.16	2.6	23.25	2.5	5.2		201		305		334		842		881	0.00	21.09	0.000	0.992
12-Jul	23.08	2.6	23.16	2.4	5.2		201		305		334		842		881	0.00	21.09	0.000	0.992
13-Jul	22.67	2.5	21.75	2.4	5.0	1	202	3	308	1	335	5	847	5	886	0.11	21.20	0.005	0.997
14-Jul	22.75	2.5	22.25	2.6	4.5	0	202	0	308	1	336	1	848	1	887	0.02	21.22	0.001	0.998
15-Jul	22.58	2.5	22.33	2.6	4.5	0	202	1	309	0	336	1	849	1	888	0.02	21.24	0.001	0.999
16-Jul	22.50	2.6	22.75	2.6	4.5		202		309		336		849		888	0.00	21.24	0.000	0.999
17-Jul	22.58	2.7	22.33	2.6	4.6	0	202	0	309	1	337	1	850	1	889	0.02	21.27	0.001	1.000

[a] Daily tagged totals include 2 fish of unknown size class.

Appendix B2.–Age composition by sex and age from samples aged from chinook salmon in the Taku River in 1998 by size group and location.

			AGE CLASS									
			1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5	**Total**
Nakina: large fish	Male	n			8		63	1	88	1	2	**163**
		%			4.9		38.7	0.6	54.0	0.6	1.2	**57.0**
	Female	n					18		102	1	2	**123**
		%					14.6		82.9	0.8	1.6	**43.0**
	Total	n			8		81	1	190	2	4	**286**
		%			2.8		28.3	0.3	66.4	0.7	1.4	
Nakina: small and medium fish	Male	n	115	4	169	1	7		1			**297**
		%	38.7	1.3	56.9	0.3	2.4		0.3			**100.3**
	Female	n					1					**1**
		%					100.0					**0.3**
	Total	n	115	4	169		8					**296**
		%	38.9	1.4	57.1		2.7					
Nakina: all chinook	Male	n	115	4	177	1	70	1	89	1	2	**460**
		%	25.0	0.9	38.5	0.2	15.2	0.2	19.3	0.2	0.4	**78.8**
	Female	n					19		102	1	2	**124**
		%					15.3		82.3	0.8	1.6	**21.2**
	Total	n	115	4	177	1	89	1	191	2	4	**584**
		%	19.7	0.7	30.3	0.2	15.2	0.2	32.7	0.3	0.7	
Kowatua: large fish	Male	n					12		24		2	**38**
		%					31.6		63.2		5.3	**44.7**
	Female	n					6		39		2	**47**
		%					12.8		83.0		4.3	**55.3**
	Total	n					18		63		4	**85**
		%					21.2		74.1		4.7	
Kowatua: small and medium fish	Male	n	7		9		2					**18**
		%	38.9		50.0		11.1					**100.0**
	Female	n										**0**
		%										**0.0**
	Total	n	7		9		2					**18**
		%	38.9		50.0		11.1					
Kowatua: all chinook	Male	n	7		9		14		24		2	**56**
		%	12.5		16.1		25.0		42.9		3.6	**54.4**
	Female	n					6		39		2	**47**
		%					12.8		83.0		4.3	**45.6**
	Total	n	7		9		20		63		4	**103**
		%	6.8		8.7		19.4		61.2		3.9	
Lower Tatsamenie: large fish	Male	n			1		8	1	5			**15**
		%			6.7		53.3	6.7	33.3			**34.9**
	Female	n					7	1	20			**28**
		%					25.0	3.6	71.4			**65.1**
	Total	n			1		15	2	25			**43**
		%			2.3		34.9	4.7	58.1			
Lower Tatsamenie: small and medium fish	Male	n	1		29		1					**31**
		%	3.2		93.5		3.2					**91.2**
	Female	n			2	1						**3**
		%			66.7	33.3						**8.8**
	Total	n	1		31	1	1					**34**
		%	2.9		91.2	2.9	2.9					
Lower Tatsamenie: all chinook	Male	n	1		30		9	1	5			**46**
		%	2.2		65.2		19.6	2.2	10.9			**59.7**
	Female	n			2	1	7	1	20			**31**
		%			6.5	3.2	22.6	3.2	64.5			**40.3**
	Total	n	1		32	1	16	2	25			**77**
		%	1.3		41.6	1.3	20.8	2.6	32.5			

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			AGE CLASS									
			1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5	**Total**
Upper Tatsamenie: large fish	Male	n			6		18	2	45			**71**
		%			8.5		25.4	2.8	63.4			**31.4**
	Female	n			3		40		106	3	3	**155**
		%			1.9		25.8		68.4	1.9	1.9	**68.6**
	Total	n			9		58	2	151	3	3	**226**
		%			4.0		25.7	0.9	66.8	1.3	1.3	
Upper Tatsamenie: small and medium fish	Male	n	13		28		2					**43**
		%	30.2		65.1		4.7					**100.0**
	Female	n										
		%										**0.0**
	Total	n	13		28		2					**43**
		%	30.2		65.1		4.7					
Upper Tatsamenie: all chinook	Male	n	13		34		20	2	45			**114**
		%	11.4		29.8		17.5	1.8	39.5			**42.4**
	Female	n			3		40		106	3	3	**155**
		%			1.9		25.8		68.4	1.9	1.9	**57.6**
	Total	n	13		37		60	2	151	3	3	**269**
		%	4.8		13.8		22.3	0.7	56.1	1.1	1.1	
Tatsamenie + Kowatua: large fish	Male	n			7		38	3	74		2	**124**
		%			5.6		30.6	2.4	59.7		1.6	**35.0**
	Female	n			3		53	1	165	3	5	**230**
		%			1.3		23.0	0.4	71.7	1.3	2.2	**65.0**
	Total	n			10		91	4	239	3	7	**354**
		%			2.8		25.7	1.1	67.5	0.8	2.0	
Tatsamenie + Kowatua: small and medium fish	Male	n	21		66		5					**92**
		%	22.8		71.7		5.4					**96.8**
	Female	n			2	1						**3**
		%			66.7	33.3						**3.2**
	Total	n	21		68	1	5					**95**
		%	22.1		71.6	1.1	5.3					
Tatsamenie + Kowatua: all chinook	Male	n	21		73		43	3	74		2	**216**
		%	9.7		33.8		19.9	1.4	34.3		0.9	**48.1**
	Female	n			5	1	53	1	165	3	5	**233**
		%			2.1	0.4	22.7	0.4	70.8	1.3	2.1	**51.9**
	Total	n	21		78	1	96	4	239	3	7	**449**
		%	4.7		17.4	0.2	21.4	0.9	53.2	0.7	1.6	
All tributaries: large fish inspected	Male	n			15		101	4	162	1	4	**287**
		%			5.2		35.2	1.4	56.4	0.3	1.4	**44.8**
	Female	n			3		71	1	267	4	7	**353**
		%			0.8		20.1	0.3	75.6	1.1	2.0	**55.2**
	Total	n			18		172	5	429	5	11	**640**
		%			2.8		26.9	0.8	67.0	0.8	1.7	
All tributaries: small and medium fish inspected	Male	n	136	4	235	1	12		1			**389**
		%	35.0	1.0	60.4	0.3	3.1		0.3			**99.0**
	Female	n			2	1	1					**4**
		%			50.0	25.0	25.0					**1.0**
	Total	n	136	4	237	2	13		1			**393**
		%	34.6	1.0	60.3	0.5	3.3		0.3			
All tributaries: all chinook inspected	Male	n	136	4	250	1	113	4	163	1	4	**676**
		%	20.1	0.6	37.0	0.1	16.7	0.6	24.1	0.1	0.6	**65.4**
	Female	n			5	1	72	1	267	4	7	**357**
		%			1.4	0.3	20.2	0.3	74.8	1.1	2.0	**34.6**
	Total	n	136	4	255	2	185	5	430	5	11	**1,033**
		%	13.2	0.4	24.7	0.2	17.9	0.5	41.6	0.5	1.1	

-continued-

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			AGE CLASS									
			1.1	2.1	1.2	2.2	1.3	2.3	1.4	2.4	1.5	**Total**
Canyon Island: large fish sampled	Male	n			2		16		23	1	1	**43**
		%			4.7		37.2		53.5	2.3	2.3	**43.0**
	Female	n					15	3	36	2	1	**57**
		%					26.3	5.3	63.2	3.5	1.8	**57.0**
	Total	n			2		31	3	59	3	2	**100**
		%			2.0		31.0	3.0	59.0	3.0	2.0	
Canyon Island: small and medium fish sampled	Male	n	82	3	70	2	6					**163**
		%	50.3	1.8	42.9	1.2	3.7					**100.0**
	Female	n										
		%										
	Total	n	82	3	70	2	6					**163**
		%	50.3	1.8	42.9	1.2	3.7					
Canyon Island: all chinook sampled	Male	n	82	3	72	2	22		23	1	1	**206**
		%	39.8	1.5	35.0	1.0	10.7		11.2	0.5	0.5	**78.3**
	Female	n					15	3	36	2	1	**57**
		%					26.3	5.3	63.2	3.5	1.8	**21.7**
	Total	n	82	3	72	2	37	3	59	3	2	**263**
		%	31.2	1.1	27.4	0.8	14.1	1.1	22.4	1.1	0.8	

Appendix C.–Computer files used to estimate the spawning abundance of chinook salmon in the Taku River in 1998.

File Name	Description
TAKUKI98.xls	Spreadsheet with chi-square tests, age and length composition, bootstrap setup and output, U.S. gillnet sampling, fish wheel catch and effort data.
41TAKU96.exe	BASIC compiled program for bootstrapping abundance estimates to estimate variance and bias.
SMMED98.dat	Data file for small & medium-sized chinook for 41TAKU96.exe.
98CI41SM.xls	Spreadsheet of chinook salmon caught and tagged at Canyon Island: tagging data; spaghetti tags recovered; age, sex and length data for chinook tagged.
98UTATSKOWA41.xls	Spreadsheet of chinook salmon sampled for tag recovery on the Kowatua River and upper Tatsamenie River: fish inspected; tag recoveries; age, sex and length data.
98NAKINA.xls	Spreadsheet of chinook salmon sampled for tag recovery at the Nakina carcass weir and at the Nahlin River live weir: fish inspected; tag recoveries; age, sex and length data; CWT recovery data.
98LTAT41.xls	Spreadsheet of chinook salmon sampled for tag recovery on the lower Tatsamenie River: fish inspected; tag recoveries; age, sex and length data.