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Optimal Production of Chinook Salmon from the Taku River

by

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May 2000

Alaska Department of Fish and Game Division of Sport Fish

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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

FISHERY MANUSCRIPT NO. 00-2

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ABSTRACT

Optimal production of adult chinook salmon *Oncorhynchus tshawytscha* from the Taku River was investigated with information from a stock assessment program (1973-1997) and catch sampling programs of the Canadian inriver gillnet fishery, U.S. gillnet fishery in Taku Inlet, the U.S. commercial troll and the U.S. recreational fishery near Juneau. Stock assessment was based on aerial surveys and mark-recapture experiments to estimate abundance of large (mostly age-1.3 and older fish) salmon over the spawning grounds. Relative age composition was estimated from 1973 through 1997 at a carcass weir on the Nakina River and during mark-recapture experiments on other tributaries. Additional mark-recapture experiments using coded-wire tags provided estimates of harvest in fisheries and abundance of emigrating smolts. Spawning abundance that would produce maximum-sustained yield (N_{MSY}) was estimated at 19,597 and 28,738 large salmon from fits of two traditional stock-recruit models to the data. No autocorrelation among residuals was detected in these fits, however, measurement error in estimates of spawning abundance and production, mostly from aerial surveys, reduced confidence in the accuracy of N_{MSY} estimates. Inspection of more precise, individual estimates of spawner and smolt abundance, adult production, and smolt size provided evidence for early density-dependent survival of young salmon and later density-independent survival of young salmon while still in freshwater and while at sea. Because observed smolt production was near maximum over a range of about 30,000 to 55,000 large spawners, this level was recommended as the best estimate for N_{MSY} at this time. We recommend that the Alaska Department of Fish and Game and the Department of Fisheries and Oceans (Canada) adopt a biological escapement goal range of 30,000 to 55,000 large spawners for management purposes for this chinook salmon stock. This corresponds to an aerial survey goal of approximately 5,800 to 10,600 large spawners, counted in five tributaries. We also recommend continuation or implementation of several stock assessment components to improve estimation of population statistics and management of this stock.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, Taku River, smolt abundance, spawning abundance, mark-recapture, age, sex and length composition, escapement goal, stock-recruit analysis.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* from the Taku River (Figure 1) are a "spring run" of salmon with adults passing through Southeast Alaska (SEAK) from late April through early July on their way to spawn in Canada from late July to mid-September. Almost all juveniles rear for one year in freshwater after emergence. These fish leave freshwater at age-1. as yearling smolt (Kissner and Hubartt 1986), then rear offshore west and north of SEAK in the Gulf of Alaska and the Bering Sea. Mature adults migrate back through SEAK after one to five years at sea. Fish maturing at a younger age (age-1.1 and -1.2 fish) are almost exclusively males, while older fish (age-1.3, -1.4. and -1.5 fish) are, on average, about 50% females. Age-1.2, -1.3, and -1.4 fish dominate the annual spawning population, while age-1.5 fish are uncommon (<5%). Most spawning occurs in clear-water tributaries to the Taku River, such as the Nakina, King Salmon, Kowatua, Hackett, Dudidontu and Nahlin rivers, and Tseta Creek (Eiler et al. *In prep*). The mainstem Taku River is turbid from late spring through late fall from silts flushed from glaciers in Alaska and British Columbia.

A commercial fishery for chinook salmon has operated in Taku Inlet since the late 1800s (Moser 1898). Commercial harvests near the terminal area (troll and gillnet) in Taku Inlet averaged 10,000 to 15,000 chinook salmon from 1900 through 1929 (Kissner 1982). Commercial gillnet harvests appear to have averaged 5,000 or fewer chinook salmon in the decades since, except during the 1950s when harvests averaged about 14,000. These figures include harvests for the entire season and include harvests of other stocks. The Taku chinook stock undoubtedly contributed to the spring troll fishery in SEAK since the early 1900s as well, but contribution rates are unknown. Prior to 1976, annual commercial harvests of chinook salmon from the Taku River were estimated to have reached approximately 15,000 or more, based on spring gillnet and troll harvests in or near Taku Inlet (Kissner 1976).

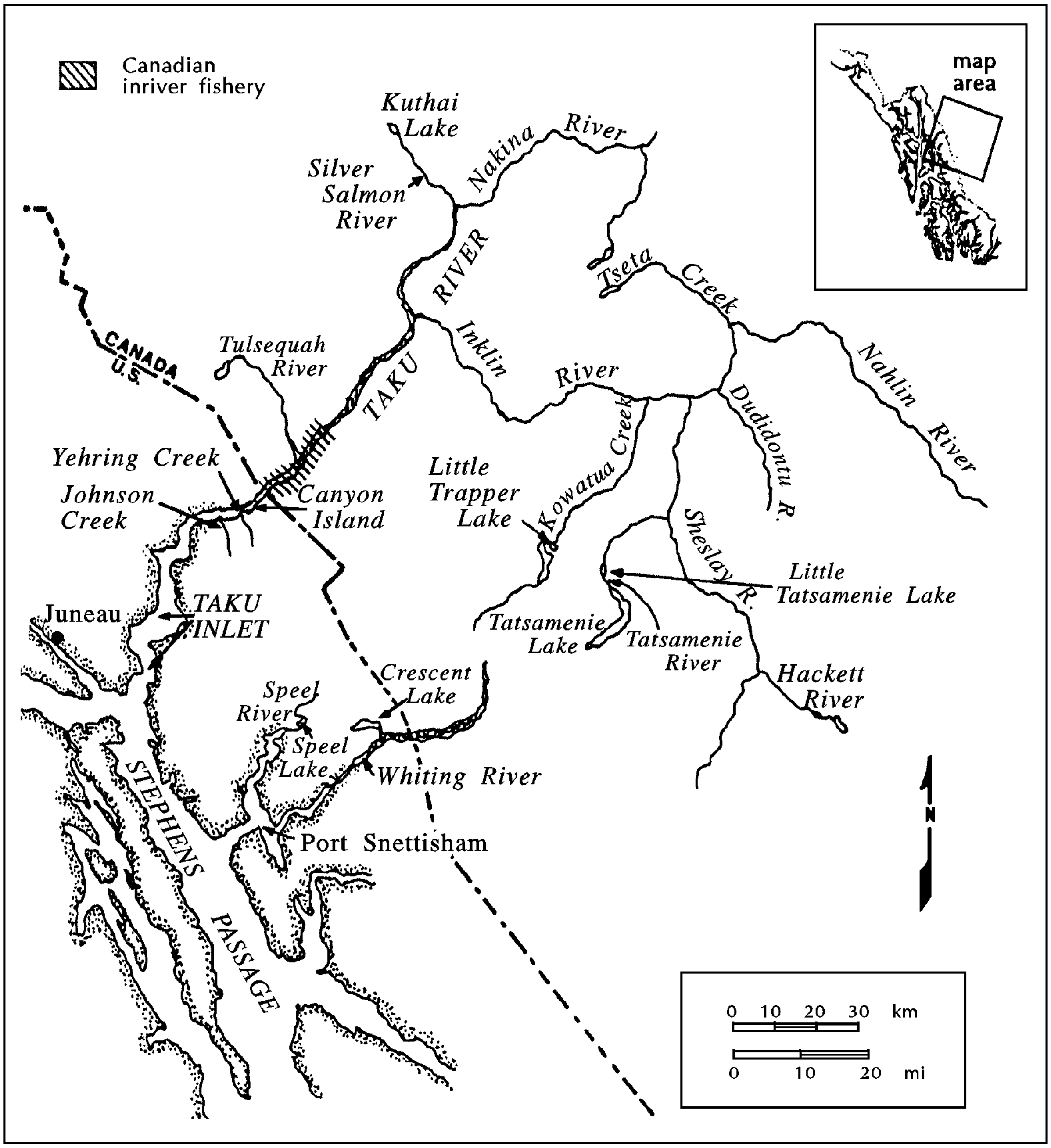

Figure 1.–Taku Inlet and Taku River drainage.

Beginning in 1976, commercial fishing for chinook salmon in SEAK was reduced substantially in terminal areas as part of what subsequently became a coast-wide, international rebuilding program under the Pacific Salmon Treaty signed in 1985. The spring troll fishery was closed in inside waters of SEAK in 1976, and in the same year, the regulatory opening date of the drift gillnet fishery in Taku Inlet (Figure 1) was delayed until the third Sunday in June. Presently, the entire annual migration is only exposed to capture in a marine recreational fishery centered near Juneau that is managed under an annual abundance-based quota for recreational fishing in all areas of SEAK. The tail end of each migration is subject to incidental capture in the commercial troll fishery in SEAK, commercial gillnet fisheries for sockeye salmon *O. nerka* in Taku Inlet and Canadian inriver fisheries. There are also inriver Canadian aboriginal and recreational fisheries. Terminal exploitation of this population is jointly managed by the U.S. and Canada through the Transboundary River Technical Committee (TTC) of the Pacific Salmon Commission (PSC) (TTC 1999).

The escapement goal for the Taku River chinook salmon stock has history dating to 1981. In 1981, the Alaska Department of Fish and Game (ADFG) began an intensive rebuilding program for chinook salmon in SEAK (ADFG 1981). This program included setting escapement goals; a survey count of 9,000 large spawners in the Nakina River became the goal for the Taku River, based on the highest survey count on record for this tributary, which was counted in 1952. With the signing of the 1985 Salmon Treaty, a drainage-wide goal range of 25,600 (U.S.) to 30,000 (Canada) large spawners was agreed to, because of differing opinions on a point estimate and an unknown expansion factor for survey counts. In 1991, the TTC jointly agreed to an index survey goal of 13,200 large spawners counted in six tributaries—Nahlin, Nakina, Dudidontu, Kowatua and Tatsamenie rivers, along with Tseta Creek (TTC 1991). This goal has been used by both nations and the PSC from 1991 to present. None of these three previous escapement goals was based on analysis of production data because little was available, though the 1991 goal did incorporate spawning distribution determined from radio telemetry in 1990.

The purpose of our analysis is to determine an optimal escapement goal range for the population of chinook salmon in the Taku River based on the best available information. An optimal escapement goal along with current stock status will be used to determine the success or failure of the rebuilding program for this population. We provide an overview of the stock assessment programs used to gather information on this population since 1973. Sources of information are cited and analyses described. Adjustments to annual estimates from stock assessment programs are described in appendices to focus attention on links between spawning abundance and subsequent production of smolts and adults.

STATISTICS

SPAWNING ABUNDANCE

Since 1973, escapements to the Taku River have been assessed with aerial surveys from helicopters. Only "large" chinook salmon, typically 3-ocean [age-1.3] 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). Age-1.1 and age-1.2 salmon (1- and 2-ocean age) were not counted because of the difficulty of seeing these fish and distinguishing them from other species. Large chinook salmon could be distinguished from smaller fish because there was little overlap in age/size distributions (Figure 2). Counts were highly correlated across tributaries (Table 1), indicating the relative strengths of year classes were the same throughout the Taku River. For this reason, 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]

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 2.

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 ADFG, the Department of

[1] Due to 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.

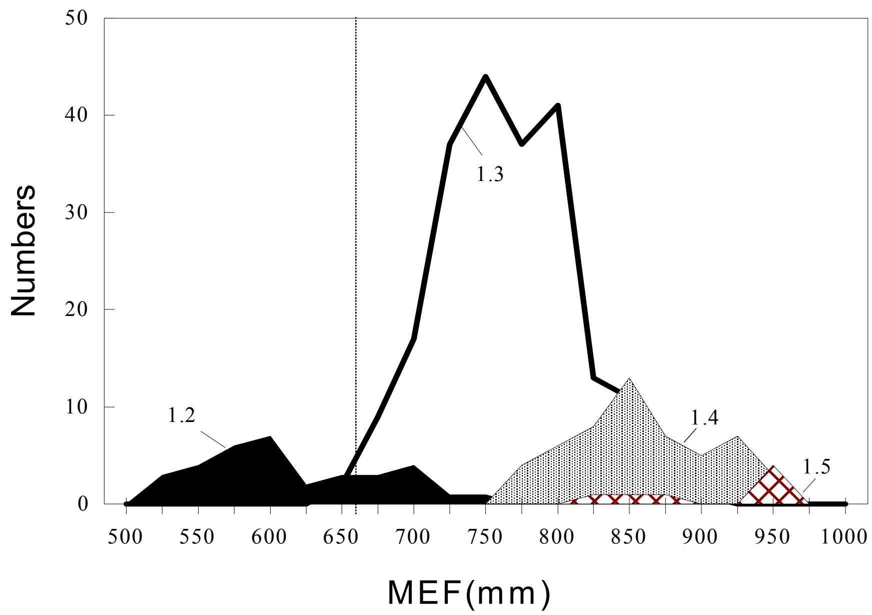

Figure 2.–Length-frequency polygons of age groups of chinook salmon sampled in fish wheels at Canyon Island on the Taku River in 1988. The dashed vertical line marks the boundary segregating "large" fish (≥660 mm MEF).

Fisheries and Oceans Canada (DFO), and the U.S. National Marine Fisheries Service (NMFS) (Pahlke and Bernard 1996; Eiler et al. *In prep*) and from cooperative tagging studies by the Division of Sport Fish (DSF) of ADFG, the Taku River Tlingit First Nation (TRTFN), CFD and DFO 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 upriver in the Nakina, Nahlin, Tatsamenie, Kowatua and Dudidontu rivers and Tseta Creek (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 et al. *In prep*). Estimated abundance was stratified into 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 2.

Abundance of spawners age-1.3 and older in years without mark-recapture experiments was estimated indirectly from an expansion factor estimated from comparison of counts C_t of large fish (≥660 mm MEF) in years with mark-recapture experiments (Table 3). Expansion factors π for individual years with experiments are 4.49 (SE = 0.63), 4.32 (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 in the accuracy of individual aerial surveys.

Age-sex composition of spawners was estimated from information gathered at a carcass weir on the Nakina River (1973-1997) and with a combination of carcass surveys, carcass weirs, and live weirs

[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.

Table 1.–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 $20 \leq df \leq 23$.

	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

Table 2.—Combined peak counts from aerial surveys, estimated total spawning abundance $\hat{N}$ with associated standard errors and approximate 95% confidence intervals for large (≥660 mm FL) chinook salmon spawning in the Taku River from 1973 through 1997. 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 relationship between counts and estimates during years with mark-recapture experiments.

Year	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**

Table 3.–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	$\hat{N}_t = C_t\,\overline{\pi}$	$v(\hat{N}_t) = C_t^2 v(\pi)$
Mean expansion factor	$\overline{\pi} = \frac{\sum_{i=1}^{k}\hat{\pi}_i}{k}$	$v(\pi) = \frac{\sum_{i=1}^{k}(\hat{\pi}_i - \overline{\pi})^2}{k-1} + \frac{\sum_{i=1}^{k} v(\hat{\pi}_i)}{k}$
Estimated expansion factor	$\hat{\pi}_i = \hat{N}_i C_i^{-1}$	$v(\hat{\pi}_i) = v(\hat{N}_i) C_i^{-2}$

on the Nahlin, Kowatua, and Tatsamenie rivers (1989, 1990, 1995–1997). Mark-recapture experiments on the Taku River (Pahlke and Bernard 1996; McPherson et al. 1996; 1997, 1998) indicated that samples taken from the latter set of three rivers were representative of all chinook salmon spawning in the Taku River, while samples taken at the carcass weir on the Nakina River were skewed to males (over-representing age-.1 and -.2 jacks) and larger females in most years. Since a complete record is available only for the Nakina River, estimates of relative age-sex composition for that subpopulation were adjusted with information from the other tributaries to complete a set of estimates for 1973–1997 (Appendix A). These adjusted estimates were combined to produce multipliers to transform estimated abundance for large fish into estimated abundance by age and gender. Estimated abundance in year t for age-sex group a and its estimated variance were calculated as:

$$\hat{N}_{a,t} = \hat{N}_t\ \hat{p}_{a,t}$$

$$v(\hat{N}_{a,t}) = v(\hat{N}_t)\hat{p}_{a,t}^2 + v(\hat{p}_{a,t})\hat{N}_t^2 - v(\hat{N}_t)v(\hat{p}_{a,t})$$

where estimated abundance $\hat{N}_t$ of large fish and its estimated variance for year t were taken from Table 2 and $\hat{p}_{a,t}$ is the appropriate multiplier for age-sex group a. Calculation of the multipliers and their estimated variances are described in Appendix B.

Table 4 contains the adjusted estimates of spawning abundance by age for all adults and by gender for large chinook salmon. Average estimated male-to-female sex ratio is 0.97 to 1 for large fish and 2.00 to 1 for chinook salmon aged 1.2 to 1.5 (age-1.2 fish are almost all males). The estimated male-to-female ratio for all ages dipped below 1 to 1 only in 1977 (0.67:1), 1994 (0.70:1), and 1997 (0.67:1).

SMOLT ABUNDANCE

Stock assessment included a tagging program to estimate smolt abundance. Smolts and/or fingerlings were implanted with coded-wire tags (CWTs) from the 1975 through 1981 broods (year classes) and from the 1991 to 1997 broods. Young fish were captured in the lower river near or downstream of the border with

Table 4.–Estimated numbers $\hat{N}_a$ of chinook salmon by age and by large (≥660 mm MEF) females and males spawning in the Taku River from 1973 through 1997. Bold numbers came directly from mark-recapture experiments. Estimated SEs for these statistics are in Appendix Table B.3.

Year	1.2	1.3	1.4	1.5	Large females	Large males
1973	8,553	7,966	6,427	172	8,929	5,631
1974	10,043	11,080	4,826	109	9,824	6,191
1975	25,074	7,998	4,800	122	4,593	8,327
1976	11,667	16,718	7,624	240	15,165	9,417
1977	4,678	12,716	16,091	689	20,466	9,030
1978	31,514	9,162	6,653	1,309	9,143	7,981
1979	28,620	18,790	2,530	297	10,997	10,620
1980	16,436	26,282	12,957	-	21,228	18,011
1981	15,597	28,133	21,426	-	25,024	24,535
1982	5,932	11,390	11,431	1,026	12,396	11,451
1983	4,571	5,935	3,705	155	4,120	5,675
1984	9,821	17,838	2,593	347	10,091	10,687
1985	12,923	25,720	10,062	134	17,447	18,469
1986	8,034	19,363	18,008	739	21,700	16,410
1987	7,715	19,856	8,291	788	12,607	16,328
1988	17,579	14,265	27,785	2,474	21,864	22,660
1989	**10,569**	**26,715**	**12,053**	**1,561**	**17,580**	**22,749**
1990	**7,095**	**20,848**	**30,124**	**1,171**	**26,749**	**25,394**
1991	21,707	24,090	23,013	4,542	27,435	24,210
1992	18,683	31,513	22,592	1,784	22,935	32,954
1993	11,217	34,594	29,762	1,769	29,976	36,149
1994	5,285	28,888	17,489	1,991	31,553	16,815
1995	**30,884**	**14,606**	**19,950**	**612**	**19,705**	**14,100**
1996	**8,005**	**71,372**	**9,901**	**143**	**40,897**	**38,122**
1997	**2,652**	**43,757**	**71,071**	**-**	**70,691**	**44,247**

baited minnow traps (Kissner and Hubartt 1986) and in later years with additional screw traps. The fraction of year class *y* tagged in year *y*+2 as smolts was estimated by summing data on adults of that year class sampled on the spawning grounds or caught at Canyon Island in years *y*+3, *y*+4, *y*+5, and/or *y*+6. Recovery of CWTs from adults on the spawning grounds showed that tagged smolts represented all subpopulations in the Taku River in near equal proportion. The estimated marked fraction of year class *y* was multiplied by the number tagged in year *y*+2 to estimate the number of smolt emigrating that year as per a simple, two-event mark-recapture experiment on a closed population (Seber 1982:60). Because too few smolt were recaptured for some year classes, estimates of smolt abundance are available only for year classes in 1975, 1976, 1979, and 1991 through 1995. Table 5 is a compendium of abundance estimates of

Table 5.–Estimated abundance of females, smolts, subsequent production of adult salmon, and estimated mean fork length for smolts for several year classes of chinook salmon in the Taku River. Standard errors for ratios (in parentheses) were approximated with the delta method (Seber 1982:7-9).

Year class	Females	Smolts	Mean smolt FL (mm)	Smolts / Females	Recruits	Adults / Smolts
1975	4,593	1,189,118	79	258.9	87,450	0.074
	(2,139)	(174,197)		(126)	(23,384)	(0.0224)
1976	15,165	1,549,052	71	102.1	65,457	0.042
	(6,478)	(374,227)		(50)	(16,615)	(0.0148)
1979	10,997	661,150	74	60.1	39,833	0.060
	(4,991)	(97,648)		(29)	(9,288)	(0.0166)
1991	27,435	2,098,862	80	76.5	196,114	0.093
	(11,842)	(295,390)		(35)	(14,153)	(0.0148)
1992	22,935	1,968,167	73	85.8	79,307 [a]	0.0403
	(10,391)	(438,569)		(43)		
1993	29,976	1,267,907	78	42.3	19,114 [b]	0.0151
	(13,573)	(564,432)		(27)		
1994	31,553	1,328,553	76	42.1		
	(13,565)	(352,068)		(21)		
1995	19,705	1,898,233	77	96.3		
	(2,644)	(626,335)		(34)		

[a] Estimate is based on final estimate of spawning abundance and preliminary statistics on harvest.

[b] Estimate is based on inputting production of age-1.4 and –1.5 salmon as the average (34% of production) over all age groups for the 1973-1991 year classes.

smolts for these year classes along with estimated abundance of the females that produced them and of the recruits they subsequently became.

MARINE HARVESTS

The coded-wire tagging program was also used, in part, to estimate likely harvests of Taku-bound chinook salmon in the commercial gillnet fishery in Taku Inlet, in the recreational fishery out of Juneau, and in the commercial troll fishery in Southeast Alaska. For year classes with tagged fish, CWTs recovered during catch sampling in the three fisheries were expanded for the fraction of the catch inspected and the estimated fraction of each year class marked as per procedures described in Bernard and Clark (1996).

These CWT expansions showed that of the mature, age-1. wild chinook salmon caught before 9 July in the commercial gillnet harvest, Taku-bound fish represented, on average, most of the harvest. We estimated harvests of Taku-bound chinook salmon in the commercial gillnet fishery by assuming that all age-1. fish during the first three or four weeks were Taku-bound (ADFG statistical weeks 25-28). This includes harvests from the third Sunday in June (average start date is 19 June) through, on average, 9 July. The gillnet harvest during these weeks averaged 1,898 chinook salmon from 1977–1997, which represents 70% of the season total in this fishery. Though some Taku-bound chinook salmon are undoubtedly caught later than this in some years, as evidenced by CWT recoveries, some harvest of other age-1. stocks is also included in our estimates and we expect these differences to cancel each other.

Estimated marine gillnet harvests were apportioned among year classes according to estimated relative age composition of the catches (Appendix C). Age samples collected from the gillnet fishery from 1982–1992 and 1995–1997 were used to estimate age composition for those years (Appendix C). Age composition for 1977–1981 and 1993–1994 were estimated by adjusting estimates of relative age composition for the Nakina River (Appendix C). For years when information is available for both the gillnet fishery and the Nakina River, regression parameters were calculated to estimate proportions by age class in the gillnet fishery in years when this fishery was not sampled. Estimated standard errors for gillnet harvests are listed in Appendix Table C2.

CWT expansions in the Juneau recreational fishery showed that of the mature, age-1. wild chinook salmon caught before late-June in this fishery, Taku-bound fish represented most of the harvests in years when random CWTs were recovered. This fishery has been sampled at relatively low rates for CWTs (9%) and, not surprisingly, few random CWTs have been recovered in this fishery. However, select CWT recoveries (heads turned in voluntarily by sport anglers), represented almost every brood year CWTd on the Taku River. We estimated Taku-bound chinook salmon in the Juneau recreational fishery by subtracting all age-0. fish and all other stocks estimated harvest from CWTs (hatchery and wild) from the spring harvests. Spring harvests include estimated harvests from late April to late June in the Juneau area. Estimated spring harvests of Taku-bound chinook salmon in the Juneau recreational fishery averaged 4,122 from 1977–1997.

These estimated marine recreational harvests were then apportioned among year classes according to estimated relative age composition of the harvests (Appendix C). Age samples collected from the Juneau recreational fishery from 1983–1997 were used to estimate age composition for those years. Age compositions for 1977–1982 were estimated by adjusting estimates of relative age composition for the Nakina River (Appendix C). Estimated standard errors for recreational harvests are listed in Appendix Table C1.

Harvests of Taku-bound chinook salmon in the commercial troll fishery in Southeast Alaska were estimated directly from CWT recoveries (Appendix Table C4). This fishery harvests myriad stocks and has been sampled at high rates for recovery of CWTs, averaging 40–45%. Given the magnitude of the harvest (over 200,000 per year average) and the high sampling rate, the likelihood of recovering CWTs from this fishery is higher than for the other two fisheries mentioned previously. This fishery has undergone large-scale changes in management; the fishery has been closed most of the spring troll period (April 16 to June 30) since 1981, when Taku-bound fish would have been harvested (Appendix D). Estimated harvests of Taku-bound chinook salmon were low following the 1976 brood year returns. Additionally, we did not have CWT estimates for the 1982–1990 year classes and we did not include estimated commercial troll harvests for these broods. Exclusion of these broods is considered negligible in the following analysis because the estimated troll exploitation rate for the 1977–1981 year classes was 2% of the total return.

These marine harvest estimates were combined with those from the inriver fishery (Table 6). This fishery occurs above the international border in Canada on the Taku River and all chinook salmon in this fishery were considered Taku-bound.

Virtually no other CWTs associated with chinook salmon of the Taku River were recovered from other marine fisheries. Incidental mortality of chinook salmon in marine fisheries was ignored in this analysis, including potential net drop-out in commercial gillnets. Only the recreational fishery near Juneau is known to cover the migration window of chinook salmon returning to the Taku River.

Some fish caught in this fishery are most likely released and some of these released fish most likely die. However, the number of released, legal-sized chinook salmon in this fishery is known to be minor, from annual creel sampling (Hubartt et al. 1999). Hence, the number of these incidentally killed chinook salmon is negligible relative to the abundance of returning adults.

INRIVER HARVESTS

Age compositions of chinook salmon caught in the inriver commercial fishery for sockeye salmon were estimated by adjusting estimates of relative age composition for the Nakina River (Appendix C). For years when information is available for both the fishery and the Nakina River, regression parameters were calculated to estimate proportions by age class in the inriver fishery in years when this fishery was not sampled. Estimated standard errors for inriver gillnet harvests are listed in Appendix Table C4. Because catches in the inriver recreational fishery are believed to be so small (<100 per year), these fish are not considered further in this analysis.

PRODUCTION

Estimated production of adults from year class y and its estimated variance were calculated as:

$$\hat{R}_y = \sum_{i=1}^{5} \hat{N}_{1.i,y+i+2} + \sum_{i=1}^{5} \hat{H}_{1.i,y+i+2}$$

$$v(\hat{R}_y) = \sum_{i=1}^{5} v(\hat{N}_{1.i,y+i+2}) + \sum_{i=1}^{5} v(\hat{H}_{1.i,y+i+2})$$

where $\hat{N}_{1.i,y+i+2}$ is the estimated number of spawners and $\hat{H}_{1.i,y+i+2}$ the estimated harvest of chinook salmon age-1.i in year y+i+2. Estimated production and estimates of their SEs are in Table 7 for year classes 1973 through 1991. Estimated production for age-1.5 salmon in the 1991 year class was not available at this writing, making the overall estimate of production for this year class negligibly conservative.

EXPLOITATION RATE

The estimated exploitation rate (Table 8) and its estimated variance were calculated as:

$$\hat{E}_y = \frac{\hat{H}_y}{\hat{R}_y}$$

$$v\left[\hat{E}_y\right] \approx \frac{v[\hat{H}_y]\hat{N}_y^2}{\hat{R}_y^4} + \frac{v[\hat{N}_y]\hat{H}^2}{\hat{R}_y^4}$$

The variance above was approximated with the delta method (Seber 1982).

ANALYSIS

MEASUREMENT ERROR

Because values of R_y and N_y are unknown for the Taku River population, their estimates were used in the analysis as substitutes. Use of estimates introduced measurement error into both independent and dependent variables. As per Bernard et al. (2000) log-normal measurement error can itself be estimated when sampling variances are calculated. For measurement error in spawning abundance

$$V[\ln(\hat{N})] = V[\ln(\hat{N})] + \sigma_u^2$$

These variances are unknown, but can be estimated as $v[\ln(\hat{N})]$ and $\hat{\sigma}_u^2$ such that

$$v[\ln(\hat{N})] = \frac{\sum[\ln(\hat{N}_y) - \overline{\ln(\hat{N})}]^2}{n-1} = 0.3033$$

$$\hat{\sigma}_u^2 = \frac{\sum \hat{\sigma}_{u,y}^2}{n} = \frac{cv^2(\hat{N}_y)}{n} = 0.1832$$

Note these calculations show estimated measurement error composed 60% (= 0.1832/0.3033) of all variation in estimated spawning abundance.

Log-normal measurement error in estimates of production was estimated as (see Bernard et al. 2000):

$$\hat{\sigma}_v^2 = \frac{\sum \hat{\sigma}_{v,y}^2}{n}$$

$$\hat{\sigma}_{v,y}^2 = v[\ln(\hat{R}_y)] \cong v(\hat{R}_y)\hat{R}_y^{-2} = cv^2(\hat{R}_y)$$

Table 6.–Estimated harvests by year and age of chinook salmon bound for the Taku River caught in commercial gillnet fisheries in Taku Inlet and in Canada, in the recreational fishery near Juneau and in the commercial troll fishery in Southeast Alaska. Standard errors are in parentheses.

Year	1.2		1.3		1.4		1.5		Total	
1977	183	(90)								
1978	1,403	(278)	1,818	(355)						
1979	3,297	(710)	5,402	(561)	1,559	(366)			10,259	(976)
1980	891	(202)	3,745	(1,022)	5,390	(404)			10,026	(1,117)
1981	543	(148)	4,930	(1,905)	3,041	(1,027)			8,514	(2,169)
1982	941	(54)	1,661	(445)	3,480	(969)	12	(9)	6,143	(1,068)
1983	725	(35)	637	(79)	1,060	(325)			2,493	(337)
1984	799	(66)	4,173	(926)	345	(61)	9	(9)	5,370	(930)
1985	777	(65)	1,983	(180)	1,703	(419)	30	(20)	4,501	(461)
1986	560	(108)	942	(121)	1,147	(133)	22	(12)	2,702	(212)
1987	505	(64)	1,031	(109)	1,039	(408)	122	(41)	2,707	(430)
1988	797	(128)	409	(135)	1,090	(129)	25	(14)	2,339	(227)
1989	868	(158)	2,452	(274)	914	(133)	118	(38)	4,357	(345)
1990	1,292	(329)	1,875	(347)	2,666	(353)	48	(22)	5,884	(595)
1991	2,183	(286)	2,252	(346)	3,657	(395)	312	(76)	8,404	(603)
1992	1,103	(234)	2,435	(350)	2,546	(354)	37	(21)	6,121	(550)
1993	1,724	(640)	4,168	(677)	6,077	(687)	170	(50)	12,139	(1,159)
1994	1,059	(531)	3,563	(541)	3,196	(377)	108	(33)	7,927	(847)
1995	4,365	(412)	2,115	(438)	2,228	(234)	159	(58)	8,867	(647)
1996	727	(547)	9,674	(1,110)	1,117	(306)	75	(31)	11,594	(1,275)
1997	241	(50)	3,702	(257)	8,748	(1,132)			12,692	(1,162)

Table 7.–Estimated production $\hat{R}_y$ by age and year class for chinook salmon in the Taku River. Standard errors are in parentheses.

Year class	1.2		1.3		1.4		1.5		Total	
1973	4,861	(3,203)	10,980	(3,946)	4,089	(1,276)			19,931	(5,266)
1974	32,917	(20,686)	24,192	(7,732)	18,347	(6,061)			75,456	(22,913)
1975	31,917	(18,120)	30,027	(11,160)	24,467	(9,540)	1,038	(543)	87,450	(23,384)
1976	17,327	(9,947)	33,063	(12,117)	14,911	(5,066)	155	(86)	65,457	(16,615)
1977	16,140	(9,846)	13,051	(4,958)	4,765	(1,660)	356	(174)	34,312	(11,164)
1978	6,873	(3,901)	6,572	(2,518)	2,938	(1,318)	164	(67)	16,547	(4,828)
1979	5,296	(3,003)	22,011	(7,348)	11,765	(4,696)	761	(404)	39,833	(9,288)
1980	10,620	(5,889)	27,703	(10,772)	19,155	(8,055)	910	(406)	58,388	(14,691)
1981	13,700	(8,083)	20,305	(8,495)	9,330	(3,870)	2,499	(1,467)	45,833	(12,442)
1982	8,594	(5,175)	20,887	(8,320)	28,875	(11,905)	1,679	(294)	60,035	(15,423)
1983	8,220	(4,945)	14,674	(6,471)	12,967	(1,770)	1,219	(264)	37,079	(8,341)
1984	18,376	(11,808)	29,167	(3,819)	32,790	(5,434)	4,854	(2,385)	85,187	(13,764)
1985	11,437	(1,589)	22,723	(3,779)	26,670	(10,244)	1,821	(1,050)	62,650	(11,097)
1986	8,387	(1,338)	26,342	(10,328)	25,138	(10,069)	1,939	(964)	61,805	(14,530)
1987	23,890	(14,085)	33,948	(13,421)	35,839	(13,300)	2,099	(970)	95,777	(23,601)
1988	19,786	(12,515)	38,762	(15,006)	20,685	(8,135)	771	(174)	80,004	(21,182)
1989	12,941	(7,438)	32,451	(12,321)	22,178	(2,600)	218	(84)	67,788	(14,651)
1990	6,344	(3,400)	16,715	(1,952)	11,018	(1,287)			34,078	(4,194)
1991	35,249	(3,848)	81,046	(7,692)	79,819	(11,120)			196,114	(14,153)
Average	15,414		26,559		21,355		1,078		64,406	

Table 8.–Estimated large spawners $\hat{N}_y$, large female spawners $\hat{N}_{y,F}$, production $\hat{R}_y$, return rate ($\hat{R}_y$ / $\hat{N}_y$) and exploitation rate $\hat{E}_y$ by year class for chinook salmon in the Taku River. Standard errors are in parentheses.

Year class	$\hat{N}_y$	$\hat{N}_{y,F}$	$\hat{R}_y$	$\frac{\hat{R}_y}{\hat{N}_{y,F}}$	$\hat{E}_y$
1973	14,564 (5,968)	8,929 (3,864)	19,931 (5,266)	2.2 (1.13)	0.179 (0.052)
1974	16,015 (6,563)	9,824 (4,236)	75,456 (22,913)	7.7 (4.05)	0.162 (0.050)
1975	12,920 (5,294)	4,593 (2,139)	87,450 (23,384)	19.0 (10.22)	0.115 (0.035)
1976	24,582 (10,073)	15,165 (6,478)	65,457 (16,615)	4.3 (2.14)	0.142 (0.046)
1977	29,497 (12,087)	20,466 (8,678)	34,312 (11,164)	1.7 (0.90)	0.095 (0.034)
1978	17,124 (7,017)	9,143 (3,997)	16,547 (4,828)	1.8 (0.95)	0.118 (0.035)
1979	21,617 (8,858)	10,997 (4,991)	39,833 (9,288)	3.6 (1.85)	0.166 (0.044)
1980	39,239 (16,080)	21,228 (9,450)	58,388 (14,691)	2.8 (1.41)	0.069 (0.018)
1981	49,559 (20,308)	25,024 (11,144)	45,833 (12,442)	1.8 (0.96)	0.061 (0.019)
1982	23,848 (9,773)	12,396 (5,426)	60,035 (15,423)	4.8 (2.46)	0.047 (0.012)
1983	9,794 (4,014)	4,120 (1,903)	37,079 (8,341)	9.0 (4.62)	0.051 (0.012)
1984	20,778 (8,514)	10,091 (4,720)	85,187 (13,764)	8.4 (4.18)	0.073 (0.013)
1985	35,916 (14,718)	17,447 (7,820)	62,650 (11,097)	3.6 (1.73)	0.103 (0.020)
1986	38,111 (15,617)	21,700 (9,523)	61,805 (14,530)	2.8 (1.42)	0.101 (0.025)
1987	28,935 (11,857)	12,607 (5,778)	95,777 (23,601)	7.6 (3.95)	0.113 (0.029)
1988	44,524 (18,245)	21,864 (9,742)	80,004 (21,182)	3.7 (1.90)	0.108 (0.030)
1989	40,329 (5,646)	17,580 (4,827)	67,788 (14,651)	3.9 (1.35)	0.112 (0.027)
1990	52,142 (9,326)	26,749 (5,831)	34,078 (4,194)	1.3 (0.32)	0.126 (0.025)
1991	51,645 (21,163)	27,435 (11,842)	196,114 (14,153)	7.1 (3.13)	0.116 (0.011)
Average	30,060	15,650	64,406	5.1	0.108

For the population in the Taku River, $\hat{\sigma}_v^2 =$ 0.0583. Estimated measurement error for the estimated log of the production-to-spawner ratio $\hat{R}_y / \hat{N}_y$ is $\hat{\sigma}_{uv,y}^2 = cv^2(\hat{R}_y) + cv^2(\hat{N}_y)$. The average over all year classes is $\hat{\sigma}_{uv}^2 = 0.2415$.

The magnitude of measurement error in estimates of production and spawning abundance for this stock was graphically displayed with the aid of simulation (Figure 3). A log-standard normal variate was randomly selected for each estimate of harvest, spawning abundance, and relative age composition, then transformed into a variate with the appropriate mean and variance, thereby creating a new set of statistics from the original. These new simulated statistics were multiplied and their products added appropriately to obtain a simulated set of data pairs $\{\tilde{R}_y, \tilde{N}_y\}$. The process was used to create 950 pairs. The cloud of simulated points spreads out horizontally from close on the y-axis out to about twice the highest estimate of spawning abundance. The cloud also spreads vertically topped by a curious wisp of points set above the cloud. The wisp is a result of the relatively precise estimate of production for the 1991 year class [$cv(\hat{R}_{91})$ = 7.0%] (due to mark-recapture experiments) and poor precision in estimates of the females that spawned them [$cv(\hat{N}_{91})$= 43%] from the expansion of an aerial survey). This contrast in precision laterally flattens and elongates the cloud of simulated points for this year class. Simulated points for the 1991 year class are set above the rest because their production was atypically strong.

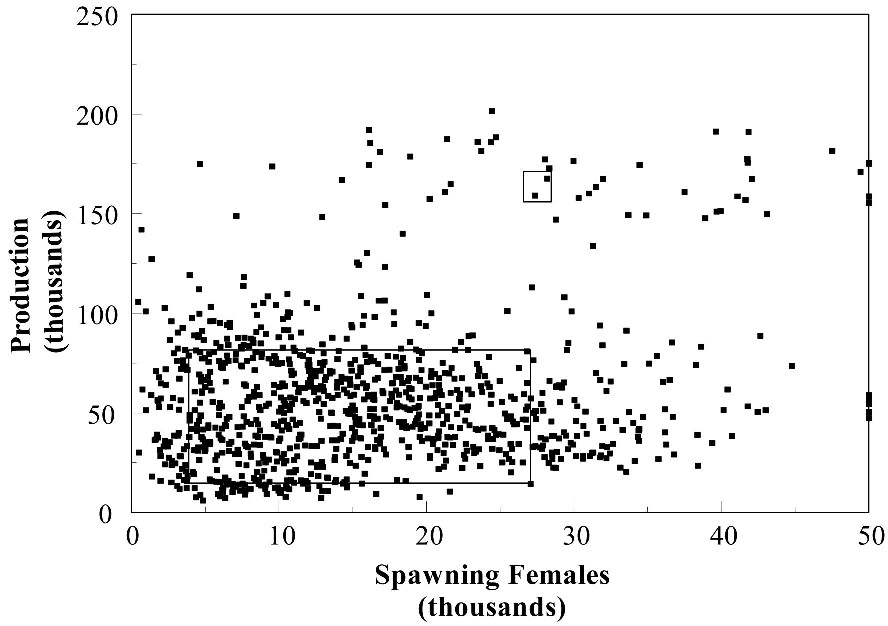

Figure 3.–Spawning abundance of females and associated production simulated from the measurement error in the original data. Boxes correspond to the range of the original data. Bands along the right edge of the plot correspond to a few instances with spawning abundance beyond 50 thousand females.

PARAMETER ESTIMATES

Two models were used in the analysis: Ricker's exponential function (Ricker 1975) $R_y = \alpha S_y \exp(-\beta N_y)\exp(\varepsilon_y)$ and Cushing's power function $R_y = \alpha' N_y^{\beta'} \exp(\varepsilon_y)$ (Cushing 1973). The latter is an approximation to the former that allows incorporation of measurement error in spawning abundance in the analysis. The term ε_y represents process error in both models where $\varepsilon_y \sim norm(0, \sigma_\varepsilon^2)$. Parameters were estimated for the linear form of Ricker's model $\ln(R_y) - \ln(N_y) = \ln(\alpha) - \beta N_y + \varepsilon_y$ (Table 9) with the computer program Systat™. Because estimated precision for brood years 1989-91 was considerably improved over earlier year classes, parameters were estimated with unweighted regression and with regression where the dependent variable was weighted by $1/\hat{\sigma}_{uv,y}^2$. No autocorrelation among residuals or higher order influence of spawning abundance could be found (as per methods in Bernard et al. 2000). Predictions by the fitted, untransformed model and the original data are given in Figure 4. Spawning abundance that on average produces maximum sustained yield (N_{MSY}) was estimated by iteratively solving the following transcendental relationship:

$$1 = (1 - \hat{\beta}\hat{N}_{msy})\exp(-\hat{\beta}\hat{N}_{msy})(1+\tau)^{-1} \exp(\ln\hat{\alpha} + \hat{\sigma}_\varepsilon^2/2)$$

for $\hat{N}_{MSY}$ where $\hat{\sigma}_\varepsilon^2 = \hat{\sigma}_r^2 - \hat{\sigma}_{uv}^2$ = 0.12 for both unweighted and weighted regressions, $\hat{\sigma}_r^2$ is the mean square error from the fitted regression, and the male-to-female ratio τ = 1. Little difference was seen between statistics for the unweighted and weighted regression ($\hat{N}_{MSY}$ = 11,629 vs.

Table 9.–Estimated parameters for unweighted and weighted regression on the log-linear transform of Ricker's model on estimates of production and spawning abundance of chinook salmon in the Taku River.

	Unweighted	**Weighted**
$\ln(\hat{\alpha})$	2.2240 (P < 0.0001)	2.3191 (P < 0.0001)
$\hat{\beta}$	-0. 00005338 (P=0.0146)	-0. 00006184 (P=0.0035)
R^2(corrected)	0. 2621	0. 3673
$\hat{\sigma}_r^2$	0. 3606	0. 3646
$\hat{\sigma}_\varepsilon^2$	0.1191	0.1231
$\hat{N}_{MSY}$ (females)	11,629	10,459
$\hat{E}_{MSY}$	0.62	0.65

10,416 females and $\hat{E}_{MSY} = \hat{\beta}\hat{N}_{MSY}$ = 62% vs. 64%) (Table 9). These estimates have been adjusted for measurement error in the dependent variable, but not for measurement error in the independent variable.

Adjustment for measurement error from estimating spawning abundance dramatically changes perspectives on values of N_{MSY} and E_{MSY}. In the log-linear transform of Cushing's model $\ln(R_y) = \ln(\alpha') - \beta' \ln(N_y) + \varepsilon_y$, estimates for parameters $\ln(\alpha')$ and β' are (see Bernard et al. 2000)

$$\hat{\beta}' = \frac{m_{XY}}{m_{XX} - \hat{\sigma}_u^2} =$$

$$\frac{(n-1)^{-1}\sum_y^n(\ln\hat{N}_y - \overline{\ln\hat{N}})(\ln\hat{R}_y - \overline{\ln\hat{R}})}{(n-1)^{-1}\sum_y^n(\ln\hat{N}_y - \overline{\ln\hat{N}})^2 - \hat{\sigma}_u^2} =$$

0.5926

$$\ln(\hat{\alpha}') = \overline{\ln\hat{R}} - \hat{\beta}'\overline{\ln\hat{N}} = 5.2726$$

The estimate for N_{MSY} (females) with this model adjusted for measurement error in both dependent and independent variables is

$$\hat{N}_{MSY} = {}^{\hat{\beta}'-1}\sqrt{\frac{1+\tau}{\hat{\alpha}'\hat{\beta}'}} = 30,917$$

where $\hat{\alpha}' = \exp(\ln\hat{\alpha}' + \hat{\sigma}_\varepsilon^2/2)$ and $\hat{\sigma}_\varepsilon^2 = \hat{\sigma}_r^2 - \hat{\sigma}_v^2 =$ 0.29. The estimate of the exploitation rate associated with N_{MSY} is

$$\hat{E}_{MSY} = 1 - \hat{\beta}' = 0.41$$

These estimates of N_{MSY} and E_{MSY} have been adjusted for measurement error in both dependent and independent variables. Parameter estimates are reported in Table 10, and predicted values in Figure 4.

Inspection of Figure 4 shows that the 1991 year class is unusually influential in determining the fit of Cushing's model to data from the Taku River. If information on that year class is excluded from

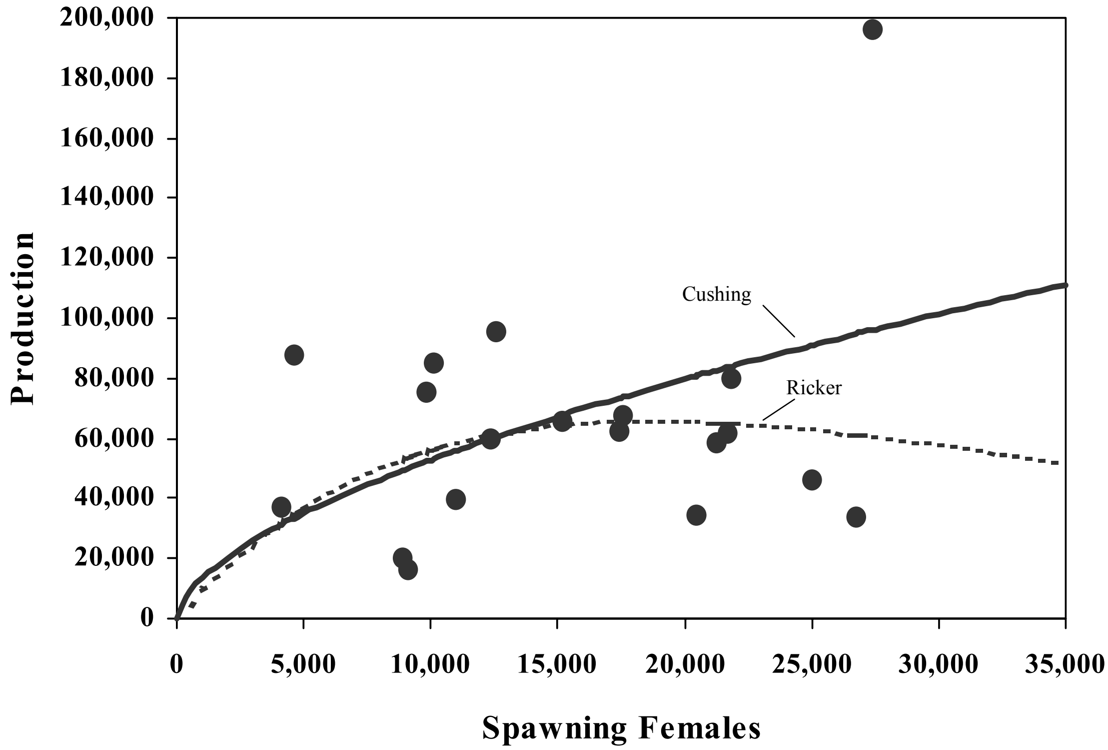

Figure 4.–Estimated production of age-1.2 to -1.5 chinook salmon in year classes 1973 through 1991 against the estimated abundance of females that spawned them, along with curves corresponding to least-squares fits of Ricker and Cushing models to all data.

Table 10.–Estimated parameters for the log-linear transform of Cushing's power function fit to all data on production and spawning abundance of chinook salmon in the Taku River and fit to data with the 1991 year class excluded.

	All data	**1991 excluded**
$\ln(\hat{\alpha}')$	5.2726	8.9688
$\hat{\beta}'$	0.5926	0.1983
R^2(corrected)	0.2841	0.0389
$\hat{\sigma}_r^2$	0.3706	0.2666
$\hat{\sigma}_\varepsilon^2$	0.3123	0.2083
$\hat{N}_{MSY}$	30,917	4,602
$\hat{E}_{MSY}$	0.41	0.80

the data and Cushing's model refit, the resulting statistics differ dramatically (Table 10) with $\hat{N}_{MSY}$ dropping to 4,602 and $\hat{E}_{MSY}$ rising to 80%.

SMOLT PRODUCTION

An analysis of the more precise statistics on production and on the auxiliary data in Table 5 on smolt production, reveals evidence to support the following:

- a wide range of spawning abundance over the years with even a wider range to come;
- density-dependent survival in the early freshwater life of young chinook salmon;
- density-independent survival in the later freshwater life of young chinook salmon;
- density-independent survival of smolts at sea; and
- an upper bound on the production of smolts from the Taku River.

The range in spawning abundance observed over the years is not an artifact of measurement error. Based on expansions of counts from aerial surveys, the lowest spawning abundances of females were 4,120 in 1983 and 4,593 in 1975 (Table 11). In 1990 the spawning abundance was estimated at 26,749 females with a mark-recapture experiment. While relative precision on the lower estimates is not good, that on the higher estimate in 1990 is good enough to show with high probability ($P<0.05$) that the six-fold increase it represents is real. The same is true for spawning abundance estimated in 1997, 2.6 times higher than in 1990 and 17 times higher than in 1983.

Density-dependent survival of young in their early freshwater existence is indicated because the highest relative production of adults occurred when spawning abundance was lowest in 1975 and 1983 (Table 11). The probability from random chance alone (measurement error) that the two smallest numbers of spawners would have the highest relative rate of production over 19 year classes is 0.0058 [$= 2(\frac{1}{19})(\frac{1}{18})$]. The next

Table 11.–Extreme estimates of female spawning abundance and their ratios with subsequent production. Standard errors are in parentheses; SE for ratios were approximated with the delta method (Seber 1982:7-9)

Year class	$\hat{N}_{y,F}$	$\frac{\hat{R}_y}{\hat{N}_{y,F}}$
1975	4,593 (2,139)	19.040 (10.225)
1983	4,120 (1,903)	9.000 (4.624)
1990	26,749 (5,831)	1.274 (0.319)
1997	70,691 (11,080)	

estimated highest ratio was 8.442 for the 1984 year class spawned by an estimated 10,091 females; the lowest estimated ratio was 1.274 for the 1990 year class.

The limited range in size of smolt (Table 5) is evidence that the density-dependent survival has an early influence on young, at least over the years for which we have estimates. The range in estimated smolt abundance (661,150 to 2,118,226) is statistically significant ($P<0.01$) while the corresponding sizes of these smolts were similar (74 vs. 73 mm FL). Lack of density-dependent growth indicates that rearing habitat was probably not a compensatory limiting factor, nor was predation a detectable depensatory factor in mortality of young. The range of 71 to 80 mm FL for smolts expressed in Table 5 is representative of all studied year classes.

Comparison of the estimated number of adults produced from an estimated number of smolts points to density-independent marine survival. Estimated smolt abundance from the 1976 and 1991 year classes (1.55 vs. 2.10 million from Table 5) were not significantly different ($P>0.20$); an estimated 4.2% returned as adults for the earlier year class and 9.3% for the later year class. While the estimated numbers of smolt are not statistically different, the return rates are (P<0.01). The estimated size of smolts for these year classes (71 and 80 mm FL) do cover the observed range. In contrast, estimated smolt abundance was significantly different for the 1975 and 1979 year classes (1.20 vs. 0.66 million, P<0.01) while their return rates were very similar (0.074 vs. 0.060; P>0.50). Estimated smolt size for the 1975 and 1979 year classes are closer: 74 vs. 79 mm FL.

The evidence in the auxiliary information underpinning a ceiling on the number of smolts produced each year by the Taku River is circumstantial. Early density-dependence in the freshwater existence of chinook salmon is the result of limited, high quality spawning habitat or limited rearing habitat for emerging young. If the earliest determinants of year-class strength are the only density-dependent factors in the life history of the population (as may be indicated), the highest production observed from a given spawning abundance captures the most information on density dependence.[3] For these reasons, the highest production ratio (smolts/female) for a given spawning abundance (females) is the best reflection of the effect of density-dependent survival on young. The year classes with the highest production ratios are 1975, 1976, 1991, 1992 and 1995 (Table 5). The other year classes, with more or fewer numbers of spawners, had estimated smolt production unexpectedly low given the estimated abundance of female parents. If there is a ceiling on smolt production in the Taku River, smolt production for the year classes with the highest production rates should follow an asymptotic, density-dependent relationship (Figure 5). However, smolt production is too similar among the year classes and the precision in estimates too poor to distinguish an asymptote. Under these circumstances, the average of the four highest smolt estimates (1976, 1991, 1992 and 1995), 1.879 million smolt with a SE of 0.451 million, is a minimal estimate of the ceiling. The 1975 year class smolt estimate was excluded from this calculation because it was significantly different from the 1991 estimate (P<0.01).

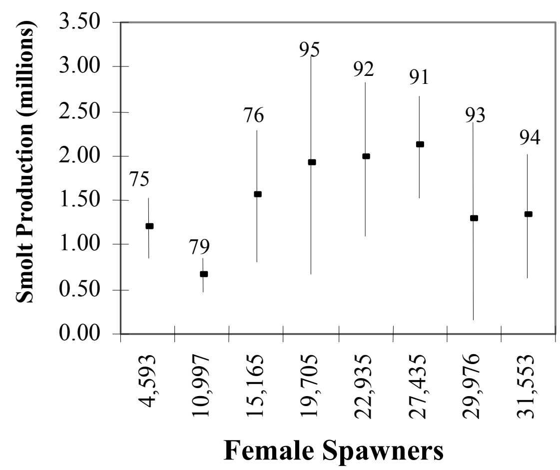

Figure 5.–Estimated smolt production and estimated abundance of female parents for the 1975, 1976, 1979, and 1991–1995 year classes. Intervals on smolt production are approximate 95% confidence intervals.

CONCLUSIONS

Given the measurement error in estimates of adult abundance, the most defensible estimate for N_{MSY} is a range from 30,000 to 55,000 large spawners, estimated as total escapement, i.e., from mark-recapture or expanded aerial survey count. This range was chosen as twice the number of females that had produced near or at the maximum number of smolt, i.e., the four highest estimates of smolt production in Figure 5. In 1976 an estimated 15,165 large females spawned and produced an estimated 1.55 million smolts that went to sea in 1978; in 1991 an estimated 27,435 large females spawned and produced an estimated 2.1 million smolts that went to sea in 1993 (Table 5). Given density-independent marine survival, maximizing smolt production with a minimal number of spawners will result on average in production near to MSY, which is the lower end of the range. The

[3] For instance, 27,345 females in 1991 produced 2.1 million smolts (Table 5), and about the same number of females (31,553) three years later produced about 1.3 million smolts. The difference of 0.8 million smolts is significant (P <0.10) and represents the effects of density-independent factors alone.

above-mentioned range, after accounting for an expansion factor of 5.20, translates to an index survey count goal of approximately 5,800 to 10,600 large spawners, summed across five tributaries—Nahlin, Nakina, Dudidontu, Kowatua and Tatsamenie rivers.

A point estimate for N_{MSY} of 35,938 can be derived from the range of 30,000 to 55,000 large spawners (age 1.3 and older). Eggers (1993) showed that for sockeye salmon (*O. nerka*), a range of 80% to 160% of N_{MSY} produces a yield that is ≥90% of MSY. If this same relationship is true for chinook salmon, two estimates of N_{MSY} for the chinook salmon in the Taku River would be 30,000/0.80 = 37,500 and 55,000/1.6 = 34,375. The average of these two estimates would be approximately 36,000 large spawners.

Parameter Estimates. Estimates of α and β (Ricker's model) for use in the CTC model were also estimated from smolt data. Smolt production over year classes with spawning escapements from 30,000 to 55,000 (1976, 1991, 1992, 1995) averaged 1,878,579 smolts (Table 2.5). The geometric mean of estimated adult-to-smolt ratios is 0.0468 (Table 5) making the expected production at N_{MSY} to be 87,982 [= (0.047)(1,878,579)] salmon. Given Hilborn's approximation (Hilborn 1985), there are two equations with two unknowns:

$$87{,}892 = \alpha(35{,}938)\exp[-\beta(35{,}938)] \text{ :Ricker's model}$$

$$35{,}938 = \frac{\ln(\alpha)}{\beta}(0.50 - 0.07\ln\alpha) \text{ :Hilborn's approximation}$$

Solving these equations produces estimates $\hat{\alpha}$ = 4.4055 and $\hat{\beta}$= 0.00001635. The estimate for the exploitation rate associated with N_{MSY} is 0.59 ($=\hat{E}_{MSY}$).

Lower levels of spawning abundance were considered too risky when survival in freshwater has a significant density-independent component. The 1975 year class began with marginally fewer females (an estimated 4,593) than in 1976 and produced marginally fewer smolt (1.2 million). Both these statistics are precise enough to feel confident of the reality of low spawning abundance and subsequently good smolt production. However, the 1979 year class produced only 0.7 million smolt from a similar spawning abundance. This difference in smolt production of 0.5 million is statistically significant (P<0.01) and represents density-independent freshwater survival.

The upper end of the N_{MSY} range reflected the higher levels of spawning abundance where high smolt production was maintained. Smolt estimates for the 1993 and 1994 year classes are lower than the higher smolt estimate from the 1991 year class. These may or may not be the result of density-independent factors, but they represented no improvement in smolt production beyond the chosen level.

We conclude that the Taku River chinook salmon stock has been rebuilt from low levels of escapements in the 1970s. Escapements in the 1970s averaged an estimated 19,500 large spawners. In contrast, estimated escapements in the 1990s have averaged 62,750 large spawners, a threefold increase.

DISCUSSION

Stability of environment, at least around average conditions, is presumed under traditional statistical analysis of stock-recruit data; the same is true under our scientific analysis of auxiliary information about chinook salmon of the Taku River. Evidence in our data for such stability is that:

- Smolt sizes were essentially the same for early and late year classes in the series;
- Maximum production of smolt is similar across year classes; and
- There was negligible or no loss of habitat during our series from land development, land use, or human habitation.

Evidence in our data against such stability of environment can be found in the marine survival for the 1991 year class (0.093) which was 58% higher (P<0.01) than the average for year classes two decades earlier (0.059). However, the 1991 year class is an outlier and other year classes from the 1990s are not returning at the same rate as the 1991 year class, as judged from returns of young age classes. Hence, we see no evidence that return rates have changed over the two decades in this data set.

All ongoing scientific investigations improve with the addition of new information; this will be especially true for future investigations of the chinook salmon of the Taku River. In the next several years, adults will return for year classes that began with considerably greater numbers of spawners than in the past. Better precision in future adult estimates from mark-recapture experiments will clarify analysis of these returns; imprecision in statistics from aerial surveys greatly hampered the current analysis. Better precision in future statistics would improve the dependability of more traditional stock-recruit analyses. Estimates of smolt abundance, especially for the 1997 year class, may provide strong clues as to how many smolts the Taku River can produce. If smolt production from this exceptionally large number of spawners is considerably above the 2.1 million maximum estimated from data available now, the current estimate of N_{MSY} would have to be increased. Unfortunately, investigating productivity of chinook salmon is not for the impatient; smolt abundance for the 1997 year class can not be estimated with reasonable accuracy until 2001 or 2002.

Alternatively, future stock assessment results may show that we overestimated escapements in earlier years, those without mark-recapture estimates. The expansion factor of 5.20 may have inflated those estimates. The mean expansion factor is 4.33, excluding 1997. If future investigations show that a lower expansion factor is more appropriate, those earlier estimates of escapement will be lowered, along with the escapement goal range.

Managing for the recommended management range of 30,000 to 55,000 large spawners may not be beyond the capability of ADFG and DFO, given refinement of our stock assessment program. We are in the process of developing preseason forecasts, relying heavily on the data developed in this manuscript. Inseason monitoring of the escapement needs to be developed. One option is to implement a test fishery in May and early June near the international border to provide inseason estimates of escapement from mark-recapture methods, similar to existing programs for sockeye and coho salmon on the Taku River (Kelley and Milligan 1999).

RECOMMENDATIONS

Since this analysis may set the stage for future considerations, we recommend some strategies to improve a future analysis and improve management.

We believe that preserving long-term stock assessment programs should continue to be one of the highest priorities for ADFG, DFO, TRTFN and the Pacific Salmon Commission (PSC). These types of programs provide information on the population dynamics of the resource, which is often poorly understood due to the lack of long-term programs. For the Taku River chinook stock we recommend that:

- Enumeration of total spawning abundance from mark-recapture studies be continued annually.
- Aerial surveys be continued annually for a number of years to refine estimates of the variability in expansion factors, until such time it is determined they are no longer needed.
- Biological sampling be continued (and improved in some cases) annually for all fisheries and in the escapement for age, sex and size structure as well as recovery of CWTs and other tags.
- Chinook smolt be CWTd annually at high rates (35,000 to 50,000).
- ADFG and DFO adopt the range of 30,000 to 55,000 large spawners as a biological escapement goal, and structure management to achieve escapements throughout the range.
- Preseason and inseason estimates of run size and escapement be developed prior to implementation of new or directed fisheries.
- An international management plan be developed and adopted by both nations through the Transboundary River Technical Committee of the PSC.

- This escapement goal be reviewed in 2003/2004, incorporating additional data available at that time.

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Appendix A:
Estimates of Relative Age-Sex Composition of Spawning Chinook Salmon

Relative age-sex composition of spawners was estimated from information gathered at a carcass weir on the Nakina River (1973-1997) and with a combination of carcass surveys, carcass weirs, and live weirs on the Nahlin, Kowatua, and Tatsamenie rivers. Mark-recapture experiments on the Taku River (Pahlke and Bernard 1996; McPherson et al. 1996; 1997, 1998) indicated that samples taken from the latter set of three rivers were representative, while samples taken at the carcass weir on the Nakina River were skewed to males and larger females in most years. Since a complete record is available only for the Nakina River, estimates of relative age-sex composition for that population were adjusted with information from the other tributaries to complete a set of estimates for 1973 – 1997.

The adjustment is based on the assumption that populations in all tributaries have the same relative age-sex composition. Comparison of statistics shows strong and weak year classes are repeated across tributaries (see Pahlke and Bernard 1996: Figure 4), and trends in counts are correlated across populations (Table 1). If these populations have the same relative age-sex compositions:

$$\theta_a = \frac{N_a}{N} = \frac{M_a}{M}$$

where M is the number of spawners in Nakina River, M_a is the subset of that population in age-sex group a, and N and N_a are the corresponding numbers for the other populations. If ρ_a is the probability of sampling a fish in group a on the Nakina River, the expected number of chinook salmon of that group in a randomly drawn sample from the Nakina River is:

$$\mathrm{E}[m_a] = M_a \rho_a$$

Similar equations exist for all age-sex groups. Because $M_a = M\,\theta_a$, $M_b = M\,\theta_b$, etc:

$$\mathrm{E}[m_a] = M\theta_a\rho_a$$
$$\mathrm{E}[m_b] = M\theta_b\rho_b$$

and so forth. If the equation for group a is divided into the equation for group b and rearranged:

$$\frac{\rho_b}{\rho_a} = \frac{\theta_a \mathrm{E}[m_b]}{\theta_b \mathrm{E}[m_a]}$$

If ρ_a is arbitrarily set to 1 and estimates plugged into the equation above:

$$\hat{w}_b = \frac{\hat{\theta}_a m_b}{\hat{\theta}_b m_a}$$

where $\hat{w}_b$ is the estimate of ρ_b relative to ρ_a. Weighted estimates for other groups can be calculated in the same way. Since estimates of relative age-sex composition are a function of the relative magnitudes of the probabilities of capture, scaling all probabilities to that for a single group has no effect on the estimates.

Solutions to $\{\boldsymbol{w}\}$ were calculated for years with mark-recapture experiments (1989, 1990, 1995-1997), then elements averaged across years to produce expansion factors (Table A.1). Relative age-sex composition for all chinook salmon age-1.2 through -1.4 were estimated from pooled samples drawn from Nahlin, Tatsamenie, and Kowatua rivers:

$$\hat{\theta}_{a,t} = \frac{n_{a,t}}{n_t}$$

where n_t is the pooled number of samples, $n_{a,t}$ the number of those samples from age-sex group a, and t is the year of sampling. The few sampled fish that were age-2. were considered inconsequential and were lumped with those age-1. Because sampling age-1.1 jacks was problematical over the years, these fish were ignored as an age-sex group. So few age-1.2 females were found (<0.01%) that these fish were also ignored. Samples for age-1.5 chinook salmon of both sexes were not adjusted because their representation in samples was so low (≤2%). The remaining five age-sex groups in the adjustment are age-1.3 females (considered group *a*), -1.4 females, -1.2 males, -1.3 males, and -1.4 males.

Table A.2 contains the adjusted estimates for relative age-sex composition for chinook salmon spawning in the Taku River from 1973-1997. For years with mark-recapture experiments, estimates of relative age-sex composition for spawners in the river were calculated directly from samples taken at on the Nahlin, Kowatua, and Tatsamenie rivers. In other years, estimates were calculated as adjustments of statistics based on samples from the Nakina River:

$$\hat{\theta}_a = \frac{m_a}{m_a + m_b \overline{w}_b^{-1} + m_c \overline{w}_c^{-1} + \ldots}$$

$$\hat{\theta}_b = \frac{m_b \overline{w}_b^{-1}}{m_a + m_b \overline{w}_b^{-1} + m_c \overline{w}_c^{-1} + \ldots}$$

and so forth. Estimated variances for $\{\hat{\theta}_t\}$ in year *t* were obtained through simulation (Table A.3). During the *k*th iteration of a simulation, two vectors of new sample sizes $\{\mathbf{n}_i'\}_k$ and $\{\mathbf{m}_t'\}_k$ were generated from the probability distributions multinom(n_i, $\{\hat{\theta}_i\}$) and multinom(m_t, $\{\hat{\phi}_t\}$) where *i* represents one of the years with mark-recapture experiments drawn at random with replacement. Elements of the vector $\{\hat{\phi}_t\}$ are estimates of relative age-sex composition from the sampling program on the Nakina River in year *t*:

$$\hat{\phi}_{a,t} = \frac{m_{a,t}}{m_{a,t} + m_{b,t} + m_{c,t} + \ldots}$$

and so forth. A new set of weights were calculated for each vector of simulated sample sizes:

$$\hat{w}'_{b,t(k)} = \frac{\hat{\theta}'_{a,i(k)} m'_{b,t(k)}}{\hat{\theta}'_{b,i(k)} m'_{a,t(k)}}$$

and so forth for the other groups. Simulated estimates of relative age-sex composition were then calculated as:

$$\hat{\theta}'_{a,t(k)} = \frac{m'_{a,t(k)}}{m'_{a,t(k)} + m'_{b,t(k)} \hat{w}'^{-1}_{b,t(k)} + m'_{c,t(k)} \hat{w}'^{-1}_{c,t(k)} + \ldots}$$

$$\hat{\theta}'_{b,t(k)} = \frac{m'_{b,t(k)} \hat{w}'^{-1}_{b,t(k)}}{m'_{a,(k)} + m'_{b,t(k)} \hat{w}'^{-1}_{b,t(k)} + m'_{c(k)} \hat{w}'^{-1}_{c,t(k)} + \ldots}$$

and so forth. Variance for each element in $\{\hat{\theta}_t\}$ was approximated as follows:

$$v(\hat{\theta}_{a,t}) \cong \frac{\sum_{k=1}^{K} (\hat{\theta}'_{a,t(k)} - \overline{\theta}'_{a,t})^2}{K-1}$$

$$v(\hat{\theta}_{b,t}) \cong \frac{\sum_{k=1}^{K} (\hat{\theta}'_{b.t(k)} - \overline{\theta}'_{b.t})^2}{K-1}$$

and so forth with *K* (=100) the number of iterations. The process was repeated for the next year. These calculations of estimated variance represent both the measurement (sampling error) at the carcass weir on the Nakina River, the measurement error from sampling on the Nahlin, Kowatua, and Tatsamenie rivers during mark-recapture experiments, and the process error (interannual variation) among the $\{\mathbf{w}_t\}$.

Simulation also provided a means of estimating the statistical bias in the procedures used to estimate $\{\theta\}$ (Table A.4). Relative statistical bias was estimated by subtracting estimates of $\hat{\theta}_{a,t}$ from the mean $\overline{\theta}'_{a,t}$ of simulated values $\hat{\theta}'_{a,t(k)}$ and dividing the difference by $\hat{\theta}_{a,t}$ (from Efron and Tibshirani 1993:124-6).

Table A1.—Solutions to {w} for years with mark-recapture experiments.

Sex	Age	1989	1990	1995	1996	1997	Average
Females	1.3	1.000	1.000	1.000	1.000	1.000	1.000
Females	1.4	1.835	5.289	2.629	2.032	1.649	2.687
Males	1.2	1.784	2.031	4.056	3.716	1.303	2.578
Males	1.3	0.999	2.507	2.839	1.896	1.585	1.965
Males	1.4	1.647	5.525	5.799	3.082	2.726	3.756

Table A2.—Estimates of relative age and sex composition for spawning chinook salmon in the Taku River adjusted for bias arising from collecting samples with a carcass weir on the Nakina River in years without mark-recapture experiments.

Year	Sex	1.2	1.3	1.4	1.5
1973	Females	-	0.181	0.216	-
	Males	0.353	0.172	0.070	0.008
1974	Females	-	0.236	0.153	-
	Males	0.368	0.200	0.039	0.004
1975	Females	-	0.047	0.083	-
	Males	0.633	0.178	0.055	0.003
1976	Females	-	0.253	0.174	-
	Males	0.309	0.215	0.042	0.007
1977	Females	-	0.203	0.387	0.012
	Males	0.133	0.168	0.089	0.008
1978	Females	-	0.077	0.114	0.013
	Males	0.619	0.124	0.038	0.015
1979	Females	-	0.193	0.036	0.004
	Males	0.546	0.202	0.018	0.002
1980	Females	-	0.220	0.167	-
	Males	0.285	0.258	0.070	-
1981	Females	-	0.181	0.207	-
	Males	0.231	0.254	0.127	-
1982	Females	-	0.153	0.248	0.020
	Males	0.192	0.230	0.142	0.015
1983	Females	-	0.114	0.173	0.005
	Males	0.305	0.305	0.092	0.005
1984	Females	-	0.256	0.071	0.009
	Males	0.310	0.336	0.016	0.002
1985	Females	-	0.225	0.135	0.003
	Males	0.255	0.307	0.075	0.000

-continued-

Table A2.—Page 2 of 2.

Year	Sex	1.2	1.3	1.4	1.5
1986	Females	-	0.185	0.277	0.011
	Males	0.169	0.235	0.118	0.005
1987	Females	-	0.185	0.146	0.016
	Males	0.204	0.361	0.083	0.005
1988	Females	-	0.065	0.275	0.020
	Males	0.271	0.166	0.184	0.020
1991	Females	-	0.126	0.216	0.041
	Males	0.284	0.207	0.105	0.022
1992	Females	-	0.091	0.210	0.012
	Males	0.240	0.336	0.099	0.012
1993	Females	-	0.126	0.251	0.013
	Males	0.141	0.321	0.138	0.010
1994	Females	-	0.338	0.229	0.022
	Males	0.097	0.201	0.098	0.015

Table A3.—Simulated SEs for estimates of relative age and sex composition for spawning chinook salmon in the Taku River adjusted for bias arising from collecting samples with a carcass weir on the Nakina River in years without mark-recapture experiments.

Year	Sex	1.2	1.3	1.4	1.5
1973	Females	-	0.056	0.060	-
	Males	0.098	0.042	0.024	0.002
1974	Females	0.000	0.063	0.053	-
	Males	0.099	0.047	0.013	0.001
1975	Females	-	0.020	0.035	-
	Males	0.098	0.051	0.023	0.001
1976	Females	-	0.061	0.053	-
	Males	0.091	0.046	0.015	0.002
1977	Females	-	0.067	0.094	0.004
	Males	0.057	0.040	0.029	0.003
1978	Females	-	0.027	0.047	0.004
	Males	0.099	0.036	0.018	0.005
1979	Females	-	0.063	0.015	0.001
	Males	0.099	0.053	0.008	0.001
1980	Females	-	0.075	0.046	-
	Males	0.082	0.054	0.026	-
1981	Females	-	0.055	0.056	-
	Males	0.077	0.050	0.038	-
1982	Females	-	0.048	0.065	0.006
	Males	0.072	0.039	0.043	0.004
1983	Females	-	0.041	0.054	0.002
	Males	0.091	0.057	0.030	0.002
1984	Females	-	0.079	0.025	0.003
	Males	0.082	0.075	0.006	0.001
1985	Females	-	0.066	0.042	0.001
	Males	0.080	0.055	0.025	0.000

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Table A3.—Page 2 of 2.

Year	Sex	1.2	1.3	1.4	1.5
1986	Females	-	0.063	0.072	0.004
	Males	0.063	0.045	0.038	0.001
1987	Females	-	0.059	0.046	0.005
	Males	0.073	0.064	0.026	0.002
1988	Females	-	0.029	0.077	0.007
	Males	0.092	0.033	0.048	0.007
1991	Females	-	0.041	0.059	0.012
	Males	0.091	0.040	0.028	0.007
1992	Females	-	0.033	0.060	0.004
	Males	0.085	0.055	0.031	0.004
1993	Females	-	0.046	0.073	0.004
	Males	0.057	0.051	0.039	0.003
1994	Females	-	0.083	0.062	0.005
	Males	0.039	0.049	0.031	0.004

Table A4.—Estimated relative statistical bias in $\{\hat{\theta}\}$ by age-sex groups of spawning chinook salmon across years without mark-recapture experiments.

	Female 1.3	Female 1.4	Female 1.5	Male 1.2	Male 1.3	Male 1.4	Male 1.5
Average	-4%	6%	-2%	2%	-1%	4%	-4%
Minimum	-10%	-1%	-8%	-3%	-6%	-7%	-10%
Maximum	7%	12%	7%	13%	1%	11%	7%

Appendix B:
Estimating Numbers of Spawning Chinook Salmon by Age and Sex

Abundance for age groups and for large females over the spawning grounds were estimated as the product of the estimated abundance of large chinook salmon and either an estimated fraction or a simulated factor. Estimated abundance by age group was used to calculate production from a year class; estimated abundance of large females constituted the spawning abundance (*S*) for analysis of production. For years with mark-recapture experiments (1989, 1990, 1995-1997), estimates were taken directly from Pahlke and Bernard (1996) and from McPherson et al. (1996, 1997, 1998).

For years without mark-recapture experiments, abundance estimates were derived from adjusted estimates of relative age composition (see Appendix A). Estimated abundance for group *a* and its estimated variance were calculated as:

$$\hat{N}_a = \hat{N}\ \hat{p}_a$$

$$v(\hat{N}_a) = v(\hat{N})\hat{p}_a^2 + v(\hat{p}_a)\hat{N}^2 - v(\hat{N})v(\hat{p}_a)$$

Statistics represented by $\hat{p}_a$ were calculated as weighted functions of samples taken at the carcass weir on the Nakina River:

$$\hat{p}_{1.2} = \frac{m_{1.2}\overline{w}_{1.2}^{-1}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

$$\hat{p}_{1.3} = \frac{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

$$\hat{p}_{1.4} = \frac{m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

$$\hat{p}_{1.5} = \frac{m_{F,1.5} + m_{M,1.5}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

$$\hat{p}_{LF} = \frac{m_{F,1.3} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{F,1.5}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

$$\hat{p}_{LM} = \frac{m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{M,1.5}}{m_{F,1.3} + m_{M,1.3}\overline{w}_{M,1.3}^{-1} + m_{F,1.4}\overline{w}_{F,1.4}^{-1} + m_{M,1.4}\overline{w}_{M,1.4}^{-1} + m_{F,1.5} + m_{M,1.5}}$$

where m_a is the number in the sample belonging to group a, *F* denotes female, *M* male, *LF* large females, *LM* large males, and the *w* are weights (see Appendix A). All age-1.2 fish are considered male. Note that because abundance estimated through mark-recapture experiments and aerial surveys is only for large fish (considered age-1.3 fish and older), $0 \leq \hat{p}_{1.3} \leq 1$, $0 \leq \hat{p}_{1.4} \leq 1$, $0 \leq \hat{p}_{1.5} \leq 1$, and $0 \leq \hat{p}_{LF} \leq 1$, while $0 \leq \hat{p}_{1.1}$ and $0 \leq \hat{p}_{1.2}$. Estimated variances were calculations during simulations described in Appendix A. Simulation also provided a means of estimating the statistical bias in the procedures used to estimate the multipliers (Table B.1). Relative statistical bias was estimated by subtracting estimates $\hat{p}_{a,t}$ from the mean $\overline{p}'_{a,t}$ of simulated values $\hat{p}'_{a,t(k)}$ and dividing the difference by $\hat{p}_{a,t}$ (from Efron and Tibshirani 1993:124-6). Table B.2 contains estimated multipliers and estimates of their SEs. Estimated abundance by age and gender, the $\hat{N}_a$, are in Table 4 in the text. Table B.3 contains the SEs for the $\hat{N}_a$.

Table B1.–Estimated relative statistical bias in $\{\hat{p}\}$ by age and large (≥660 mm MEF) female and male spawning chinook salmon across years without mark-recapture experiments.

	1.2	1.3	1.4	1.5	Large Females	Large Males
Average	9%	-2%	5%	-3%	0%	0%
Minimum	2%	-5%	0%	-9%	-3%	-5%
Maximum	21%	0%	9%	5%	4%	4%

Table B2.—Simulated multipliers used to calculate numbers of spawning chinook salmon in the Taku River by age and numbers of large (≥660 mm MEF) females from estimated abundance of large spawning chinook salmon of both sexes for years without mark-recapture experiments.

Year		1.2	1.3	1.4	1.5	Large females	Large males
1973	$\hat{p}_a$	0.587	0.547	0.441	0.012	0.613	0.387
	SE	0.276	0.072	0.075	0.003	0.079	0.079
1974	$\hat{p}_a$	0.627	0.692	0.301	0.007	0.613	0.387
	SE	0.286	0.070	0.071	0.002	0.076	0.076
1975	$\hat{p}_a$	1.941	0.619	0.372	0.009	0.356	0.644
	SE	0.847	0.071	0.072	0.003	0.073	0.073
1976	$\hat{p}_a$	0.475	0.680	0.310	0.010	0.617	0.383
	SE	0.206	0.066	0.068	0.002	0.069	0.069
1977	$\hat{p}_a$	0.159	0.431	0.546	0.023	0.694	0.306
	SE	0.081	0.088	0.095	0.008	0.070	0.070
1978	$\hat{p}_a$	1.840	0.535	0.389	0.076	0.534	0.466
	SE	0.873	0.066	0.082	0.023	0.075	0.075
1979	$\hat{p}_a$	1.324	0.869	0.117	0.014	0.509	0.491
	SE	0.591	0.030	0.032	0.003	0.092	0.092
1980	$\hat{p}_a$	0.419	0.670	0.330	0.000	0.541	0.459
	SE	0.173	0.069	0.069	0.000	0.087	0.087
1981	$\hat{p}_a$	0.315	0.568	0.432	0.000	0.505	0.495
	SE	0.140	0.070	0.070	0.000	0.081	0.081
1982	$\hat{p}_a$	0.249	0.478	0.479	0.043	0.520	0.480
	SE	0.118	0.065	0.075	0.013	0.074	0.074
1983	$\hat{p}_a$	0.467	0.606	0.378	0.016	0.421	0.579
	SE	0.222	0.061	0.064	0.005	0.083	0.083
1984	$\hat{p}_a$	0.473	0.859	0.125	0.017	0.486	0.514
	SE	0.192	0.033	0.035	0.004	0.101	0.101
1985	$\hat{p}_a$	0.360	0.716	0.280	0.004	0.486	0.514
	SE	0.157	0.057	0.058	0.001	0.082	0.082

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Table B2.—Page 2 of 2.

Year		1.2	1.3	1.4	1.5	Large females	Large males
1986	$\hat{p}_a$	0.211	0.508	0.473	0.019	0.569	0.431
	SE	0.097	0.074	0.078	0.006	0.083	0.083
1987	$\hat{p}_a$	0.267	0.686	0.287	0.027	0.436	0.564
	SE	0.122	0.056	0.059	0.008	0.083	0.083
1988	$\hat{p}_a$	0.395	0.320	0.624	0.056	0.491	0.509
	SE	0.194	0.058	0.072	0.022	0.080	0.080
1991	$\hat{p}_a$	0.420	0.466	0.446	0.088	0.531	0.469
	SE	0.196	0.054	0.072	0.027	0.067	0.067
1992	$\hat{p}_a$	0.334	0.564	0.404	0.032	0.410	0.590
	SE	0.164	0.061	0.066	0.012	0.073	0.073
1993	$\hat{p}_a$	0.170	0.523	0.450	0.027	0.453	0.547
	SE	0.082	0.069	0.074	0.009	0.081	0.081
1994	$\hat{p}_a$	0.109	0.597	0.362	0.041	0.652	0.348
	SE	0.050	0.065	0.074	0.010	0.079	0.079

Table B3.—Estimated SEs for estimated numbers $\hat{N}_a$ of chinook salmon by age and by large (≥660 mm MEF) females and males spawning in the Taku River from 1973 through 1997. Bold numbers came directly from mark-recapture experiments.

	1.2	1.3	1.4	1.5	Large Females	Large Males
1973	5,577	3,458	2,884	87	3,864	2,621
1974	6,435	4,701	2,332	53	4,236	2,859
1975	15,670	3,424	2,209	68	2,139	3,560
1976	7,267	7,074	3,610	118	6,478	4,271
1977	3,203	5,917	7,256	389	8,678	4,322
1978	20,686	3,946	3,119	690	3,997	3,555
1979	18,120	7,732	1,276	140	4,991	4,852
1980	9,947	11,160	6,061	-	9,450	8,253
1981	9,846	12,117	9,540	-	11,144	10,961
1982	3,901	4,958	5,066	543	5,426	5,066
1983	3,003	2,518	1,660	86	1,903	2,485
1984	5,889	7,348	1,318	174	4,720	4,936
1985	8,083	10,772	4,696	67	7,820	8,205
1986	5,175	8,495	8,055	404	9,523	7,538
1987	4,945	8,320	3,870	406	5,778	7,174
1988	11,808	6,471	11,905	1,467	9,742	10,043
1989	**1,589**	**3,819**	**1,770**	**294**	**4,827**	**4,191**
1990	**1,338**	**3,779**	**5,434**	**264**	**5,831**	**3,218**
1991	14,085	10,328	10,244	2,385	11,842	10,596
1992	12,515	13,421	10,069	1,050	10,391	14,213
1993	7,438	15,006	13,300	964	13,573	15,899
1994	3,400	12,321	8,135	970	13,565	8,020
1995	**3,848**	**1,952**	**2,600**	**174**	**2,633**	**2,295**
1996	**1,097**	**7,692**	**1,287**	**84**	**4,781**	**4,588**
1997	**639**	**6,600**	**11,120**	**-**	**11,080**	**7,032**

Appendix C:
Estimates of Age Composition of Harvested Chinook Salmon

Four age groups are represented in the age composition of harvests in commercial and recreational fisheries: age-1.2, -1.3, -1.4, and -1.5 chinook salmon. The few sampled fish that were determined to have freshwater age 2. were considered anomalous and were lumped with those with age 1. Virtually no age-1.1 jacks have been harvested in these fisheries.

Marine Harvest

We estimated harvest by age of Taku-bound chinook salmon in the marine gillnet fishery during its first three or four weeks when these fish are still moving through the fishery. The fishery starts on the third Sunday in June (Appendix D) and judging from information from Canyon Island, almost all of the Taku-bound chinook salmon have past through the fishery by July 9. Harvest by age and its estimated variance were estimated as:

$$\hat{H}_{a,t} = H_t \hat{p}_{a,t}$$

$$v(\hat{H}_{a,t}) = H_t^2 v(\hat{p}_{a,t})$$

where H_t is harvest in year t and $p_{a,t}$ the fraction of the harvest comprised of age group a that year. Harvests are reported on fish tickets and are considered known without error. Relative age composition in years when this fishery was not sampled (1977-1981 and 1993-1994) were predicted from adjusting estimates from spawners (Appendix Table A.2) with regressions on data from other years.

Regressions to predict missing data were dual in nature. Samples were first split into two groups: age-1.4 fish in one group and age-1.2 and -1.3 fish in the other (samples of fish age 1.1 and 1.5 were ignored). Fractions of samples represented by both groups were normalized, then the fraction of age-1.4 fish in samples from the fishery regressed against the normalized fraction for spawners. Estimated variance for predictions were estimated with eq. 1.4.11 in Draper and Smith (1981:30). The fraction predicted for the age-1.2/-1.3 group was the complement of the prediction for the age-1.4 fish; the estimated variance for both groups is the same. The second step involved splitting the age-1.2 and age-1.3 into two groups by normalizing their fractions against the prediction for both age groups combined. Fractions of samples represented in both groups were normalized, then fraction of age-1.3 fish in samples from the fishery were regressed against the normalized fraction for spawners. The predicted fraction for the age-1.2 fish was the complement of the fraction predicted for the age-1.3 fish. Variances of predictions were estimated as described before.

Harvests of Taku-bound chinook salmon in the commercial troll fishery in Southeast Alaska were estimated from CWT recoveries as per Bernard and Clark (1996). Some brood years were not tagged (1973-1974 and 1982-1990). Estimates were made for the 1973 and 1974 broods. No estimates were made for the 1982-1990 broods, but in consideration of the major reductions in the spring troll fishery in Southeast Alaska in the years those fish returned, lack of estimates are considered to have a negligible effect in the analysis.

Estimated age composition of Taku-bound chinook salmon harvested by the recreational fishery in the Juneau area was calculated as the product of the estimated spring harvest and the estimated or predicted relative age composition of the catch. This spring fishery runs from April through late June and covers the bulk of the Taku-bound migration. Age-0. fish and contributions of other stocks, estimated from coded-wire tag (CWT) recoveries, were first subtracted from estimated harvest Relative age composition in years when this fishery was not sampled for age data (1977-1982) was predicted by adjusting estimates from spawners with regressions on data from 1983-1997 when both the recreational fishery and escapements were sampled. Regression were as described above with the exception that only age-1.3 and -1.4 salmon were involved. Harvest by age was estimated along with its estimated variance as follows:

$$\hat{H}_{a,t} = \hat{H}_t \hat{p}_{a,t}$$

$$v(\hat{H}_{a,t}) = \hat{H}_t^2 v(\hat{p}_{a,t}) + v(\hat{H}_t)\hat{p}_{a,t}^2 - v(\hat{H}_t)v(\hat{p}_{a,t})$$

Harvests in this fishery were estimated from onsite creel surveys from 1977-1997.

Inriver Harvest

Relative age composition of chinook salmon harvested in the Canadian inriver gillnet fishery was estimated from information gathered on the spawning grounds and sporadically from the fishery. The fishery began in 1979, and was sampled in 1983-1987 and in 1997 to estimate age composition. Fractions for relative age composition of harvests in other years were predicted with regressions following the same procedures described for the marine gillnet fishery. Because all harvest in this commercial fishery was reported, subsequent estimates of harvest by age were calculated with the same equations as were used for the marine gillnet fishery.

Table C1.—Estimated harvests by year and age of chinook salmon bound for the Taku River caught in the recreational (sport) fishery near Juneau. Standard errors are in parentheses. Estimates in bold come from regressions of age composition.

Year	1.2		1.3		1.4		1.5		Total	
1977			**828**	**(318)**	**1,622**	**(355)**			2,450	(278)
1978			**781**	**(221)**	**892**	**(226)**			1,673	(190)
1979			**1,386**	**(292)**	**467**	**(252)**			1,853	(211)
1980			**1,598**	**(397)**	**1,302**	**(383)**			2,900	(329)
1981			**880**	**(254)**	**1,051**	**(262)**			1,931	(219)
1982			**616**	**(204)**	**955**	**(220)**			1,571	(178)
1983	61	(22)	514	(77)	514	(77)			1,089	(133)
1984	95	(29)	826	(121)	280	(56)	9	(9)	1,210	(166)
1985	60	(28)	1,162	(168)	627	(109)	15	(14)	1,863	(241)
1986	5	(5)	243	(45)	493	(76)	13	(8)	755	(107)
1987	26	(17)	545	(87)	372	(70)	77	(30)	1,019	(128)
1988	2	(3)	234	(56)	505	(102)	25	(14)	765	(144)
1989	109	(39)	1,183	(225)	462	(104)	97	(36)	1,857	(337)
1990	99	(34)	538	(115)	1,349	(257)	48	(22)	2,039	(377)
1991	333	(78)	1,275	(212)	2,356	(360)	235	(62)	4,199	(609)
1992	12	(12)	1,316	(260)	1,734	(333)	37	(21)	3,099	(574)
1993	55	(27)	1,449	(223)	4,185	(567)	170	(50)	5,860	(776)
1994	122	(35)	649	(106)	1,793	(243)	108	(33)	2,672	(347)
1995	357	(75)	1,614	(186)	1,414	(170)	100	(38)	3,500	(324)
1996	78	(34)	3,252	(362)	736	(122)	55	(29)	4,121	(441)
1997			1,861	(228)	4,130	(417)			5,991	(567)

Table C2.—Estimated harvests by year and age of chinook salmon bound for the Taku River caught in the commercial gillnet fishery in Taku Inlet. Standard errors are in parenthesis. Estimates in bold come from regressions of age composition.

Year	1.2	1.3	1.4	1.5	Total
1973	239 (118)	1,255 (254)	6,634 (291)	299 (132)	8,427 (0)
1974	35 (35)	637 (132)	1,842 (140)	106 (61)	2,620 (0)
1975	69 (49)	1,039 (136)	970 (136)	35 (35)	2,113 (0)
1976	**834 (201)**	**500 (201)**	**209 (128)**		1,543 (0)
1977	**183 (90)**	**277 (90)**	**227 (58)**		686 (0)
1978	**1,403 (278)**	**0 (278)**	**128 (131)**		1,531 (0)
1979	**2,675 (478)**	**204 (478)**	**55 (266)**		2,934 (0)
1980	**771 (199)**	**544 (199)**	**233 (127)**		1,549 (0)
1981	**476 (146)**	**419 (146)**	**253 (93)**		1,148 (0)
1982	923 (53)	479 (47)	347 (42)	12 (9)	1,809 (0)
1983	304 (19)	50 (13)	50 (13)		429 (0)
1984	431 (41)	382 (41)	49 (19)		890 (0)
1985	717 (58)	588 (57)	226 (41)		1,539 (0)
1986	501 (106)	563 (109)	501 (106)		1,596 (0)
1987	458 (58)	423 (58)	141 (40)	23 (17)	1,057 (0)
1988	407 (64)	174 (52)	232 (58)		833 (0)
1989	379 (45)	823 (51)	243 (39)	21 (12)	1,466 (0)
1990	946 (252)	946 (252)	568 (218)		2,459 (0)
1991	925 (124)	797 (120)	797 (120)	77 (44)	2,596 (0)
1992	368 (44)	702 (50)	361 (44)		1,430 (0)
1993	**1,254 (583)**	**2,035 (583)**	**1,200 (368)**		4,489 (0)
1994	**622 (394)**	**1,661 (394)**	**672 (240)**		2,955 (0)
1995	2,652 (145)	501 (118)	295 (94)	59 (43)	3,506 (0)
1996	263 (40)	1,860 (53)	250 (39)	20 (12)	2,393 (0)
1997	137 (29)	920 (62)	1,349 (63)		2,406 (0)

Table C3.—Estimated harvests by year and age of chinook salmon bound for the Taku River caught in the gillnet fishery in Canada in the Taku River. Standard errors are in parentheses.

Year	1.2		1.3		1.4		1.5		Total	
1979	97	(24)							97	(0)
1980	120	(34)	63	(34)	42	(16)			225	(0)
1981	67	(23)	44	(23)	49	(11)			159	(0)
1982	19	(8)	14	(8)	21	(4)			54	(0)
1983	360	(20)	74	(14)	78	(14)			556	(0)
1984	273	(43)	212	(43)	15	(15)			515	(0)
1985			233	(33)	102	(32)	15	(14)	350	(0)
1986	54	(19)	135	(26)	153	(27)	9	(9)	352	(0)
1987	21	(21)	64	(32)	127	(36)	21	(21)	233	(0)
1988	389	(110)	0	(110)	352	(54)			741	(0)
1989	379	(147)	446	(147)	209	(73)			1,034	(0)
1990	247	(208)	391	(208)	749	(106)			1,386	(0)
1991	924	(246)	181	(246)	504	(111)			1,609	(0)
1992	723	(229)	418	(229)	451	(110)			1,592	(0)
1993	415	(261)	684	(261)	692	(125)			1,790	(0)
1994	315	(354)	1,253	(354)	732	(159)			2,300	(0)
1995	1,356	(378)	0	(378)	519	(130)			1,875	(0)
1996	386	(545)	2,957	(545)	131	(277)			3,475	(0)
1997	104	(41)	921	(101)	1,790	(104)			2,816	(0)

Table C4.—Estimated harvests by year and age of chinook salmon bound for the Taku River caught in the commercial troll fishery in Southeast Alaska. Standard errors are in parentheses.

Year	1.2		1.3		1.4		1.5		Total	
1978			1,038						1,038	(NE)
1979	525	(525)	3,812		1,038				5,375	(NE)
1980			1,540	(920)	3,812				5,352	(NE)
1981			3,587	(1,882)	1,689	(988)			5,276	(2,126)
1982			552	(393)	2,157	(943)			2,709	(1,022)
1983					419	(316)			419	(316)
1984			2,754	(916)					2,754	(916)
1985					749	(401)			749	(401)
1986										
1987					399	(399)			399	(399)
1996			1,605	(895)					1,605	(895)
1997					1,479	(1,045)			1,479	(1,045)

Appendix D:
Summary of Regulations in Southeast Alaska for Recreational, Commercial Gillnet and Commercial Troll Fisheries, which Pertain to the Marine Harvest of Taku-bound Chinook Salmon

Table D1.—Southeast Alaska (SEAK) chinook salmon harvest levels, Alaska hatchery contributions to SEAK harvests, and harvest management targets, 1965-1997 in thousands of chinook salmon [a].

Year	Commercial harvest	Sport harvest	Total all gear SEAK harvest	Alaska hatchery contribution	SEAK harvest minus AK hatchery contribution	Harvest target
1965	337	13	350	0	350	none
1966	308	13	321	0	321	none
1967	301	13	314	0	314	none
1968	331	14	345	0	345	none
1969	314	14	328	0	328	none
1970	323	14	337	0	337	none
1971	334	15	349	0	349	none
1972	286	15	301	0	301	none
1973	344	16	360	0	360	none
1974	346	17	363	0	363	none
1975	300	17	317	0	317	none
1976	241	17	258	0	258	none
1977	285	17	302	0	302	none
1978	400	17	417	0	417	none
1979	366	17	383	0	383	none
1980	324	20	344	7	337	286-320[b]
1981	268	21	289	2	287	243-286[b]
1982	290	26	316	1	315	243-286[b]
1983	289	22	311	2	309	243-272[b]
1984	268	22	290	5	285	243-272[b]
1985	251	25	276	14	262	263[c]
1986	260	23	283	18	265	254[c]
1987	258	24	282	24	258	263[c]
1988	252	26	278	30	248	263[c]
1989	260	31	291	34	257	263[c]
1990	315	51	366	62	304	302[c]
1991	296	60	356	70	286	273[c]
1992	215	43	258	45	213	263[c]
1993	254	49	303	39	264	263[d]
1994	221	42	263	38	225	240[d]
1995	186	50	236	66	170	230[d]
1996	178	42	220	75	145	140-155[d]
1997	271	68	340	55	285	302[d]

[a] Data Sources: commercial harvests, Alaska hatchery contributions, and harvest targets: Dave Gaudet, personal communication; sport harvests taken from 1977-1996 statewide harvest surveys, 1997 sport harvest is a projection.

[b] Guideline harvest levels established by Alaska Board of Fisheries and North Pacific Fisheries Management Council; ranges included allowances for Alaska Hatchery chinook salmon and were applicable to commercial fisheries only.

[c] Ceilings established by the U.S.-Canada Pacific Salmon Treaty, SEAK ceilings applied to all gear harvests minus Alaska hatchery add-on.

[d] Ceilings imposed on SEAK fishery through NMFS Section 7 ESA consultations; ceilings applied to all gear harvests minus Alaska hatchery add-on, similar to previous ceilings established through Pacific Salmon Treaty.

Table D2.—Sport fishing pre-season booklet regulations in Southeast Alaska affecting the Taku River chinook salmon stock, 1961-1998.

Year	Salt-water season	Saltwater bag and possession limits	Saltwater size limit	Saltwater methods & means restrictions	Specially closed salt waters	Freshwater Regulations
1961	1/1-12/31	50 lb and 1 fish or 3 fish, whichever is less restrictive	26 inches in fork length	no special restrictions	none	fifteen immature salmon daily or in possession
1962	1/1-12/31	same as 1961	same as 1961	salmon shall not be taken by means of treble hook(s)	none	season: 1/1 -12/31; 2 fish per day and in possession over 20 inches; no limit on adult fish under 20 inches
1963	1/1-12/31	three fish daily and in possession	same as 1961	same as 1962	none	closed to king salmon fishing
1964	1/1-12/31	same as 1963	no size restriction	no special restrictions	none	same as 1963
1965	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1966	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1967	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1968	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1969	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1970	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1971	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1972	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1973	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1974	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1975	1/1-12/31	same as 1963	same as 1964	same as 1964	none	same as 1963
1976	1/1-12/31	three fish daily and in possession in SEAK; one fish daily and in possession in all waters south of the latitude of Pt Sherman to the latitude of Pt Couverden in Lynn Canal and south to the latitude of Limestone Inlet in Stephens Passage	26 inch minimum size limit	no special restrictions	Limestone Inlet to Point Louisa including backside of Douglas Island: Closed to king salmon fishing from 4/15-6/14	closed to king salmon fishing
1977	1/1-12/31	same as 1976	28 inch minimum size limit	same as 1976	same as 1976	same as 1976
1978	1/1-12/31	same as 1976	same as 1977	same as 1976	same as 1976	same as 1976
1979	1/1-12/31	same as 1976	same as 1977	same as 1976	Limestone Inlet to Point Louisa including backside of Douglas Island: Closed to king salmon fishing from 4/16-6/14	same as 1976
1980	1/1-12/31	same as 1976	28 inch minimum size limit from 6/15-3/31; any size of king salmon legal from 4/1-6/14	same as 1976	same as 1979	same as 1976
1981	1/1-12/31	same as 1976	same as 1980	same as 1976	same as 1979	same as 1976
1982	1/1-12/31	same as 1976	same as 1980	same as 1976	same as 1979	same as 1976

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Table D2.—Page 2 of 2.

Year	Salt-water season	Saltwater bag and possession limits	Saltwater size limit	Saltwater methods & means restrictions	Specially closed salt waters	Freshwater Regulations
1983	1/1-12/31	two fish daily and in possession	28 inch minimum size limit; except, those less than 28 inches with a tag or clipped adipose fin can be retained	not more than 6 lines may be fished from a charter vessel	Limestone Inlet to Point Louisa including backside of Douglas Island: Closed to king salmon fishing from 4/16-6/14	closed to king salmon fishing
1984	1/1-12/31	same as 1983	same as 1983	same as 1983	same as 1983	same as 1983
1985	1/1-12/31	same as 1983	same as 1983	same as 1983	same as 1983	same as 1983
1986	1/1-12/31	same as 1983	same as 1983	same as 1983	same as 1983	same as 1983
1987	1/1-12/31	same as 1983	same as 1983	same as 1983	same as 1983	same as 1983
1988	1/1-12/31	same as 1983	same as 1983	same as 1983	same as 1983	same as 1983
1989	1/1-12/31	same as 1983	28 inch minimum size limit	not more than 6 lines may be fished from any vessel sport fishing	Taku Inlet north of a line from Point Bishop to Dorothy Creek: Closed to king salmon fishing from 4/16- 6/14	closed to king salmon fishing[a]
1990	1/1-12/31	same as 1983	same as 1989	same as 1989	same as 1989	same as 1989
1991	1/1-12/31	same as 1983	same as 1989	same as 1989	same as 1989	same as 1989
1992	1/1-12/31	same as 1983	same as 1989	same as 1989 with the addition of: sport fishing may only be conducted by the use of a single line per angler	same as 1989	same as 1989
1993	1/1-12/31	same as 1983	same as 1989	same as 1992	same as 1989	same as 1989
1994	1/1-12/31	two fish daily and in possession	28 inch minimum size limit	same as 1992	Taku Inlet north of a line from Cooper Point to the mouth of Dorothy Creek: Closed to king salmon fishing from 4/16- 6/14	closed to king salmon fishing[1]
1995	1/1-12/31	same as 1994	same as 1994	same as 1992	same as 1994	same as 1994
1996	1/1-12/31	same as 1994	same as 1994	same as 1992	same as 1994	same as 1994
1997	1/1-12/31	two fish daily and in possession; in addition, for nonresidents, the annual limit is four fish	same as 1994	Operators and crew members working on a charter vessel may not retain king salmon while clients are aboard; the maximum number of lines allowed is equal to number of paying clients	same as 1994	same as 1994
1998	1/1-12/31	same as 1997	same as 1994	same as 1997	same as 1994	same as 1994

[a] Since 1989 ADFG has had the authority to open king salmon fishing in freshwater under certain circumstances and the book regulations if this were to occur are as follows: in all freshwater systems opened by emergency order to fishing for king salmon, the bag and possession limit is 2 fish 28 inches or more in length and 2 fish less than 28 inches in length; otherwise freshwaters are closed to king salmon fishing. To date, ADFG has not opened king salmon fishing in the Taku River under this authority.

Table D3.—Commercial fishing pre-season booklet regulations for drift gillnets in District 111 of Southeast Alaska likely affecting the Taku River chinook salmon stock, 1960-1998 [a].

Year	Season opening date(s) and fishing period(s)	Gillnet mesh regulations	Gillnet Length Regulations	Gillnet spacing regulations	Chinook size limits
1960	5/1-E.O. date: 72 hrs/wk	6" and smaller: 50 meshes; $6^{1/8}$-7": 45 meshes; $7^{1/8}$-9": 40 meshes	50 fathom min. & 150 fathom max.	100 yard minimum spacing	26" limit except from 5/1-7/13 when there was no size limit
1961	5/1-E.O. date: 96 hrs/wk	same as 1960	same as 1960	same as 1960	same as 1960
1962	4/30-6/15: 24 hrs/wk 6/16-E.O. date: 96 hrs/wk	same as 1960	same as 1960	same as 1960	same as 1960
1963	4/29-6/14: 24 hrs/wk 6/15-E.O. date: 72 hrs/wk	less than 8" - 60 mesh max.; 8" and larger - 40 mesh max.	same as 1960	same as 1960	same as 1960
1964	4/27-6/12: 24 hrs/wk 6/15-E.O. date: 72 hrs/wk	same as 1963	same as 1960	same as 1960	same as 1960
1965	4/24-6/11: 24 hrs/wk 6/12-E.O. date: 72 hrs/wk	same as 1963 except, 40 mesh max. before 6/12	same as 1960	same as 1960	same as 1960
1966	same as 1965	same as 1965	same as 1960	same as 1960	same as 1960
1967	4/30-6/17: 24 hrs/wk; 6/18-E.O. date: 72 hrs/wk	same as 1965	same as 1960	same as 1960	same as 1960
1968	4/28-6/15: 24 hrs/wk 6/16-E.O. date: 72 hrs/wk	same as 1965	same as 1960	same as 1960	same as 1960
1969	4/27-6/14: 24 hrs/wk 6/15-E.O. date: 72 hrs/wk	same as 1965 except, 40 mesh max. before 6/15; 6" max. from 6/15-7/20	same as 1960	same as 1960	same as 1960
1970	4/26-6/13: 24 hrs/wk 6/14-E.O. date: 72 hrs/wk	60 mesh max. for nets smaller than 8"; 40 mesh max. for nets 8" or larger; 40 mesh max. before 6/14; 6" max. from 6/14-7/20	not less than 100 fathoms or more than 150 fathoms except after 6/13, max. length increases to 200 fathoms	same as 1960	same as 1960
1971	5/2-6/12: 24 hrs/wk 6/13-E.O. date: 72 hrs/wk	60 mesh max. for nets smaller than 8"; 40 mesh max. for nets 8" or larger; 40 mesh max. before 6/14; 6" max. from 6/14-7/20	not less than 100 fathoms or more than 150 fathoms except after 6/13, max. length increases to 200 fathoms	100 yard minimum spacing	no size limit
1972	4/30-6/17: 24 hrs/wk; 6/18-E.O. date: 72 hrs/wk	same as 1971; except, 40 mesh restriction in effect before 6/17; 6" mesh max. from 6/18-7/18	same as 1971; except date of change was 6/18	none	none
1973	last Sunday in April-3rd Saturday in June: 24 hrs/wk 3rd Sunday in June-E.O. date: 72 hrs/wk	60 mesh max. for nets smaller than 8"; 40 mesh max. for nets 8" or larger; 40 mesh max. before 3rd Sunday in June; 6" max. from 3rd Sunday in June-7/18	not less than 100 fathoms or more than 150 fathoms except after 3rd Sunday in June, max. length increases to 200 fathoms	none	none
1974	same as 1973	same as 1973	same as 1973	none	none
1975	same as 1973	same as 1973	same as 1973	none	none
1976	Spring-time gill netting closed Season Opens: 3rd Monday in June-E.O. date: 72 hrs/wk	same as 1973; except, mesh not less than $5^{3/8}$ inches during a season specified by E.O.	not less than 100 fathoms or more than 150 fathoms except after 3rd Saturday in June, max. length increases to 200 fathoms	none	none
1977	same as 1976	same as 1976	same as 1976	none	none
1978	same as 1976	same as 1976	same as 1976	none	none
1979	same as 1976	same as 1976	same as 1976	none	none
1980	same as 1976	same as 1976	same as 1976	none	none
1981	same as 1976	same as 1976	same as 1976	none	none
1982	same as 1976	same as 1976	same as 1976	none	none
1983	3rd Sunday in June-E.O. date: 72 hrs/wk	same as 1976	same as 1976	none	none

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Year	Season opening date(s) and fishing period(s)	Gillnet mesh regulations	Gillnet Length Regulations	Gillnet spacing regulations	Chinook size limits
1984	same as 1983	same as 1976; except, during E.O. pink salmon seasons, mesh size may not be more than 5”	same as 1976	none	none
1985	3rd Sunday in June-E.O. date: 72 hrs/wk	60 mesh max. for nets smaller than 8”; 40 mesh max. for nets 8” or larger; 40 mesh max. before 3rd Sunday in June; 6” max. from 3rd Sunday in June-7/18; max. mesh size in Section 11-B through 7/30 is 6” and in Section 11-C through 7/18 is 6”; during E.O. pink salmon seasons, mesh size may not be less than $5^{3/8}$ inches	not less than 100 fathoms or more than 150 fathoms except after 3rd Saturday in June, max. length increases to 200 fathoms	none	no size limit
1986	3rd Sunday in June-E.O. date: hrs/wk not specified *Drift gill net quota established by Board of Fisheries in 1986 at 7,600 chinook salmon per regulatory year for all of SEAK*	60 mesh max. for nets smaller than 8”; 40 mesh max. for nets 8” or larger; 40 mesh max. before 3rd Sunday in June; Section 11-B max. of 6” through 6/30 and Section 11-C max. of 6” through 6/18; for the protection of pink salmon, $5^{3/8}$”; for the harvest of chum salmon, 6”	same as 1985	none	none
1987	same as 1986	same as 1986	same as 1985	none	none
1988	same as 1986	same as 1986	same as 1985	none	none
1989	same as 1986	same as 1986	same as 1985	none	none
1990	same as 1986	same as 1986	same as 1985	none	none
1991	same as 1986	same as 1986	same as 1985	none	none
1992	same as 1986	same as 1986	same as 1985	none	none
1993	same as 1986	same as 1986	same as 1985	none	none
1994	same as 1986	same as 1986; except, 40 mesh max. before 2nd Sunday in June; district-wide 6” max. through 4th Saturday in June	same as 1985	none	none
1995	same as 1986	same as 1994	same as 1985	none	none
1996	3rd Sunday in June-E.O. date: hrs/wk not specified	60 mesh max. for nets smaller than 8”; 40 mesh max. for nets 8” or larger; 40 mesh max. before 2nd Sunday in June; max. mesh of 6” through 4th Saturday in June throughout District; for the protection of pink salmon, $5^{3/8}$ inches; for the harvest of chum salmon, 6”	not less than 100 fathoms or more than 150 fathoms except after 3rd Saturday in June, max. length increases to 200 fathoms	none	no size limit
1997	same as 1996	60 mesh max. for nets smaller than 8”; 40 mesh max. for nets 8” or larger; 40 mesh max. before 2nd Sunday in June; max. mesh of 6” through 4th Saturday in June; min. size is 6” during periods announced by E.O.	same as 1996	none	none
1998	same as 1996	same as 1997	same as 1996	none	none

[a] Prior to 1945, gill netting opened on or before May 10 and fishing time was limited only by weather and the general regulation of 1906 which provided for a weekly closure from 6 PM Saturday to 6 PM Monday. Between 1945 and 1953, gill nets were fished in Taku Inlet up to 5.5 days per week through May followed by a three week closure in June. In 1953 and 1954, the fishing period was reduced to 4 days per week in May and June. From 1955-1959, the fishing period was reduced to 3 days per week (72 hours) from May 1st through the Emergency Order (E.O.) closing date.

Table D4.—Major regulatory actions taken in the management of the Southeast Alaska troll fishery for chinook salmon over the past 75 years.

Year	Major Regulatory Actions Associated with Management of Southeast Alaska Troll Fishery
Prior to 1924	Congressional Act in 1906 provided for 36 hour per week closure in all waters of Alaska, but very little enforcement was conducted.
Prior to 1950	Troll fishery was unlimited by area restrictions and continued year round. Trollers were limited to four lines in Territorial waters. In 1941, a minimum size of 6 lbs. dressed weight for chinook was implemented. In 1941, Burroughs Bay was closed to trolling from 8/16-10/5.
1950	"Outside" waters were closed from 10/31 to 3/15. Portions of northern Lynn Canal were closed from 5/31 to 6/25. Northern Behm Canal was closed from 5/1 to 7/15.
1951	Chinook size limit was modified to either 6 lbs. dressed weight or 26 inches in fork length.
1958	Additional area restrictions were imposed with the closing of portions of Stephens Passage.
1959	Trolling was prohibited in Stikine Straight south of Vank Island during November and December.
1960	Trollers were limited to 4 fishing lines and use of single hooks in State waters and "outside" waters were closed from 11/1 to 4/15.
1962	A portion of northern Behm Canal was closed to trolling. Trolling was limited to 1 day per week in Districts 11A and 11B from late April to mid-June.
1965	The District 8 troll season was open only during days the gill net fishery was open during the gill net season.
1970	Trolling in Yakutat Bay was restricted to the same days as the set net fishery was open.
1971	Trolling was limited to 1 day per week in District 111, District 112 north of Point Couverden and District 115C from 5/1 to the 3rd Sunday of June.
1973	Yakutat Bay was opened to winter troll fishing.
1974	All State waters north and west of Cape Suckling were closed to troll fishing.
1975	Power trolling was placed under limited entry with 940 permits allowed.
1976	District 11, District 12 north of Point Couverden, and Districts 15B and 15C were closed to trolling from 4/16 to 6/14. District 11A was closed to trolling from 4/16 to 8/14.
1977	Federal waters of the Fishery Conservation Zone west of Cape Suckling were closed to troll fishing. The chinook salmon minimum size length was increased to 28 inches. Waters in east Behm Canal and in Boca de Quadra were closed to troll fishing.
1978	The eastern Sumner Strait portions of District 6 and adjoining District 8 were closed to trolling from 4/16 to 6/14. The northern Clarence Straight portion of District 6 and adjoining District 8 were closed to trolling from 4/16 to 8/14. District 8 was closed to trolling from 4/16 to the third Monday in June. The southern Frederick Sound portion of District 10 and adjoining District 8 was closed to trolling from 4/16 to 6/14.
1979	A 8-day "on" and 6-day "off" fishing period was implemented for the troll fishery in Districts 12 north of Point Hepburn and in Districts 14, 15A and 15C. Districts 11A and 11B were closed to trolling all year. "Outside" waters were closed to hand trolling.
1980	First of the annual management targets was established for the harvest of chinook salmon in Southeast Alaska by the Alaska Board of Fisheries and the North Pacific Fishery Management Council; a guideline harvest target of 286,000 to 320,000 chinook salmon in the commercial fishery. Limited entry for hand trolling was implemented, 2,150 permits were issued, 1,300 of them as non-transferable permits. The number of lines allowed to be fished in the Federal Conservation Zone was limited to 4 lines per vessel south of Cape Spencer and 6 lines per vessel between Cape Spencer and Cape Suckling with a limit of 6 operational gurdies. A 10-day chinook non-retention period for the troll fishery from 6/15 to 6/24 was implemented and a 9/21 to 9/30 closure of the troll fishery was implemented.
1981	Guideline harvest of 272,000 to 285,000 chinook was established by Alaska Board of Fisheries; North Pacific Fishery Management Council set guideline at 243,000 to 286,000 chinook. The troll fishery was closed from 4/15 to 5/15 for conservation of mature chinook salmon spawners of local origin. A 6/25 to 7/5 chinook non-retention period was implemented. A troll fishery closure from 8/10 to 8/19 was implemented. A 9/4 to 9/12 chinook non-retention period was implemented. The Federal Conservation Zone was closed from 8/10 to 9/20 except in Yakutat Bay. With the exception of Yakutat Bay, the troll fishery was closed from 9/21 to 9/30. A winter chinook troll fishing season was established from 10/1 to 4/14, a summer troll fishing season was established from 4/15 to 9/20. Portions of District 116 were included in waters open to the winter troll fishery. Hand troll gear was limited to 2 gurdies or 4 fishing poles and the hand troll closure in "outside" waters was repealed.
1982	Alaska Board of Fisheries and the North Pacific Fishery Management Council set a guideline harvest of 257,000 chinook with a range from 243,000 to 286,000 chinook (including an estimated 1,500 chinook produced by Alaskan hatcheries). The troll fishery was closed from 5/15 to 6/14. A chinook non-retention period from 6/7 to 6/17 and from 7/29 to 9/19 was implemented. Undersized chinook with adipose finclips were allowed to be retained by troll fishermen so long as the heads were submitted to ADFG.

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1983	Guideline harvest level was again set at 243,000 to 286,000 chinook salmon for the commercial fishery, including the winter troll harvest from 10/1/83 to 4/14/84 by the Alaska Board of Fisheries and the North Pacific Fishery Management Council. Troll fishery was closed from 4/15 to 6/5 and from 7/1 to 7/10. The troll fishery was closed to chinook retention from 7/30 to 9/20.
1984	Guideline harvest level of 243,000 to 272,000 chinook salmon was again set by the Alaska Board of Fisheries and the North Pacific Fishery Management Council for the commercial fishery, including the winter troll harvest. The troll fishery was closed from 5/15 to 6/5 and from 7/1 to 7/10. The troll fishery was closed to the retention of chinook from 7/30 to 9/20.
1985	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 263,000. The summer season definition was extended to 9/30. The troll fishery was closed from 4/15 to 6/3 and from 6/13 to 6/30. Troll fishery chinook non-retention was implemented from 7/23 to 8/24 and from 8/27 to 9/20.
1986	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 254,000 fish plus an Alaska hatchery add-on. The troll fishery was closed from 4/15 to 6/20. Selected areas were closed from 7/9 to the end of the season to reduce chinook catch rates. Remaining areas were closed to chinook retention from 7/16 to 8/20. Troll fishery chinook non-retention was implemented from 8/27 to 8/31 and from 9/10 to 9/20. Experimental troll fisheries were allowed in Wrangell Narrows and near Little Port Walter from 6/2 to 6/3, from 6/9 to 6/10, and from 6/16 to 6/17 to harvest hatchery chinook. The 8-day “on” and 6-day “off” fishing periods in District 14 and waters of District 12 south of Point Couverden were repealed. The prior regulation allowing the retention of under-sized chinook with missing adipose fins was repealed.
1987	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 263,000 fish plus an Alaska hatchery add-on. The general summer troll fishery was closed from 4/15 to 6/20. Selected areas were closed from 7/4 to the end of the season to reduce chinook catch rates. Remaining areas were closed to chinook retention from 7/13 to 8/2 and from 8/13 to 9/20. Experimental troll fisheries near four Alaskan hatcheries were allowed during June prior to the 6/20 summer season opening.
1988	The Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 263,000 fish plus an Alaska hatchery add-on. The general summer troll fishery was closed from 4/15 to 6/30. Chinook non-retention was implemented from 7/12 to 9/20. Experimental troll fisheries near five Alaskan hatcheries were allowed during June and terminal troll fisheries were operated continuously during June in Wrangell Narrows and Carroll Inlet.
1989	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 263,000 fish plus an Alaska hatchery add-on. The general summer troll fishery was closed from 4/15 to 6/30. Chinook non-retention was implemented from 7/13 to 9/20. Experimental troll fisheries in 9 areas near Alaskan hatcheries were allowed during June (6/12 to 6/13 and 6/26 to 6/28) and terminal troll fisheries were operated during June in Wrangell Narrows (6/12) and Carroll Inlet (6/11 to 6/29). Hatchery access troll fisheries were opened in most of the “inside” waters for two 3-day periods in June during weeks without experimental troll fisheries.
1990	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 302,000 fish plus an Alaska hatchery add-on. The general summer troll fishery was closed from 4/15 to 6/30. Chinook non-retention was implemented from 7/23 to 8/22 and from 8/25 to 9/20. Experimental and hatchery access troll fisheries near Alaskan hatcheries were allowed during June. Additional terminal areas were opened to troll fishing in Earl West Cove. A quota of 30,000 chinook excluding Alaska hatchery add-on fish was implemented for the spring-time troll fisheries. A portion of District 111A, the backside of Douglas Island was opened to trolling during the winter season (10/1 to 4/15).
1991	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 273,000 fish plus an Alaska hatchery add-on that was projected at 57,800 chinook salmon. The general summer troll fishery was closed from 4/15 to 6/30. Chinook non-retention was implemented from 7/8 to 9/20. Experimental and hatchery access troll fisheries near Alaskan hatcheries were allowed during June. A quota of 40,000 chinook excluding Alaska hatchery add-on fish was implemented for the spring-time troll fisheries.
1992	The U.S.-Canada Pacific Salmon Treaty set a ceiling for the harvest of chinook salmon in Southeast Alaska by all gear groups as 263,000 fish plus an Alaska hatchery add-on that was projected at 69,000 chinook salmon. The Alaska Board of Fisheries allocated 83% of the ceiling to the troll fishery after accounting for a 20,000 chinook allocation for commercial net fisheries. Winter and spring-time troll fisheries occurred similar to 1991. The general summer troll fishery was closed from April 15 to June 30. The general summer season opening occurred from 7/1 to 7/6. The troll fishery was closed to chinook retention from 7/7 to 8/20 and areas of high chinook abundance were closed to fishing through 9/20. The troll fishery reopened to chinook retention from 8/21 to 8/25 and from 9/12 to 9/20. From 8/26-9/11 chinook non-retention was implemented. Snake River fall chinook salmon listed as “threatened” under the U.S. Endangered Species Act (ESA)

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Table D4.–Page 3 of 3.

1993	The Alaska Department of Fish and Game managed the chinook salmon harvest in Southeast Alaska for a ceiling of 263,000 fish plus the Alaska hatchery add-on estimated to be 35,900 fish after receiving a Section 7 ESA consultation from the National Marine Fisheries Service. The U.S.-Canada Pacific Salmon Treaty Annex concerning chinook salmon catch ceilings expired in 1992 and an annex has not since been successfully negotiated by the parties to the treaty. The start of the winter troll fishery was delayed until 10/11 and operated until 4/14. As a result of the ESA consultation, the spring-time hatchery access fishery did not occur. Experimental and terminal fisheries did occur. The general summer season opening was delayed until 7/1 and remained open until 7/6. The troll fishery was closed from 7/7 to 7/11. The troll fishery was reopened on 7/12 with chinook non-retention and with areas of high chinook abundance closed to fishing. The troll fishery reopened to chinook retention from 9/12 to 9/20.
1994	The Alaska Department of Fish and Game managed the chinook salmon harvest in Southeast Alaska for a ceiling of 240,000 fish plus the Alaska hatchery add-on after receiving a Section 7 ESA consultation from the National Marine Fisheries Service. The Alaska Board of Fisheries allocated 82% of the ceiling to the troll fishery after accounting for a 20,000 chinook allocation for commercial net fisheries. The Alaska Board of Fisheries allocated 45,000 of the troll allocation to the winter troll fishery and 70% of remaining troll harvest to a summer fishery with an initial opening beginning July 1. The winter troll fishery took place from 10/11 to 4/14. Spring-time troll fisheries consisting of terminal and experimental fisheries were conducted between early May and 6/30. The general summer troll fishery opened on 7/1 and closed on 7/8. From 7/8 to 9/20, areas of high chinook abundance were closed to troll fishing. Chinook non-retention in the troll fishery was implemented from 7/8 to 8/28. Chinook retention was allowed by trollers from 8/29 to 9/2. Non-retention of chinook in the troll fishery was implemented from 9/3 to 9/20.
1995	The Alaska Department of Fish and Game initially managed the chinook salmon harvest in Southeast Alaska for a ceiling of 230,000 fish plus the Alaska hatchery add-on after receiving a Section 7 ESA consultation from the National Marine Fisheries Service. Part way through the general summer season, a temporary restraining order issued by the U.S. District Court, Western District of Washington resulted in the fishery being closed well before reaching the target harvest level. The Alaska Board of Fisheries allocated 81% of the ceiling to the troll fishery after accounting for a 20,000 chinook allocation for commercial net fisheries. The winter troll fishery took place from 10/11 to 4/14. Spring-time troll fisheries consisting of terminal and experimental fisheries were conducted between early May and 6/30. The general summer troll fishery opened on 7/1 and closed on 7/10. From 7/11 to 9/20, areas of high chinook abundance were closed to troll fishing. Chinook non-retention in the troll fishery was implemented from 7/11 to 7/30. Chinook retention was allowed by trollers from 7/31 to 8/5. Non-retention of chinook in the troll fishery was implemented from 8/6 to 9/20.
1996	The Alaska Department of Fish and Game managed the chinook fisheries in Southeast Alaska for a harvest of 140,000 to 155,000 fish plus the Alaska hatchery add-on after receiving a Section 7 ESA consultation from the National Marine Fisheries Service and upon the State of Alaska signing a 6/24/96 letter of agreement with southern U.S. representatives of the U.S.-Canada Treaty regarding an abundance-based approach to managing chinook salmon fisheries in Southeast Alaska. The Alaska Board of Fisheries allocated 80% of the ceiling to the troll fishery after accounting for a 20,000 chinook allocation for commercial net fisheries. The winter troll fishery took place from 10/11 to 4/14. Spring-time troll fisheries consisting of terminal and experimental fisheries were conducted between early May and 6/30. The general summer troll fishery opened on 7/1 and closed on 7/10. From 7/11 to 9/20, areas of high chinook abundance were closed to troll fishing. Chinook non-retention in the troll fishery was implemented from 7/11 to 7/30. Chinook retention was allowed by trollers from 8/19 to 8/20. Non-retention of chinook in the troll fishery was implemented from 8/21 to 9/20.
1997	The Alaska Department of Fish and Game managed the chinook salmon harvest in Southeast Alaska for a ceiling of 302,000 fish plus the Alaska hatchery add-on after receiving a Section 7 ESA consultation from the National Marine Fisheries Service and applying measures as called for in the 6/24/96 letter of agreement concerning management of SEAK chinook fisheries. The winter troll fishery took place from 10/11 to 4/14. Spring-time troll fisheries consisting of terminal and experimental fisheries were conducted between early May and 6/30. The general summer troll fishery opened on 7/1 and closed on 7/7. After 7/7 areas of high chinook abundance were closed to troll fishing. Chinook non-retention in the troll fishery was implemented from 7/8 to 8/17. Chinook retention was allowed by trollers from 8/18 to 8/24 and again from 8/30-9/5. Non-retention of chinook in the troll fishery was implemented from 8/25 to 8/29 and again from 9/6-9/23.

Appendix E. Estimates of Smolt Abundance

Smolt abundance was estimated for several year classes, using a two-sample, mark-recapture experiment with Petersen's estimator as modified by Chapman (1951):

$$\hat{N}_{s,y} = \frac{(n_{c,y}+1)(n_{e,y}+1)}{m_{e,y}+1} - 1$$

$$v[\hat{N}_{s,y}] = \frac{\hat{N}_{s,y}(n_{c,y}-m_{e,y})(n_{e,y}-m_{e,y})}{(m_{e,y}+1)(m_{e,y}+2)}$$

where $\hat{N}_{s,y}$ is the number of smolt leaving the Taku River from year class *y*, $n_{c,y}$ is the number of smolt tagged from year class *y*, $n_{e,y}$ is the number of adults sampled in the escapement in subsequent years from year class *y*, and $m_{e,y}$ is the number of adults in that sample with missing adipose fins.

Young chinook salmon were captured and implanted with coded-wire tags (CWTs) in the Taku River from the 1975-1981 and 1991-present year classes (Table E.1). Too few smolt were tagged for year classes 1977, 1978, 1980 and 1981 to produce estimates of smolt abundance. Consequently, we estimated smolt abundance for the 1975, 1976, 1979 and 1991-1995 year classes. Young fish were captured in the mainstem of the Taku River with baited minnow traps (Kissner and Hubartt 1986) for the 1975-1981 year classes and with rotary screw traps and minnow traps in later years. Numbers of smolt CWTd ranged from approximately 9,000 to 11,000 for the 1975, 1976, 1979 and 1991-1993 year classes to about 38,000 for the 1995 year class.

Adults were inspected on the spawning grounds or in fish wheels at Canyon Island (near the international border) to estimate the fraction of year class *y* tagged in year *y*+2 as smolt.

Adults were inspected in years *y*+3 (age 1.1), *y*+4 (age 1.2), *y*+5 (age 1.3), *y*+6 (age 1.4) and *y*+7 (age 1.5).

Table E1.—Numbers of smolt CWTd, adults inspected and marked, and estimated smolt abundance and associated SEs for Taku River chinook salmon.

Year Class	$n_{c,y}$	$n_{e,y}$	$m_{e,y}$	$\hat{N}_{s,y}$	SE
1975	9,912	5,397	44	1,189,118	174,197
1976	9,550	2,594	15	1,549,052	374,227
1979	8,961	3,245	43	661,150	97,648
1991	10,015	10,267	48	2,098,862	295,390
1992	9,858	3,792	18	1,968,167	438,569
1993	11,121	455	3	1,267,907	564,432
1994	21,588	799	12	1,328,553	352,068
1995	37,869	400	7	1,898,233	626,335

Details

Escapement sampling for the returning adults from the 1975-1981 year classes was limited to the Nakina River (Figure 1). The Nakina River produces more chinook than any other tributary in the Taku River drainage (Pahlke & Bernard 1996; Eiler et al. *In prep*). It also has the longest standing stock assessment program in the Taku River. A carcass weir has been operated on this tributary each year since 1973 and an average of 1,000 fish have been sampled annually for age, sex and length. Additionally, all other chinook caught at the weir (up to 4,500) have been sampled for sex and length. In order to estimate smolt abundance (for the 1975, 1976 and 1979 year classes) from recoveries in the Nakina River, samples from this subpopulation must be representative of the entire drainage.

Sampling for the 1991-1995 year classes indicate that tagged smolt represented all subpopulations in the Taku River in near equal proportions (Table E.2). For example, the marked fraction of fish sampled from the 1991 year class at Canyon Island (0.0056) was not different than the marked fraction of fish sampled at Nakina River (0.0043) (P = 0.40, χ^2 = 0.70). Similarly, the marked fraction of fish sampled from the 1992 year class at Canyon Island (0.0052) was not different that the marked fraction of fish sampled at Nakina River (0.0044) ($P=0.77$, $\chi^2 = 0.08$). The benchmark for the entire run is Canyon Island. At this location, fish are sampled from fish wheel catches throughout the duration of the adult migration. Canyon Island is located in the lower river below all known chinook spawning areas and catches are composed of all subpopulations.

Our analysis included smolt estimates from the 1993-1995 year classes, for which adult returns are incomplete (Table E.2). Results from earlier brood years indicate that estimates of smolt abundance are relatively invariant as the results accumulate across a given brood. For example, the estimated smolt abundance varied from 1.2 to 1.4 million across the five age classes for the 1975 year class, from 1.4 to 1.6 million for the 1976 year class and from 0.6 to 0.7 million for the 1979 year class. Estimated smolt abundance ranged from 2.1 to 2.2 million for the 1991 year class across the accumulated data for age-1.2 to age-1.4 fish. Smolt estimates seldom varied after two age classes or five marked adults were recovered.

The narrow ranges of estimated smolt abundance through the course of accumulated data over each year class indicates that the marked fraction is consistent across age classes. The marked fractions were virtually the same ($P=0.96$, $\chi^2 = 0.27$) for age-1.1 fish (0.0050), age-1.2 fish (0.0042), age-1.3 fish (0.0048) and age-1.4 fish (0.0050) sampled from the 1991 year class. The marked fractions were almost as consistent for the other complete years classes, 1975 (($P=077$, $\chi^2 = 1.14$), 1976 ($P=0.89$, $\chi^2 = 0.59$), and for 1979 ($P=0.46$, $\chi^2 = 2.56$). Summarily, estimates of smolt production were consistent across age classes, but precision increased as information accumulated.

Table E2.—Smolt tagged, adults subsequently sampled for marks, marked fraction, estimated smolt abundance with standard errors for year classes 1975, 1976, 1979 and 1991-1995 for Taku River chinook salmon.

y	$n_{c,y}$				$n_{e,y}$	$m_{e,y}$		$\hat{N}_{s,y}$	$SE(\hat{N}_{s,y})$
Year Class	Smolt CWTd	Year Adults Sampled	Age	Location Sampled	Adults Examined	Marked Adults	Marked Fraction	Estimated Smolt	SE Smolt Estimate
1975		1978	1.1	Nakina River	2,192	15	0.0068	1,358,700	328,064
		1979	1.2	Nakina River	1,352	12	0.0089	1,255,056	231,808
		1980	1.3	Nakina River	646	5	0.0077	1,258,950	214,698
		1981	1.4	Nakina River	1,184	12	0.0101	1,184,052	173,452
		1982	1.5	Nakina River	23	0	0.0000	1,189,118	174,197
1975	**9,912**	**1978-1982**	**1.1-1.5**	**Cumulative Total**	**5,397**	**44**	**0.0082**	**1,189,118**	**174,197**
1976		1979	1.1	Nakina River	675	3	0.0044	1,614,118	719,566
		1980	1.2	Nakina River	542	3	0.0055	1,454,139	585,655
		1981	1.3	Nakina River	563	3	0.0053	1,417,527	511,171
		1982	1.4	Nakina River	811	6	0.0074	1,375,343	373,793
		1983	1.5	Nakina River	3	0	0.0000	1,376,935	374,227
1976	**9,550**	**1979-1983**	**1.1-1.5**	**Cumulative Total**	**2,594**	**15**	**0.0058**	**1,549,052**	**374,227**
1979		1982	1.1	Nakina River	856	11	0.0129	640,035	176,149
		1983	1.2	Nakina River	1,134	17	0.0150	615,287	111,334
		1984	1.3	Nakina River	490	3	0.0061	694,834	119,958
		1985	1.4	Nakina River	757	12	0.0159	659,521	97,405
		1986	1.5	Nakina River	8	0	0.0000	661,150	97,648
1979	**8,961**	**1982-1986**	**1.1-1.5**	**Cumulative Total**	**3,245**	**43**	**0.0133**	**661,150**	**97,648**
1991		1994	1.1	Canyon Island	400	2	0.0050	1,338,804	666,794
		1995	1.2	Canyon Island	980	6	0.0061		
				Nakina River	1,230	4	0.0033		
				Nahlin River	1,172	3	0.0026		
				Tats/Kowatua	180	2	0.0111		
				Subtotal	3,562	15	0.0042	2,230,437	539,313
				Cum. Subtotal	3,962	17	0.0043	2,205,188	504,301
		1996	1.3	Canyon Island	1,330	6	0.0045		
				Nakina River	1,801	9	0.0050		
				Subtotal	3,131	15	0.0048	1,960,631	473,928
				Cum. Subtotal	7,093	32	0.0045	2,153,135	367,793
		1997	1.4	Canyon Island	674	5	0.0074		
				Nakina River	2,500	11	0.0044		
				Subtotal	3,174	16	0.0050	1,870,634	439,358
1991	**10,015**	**1994-1997**	**1.1-1.4**	**Cumulative Total**	**10,267**	**48**	**0.0047**	**2,098,862**	**295,390**

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Table E2.—Page 2 of 2.

y Year Class	$n_{c,y}$ Smolt CWTd	Year Adults Sampled	Age	Location Sampled	$n_{e,y}$ Adults Examined	$m_{e,y}$ Marked Adults	Marked Fraction	$\hat{N}_{s,y}$ Estimated Smolt	$SE(\hat{N}_{s,y})$ SE Smolt Estimate
1992		1995	1.1	Canyon Island	162	2	0.0123		
				Nakina River	122	0	0.0000		
				Nahlin River	14	0	0.0000		
				Tats/Kowatua	7	0	0.0000		
				Subtotal	305	2	0.0066	1,005,617	500,262
		1996	1.2	Canyon Island	390	1	0.0026		
				Nakina River	487	2	0.0041		
				Tatsamenie River	70	1	0.0143		
				Subtotal	947	4	0.0042	1,869,265	760,916
				Cum. Subtotal	1,252	6	0.0048	1,764,760	621,971
		1997	1.3	Canyon Island	376	1	0.0027		
				Nakina River	1,212	5	0.0041		
				Tatsamenie River	234	1	0.0043		
				Subtotal	1,822	7	0.0038	2,246,619	746,925
				Cum. Subtotal	3,074	13	0.0042	2,165,458	557,449
		1998	1.4	Canyon Island	237	2	0.0084		
				Nakina River	214	2	0.0093		
				Tatsamenie River	267	1	0.0037		
				Subtotal	718	5	0.0070	1,181,436	444,539
1992	**9,858**	**1995-1998**	**1.1-1.4**	**Cumulative Total**	**3,792**	**18**	**0.0047**	**1,968,167**	**438,569**
1993		1996	1.1	Canyon Island	25	1	0.0400		
				Nakina River	18	0	0.0000		
				Subtotal	43	1	0.0233	244,683	138,008
		1997	1.2	Canyon Island	73	1	0.0137		
				Nakina River	110	0	0.0000		
				Subtotal	183	1	0.0055	1,023,223	587,486
		1998	1.3	Canyon Island	129	1	0.0078		
				Nakina River	100	0	0.0000		
				Subtotal	229	1	0.0044	1,279,029	735,164
1993	**11,121**	**1996-1998**	**1.1-1.3**	**Cumulative Total**	**455**	**3**	**0.0066**	**1,267,907**	**564,432**
1994		1997	1.1	Canyon Island	151	2	0.0132		
				Nakina River	108	2	0.0185		
				Subtotal	259	4	0.0154	1,122,627	453,830
		1998	1.2	Canyon Island	251	4	0.0159		
				Nakina River	200	3	0.0150		
				Tats/Kowatua	89	1	0.0112		
				Subtotal	540	8	0.0148	1,297,738	406,868
1994	**21,588**	**1997-1998**	**1.1-1.2**	**Cumulative Total**	**799**	**12**	**0.0150**	**1,328,553**	**352,068**
1995		1998	1.1	Canyon Island	263	5	0.0190		
				Nakina River	137	2	0.0146		
1995	**37,869**	**1998**	**1.1**	**Cumulative Total**	**400**	**7**	**0.0175**	**1,898,233**	**626,335**

Appendix F.–Computer data files used create this manuscript.

FILE NAME	DESCRIPTION
TAKUSRREP.XLS	Excel (Office 97) workbook with spreadsheets with data and calculations of smolt abundance, estimates of escapements and associated standard errors, estimates of harvests and associated standard errors, and statistical tests for discriminating differences or similarities in parameter estimates.
SMOLTLEN.XLS	Excel (Office 97) workbook with separate spreadsheets of smolt length and weight measurements for Taku River chinook salmon smolt each year from 1993 to 1998 (1991-1996 broods).