Fishery Manuscript No. 00-1

Optimal Production of Chinook Salmon from the Stikine River

by

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July 2000

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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July 2000

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K)

The Fishery Manuscript series was established in 1987 for the publication of technically-oriented results of several years' work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods. Fishery Manuscripts are intended for fishery and other technical professionals. Fishery Manuscripts are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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This document should be cited as:
Bernard, D. R., S. A. McPherson, K. A. Pahlke, and P. Etherton. 2000. Optimal production of chinook salmon from the Stikine River. Alaska Department of Fish and Game, Fishery Manuscript No. 00-1, Anchorage.

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ACKNOWLEDGMENTS

The authors thank Paul Kissner, formerly of the Alaska Department of Fish and Game (ADFG), who implemented the stock assessment program on the Stikine River in the early 1970s. He standardized aerial surveys and initiated age/sex/size sampling. We thank Sandy Johnston of Canadian Department of Fisheries and Oceans (CDFO) for his assistance during the evolution of the program. We thank John H. Clark of ADFG for assistance with the regulations appendix and other aspects of this paper. We thank the following personnel for field work required to complete the 1996 and 1997 mark-recapture experiments and the 1997 radiotelemetry project: Tom Rockne, Dave Dreyer, Ron Hulse, Alicia Bachinsky and Peter Branson (ADFG); Colin Barnard, Alex Joseph, Gerald Quash, Martin Kienzler, Henry Vance, Wayne Dennis and Chuck Shewen (CDFO and Tahltan First Nation). Additionally, Colin Barnard ran the Little Tahltan weir and collected associated biological data since its inception in 1985. Personnel of the CDFO lab in Nanaimo, B. C., and Paul Kissner, Mark Olsen and Sue Millard of ADFG inspected many of the scales collected over the years. Various members of: (1) the Transboundary Technical Committee of the Pacific Salmon Commission (PSC), (2) the Chinook Technical Committee of the PSC, (3) the Salmon Escapement Goal Review Committee of ADFG, and (4) the Salmon Subcommittee of the Pacific Scientific Advice Review Committee of CDFO provided helpful review comments on this manuscript. Alma Seward prepared the final text layout of this manuscript, and Steve Fleischman assisted with the analysis. This work was partially funded by aid authorized under the U.S. Federal Sport Fish Restoration Act, by Canada, the Tahltan First Nation, and by recreational anglers fishing in Alaska.

ABSTRACT

Optimal production of adult chinook salmon *Oncorhynchus tshawytscha* from the Stikine River was investigated with information from a stock assessment program (1975-1997) and catch sampling programs on the Canadian inriver commercial and aboriginal gillnet fisheries and on the U.S. marine commercial gillnet and recreational fisheries. Stock assessment was based on aerial surveys, mark-recapture experiments to estimate abundance of large (mostly age 1.3 and older) salmon over the spawning grounds, a weir over the Little Tahltan River, and a radiotelemetry study to determine distribution of spawning salmon. Counts at the weir on the Little Tahltan River represented on average an estimated 19% of all large spawners in the Stikine River watershed; depending on water clarity, an estimated 48% or 36% of large fish above the weir were counted on average in aerial surveys. Estimates of relative age composition from carcass surveys (1981 – 1988) on the Little Tahltan River were similar to estimates from samples taken at the weir (1985 – 1988). Few age 1.2 salmon were present over the spawning grounds in any year; salmon age 1.4 usually dominated. Measurement error in estimated spawning abundance was an estimated 9% of all variance. Residuals from a fit of a linearized, log-transformed version of Ricker's exponential stock-recruit model to the data showed no autocorrelation in process error. Spawning abundance that would on average produce maximum sustained yield (10,983) was estimated at 17,368 large chinook salmon with simulated 90% confidence intervals of 11,838 and 39,907. Some statistical bias (~18%) was indicated in the estimate. Considering that estimated spawning abundance has been above 17,368 large chinook salmon since 1986 (excluding 1995), we concluded that this population has probably recovered from overfishing incurred in the 1970's. We recommend annual aerial surveys be suspended, reinstatement of a coded-wire tag program to estimate marine harvests and smolt abundance, and continuation of the current stock assessment program based on catch sampling, escapement sampling, the mark-recapture experiment, and the weir on the Little Tahltan River.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, Stikine River, spawning abundance, mark-recapture; age composition, escapement goal, stock-recruit analysis, maximum-sustained yield.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* from the Stikine River (Figure 1) are a "spring run" of salmon with almost all adults spawning in Canada from late July to mid-September. Almost all juveniles rear for just over a year in fresh water after emergence and smolt at age 1. While at sea, these young generally rear offshore away from troll, sport, and net fisheries; then, after 1–5 years, they mature and return to the river through Southeast Alaska from late April through early July (Kissner and Hubartt 1986). Fish maturing at a younger age (age 1.1 and 1.2) are almost exclusively males, whereas older fish (ages 1.3, 1.4. and 1.5) are a mixture of males and females. Ages 1.3 and 1.4 dominate the annual spawning migration, although age 1.2 fish occasionally are abundant; age 1.1 and 1.5 fish are uncommon (<5%). Because of natural barriers to migration, spawning is limited to the lower mainstem and to downstream tributaries, such as the Tahltan and Little Tahltan rivers, the Chutine, Katete, Craig, Barrington and Tuya rivers, and Beatty, Christina, Verrett, Shakes, Sixmile, Andrew, and Tashoots creeks (Pahlke and Etherton 1999, FISS 1991). The mainstem Stikine River is turbid from late spring through early fall from glacial silt. Chinook salmon in the Stikine River are speculated to have the same genetic origin as chinook salmon in the nearby Taku River (see Gharrett et al. 1987), another transboundary river.

Presently, the annual migration is targeted in marine waters only in a recreational fishery centered near Wrangell and Petersburg, Alaska beginning early in May each year. Beginning in 1976, commercial fishing on chinook salmon in Southeast Alaska was curtailed in response to a perceived decade of overfishing. Fishing grounds for the spring troll fishery were reduced in 1976, and in the same year, the opening of the drift gillnet fishery offshore of the Stikine River (Figure 1) was pushed back to the third Monday in June, allowing about two-thirds to three

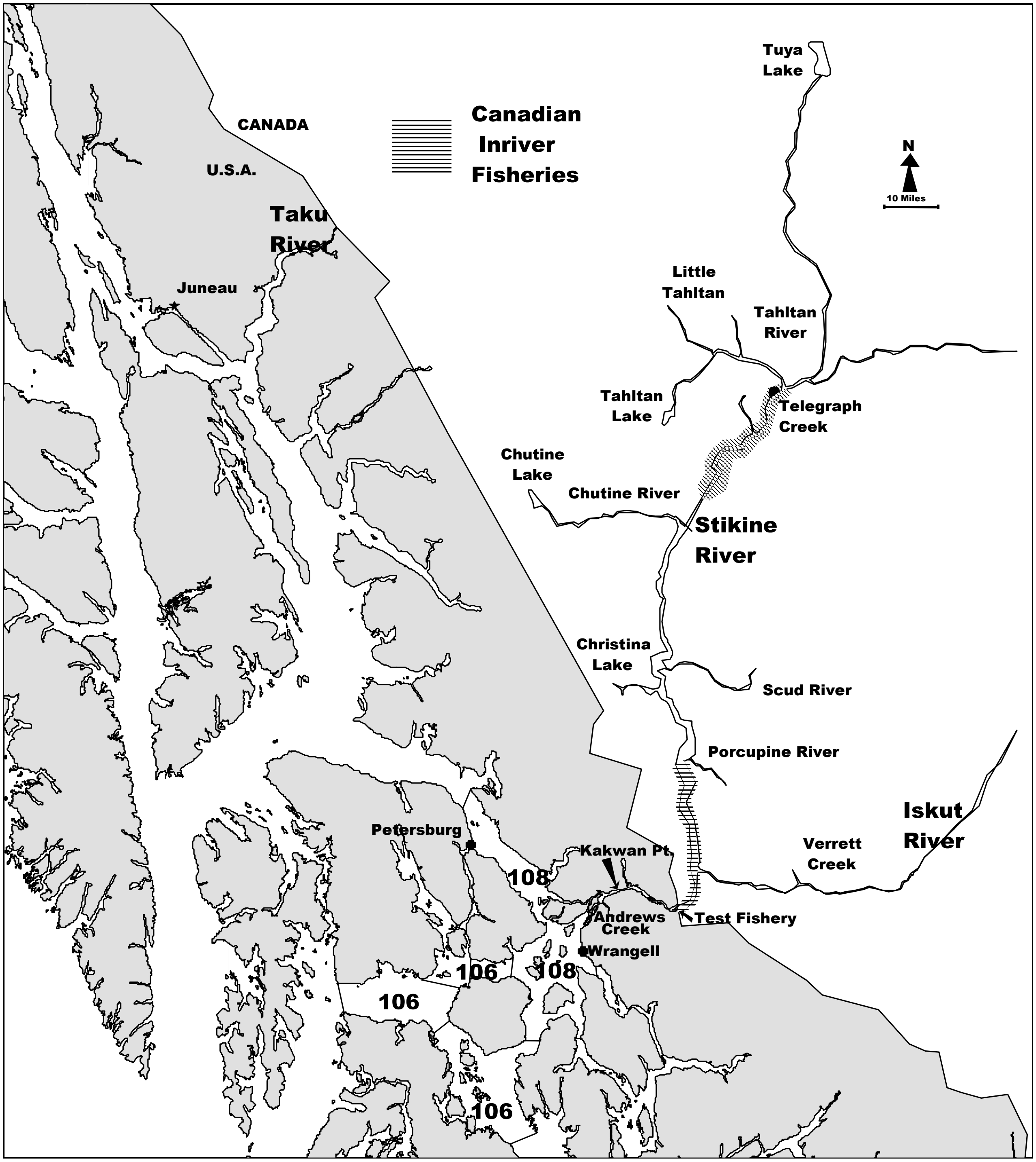

Figure 1.–Map of Stikine River drainage and nearby offshore waters including U. S. Districts 106 and 108. In 1997, Canada extended the inriver commercial fishery upstream to within 5 km of the confluence of Christina Lake outlet.

quarters of the migration to pass before the fishery starts. There is no direct information on catches of Stikine-bound chinook salmon in this delayed marine gillnet fishery or in the recreational marine fishery. There is some potential for small incidental harvest in the winter and summer troll fisheries (Kissner and Hubartt 1986).

Once inside the Stikine River, chinook salmon are exposed to Canadian gillnet fisheries. A commercial fishery for sockeye salmon just over the border (Figure 1) starts after about half the migration of chinook salmon has passed. Farther upstream there is a combination of commercial and aboriginal gillnet fisheries, the latter targeting both chinook and sockeye salmon. A few hundred to a few thousand chinook salmon are harvested annually in these inriver fisheries. Both inriver and terminal marine fisheries are cooperatively managed by the U.S. and Canada through the Transboundary Technical Committee (TTC) of the Pacific Salmon Commission (PSC).

The purpose of our analysis is to estimate the spawning abundance of chinook salmon in the Stikine River that is associated with maximum sustained yield (N_{MSY}). As specified in the Pacific Salmon Treaty between Canada and the U. S. (PSC 1985: chapters 1 and 3), escapements (spawning abundance) of chinook salmon should be at or above N_{MSY} by 1998 for populations in general, and by 1995 for the population in the Stikine River. We estimated N_{MSY} with information dating back to 1975 from international and national stock assessment and catch sampling programs in the U.S. and Canada. Adjustments to annual estimates from these programs are described in appendices to focus attention on links between spawning abundance and subsequent production.

STATISTICS

SPAWNING ABUNDANCE

In 1975, the Division of Sport Fish (DSF) of the Alaska Department of Fish and Game (ADF&G) began assessing chinook salmon spawning in stretches of the Little Tahltan and Tahltan rivers. Chinook salmon were counted annually from helicopters according to fixed schedules and protocols as an index of abundance (see Pahlke 1998). Three different individuals conducted surveys, one from 1975 through 1987, his successor from 1988 through 1989, and the current surveyor from 1990 to the present. Tenure allowed some overlap for training the second and third surveyors. All three recorded their subjective judgment as to water clarity during surveys (excellent, normal, poor). Surveys were expanded in 1980 to cover parts of Beatty Creek. Only large chinook salmon, typically 3-ocean age [age1.3] and older (most >660 mm mid-eye to fork of tail [MEF]), were counted. Large fish could be distinguished from small chinook salmon age 1.1 and age 1.2 (1- and 2-ocean age) from the air because of dramatic differences in size between fish age 1.2 and 1.3 (Figure 2). Smaller chinook salmon (most <660 mm MEF) were not counted from the air because they could not be distinguished from other species.

We used only aerial indices from the Little Tahltan River to estimate abundance of large spawners prior to 1985. These indices were compared directly with counts of large chinook salmon through a weir after 1984 and to indices from Beatty Creek and the Tahltan River. Beginning in 1985, the Canadian Department of Fisheries and Oceans (CDFO) counted chinook salmon through a weir on the Little Tahltan River. The weir was installed on the downstream margin of the area surveyed by DSF from helicopters. Counts at the weir were segregated into large (most >660 mm mid-eye to fork of tail [MEF]) and small fish. Indices and counts from the Little Tahltan River and Beatty Creek were highly correlated ($P < 0.01$, Table 1), indicating that indices from Beatty Creek held little additional information. Indices from the Tahltan River were poorly correlated with measures of abundance from either the Little Tahltan River or Beatty Creek. Waters of the Tahltan River issue from glaciers to a varying degree; the resulting high frequency of poor water clarity during surveys of the Tahltan River compromised these surveys. In 1996 and 1997, abundance of large spawners in the Stikine River was estimated with two-event, closed-population mark-recapture experiments (see Seber 1982:59-60) based on cooperative tagging and radiotelemetry studies by the DSF, CDFO, and the Tahltan First Nation (Pahlke and Etherton 1997, 1999). Adults were captured with

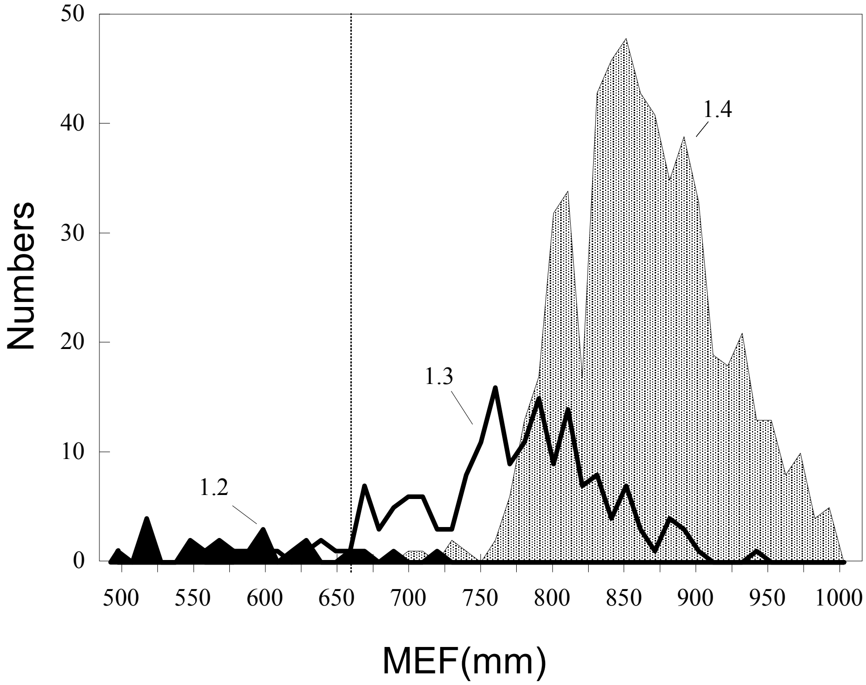

Figure 2.–Length-frequency polygons of age groups of chinook salmon sampled at the weir on the Little Tahltan River in 1997. Dotted vertical line marks boundary for "large" fish (≥ 660 mm MEF).

Table 1.–Pearson correlation coefficients among counts of large (most >660 mm MEF) chinook salmon in four locations within the Stikine River watershed from 1975 to 1997. Degrees of freedom in parentheses.

	Little Tahltan (at weir)	Tahltan River	Beatty Creek
Little Tahltan (aerial survey)	0.86(12)	0.54(18)	0.87(16)
Little Tahltan (weir)		0.41(9)	0.87(11)
Tahltan River			0.62(13)

drift gillnets near Kakwan Point (Figure 1) and marked (first sampling event). Sampling protocols at Kakwan Point were standardized to promote proportional sampling and equal probability of capture for chinook salmon regardless of their migratory timing past the point. Adults were sampled at the weir on the Little Tahltan River, on the spawning grounds in Verrett Creek, and in the two Canadian commercial gillnet fisheries (these four sites together comprise the second sampling event). Marked fish recovered in marine commercial fisheries and from surveys of tributaries downstream of Kakwan Point (Andrew and North Arm creeks) were censored from the marked population, making initial abundance estimates germane to large salmon from tributaries in Canada. Catches of large salmon in inriver fisheries were subtracted from these initial estimates to produce estimated numbers of spawning chinook salmon in the Stikine River. Estimated abundance was stratified into fish age 1.2 and fish age 1.3 and older; the latter group is considered the same as large fish (Figure 2). Abundance estimates and estimated SEs are listed in Table 2. Radio transmitters were implanted in a systematically selected subset of marked fish in 1997.

Table 2.–Indices, counts, estimated abundance $\hat{N}$ along with its estimated standard error and estimated 95% confidence intervals for large (most >660 mm MEF) chinook salmon spawning in the Stikine River from 1975 through 1997. Statistics in boldface come directly from mark-recapture experiments, shaded statistics are expansions from counts at the weir, and statistics in italics are expansions of indices from aerial surveys. Labels in parentheses correspond to subjective judgments of water clarity during aerial surveys: **E** = excellent, **N** = normal, **P** = poor.

	INDICES (survey)		COUNTS (weir)	$\hat{N}$	SE($\hat{N}$)	$\hat{N}$ -1.96 SE($\hat{N}$)	$\hat{N}$ +1.96 SE($\hat{N}$)
1975	700	**(E)**		*7,571*	*1,623*	*4,389*	*10,752*
1976	400	**(N)**		*5,723*	*933*	*3,895*	*7,550*
1977	800	**(P)**		*11,445*	*1,865*	*7,790*	*15,101*
1978	632	**(E)**		*6,835*	*1,465*	*3,963*	*9,707*
1979	1,166	**(E)**		*12,610*	*2,704*	*7,311*	*17,910*
1980	2,137	**(N)**		*30,573*	*4,982*	*20,809*	*40,338*
1981	3,334	**(E)**		*36,057*	*7,731*	*20,905*	*51,210*
1982	2,830	**(N)**		*40,488*	*6,598*	*27,557*	*53,419*
1983	594	**(E)**		*6,424*	*1,377*	*3,725*	*9,124*
1984	1,294	**(E)**		*13,995*	*3,000*	*8,114*	*19,876*
1985	1,598	**(E)**	3,114	16,037	2,392	11,349	20,725
1986	1,201	**(E)**	2,891	14,889	2,221	10,536	19,241
1987	2,706	**(E)**	4,783	24,632	3,674	17,432	31,833
1988	3,796	**(E)**	7,292	37,554	5,601	26,576	48,532
1989	2,527	**(E)**	4,715	24,282	3,622	17,184	31,381
1990	1,755	**(E)**	4,392	22,619	3,374	16,007	29,231
1991	1,768	**(E)**	4,506	23,206	3,461	16,422	29,990
1992	3,607	**(E)**	6,627	34,129	5,090	24,152	44,106
1993	4,010	**(P)**	11,449	58,962	8,794	41,726	76,199
1994	2,422	**(N)**	6,426	33,094	4,936	23,420	42,768
1995	1,117	**(N)**	3,259	16,784	2,503	11,877	21,690
1996	1,920	**(N)**	4,840	**23,886**	**2,773**	**18,451**	**29,321**
1997	1,907	**(N)**	5,613	**28,185**	**2,977**	**22,350**	**34,020**

Abundance of spawners age 1.3 and older (large spawners) in years without mark-recapture experiments after 1984 was estimated indirectly by expanding counts $C_{W,t}$ of large fish at the weir on Little Tahltan River in year t (Table 3). Expansion factors π_i for 1996 and 1997 were estimated at 4.94 (SE = 0.57) and 5.03 (SE = 0.53), respectively. In 1997, 181 large chinook salmon fitted with radio transmitters reached the spawning grounds in the Stikine River, 33 of which spawned in the Little Tahltan River. An estimated expansion factor based on these fish is 5.48 with SE = 0.95. This estimated SE was obtained through resampling the 181 (= m_i) fish such that $\hat{\pi}'^{-1}_{i,b} \sim binom(\hat{\pi}_i^{-1}, m_i)$ with $v(\hat{\pi}'_i)$ calculated as per eq. 6.6 of Efron and Tibshirani (1993:47). The average over these three estimates is $\bar{\pi} = 5.15$ and its estimated variance $v(\pi) =$ 0.59. Note that $v(\pi)$ instead of $v(\bar{\pi})$ was used to capture measurement error from mark-recapture experiments and variation in expansion factors across years. Resulting estimates of abundance and their associated statistics are in Table 2.

Abundance of large spawners for years before operation of the weir on the Little Tahltan River was estimated through a double expansion. Counts from aerial surveys were first expanded to predict counts from the weir had it been in operation (Table 4). Expansion factors (ρ) were

Table 3.–Equations used to expand counts $C_{W,t}$ at the weir on the Little Tahltan River into estimates of abundance N_t of large (most >660 mm MEF) chinook salmon spawning in the Stikine River, where t is year, k is the number of estimates of π, π is the ratio (expansion factor) where i denotes years with mark-recapture experiments, m the number of spawning large salmon with radio transmitters, and m_{LT} the number with transmitters that spawned in the Little Tahltan River.

	Statistic	Estimated variance
Expansion	$\hat{N}_t = C_{W,t}\,\bar{\pi}$	$v(\hat{N}_t) = C_{W,t}^2 v(\pi)$
Mean expansion factor	$\bar{\pi} = \frac{\sum_{i=1}^{k} \hat{\pi}_i}{k}$	$v(\pi) = \frac{\sum_{i=1}^{k} (\hat{\pi}_i - \bar{\pi})^2}{k-1} + \frac{\sum_{i=1}^{k} v(\hat{\pi}_i)}{k}$
Estimated expansion factor	$\hat{\pi}_i = \hat{N}_i C_{W,i}^{-1}$ $\hat{\pi}_i = m_i / m_{i,LT}$	$v(\hat{\pi}_i) = v(\hat{N}_i) C_{W,i}^{-2}$ Simulation

Table 4.–Equations used to expand aerial indices $C_{H,t}$ for the Little Tahltan River into estimates of abundance N_t of large (most >660 mm MEF) chinook salmon spawning in the Stikine River, where t is year (1975 –1984), k is the number of estimates of ρ, ρ is the ratio (expansion factor) between counts from aerial surveys and counts $C_{i,W}$ from the weir, where i denotes years 1985–1997.

	Statistic	Estimated variance
Expansion	$\hat{N}_t = C_{H,t}\,\bar{\pi}\bar{\rho}$	$v(\hat{N}_t) = C_{H,t}^2 \left[\bar{\rho}^2 v(\pi) + \bar{\pi}^2 v(\rho) - v(\pi)v(\rho)\right]$
Mean expansion factor	$\bar{\rho} = \frac{\sum_{i=1}^{k} \rho_i}{k}$	$v(\rho) = \frac{\sum_{i=1}^{k} (\rho_i - \bar{\rho})^2}{k-1}$
Estimated expansion factor	$\rho_i = C_{W,i} C_{H,i}^{-1}$	

developed for surveys with excellent and with poor or normal water clarity for years 1985–1997 (Table 5). Because statistics under normal and poor conditions were so similar, data were pooled to produce only two conditions: excellent and normal/poor. Counts from the "virtual" weir were expanded by $\overline{\pi}$ (Table 3) to estimate the number of large chinook salmon spawning in the Stikine River (Table 4). Table 2 contains the final estimates of spawning abundance for 1975–1984.

Age composition of spawners was estimated from data gathered at the weir on the Little Tahltan River (1985–1997) and from carcass surveys (1981–1988) (Table 6 and Appendix A). Females constituted a median 54% (range 42–62%)

Table 5.–Mean expansion factors and their estimated population variances between aerial indices of large (most >660 MEF) salmon and counts through the weir on the Little Tahltan River.

Water clarity	$\overline{\rho}$	$v(\rho)$
Excellent	2.100	0.107
Normal	2.759	0.042
Poor	2.855	–
Normal/poor	2.778	0.034

Table 6.–Estimated numbers $\hat{N}_a$ of chinook salmon by age spawning in the Stikine River from 1981 through 1997. (Standard error in parentheses.)

	1.2 (SE)	**1.3** (SE)	**1.4** (SE)	**1.5** (SE)
1981	829 (250)	8,690 (1,947)	27,187 (5,856)	180 (113)
1982	1,255 (449)	7,085 (1,427)	32,917 (5,436)	445 (213)
1983	3,289 (915)	2,448 (625)	3,668 (854)	308 (147)
1984	1,497 (489)	12,260 (2,652)	1,651 (492)	84 (84)
1985	770 (278)	3,239 (596)	12,669 (1,922)	128 (19)
1986	685 (243)	4,839 (824)	9,812 (1,521)	238 (95)
1987	1,182 (406)	5,370 (1,036)	18,351 (2,827)	887 (277)
1988	601 (240)	3,455 (815)	33,386 (5,024)	676 (245)
1989	510 (207)	8,669 (1,416)	10,854 (1,727)	4,735 (882)
1990	1,990 (432)	1,742 (358)	19,656 (2,949)	1,221 (272)
1991	1,485 (372)	8,958 (1,428)	13,483 (2,073)	766 (236)
1992	478 (183)	7,304 (1,201)	26,791 (4,028)	68 (35)
1993	177 (120)	5,601 (1,053)	51,887 (7,770)	1,474 (413)
1994	662 (220)	3,740 (664)	26,641 (4,004)	2,714 (542)
1995	3,659 (706)	4,095 (703)	10,775 (1,660)	1,930 (381)
1996	1,696 (346)	17,174 (2,061)	6,616 (929)	96 (72)
1997	930 (245)	6,483 (867)	21,533 (2,342)	169 (86)

of spawners in samples taken at the weir. Age 1.4 fish dominated samples (75%); there were few fish age 1.2 or 1.5.

COMMERCIAL/ABORIGINAL HARVESTS

Estimates of age composition of chinook salmon caught in inriver commercial and aboriginal fisheries were calculated using estimates of relative age composition from the weir and from carcass surveys on the Little Tahltan River. Harvests were reported as "jacks" (age 1.2) and adults (older salmon) in most years; however, no such distinction was made in catches during the first few years in each inriver fishery. In the former case, jacks were considered to be age 1.2 and their catch known without error. Numbers of older fish harvested were estimated with multipliers estimated from escapement:

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

where H_t is the harvest of adults in year t and $\theta_{a,t}$ is the multiplier for age group a in year t. Estimates for multipliers and their SEs along with how they were derived and calculated are given in Appendix A. Estimated variance for estimated catch was calculated as:

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

When harvest of jacks was not recorded separately, estimates of relative age composition ($\hat{p}_{a,t}$) from the weir and carcass surveys were used in the equations above instead of multipliers (see Appendix A for estimates of relative age composition).

COMMERCIAL MARINE HARVESTS

Age composition of harvests of Stikine-bound chinook salmon in the commercial gillnet fishery offshore of the river mouth (U.S. District 108) was estimated by first discounting catches for hatchery production. Estimated harvests of hatchery-produced chinook salmon from Alaska ranged from 310 to 850 since 1989. Prior to that year, harvests of all fish were small (except for 1982, only a hundred or so fish). Catch sampling for coded-wire tags (CWTs) began in 1994 and showed that on average 32.6% of harvests through 1997 were of hatchery origin. Catches from 1990 through 1993 were reduced by this fraction to produce estimates of naturally produced chinook salmon in the harvest. For 1994–97, direct estimates of the harvests of hatchery-produced salmon were subtracted from the catches.

The remaining chinook salmon in the harvest and all chinook salmon harvested from 1981 through 1990 were considered to have the same relative age composition as the gillnet fishery in the lower river. Both fisheries use similar gear to fish roughly the same salmon. Age composition in the marine fishery was therefore estimated as

$$\hat{H}_{a,t} = \hat{H}_t \frac{\hat{H}'_{a,t}}{\sum_{a'} \hat{H}'_{a',t}}$$

where $\hat{H}_{a,t}$ and $\hat{H}_t$ correspond to the marine fishery, and $\hat{H}'_{a,t}$ and $\hat{H}'_{a',t}$ correspond to the lower inriver fishery. Considering the assumptions needed to calculate these statistics, and considering the few fish involved, variances were not estimated. Because harvests of Stikine River chinook salmon are thought to be negligible in troll fisheries, these potential harvests were not included in calculations.

RECREATIONAL HARVESTS

Age composition of harvests of Stikine-bound chinook salmon in the recreational fishery near Petersburg and Wrangell was also estimated by first discounting catches for hatchery production. Hatchery contributions to the harvest were estimated from catch sampling for CWTs since 1981 (see Hubartt et al. 1997 for details). Estimated contributions were subtracted from estimated harvest, with the remainder considered to have been bound for the Stikine River. The longstanding size limit for retaining chinook salmon in this fishery has been 710 mm (28 inches) total length (see Table E2), so the numbers of age 1.2 fish in the harvest were considered nil and were not estimated.

Age composition of harvests was estimated as the product of the harvest of naturally produced salmon and the relative age composition among large chinook salmon spawning in the Stikine River:

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

where $\hat{H}_t$ is the estimated harvest of naturally produced large chinook salmon in year t and $\hat{\theta}_{a,t}$ is the multiplier for age a in year t (see Appendix A). Estimated variance was calculated as per the product of two variates as per Goodman (1960):

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

Estimated variances $v(\hat{H}_t)$ were calculated from the statewide harvest survey [see Howe et al. (1998) for an example of the survey]. The average CV for harvest estimates in this postal survey for the Petersburg/Wrangell area (12%) was used to calculate variances.

COMBINED HARVESTS

The combined harvest for each year was calculated by summing estimated harvests over the individual fisheries (Table 7). Because all sampling programs were independent (with one exception), estimated variance for the combined harvest is the sum of the variances estimated for the individual fisheries. The one exception concerns the marine gillnet fishery where relative age composition was estimated from the lower in-river gillnet fishery. However, variances were not estimated for the marine fishery, thereby avoiding a problem with calculating covariances.

Table 7.–Estimate of combined harvests by year and age of chinook salmon in recreational fisheries near Petersburg and Wrangell, in terminal marine gillnet fisheries in the U. S., and in commercial and aboriginal gillnet fisheries in Canada. (Standard error in parentheses.)

	1.2 (SE)	**1.3** (SE)	**1.4** (SE)	**1.5** (SE)
1981	37 (4)	973 (80)	3,048 (220)	20 (6)
1982	101 (16)	1,169 (106)	5,421 (337)	74 (20)
1983	692 (3)	1,556 (194)	2,332 (237)	195 (62)
1984	63 (0)	2,549 (244)	348 (67)	18 (15)
1985	193 (1)	855 (111)	3,337 (297)	33 (0)
1986	1,007 (0)	1,450 (119)	2,945 (212)	73 (18)
1987	475 (0)	845 (73)	2,874 (148)	139 (22)
1988	478 (0)	459 (56)	4,423 (266)	92 (19)
1989	318 (0)	2,047 (144)	2,561 (170)	1,118 (98)
1990	1,059 (0)	522 (65)	5,878 (451)	367 (52)
1991	955 (0)	2,225 (188)	3,349 (268)	190 (36)
1992	292 (0)	1,213 (100)	4,460 (318)	8 (5)
1993	467 (0)	648 (67)	6,013 (449)	175 (30)
1994	542 (0)	584 (41)	4,159 (211)	421 (35)
1995	1,200 (0)	954 (64)	2,493 (135)	442 (38)
1996	516 (0)	4,090 (220)	1,566 (104)	20 (8)
1997	385 (0)	2,162 (126)	7,167 (305)	54 (14)

The estimated combined harvest should be biased high, because all estimated harvest of naturally produced chinook salmon in marine fisheries were considered Stikine-bound. Most likely some of these fish were from other populations returning to other rivers. However, this bias should have a negligible effect on subsequent analysis, considering the size of the harvest and the background precision of other estimates.

The estimated combined harvest probably represents almost all fishing-induced mortality. Some mature and perhaps some immature chinook salmon from the Stikine River are most likely caught in fisheries other than those described above, or were caught in recreational fisheries, released, and subsequently died from the experience. However, coded-wire tagging programs from 1978 through 1981 showed that members of this population rear in relatively unfished waters and are exposed to fishing only during a short time as they return to Southeast Alaska (Kissner and Hubartt 1986). We presumed that all Stikine-bound chinook salmon caught in marine gillnet fisheries were retained. Considering the paucity of age 1.2 fish among the Stikine River population and the relatively small size of the recreational fishery near Petersburg and Wrangell, we believe few salmon of this age were caught in the recreational fishery. Since the area-wide spring closures beginning in 1982–83, the U.S. commercial troll fishery starts too late to intercept very many Stikine-bound chinook salmon.

The combined harvest represents on average an annual estimated exploitation rate of 18% (Figure 3). Since 1981, the estimated rate has ranged from just under 10% (1981) to just under 33% (1983).

PRODUCTION

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

$$\hat{R}_y = \sum_{i=1}^{4} \hat{N}_{1.i,y+i+2} + \sum_{i=1}^{4} \hat{H}_{1.i,y+i+2}$$

$$v(\hat{R}_y) = \sum_{i=1}^{4} v(\hat{N}_{1.i,y+i+2}) + \sum_{i=1}^{4} v(\hat{H}_{1.i,y+i+2})$$

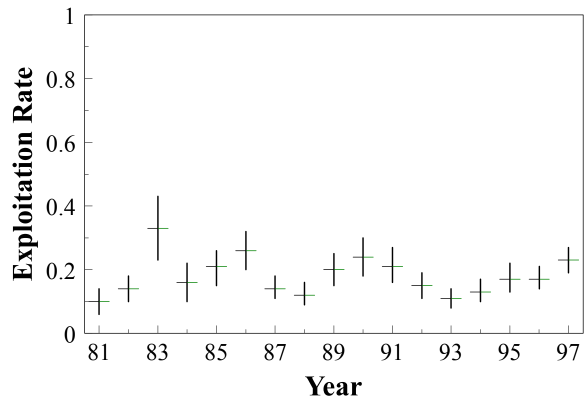

Figure 3.–Estimated annual exploitation rates and their 95% approximate confidence intervals for chinook salmon returning to the Stikine River. Confidence intervals are based on variances approximated with the delta method (see Appendices A and B).

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 shown in Table 8 for year classes 1977 through 1991. Estimated production for age 1.2 salmon in the 1977 year class was not available, making the overall estimate of production for this year class negligibly conservative. Likewise, estimated production of fish age 1.5 in the 1991 year class was not available when this report was written. Because there was no information on age composition in 1980 when the 1975 year class would have been age 1.3, no statistics on production is available on this year class. The average CV for estimated production over year classes 1977 through 1991 is 9.8%; in contrast, the average CV for estimated spawning abundance for the same year classes is 17.9%. Figure 4 has some standard plots of estimates.

ANALYSIS

MEASUREMENT ERROR

Spawning abundance that produces maximum-sustained yield was estimated by regressing the log of estimated production-to-spawner ratios against estimates of spawning abundance, setting

Table 8.–Estimated production $\hat{R}_y$ by year class and the estimated abundance of their parents $\hat{N}_y$ age 1.3 and older for the population of chinook salmon spawning in the Stikine River. (Standard error in parentheses; coefficient of variation in percent.)

Year class	$\hat{N}_y$	SE($\hat{N}_y$)	CV($\hat{N}_y$)	$\hat{R}_y$	SE($\hat{R}_y$)	CV($\hat{R}_y$)
1977	11,445	(1,865)	16.3%	15,223	(1,704)	11.2%
1978	6,835	(1,465)	21.4%	7,520	(936)	12.4%
1979	12,610	(2,704)	21.4%	35,107	(3,423)	9.8%
1980	30,573	(4,982)	16.3%	19,438	(1,744)	9.0%
1981	36,057	(7,731)	21.4%	29,245	(2,974)	10.2%
1982	40,488	(6,598)	16.3%	51,568	(5,219)	10.1%
1983	6,424	(1,377)	21.4%	20,575	(1,980)	9.6%
1984	13,995	(3,000)	21.4%	38,284	(3,322)	8.7%
1985	16,037	(2,392)	14.9%	20,000	(2,132)	10.7%
1986	14,889	(2,221)	14.9%	47,132	(4,331)	9.2%
1987	24,632	(3,674)	14.9%	71,951	(7,903)	11.0%
1988	37,554	(5,601)	14.9%	39,733	(4,167)	10.5%
1989	24,282	(3,622)	14.9%	17,947	(1,798)	10.0%
1990	22,619	(3,374)	14.9%	14,659	(1,195)	8.2%
1991	23,206	(3,461)	14.9%	54,824	(3,221)	5.9%

the first derivative of the result to one, and solving the relationship for $\hat{N}_{MSY}$. We used Ricker's two-parameter model (Ricker 1975: section 11.6) in our regression analysis:

$$\ln(R_y) - \ln(N_y) = \ln(\alpha) - \beta N_y + \varepsilon_y$$

where α is the density-independent parameter, β the density-dependent parameter, and ε_y represents process error with mean 0 and variance σ_ε^2.

Because spawning abundance and production are not known for the Stikine River, but were estimated, $\hat{R}_y \to R_y$ and $\hat{N}_y \to N_y$ into the stock-production model. In reality:

$$\hat{R}_y = R_y \exp(v_y)$$

$$\hat{N}_y = N_y \exp(u_y)$$

where v_y and u_y represent measurement error with means 0 and variance σ_v^2 and σ_u^2. Similarity across years among CVs for estimates of production and spawning abundance (see Table 8) is evidence that measurement error in these data is log normal. Transforming the above relationships accordingly produces:

$$\ln(\hat{R}_y) = \ln(R_y) + v_y$$

$$\ln(\hat{N}_y) = \ln(N_y) + u_y$$

Measurement error in the independent variable, spawning abundance, is a function of sampling. From Cochran (1977:274-6), variance in $\ln(\hat{N})$ would have a two-stage structure with annual variation among the N plus measurement error for each estimate $\hat{N}_y$:

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

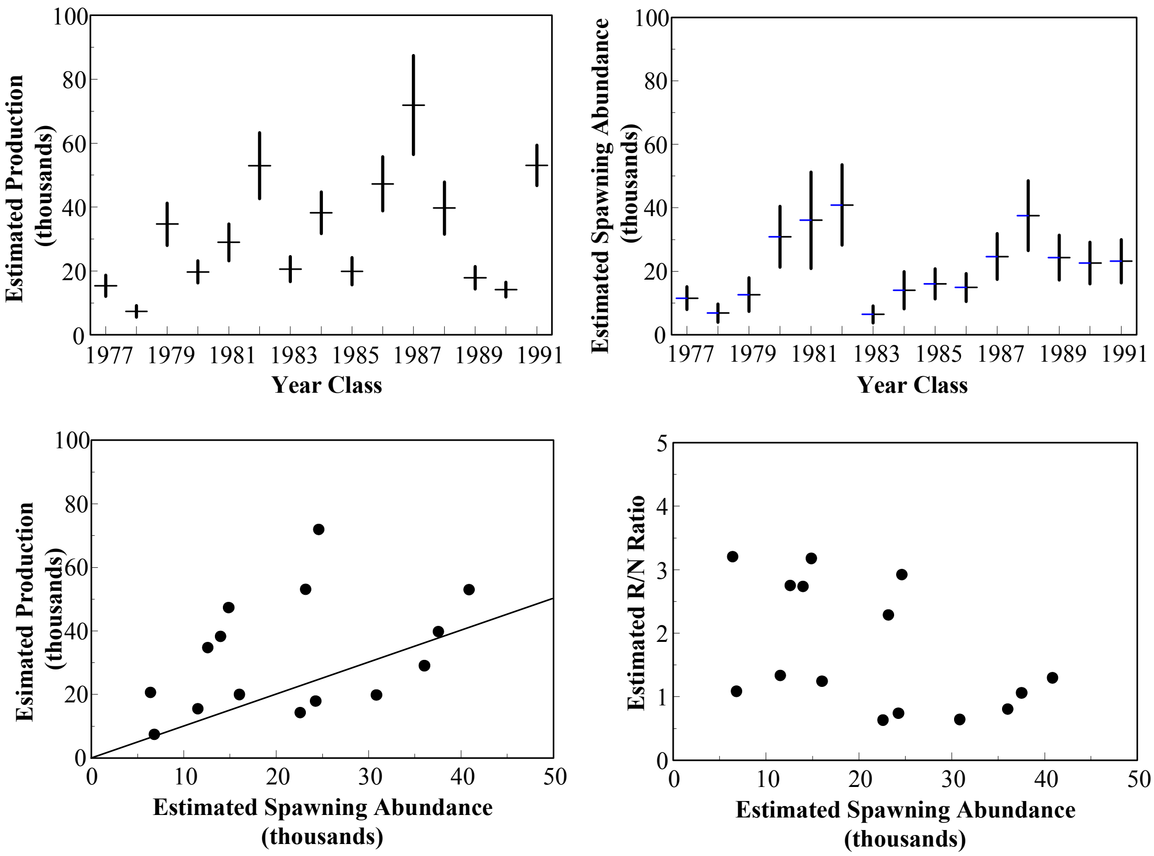

Figure 4.–Estimated production $\hat{R}_y$ by year class, estimated spawning abundance $\hat{N}_y$ of salmon age 1.3 and older, and their estimated 95% confidence intervals.

These variances were estimated as follows:

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

$$\hat{\sigma}_u^2 = \frac{\sum \hat{\sigma}_{u,y}^2}{n}$$

$$v[\ln(N)] = v[\ln(\hat{N})] - \hat{\sigma}_u^2$$

where n is the number of year classes (15) in the data. The estimates $\hat{\sigma}_{u,y}^2$ are related to the sampling variances represented in Table 8 in the form of SEs. Those sampling variances were log transformed as were estimates. From the delta method (Seber 1982:7-9):

$$\hat{\sigma}_{u,y}^2 = v[\ln(\hat{N}_y)] \cong v(\hat{N}_y)\hat{N}_y^{-2} = \mathrm{CV}^2(\hat{N}_y)$$

For the population in the Stikine River, $v[\ln(\hat{N})]$ = 0.3352 and $\hat{\sigma}_u^2$ = 0.0316. Thus, measurement error in spawning abundance represents about 9% of overall variation in the independent variable, so we ignored its presence in the regression analysis with little consequence (see Appendix C).

Measurement error in the dependent variable (the ratio of production to spawning abundance) is also a function of sampling variances. Again using the delta method (Seber 1982:7-9):

$$\hat{\sigma}_{uv,y}^2 = v[\ln(\hat{R}_y / \hat{N}_y)] = \mathrm{CV}^2(\hat{R}_y) + \mathrm{CV}^2(\hat{N}_y)$$

where $\sigma_{uv,y}^2$ is the variance of $v_y - u_y$ for each year class. The expected measurement error for the dependent variable on the whole is the average over year classes represented in the study:

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

For the population in the Stikine River, $\hat{\sigma}^2_{uv}$ = 0.0407.

PARAMETER ESTIMATES

Parameters were estimated with the regression option in the computer program PROC REG written and supported by SAS (Table 9). Plots of residuals against predicted values of the dependent variable indicated spawning abundance has no additional predictive power (Figure 5); there was no evidence of autocorrelation among residuals. The model represented 24% of the variation in the dependent variable; however, that representation dropped to 18% after being corrected for the mean. Predictions by the fitted, untransformed model and the original data are in Figure 6.

Spawning abundance that on average produces maximum sustained yield (N_{MSY}) was estimated by solving the following relationship derived from Ricker (1975: p. 347, Model 1, entry 17):

$$1 = (1 - \hat{\beta}N_{MSY})\exp[\ln(\hat{\alpha}) - \hat{\beta}N_{MSY} + \hat{\sigma}^2_{\varepsilon}/2]$$

The term $\exp(\hat{\sigma}^2_{\varepsilon}/2)$ in the equation above represents a correction for process error (Hilborn 1985). Because measurement error is included in the dependent variable, $\hat{\sigma}^2_{\varepsilon} = \hat{\sigma}^2_r - \hat{\sigma}^2_{uv}$ where $\hat{\sigma}^2_r$ is the residual mean squares in the fitted model (see Appendix D). For our study, $\hat{\sigma}^2_{\varepsilon}$ = 0.3021 – 0.0407 = 0.2613. Solving the above equation with these substitutions produced the estimate $\hat{N}_{MSY}$ = 17,368 large chinook salmon (age 1.3 and older).

SIMULATION

The estimated variance $v(\hat{N}_{MSY})$ and 90% confidence intervals for $\hat{N}_{MSY}$ were calculated through non-parametric bootstrapping of residuals from the regression (Efron and Tibshirani 1993:111-5).

Table 9.–Estimated parameters for regression with Ricker's model on estimates of production and spawning abundance of chinook salmon in the Stikine River.

	Statistic
$\ln(\hat{\alpha})$	0.95189 (P = 0.0057)
$v[\ln(\hat{\alpha})]$	0.08725
$\hat{\beta}$	0.000026592 (P = 0.0526)
$v[\hat{\beta}]$	1.5552×10^{-10}
$cov[\ln(\hat{\alpha}), \hat{\beta}]$	3.1438×10^{-6}
R^2	0.2592
R^2(corrected)	0.2021

Residuals were calculated as differences between observed and predicted values:

$$\zeta_y = Y_y - \hat{E}[Y_y]$$

where $Y_y \equiv \ln(\hat{R}_y/\hat{N}_y)$ and $\hat{E}[Y_y]$ is the predicted value. A new set of dependent variables is then generated by sampling the residuals from the original regression:

$$\tilde{Y}_y = \zeta^*_y + \hat{E}[Y_y]$$

where the ζ^*_y are drawn randomly with replacement from the original vector ζ of the n original residuals. The $\tilde{Y}_y$ were regressed against the $\hat{N}_y$, and the result used to calculate a simulated estimate, $\tilde{N}_{MSY}$. This process was repeated 1000 times to generate 1000 new estimates { $\tilde{N}_{MSY(k)}$ } where k = 1→ 1000. Over all K (= 1000)

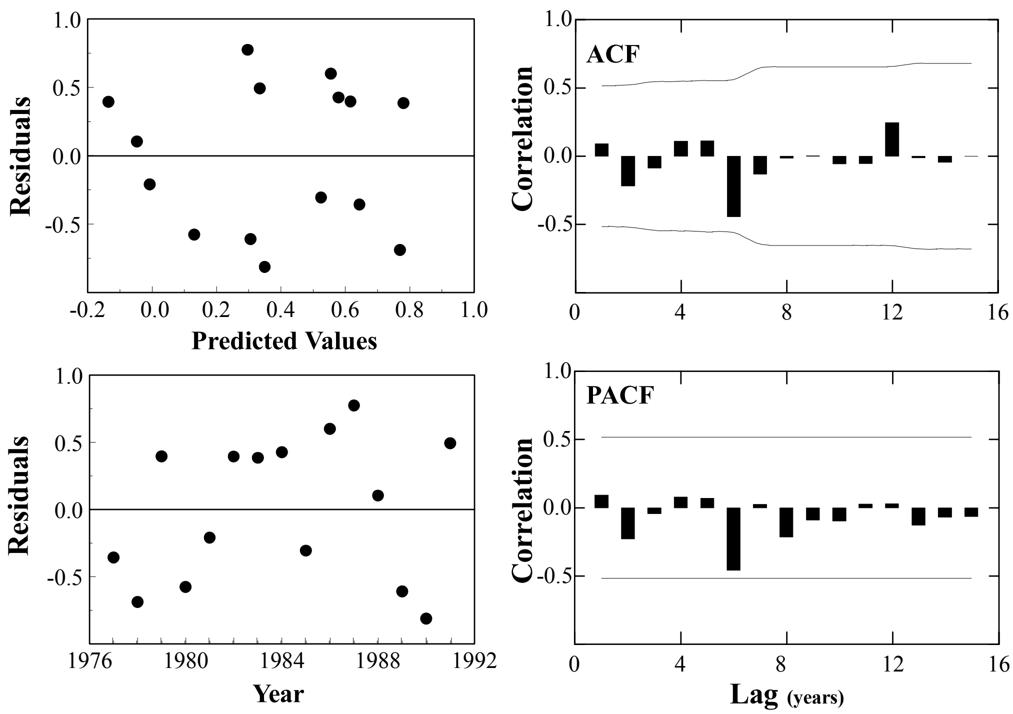

Figure 5.–Residuals from Ricker's model plotted against predicted values of R_y and years (year classes) and autocorrelations (ACF) and partial autocorrelations (PACF) among residuals.

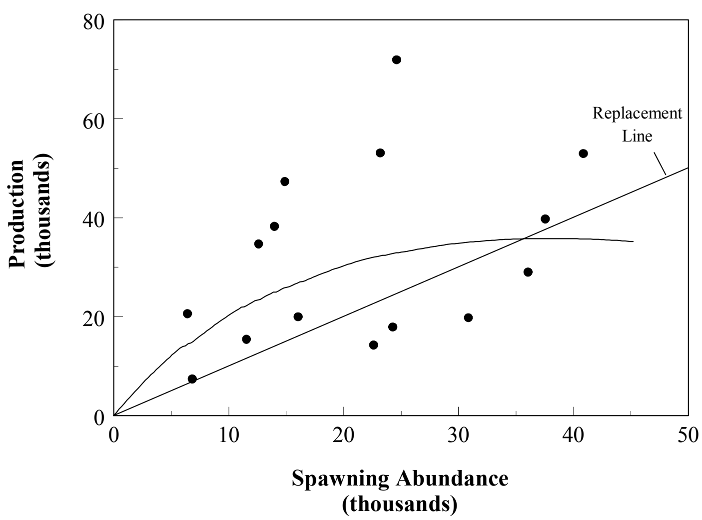

Figure 6.–Estimated production of age 1.2-5 chinook salmon in year classes 1977–1991 against the estimated spawning abundance of their parents age 1.3 and older for the population in the Stikine River.

simulations, the estimated variance (from Efron and Tibshirani 1993:47) is:

$$v(\hat{N}_{MSY}) = \frac{\sum_{k=1}^{K}(\tilde{N}_{MSY(k)} - \overline{N}_{MSY})^2}{K-1}$$

where $\overline{N}_{MSY} = K^{-1}\sum_{k=1}^{K}\tilde{N}_{MSY(k)}$. The difference between $\hat{N}_{MSY}$ and $\overline{N}_{MSY}$ is an indication of statistical bias in the former statistic (note this statistical bias is assumed to arise only from process error in the regressions. The percentile method (Efron and Tibshirani 1993:124-126) was used to provide 90% confidence intervals about $\hat{N}_{MSY}$. Estimated relative bias in $\hat{N}_{MSY}$ is 18% [= (20,747–17,368)1/17,368), and the simulated 90% confidence interval about $\hat{N}_{MSY}$ is 11,838 and 39,907. Because of the estimated relative bias in $\hat{N}_{MSY}$, the standard error as estimated from the simulations ballooned to an incredible value. As an alternative, the lower and upper 2.5% of the $\tilde{N}_{MSY(k)}$ were trimmed, and the estimated standard error $SE(\hat{N}_{MSY})$ recalculated as 11,107, a quarter of the trimmed range.

DISCUSSION

Our estimate of spawning abundance of chinook salmon in the Stikine River that on average will produce MSY is biased slightly low ($\hat{N}_{MSY} < N_{MSY}$). Measurement error in estimates of spawning abundance, if ignored when estimating parameters, will make a salmon population appear more productive than it is (Hilborn and Walters 1992:288). By ignoring measurement error on the spawning grounds as we did, our estimate of 17,368 large chinook salmon is so biased. The true value is higher, but in our case, negligibly higher (Appendix C). There is considerable spread in spawning abundance over the years in the Stikine River (just over an order of magnitude), so much so that estimated measurement error represents only 9% of overall variation in spawning abundance.

There is also some possible bias in $\hat{N}_{MSY}$ arising from measurement error in estimates of production. Our assumption that all naturally produced chinook salmon harvested in the recreational fishery near Petersburg and Wrangell and in the gillnet fishery off the mouth of the river were bound for the Stikine River obviously results in this river appearing more productive than it is (again, $\hat{N}_{MSY} < N_{MSY}$). In contrast, ignoring catches of Stikine-bound salmon in the U. S. troll fishery would tend to bias $\hat{N}_{MSY}$ the other way ($\hat{N}_{MSY} > N_{MSY}$). From 1979 to 1981, 93,428 age 0. chinook salmon were released with CWTs in the Stikine River; an estimated 38 of these fish (after expansion for catch sampling) were subsequently caught as adults in the troll fishery from 1982 to 1985 (Kissner and Hubartt 1986). Given arguably reasonable rates of freshwater survival (50%) and of subsequent return of smolts as adults (4%), a crude rate of exploitation in the troll fishery would be about 2%. The bias in $\hat{N}_{MSY}$ implied by ignoring such a rate is probably more than offset by presuming all recreational harvest to have been Stikine-bound. Regardless, catches of Stikine-bound chinook salmon in these fisheries would be small relative to escapement into the Stikine River, indicating that bias from our assumptions should also be small.

The statistical bias found in $\hat{N}_{MSY}$ through simulation is a result of the poor fit of Ricker's model to the data. Density dependence was barely detectable against the background of process error in these data. More data on more year classes should improve, but not solve, this situation. The solution lies in fitting a more complex model to the data, one that incorporates an additional biological and/or environmental variable.

Once biases and measurement errors have been set aside, the most striking feature of the estimated relationship between production and spawning abundance is the importance of density-independent mortality. Four recent year classes demonstrate the effect of density independent factors (Table 10). Estimated abundance of spawners that produced the 1987, 1989, 1990, and 1991 year classes was essentially the same, ranging from 22,619 to 24,632 large chinook

Table 10.–Estimated spawning abundance and return-per-spawner along with its estimated SE for four recent year classes.

Year class	$\hat{N}$	$\hat{R}/\hat{N}$	SE($\hat{R}/\hat{N}$)
1987	24,632	2.92	0.54
1989	24,282	0.74	0.13
1990	22,619	0.63	0.11
1991	23,206	2.29	0.37

salmon, yet production from these year classes ranged from 0.63 to 2.93 fish per spawner. This range is statistically significant ($P < 0.01$). Whether these shifts in year-class strength arose from environmental factors in fresh water or in the ocean is unknown. Regardless, this variation in production is a strong argument that the stock-production relationship should include a variable representing survival rates. Unfortunately, no data concerning survival rates for this stock of chinook salmon, or any nearby, are available.

CONCLUSIONS AND RECOMMENDATIONS

Chinook salmon in the Stikine River have apparently recovered from the recruitment overfishing of the 1970s. When the rebuilding program was incorporated into the Pacific Salmon Treaty in 1985, the goal was to achieve 19,800 to 25,000 large spawners in the Canadian portion of the Stikine River by 1995 (PSC 1985: Annex IV, Chapter 1, p. 11). This goal was determined by expanding aerial indices in years believed to be free from overfishing. Because no estimates of abundance or distribution of chinook salmon across the watershed were available at the time, expansions were largely a matter of professional judgment. With no scientific data to support these expansions, and with seven years of data from the weir on the Little Tahltan River, the Trans-boundary Technical Committee (TTC) of the PSC substituted a count of 5,300 chinook salmon through the weir as the new rebuilding goal (TTC 1991:12). Although the old goal of 25,000 for the watershed and the new goal of 5,300 for the Little Tahltan River were based on the best evidence available at the time, no scientific studies had then been conducted to determine if either goal realistically represented a "rebuilt" population.

Consider our estimate of N_{MSY} (17,368 large spawners) as the metric against which rebuilding should be judged (see Table 2). Estimated spawning abundance has been below 17,368 large spawners in 10 of the last 23 years, 5 of the 10 occurring in years 1975 through 1979, and only in one year since 1986. Since 1986, estimated spawning abundance ranged from a low of 16,784 in 1995 (ironically the target year for rebuilding) to a high of 58,962 in 1993, with a median of 24,632. This rebuilding occurred as the stock continued to sustain an average annual exploitation rate of 18%. Our estimate of N_{MSY} corresponds to 3,300 counts through the weir on the Little Tahltan River or 1,188 to 1,584 counts in aerial surveys above the weir (depending on water clarity).

Aerial surveys over the Stikine River should be discontinued. Surveys of the variably occluded Tahltan River provide poor information at best, and aerial surveys over Beatty Creek provide little information over what can be expected from flying over the Little Tahltan River. We now have 13 years in which counts from the weir on the Little Tahltan River and indices from aerial surveys can be compared. This sample size is sufficient to establish the relationship between the two sources of information. We used that relationship to adjust aerial indices from surveys prior to 1985. No similar adjustment will be needed in the future. Although the relationship between counts at the weir and estimated abundance for the watershed should be refined with more samples, these samples will come from operating the weir and conducting mark-recapture experiments. Aerial surveys will play no part in these activities.

A coded-wire tag program should be reinstated in the Stikine River. The old program that started over 20 years ago qualitatively showed that chinook salmon from the Stikine River were lightly exploited at sea. With the widespread existence of catch-sampling programs for marine commercial and recreational fisheries, a new tagging program could give defensible estimates of harvest in all marine fisheries. More importantly, a coded-wire tagging (CWT) program would provide estimates of the number of smolt migrating annually from the Stikine River. This information can be used to estimate marine and freshwater survival rates that could be used in a more complex, more accurate model of the stock-production relationship for chinook salmon in the Stikine River. Such information has proved extremely useful in investigating productivity of chinook salmon in the nearby Taku River (McPherson et al. 2000).

Reinstatement of such a CWT program would complete the list of new research recommended by the Pacific Salmon Commission in 1990 (TTC 1990: Table 5). This list consisted of "Escapement Estimation", "Escapement Goal Analysis", and "Catch Accounting" for the chinook salmon of the Stikine River. A CWT program would provide information for catch accounting. Pahlke (1998) and Pahlke and Etherton (1997, 1999) describe methods and results of estimating escapement. Our report synthesizes information to analyze escapement goals for chinook salmon in the Stikine River.

Sampling to estimate age composition of catches and escapements should continue. Troll fisheries, recreational fisheries near Petersburg and Wrangell, terminal gillnet fisheries in U.S. Districts 106 and 108, Canadian aboriginal and commercial gillnet fisheries, and major spawning grounds should all be sampled with enough intensity to provide estimates with precision on par with historical statistics. Knowledge of catch and escapement by age is essential to estimating production by year class, and subsequently to our understanding of the stock-production relationship for chinook salmon in the Stikine River.

The weir program to count chinook salmon into the Little Tahltan River and a mark-recapture experiment to estimate abundance into the Canadian portion of the Stikine River watershed should continue for at least another cycle; i.e., six years. The information would be used along with information on age composition to add statistical rigor to the estimated stock-recruit relationship. Our knowledge on migratory timing through fisheries of different spawning populations within the river would also be increased, knowledge useful for the management of fisheries on this stock.

An escapement goal range of 14,000 to 28,000 adult spawners (3-5 ocean-age) is recommended for chinook salmon spawning in the Stikine River. Corresponding values for counts through the weir on the Little Tahltan River are 2,700 and 5,300. The limits of this range are approximately 0.8 and 1.6 times the estimate of N_{MSY} as per methods in Eggers (1993). These multipliers are the result of simulations showing that spawning abundance within the range produces on average yields >90% of MSY. The Chinook Technical Committee of the PSC and an internal review committee of ADFG accepted this range in the spring of 1999 as the new goal for this stock. The Pacific Stock Assessment and Research Committee of CDFO declined to pass judgment on this range in deference to a decision by the Transboundary Technical Committee; the TTC accepted the range in March, 2000.

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APPENDIX A: ESTIMATES OF AGE COMPOSITION OF SPAWNING CHINOOK SALMON

Age composition of spawners was estimated from information gathered at the weir on the Little Tahltan River (1985–1997) and from carcass surveys at that same river (1981–1988). Because samples at the weir were systematically drawn, resulting estimates were considered representative of spawners in that tributary. Because counts of large chinook salmon (≥660 mm MEF) at the weir were highly correlated with counts from other streams (Table 1), estimates of relative age composition for the Little Tahltan River were considered relevant to all spawners in the Stikine River. Mark-recapture experiments in 1996 and 1997 (Pahlke and Etherton 1997, 1999) also provide evidence that estimates for the Little Tahltan River are representative of all chinook salmon spawning in the Stikine River, at least all large spawners. Because estimates of relative age composition from carcass surveys are similar to estimates from the weir for 1985–1988 (Figure A1), estimates of relative age composition from carcass surveys for 1981–1984 were considered representative of all adults spawning in the Stikine River during those years. Data collected at the weir and during the carcass surveys were pooled for years 1985–1988. Tallies of samples by age are listed in Table A1. The few chinook salmon determined to have freshwater age 0. and 2. were pooled with those of age 1. Table A2 contains estimates of relative age composition and estimates of their associated SEs.

Estimated age composition and its estimated variance were calculated as follows:

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

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

where N_t is the abundance of large chinook salmon (essentially age 1.3 and older) and $\theta_{a,t}$ is the multiplier for age group a in year t. There were four age groups: chinook salmon age 1.2, age, 1.3, age 1.4, and age 1.5. All age 1.2 chinook salmon were considered males, while the older age groups were a mixture of both sexes. Multipliers were estimated as:

$$\hat{\theta}_{a,t} = \frac{m_{a,t}}{m_t - m_{1.2,t}}$$

where m_t is the sample size at the weir (and/or carcass survey) in year t (Appendix Table A1). Resulting estimates of age composition are listed in Table 6 along with their estimated SEs. Annual estimates of the spawning abundance for chinook salmon of all ages and estimates of their variance were calculated as:

$$\hat{N}_{ALL,t} = \hat{N}_t(1 + \hat{\theta}_{1.2,t})$$

$$v(\hat{N}_{ALL,t}) = v(\hat{N}_t)(1 + \hat{\theta}_{1.2,t})^2 + \hat{N}_t^2 v(\hat{\theta}_{1.2,t}) - v(\hat{N}_t)v(\hat{\theta}_{1.2,t})$$

Estimated variance for the multipliers was approximated with simulation. During the kth iteration of a simulation for year t, a vector of new sample sizes $\{\mathbf{m}_t'\}_k$ was generated from the probability distribution multinom $(m_t, \{\hat{p}_t\})$ where $\hat{p}_{a,t} = m_{a,t}/m_t$. The multiplier was recalculated with simulated data:

$$\hat{\theta}'_{a,t(k)} = \frac{m'_{a,t(k)}}{m_t - m'_{1.2,t(k)}}$$

After K (= 100) iterations, variance for each multiplier was approximated as per methods in Efron and Tibshirani (1993:47):

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

where

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

The process was repeated for the next year. Estimated multipliers and their approximate SEs are listed in Table A3.

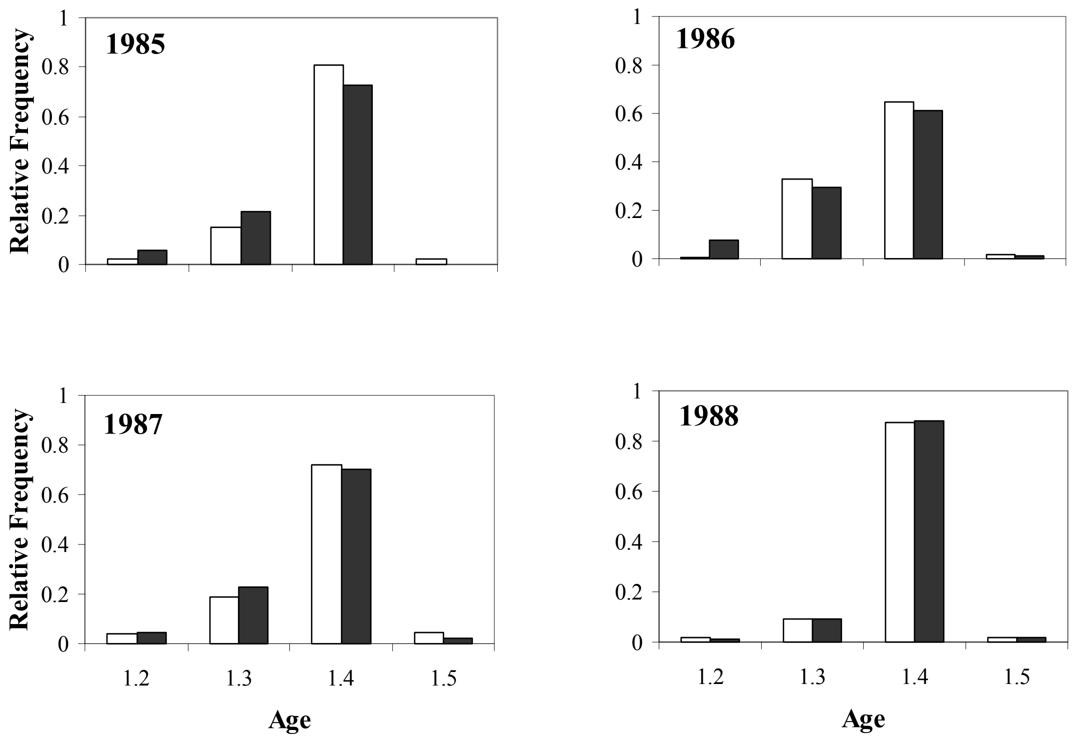

Figure A1.–Comparisons of relative age frequencies of chinook salmon sampled at the weir on the Little Tahltan River (white bars) **and during carcass surveys on the same river** (black bars).

Table A1.–Sample size m_t and samples by age $m_{a,t}$ of chinook salmon spawning in the Stikine River from 1981 through 1997.

	m_t	1.2	1.3	1.4	1.5		m_t	1.2	1.3	1.4	1.5
1981	837	19	197	617	4	1991	518	31	188	283	16
1982	370	11	63	292	4	1992	674	9	142	522	1
1983	127	43	32	48	4	1993	634	2	60	556	16
1984	197	19	156	21	1	1994	648	13	72	511	52
1985	528	24	102	398	4	1995	520	93	104	274	49
1986	638	28	198	402	10	1996	515	34	346	133	2
1987	461	21	96	328	16	1997	525	17	117	388	3
1988	716	11	65	627	13						
1989	340	7	119	149	65						
1990	522	42	37	417	26						

Table A2.–Estimated relative age composition of chinook salmon spawning in the Stikine River from 1981 through 1997. (Standard error in parentheses.)

	1.2 (SE)	**1.3** (SE)	**1.4** (SE)	**1.5** (SE)
1981	0.023 (0.005)	0.235 (0.015)	0.737 (0.015)	0.005 (0.002)
1982	0.030 (0.009)	0.170 (0.020)	0.789 (0.021)	0.011 (0.005)
1983	0.339 (0.042)	0.252 (0.039)	0.378 (0.043)	0.031 (0.016)
1984	0.096 (0.021)	0.792 (0.029)	0.107 (0.022)	0.005 (0.005)
1985	0.045 (0.009)	0.193 (0.017)	0.754 (0.019)	0.008 (0.004)
1986	0.044 (0.008)	0.310 (0.018)	0.630 (0.019)	0.016 (0.005)
1987	0.046 (0.010)	0.208 (0.019)	0.711 (0.021)	0.035 (0.009)
1988	0.015 (0.005)	0.091 (0.011)	0.876 (0.012)	0.018 (0.005)
1989	0.021 (0.008)	0.350 (0.026)	0.438 (0.027)	0.191 (0.021)
1990	0.080 (0.012)	0.071 (0.011)	0.799 (0.018)	0.050 (0.010)
1991	0.060 (0.010)	0.363 (0.021)	0.546 (0.022)	0.031 (0.008)
1992	0.013 (0.004)	0.211 (0.016)	0.774 (0.016)	0.001 (0.001)
1993	0.003 (0.002)	0.095 (0.012)	0.877 (0.013)	0.025 (0.006)
1994	0.020 (0.006)	0.111 (0.012)	0.789 (0.016)	0.080 (0.011)
1995	0.179 (0.017)	0.200 (0.018)	0.527 (0.022)	0.094 (0.013)
1996	0.066 (0.011)	0.672 (0.021)	0.258 (0.019)	0.004 (0.003)
1997	0.032 (0.008)	0.223 (0.018)	0.739 (0.019)	0.006 (0.003)

Table A3.–Estimated multipliers $\hat{\theta}_a$ used to calculate estimated age composition of chinook salmon spawning in the Stikine River from 1981 through 1997. (Standard error in parentheses.)

	1.2 (SE)	**1.3** (SE)	**1.4** (SE)	**1.5** (SE)
1981	0.023 (0.005)	0.241 (0.016)	0.754 (0.016)	0.005 (0.003)
1982	0.031 (0.010)	0.175 (0.021)	0.813 (0.022)	0.011 (0.005)
1983	0.512 (0.093)	0.381 (0.054)	0.571 (0.053)	0.048 (0.021)
1984	0.107 (0.027)	0.876 (0.026)	0.118 (0.025)	0.006 (0.006)
1985	0.048 (0.016)	0.202 (0.022)	0.790 (0.022)	0.008 (0.000)
1986	0.046 (0.015)	0.325 (0.027)	0.659 (0.028)	0.016 (0.006)
1987	0.048 (0.015)	0.218 (0.027)	0.745 (0.029)	0.036 (0.010)
1988	0.016 (0.006)	0.092 (0.017)	0.889 (0.018)	0.018 (0.006)
1989	0.021 (0.008)	0.357 (0.024)	0.447 (0.025)	0.195 (0.022)
1990	0.088 (0.014)	0.077 (0.011)	0.869 (0.014)	0.054 (0.009)
1991	0.064 (0.013)	0.386 (0.022)	0.581 (0.022)	0.033 (0.009)
1992	0.014 (0.005)	0.214 (0.015)	0.785 (0.015)	0.002 (0.001)
1993	0.003 (0.002)	0.095 (0.011)	0.880 (0.012)	0.025 (0.006)
1994	0.020 (0.006)	0.113 (0.011)	0.805 (0.015)	0.082 (0.011)
1995	0.218 (0.027)	0.244 (0.021)	0.642 (0.025)	0.115 (0.015)
1996	0.071 (0.012)	0.719 (0.022)	0.277 (0.022)	0.004 (0.003)
1997	0.033 (0.008)	0.230 (0.019)	0.764 (0.020)	0.006 (0.003)

APPENDIX B: ESTIMATES OF AGE COMPOSITION OF HARVESTED CHINOOK SALMON

Table B1.–Estimated harvests by year and age of chinook salmon in the upriver aboriginal gillnet fishery in Canada. Standard error in parentheses.

	Jacks	Adults	1.2 (SE)	1.3 (SE)	1.4 (SE)	1.5 (SE)
1981		586	13 (3)	138 (9)	432 (9)	3 (1)
1982		618	18 (5)	105 (12)	488 (13)	7 (3)
1983	215	851	215 (0)	324 (46)	486 (45)	41 (18)
1984	59	643	59 (0)	564 (17)	76 (16)	4 (4)
1985	94	793	94 (0)	160 (18)	626 (18)	6 (0)
1986	569	1,026	569 (0)	333 (27)	676 (29)	17 (6)
1987	183	1,183	183 (0)	258 (32)	882 (34)	43 (12)
1988	197	1,178	197 (0)	109 (20)	1,048 (21)	22 (8)
1989	115	1,078	115 (0)	385 (26)	482 (27)	210 (24)
1990	259	633	259 (0)	49 (7)	550 (9)	34 (6)
1991	310	753	310 (0)	291 (16)	438 (17)	25 (6)
1992	131	911	131 (0)	195 (13)	715 (14)	1 (1)
1993	142	929	142 (0)	88 (10)	817 (12)	24 (6)
1994	191	698	191 (0)	79 (8)	562 (10)	57 (8)
1995	244	570	244 (0)	139 (12)	366 (14)	65 (9)
1996	156	722	156 (0)	519 (16)	200 (16)	3 (2)
1997	94	1,155	94 (0)	266 (22)	882 (23)	7 (3)

Table B2.–Estimated harvests by year and age of chinook salmon in the upriver commercial gillnet fishery in Canada. Standard error in parentheses.

	Jacks	Adults	1.2 (SE)	1.3 (SE)	1.4 (SE)	1.5 (SE)
1981		154	3 (1)	36 (2)	114 (2)	1 (0)
1982		76	2 (1)	13 (1)	60 (2)	1 (0)
1983		75	25 (3)	19 (3)	28 (3)	2 (1)
1984	No fishery					
1985		62	3 (1)	12 (1)	47 (1)	0 (0)
1986	41	104	41 (0)	34 (3)	69 (3)	2 (1)
1987	19	109	19 (0)	24 (3)	81 (3)	4 (1)
1988	46	175	46 (0)	16 (3)	156 (3)	3 (1)
1989	17	54	17 (0)	19 (1)	24 (1)	11 (1)
1990	20	48	20 (0)	4 (1)	42 (1)	3 (0)
1991	32	117	32 (0)	45 (3)	68 (3)	4 (1)
1992	19	56	19 (0)	12 (1)	44 (1)	0 (0)
1993	2	44	2 (0)	4 (0)	39 (1)	1 (0)
1994	1	76	1 (0)	9 (1)	61 (1)	6 (1)
1995	17	9	17 (0)	2 (0)	6 (0)	1 (0)
1996	44	41	44 (0)	29 (1)	11 (1)	0 (0)
1997	6	45	6 (0)	10 (1)	34 (1)	0 (0)

Table B3.–Estimated harvests by year and age of chinook salmon in the lower river commercial gillnet fishery in Canada. Standard error in parentheses.

	Jacks	Adults	1.2 (SE)	1.3 (SE)	1.4 (SE)	1.5 (SE)
1981		664	15 (3)	156 (10)	489 (10)	3 (2)
1982		1,693	50 (15)	288 (33)	1,336 (36)	18 (9)
1983	430	492	430 (0)	187 (26)	281 (26)	24 (10)
1984	No fishery					
1985	91	256	91 (0)	52 (6)	202 (6)	2 (0)
1986	365	806	365 (0)	262 (21)	531 (23)	13 (5)
1987	242	909	242 (0)	198 (24)	678 (26)	33 (9)
1988	201	1,007	201 (0)	93 (17)	896 (18)	19 (6)
1989	157	1,537	157 (0)	549 (37)	688 (38)	300 (34)
1990	680	1,569	680 (0)	121 (18)	1,363 (22)	85 (15)
1991	318	641	318 (0)	247 (14)	372 (14)	21 (6)
1992	89	873	89 (0)	186 (13)	685 (13)	1 (1)
1993	164	830	164 (0)	79 (9)	730 (10)	21 (5)
1994	158	1,016	158 (0)	115 (12)	818 (15)	83 (11)
1995	599	1,067	599 (0)	260 (22)	685 (26)	122 (16)
1996	221	1,708	221 (0)	1,229 (37)	472 (37)	7 (5)
1997	186	3,283	186 (0)	756 (63)	2,507 (64)	19 (10)

Table B4.–Estimated harvests by year and age of chinook salmon in the marine gillnet fishery in U. S. District 108. Age composition for 1984 was interpolated from statistics for 1983 and 1985.

	All catch	Estimated hatchery catch	Estimated wild catch	1.2	1.3	1.4	1.5
1981	283		283	6	67	209	1
1982	1,033		1,033	31	176	815	11
1983	47		47	22	10	14	1
1984	14		14	4	4	5	1
1985	20		20	5	3	11	0
1986	102		102	32	22	47	1
1987	149		149	31	29	86	3
1988	206		206	34	16	153	3
1989	310		310	29	102	125	55
1990	557	227	330	100	18	200	13
1991	1,504	613	891	295	230	345	20
1992	967	394	573	53	111	408	1
1993	1,628	663	965	159	76	708	22
1994	1,996	571	1,425	192	138	994	100
1995	1,702	758	944	340	154	384	66
1996	1,717	840	877	95	569	213	0
1997	2,566	740	1,826	99	399	1,318	9

Table B5.–Estimated harvests by year and age of wild chinook salmon in the marine recreational fishery near Petersburg and Wrangell, Alaska. Standard error in parentheses.

	Estimated wild harvest	1.3	1.4	1.5
1981	2,392 (287)	576 (79)	1,804 (220)	12 (7)
1982	3,347 (402)	587 (99)	2,722 (335)	37 (17)
1983	2,666 (320)	1,016 (188)	1,523 (230)	127 (58)
1984	2,260 (271)	1,981 (245)	267 (65)	13 (14)
1985	3,104 (372)	628 (101)	2,451 (301)	25 (3)
1986	2,462 (295)	799 (116)	1,622 (206)	40 (15)
1987	1,539 (185)	336 (58)	1,147 (145)	56 (17)
1988	2,440 (293)	225 (49)	2,170 (264)	45 (16)
1989	2,775 (333)	992 (136)	1,242 (164)	542 (89)
1990	4,285 (514)	330 (61)	3,723 (450)	232 (47)
1991	3,658 (439)	1,412 (187)	2,126 (267)	120 (36)
1992	3,322 (399)	709 (99)	2,608 (317)	5 (3)
1993	4,227 (507)	401 (67)	3,719 (449)	107 (28)
1994	2,142 (257)	243 (37)	1,724 (209)	175 (31)
1995	1,640 (197)	399 (59)	1,052 (133)	188 (33)
1996	2,424 (291)	1,744 (216)	670 (96)	10 (7)
1997	3,176 (381)	731 (106)	2,426 (298)	19 (10)

Annual exploitation rates U_t for chinook salmon were estimated as follows:

$$\hat{U}_t = \frac{\hat{H}_{ALL,t}}{\hat{H}_{ALL,t} + \hat{N}_{ALL,t}}$$

where $\hat{H}_{ALL,t}$ is the estimated harvest of chinook salmon of all ages in year t, and $\hat{N}_{ALL,t}$ is the estimated spawning abundance of chinook salmon of all ages in year t. Calculation of $\hat{N}_{ALL,t}$ is described in Appendix A. Calculation of $\hat{H}_{ALL,t}$ is the sum of the tallied harvests of jacks and adults of wild origin in all commercial and aboriginal fisheries plus the estimated harvest of wild chinook salmon in the marine recreational fishery (see tables above for statistics). Variance for estimated exploitation rates can be approximated with the delta method (Seber 1982:7-9):

$$v(\hat{U}_t) \cong v(\hat{H}_{ALL,t})\frac{\hat{N}^2_{ALL,t}}{\left(\hat{H}_{ALL,t} + \hat{N}_{ALL,t}\right)^4} + v(\hat{N}_{ALL,t})\frac{\hat{H}^2_{ALL,t}}{\left(\hat{H}_{ALL,t} + \hat{N}_{ALL,t}\right)^4}$$

Since harvest is estimated only for the recreational fishery and "known" for other fisheries (at least for our purposes), estimated variance $v(\hat{H}_{ALL,t})$ is the estimated variance for the recreational fishery.

APPENDIX C: MEASUREMENT ERROR IN ESTIMATES OF SPAWNING ABUNDANCE AND OPTIMAL YIELD

The log-linear transform of Cushing's model $\ln(\hat{R}_y) = \ln(\alpha') + \beta' \ln(\hat{N}_y) + \varepsilon_y$ can be used to compensate for the presence of measurement error in spawning abundance (Fuller 1987:13-26; Quinn and Deriso 1999:108-111). Estimates for parameters $\ln(\alpha')$ and β' for chinook salmon in the Stikine River are:

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

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

$$= 0.5727$$

$$\widehat{\ln(\alpha')} = \overline{\ln \hat{R}} - \hat{\beta}' \overline{\ln \hat{N}} = 4.5864$$

with a coefficient of determination (R^2) of 41% (see Section on Measurement Error for definitions of notation). The estimate for N_{MSY} with this model adjusted for measurement error in both dependent and independent variables is

$$\hat{N}_{MSY} = \sqrt[\hat{\beta}'-1]{(\hat{\alpha}'\hat{\beta}')^{-1}} = 17{,}730$$

where

$$\hat{\alpha}' = \exp(\widehat{\ln \alpha'} + \hat{\sigma}_\varepsilon^2 / 2)$$

and

$$\hat{\sigma}_\varepsilon^2 = \hat{\sigma}_r^2 - \hat{\sigma}_v^2 = 0.3221 - 0.0097 = 0.3124.$$

The statistic $\hat{\sigma}_v^2$ is the average of the $cv^2(\hat{R}_y)$ (see Table 8 and Appendix D). The similarity in estimates of N_{MSY} (17,368 vs. 17,730) for both Ricker's and Cushing's models indicates that measurement error in spawning abundance representing 9% of overall variation in N_y was a negligible factor. Predicted values from both fits were similar over the range of data observed in this study, but diverged at higher numbers of spawners (Figure C1).

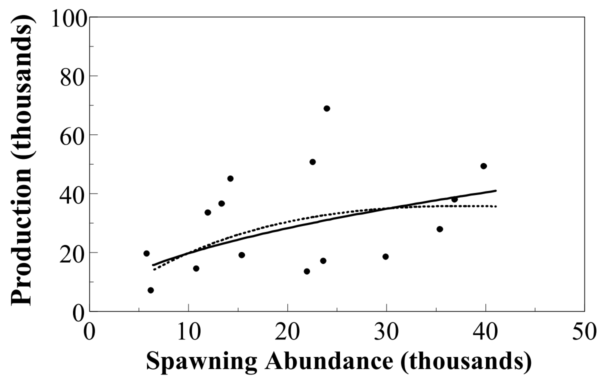

Figure C1.–Estimates and predictions of production for the 1977–91 year classes of chinook salmon in the Stikine River. Predictions are from fits of Ricker's (dotted line) and Cushing's (solid line) models.

APPENDIX D: MEASUREMENT ERROR IN ESTIMATES OF PRODUCTION AND OPTIMAL YIELD

The stochastic version of Ricker's model is:

$$R_i = \alpha N \exp(-\beta N)\exp(\varepsilon_i)$$

where i corresponds to a specific level of production R given a spawning abundance N, where α and β are parameters and $\exp(\varepsilon_i)$ is a log-normal expression of the "process error", meaning $\varepsilon_i \sim norm(0, \sigma_\varepsilon^2)$. When R_i is unknown, estimates are used in its stead. If $\hat{R}_i = R_i \exp(v_i)$ with $\exp(v_i)$ an expression of log-linear measurement error such that $v_i \sim norm(0, \sigma_v^2)$, the substitutions are equivalent to multiplying the stochastic equation above by $\exp(v_i)$ to get:

$$\hat{R}_i / N = \alpha \exp(-\beta N)\exp(r_i)$$

where $r_i = \varepsilon_i + v_i$ with ε representing process error and v measurement error (forget about measurement error in N for this discussion). The linear form of the equation immediately above is fit to data, resulting in estimates of α, β, and $\hat{\sigma}_r^2$ (the mean-squared error). However, the estimate of α would be biased by the factor $\exp(\sigma_\varepsilon^2/2)$ because of the linear transformation (Hilborn 1985). The residual mean square from the linear fit represents both process and measurement error such that $\sigma_r^2 = \sigma_\varepsilon^2 + \sigma_v^2$. If σ_v^2 is known (or estimated), the appropriate correction could be calculated (or estimated).

Calculating an unbiased estimate of σ_v^2 is possible if there are estimates of variance for estimates of production. With the method of moments, $V(\hat{R}_i) = \mathrm{E}[\hat{R}_i^2] - (\mathrm{E}[\hat{R}_i])^2$. Substituting $\hat{R}_i = R_i \exp(v_i)$:

$$V(\hat{R}_i) = \mathrm{E}[R_i^2 \exp(v_i)^2] - (\mathrm{E}[R_i \exp(v_i)])^2$$

Because R_i is considered fixed in the context of a sampling program:

$$V(\hat{R}_i) = R_i^2 \mathrm{E}[\exp(v_i)^2] - R_i^2(\mathrm{E}[\exp(v_i)])^2$$

Rearranging and simplifying:

$$\frac{V(\hat{R}_i)}{R_i^2} = \mathrm{E}[\exp(2v_i)] - (\mathrm{E}[\exp(v_i)])^2$$

Remember that for a generic variable :

$$\mathrm{E}[\exp(tx)] = \exp\left[\frac{t^2}{2}\sigma_x^2\right]$$

where t is a scalar constant. In our situation, $t = 1$ or 2, and $x \equiv$ v:

$$\mathrm{E}[\exp(2v_i)] = \exp(2\sigma_v^2)$$

$$\mathrm{E}[\exp(v_i)] = \exp(\sigma_v^2/2)$$

With substitution:

$$\frac{V(\hat{R}_i)}{R_i^2} = \exp(2\sigma_v^2) - [\exp(\sigma_v^2/2)]^2 =$$

$$= \exp(2\sigma_v^2) - \exp(\sigma_v^2)$$

Note that in the rules above governing the exponential series:

$$\exp(tx) = 1 + \frac{(tx)^1}{1!} + \frac{(tx)^2}{2!} + \frac{(tx)^3}{3!} + \frac{(tx)^4}{4!} + ...$$

Because in our context $1 > \sigma_r^2 > \sigma_v^2$, the higher terms of the expansion are negligible, making $\exp(\sigma_v^2) \cong 1 + \sigma_v^2$. With substitution:

$$\frac{V(\hat{R}_i)}{R_i^2} = 1 + 2\sigma_v^2 - (1 + \sigma_v^2) = \sigma_v^2$$

Note that the true CVs are invariant regardless of the value of i or N. Since estimates of the CVs are variable, the estimate of σ_v^2 is the expectation of estimates over brood years for which there are estimates:

$$\hat{\sigma}_v^2 = \mathrm{E}\left[\frac{V(\hat{R}_i)}{R_i^2}\right] = \frac{\sum_i cv^2(\hat{R}_i)}{n}$$

where n is the number of estimates of production for which we have estimated the variance of $\hat{R}_i$.

APPENDIX E:

SUMMARY OF REGULATIONS IN SOUTHEAST ALASKA FOR RECREATIONAL, COMMERCIAL GILLNET, AND COMMERCIAL TROLL FISHERIES WHICH PERTAIN TO MARINE HARVEST OF STIKINE-BOUND CHINOOK SALMON

Table E1.–Southeast Alaska (SEAK) chinook salmon harvest levels, Alaska hatchery contributions, and harvest management targets, 1965–1997 (in thousands of fish)[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 E2.–Sport fishing pre-season booklet regulations in Southeast Alaska affecting the Stikine 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	3 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	3 fish daily and in possession	26 inch mini-mum size limit	no special restrictions		closed to king salmon fishing
1977	1/1-12/31	same as 1976	28 inch mini-mum 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	Greys Pass closed, remaining area of Dist 8 bag limit 1 from 4/16-6/14	same as 1976

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Table E2.– Page 2 of 3.

Year	Salt-water season	Saltwater bag and possession limits	Saltwater size limit	Saltwater methods & means restrictions	Specially closed salt waters	Freshwater regulations
1979	1/1-12/31	same as 1976	same as 1977	same as 1976	Same as 1978 plus northern District 7 also 1 fish bag limit	same as 1976
1980	1/1-12/31	same as 1976	28 inch minimum size limit 6/15-3/31; any size king salmon legal 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
1983	1/1-12/31	2 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	Greys Pass closed, bag limit 2 on remaining area of Dist 8 and northern Dist 7	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 mini-mum size limit	same as 1983	same as 1983	closed to king salmon fishing[a]
1990	1/1-12/31	same as 1983	same as 1989	same as 1983	same as 1983	same as 1989
1991	1/1-12/31	same as 1983	same as 1989	same as 1983	same as 1983	same as 1989
1992	1/1-12/31	same as 1983	same as 1989	same as 1983– with addition of: sport fishing may only be con-ducted by the use of a single line per angler	same as 1983	same as 1989
1993	1/1-12/31	same as 1983	same as 1989	same as 1992	same as 1983	same as 1989

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Table E2.–Page 3 of 3.

Year	Salt-water season	Saltwater bag and possession limits	Saltwater size limit	Saltwater methods & means restrictions	Specially closed salt waters	Freshwater regulations
1994	1/1-12/31	2 fish daily and in possession	28 inch minimum size limit	sport fishing may only be conducted by the use of a single line per angler and not more than 6 lines may be fished from any vessel	Same as 1993	closed to king salmon fishing[a]
1995	1/1-12/31	same as 1994	same as 1994	same as 1994	same as 1994	same as 1994
1996	1/1-12/31	same as 1994	same as 1994	same as 1994	same as 1994	same as 1994
1997	1/1-12/31	2 fish daily and in possession; in addition, for nonresidents, the annual limit is 4 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 fresh water 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 fresh waters are closed to king salmon fishing. To date, ADFG has not opened king salmon fishing in fresh water under this authority.

Table E3.–Commercial fishing pre-season booklet regulations for drift gill nets in U. S. District 108 of Southeast Alaska likely affecting the Stikine River chinook salmon stock, 1960–1998[a].

Year	Season opening date(s) and fishing period(s)	Gillnet mesh regulations	Gillnet length regulations	Chinook size limits
1960	5/1-E.O. date: 96 hrs/wk	6" and smaller: 50 meshes; $6^{1/8}$-7": 45 meshes; $7^{1/8}$-9": 40 meshes; min 8.5" prior 6/20; max 6" 6/20-7/19	125 fathom min. & 300 fathom max.	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
1962	4/30-: 6/16-E.O. date: 96 hrs/wk	same as 1960	Same as 1960	same as 1960
1963	4/29-6/14: 96 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
1964	4/27-6/12: 96 hrs/wk 6/15-E.O. date: 72 hrs/wk	same as 1963	Same as 1960	same as 1960
1965	5/2-6/11: 24 hrs/wk 6/12-E.O. date: 72 hrs/wk	same as 1963	Same as 1960	same as 1960
1966	same as 1965	same as 1965	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
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
1969	4/27-6/14: 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
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. 6/14-7/20	Not less than 125 fathoms or more than 300 fathoms	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 125 fathoms or more than 300 fathoms	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;	none

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Year	Season opening date(s) and fishing period(s)	Gillnet mesh regulations	Gillnet length regulations	Chinook size limits
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	same as 1971;	None
1974	same as 1973	same as 1973	same as 1973	None
1975	same as 1973	same as 1973	same as 1973	None
1976	Season Opens: last Monday in April-E.O. date: 72 hrs/wk	Same as 1973; except, mesh not less than $5^{1/2}$ inches during a season specified by E.O.		None
1977	same as 1976	Same as 1976	same as 1976	None
1978	Spring-time gill netting closed Season opens 3rd Monday in June; 72 hrs/wk	Same as 1976	same as 1976	None
1979	same as 1978	Same as 1976	same as 1976	None
1980	same as 1978	Same as 1976	same as 1976	None
1981	same as 1978	Same as 1976	same as 1976	None
1982	same as 1978	Same as 1976	same as 1976	None
1983	3rd Sunday in June-E.O. date: 72 hrs/wk	Same as 1976	same as 1976	None
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
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. during E.O. pink salmon seasons, mesh size may not be less than $5^{1/2}$ inches	not less than 125 fathoms or more than 300 fathoms	no size limit

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Year	Season opening date(s) and fishing period(s)	Gillnet mesh regulations	Gillnet length regulations	Chinook size limits
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; for the protection of pink salmon, $5^{3/8}$”; for the harvest of chum salmon, 6”	same as 1985	none
1987	Same as 1986	same as 1986	same as 1985	none
1988	Same as 1986	same as 1986	same as 1985	none
1989	Same as 1986	same as 1986	same as 1985	none
1990	Same as 1986	same as 1986	same as 1985	none
1991	Same as 1986	same as 1986	same as 1985	none
1992	Same as 1986	same as 1986	same as 1985	none
1993	Same as 1986	same as 1986	same as 1985	none
1994	2nd Sunday in June	Same as 1986; district-wide 6” max. through July 18	same as 1985	none
1995	Same as 1994	same as 1994	same as 1985	none
1996	Same as 1994	Same as 1994	Same as 1985	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
1998	Same as 1996	same as 1997	same as 1996	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.

Table E4.–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.

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YEAR	MAJOR REGULATORY ACTIONS ASSOCIATED WITH MANAGEMENT OF SOUTHEAST ALASKA TROLL FISHERY
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 fin clips were allowed to be retained by troll fishermen so long as the heads were submitted to ADFG.
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.

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YEAR	MAJOR REGULATORY ACTIONS ASSOCIATED WITH MANAGEMENT OF SOUTHEAST ALASKA TROLL FISHERY
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)
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.

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YEAR	MAJOR REGULATORY ACTIONS ASSOCIATED WITH MANAGEMENT OF SOUTHEAST ALASKA TROLL FISHERY
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.