Fishery Manuscript No. 98-2

Biological Escapement Goal for Klukshu River Chinook Salmon

by

Scott A. McPherson,

Peter Etherton,

and

John H. Clark

November 1998

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

FISHERY MANUSCRIPT NO. 98-2

BIOLOGICAL ESCAPEMENT GOAL FOR KLUKSHU RIVER CHINOOK SALMON

by

Scott A. McPherson
Alaska Department of Fish and Game, Division of Sport Fish, Douglas, Alaska

Peter Etherton
Canadian Department of Fisheries and Oceans, Whitehorse, Yukon Territory, Canada

and

John H. Clark
Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Helena, Montana

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

November 1998

Development of this manuscript was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-12 and F-10-13, Job No. S-1-3.

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. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

Scott A. McPherson
Alaska Department of Fish and Game, Division of Sport Fish, Region I
Douglas Island Center Building, Douglas, AK 99824-0020, USA

Peter Etherton
Canadian Department of Fisheries and Oceans
Suite 100, 419 Range Road, Whitehorse, Yukon Territory Y1A3V1

John H. Clark
Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development
4240 Jimtown Road, Helena MT 59602,USA

This document should be cited as:
McPherson, Scott A., Peter Etherton, and John H. Clark. 1998. Biological escapement goal for Klukshu River chinook salmon. Alaska Department of Fish and Game, Fishery Manuscript No. 98-2, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF TABLES (continued)

Table **Page**

LIST OF TABLES (continued)

LIST OF FIGURES

PREFACE

This report is an updated version of a draft report written in 1995 entitled "*Biological Escapement Goal for Alsek River System Chinook Salmon*" by John H. Clark, Peter Etherton, and Scott A. McPherson. The 1995 draft report was reviewed by:

(1) the Transboundary Technical Committee of the Pacific Salmon Commission;

(2) some U.S. and Canadian members of the Chinook Technical Committee of the Pacific Salmon Commission;

(3) the Salmon Subcommittee of the Pacific Stock Assessment Review Committee (Canada); and

(4) the Salmon Escapement Goal Review Committee of the Alaska Department of Fish and Game.

Various recommendations made by these reviewers (and by other fishery professionals) were incorporated into the present report. As did the earlier report, this report provides recommendations to the Alaska Department of Fish and Game and to the Canadian Department of Fisheries and Oceans to change the existing Klukshu River escapement goal for chinook salmon.

THE AUTHORS

ABSTRACT

Available information consisting of harvests, escapements, and age composition of chinook salmon *Oncorhynchus tshawytscha* returning to the Klukshu River, a tributary of the Tatshenshini River on the Alsek River system, during the years 1976–1996 was analyzed. Total escapement of chinook salmon to the Alsek River system is not estimated annually. Instead, total escapement of chinook salmon in the Klukshu River, an Alsek River tributary, is enumerated annually; therefore, emphasis of the analysis in this report is on the Klukshu River stock of chinook salmon. The Klukshu River escapements of chinook salmon were combined with estimated harvests of Klukshu River origin chinook salmon in Canadian and U.S. fisheries based upon three alternate assumptions concerning the stock composition of chinook salmon harvested in the U.S. Alsek gillnet fishery. Estimated age-specific upstream runs (escapements plus Canadian harvest) of Klukshu River origin chinook salmon were added to the three alternate sets of U.S. harvests to estimate annual age-specific total runs for the years 1976–1996. These three sets of estimated total escapements and estimated total recruitments for brood years 1976–1991 were used to develop spawner-recruit relationships. These spawner-recruit relationships were used to estimate a range of escapement levels of chinook salmon that is estimated to provide near-maximum sustained yield in U.S. and Canadian fisheries, after a battery of tests and discussion. These included analysis by regression techniques, examination of measurement error and bias, tabulation of probabilities of return by spawning stock size in a Markovian approach, and calculation of loss functions given alternative spawner-recruit parameters. A biological escapement goal range of 1,100 to 2,300 chinook salmon spawners in the Klukshu River is recommended. Such a management policy is expected to provide a sustained yield to Canadian and U.S. fisheries of about 1,500 to 2,500 Klukshu River system chinook salmon per year.

The proportion of Klukshu River origin chinook salmon harvested in the U.S. Alsek gillnet fishery is unknown and requires further research; recommendations are made concerning this needed research. Until these needed data are available, we recommend that U.S. and Canadian fisheries be managed to achieve Klukshu River spawning escapements of chinook salmon that are expected to result in sustained yields near or slightly less than maximum harvests. This can best be achieved by managing fisheries to allow 1,100 to 2,300 chinook salmon to escape and spawn in the Klukshu River system, the primary escapement monitoring location for chinook salmon in the Alsek River drainage.

We recommend that the Alaska Department of Fish and Game and the Canadian Department of Fisheries and Oceans:

1) adopt a range of 1,100 to 2,300 chinook spawners in the Klukshu River as a formal biological escapement goal range.
2) that a management plan be developed to achieve this range, which is the Klukshu River weir count minus anticipated harvest in the Canadian aboriginal fishery upstream of the weir.
3) that the two agencies reach a harvest sharing agreement by incorporating this escapement goal range and that this policy be used by U.S. and Canadian fishery managers over the next several years.
4) that the Klukshu River (and Alsek River) chinook salmon escapement goal be reevaluated in the year 2001.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, Alsek River, Klukshu River, transboundary river management, brood table, spawner-recruit, escapement goal.

INTRODUCTION

The Alsek River originates in the Yukon Territory of Canada and flows south, terminating in the Gulf of Alaska about 75 km southeast of Yakutat Alaska (Figure 1). The Alsek River drainage supports spawning populations of anadromous Pacific salmon, including chinook salmon *Oncorhynchus tshawytscha*; however, most anadromous production in the Alsek drainage is limited to the Tatshenshini River because of a velocity barrier on the lower Alsek near Lowell Glacier. Significant chinook salmon spawning has been documented to occur annually in the

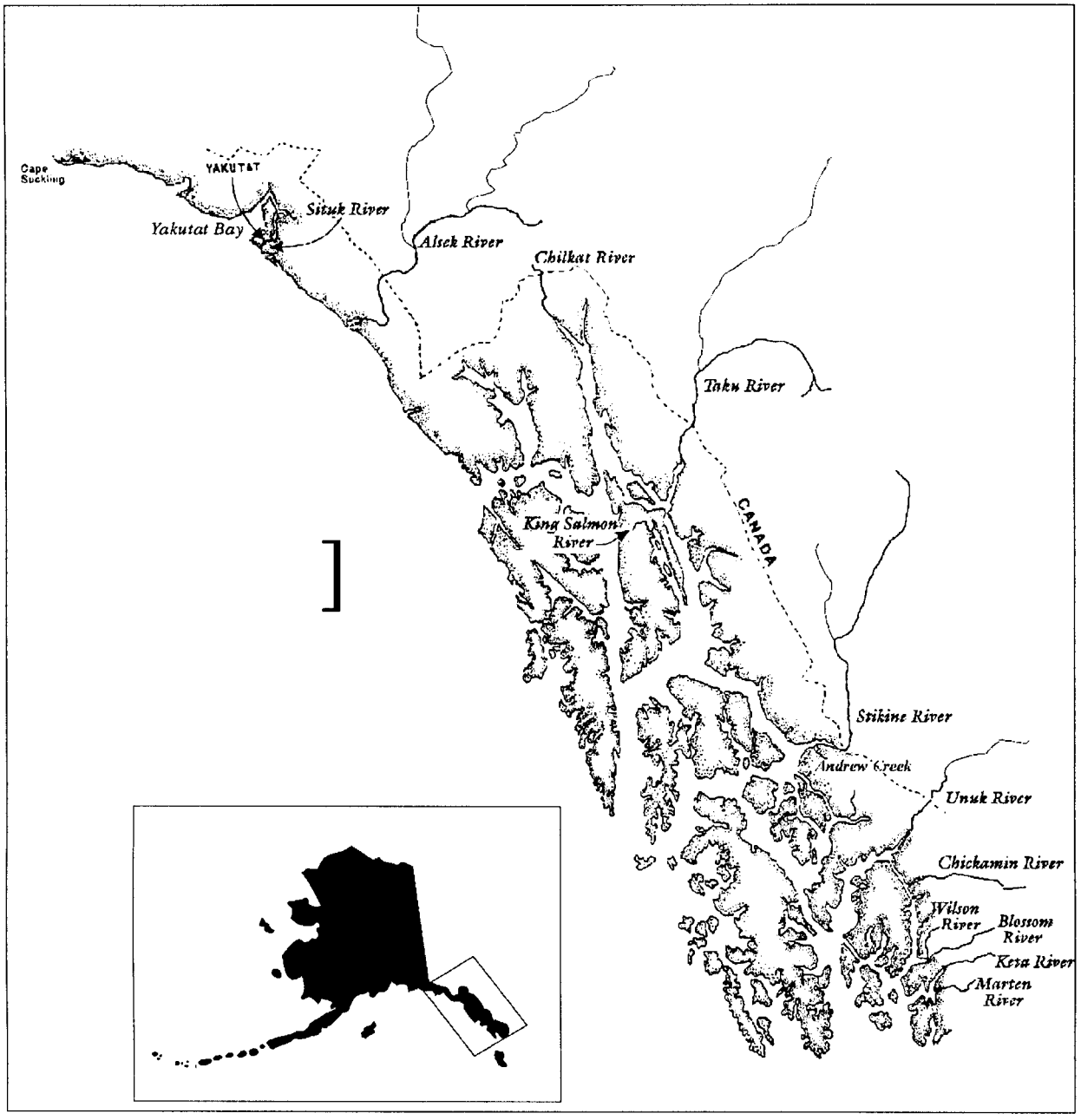

Figure 1.–Location of major chinook salmon rivers in Southeast Alaska, Yukon Territory, and northern British Columbia.

Alsek River drainage in various streams tributary to the Tatshenshini River, including the Klukshu River, the Blanchard River, the Takhanne River, and Goat Creek (Figures 2 and 3). Other significant chinook salmon spawning areas probably exist downstream of the confluence of the Klukshu and Tatshenshini rivers such as in mainstream areas of the Tatshenshini and Alsek rivers; chinook spawning is known to occur in other Tatshenshini tributaries such as Village, Kane, Silver, Bridge, Detour, O'Connor, Low Fog and Stanley creeks, as well as Bridge River (Figure 3).

Chinook salmon returning to spawn in the Alsek River and its tributaries are harvested in sport and aboriginal fisheries in Canada and in commercial, subsistence, and personal use fisheries in the United States. Harvest management of Alsek River chinook salmon is coordinated under the Pacific Salmon Commission (PSC) process as part of the Pacific Salmon Treaty (PST) adopted by the United States and Canada in 1985. Management of the three transboundary rivers (Alsek, Taku and Stikine) is specifically assigned to the Transboundary River Technical Committee (TRTC). Intent of the coordinated management program for Alsek chinook at the current time is to achieve an internationally agreed upon escapement goal of 4,700 chinook salmon in the Klukshu River. A 1991 report by the TRTC (PSC 1991) provides a chronology of the current chinook salmon escapement goal as follows:

> *"Escapement of chinook salmon to the Alsek River has been enumerated, using standardized methods, at a weir on the Klukshu River since 1976 (Table 1). The highest count recorded between 1976 and 1981 when the goals were originally set was 4,403 chinook, which occurred in 1979. The U.S. originally used this level, rounded to 4,400 fish, as the escapement goal while Canada considered this level to still represent a depressed stock level and set 5,000 as their goal. The TRTC recommends that 4,700 chinook, an average of the two numbers, be used as the escapement goal for the Klukshu River until a better goal is developed. Age specific terminal catch and Klukshu escapement data is available from 1982. By 1995 there will be 10 brood years of data available for spawner-recruit analysis which will, hopefully, lead to a more biologically based escapement goal.*
>
> *Annual spawning escapements for the Klukshu River are determined by subtracting the Indian* [aboriginal] *food fish catch above the weir from the weir count. Because of the interest in the CTC* [Chinook Technical Committee–PSC] *in looking at escapement to the entire Alsek River and because several different methods of expanding and accounting for in-river catches had been used, in 1989 the TRTC developed a recommended procedure. To estimate the spawning escapement to the entire system, both Parties agreed to double the weir count and then subtract all Canadian sport and Indian food catches. The escapement goals used in the CTC annual reports do not reflect this expansion procedure. The U.S. Alsek goal used by the CTC of 5,000 chinook salmon for the entire Alsek River used in the CTC annual reports was mistakenly derived from 3,200 fish as the highest escapement level between 1976 and 1980; a factor of 1.56 (1.0/0.64) was used to expand the number to represent the entire system. The Canadian goal of 12,500 chinook for the entire Alsek was derived from Canada's original Klukshu goal of 5,000 chinook and an expansion factor of 2.5. Unless terminal and in-river catches increase significantly, the TRTC recommends that expansion factors not be used and just the spawning escapements to the Klukshu River be used to assess rebuilding."*

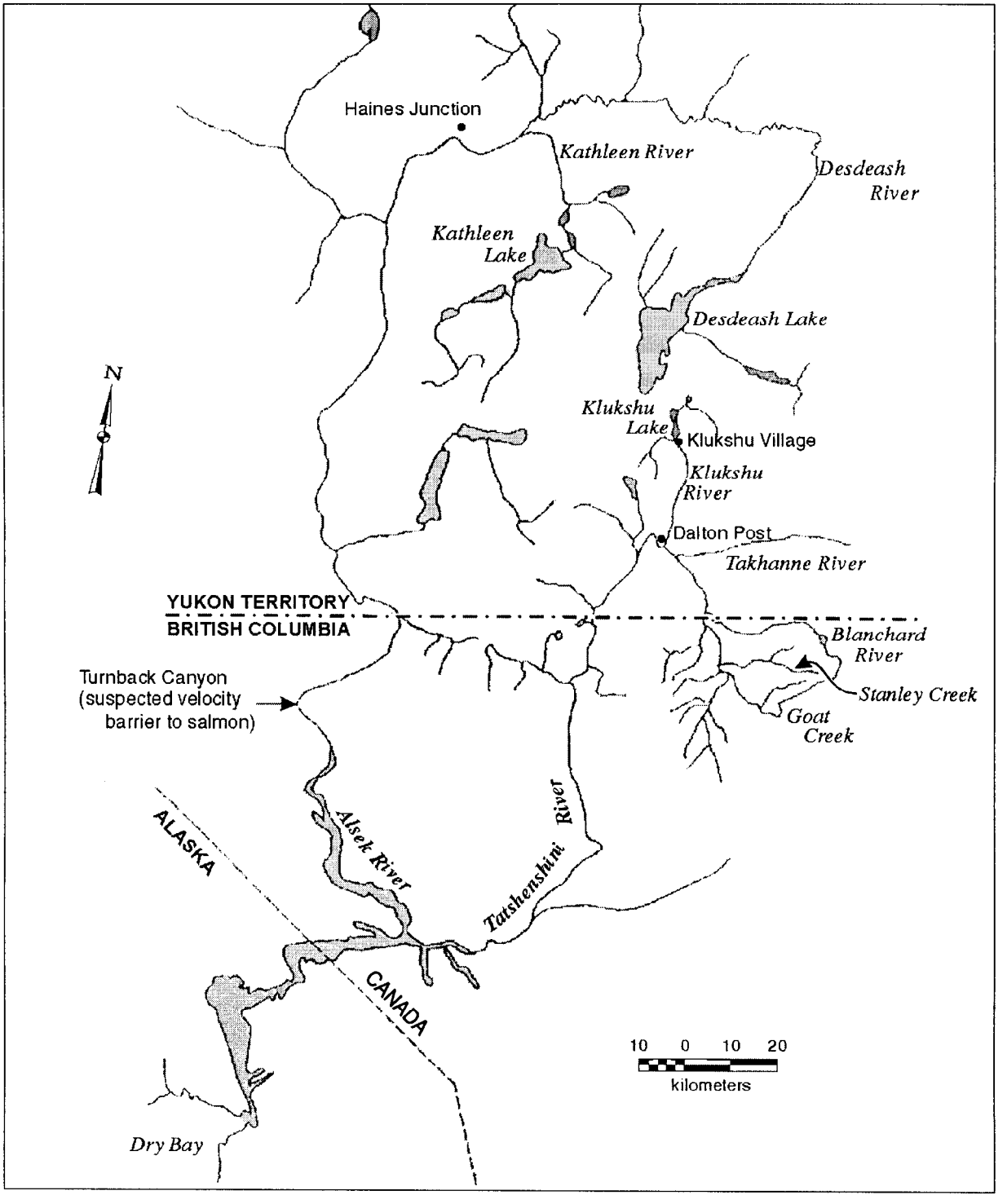

Figure 2.–Location of Canadian provincial and U.S./Canada boundaries that transect the Alsek River drainage from its headwaters in Yukon Territory to its terminus in Dry Bay, Alaska.

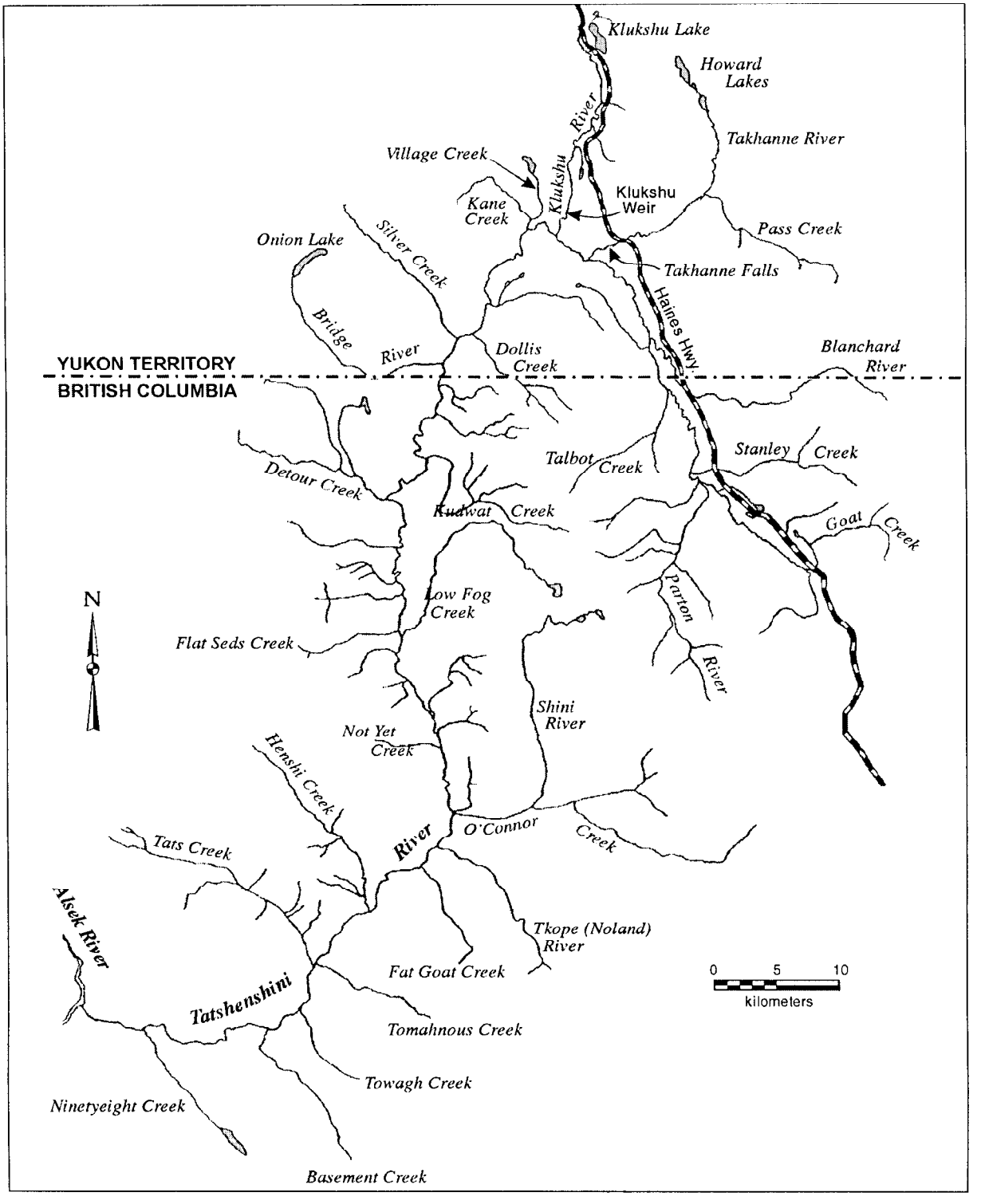

Figure 3.–Tatshenshini River drainage and associated tributaries, Yukon Territory and northern British Columbia.

The intent of this report is to summarize available age composition, harvest, and escapement information for chinook salmon from the Klukshu River (tributary of Tatshenshini River) and to estimate the Klukshu River chinook salmon escapement level that these data predict will result in maximum or near-maximum sustained yield to Canadian and U.S. fisheries. This is the analysis that the TRTC referred to in 1991 when they said (PSC 1991):

> *"By 1995 there will be 10 brood years of data available for spawner-recruit analysis which will, hopefully, lead to a more biologically based escapement goal."*

BACKGROUND AND AVAILABLE DATA

The Chinook Technical Committee (CTC) of the Pacific Salmon Commission (PSC) annually uses about 45 indicator stocks distributed along the Pacific Coast (stocks returning to spawn in rivers located from central Oregon to Southeast Alaska and the Yukon Territory) to evaluate coastwide status of naturally spawning chinook salmon with respect to the PST chinook rebuilding program objectives of: (1) halting escapement declines, and (2) attaining escapement goals by 1998. The Alsek/Klukshu River chinook salmon stock is one of these naturally spawning chinook salmon indicator stocks. The status of this stock has consistently been classified by the CTC as "*not rebuilding*" (for example, see CTC 1994), predominantly because annual escapements have been substantially below the internationally agreed upon goal of 4,700 chinook salmon in the Klukshu River. To date, technical reports have been unclear as to why the Alsek chinook salmon stock has not responded to the PSC chinook rebuilding program. As the TRTC stated in 1991:

> *"The Klukshu chinook stock has not responded to the rebuilding program; the escapement levels since 1981 have varied less than between 1977 and 1981 and have shown no discernible increasing or decreasing trend. It is not known why this stock is not responding, particularly since inriver U.S. and Canadian catches have been relatively low compared to Klukshu escapement levels. It is hoped that results from a coded wire tag study available starting in 1992 will provide information on the distribution of this stock in marine catches and perhaps an indication as to whether high exploitation rates are limiting the escapement into the river."*

An inherent assumption of the PSC chinook rebuilding program is that chinook stocks coastwide were generally depressed before PST implementation. However, as the CTC (1994) states: "*not all chinook stocks were declining.*" Further, only scanty scientific information was available for most of the chinook salmon stocks assumed to be depressed when the PSC chinook rebuilding program was begun in the early 1980s. Such was the case for the Alsek and Klukshu chinook salmon stocks. U.S. and Canadian fishery management agencies (Alaska Department of Fish and Game [ADFG] and Canadian Department of Fisheries and Oceans [CDFO]) assumed the Alsek chinook salmon stock was depressed and consequently adopted very conservative escapement goal policies. Interim escapement goals set in 1981 to 1991 were initially set at or above the highest escapement enumeration observed prior to 1981. Coupled with international fishery restrictions, it was anticipated that these very conservative escapement goal policies would greatly increase annual escapements. However, this result would only occur if the stock were, in fact, depressed, and if the escapement goals defined by these agency policies were less than or a reasonable approximation of the optimum escapement level (annual escapement level that would, on average, maximize long-term yield to fisheries).

PSC technical committees have long recognized that the escapement goals developed at the time of PST implementation were not necessarily good estimates or even estimates of optimal escapement. As the TRTC stated in 1991:

"While the new joint escapement goals are not considered better estimates of optimal escapement than those originally used by either of the Parties, they do incorporate improvements, including both data correction and refinements in the old methods. Most important, they provide a single estimate for each river that can be used to assess rebuilding. Exploratory spawner-recruit analyses are currently being done based upon age-specific data from weir samples and it is hoped that by 1995 a sufficient number of years of data and range of escapements will be available to develop estimates of optimal escapement goals that have a better biological basis."

Thus, it has long been recognized by technical staff associated with the PSC that the existing international escapement goal of 4,700 chinook salmon in the Klukshu River has little biological basis and that quantitative analysis of spawner-recruit relationships was required to develop estimates of optimal escapement for the Klukshu River chinook salmon stock.

The remainder of this section of the report provides a summary of the biological data currently available concerning the Alsek/ Klukshu chinook salmon stock. Available information concerning the life history of these fish is followed by available data from fisheries which potentially harvest this stock of chinook salmon. Available data concerning abundance and age composition of this stock of chinook salmon in escapements is followed by available information concerning catch levels and age composition of chinook salmon harvested in fisheries thought to potentially impact this stock of salmon. Regulatory history of fisheries is also summarized. Based upon this review of available stock and fishery data, spawner-recruit databases were developed and analyzed in the following sections of this report.

LIFE HISTORY OF ALSEK AND KLUKSHU CHINOOK SALMON

The Alsek River drainage encompasses about 19,000 km^2, much of which is inaccessible to anadromous salmonids because of velocity barriers (Figure 2). The largest tributaries are the Dezadeash (inaccessible) and Tatshenshini (accessible) rivers. The Klukshu and upper Tatshenshini rivers are accessible by road near Dalton Post, Yukon Territory (Figure 3). The Tatshenshini River drains approximately 7,655 km^2 and the Klukshu River drainage is about 260 km^2. Known chinook salmon spawning occurs in the tributaries of the Tatshenshini River including the Klukshu, Blanchard, Takhanne and Bridge rivers and in Village, Kane, Silver, Detour, O'Connor, Low Fog, Stanley and Goat creeks (Figure 3). Chinook salmon likely spawn in other locations as well, but are not thought to be present in the upper portion of the Alsek upstream of the Lowell Glacier due to a velocity barrier.

The entire Alsek chinook salmon run, as well as the Klukshu River stock, is a "spring" run. Most maturing adults enter the Alsek River from mid-May through mid-June. Peak spawning occurs in early August. Juveniles hatch the following spring and most rear inriver for 1 year before smolting and migrating to the ocean. The CDFO operated an inclined plane trap located about 500 meters upstream from the mouth of the Klukshu River in 1986, where 692 chinook salmon smolt (age 1+) and 11,579 fry (age 0) were caught (Table 1). Peak downstream migration for the chinook salmon smolt in 1986 took place from June 8 to 14, and significant downstream migrations took place from May 18 through June 28. Large numbers of fry were caught from July 27 through August 30; a smaller downstream movement of fry took place from mid-May through late June. These fry likely distributed themselves downstream in the Tatshenshini River where they overwintered before smolting the following year. This tributary-to-mainstem migration and rearing of chinook salmon fry is similar to other large and medium-sized glacial rivers in the region (Taku, Stikine, Unuk and Chickamin), based on wild-stock fry and smolt trapping (Kissner and Hubartt 1986).

Table 1.–Catch per week of chinook salmon fry and smolt in an inclined-plane trap fished about 500 meters upstream from the mouth of the Klukshu River in 1986.

Statistical week	Week ending	Number of fry caught	Number of smolt caught
21	24–May	124	56
22	31–May	56	51
23	07–Jun	288	124
24	14–Jun	226	312
25	21–Jun	270	35
26	28–Jun	132	51
27	05–Jul	3	2
28	12–Jul	1	0
29	19–Jul	1	7
30	26–Jul	1	0
31	02–Aug	865	0
32	09–Aug	3,994	7
33	16–Aug	2,366	15
34	23–Aug	2,562	32
35	30–Aug	645	0
36	06–Sep	0	0
37	13–Sep	0	0
38	20–Sep	45	0
39	27–Sep	0	0
Total		11,579	692

Freshwater age composition of the Alsek River chinook salmon stock is dominated by age-1. (one-freshwater annuli) fish; a few age-2. fish have been documented, and age-0. fish are rare. Ocean ages vary from 1 to 5, age-.3 (three-ocean-age) fish being the most common. Overall ages vary from 3 to 7, age-5 fish being the most common. More than 95% of age-.1 and -.2 fish are males. Details concerning age composition of chinook escapements and harvests are provided in later sections of this report.

Upper Tatshenshini chinook salmon have been coded wire tagged to better understand where and when these fish are harvested. Some tagging by ADFG and CDFO has occurred for most brood years between 1983 and 1996, and releases of these fish occurred in most years between 1985 and 1993. These studies have resulted in a total of 91,107 chinook salmon being tagged with coded wire tags and released back into upper Tatshenshini River tributaries (Table 2). Through 1996, 35 chinook salmon with coded wire tags from this tagging effort have been recovered. Fifteen of these tagged chinook salmon were recovered at the Klukshu River weir, five tagged chinook salmon were recovered from the Canadian sport fishery, one tagged chinook salmon was recovered from the Canadian aboriginal fishery, thirteen tagged chinook salmon were recovered from the U.S. Alsek gillnet fishery, and one tagged chinook salmon was recovered from the U.S. Yakutat Bay subsistence/personal use gillnet fishery, just north of the Alsek River. Details concerning recoveries of these coded wire tagged chinook salmon from the Alsek River are provided in later sections of this report.

Description of Klukshu Weir and Other Escapement Programs

Chinook salmon have been enumerated by CDFO, using standardized methods, at a weir located just upstream of the mouth of the Klukshu River since 1976. Annual spawning escapements of chinook salmon in the Klukshu River system have been estimated annually by subtracting from the weir count: (1) Canadian aboriginal fishery harvests taken upstream of the weir site; (2) Canadian sport fishery harvests taken above the weir site (1976–1978 only); and (3) brood stock removed at the weir site (if any). Counts of chinook salmon at the Klukshu River weir during the 21-year period of 1976–1996 averaged 2,690 fish ranging from a low of 1,278 fish in 1976 to a high of 5,678 in 1995 (Table 3). Estimated escapement of chinook salmon in the Klukshu River drainage during this 21-year period averaged 2,428 fish, ranging from a low of 1,064 fish in 1976 to a high of 5,397 fish in 1995.

Chinook salmon escapements in tributaries of the Alsek River have been monitored with helicopter-based aerial surveys by ADFG since 1981, which count only a fraction of the total escapement at a given location. Limited aerial surveys of Alsek River tributaries to enumerate chinook salmon escapements prior to 1981 were made with fixed wing aircraft and were unusable. Since 1981, aerial helicopter counts of chinook salmon in the Klukshu River have been conducted to provide some continuity in estimates in the event the weir

Table 2.–Number of chinook salmon released with coded wire tags in the Alsek River drainage by tag code, agency, brood year, and release year.

Tag code	Agency	Stock	Brood year	Release year	Number released and CWT tagged
42528	ADFG	Alsek River	1983	1985	48
023531*1	CDFO	Klukshu River	1984	1986	743
42552	ADFG	Tatshenshini	1985	1986	5,211
023531*2	CDFO	Klukshu River	1985	1986	219
42929	ADFG	Tatshenshini	1987	1988	8,722
42930	ADFG	Tatshenshini	1987	1988	7,426
43112	ADFG	Tatshenshini	1988	1989	10,279
43115	ADFG	Tatshenshini	1988	1989	7,851
26326	CDFO	Klukshu River	1988	1989	10,548
43117	ADFG	Tatshenshini	1989	1990	9,184
43118	ADFG	Tatshenshini	1989	1990	8,088
43340	ADFG	Tatshenshini	1989	1990	530
25050	CDFO	Klukshu River	1989	1990	1,117
180921	CDFO	Klukshu River	1991	1992	5,695
201010403	CDFO	Klukshu River	1992	1993	3,667
201010514	CDFO	Klukshu River	1995	1996	2,051
201010512	CDFO	Klukshu River	1995	1996	11,764
Total					91,107

Table 3.–Chinook salmon escapements enumerated at the Klukshu River weir and counted during aerial surveys of Alsek drainage tributaries, 1976–1996.

Year	Klukshu River weir count	Estimated Klukshu weir escapement	Klukshu River aerial survey	Blanchard River aerial survey	Takhanne River aerial survey	Goat Creek aerial survey
1976	1,278	1,064	–	–	–	–
1977	3,144	2,698	–	–	–	–
1978	2,976	2,530	–	–	–	–
1979	4,404	3,104	–	–	–	–
1980	2,637	2,487	–	–	–	–
1981	2,113	1,963	–	–	–	–
1982	2,369	1,969	633	–	–	–
1983	2,537	2,237	917	–	–	–
1984	1,672	1,572	–	304	158	28
1985	1,458	1,283	–	232	184	–
1986	2,709	2,607	738	556	358	142
1987	2,616	2,491	933	624	295	85
1988	2,037	1,994	–	437	169	54
1989	2,456	2,202	893	–	158	34
1990	1,915	1,698	1,381	–	325	32
1991	2,489	2,223	–	121	86	63
1992	1,367	1,243	261	86	77	16
1993	3,303	3,221	1,058	326	351	50
1994	3,727	3,620	–	349	342	47
1995	5,678	5,397	1,053	338	260	–
1996	3,599	3,382	788	131	230	12
Average	2,690	2,428	866	319	230	51

program is discontinued in the future. However, the escapement of chinook salmon in the Klukshu River in some stretches is difficult to survey from the air because of overhanging vegetation and deep pools. Since 1981, 10 aerial surveys of the Klukshu River to count chinook salmon escapements have been made; counts averaged 866 chinook salmon, ranging from 261 fish in 1992 to 1,381 fish in 1990 (Table 3). Helicopter counts in the Klukshu River have averaged 31% of the weir count. Eleven aerial surveys of the Blanchard River have been made since 1981; counts have averaged 319 fish and ranged from 86 fish in 1992 to 624 fish in 1987 (Table 3). Thirteen aerial counts of chinook salmon escapements in the Takhanne River have been made since 1981; counts averaged 230 fish and ranged from 77 fish in 1992 to 358 fish in 1986. In Goat Creek, 11 aerial surveys have averaged 51 fish and have ranged from 12 fish in 1996 to 142 fish in 1986.

Chinook salmon have been sampled for age, sex, and length composition from the Klukshu River weir each year since 1976 except in 1985. From 1976 to 1984, chinook salmon carcasses were collected at the weir and used to document age composition (Table 4). The sample size of aged fish in several of these years was low, ranging from 13 aged in 1984 to 130 aged in 1977. The most common year class (total age) was age 6, followed by age 5, age 4, age 7, and age 3 (Table 5). From 1986 through 1996, live fish were trapped at the Klukshu River weir and sampled for age, sex, and length composition (Table 6). Sample sizes were substantially higher than was the case when carcasses were collected, ranging from 219 fish aged in 1988 to 777 fish aged in 1995 (Table 6). The most common year-class (total age) in live samples was age-5, followed by age-6, age-4, age-3, and age-7 (Table 7). Estimates of age-class percentages

Table 4.–Number of aged samples and distribution by age for chinook salmon carcasses sampled at Klukshu River weir, 1976–1984.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1976	0	1	19	35	0	55
1977	1	31	46	51	1	130
1978	0	9	39	33	0	81
1979	0	6	41	36	0	83
1980	0	0	12	28	0	40
1981	0	2	5	8	2	17
1982	0	4	13	12	0	29
1983	0	1	17	11	0	29
1984	0	1	3	8	1	13
Sums 1976–1984	1	55	195	222	4	477

Table 5.–Estimated age composition of chinook salmon carcasses sampled at the Klukshu River weir, 1976–1984.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1976	0.0%	1.8%	34.5%	63.6%	0.0%	100.0%
1977	0.8%	23.8%	35.4%	39.2%	0.8%	100.0%
1978	0.0%	11.1%	48.1%	40.7%	0.0%	100.0%
1979	0.0%	7.2%	49.4%	43.4%	0.0%	100.0%
1980	0.0%	0.0%	30.0%	70.0%	0.0%	100.0%
1981	0.0%	11.8%	29.4%	47.1%	11.8%	100.0%
1982	0.0%	13.8%	44.8%	41.4%	0.0%	100.0%
1983	0.0%	3.4%	58.6%	37.9%	0.0%	100.0%
1984	0.0%	7.7%	23.1%	61.5%	7.7%	100.0%
Averages	0.2%	11.5%	40.9%	46.5%	0.8%	100.0%

Table 6.–Number of aged samples and distribution by age for live chinook salmon sampled at Klukshu weir, 1986–1996.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1986	0	53	227	61	0	341
1987	0	23	181	117	2	323
1988	1	29	65	123	1	219
1989	0	132	220	371	1	723
1990	0	29	134	88	1	252
1991	1	11	163	230	13	418
1992	11	29	97	192	0	330
1993	15	31	142	127	1	316
1994	2	201	256	251	9	719
1995	2	60	595	120	0	777
1996	4	89	203	204	0	500

Table 7.–Estimated age composition of live chinook salmon sampled at Klukshu weir, 1986–1996.

Year	Age 3 (SE)	Age 4 (SE)	Age 5 (SE)	Age 6 (SE)	Age 7 (SE)
1986	0.0% (0.0%)	15.5% (1.8%)	66.6% (2.4%)	17.9% (1.9%)	0.0% (0.0%)
1987	0.0% (0.0%)	7.0% (1.3%)	56.1% (2.6%)	36.3% (2.5%)	0.6% (0.4%)
1988	0.4% (0.4%)	13.2% (2.2%)	29.6% (2.9%)	56.3% (3.2%)	0.5% (0.4%)
1989	0.0% (0.0%)	18.2% (1.2%)	30.5% (1.4%)	51.3% (1.6%)	0.1% (0.1%)
1990	0.1% (0.2%)	11.6% (1.9%)	53.2% (2.9%)	34.9% (2.8%)	0.2% (0.3%)
1991	0.2% (0.2%)	2.6% (0.7%)	39.0% (2.2%)	55.1% (2.2%)	3.1% (0.8%)
1992	3.4% (0.9%)	8.9% (1.4%)	29.4% (2.2%)	58.3% (2.4%)	0.0% (0.0%)
1993	4.7% (1.1%)	9.8% (1.6%)	45.0% (2.7%)	40.3% (2.6%)	0.3% (0.3%)
1994	0.3% (0.2%)	28.0% (1.5%)	35.6% (1.6%)	35.0% (1.6%)	1.2% (0.4%)
1995	0.3% (0.2%)	7.7% (0.9%)	76.6% (1.4%)	15.4% (1.2%)	0.0% (0.0%)
1996	0.8% (0.4%)	17.8% (1.6%)	40.6% (2.0%)	40.8% (2.0%)	0.0% (0.0%)

for abundant age-classes are relatively precise (for example, SE for age-5 age composition estimate in 1996 = 2.0%; age composition estimate = 40.6%).

Chinook salmon passing upstream of the Klukshu River weir have been sampled annually since 1986 to recover coded wire tags (Table 8). Of a total 31,896 chinook salmon counted over this period, 6,918 (21.7%) have been examined to detect missing adipose fins (an indicator of the presence of coded wire tags). Annual sampling rates have ranged from a low of 11.5% of the weir count in 1993 to a high of 35.1% in 1991 (Table 8). Fourteen of the 15 total chinook salmon with coded wire tags sampled from the Klukshu River weir have been decoded (Table 9), and all of these fish were tagged in tributaries of the Alsek River (either the Klukshu or the Tatshenshini rivers) by CDFO or ADFG staff.

Description of Canadian and U.S. Fisheries

Fisheries believed to be significant sources of mortality to the Alsek chinook salmon stock, and hence, the Klukshu chinook salmon stock, include the Canadian aboriginal fishery, the Canadian sport fishery, the U.S. Alsek commercial set gillnet fishery, and the U.S. Alsek subsistence/personal use fishery. This section of the report provides descriptions and summary fishery statistics for these fisheries. Two additional U.S. fisheries are described as well: the Yakutat Bay fishery and the Southeast Alaska troll fishery, to provide an explanation as to why these fisheries are not thought to be significant sources of fishing mortality to Alsek chinook salmon stocks under present management regimes.

Canadian Aboriginal Fishery

Tatshenshini salmon have provided the basis for a traditional subsistence fishery (hereafter referred to as the Canadian aboriginal fishery) in the Klukshu River and Village, Goat and Detour creeks (Figure 3) for generations predating European contact. At present, between 100 and 150 members of the Champagne Aishihik First Nations harvest salmon primarily via fish traps and gaffs. All of the fish trapping (two traps) and the majority of the gaffing is conducted in the Klukshu River. Minor gaffing occurs at Village and Goat Creek, and the Blanchard River. The Detour Creek fishery has long been abandoned.

Table 8.–Coded wire tag sampling at Klukshu weir, 1986–1996.

Year	Weir count	Number of chinook sampled	Percent of count of chinook sampled	Number of chinook with coded wire tags
1986	2,709	544	20.1	0
1987	2,616	629	24.0	0
1988	2,037	264	13.0	0
1989	2,456	790	32.2	0
1990	1,915	502	26.2	0
1991	2,489	874	35.1	0
1992	1,367	389	28.5	0
1993	3,303	381	11.5	3
1994	3,727	822	22.1	11
1995	5,678	909	16.0	0
1996	3,599	814	22.6	1
Sums	31,896	6,918	21.7	15
Averages	2,900	629	21.7	6 per year since 1993

Table 9.–Origin of coded wire tagged chinook recovered at Klukshu weir, 1986–1996.

Year	Tag code	Tagging agency	Tagged stock	Brood year
1993	42929	ADFG	Tatshenshini	1987
1993	43112	ADFG	Tatshenshini	1988
1993	26326	CDFO	Klukshu	1988
1994	42930	ADFG	Tatshenshini	1987
1994	26326	CDFO	Klukshu	1988
1994	26326	CDFO	Klukshu	1988
1994	26326	CDFO	Klukshu	1988
1994	43112	ADFG	Tatshenshini	1988
1994	43112	ADFG	Tatshenshini	1988
1994	43118	ADFG	Tatshenshini	1989
1994	43118	ADFG	Tatshenshini	1989
1994	43118	ADFG	Tatshenshini	1989
1994	43340	ADFG	Tatshenshini	1989
1994	43117	ADFG	Tatshenshini	1989
1996	not read yet			unknown

The traps are installed at the outlet of Klukshu Lake to harvest primarily sockeye salmon en route to the spawning shoals. A large portion of both the sockeye and chinook salmon catch is harvested in the gaff fishery, which occurs throughout the length of the Klukshu River; but fishing sites are limited to areas with reasonable road access, including the mouth of the Klukshu River immediately below the CDFO enumeration weir, at a culvert where the Haines Highway crosses the Klukshu River, at the mouth of Klukshu Lake, and at two road access sites located about midway between Klukshu Lake and the mouth of the Klukshu River (Figure 3). Gaffing of sockeye and chinook salmon also occurs at Village Creek. A small chinook salmon gaff fishery is occasionally active at Goat Creek.

Limitations have been in place since 1976 on the use of both fish traps and gaffs. Fishery management plans are developed in concert with the Champagne Aishihik First Nations and reflect the sockeye and chinook salmon run strengths and the requirements of the First Nations people. Fishing plans vary, depending on the annual run strengths of salmon and requirements of the First Nations people, but typically fish traps are restricted to 1–2 days per week prior to August 15 to better protect the early run of sockeye salmon. After August 15, fishing times for the traps are increased to 3–4 days per week. Gaffing is limited to 1–2 days per week, for elders only, prior to August 15. Gaffing is increased to up to 7 days per week after August 15.

Harvests in the Canadian aboriginal fishery are estimated through interviews with fishers. Prior to 1993, aboriginal fishers were interviewed by CDFO staff on a periodic basis to inquire about catches. Since 1993, a staff member from the Champagne Aishihik Band has conducted these interviews. Harvest information collected during these interviews is expanded on the basis of sampling coverage to develop an overall annual harvest estimate for the Canadian aboriginal fishery.

During the 21-year period of 1976–1996, Canadian aboriginal fishery harvests of chinook salmon have ranged from an estimated low of 43 fish in 1988 to an estimated high of 1,300 fish in 1979 and harvests have averaged 298 fish (Table 10). The majority of the harvest has been taken above the Klukshu weir, but chinook salmon have also been harvested below the weir since 1991 (Table 10). It is likely that chinook salmon harvests similar to the 1976–1996 average of about 300 fish have occurred for many decades

Table 10.–Harvests of chinook salmon in the Canadian aboriginal and sport fisheries, 1976–1996.

	Canadian aboriginal fishery			Canadian sport fishery			
Year	Below weir	Above weir	Total	Dalton Post	Blanchard River	Takhanne River	Total
1976	0	150	150	130	45	25	200
1977	0	350	350	195	67	38	300
1978	0	350	350	195	67	38	300
1979	0	1,300	1,300	422	146	82	650
1980	0	150	150	130	45	25	200
1981	0	150	150	150	200	50	400
1982	0	400	400	183	110	40	333
1983	0	300	300	202	60	50	312
1984	0	100	100	275	125	50	450
1985	0	175	175	170	20	20	210
1986	0	102	102	125	20	20	165
1987	0	125	125	326	113	63	502
1988	0	43	43	249	87	48	384
1989	0	234	234	215	75	41	331
1990	0	202	202	468	162	91	721
1991	268	241	509	384	29	17	430
1992	60	88	148	79	6	18	103
1993	88	64	152	170	25	42	237
1994	190	99	289	197	69	38	304
1995	320	260	580	601	330	113	1,044
1996	233	215	448	423	78	149	650
Averages	55	243	298	252	89	51	392

and it may be that these historic harvests were several-fold higher.

Because the Canadian aboriginal fishery harvests have not been completely enumerated, but instead, the fishery has been monitored through expanded fisher interviews, there is sampling error associated with the harvest estimates. Staff closely associated with the sampling program believe that the coefficient of variation associated with these estimates is 20%, i.e., 95% relative precision of ±39%. For example, the harvest estimate of 215 chinook salmon harvested above the Klukshu weir in 1996 (Table 10) has an associated estimated standard error of 43 fish.

Chinook salmon harvested in the Canadian aboriginal fishery have been sampled to document age, sex, and length composition during four of the 21 years since 1976. Sample sizes of aged fish have ranged from 8 in 1984 to 27 in 1978 (Table 11). The most common age year-class has been age-5 fish, followed by age-6 fish, age-4 fish, and age-3 fish (Table 12). Because all Canadian aboriginal fishery harvests before 1991 occurred above the Klukshu weir, separate age compositions were not required; for 1991–1996 age composition for harvests in this fishery below the weir are explained later in this report.

Chinook salmon harvested in the Canadian aboriginal fishery have not been sampled annually to recover coded wire tags. However, a single chinook salmon with a coded wire tag that was harvested in the 1990 fishery was voluntarily returned to CDFO. The fish was a brood year 1985 release trapped and tagged by ADFG and released in the Tatshenshini River.

Canadian Sport Fishery

Tatshenshini chinook salmon stocks have probably been exploited to varying degrees by sport anglers since the turn of the century, when miners entered the Klukshu area via the Dalton Trail. The construction of the Haines Road in 1943 resulted in improved access to the area, and the upgrading of the Haines Highway, combined

Table 11.–Number of aged samples and distribution by age for chinook salmon sampled from the Canadian aboriginal fishery in the Alsek drainage, 1976–1996.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	20	7	0	27
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	2	4	7	0	13
1983	0	0	0	0	0	0
1984	0	0	3	5	0	8
1985	1	1	8	11	0	21
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
Sums: 1976–1996	1	3	35	30	0	69

Table 12.–Estimated age composition of chinook salmon sampled from the Canadian Alsek aboriginal fishery, 1976–1996.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1976	–	–	–	–	–	–
1977	–	–	–	–	–	–
1978	0.0%	0.0%	74.1%	25.9%	0.0%	100.0%
1979	–	–	–	–	–	–
1980	–	–	–	–	–	–
1981	–	–	–	–	–	–
1982	0.0%	15.4%	30.8%	53.8%	0.0%	100.0%
1983	–	–	–	–	–	–
1984	0.0%	0.0%	37.5%	62.5%	0.0%	100.0%
1985	4.8%	4.8%	38.1%	52.4%	0.0%	100.0%
1986	–	–	–	–	–	–
1987	–	–	–	–	–	–
1988	–	–	–	–	–	–
1989	–	–	–	–	–	–
1990	–	–	–	–	–	–
1991	–	–	–	–	–	–
1992	–	–	–	–	–	–
1993	–	–	–	–	–	–
1994	–	–	–	–	–	–
1995	–	–	–	–	–	–
1996	–	–	–	–	–	–
Avg.	1.4%	4.3%	50.7%	43.5%	0.0%	100.0%

with increased CDFO activity, have resulted in increasing angler interest from 1976 to present.

At present, chinook and other salmon are taken in a very popular and concentrated sport fishery conducted in the upper Tatshenshini River system. The fishery is unique in that it is one of the few inland Canadian sport fisheries where it is legal to harvest sockeye salmon *Oncorhynchus nerka*. Sport fishing is concentrated at the confluence of the Klukshu and Tatshenshini rivers, with minor fishing activity at the mouth of Village Creek, and in the mainstem of the Takhanne, Tatshenshini, and Blanchard rivers (see Figure 3).

The sport fishery has grown in popularity in recent years, necessitating increased management controls. As many as 100 anglers may be concentrated at the mouth of the Klukshu River, and it is probable that the migration of Klukshu-bound salmon may be impeded by the heavy angling pressure. Management is executed by gear (single hooks only), quota (two salmon per day, only one of which may be a chinook salmon over 50 cm; two days possession limit), by time (fishing permitted at the mouth of the Klukshu from 0600 hours on Saturdays to 1200 hours Tuesdays), and by area closures (most of the Klukshu River is closed to sport fishing, as are B.C. sections of the Tatshenshini, Takhanne, and Blanchard rivers; these closures are implemented to protect spawning salmon). Quotas are varied occasionally, depending on the magnitude of runs.

Harvests in the Canadian sport fishery are estimated through onsite interviews with sport anglers. Because most sport fishing occurs just downstream of the Klukshu River weir near the mouth of the river, weir staff conduct most of the angler interviews. Weir staff attempt to interview anglers every 2 hr to assess angling effort and

catch. Catches are sampled for baseline biological characteristics, including length, weight, sex and age. Some fishing also occurs at the Cable Crossing, located further away from the weir site but accessible by weir staff, and periodically these staff travel by all-terrain vehicle to interview those anglers as well. Collectively, these harvests are expanded on the basis of sampling coverage, and catches are grouped as Dalton Post sport fishery harvests. The Dalton Post angler interview program has been in place annually since 1976.

Sport anglers in the Blanchard River and the Takhanne River are interviewed periodically by CDFO patrolmen, and sport harvest estimates at these sites are based upon expansions of the sampled periods. Coverage of the sport fisheries in the Blanchard and Takhanne Rivers is less than is the case for the Dalton Post program, and in some years since 1976 the interview program did not take place. In years when sampling did not take place, estimates of sport fishery harvests of chinook salmon from the Blanchard and Takhanne Rivers are based upon the average proportions of the harvests at these sites in comparison to Dalton Post sport fishery harvests during years when all sites were sampled.

During the 21-year period of 1976–1996, Canadian sport fishery harvests of chinook salmon have ranged from an estimated low of 200 fish in 1976 to an estimated high of 1,044 fish in 1995, and harvests have averaged 392 fish (Table 10). Approximately 65% of the overall sport fishery harvest of chinook salmon has been taken in the Dalton Post sport fishery, about 23% taken from the Blanchard River, and the remaining 12% from the Takhanne River. It is likely that only a few hundred chinook salmon were harvested by Canadian sport anglers in the few decades prior to the 1970s, although catches may have been higher around the turn of the century when miners were actively using the Dalton Trail.

Because the harvests have not been completely enumerated, but instead, the fishery has been monitored through expanded angler interviews, there is sampling error associated with the harvest estimates. Staff closely associated with the sampling program believe that the coefficient of variation associated with these estimates is 10% (95% relative precision = ± 20%). This is because the majority of the harvest is closely monitored on a 2-hr basis by Klukshu weir staff. It is believed that sport fishery harvest estimates associated with the Blanchard and Takhanne Rivers have a 20% coefficient of variation.

Chinook salmon harvested in the Canadian sport fishery have been sampled each year since 1976 to document age, sex, and length composition. Sample sizes of aged fish have ranged from 10 in 1976 to 211 in 1990 (Table 13). The most common year-class of chinook salmon harvested by the Canadian sport fishery has been age-5 fish, followed by age-6 fish, age-4 fish, age-7 fish and age-3 fish (Table 14). Precision of annual age composition estimates is influenced by annual sample sizes and harvest levels. In most years, age percentages for abundant age-classes are relatively precise (for example, SE for age-5 age composition in 1996 = 2.5%; age composition estimate = 45.1%).

Table 13.–Number of aged samples and distribution by age for chinook salmon sampled from the Klukshu/Dalton Post Canadian sport fishery, 1976–1996.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1976	0	3	3	4	0	10
1977	1	16	24	10	0	51
1978	0	1	10	2	0	13
1979	0	0	7	8	0	15
1980	0	1	10	14	0	25
1981	0	4	16	26	0	46
1982	2	17	60	55	0	134
1983	0	2	61	17	0	80
1984	2	5	44	55	1	107
1985	0	7	37	27	0	71
1986	0	3	41	12	0	56
1987	0	2	74	66	0	142
1988	0	2	24	58	0	84
1989	0	7	55	43	3	108
1990	1	5	145	57	3	211
1991	0	0	52	54	2	108
1992	0	6	6	10	0	22
1993	0	10	45	30	3	88
1994	0	24	54	61	0	139
1995	0	2	84	14	0	100
1996	1	6	92	103	2	204

Table 14.–Estimated age composition of chinook salmon harvested in the Canadian sport fishery, 1976–1996.

Year	Age 3 (SE)	Age 4 (SE)	Age 5 (SE)	Age 6 (SE)	Age 7 (SE)
1976	0.0% (0.0%)	30.0% (14.7%)	30.0% (14.7%)	40.0% (15.7%)	0.0% (0.0%
1977	2.0% (1.7%)	31.4% (5.6%)	47.1% (6.1%)	19.6% (4.8%)	0.0% (0.0%)
1978	0.0% (0.0%)	7.7% (7.4%)	76.9% (11.8%)	15.4% (10.1%)	0.0% (0.0%)
1979	0.0% (0.0%)	0.0% (0.0%)	46.7% (13.1%)	53.3% (13.1%)	0.0% (0.0%)
1980	0.0% (0.0%)	4.0% (3.6%)	40.0% (9.0%)	56.0% (9.1%)	0.0% (0.0%)
1981	0.0% (0.0%)	8.7% (3.5%)	34.8% (5.9%)	56.5% (6.2%)	0.0% (0.0%)
1982	1.5% (0.5%)	12.7% (1.5%)	44.8% (2.2%)	41.0% (2.2%)	0.0% (0.0%)
1983	0.0% (0.0%)	2.5% (1.4%)	76.3% (3.7%)	21.3% (3.6%)	0.0% (0.0%)
1984	1.9% (1.0%)	4.7% (1.6%)	41.1% (3.7%)	51.4% (3.8%)	0.9% (0.7%)
1985	0.0% (0.0%)	9.9% (2.7%)	52.1% (4.6%)	38.0% (4.4%)	0.0% (0.0%)
1986	0.0% (0.0%)	5.4% (2.3%)	73.2% (4.4%)	21.4% (4.1%)	0.0% (0.0%)
1987	0.0% (0.0%)	1.4% (0.7%)	52.1% (3.2%)	46.5% (3.2%)	0.0% (0.0%)
1988	0.0% (0.0%)	2.4% (1.4%)	28.6% (4.0%)	69.0% (4.1%)	0.0% (0.0%)
1989	0.0% (0.0%)	6.5% (1.7%)	50.9% (3.4%)	39.8% (3.3%)	2.8% (1.1%)
1990	0.5% (0.4%)	2.4% (0.8%)	68.7% (2.4%)	27.0% (2.3%)	1.4% (0.6%)
1991	0.0% (0.0%)	0.0% (0.0%)	48.1% (4.1%)	50.0% (4.1%)	1.9% (1.1%)
1992	0.0% (0.0%)	27.3% (8.3%)	27.3% (8.3%)	45.5% (9.2%)	0.0% (0.0%)
1993	0.0% (0.0%)	11.4% (2.4%)	51.1% (3.7%)	34.1% (3.5%)	3.4% (1.4%)
1994	0.0% (0.0%)	17.3% (1.7%)	38.8% (2.3%)	43.9% (2.3%)	0.0% (0.0%)
1995	0.0% (0.0%)	2.0% (1.3%)	84.0% (3.4%)	14.0% (3.2%)	0.0% (0.0%)
1996	0.5% (0.4%)	2.9% (0.9%)	45.1% (2.5%)	50.5% (2.5)%	1.0% (0.5%)

Chinook salmon harvested in the Canadian sport fishery have been sampled annually to recover coded wire tags since 1986 (Table 15); of 3,237 chinook salmon harvested since that time, 1,808 (56%) have been examined to detect missing adipose fins (an indicator of the presence of coded wire tags). Annual sampling rates have ranged from a low of 17.5% of the harvest sampled in 1995 to a high of 81.4% of the harvest sampled in 1989 (Table 15). Five chinook salmon with coded wire tags from the Canadian sport fishery have been decoded (Table 16), and all five were tagged in tributaries of the Alsek River (either the Klukshu or the Tatshenshini Rivers) by CDFO or ADFG staff.

U.S. Alsek Commercial and Subsistence/Personal Use Fisheries

Alsek fisheries have occurred on the U.S. side of the border (see Figure 2) both within the river (fishing district 182-30) and occasionally, in the surf as the river enters the Gulf of Alaska (fishing district 182-31). Two types of fisheries have occurred; commercial set gillnet fishing and subsistence/personal use set gillnet fishing. Alsek fisheries operating in both the river and the surf area, where the river enters the Gulf of Alaska, have harvested Alsek salmon since before 1900. Harvests in the commercial fishery are enumerated from fish tickets (sales receipts issued to fishers from processors when their catches are sold). Commercial harvests are considered a census with no sampling error. Harvests in the

Table 15.–Canadian sport fishery sampling for coded wire tags, 1986–1996.

Year	Chinook catch	Number of chinook sampled	Percent of fishery sampled	Number of coded wire tags
1986	125	64	51.2	0
1987	326	231	70.9	0
1988	249	145	58.2	0
1989	215	175	81.4	0
1990	468	316	67.5	0
1991	384	228	59.4	0
1992	79	30	38.0	1
1993	170	103	60.6	2
1994	197	151	76.6	2
1995	601	105	17.5	0
1996	423	260	61.5	0
Sums	3,237	1,808	55.9	5
Averages	294	164	55.9	5 since 1992

Table 16.–Origin of coded wire tagged chinook salmon recovered from the Canadian sport fishery, 1986–1996.

Year	Tag code	Tagging agency	Tagged stock	Brood year
1992	42929	ADFG	Tatshenshini	1987
1993	26326	CDFO	Klukshu	1988
1993	26326	CDFO	Klukshu	1988
1994	43112	ADFG	Tatshenshini	1988
1994	43112	ADFG	Tatshenshini	1988

subsistence/personal use fishery are enumerated from catch reports returned to ADFG for permits issued to fishery participants. Annual subsistence/personal use harvests were assigned a 30% coefficient of variation (95% relative precision = ±59%), because not all harvest permits are returned. This is probably overestimating uncertainty in these estimates.

Since 1961, approximately 20 fishers have participated in the U.S. Alsek commercial fishery. The number of participants varies by fishing period and year. Peak participation in the fishery during May and June during the 36-year period of 1961–1996 was 35 fishers during statistical week 21 (about May 22) in 1961. In 1996, there were 22 participants during the first opening (June 3), 25 participants during the second and third openings (June 10 and June 17–18), and 16 participants during the fourth opening (June 24–26).

Since 1941, U.S. Alsek commercial harvests have ranged from a low of 0 chinook salmon harvested in 1942 and 1943 (when the lack of processing facilities precluded harvests) to a high of 6,226 chinook salmon in 1945 (Table 17). Five-year average harvests have ranged from a high of about 2,500 chinook salmon annually harvested during the 1941–1945 period to a low of about 300 chinook salmon annually harvested during the 1986–1990 period (Table 17). Historic catch data for the U.S. Alsek fishery indicate that annual harvests of about 1,500 chinook salmon are sustainable, in that these levels of harvests occurred on average over the continuous 40-year period of 1941–1980 (the 40 years prior to the signing of the PST). These sustainable catches would have been in addition to the 500 or so chinook salmon likely harvested in the Canadian aboriginal (300 fish long-term average) and sport (200 fish long-term average) fisheries as described above, providing a minimum estimate of long-term sustainable yield of Alsek chinook salmon of about 2,000 fish annually (assuming little harvest in other fisheries). Catches of chinook salmon in the U.S. Alsek commercial fishery since the signing of the PST have been substantially less, averaging about 375 chinook salmon per year during the 16-year period of 1981–1996. As explained below, this almost fourfold drop in U.S. Alsek commercial catches since the signing of the PST has been the direct result of very conservative fishery regulations.

The U.S. Alsek commercial fishery has been regulated by a preseason booklet of regulations adjusted inseason by emergency orders. Annual dates for the opening of the fishery have varied greatly. By preseason booklet regulations, the fishery has opened on the first Monday in June since 1975. In earlier years, the fishery opened as early as May 14 (Table 18). Preseason booklet regulations have typically allowed for four days of set gillnet fishing per week (Table 18). However, actual openings have been delayed and are typically shorter as announced by emergency order during the early part of the season, and this has been especially so since the signing of the PST. For instance, in 1996, the first Monday in June was June 3, and the fishery was opened for 12 hours. Subsequently, the fishery was only open for one day during the second opening (June 10), for two days during the third period (June 17–18), and for three days during the fourth opening (June 24–26). The primary rationale used in emergency orders announcing these short openings during the June fishery since the early 1980s has been the habitual failure of the Klukshu River to reach its chinook salmon escapement goal and real or perceived conservation concerns for the early sockeye run.

Commercial fishing gear has been limited to 25 fathoms of mesh per net with a cumulative limit of 75 fathoms of mesh being fished. Since 1981, mesh has been limited to 50 fathoms in total during

Table 17.–Annual harvests of chinook salmon in the U.S. Alsek River commercial gillnet fishery, 1941–1996.

Year(s)	Harvest	Year(s)	Harvest
1941	3,943	1971	1,222
1942	0	1972	1,827
1943	0	1973	1,757
1944	2,173	1974	1,162
1945	6,226	1975	1,379
1941–1945 Average	2,468	1971–1975 Average	1,469
1946	1,161	1976	512
1947	266	1977	1,402
1948	853	1978	2,441
1949	72	1979	2,525
1950	unknown	1980	1,382
1946–1949 Average	588	1976–1980 Average	1,652
1951	151	1981	779
1952	2,020	1982	532
1953	1,383	1983	93
1954	1,833	1984	46
1955	2,883	1985	213
1951–1955 Average	1,654	1981–1985 Average	333
1956	3,253	1986	481
1957	1,800	1987	347
1958	888	1988	223
1959	969	1989	228
1960	525	1990	78
1956–1960 Average	1,487	1986–1990 Average	271
1961	2,120	1991	103
1962	2,278	1992	301
1963	131	1993	300
1964	591	1994	805
1965	719	1995	670
1961–1965 Average	1,168	1991–1995 Average	436
1966	934	1996	771
1967	225		
1968	215		
1969	685		
1970	1,128		
1966–1970 Average	637		

the early portion of the fishery to further limit chinook salmon catches. During 1967 and 1968 chinook had to exceed 26 inches to be retained. In other years, any size chinook salmon could be retained by commercial set gillnet fishers (Table 18). The upper portion of the Alsek River (in the U.S.) has been closed to fishing and the amount of river closed has varied by season and by year (Table 18).

The combined result of relatively late openings with short fishing periods during the first few weeks of the year, coupled with other restrictive regulations, have greatly limited chinook salmon catches since the early 1980s. Another result of this fishing pattern is that the majority of the Alsek chinook run has passed upstream without being exploited prior to the start of U.S. Alsek fishing season (Figure 4). Consequently, the exploitation rate of chinook salmon by the U.S. Alsek commercial fishery since the mid-1960s has been relatively low, because fishing typically does not start until well after the peak of the migration has passed upstream above the fishing

Table 18.–Regulatory booklet regulations for the U.S. Alsek set gillnet fishery, 1941–1996.

Year	Regulatory booklet fishing season	Days of fishing per week	Fathoms of gillnet		Size of mesh	Chinook size limit	Alsek River closed waters
			Per net	Cumulative			
1941	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1942	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1943	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1944	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1945	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1946	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1947	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1948	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1949	5/15–9/30	4	25	75	no restr.	none	upper 31 miles of river
1950	6/1–9/30	4	25	75	no restr.	none	upper 32 miles of river
1951	6/18–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1952	6/1–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1953	6/1–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1954	6/1–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1955	6/1–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1956	6/1–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1957	6/3–9/30	4	25	75	no restr.	none	upper 33.5 miles of river
1958	6/2–9/30	4.5	25	75	no restr.	none	upper 33.5 miles of river
1959	6/1–9/30	4.5	25	75	no restr.	none	upper 33.5 miles of river
1960	5/30–9/30	2.5	25	75	no restr.	none	upper 33.5 miles of river
1961	5/15-Announcement	4	25	75	no restr.	none	upper 33.5 miles of river
1962	5/14-Announcement	4	25	75	no restr.	none	upper 33.5 miles of river
1963	6/3-Announcement	4	25	75	no restr.	none	before 6/15: upper 44 miles [a]
1964	6/1-Announcement	4	25	75	no restr.	none	before 6/13: upper 44 miles
1965	5/31-Announcement	4	25	75	no restr.	none	before 6/12: upper 44 miles
1966	5/30-Announcement	4	25	75	no restr.	None	before 6/12: upper 44 miles
1967	6/5-Announcement	4	25	75	no restr.	26" min.	before 6/18: upper 44 miles
1968	6/3-Announcement	4	25	75	no restr.	26" min.	before 6/16: upper 44 miles
1969	6/2-Announcement	4	25	75	no restr.	26" min.	upper 34 miles of river
1970	6/1-Announcement	4	25	75	no restr.	none	upper 34 miles of river
1971	5/31-Announcement	4	25	75	no restr.	none	upper 34 miles of river
1972	5/31-Announcement	4	25	75	no restr.	none	upper 34 miles of river
1973	6/4-Announcement	4	25	75	no restr.	none	upper 34 miles of river
1974	6/4-Announcement	4	25	75	no restr.	none	upper 34 miles of river
1975	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1976	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1977	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1978	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1979	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1980	1st Mon. in June-E.O.	4	25	75	no restr.	none	upper 34 miles of river
1981	1st Mon. in June-E.O.	4	25	50 early	no restr.	none	upper 34 miles of river
1982	1st Mon. in June-E.O.	4	25	50 early	no restr.	none	upper 34 miles of river
1983	1st Mon. in June-E.O.	4	25	50 early	no restr.	none	upper 34 miles of river
1984	1st Mon. in June-E.O.	4	25	50 early	no restr.	none	upper 34 miles of river
1985	1st Mon. in June-E.O.	4	25	50 early	no restr.	none	upper 34 miles of river
1986	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1987	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1988	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1989	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1990	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1991	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1992	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1993	1st Mon. in June -E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1994	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1995	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river
1996	1st Mon. in June-E.O.	4	25	50 early	6" or less	none	upper 34 miles of river

[a] After these dates, the upper 33.5 miles of river were closed to commercial fishing during the years 1963–1968.

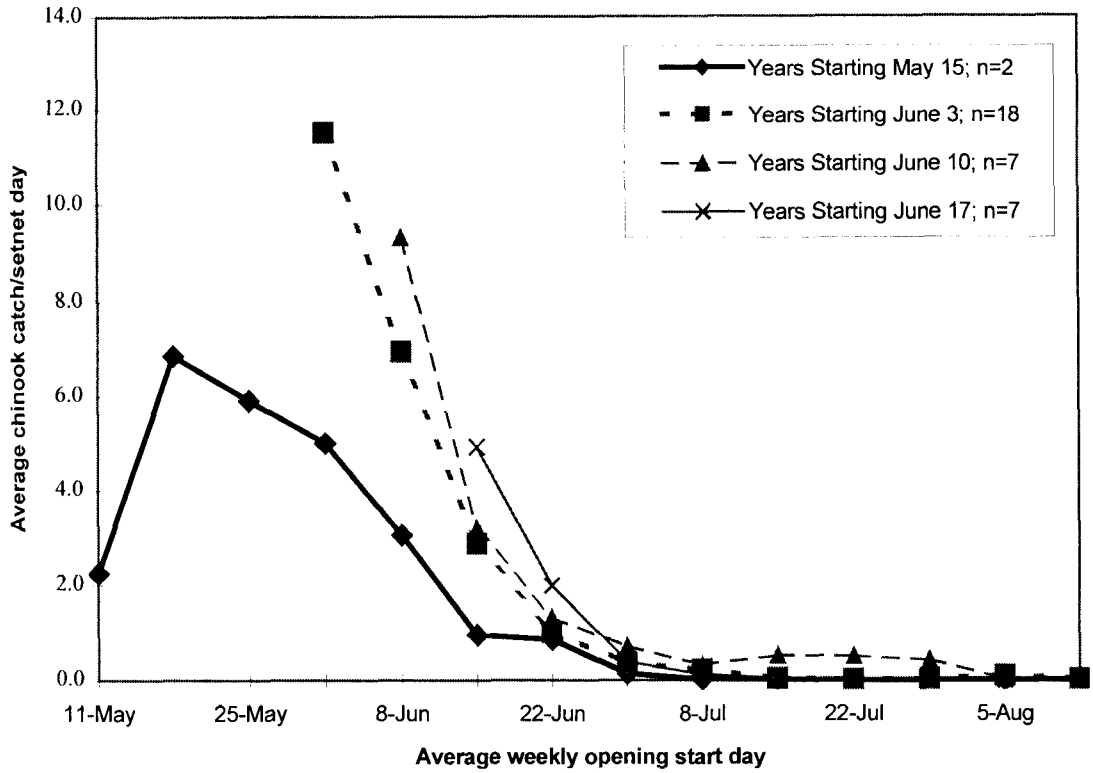

Figure 4.–Average chinook salmon catch per set gillnet day of fishing by week in the U.S. Alsek commercial fishery, 1961–1995. Annual data are grouped according to statistical week that the commercial fishery was opened. In 1961 and 1962, the fishery opened on statistical week 20, about May 15. The fishery opened on statistical week 23 or about June 3 in 1963–1975, in 1978–1981, and in 1995. The fishery opened on statistical week 24 or about June 10 in 1976, 1977, 1982, 1987, 1989, 1992, and 1994. The fishery opened on statistical week 25 or about June 17 in 1984, 1985, 1986, 1988, 1990, 1991, and 1993. In 1983, the fishery opened on statistical week 26 or about June 24; because an opening this late occurred only once, the data are not shown.

districts (Figure 4), and because fishing time during the remainder of the chinook salmon run has been very limited.

Chinook salmon harvested in the U.S. Alsek commercial set gillnet fishery have been sampled annually to document age, sex, and length composition since 1982. Sample sizes of aged fish have ranged from 18 in 1990 to 473 in 1996 (Table 19). The most common year-class of chinook salmon harvested by the U.S. Alsek commercial fishery has been age-5 fish, followed by age-4 fish, age-6 fish, age-3 fish and age-7 fish (Table 20). Precision of annual age composition estimates is influenced by annual sample sizes and harvest levels. In most years, age composition estimates are relatively precise.

Chinook salmon harvested in the U.S. Alsek commercial set gillnet fishery have been annually sampled to recover coded wire tags since 1990 (Table 21). During this time, 3,028 chinook salmon have been harvested, and 1,754 of those (58%) have been examined to detect missing adipose fins (an indicator of the presence of coded wire tags). Annual sampling rates have ranged from a low of 4.3% of the harvest sampled in 1993 to a high of 83.4% of the harvest sampled in 1992 (Table 21). Fourteen chinook salmon with coded wire tags

Table 19.–Number of aged samples and distribution by age for chinook salmon sampled from the U.S. Alsek River commercial set gillnet fishery, 1982–1996.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total
1982	0	20	28	34	1	83
1983	1	4	20	16	0	41
1984	1	5	10	5	0	21
1985	0	14	29	11	0	54
1986	1	59	93	10	0	163
1987	2	10	71	31	0	114
1988	1	34	33	42	0	110
1989	0	92	73	26	0	191
1990	0	6	8	4	0	18
1991	3	12	30	17	1	63
1992	2	92	48	48	5	195
1993	0	62	70	20	0	152
1994	0	142	50	14	3	209
1995	5	100	228	28	2	363
1996	4	200	151	118	0	473

from this fishery have been decoded (Table 22) and all but one were tagged in tributaries of the Alsek River (either the Klukshu or Tatshenshini rivers). The single exception was a chinook salmon tagged at Robertson Creek Hatchery (located on the west coast of Vancouver Island, British Columbia) and recovered from the Alsek fishery in 1991. These data indicate that the vast majority of chinook salmon harvested in the U.S. Alsek commercial fishery are Alsek origin fish. In later portions of this report, all chinook salmon harvested in the Alsek fishery are assumed to be Alsek origin fish, and various assumptions are used to allocate these harvests to the Klukshu River.

The U.S. Alsek subsistence/personal use fishery (hereafter referred to as the Alsek subsistence fishery) has occurred for decades. The harvest is taken predominantly by commercial fishers during closed commercial fishing periods. The harvest is taken with commercial fishing gear. A subsistence fishing permit is required and includes mandatory reporting of harvests. Because not all permits are returned (16–20%), the reported harvest is expanded accordingly to estimate the total subsistence harvest. Subsistence fishing periods are announced during periods when the commercial fishery is closed. Duration of fishing time is very limited typically being one day per week.

Annual harvests of chinook salmon in the Alsek subsistence fishery have been relatively low in comparison to commercial harvests. Since 1986, annual subsistence harvests have ranged from 13 to 90 chinook salmon (Table 23). During the 11 year period of 1986–1996, annual subsistence harvests have averaged 41 chinook salmon while commercial harvests have averaged 432 chinook salmon or 90.6% of the combined harvest (Table 23). Chinook salmon are taken in the subsistence fishery for personal consumption along with other species of salmon. It is unlikely that subsistence

Table 20.–Estimated age composition of chinook salmon harvested in the U.S. Alsek River commercial set gillnet fishery, 1982–1996.

Year	Age 3 (SE)	Age 4 (SE)	Age 5 (SE)	Age 6 (SE)	Age 7 (SE)
1982	0.0% (0.0%)	24.1% (4.7%)	33.7% (5.2%)	41.0% (5.4%)	1.2% (1.2%)
1983	2.4% (2.4%)	9.8% (4.7%)	48.8% (7.9%)	39.0% (7.7%)	0.0% (0.0%)
1984	4.8% (4.8%)	23.8% (9.5%)	47.6% (11.2%)	23.8% (9.5%)	0.0% (0.0%)
1985	0.0% (0.0%)	25.9% (6.0%)	53.7% (6.8%)	20.4% (5.5%)	0.0% (0.0%)
1986	0.6% (0.6%)	36.2% (3.8%)	57.1% (3.9%)	6.1% (1.9%)	0.0% (0.0%)
1987	1.8% (1.2%)	8.8% (2.7%)	62.3% (4.6%)	27.2% (4.2%	0.0% (0.0%)
1988	0.9% (0.9%)	30.9% (4.4%)	30.0% (4.4%)	38.2% (4.7%)	0.0% (0.0%)
1989	0.0% (0.0%)	48.2% (3.6%)	38.2% (3.5%)	13.6% (2.5%)	0.0% (0.0%)
1990	0.0% (0.0%)	33.3% (11.4%)	44.4% (12.1%)	22.2% (10.1%)	0.0% (0.0%)
1991	4.8% (2.7%)	19.0% (5.0%)	47.6% (6.3%)	27.0% (5.6%)	1.6% (1.6%)
1992	1.0% (0.7%)	47.2% (3.6%)	24.6% (3.1%)	24.6% (3.1%)	2.6% (1.1%)
1993	0.0% (0.0%)	40.8% (4.0%)	46.1% (4.1%)	13.2% (2.8%)	0.0% (0.0%)
1994	0.0% (0.0%)	67.9% (3.2%)	23.9% (3.0%)	6.7% (1.7%)	1.4% (0.8%)
1995	1.4% (0.6%)	27.5% (2.3%)	62.8% (2.5%)	7.7% (1.4%)	0.6% (0.4%)
1996	0.8% (0.4%)	42.3% (2.3%)	31.9% (2.1%)	24.9% (2.0%)	0.0% (0.0%)

Table 21.–Commercial harvests of chinook salmon and sampling for coded wire tags in the U.S. Alsek gillnet fishery, 1986–1996.

Year	Chinook harvest	Chinook sampled	Percent of harvest sampled	No. of CWTs recovered
1986	481	0	–	–
1987	347	0	–	–
1988	223	0	–	–
1989	228	0	–	–
1990	78	19	24.4	0
1991	103	66	64.1	1
1992	301	251	83.4	4
1993	300	13	4.3	1
1994	805	522	64.8	7
1995	670	394	58.8	1
1996	771	489	63.4	0
1990–1996 sums:	3,028	1,754	58.6	14
1990–1996 averages:	433	251	58.6	2

catches of chinook salmon in the Alsek fishery were higher during earlier years and it is believed that the subsistence catch has likely averaged about 50 chinook salmon for decades. Because subsistence-caught chinook salmon in the Alsek fishery are taken, by and large, by the same fishermen with the same gear as is the case with the commercial harvest, it is believed that catch composition is similar. Therefore, annual commercial and subsistence harvests are combined for analysis later in this report.

U.S. Yakutat Bay Commercial and Subsistence/Personal Use Fisheries

Because one chinook salmon with a coded wire tag was recovered from the Yakutat Bay gillnet fishery (Figure 1), a description of the fishery is provided in this report. The Yakutat Bay gillnet fishery consists of a commercial fishery prosecuted with set gillnets and a subsistence/personal use fishery composed largely of the same fishermen using their set gillnet gear during subsistence fishing periods announced during closures of the commercial fishery. Harvests in the commercial fishery are documented with fish tickets, and harvests in the subsistence/personal use fishery are documented with catch reports returned to ADFG from permitted fishermen.

The commercial fishery takes place in the open waters of Yakutat Bay (fishing district 183-10; Figure 5). An average of 28 fishermen participated in the fishery between 1991 and 1996, the lowest participation rate being 23 fishermen in 1995, and the highest being 38 fishermen in 1991.

Table 22.–Origins of coded wire tagged chinook salmon from the U.S. Alsek gillnet fishery, 1991–1996.

Year	Tag code	Tagging agency	Stock origin	Brood year
1991	25701	CDFO	Robertson Creek	unknown
1992	42929	ADFG	Tatshenshini	1987
1992	43112	ADFG	Tatshenshini	1988
1992	43112	ADFG	Tatshenshini	1988
1992	26326	CDFO	Klukshu	1988
1993	43118	ADFG	Tatshenshini	1989
1994	43115	ADFG	Tatshenshini	1988
1994	26326	CDFO	Klukshu	1988
1994	43117	ADFG	Tatshenshini	1989
1994	43118	ADFG	Tatshenshini	1989
1994	43118	ADFG	Tatshenshini	1989
1994	43340	ADFG	Tatshenshini	1989
1994	43340	ADFG	Tatshenshini	1989
1995	43117	ADFG	Tatshenshini	1989

Table 23.–Comparison of chinook salmon harvests in the U.S. Alsek commercial and subsistence fisheries, 1986–1996.

Year	Commercial harvest	Subsistence harvest	Total gillnet	Percent commercial
1986	481	22	503	95.6
1987	347	27	374	92.8
1988	223	13	236	94.5
1989	228	20	248	91.9
1990	78	85	163	47.9
1991	103	38	141	73.0
1992	301	15	316	95.3
1993	300	37	337	89.0
1994	805	90	895	89.9
1995	670	51	721	92.9
1996	771	51	822	93.8
Averages	392	41	432	90.6

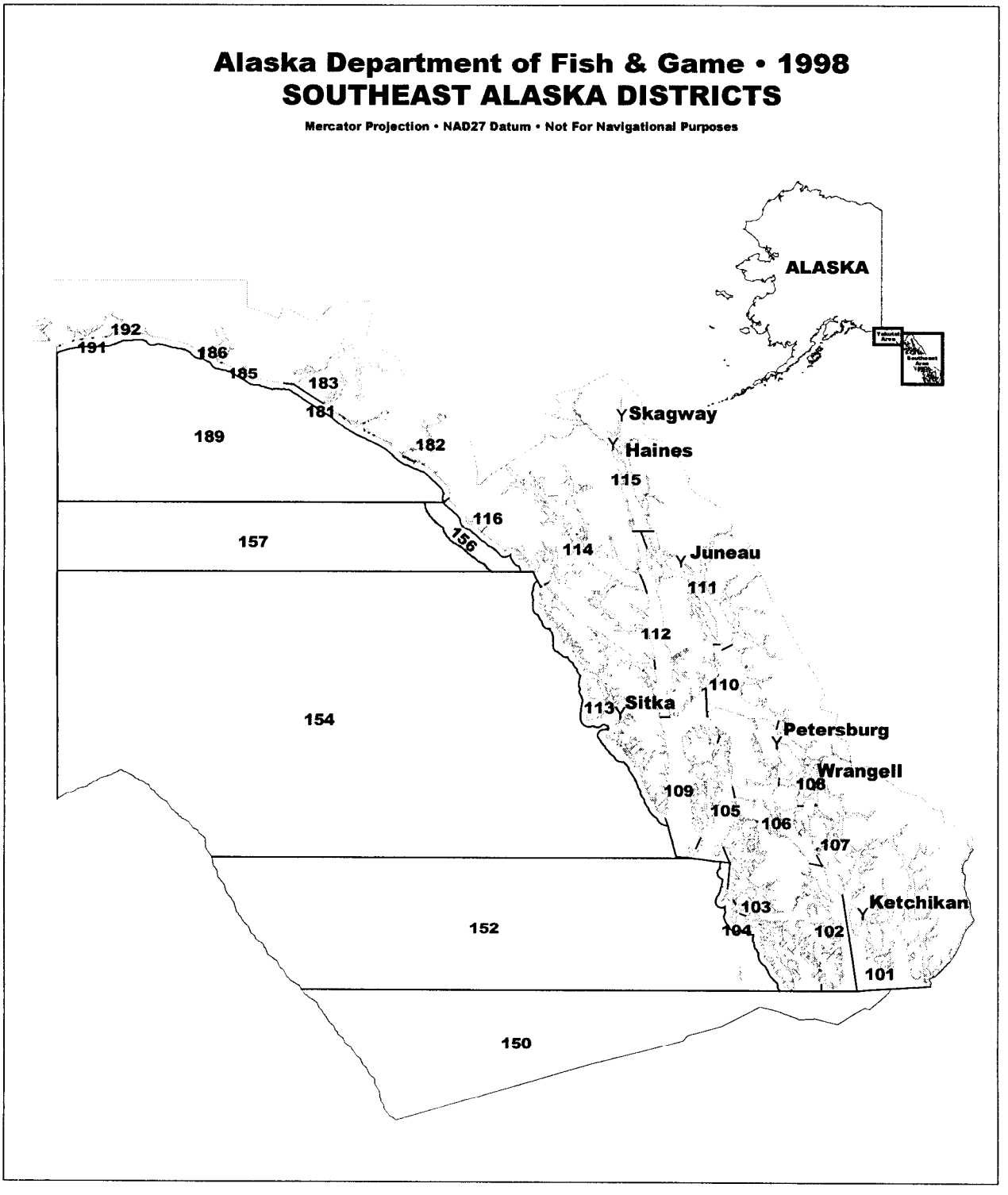

Figure 5.–Alaska Department of Fish and Game commercial fishing district boundaries in Southeast Alaska.

The fishery typically opens in mid-June with 2–4 days of fishing per week taking place for the first month. The number of days the fishery was open between 1991 and 1996 averaged 72 days and ranged from 57 days (1991) to 86 days (1995).

The Yakutat Bay commercial fishery targets sockeye salmon. The average sockeye salmon catch from 1991 to 1996 was about 21,000 fish. Chinook salmon are caught incidental to target catches. The average commercial harvest of chinook salmon in the Yakutat Bay commercial fishery between 1986 and 1996 was 244 fish; chinook harvests ranged from a low of 147 fish in 1992 to a high of 392 fish in 1991 (Table 24).

Yakutat Bay commercial harvests of chinook salmon have been sampled to recover coded wire tags during 9 of the 11 years since 1986 (Table 25). During that 11-year period, 2,686 chinook salmon were harvested and 459 of these fish were sampled for coded wire tags (17.1% sampling rate over the 11-year period). Annual sampling rates during the past 11 years have ranged from 0% of the catch sampled in 1988 and 1989 to a high of 54% of the catch sampled in 1994.

The 1986–1996 sampling program resulted in the recovery of 19 chinook salmon with coded wire tags from the Yakutat Bay commercial fishery. These tags were placed on chinook salmon in a variety of locations ranging from Cook Inlet, Alaska, to the State of Washington (Table 26); additionally, analysis of scale patterns indicate that the nearby Situk River contributes significantly to this harvest (ADFG, unpublished data). These results indicate that the Yakutat Bay commercial harvest of chinook salmon is composed of a large conglomerate of stocks coastwide rather than being a harvest that targets specific stocks of chinook salmon, with the possible exception of the Situk River.

The Yakutat Bay subsistence/personal use fishery typically harvests fewer chinook salmon than the commercial fishery (Table 24). During the 11-year period of 1986–1996, commercial harvests averaged 244 chinook salmon while subsistence/personal use harvests averaged 198 chinook salmon. The subsistence/personal use fishery is not sampled by ADFG to recover coded wire tags; it is believed that the catch composition is similar to the commercial fishery in that the same fishermen using the same gear represent the harvest sector. In 1994, a fisher provided a voluntary coded wire tag return to ADFG from a chinook salmon harvested in the Yakutat Bay subsistence fishery. The chinook salmon was originally tagged in the Alsek River drainage and was a brood year 1988 release.

Table 24.–Comparison of harvests in the U.S. Yakutat Bay commercial and subsistence gillnet fisheries, 1986–1996.

Year	Commercial fishery	Subsistence fishery	Ratio of harvests
1986	212	295	0.72
1987	329	67	4.88
1988	196	64	3.04
1989	297	184	1.62
1990	304	185	1.64
1991	392	155	2.54
1992	147	140	1.05
1993	148	163	0.91
1994	211	271	0.78
1995	266	391	0.68
1996	184	263	0.70
Averages	244	198	1.23

Table 25.–Chinook salmon harvests and sampling for coded wire tags, U.S. Yakutat Bay commercial set gillnet fishery, 1986–1996.

Year	Chinook catch	Number of chinook sampled	Percent of catch sampled	Number of CWTs recovered
1986	212	2	0.9	1
1987	329	16	4.9	1
1988	196	0	0.0	0
1989	297	0	0.0	0
1990	304	9	3.0	2
1991	392	149	38.0	8
1992	147	31	21.1	1
1993	148	73	49.3	2
1994	211	114	54.0	4
1995	266	25	9.4	0
1996	184	40	21.7	0
Sums	2,686	459	17.1	19
Averages	244	42	17.1	2

Table 26.–Origin of coded wire tagged chinook salmon from the U.S. Yakutat Bay commercial set gillnet fishery, 1986–1996.

	GEOGRAPHIC AREA OF ORIGIN					
	Alaska				State of	
Year	Cook Inlet	Yakutat	South-east	B.C.	Wash-ington	Annual sums
1986	1	–	–	–	–	1
1987	–	–	1	–	–	1
1988	–	–	–	–	–	0
1989	–	–	–	–	–	0
1990	–	–	1	1	–	2
1991	–	–	1	6	1	8
1992	–	–	1	–	–	1
1993	–	1	–	–	1	2
1994	–	–	2	2	–	4
1995	–	–	–	–	–	0
1996	–	–	–	–	–	0
Sums	1	1	6	9	2	19

For the following reasons, it is believed that few Alsek origin chinook salmon are harvested in the Yakutat Bay fisheries: (1) because of the lack of finding these fish in the ADFG random catch sampling program over the past 11 years; (2) because of the documented presence of so many other stocks in the fishery from the random sampling program; (3) because only limited fishing time is allowed during May and June when maturing Alsek chinook salmon would potentially be passing through this area; and, (4) because overall chinook salmon catches are relatively small. Yakutat Bay fisheries are not considered to be a significant source of mortality to Alsek chinook salmon runs and the remainder of this report makes no attempt to allocate a portion of this catch to the Alsek chinook salmon stock nor to any of its components, including the Klukshu chinook salmon stock.

U.S. Troll Fishery

The Southeast Alaska (SEAK) commercial troll fishery occurs in marine waters of the State of Alaska and offshore in the Federal Exclusive Economic Zone east of the longitude of Cape Suckling (Figure 5). The commercial troll fleet comprises hand troll and power troll gear types. Vessels using hand troll gear are limited to two lines on hand-operated gurdies or four sport fishing poles. Vessels using power troll gear are generally larger than those using hand troll gear. Power trollers are limited to four lines on power operated gurdies, except within the Exclusive Economic Zone north of the latitude of Cape Spencer, where six lines may be used.

The SEAK power troll fishery became a limited entry fishery in 1975, and since that time the number of power troll permits fished has remained relatively constant at about 800 vessels fishing annually. The hand troll fishery became a limited entry fishery in 1980, and the number of permits fished has steadily declined since that time from 1,713 hand troll permits fished in 1980 to 414 hand troll permits fished in 1996.

The commercial troll fishery primarily harvests chinook and coho salmon *Oncorhynchus kisutch* and historically, the troll fishery harvested 80–90% of the chinook salmon landed in Southeast Alaska. Commercial trolling for chinook salmon occurs during both winter and spring/summer seasons. The winter troll fishery takes place between October 1 and April 14, primarily in the more protected inside waters of Southeast Alaska, well south of the Alsek River. The spring/summer season is April 15 through September 20 and comprises three fisheries: (1) experimental; (2) terminal; and (3) general summer. The troll fishery is presently closed from April 15 to July 1 (see narrative below) except for the experimental and terminal fisheries, which are intended to increase the harvest of Alaska hatchery-produced chinook salmon. They occur during May and June in the inside, more protected, waters near hatchery release sites or along migration corridors well south of the Alsek River—exceptions being a limited June fishery in Yakutat Bay from 1989–1992. Catches in the experimental and terminal fisheries are generally small. Under present management, the general summer fishery opens July 1, and this fishery takes place both in the inside, more protected, waters and in offshore waters.

Because the troll fishery represents the largest harvest sector for chinook salmon in Southeast Alaska, agency staff in the early 1980s (when the

existing Klukshu chinook escapement goal policy was adopted and the PST was signed) believed that this fishery likely represented the largest source of fishing mortality to the Alsek chinook salmon stock. Analysis of information available today refutes this assumption and, in fact, indicates that the Southeast Alaska troll fishery exerts little or no mortality on Klukshu/Upper Tatshenshini chinook salmon stocks under present management regimes. It is likely that before 1984 the SEAK troll fishery did harvest some, but thought to be low, numbers of Alsek River chinook salmon.

Conservative management of the Southeast Alaska troll fishery was implemented in the early 1980s in concert with the setting of chinook salmon escapement objectives in Southeast Alaska and with the signing of the PST. The general spring/summer season for the troll fishery has been successively shortened. The general spring/summer fishery was open for almost 170 days per year during the late 1970s (April 15–Sept. 30; Table 27). In 1980, 20 days were closed to chinook fishing (July 15–24 and Sept. 21–30); 149 days were open during the spring/summer season. In 1981, 1982 and 1983, 101, 65, and 60 days were open to chinook retention, and the season opening was delayed until May 15. From 1984 to 1987, the general spring/summer opening was delayed until June, and between 23 and 45 days were open to chinook retention. Since 1988, the general summer opening has been delayed until July 1 and between 4.5 and 24 days have been open to fishing; the spring fishery has been closed except for experimental and terminal openings in inside waters, which have occurred primarily in June. These and other regulatory actions have been taken by ADF&G to help conserve chinook salmon on a coastwide basis and to aid in the PST chinook salmon rebuilding program.

Sampling of Southeast Alaska commercial troll harvests of chinook salmon for coded wire tags has taken place annually since the early 1980s (Table 28). During the 11-year period of 1986–1996, the commercial troll fishery accounted for a cumulative harvest of over 2.2 million chinook salmon; over 800,000 of these fish were examined by ADF&G staff for missing adipose fins (an indicator of the presence of coded wire tags), and more than 50,000 such fish were found, the vast majority of which had their heads dissected to successfully recover coded wire tags.

Sampling effort is spread throughout the region and all troll harvests receive some coverage; overall sampling rate during this 11-year period was 37%, ranging from the lowest annual sampling rate of 28% in 1986 to the highest of about 45% in 1994 (Table 28). No Alsek origin chinook salmon have been recovered from the Southeast Alaska troll fishery, even though almost 80,000 chinook salmon juveniles were tagged and released with coded wire tags in the Alsek drainage between 1985 and 1993. These fishery statistics indicate that the Southeast Alaska troll fishery exerts either no measurable level of mortality or none at all on upper Tatshenshini chinook salmon stocks under present management regimes.

The fact that the Southeast Alaska troll fishery does not inflict measurable mortality on upper Tatshenshini chinook salmon stocks under present management regimes is substantiated by other fishery statistics. With the advent of coded wire tag (CWT) technology since the early 1980s, it has become clear that most chinook salmon from transboundary stocks of chinook salmon from the Alsek, Taku, and Stikine rivers rear in areas of the Pacific Ocean (Bering Sea, Gulf of Alaska, etc.) other than the nearshore waters of Southeast Alaska where the troll fishery is prosecuted (Kissner and Hubartt 1986). Virtually no recoveries of coded wire tags from immature transboundary chinook salmon have been made by any gear type in fisheries in Southeast Alaska, with the minor exception of age-1.1 fish in seine fisheries in August or September. Therefore, harvests of Alsek chinook stocks in the Southeast Alaska troll fishery would be limited to maturing fish. Maturing chinook salmon returning to the Alsek River (eastward from the Gulf of Alaska) primarily pass through the Alsek commercial set gillnet fishery from mid-May to mid-June (Figure 4). Hence, maturing Alsek chinook salmon would have to be caught in the troll

Table 27.–Summer seasons and fishing effort associated with the U.S. troll fishery, 1978–1996.

Year	Dates open to chinook retention	No. of days troll fishery open to chinook retention	Boat-days of fishing effort during chinook retention fishing periods	No. of days troll fishery open to chinook nonretention	Boat-days of fishing effort during chinook nonretention fishing periods	No. of days troll fishery closed
1978	4/15–9/30	169	–	0	0	0
1979	4/15–9/30	169	–	0	0	0
1980	4/15–7/14					
	7/25–9/20	149	–	0	0	20
1981	5/15–6/25					
	7/5–8/6					
	8/20–9/3					
	9/13–9/20	101	76,751	9	3,526	59
1982	5/15–6/6					
	6/17–7/28	65	53,371	44	37,727	60
1983	5/15–6/8					
	7/1–8/4	60	48,734	37	18,396	72
1984	6/5–6/30					
	7/11–7/29	45	33,641	43	29,583	81
1985	6/3–6/12					
	7/1–7/22					
	8/25–8/26	33.6	30,934	48.4	35,509	87
1986	6/20–7/15					
	8/21–8/26					
	9/1–9/9	41	26,496	42	37,265	86
1987	6/20–7/12	23	19,079	60	37,219	86
1988	7/1–7/12	12	9,509	47	27,344	110
1989	7/1–7/13	13	9,585	59	38,424	97
1990	7/1–7/22					
	8/23–8/24	24	17,175	48	29,528	97
1991	7/1–7/8	7.5	4,718	64.5	32,556	97
1992	7/1–7/4					
	8/23	4.5	2,882	67.5	36,306	97
1993	7/1–7/6					
	8/21–8/25					
	9/12–9/20	20	7,635	49	35,156	100
1994	7/1–7/7					
	8/29–9/2	12	6,434	78	35,718	79
1995	7/1–7/10					
	7/30–8/5	17	7,807	65	24,002	87
1996	7/1–7/10					
	8/19–8/20	12	5,161	65	23,262	92

fishery before mid-June. The vast majority of the troll fishery has occurred after July 1, and, since 1988, the troll fishery has been closed in the Yakutat area and on the Fairweather grounds from April 15 to June 30, thus precluding any harvest of maturing Alsek chinook salmon since 1988.

Spring troll catches in the Yakutat Area offshore and on the Fairweather grounds from April 15 through June 30 in the years 1969–1987 averaged about 24,000 chinook salmon, and ranged from about 3,000 in 1972 to about 39,000 in 1977 (Table 29). Analysis of coded wire tags has shown

Table 28.–Chinook salmon sampled for coded wire tags, Southeast Alaska troll fishery, 1986–1996.

Year	Troll catch	Number of chinook sampled	Percent of count of chinook sampled	Number of adipose clips
1986	238,597	65,885	27.61	3,694
1987	264,362	95,916	36.28	6,015
1988	202,157	87,723	43.39	5,173
1989	225,521	82,645	36.65	4,803
1990	282,335	93,467	33.10	8,621
1991	251,336	95,246	37.90	6,687
1992	159,467	69,983	43.89	3,938
1993	222,800	84,163	37.78	3,892
1994	149,989	67,650	45.10	3,628
1995	110,651	37,885	34.24	2,453
1996	103,509	39,900	38.55	1,811

that these spring harvests include contributions from myriad stocks, including spring stocks from the Taku, Stikine, Chilkat, Unuk, and Chickamin rivers and Andrew Creek. Spring and fall stocks from British Columbia and Washington and Oregon were also present. It is not known what contribution of Alsek stocks were to these harvests. However, weir counts at Klukshu River did not increase during the period 1988–1992. Thus, it is likely that the 1980s perception that the Southeast Alaska troll fishery was a major source of mortality to the Alsek chinook salmon stock was probably erroneous. For these reasons, and on the basis of solid technical footing, troll fisheries are not considered to be a significant source of mortality to Alsek chinook salmon runs, certainly under present—and probably not historical— management regimes, and the remainder of this report makes no attempt to allocate a portion of this catch to the Alsek chinook salmon stock nor to any of its components, including the Klukshu chinook salmon stock.

SPAWNER-RECRUIT ANALYSIS

Because the Klukshu River weir enumerates only a portion of the chinook salmon escapement in the Alsek River drainage, and because fisheries such as the U.S. Alsek gillnet fishery harvest a mixture of chinook salmon bound for various Alsek River system spawning grounds, development of spawner-recruit relationships require that either the Klukshu River escapement database be expanded to represent the entire Alsek run or that the harvests in fisheries such as the U.S. Alsek fishery be allocated to Klukshu origin.

In the 1995 draft of this report, we chose to expand Klukshu River weir counts by various factors to develop a proxy database for overall Alsek River system chinook salmon escapements, rather than allocate harvests to Klukshu origin versus other Alsek origin stocks of chinook salmon. Reviewers of the 1995 draft report recommended the alternate approach. Therefore, the current analysis focuses on Klukshu origin chinook salmon, based on that recommendation, the long-term view that Klukshu weir will remain as the primary management tool for indexing Alsek River (Tatshenshini) chinook salmon escapements, and because estimates of total returns are much more precise using this approach.

As described in previous sections, Alsek origin chinook salmon, and therefore, Klukshu origin chinook salmon are harvested in significant numbers in three fisheries: the Canadian aboriginal fishery, the Canadian sport fishery, and the U.S. Alsek commercial and subsistence/personal use fishery. Direct numerical estimates of the Klukshu origin chinook salmon harvests in the two Canadian fisheries are available with assumptions of the percentage Klukshu fish in the sport harvests; broader assumptions need to be made to allocate the U.S. Alsek chinook salmon fishery to Klukshu origin versus non-Klukshu origin components.

The following sections of this report develop alternate spawner-recruit relationships for the Klukshu River system stock of chinook salmon based upon three assumptions concerning the proportion of Klukshu origin chinook salmon in the U.S. Alsek gillnet fishery. The following sections of this report describe how the number of chinook salmon in the escapements and harvests were estimated, how the age composition and associated measures of precision of these escapements and harvests were estimated.

Table 29.–Spring (4/15–6/30), summer(7/1–9/30), and annual U.S. troll fishery harvests of chinook salmon from the Yakutat area and from the Fairweather grounds, along with annual U.S. troll fishery harvests of chinook salmon from all of Southeast Alaska, 1969–1996.

Year	Yakutat area harvest in spring[a] (4/15–6/30) (Districts: 181, 183, 186, 189)	Fairweather grounds harvest in spring (4/15–6/30) (Districts: 116, 156, 157)	Spring[a] harvest in combined Yakutat area and Fairweather grounds	Yakutat area harvest in summer (7/1–9/30)	Fairweather grounds harvest in summer (7/1–9/30)	Summer harvest in combined Yakutat area and Fairweather grounds	Annual troll harvest from Yakutat area	Annual troll harvest from Fairweather grounds	Annual troll harvest in all of Southeast Alaska
1969	737	22,601	23,338	2,184	43,781	45,965	2,921	66,382	290,168
1970	1,473	34,659	36,132	6,110	14,160	20,270	7,583	48,819	304,602
1971	2,386	30,988	33,374	5,822	18,030	23,852	8,208	49,018	311,439
1972	403	2,368	2,771	3,141	32,940	36,081	3,544	35,308	242,282
1973	343	32,674	33,017	1,343	71,137	72,480	1,686	103,811	307,806
1974	1,659	35,836	37,495	3,860	28,607	32,467	5,519	64,443	322,101
1975	508	21,247	21,755	2,703	23,234	25,937	3,211	44,481	287,342
1976	677	13,124	13,801	3,902	22,001	25,903	4,579	35,125	231,239
1977	23,524	15,006	38,530	12,137	17,317	29,454	35,661	32,323	271,735
1978	20,899	12,325	33,224	16,901	12,203	29,104	37,800	24,528	375,433
1979	13,104	11,863	24,967	6,553	13,759	20,312	19,657	25,622	334,317
1980	19,020	7,725	26,745	9,227	12,742	21,969	28,247	20,467	303,874
1981	11,299	16,516	27,815	3,254	6,687	9,941	14,553	23,203	248,791
1982	13,923	17,109	31,032	4,136	5,496	9,632	18,059	22,605	242,315
1983	1,514	20,419	21,933	2,275	6,224	8,499	3,789	26,643	269,790
1984	7,511	9,438	16,949	932	6,928	7,860	8,443	16,366	235,699
1985	1,819	12,411	14,230	6,697	9,781	16,478	8,516	22,192	216,089
1986	538	16,435	16,973	9,410	13,636	23,046	9,948	30,071	237,698
1987	2,348	7,001	9,349	4,765	11,348	16,113	7,113	18,349	242,562
1988	0	0	0	5,641	19,020	24,661	5,641	19,020	231,185
1989	338	0	0	4,462	47,453	51,915	4,800	47,453	235,609
1990	52	0	0	8,480	50,840	59,320	8,532	50,840	287,100
1991	206	0	0	6,121	20,119	26,240	6,327	20,119	263,091
1992	171	0	0	1,503	1,181	2,684	1,674	1,181	183,354
1993	0	0	0	14,924	2,041	16,965	14,924	2,041	226,561
1994	0	0	0	4,474	15,141	19,615	4,474	15,141	186,167
1995	0	0	0	2,785	12,215	15,000	2,785	12,215	138,115
1996	0	0	0	4,326	7,293	11,619	4,326	7,293	141,407

[a] Spring harvests in Yakutat area for 1989–1992 occurred in Yakutat Bay in hatchery access openings in June.

AGE COMPOSITION ESTIMATES

Previous sections of this report provide information concerning available age composition estimates for Klukshu River system chinook salmon escapements as well as available age composition estimates for chinook salmon in the Canadian and U.S. fisheries of interest. Unbiased samples were not taken in all years at Klukshu weir for estimating age distribution, and estimates of age composition were not available for some years in the U.S. gillnet and Canadian aboriginal harvest below the weir. Accordingly, age composition estimates that are available were analyzed to determine how best to develop proxy estimates for the missing components. Direct estimates of the age composition of chinook salmon in the Canadian Klukshu/Dalton

Post (KL/DP) sport fishery were available each year from 1976 to 1996 (Table 30). Even though sample sizes were relatively low from 1976–1980, virtually none of these data points were used in building the spawner-recruit tables, which covered the 1976–1991 broods. That is, escapement enumeration began in 1976 and the first significant return of chinook from the 1976 brood year occurred with age-5 fish in 1981. From 1981–1996 an average of 43% of the KL/DP sport harvest was sampled and aged (Table 31).

Age composition of chinook salmon harvested in the Canadian aboriginal fishery has only been sampled during four of the twenty-one years since 1976 and all are based on relatively small sample sizes (Table 30). Chi-squared tests indicated that age composition of chinook salmon harvested in the two Canadian fisheries were not statistically different during any of the four years that sampling occurred in both fisheries; indicating that age composition estimates for the KL/DP sport fishery could be used for years where harvests in the Aboriginal fishery occurred below Klukshu weir; i.e., from 1991–1996. Prior to 1991, all Aboriginal fishery harvests occurred above the weir and did not need separate age composition estimates.

Annual age composition estimates for chinook salmon counted past Klukshu River weir, the vast majority (~85%) of the annual Klukshu run, were estimated directly from live fish sampled at the weir from 1986–1996, when 16% (average number sampled = 447; average weir count = 2,900), on average, of the weir count was sampled for ageable samples (Table 31). From 1976–1985, a pooled sample from the KL/DP sport fishery, the Aboriginal fishery and carcass samples from Klukshu weir were used to estimate the Klukshu weir age composition. Sample sizes ranged between 63 and 181 annually for the pooled sample (Table 32). Klukshu weir age compositions were compared to the pooled Canadian harvest samples with chi-squared analysis. Results indicated that annual age compositions were usually not statistically different during years when carcass samples were collected at Klukshu River weir, but were usually different when chinook salmon were live-sampled at the Klukshu River weir (Table 30). Plots of annual year class percentages (annual Canadian sport fishery samples, annual Klukshu River weir carcass samples, annual Klukshu River weir live samples, and pooled samples from the Canadian fisheries and Klukshu River weir carcasses) for age-4, age-5, and age-6 chinook salmon demonstrated that annual trends were similar and that pooling of age composition data was a better approach (less biased) than was averaging across years because of interannual variability in age composition of returns (Figure 6). Therefore, we elected to pool annual age composition samples collected from Canadian fisheries with samples collected from chinook salmon carcasses collected at Klukshu River weir to estimate weir age compositions for 1976–1985; we halved the annual sample size for estimating precision of age composition. These pooled samples were slightly biased towards larger, older fish; i.e., the pooled samples (1976–1985) averaged 9% age-4, 45% age-5 and 45% age-6 and the live samples from Klukshu weir (1986–1995) averaged 12% age-4, 46% age-5 and 40% age-6. We believe use of the pooled estimates for Klukshu weir adds little bias in estimating spawner-recruit parameters. Standard errors associated with pooled age composition estimates are relatively small for the major age-classes (age 4–6 chinook salmon) indicating relatively good precision (Table 33); these standard errors were not corrected for finite population size due to the aforementioned bias and the sample size was halved in calculating precision.

The U.S. Alsek gillnet fishery was sampled annually to estimate age composition of the chinook salmon harvests from 1982–1996 (Table 19). Trends in annual age compositions were similar to the pooled age composition during the years 1982–1985 (Table 33); however, the U.S. Alsek fishery tended to harvest younger (more age-4) chinook salmon and fewer older (age-6) chinook salmon, with percentages for age-5 fish similar to those in weir and Canadian sport fish samples (Figure 7). Estimates of annual age compositions for the years 1976–1981 in the U.S. Alsek fishery were needed to develop brood tables of returns for early years, but are only

Table 30.–Annual age composition comparisons for Alsek River system chinook salmon sampled from the Canadian sport fishery (SF) versus the Canadian aboriginal fishery (AF) and from the Klukshu River weir project versus the combination of Canadian sport and aboriginal fisheries. Age samples collected at Klukshu River weir from 1976–1984 were carcass samples; samples from 1986–1996 were live-sampled.

	No. of chinook sampled		Statistical comparison					Statistical comparison		
Year	Sport fishery (SF)	Aboriginal fishery (AF)	df	χ^2	Sig. level	Klukshu weir	SF + AF	df	χ^2	Sig. level
1976	10	0	–	–	–	55	10	2	11.76	1%
1977	51	0	–	–	–	130	51	2	6.27	5%
1978	13	27	2	2.52	NS	81	40	2	8.35	5%
1979	15	0	–	–	–	83	15	1	0.20	NS
1980	25	0	–	–	–	40	25	1	4.41	5%
1981	46	0	–	–	–	17	46	2	0.24	NS
1982	134	13	3	1.26	NS	29	147	2	0.02	NS
1983	80	0	–	–	–	29	80	2	3.30	NS
1984	107	8	4	0.80	NS	13	115	2	1.10	NS
1985	71	21	3	6.50	NS	0	92	–	–	–
1986	56	0	–	–	–	341	56	2	4.16	NS
1987	142	0	–	–	–	323	142	3	9.56	5%
1988	84	0	–	–	–	219	84	4	9.44	NS
1989	108	0	–	–	–	723	108	3	27.31	1%
1990	211	0	–	–	–	252	211	4	22.93	1%
1991	108	0	–	–	–	418	108	4	5.69	NS
1992	22	0	–	–	–	330	22	3	8.26	5%
1993	88	0	–	–	–	316	88	4	12.32	5%
1994	139	0	–	–	–	719	139	4	10.16	1%
1995	100	0	–	–	–	777	100	3	5.12	NS
1996	204	0	–	–	–	500	204	4	32.46	1%
Totals	1,814	69	4 comparisons			5,395	1,883	20 comparisons		

Conclusions: **Annual age compositions of chinook salmon samples from the two Canadian fisheries were similar; age data from both fisheries can be pooled to provide estimates based upon larger sample sizes. Annual age compositions of chinook salmon sampled from Canadian fisheries were usually similar to age compositions of chinook salmon sampled as carcasses at Klukshu River weir (1976–1984, 5 of 9 comparisons). Annual age compositions of chinook salmon sampled from Canadian fisheries were usually different from age compositions of chinook salmon that were live sampled at Klukshu River weir (1986–1996, 5 of 11 comparisons). Annual chinook salmon age samples collected from: (1) the Canadian sport fishery, (2) the Canadian aboriginal fishery, and (3) carcass samples from the Klukshu River weir are pooled by year to estimate age composition of the chinook salmon escapement in the Klukshu River for years when live sampling was not conducted (1976–1985).**

Table 31.–Percentages of chinook salmon abundance aged for U.S. and Canadian harvests and Klukshu weir count, 1976–1996.

Year	U.S. comm. & subsistence			Klukshu weir			Canadian sport (Klukshu/Dalton Post)		
	N	Harvest	Percent sampled	*N*	Weir count	Percent sampled	*N*	Harvest	Percent sampled
1976	0	525	0.0	55	1,278	4.3	10	130	7.7
1977	0	1,420	0.0	130	3,144	4.1	51	195	26.2
1978	0	2,441	0.0	81	2,976	2.7	13	195	6.7
1979	0	2,605	0.0	83	4,404	1.9	15	422	3.6
1980	0	1,439	0.0	40	2,637	1.5	25	130	19.2
1981	0	811	0.0	17	2,113	0.8	46	150	30.7
1982	83	619	13.4	29	2,369	1.2	134	183	73.2
1983	41	124	33.1	29	2,537	1.1	80	202	39.6
1984	21	46	45.7	13	1,672	0.8	107	275	38.9
1985	54	229	23.6	0	1,458	0.0	71	170	41.8
1986	163	503	32.4	341	2,709	12.6	56	125	44.8
1987	114	374	30.5	323	2,616	12.3	142	326	43.6
1988	110	236	46.6	219	2,037	10.8	84	249	33.7
1989	191	248	77.0	723	2,456	29.4	108	215	50.2
1990	18	163	11.0	252	1,915	13.2	211	468	45.1
1991	63	141	44.7	418	2,489	16.8	108	384	28.1
1992	195	316	61.7	330	1,367	24.1	22	79	27.8
1993	152	337	45.1	316	3,303	9.6	88	170	51.8
1994	209	895	23.4	719	3,727	19.3	139	197	70.6
1995	363	721	50.3	777	5,678	13.7	100	601	16.6
1996	473	822	57.5	500	3,599	13.9	204	423	48.2
Avg. 1981–96	141	412	37.2	313	2,628	11.2	106	264	42.8
Avg. 1976–85	20	1,026	11.6	48	2,459	1.9	55	205	28.7
Avg. 1986–96	186	432	43.7	447	2,900	16.0	115	294	41.9

Table 32.–Number of aged samples and distribution by age for chinook salmon in the pooled sample composed of all chinook salmon samples aged from the Canadian aboriginal fishery, the Canadian sport fishery, and carcasses collected at Klukshu River weir, 1976–1985.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run
1976	0	4	22	39	0	65
1977	2	47	70	61	1	181
1978	0	10	69	42	0	121
1979	0	6	48	44	0	98
1980	0	1	22	42	0	65
1981	0	6	21	34	2	63
1982	2	23	77	74	0	176
1983	0	3	78	28	0	109
1984	2	6	50	68	2	128
1985	1	8	45	38	0	92

essential for age-4 fish in 1980, and for age-4 and -5 fish in 1981. We developed age-specific conversion rates from the upstream pooled sample to the U.S. Alsek fishery for 1982–1985, in order to estimate the age composition in the U.S. Alsek fishery for 1976–1981, essentially doubling the age-4 percentage and halving the age-6 percentage in the upstream pooled sample. Although we recognize that there are biases associated with this approach, only three stratum (age-4 fish in 1980 and 1981 and age-5 fish in 1981) are used in the spawner-recruit relationships, as discussed later in this report, and hence the effect of this bias is inconsequential in calculating returns for the 1976–1991 broods, spawner-recruit parameters, and estimates of optimum escapement.

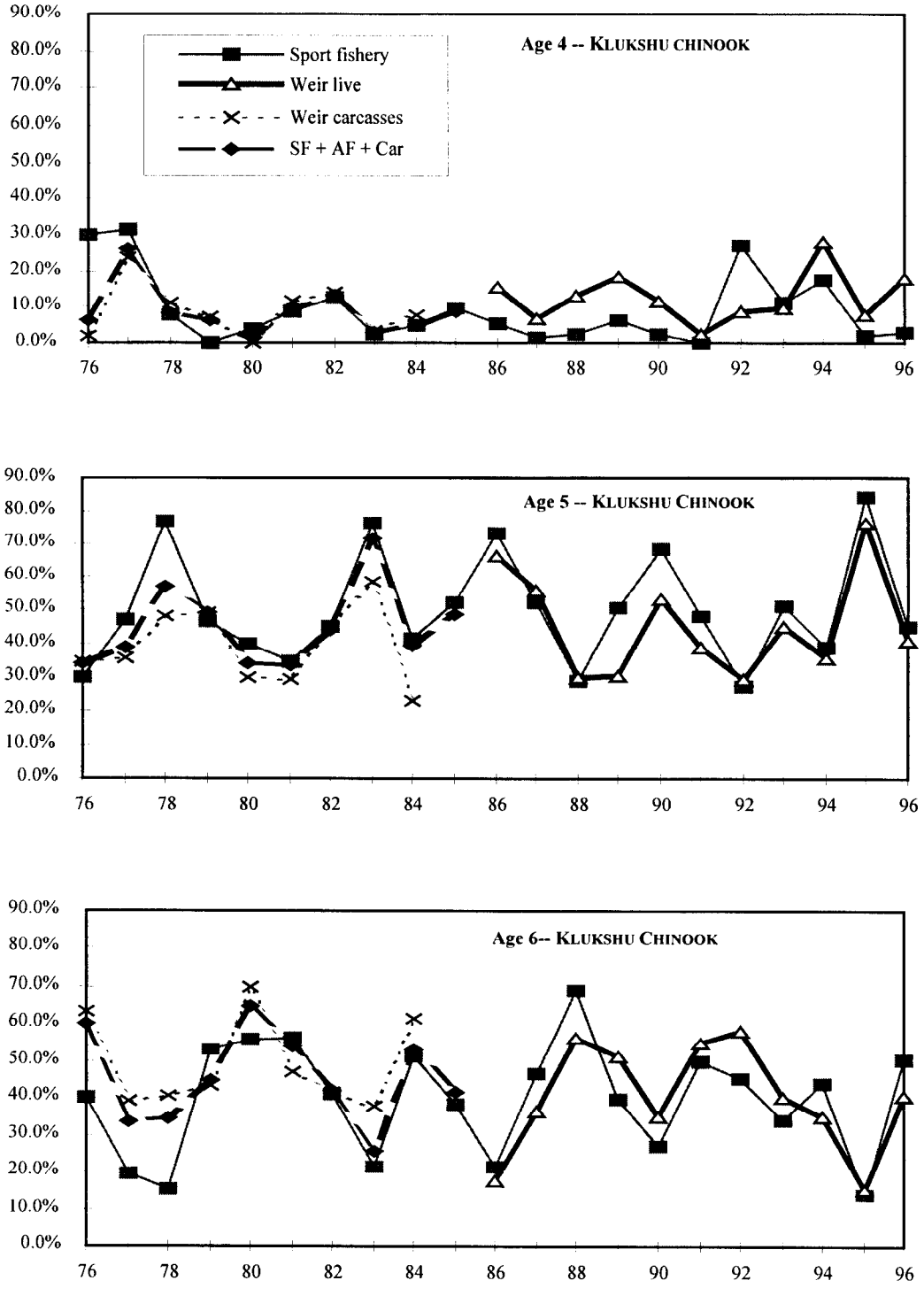

Figure 6.–Age composition of chinook salmon sampled from the Canadian sport fishery (Sport fishery), **from live fish at the Klukshu River weir** (Weir live), **from carcasses collected at the Klukshu River weir** (Weir carcasses), **and pooled samples collected from the Canadian sport fishery, the Canadian aboriginal fishery, and Klukshu River weir carcasses** (SF + AF + Car), **1976–1996.**

Table 33.–Age composition estimates for the annual pooled samples composed of all chinook salmon samples aged from the Canadian aboriginal fishery, the Canadian sport fishery, and carcasses collected at Klukshu River weir, 1976–1985.

Year	Age 3 (SE)	Age 4 (SE)	Age 5 (SE)	Age 6 (SE)	Age 7 (SE)
1976	0.0% (0.0%)	6.2% (3.0%)	33.8% (5.9%)	60.0% (6.1%)	0.0% (0.0%)
1977	1.1% (0.8%)	26.0% (3.3%)	38.7% (3.6%)	33.7% (3.5%)	0.6% (0.6%)
1978	0.0% (0.0%)	8.3% (2.5%)	57.0% (4.5%)	34.7% (4.3%)	0.0% (0.0%)
1979	0.0% (0.0%)	6.1% (2.4%)	49.0% (5.1%)	44.9% (5.1%)	0.0% (0.0%)
1980	0.0% (0.0%)	1.5% (1.5%)	33.8% (5.9%)	64.6% (6.0%)	0.0% (0.0%)
1981	0.0% (0.0%)	9.5% (3.7%)	33.3% (6.0%)	54.0% (6.3%)	3.2% (2.2%)
1982	1.1% (0.8%)	13.1% (2.5%)	43.8% (3.8%)	42.0% (3.7%)	0.0% (0.0%)
1983	0.0% (0.0%)	2.8% (1.6%)	71.6% (4.3%)	25.7% (4.2%)	0.0% (0.0%)
1984	1.6% (1.1%)	4.7% (1.9%)	39.1% (4.3%)	53.1% (4.4%)	1.6% (1.1%)
1985	1.1% (1.1%)	8.7% (3.0%)	48.9% (5.2%)	41.3% (5.2%)	0.0% (0.0%)

KLUKSHU CHINOOK SALMON ESCAPEMENTS

Although Klukshu River weir counts are considered a census, Canadian fisheries occur upstream of the weir (only aboriginal after 1978) and estimates of these harvests are subtracted from the weir count to provide an estimate of the annual escapements of chinook salmon in the Klukshu River system. Consequently, there is sampling error associated with these chinook salmon escapement estimates. Estimates of the standard errors associated with the annual Klukshu River system chinook salmon escapements were calculated by taking into consideration the standard errors associated with upstream fishery harvests (Table 34). Ninety-five percent relative precision (95% RP = one-half of 95% CI/escapement estimate) averaged 4.1% during the 21-year period of 1976–1996 and ranged from a low of 0.8% RP in 1988 and 1993, when Canadian fisheries harvested few fish upstream of the weir site, to a high of 16.4% in 1979 when an estimated 1,300 chinook salmon were harvested upstream of the weir site (Table 34).

HARVESTS OF KLUKSHU ORIGIN CHINOOK SALMON

Annual Canadian harvests allocated to the Klukshu River origin chinook salmon stock in this analysis included 70% of the Canadian Klukshu/Dalton Post sport fishery harvests of chinook salmon taken below the weir (see Table 10), the Canadian aboriginal fishery harvests taken upstream of the Klukshu River weir (Table 10), and 95% of the Canadian aboriginal fishery harvests of chinook salmon that occurred downstream of the Klukshu River weir (Table 10). Although annual estimates of the stock composition of chinook salmon in the Canadian aboriginal fishery downstream of the Klukshu River weir are not available, siting of the fishery leads us to believe that only a very small portion of this harvest is of non-Klukshu origin chinook salmon. Similarly, siting of the Klukshu/ Dalton Post sport fishery leads us to believe that 70% of chinook salmon harvested are of Klukshu River origin and siting of the sport fisheries in the Blanchard River and Takhanne River lead us to believe that none of these fish are of Klukshu River origin.

Annual harvests of chinook salmon in the U.S. Alsek commercial set gillnet fishery are provided in Table 17 and annual harvests in the subsistence/personal use fishery are provided in Table 23. Annual estimates of the proportion of Klukshu River origin chinook salmon in the U.S. Alsek fisheries are not available, although based on fishery statistics, timing, participants, and gear types used we believe that both fisheries harvest the same stocks and that virtually all of the chinook salmon harvested are of Alsek River origin. Aerial surveys of chinook salmon in the Klukshu River, the Blanchard River, the Takhanne River, and Goat Creek occurred in 1986, 1987, 1992, 1993, and 1996 (see Table 3). Based on these surveys, which include only a portion of known chinook spawning tributaries in the Alsek River drainage, 53% of the chinook salmon were observed in the Klukshu River system. Based upon this relative proportion of

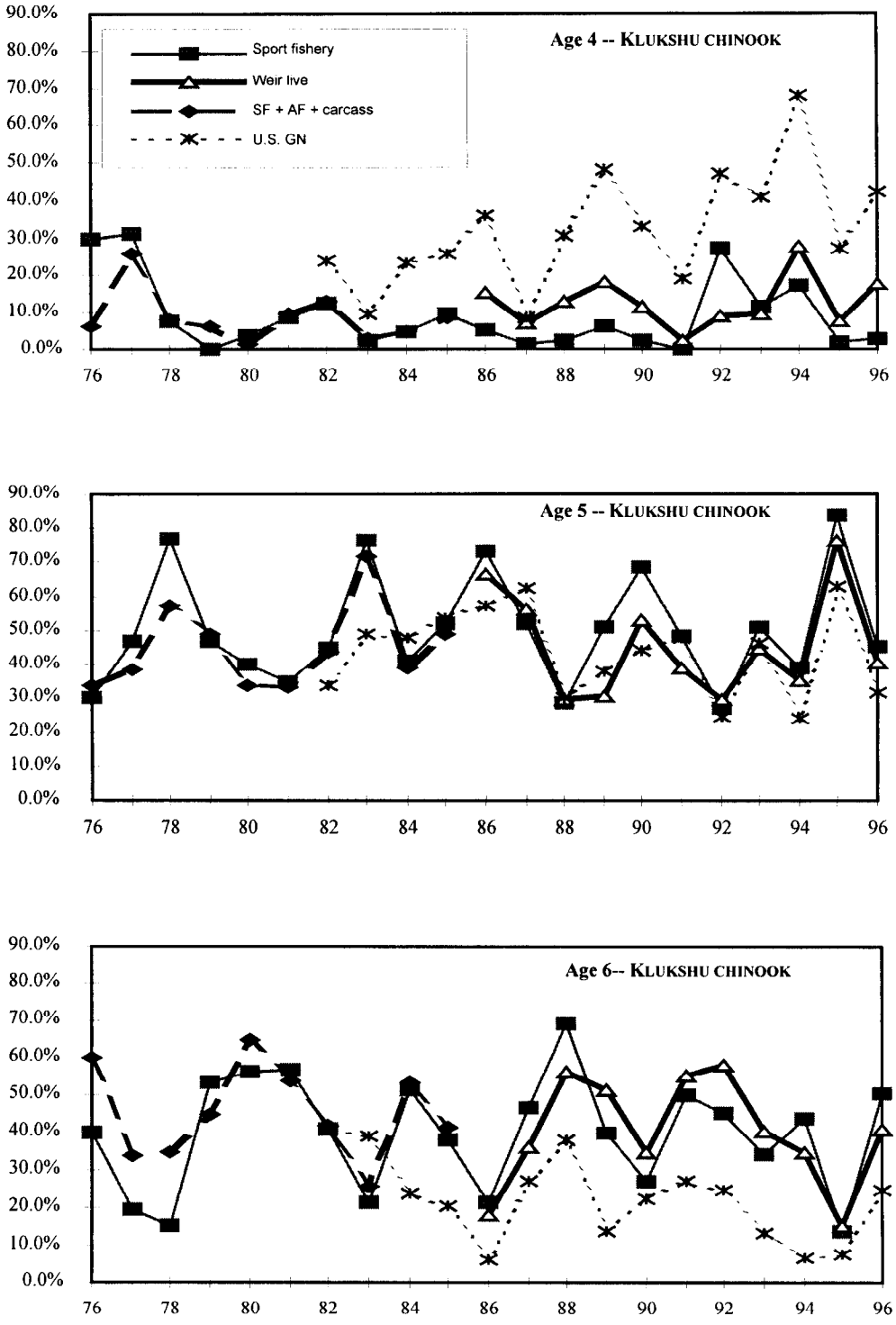

Figure 7.–Age composition of chinook salmon sampled from the Canadian sport fishery (Sport fishery), **from live fish at the Klukshu River weir** (Weir live), **pooled samples collected from the Canadian sport fishery, the Canadian aboriginal fishery, and Klukshu River weir carcasses** (SF + AF + carcass), **and from the U.S. Alsek River fishery** (U.S. GN), **1976–1996.**

Table 34.–Estimated number of chinook salmon spawning in the Klukshu River system and estimates of standard errors, 1976–1996.

Year	Canadian aboriginal fishery		Canadian sport fishery		Brood stock removal	Total removal above weir		Klukshu weir count	Klukshu chinook salmon escapement [a]		
	Estimate	SE	Estimate	SE		Estimate	SE		Estimate	SE	95% RP
1976	150	30	64	13	0	214	33	1,278	1,064	33	6.0%
1977	350	70	96	19	0	446	73	3,144	2,698	73	5.3%
1978	350	70	96	19	0	446	73	2,976	2,530	73	5.6%
1979	1,300	260	0	0	0	1,300	260	4,404	3,104	260	16.4%
1980	150	30	0	0	0	150	30	2,637	2,487	30	2.4%
1981	150	30	0	0	0	150	30	2,113	1,963	30	3.0%
1982	400	80	0	0	0	400	80	2,369	1,969	80	8.0%
1983	300	60	0	0	0	300	60	2,537	2,237	60	5.3%
1984	100	20	0	0	0	100	20	1,672	1,572	20	2.5%
1985	175	35	0	0	0	175	35	1,458	1,283	35	5.3%
1986	102	20	0	0	0	102	20	2,709	2,607	20	1.5%
1987	125	25	0	0	0	125	25	2,616	2,491	25	2.0%
1988	43	9	0	0	0	43	9	2,037	1,994	9	0.8%
1989	234	47	0	0	20	254	47	2,456	2,202	47	4.2%
1990	202	40	0	0	15	217	40	1,915	1,698	40	4.7%
1991	241	48	0	0	25	266	48	2,489	2,223	48	4.2%
1992	88	18	0	0	36	124	18	1,367	1,243	18	2.8%
1993	64	13	0	0	18	82	13	3,303	3,221	13	0.8%
1994	99	20	0	0	8	107	20	3,727	3,620	20	1.1%
1995	260	52	0	0	21	281	52	5,678	5,397	52	1.9%
1996	215	43	0	0	2	217	43	3,599	3,382	43	2.5%
Avg.	243	49	85	17	18	262	49	2,690	2,428	49	4.1%

[a] Annual estimates of the number of spawning chinook salmon are based on Klukshu weir counts minus estimates of Canadian aboriginal fishery harvests upstream of the weir, minus estimates of Canadian sport fishery harvests upstream of the weir (1976–1978 only), minus brood stock removals (1989–1996). In developing estimates of standard errors, we estimated that CV = 20% for annual Canadian aboriginal fishery harvest estimates and 10% for annual Canadian sport fishery harvest estimates. Brood stock removals and Klukshu weir counts were assumed to be censuses.

spawning chinook salmon, we chose to use 55% as a median estimate of the proportion of Klukshu origin chinook salmon in U.S. Alsek fisheries. This stock composition estimate is based on existing knowledge of primarily upper river stocks, and there could be other, indeed major, stocks located in other portions of the drainage. We also chose 30% and 100% Klukshu origin chinook salmon to use as alternate assumptions concerning the proportion of Klukshu origin chinook salmon in U.S. Alsek fisheries. Obviously, the true proportion cannot be greater than 100%, but it could be less than 30%. However, the 100% assumption, in reality, allows for some indirect harvest in other U.S. fisheries and is thought to be a liberal (maximum) estimate of U.S. harvests of Klukshu origin chinook salmon. If the true proportion of Klukshu origin chinook salmon in U.S. Alsek fisheries is less than 30%, then the impact of this fishery on Klukshu River chinook salmon escapements is even less than our analysis indicates. Lacking a direct study to estimate proportions of Klukshu origin chinook salmon in U.S. Alsek fisheries, we believed it best to proceed with the analysis using all three alternate assumptions and to examine the differences in parameter estimates. Hence, analyses in later sections of this report include all three approaches. We assigned a coefficient of variation of 30% (95% RP = ±59%) to annual U.S. harvests under the 55% and 30% assumptions; under the 100% assumption the U.S.

commercial harvest is a complete census and the subsistence harvest was assumed to have a 30% coefficient of variation in all years.

TOTAL RUNS OF KLUKSHU RIVER CHINOOK SALMON

Annual counts at Klukshu River weir were multiplied by estimated age composition (proportion by age or year class) to develop estimates of the number of age 3–7 fish that passed upstream. These age-specific estimates were added to annual age 3–7 specific estimates of numbers of Klukshu River system chinook salmon harvested in Canada below the weir and were also added to estimates in the U.S. gillnet fishery downstream under the three alternate harvest allocation scenarios, in order to estimate annual total runs by age for the years 1976–1996. Under the 100% assumption, production of Klukshu River chinook salmon has averaged 3,625 fish from 1976–1996 and have ranged from a low of 1,795 fish in 1992 to a high of 7,304 fish in 1979 (Table 35). Standard errors associated with these estimates have been relatively small (Table 36) with average coefficients of variation for these estimates of total runs averaging 0.9% during the 21-year period of 1976–1996 (Table 37). Using the 55% assumption, total runs have averaged 3,303 chinook salmon during the 21-year period of 1976–1996, with an estimated high of 6,800 fish in 1995 and an estimated low of 1,613 in 1976 (Table 38); again relatively small standard errors associated with these estimates (Table 39) lead to relatively small coefficients of variation (average CV = 5%) for the estimates (Table 40). Total runs of chinook salmon to the Klukshu River system under the 30% assumption averaged 3,124 fish during 1976–1996 (Table 41); standard errors

Table 35.–Estimated annual total runs of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 100% assumption to apportion U.S. Alsek fishery harvests.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run[a]
1976	0	191	617	1,041	0	1,849
1977	58	1,605	1,609	1,339	22	4,633
1978	0	818	2,987	1,681	0	5,486
1979	0	744	3,494	3,066	0	7,304
1980	0	119	1,450	2,598	0	4,167
1981	0	429	982	1,531	87	3,029
1982	29	475	1,303	1,302	7	3,116
1983	3	85	1,983	730	0	2,802
1984	32	98	754	998	28	1,911
1985	16	198	898	694	0	1,806
1986	3	607	2,155	535	0	3,300
1987	7	219	1,819	1,158	16	3,218
1988	11	346	724	1,356	10	2,447
1989	0	576	920	1,353	6	2,855
1990	4	284	1,316	794	9	2,406
1991	12	92	1,289	1,672	89	3,154
1992	49	302	510	926	8	1,795
1993	155	483	1,744	1,443	17	3,843
1994	11	1,705	1,664	1,503	58	4,941
1995	27	650	5,412	1,031	4	7,124
1996	38	1,003	1,957	1,935	5	4,938
Averages:						
1976–1985	14	476	1,608	1,498	14	3,610
1986–1995	28	526	1,755	1,177	22	3,508
1976–1996	22	525	1,695	1,366	17	3,625

[a] Annual total return estimates developed by adding Klukshu River weir counts of chinook salmon to estimated chinook salmon harvests downstream that were apportioned to the Klukshu run. Annual harvests included: (1) 100% of U.S. Alsek fishery chinook salmon harvests; (2) 70% of Canadian Klukshu/Dalton Post sport fishery harvests; and (3) 95% of Canadian aboriginal fishery harvests downstream of the Klukshu River weir (1991–1996 only).

Table 36.–Estimated standard errors for annual total run estimates of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 100% assumption to apportion U.S. Alsek fishery harvests. Estimated annual standard errors include variances for (1) estimating age proportions in the U.S. Alsek fishery; (2) U.S. subsistence harvest; (3) estimating age proportion in the Canadian fisheries downstream of the weir; (4) estimating Canadian aboriginal fishery harvests downstream of Klukshu River weir (harvests assumed to have CV = 20%); and (5) estimating Canadian sport fishery harvests occurring downstream of Klukshu River weir (harvests assumed to have CV = 10%). Klukshu River weir counts and brood stock removals were assumed to be censuses.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run
1976	0	53	88	92	0	10
1977	31	127	132	125	19	15
1978	0	153	208	190	0	14
1979	0	180	296	291	0	64
1980	0	70	199	203	0	25
1981	0	102	144	153	52	23
1982	19	67	95	95	7	29
1983	3	40	111	107	0	17
1984	19	32	73	75	18	19
1985	16	45	78	77	0	13
1986	3	53	68	54	0	11
1987	5	36	71	69	11	24
1988	9	45	61	67	9	18
1989	0	31	38	40	3	16
1990	4	41	65	58	6	42
1991	6	19	70	72	20	79
1992	12	24	33	36	4	17
1993	37	55	91	88	10	32
1994	7	66	69	65	16	55
1995	11	54	126	74	3	110
1996	14	61	84	86	3	79
Averages:						
1976–1985	9	87	142	141	10	23
1986–1995	9	43	69	62	8	40
1976–1996	9	65	105	101	9	34

Table 37.–Estimated coefficients of variation (CV) for annual total run estimates of Klukshu River chinook salmon by age, calculated by using the 100% assumption to apportion U.S. Alsek fishery harvests for 1976–1996.

Year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	Estimated total run	Estimated CV of total run
1976		28.0%	14.2%	8.8%		1,849	0.5%
1977	53.1%	7.9%	8.2%	9.4%	88.5%	4,633	0.3%
1978		18.7%	7.0%	11.3%		5,486	0.3%
1979		24.3%	8.5%	9.5%		7,304	0.9%
1980		58.7%	13.7%	7.8%		4,167	0.6%
1981		23.9%	14.6%	10.0%	60.2%	3,029	0.8%
1982	65.9%	14.2%	7.3%	7.3%	100.0%	3,116	0.9%
1983	100.0%	47.3%	5.6%	14.7%		2,802	0.6%
1984	58.4%	32.4%	9.7%	7.5%	66.1%	1,911	1.0%
1985	100.0%	22.9%	8.7%	11.0%		1,806	0.7%

-continued-

Table 37.–(continued)

Year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	Estimated total run	Estimated CV of total run
1986	100.0%	8.8%	3.2%	10.0%		3,300	0.3%
1987	70.4%	16.6%	3.9%	5.9%	66.5%	3,218	0.8%
1988	79.9%	13.1%	8.4%	4.9%	91.1%	2,447	0.7%
1989		5.4%	4.1%	2.9%	45.1%	2,855	0.6%
1990	107.4%	14.6%	4.9%	7.3%	63.8%	2,406	1.7%
1991	53.7%	20.9%	5.4%	4.3%	22.8%	3,154	2.5%
1992	24.5%	8.0%	6.5%	3.9%	44.3%	1,795	1.0%
1993	24.1%	11.3%	5.2%	6.1%	60.0%	3,843	0.8%
1994	61.6%	3.9%	4.1%	4.4%	26.8%	4,941	1.1%
1995	41.8%	8.3%	2.3%	7.2%	70.6%	7,124	1.5%
1996	36.3%	6.1%	4.3%	4.4%	52.4%	4,938	1.6%
Averages:							
1976–1985	75.5%	27.8%	9.8%	9.7%	78.7%	3,610	0.7%
1986–1995	62.6%	11.1%	4.8%	5.7%	54.6%	3,508	1.1%
1976–1996	65.1%	18.8%	7.1%	7.6%	61.3%	3,625	0.9%

Table 38.–Estimated annual total runs of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 55% assumption to apportion U.S. Alsek fishery harvests.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run[a]
1976	0	147	540	926	0	1,613
1977	48	1,260	1,447	1,220	20	3,994
1978	0	563	2,430	1,394	0	4,388
1979	0	531	2,954	2,647	0	6,132
1980	0	85	1,216	2,218	0	3,519
1981	0	331	874	1,382	78	2,664
1982	29	408	1,209	1,188	4	2,837
1983	2	80	1,956	708	0	2,746
1984	31	93	745	993	28	1,890
1985	16	171	843	673	0	1,703
1986	2	525	2,026	521	0	3,074
1987	4	204	1,714	1,112	16	3,050
1988	10	313	692	1,316	10	2,341
1989	0	522	877	1,338	6	2,743
1990	4	260	1,283	778	9	2,333
1991	9	80	1,259	1,655	88	3,090
1992	48	235	475	891	4	1,653
1993	155	422	1,674	1,423	17	3,691
1994	11	1,431	1,567	1,476	52	4,538
1995	22	561	5,208	1,006	2	6,800
1996	35	847	1,839	1,842	5	4,569
Averages:						
1976–1985	13	367	1,421	1,335	13	3,149
1986–1995	26	455	1,678	1,151	20	3,331
1976–1996	20	432	1,563	1,272	16	3,303

[a] Annual total return estimates developed by adding Klukshu River weir counts of chinook salmon to estimated chinook salmon harvests downstream that were apportioned to the Klukshu run. Annual harvests included: (1) 55% of the U.S. Alsek fishery harvests of chinook salmon, (2) 70% of Canadian Klukshu/Dalton Post sport fishery harvests, and (3) 95% of the Canadian aboriginal fishery harvests downstream of the Klukshu River weir (1991–1996 only).

Table 39.–Estimated standard errors for annual total run estimates of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 55% assumption to apportion U.S. Alsek fishery harvests. Estimated annual standard errors include variances for (1) estimating age proportions in the U.S. Alsek fishery; (2) U.S. commercial and subsistence harvest (CV = 30%); (3) estimating age proportion in the Canadian fisheries downstream of the weir; (4) estimating Canadian aboriginal fishery harvests downstream of Klukshu River weir (harvests assumed to have CV = 20%); and (5) estimating Canadian sport fishery harvests occurring downstream of Klukshu River weir (harvests assumed to have CV = 10%). Klukshu River weir counts and brood stock removals were assumed to be censuses.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run
1976	0	47	82	86	0	87
1977	28	116	123	118	18	235
1978	0	121	176	163	0	403
1979	0	149	265	262	0	434
1980	0	58	180	182	0	238
1981	0	92	136	144	50	135
1982	19	64	92	92	6	103
1983	2	40	111	107	0	25
1984	19	32	73	75	18	21
1985	16	44	78	76	0	40
1986	2	52	67	53	0	83
1987	3	36	70	68	11	66
1988	9	45	61	67	9	43
1989	0	30	37	39	3	44
1990	4	39	63	56	6	42
1991	6	18	70	71	20	82
1992	12	23	32	35	3	55
1993	37	54	90	88	10	63
1994	7	61	66	65	15	155
1995	11	53	125	74	2	161
1996	14	59	84	85	3	156
Averages:						
1976–1985	8	76	132	131	9	172
1986–1995	9	41	68	62	8	79
1976–1996	9	59	99	96	8	127

Table 40.–Estimated coefficients of variation (CV) for annual total run estimates of Klukshu River chinook salmon by age, calculated by using the 55% assumption to apportion U.S. Alsek fishery harvests for 1976–1996.

Year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	Estimated total run	Estimated CV of total run
1976		32.1%	15.2%	9.2%		1,613	5.4%
1977	57.9%	9.2%	8.5%	9.7%	92.8%	3,994	5.9%
1978		21.5%	7.2%	11.7%		4,388	9.2%
1979		28.1%	9.0%	9.9%		6,132	7.1%
1980		67.5%	14.8%	8.2%		3,519	6.8%
1981		27.7%	15.5%	10.4%	63.9%	2,664	5.1%
1982	65.9%	15.7%	7.6%	7.7%	134.3%	2,837	3.6%
1983	130.0%	50.2%	5.7%	15.1%		2,746	0.9%
1984	60.0%	33.9%	9.8%	7.6%	66.1%	1,890	1.1%
1985	100.0%	25.9%	9.2%	11.3%		1,703	2.3%

-continued-

Table 40.–(continued)

Year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	Estimated total run	Estimated CV of total run
1986	129.0%	9.8%	3.3%	10.2%		3,074	2.7%
1987	90.9%	17.4%	4.1%	6.1%	66.5%	3,050	2.2%
1988	86.2%	14.3%	8.8%	5.1%	91.1%	2,341	1.8%
1989		5.8%	4.2%	2.9%	45.1%	2,743	1.6%
1990	107.4%	14.9%	4.9%	7.2%	63.8%	2,333	1.8%
1991	65.2%	23.1%	5.5%	4.3%	23.0%	3,090	2.7%
1992	25.0%	9.7%	6.8%	4.0%	57.0%	1,653	3.3%
1993	24.1%	12.7%	5.4%	6.2%	60.0%	3,691	1.7%
1994	61.6%	4.2%	4.2%	4.4%	28.1%	4,538	3.4%
1995	48.1%	9.4%	2.4%	7.4%	90.9%	6,800	2.4%
1996	39.1%	7.0%	4.5%	4.6%	52.4%	4,569	3.4%
Averages:							
1976–1985	82.8%	31.2%	10.3%	10.1%	89.3%	3,149	4.7%
1986–1995	70.8%	12.1%	5.0%	5.8%	58.4%	3,331	2.4%
1976–1996	72.7%	21.0%	7.5%	7.8%	66.8%	3,303	3.5%

Table 41.–Estimated annual total runs of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 30% assumption to apportion U.S. Alsek fishery harvests.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run[a]
1976	0	122	498	862	0	1,482
1977	43	1,068	1,357	1,153	19	3,639
1978	0	421	2,121	1,235	0	3,778
1979	0	412	2,655	2,414	0	5,481
1980	0	67	1,085	2,008	0	3,160
1981	0	276	813	1,299	73	2,461
1982	29	371	1,156	1,125	2	2,683
1983	1	77	1,941	696	0	2,715
1984	30	91	739	991	28	1,879
1985	16	156	812	661	0	1,646
1986	1	479	1,955	513	0	2,948
1987	2	196	1,656	1,086	16	2,956
1988	10	295	674	1,293	10	2,282
1989	0	493	853	1,329	6	2,681
1990	4	246	1,265	768	9	2,292
1991	7	73	1,242	1,645	87	3,055
1992	47	197	456	871	2	1,574
1993	155	387	1,635	1,412	17	3,607
1994	11	1,279	1,514	1,461	49	4,314
1995	20	511	5,095	992	1	6,619
1996	33	760	1,773	1,791	5	4,363
Averages:						
1976–1985	12	306	1,318	1,244	12	2,892
1986–1995	26	416	1,634	1,137	20	3,233
1976–1996	19	380	1,490	1,219	15	3,124

[a] Annual total return estimates developed by adding Klukshu River weir counts of chinook salmon to estimated chinook salmon harvests downstream that were apportioned to the Klukshu run. Annual chinook salmon harvests included: (1) 30% of the U.S. Alsek fishery harvests of chinook salmon; (2) 70% of Canadian Klukshu/Dalton Post sport fishery harvests; and (3) 95% of the Canadian aboriginal fishery harvests downstream of the Klukshu River weir (1991–1996 only).

associated with these estimates are relatively small (Table 42) and coefficients of variation are relatively small (average CV = 3%; Table 43). In all cases, the vast majority of the total runs of chinook salmon are estimated to have accrued to the escapement (Figure 8). These annual escapements, coupled with the aboriginal harvest above the weir, are considered a census, leading to very precise estimates of the total annual runs of chinook salmon to the Klukshu River system under all three U.S. Alsek fishery harvest allocation scenario assumptions.

BROOD YEAR RETURNS OF KLUKSHU RIVER CHINOOK SALMON

Age-specific estimates of the annual total runs of Klukshu River chinook salmon were used to develop three paired data sets (one data set for each of the three U.S. harvest allocation assumptions) consisting of estimated brood year escapements for each year *i* in the years 1976 through 1991 and the resultant sum of recruits in years *i*+3, *i*+4, *i*+5, *i*+6, and *i*+7. Because recruitment of age-6 fish from BY 1991 could not be directly summed (return year is 1997), the brood year 1991 total return was estimated as the average of 58% of the total return of age 3–5 fish for brood years 1976–1990. Because age-7 returns are minor (< 5%) for brood years 1976–1989, the brood year return for 1990 was calculated as the total return for ages 3–6 (age-7 fish from brood year 1990 will return in 1997).

Under the 100% assumption, estimated total returns of chinook salmon to the Klukshu River

Table 42.–Estimated standard errors for annual total run estimates of Klukshu River chinook salmon by age, 1976–1996, calculated by using the 30% assumption to apportion U.S. Alsek fishery harvests.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Total run
1976	0	44	80	83	0	48
1977	26	110	120	115	18	129
1978	0	103	159	149	0	220
1979	0	132	249	247	0	242
1980	0	51	170	172	0	131
1981	0	86	132	140	49	76
1982	19	63	91	91	4	57
1983	2	40	111	107	0	18
1984	19	32	73	75	18	20
1985	16	44	77	76	0	24
1986	2	51	66	53	0	46
1987	2	35	70	67	11	41
1988	9	45	60	66	9	27
1989	0	30	37	39	3	27
1990	4	38	62	56	6	36
1991	5	18	70	71	20	80
1992	12	22	32	35	2	33
1993	37	53	90	88	10	43
1994	7	59	65	64	14	94
1995	11	52	124	74	1	127
1996	14	58	83	85	3	107
Averages:						
1976–1985	8	71	126	126	9	96
1986–1995	9	40	68	61	8	55
1976–1996	9	56	96	93	8	77

Estimated annual standard errors include variances for: (1) estimating age proportions in the U.S. Alsek fishery; (2) U.S. commercial and subsistence harvest (CV = 30%); (3) estimating age proportion in the Canadian fisheries downstream of the weir; (4) estimating Canadian aboriginal fishery harvests downstream of Klukshu River weir (harvests assumed to have CV = 20%); and (5) estimating Canadian sport fishery harvests occurring downstream of Klukshu River weir (harvests assumed to have CV = 10%). Klukshu River weir counts and brood stock removals were assumed to be censuses.

Table 43.–Estimated coefficients of variation (CV) for annual total run estimates of Klukshu River chinook salmon by age, calculated by using the 30% assumption to apportion U.S. Alsek fishery harvests for 1976–1996.

Year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	Estimated total run	Estimated CV of total run
1976		35.9%	16.0%	9.6%		1,482	3.2%
1977	61.9%	10.3%	8.8%	10.0%	95.9%	3,639	3.5%
1978		24.5%	7.5%	12.1%		3,778	5.8%
1979		32.1%	9.4%	10.2%		5,481	4.4%
1980		76.6%	15.7%	8.6%		3,160	4.1%
1981		31.3%	16.2%	10.8%	66.6%	2,461	3.1%
1982	65.9%	16.9%	7.9%	8.0%	183.8%	2,683	2.1%
1983	179.5%	52.1%	5.7%	15.4%		2,715	0.7%
1984	61.0%	34.9%	9.9%	7.6%	66.1%	1,879	1.1%
1985	100.0%	28.0%	9.5%	11.5%		1,646	1.4%
1986	175.4%	10.6%	3.4%	10.3%		2,948	1.6%
1987	123.9%	18.0%	4.2%	6.2%	66.5%	2,956	1.4%
1988	90.4%	15.1%	9.0%	5.1%	91.1%	2,282	1.2%
1989		6.1%	4.3%	3.0%	45.1%	2,681	1.0%
1990	107.4%	15.3%	4.9%	7.2%	63.8%	2,292	1.6%
1991	76.7%	24.8%	5.6%	4.3%	23.1%	3,055	2.6%
1992	25.3%	11.2%	7.0%	4.0%	77.5%	1,574	2.1%
1993	24.1%	13.8%	5.5%	6.2%	60.0%	3,607	1.2%
1994	61.6%	4.6%	4.3%	4.4%	29.0%	4,314	2.2%
1995	53.1%	10.2%	2.4%	7.4%	123.4%	6,619	1.9%
1996	40.7%	7.7%	4.7%	4.7%	52.4%	4,363	2.5%
Averages:							
1976–1985	93.7%	34.3%	10.7%	10.4%	103.1%	2,892	3.0%
1986–1995	82.0%	13.0%	5.1%	5.8%	64.4%	3,233	1.7%
1976–1996	83.1%	22.9%	7.7%	7.9%	74.6%	3,124	2.3%

system have averaged 3,166 chinook salmon from the 1976–1990 brood years, ranging from the lowest return of 1,550 chinook salmon from the 1980 brood year to the highest return of 9,207 chinook salmon from the 1990 brood year (Table 44). Coefficients of variation for 1976–1990 brood year return estimates under the 100% assumption averaged 8.7% (Table 45). Estimated total returns of chinook salmon from brood years 1976–1990 averaged 3,002 fish under the 55% assumption (Table 46); coefficients of variation for these total returns averaged 8.9% (Table 47). Under the 30% assumption, estimated total returns of chinook salmon from brood years 1976–1990 averaged 2,911 fish (Table 48), and coefficients of variation for these estimates averaged 9.1% (Table 49). Trends for the U.S. fishery were very similar for all three assumptions, principally because harvests make up but a small portion of estimated total returns.

SPAWNER-RECRUIT PARAMETERS

The Ricker stock recruitment curve (Ricker 1954) has been widely used in population dynamics. Many studies have fit the Ricker curve to spawner-recruit data and then calculated optimum escapement (Hilborn 1985). The Ricker (1975, Appendix III, Curve 1) spawner-recruit model is

$$R = S \alpha e^{-\beta S} \qquad (1)$$

where R = total return of all ages, S = number of large spawners, and α and β = parameters to be estimated. A variation of this model (see below) was used to estimate spawning requirements and other population parameters.

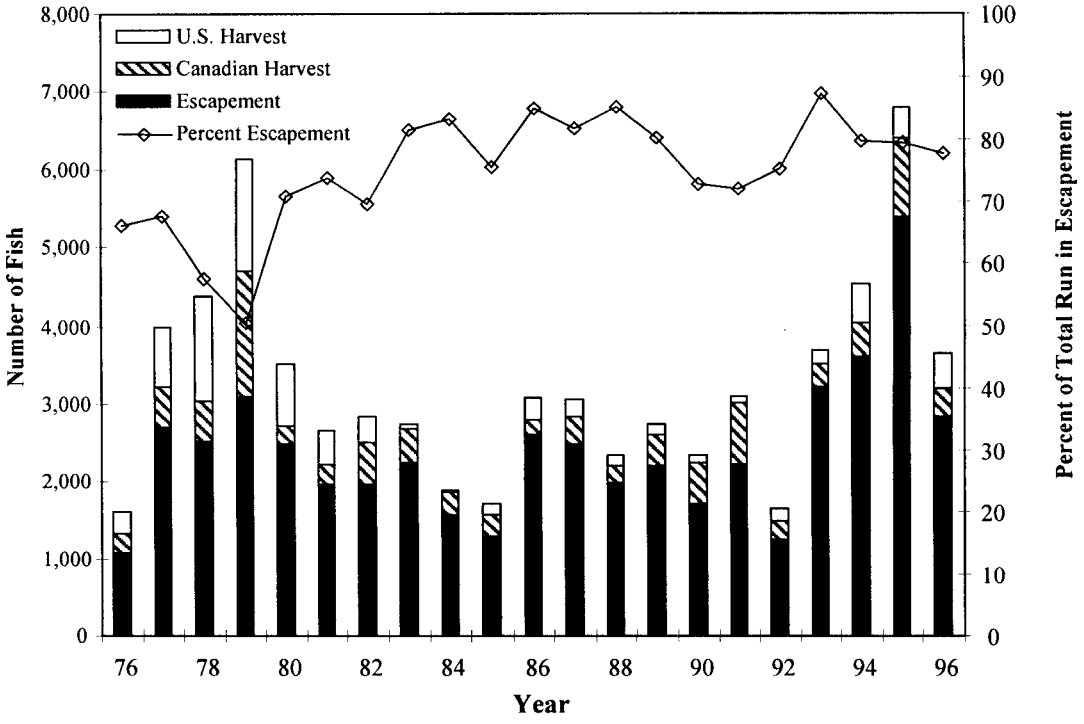

Figure 8.–Estimated total runs of Klukshu River chinook from 1976–1996 (left axis) **with estimated escapements, Canadian harvests and U.S. harvests (assuming that 55% of the U.S. Alsek fishery is composed of Klukshu River origin chinook salmon).**

Parameter α is an estimate of the number of returning adults, from a given spawning adult, in the absence of density dependence, and is a measure of the productivity rate of a stock. The parameter β is a measure of capacity and the inverse of β is the number of spawners that produces the theoretical average maximum return (Pm) for the stock of interest. When estimated, these two parameters are used to calculate expected total return from a given level of spawners. The result is a curvilinear line that is dome-shaped, showing a decrease in total returns to the right of $1/\beta$ (Pm) as the number of spawners increases (Figure 9). The rate of ascent of total returns on the left side of Pm is greater than the rate of descent of total returns on the right side.

Several other parameters of interest to fishery managers can be derived from α and β [see Appendix III, Curve No. 1 in Ricker (1975)]. Optimal escapement (P_S), is estimated by an iterative solution of

$$1 = (1 - \beta P_s)\, \alpha \exp(-\beta P_s) \qquad (2)$$

In Figure 9 (a hypothetical example), the lower diagonal line is the number of spawners, and the difference between spawners and returns (the curved line) is the available harvest. The right-hand side of equation (2) is the slope (first derivative) of equation (1) at a given number of spawners. When the slope = 1.0 (i.e., the tangent at P_S, R_S), the difference between spawners and returns is maximized. This level of spawners (P_S) producing MSY is defined as the biological escapement goal (BEG) by ADF&G in the salmon escapement goal policy adopted in 1992.

Parameters were estimated from nonlinear least squares (steepest descent method) using a modification (natural log transformation) of equation (1):

Table 44.–Estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 100% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	Estimated escapement	Estimated returns by age					Estimated total return
		Age 3	Age 4	Age 5	Age 6	Age 7	
1971	unknown			617	1,339	0	1,956
1972	unknown		191	1,609	1,681	0	3,481
1973	unknown	0	1,605	2,987	3,066	0	7,657
1974	unknown	58	818	3,494	2,598	87	7,055
1975	unknown	0	744	1,450	1,531	7	3,733
1976	1,064	0	119	982	1,302	0	2,404
1977	2,698	0	429	1,303	730	28	2,489
1978	2,530	0	475	1,983	998	0	3,457
1979	3,104	29	85	754	694	0	1,563
1980	2,487	3	98	898	535	16	1,550
1981	1,963	32	198	2,155	1,158	10	3,553
1982	1,969	16	607	1,819	1,356	6	3,804
1983	2,237	3	219	724	1,353	9	2,307
1984	1,572	7	346	920	794	89	2,155
1985	1,283	11	576	1,316	1,672	8	3,583
1986	2,607	0	284	1,289	926	17	2,516
1987	2,491	4	92	510	1,443	58	2,107
1988	1,994	12	302	1,744	1,503	4	3,564
1989	2,202	49	483	1,664	1,031	5	3,233
1990	1,698	155	1,705	5,412	1,935		9,207
1991	2,223	11	650	1,957			4,514[a]
Statistics for 1976–1990:							
Averages	2,127	21	401	1,565	1,162	18	3,166
Minimum	1,064	0	85	510	535	0	1,550
Maximum	3,104	155	1,705	5,412	1,935	89	9,207

[a] BY 1991 total return estimated as the average of 58% of total return at age 3–5 for BY 1976–1990.

$$\ln(\hat{R}_i)=\ln(\hat{\alpha})+\ln(\hat{S}_i)-\hat{\beta}\hat{S}_i+\varepsilon_i \qquad (3)$$

where ln ($\hat{R}_i$) = the natural log of estimated total returns for brood *i;* ln ($\hat{S}_i$) = the natural log of estimated large spawners in brood year *i;*

$$\varepsilon_i=\frac{\ln(\hat{R}_i)-\ln(R^+)}{\sqrt{\left(1-\frac{z}{n}\right)}};$$

R^+ is the predicted return for a given stock, using the estimated α and β for that stock and data set; *z* is the number of parameters estimated (two); and *n* is the number of brood years in the data set. The denominator for estimating ε is a correction factor for bias of residuals, used in the bootstrap section below (Wu 1986).

Three paired data sets consisting of the estimated escapements and the total returns produced from these escapements for brood years 1976–1991 (n = 16 per set) were used to develop spawner-recruit relationships by fitting these paired data sets with the above model.

Three spawner-recruit relationships were developed, one for each of the three alternate U.S. Alsek fishery allocation assumptions. Once these spawner-recruit relationships were calculated, a series of parameters were estimated including: (1) carrying capacity, or the point on the modeled spawner-recruit line where it intersects the replacement line; (2) the estimated escapement that produces the maximum number of recruits, or highest point on the curve (estimated maximum recruitment escapement); and (3) the optimum

Table 45.–Coefficients of variation (CV) for estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 100% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	CV for estimated total return	95% RP for estimated total return
1971			14.2%	9.4%	0.0%	7.8%	15.3%
1972		28.0%	8.2%	11.3%	0.0%	6.8%	13.4%
1973	0.0%	7.9%	7.0%	9.5%	0.0%	5.0%	9.7%
1974	53.1%	18.7%	8.5%	7.8%	60.2%	5.6%	11.0%
1975	0.0%	24.3%	13.7%	10.0%	100.0%	8.3%	16.2%
1976	0.0%	58.7%	14.6%	7.3%	0.0%	7.7%	15.2%
1977	0.0%	23.9%	7.3%	14.7%	66.1%	7.1%	13.9%
1978	0.0%	14.2%	5.6%	7.5%	0.0%	4.3%	8.5%
1979	65.9%	47.3%	9.7%	11.0%	0.0%	7.4%	14.4%
1980	100.0%	32.4%	8.7%	10.0%	66.5%	6.5%	12.8%
1981	58.4%	22.9%	3.2%	5.9%	91.1%	3.1%	6.0%
1982	100.0%	8.8%	3.9%	4.9%	45.1%	3.0%	5.8%
1983	100.0%	16.6%	8.4%	2.9%	63.8%	3.5%	6.9%
1984	70.4%	13.1%	4.1%	7.3%	22.8%	3.9%	7.7%
1985	79.9%	5.4%	4.9%	4.3%	44.3%	2.8%	5.6%
1986	0.0%	14.6%	5.4%	3.9%	60.0%	3.6%	7.0%
1987	107.4%	20.9%	6.5%	6.1%	26.8%	4.6%	9.1%
1988	53.7%	8.0%	5.2%	4.4%	70.6%	3.2%	6.3%
1989	24.5%	11.3%	4.1%	7.2%	52.4%	3.6%	7.0%
1990	24.1%	3.9%	2.3%	4.4%		1.8%	3.6%
1991	61.6%	8.3%	4.3%			2.2%	4.4%
Statistics for 1976–1990:							
Averages	52.3%	20.1%	6.3%	6.8%	43.5%	4.4%	8.7%
Minimum	0.0%	3.9%	2.3%	2.9%	0.0%	1.8%	3.6%
Maximum	107.4%	58.7%	14.6%	14.7%	91.1%	7.7%	15.2%

Table 46.–Estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 55% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	Estimated escapement	Estimated returns by age					Estimated total return
		Age 3	Age 4	Age 5	Age 6	Age 7	
1971	unknown			540	1,220	0	1,760
1972	unknown		147	1,447	1,394	0	2,988
1973	unknown	0	1,260	2,430	2,647	0	6,337
1974	unknown	48	563	2,954	2,218	78	5,862
1975	unknown	0	531	1,216	1,382	4	3,132
1976	1,064	0	85	874	1,188	0	2,147
1977	2,698	0	331	1,209	708	28	2,275
1978	2,530	0	408	1,956	993	0	3,358
1979	3,104	29	80	745	673	0	1,526
1980	2,487	2	93	843	521	16	1,475
1981	1,963	31	171	2,026	1,112	10	3,350
1982	1,969	16	525	1,714	1,316	6	3,577

-continued-

Table 46.–(continued)

Brood year	Estimated escapement	Estimated returns by age					Estimated total return
		Age 3	Age 4	Age 5	Age 6	Age 7	
1983	2,237	2	204	692	1,338	9	2,244
1984	1,572	4	313	877	778	88	2,059
1985	1,283	10	522	1,283	1,655	4	3,475
1986	2,607	0	260	1,259	891	17	2,426
1987	2,491	4	80	475	1,423	52	2,034
1988	1,994	9	235	1,674	1,476	2	3,395
1989	2,202	48	422	1,567	1,006	5	3,048
1990	1,698	155	1,431	5,208	1,842		8,637
1991	2,223	11	561	1,839			4,156[a]
Statistics for 1976–1990:							
Averages	2,127	21	344	1,493	1,128	17	3,002
Minimum	1,064	0	80	475	521	0	1,475
Maximum	3,104	155	1,431	5,208	1,842	88	8,637

[a] BY 1991 total return estimated as the average of 58% of total return at age 3–5 for BY 1976–1990.

Table 47.–Coefficients of variation (CV) for estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 55% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	CV for estimated total return	95% RP for estimated total return
1971			15.2%	9.7%	0.0%	8.2%	16.1%
1972		32.1%	8.5%	11.7%	0.0%	7.0%	13.8%
1973	0.0%	9.2%	7.2%	9.9%	0.0%	5.3%	10.4%
1974	57.9%	21.5%	9.0%	8.2%	63.9%	5.9%	11.6%
1975	0.0%	28.1%	14.8%	10.4%	134.3%	8.8%	17.2%
1976	0.0%	67.5%	15.5%	7.7%	0.0%	8.1%	15.9%
1977	0.0%	27.7%	7.6%	15.1%	66.1%	7.4%	14.6%
1978	0.0%	15.7%	5.7%	7.6%	0.0%	4.4%	8.7%
1979	65.9%	50.2%	9.8%	11.3%	0.0%	7.5%	14.7%
1980	130.0%	33.9%	9.2%	10.2%	66.5%	6.8%	13.3%
1981	60.0%	25.9%	3.3%	6.1%	91.1%	3.2%	6.3%
1982	100.0%	9.8%	4.1%	5.1%	45.1%	3.1%	6.1%
1983	129.0%	17.4%	8.8%	2.9%	63.8%	3.6%	7.1%
1984	90.9%	14.3%	4.2%	7.2%	23.0%	4.1%	7.9%
1985	86.2%	5.8%	4.9%	4.3%	57.0%	2.9%	5.6%
1986	0.0%	14.9%	5.5%	4.0%	60.0%	3.6%	7.1%
1987	107.4%	23.1%	6.8%	6.2%	28.1%	4.8%	9.3%
1988	65.2%	9.7%	5.4%	4.4%	90.9%	3.3%	6.5%
1989	25.0%	12.7%	4.2%	7.4%	52.4%	3.7%	7.3%
1990	24.1%	4.2%	2.4%	4.6%		1.9%	3.8%
1991	61.6%	9.4%	4.5%			2.4%	4.7%
Statistics for 1976–1990:							
Averages	58.9%	22.2%	6.5%	6.9%	46.0%	4.6%	8.9%
Minimum	0.0%	4.2%	2.4%	2.9%	0.0%	1.9%	3.8%
Maximum	130.0%	67.5%	15.5%	15.1%	91.1%	8.1%	15.9%

Table 48.–Estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 30% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	Estimated escapement	Estimated returns by age					Estimated total return
		Age 3	Age 4	Age 5	Age 6	Age 7	
1971	unknown			498	1,153	0	1,651
1972	unknown		122	1,357	1,235	0	2,714
1973	unknown	0	1,068	2,121	2,414	0	5,603
1974	unknown	43	421	2,655	2,008	73	5,199
1975	unknown	0	412	1,085	1,299	2	2,799
1976	1,064	0	67	813	1,125	0	2,005
1977	2,698	0	276	1,156	696	28	2,156
1978	2,530	0	371	1,941	991	0	3,302
1979	3,104	29	77	739	661	0	1,506
1980	2,487	1	91	812	513	16	1,433
1981	1,963	30	156	1,955	1,086	10	3,238
1982	1,969	16	479	1,656	1,293	6	3,450
1983	2,237	1	196	674	1,329	9	2,209
1984	1,572	2	295	853	768	87	2,006
1985	1,283	10	493	1,265	1,645	2	3,415
1986	2,607	0	246	1,242	871	17	2,376
1987	2,491	4	73	456	1,412	49	1,994
1988	1,994	7	197	1,635	1,461	1	3,301
1989	2,202	47	387	1,514	992	5	2,945
1990	1,698	155	1,279	5,095	1,791		8,320
1991	2,223	11	511	1,773			3,958[a]
Statistics for 1976–1990:							
Averages	2,127	20	312	1,454	1,109	16	2,911
Minimum	1,064	0	67	456	513	0	1,433
Maximum	3,104	155	1,279	5,095	1,791	87	8,320

[a] BY 1991 total return estimated as the average of 58% of total return at age 3–5 for BY 1976–1990.

escapement, or the point on the modeled spawner-recruit line where harvestable surplus is at a maximum (estimated MSY escapement). Use of the 100% assumption resulted in an estimate of optimum escapement for the Klukshu River system chinook salmon stock at 893 fish (Table 50).

The spawner-recruit relationship developed indicated that maximum surplus yield from the Klukshu River system chinook salmon stock is about 2,800 fish, and, if managed at the indicated optimum escapement, the sustainable exploitation rate would be about 75% and this yield would be provided indefinitely. Replacement escapement, or the point in the spawner-recruit relationship where harvestable surplus fell to zero, was 2,553 chinook salmon, and maximum stock size occurred with an escapement level of 1,186 chinook salmon in the escapement.

Use of the 55% and the 30% assumptions resulted in spawner-recruitment statistics for the Klukshu River system chinook salmon stock that were quite similar to the 100% model, indicating that the spawner-recruitment relationship is insensitive to how the U.S. Alsek fishery was allocated to the Klukshu versus non-Klukshu components (within the range of assumptions used for allocating U.S. Alsek harvests, 30–100%). Estimated optimum escapements from the three spawner-recruitment relationships ranged from 887 to 893 fish; estimated replacement escapements ranged from 2,464 to 2,553 fish; and estimated maximum recruitment escapements ranged from 1,186 to 1,228 fish (Table 50). Estimated maximum sustainable yields for the Klukshu River system

Table 49.–Coefficients of variation (CV) for estimated brood year (BY) returns of Klukshu River chinook salmon by age, calculated by using the 30% assumption to apportion U.S. Alsek fishery harvests for BY 1971–1991.

Brood year	CV for age 3	CV for age 4	CV for age 5	CV for age 6	CV for age 7	CV for estimated total return	95% RP for estimated total return
1971			16.0%	10.0%	0.0%	8.5%	16.6%
1972		35.9%	8.8%	12.1%	0.0%	7.2%	14.2%
1973	0.0%	10.3%	7.5%	10.2%	0.0%	5.6%	11.0%
1974	61.9%	24.5%	9.4%	8.6%	66.6%	6.3%	12.3%
1975	0.0%	32.1%	15.7%	10.8%	183.8%	9.2%	18.0%
1976	0.0%	76.6%	16.2%	8.0%	0.0%	8.4%	16.4%
1977	0.0%	31.3%	7.9%	15.4%	66.1%	7.7%	15.1%
1978	0.0%	16.9%	5.7%	7.6%	0.0%	4.5%	8.8%
1979	65.9%	52.1%	9.9%	11.5%	0.0%	7.6%	14.9%
1980	179.5%	34.9%	9.5%	10.3%	66.5%	6.9%	13.6%
1981	61.0%	28.0%	3.4%	6.2%	91.1%	3.3%	6.4%
1982	100.0%	10.6%	4.2%	5.1%	45.1%	3.2%	6.3%
1983	175.4%	18.0%	9.0%	3.0%	63.8%	3.6%	7.1%
1984	123.9%	15.1%	4.3%	7.2%	23.1%	4.1%	8.1%
1985	90.4%	6.1%	4.9%	4.3%	77.5%	2.9%	5.7%
1986	0.0%	15.3%	5.6%	4.0%	60.0%	3.7%	7.2%
1987	107.4%	24.8%	7.0%	6.2%	29.0%	4.8%	9.5%
1988	76.7%	11.2%	5.5%	4.4%	123.4%	3.4%	6.7%
1989	25.3%	13.8%	4.3%	7.4%	52.4%	3.8%	7.5%
1990	24.1%	4.6%	2.4%	4.7%		2.0%	3.9%
1991	61.6%	10.2%	4.7%			2.5%	4.9%
Statistics for 1976–1990:							
Averages	68.6%	24.0%	6.7%	7.0%	49.9%	4.7%	9.1%
Minimum	0.0%	4.6%	2.4%	3.0%	0.0%	2.0%	3.9%
Maximum	179.5%	76.6%	16.2%	15.4%	123.4%	8.4%	16.4%

chinook salmon stock ranged from 2,316 to 2,729 fish and indicated optimal exploitation rates to achieve MSY with OY escapements ranged from 72% to 75%. Because these estimates are likely biased without some correction for measurement and process error, and because of the lack of experience of observed returns from spawners below 1,064 fish, we proceeded with further spawner-recruit analyses detailed below.

BOOTSTRAP ANALYSIS OF SPAWNER-RECRUIT PARAMETERS

Both the variance (mean square error) and confidence intervals for $\hat{\alpha}$, $\hat{\beta}$ and $\hat{P}_s$ under each of the three U.S. Alsek fishery harvest allocation assumptions were estimated with modifications of bootstrap procedures in McPherson (1990).

Three bootstraps, each consisting of 1,000 replicates were run, one for each of the assumptions concerning the U.S. Alsek fishery allocation. Error structure for Y (total returns) was assumed to be multiplicative-lognormal, and error structure of X (escapements) was assumed to be multiplicative (Walters and Ludwig 1981). Walters and Ludwig (1981) showed that multiplicative error structure for escapements, either normally or uniformly distributed, produced essentially the same results.

For each bootstrap run, the original data set (Table 51) was fit using equation (3), and bias corrected residuals (ε_i) were stored. For each replicate, the same number of X and Y observations in the original data set were calculated. Each Y observation in a replicate was calculated as $R_i^* = R_i^+ + \varepsilon$ (selected at random with

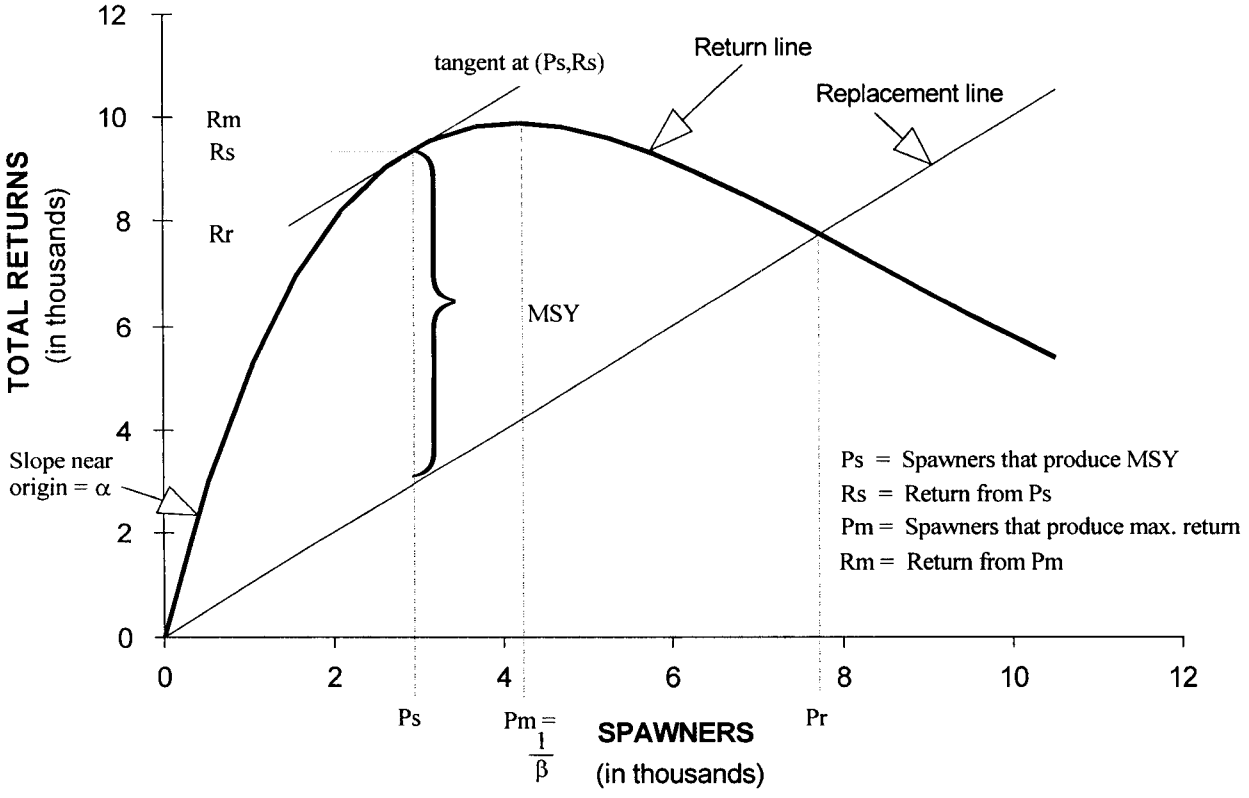

Figure 9.–Ricker curve illustrating spawners (P) and total returns (R) at replacement (r), maximum return (m) and maximum sustained yield (s) levels.

replacement). Each X observation was calculated as $S_i^* = S_i\, p^*$, where p^* was a random number 1.0 $\pm$ Xvar, where Xvar was conservatively estimated at 0.10 for Klukshu escapements (±10% spawner variation). A new set of statistics $\{S_i^*, R_i^*\}$ along with new estimates for $\hat{P}_s^*$, $\hat{\alpha}^*$ and $\hat{\beta}^*$ were generated from each bootstrap sample, and 1,000 such bootstrap samples were drawn, creating the empirical distributions $\hat{F}(\hat{P}_s^*), \hat{F}(\hat{\alpha}), \hat{F}(\hat{\beta})$, which are estimates of $\mathrm{F}(P_s^*)$, $\mathrm{F}(\hat{\alpha})$, and $\mathrm{F}(\hat{\beta})$. The difference between the average of bootstrap estimates and the original estimate is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2).

Confidence intervals were estimated from $\hat{F}(\hat{P}_s^*), \hat{F}(\hat{\alpha}), \hat{F}(\hat{\beta})$ with the percentile method (Efron and Tibshirani 1993, Section 13.3).

Variance was estimated as

$$v(\hat{P}_s^*) = (B-1)^{-1} \sum_{b=1}^{B} \left(\hat{P}_{s(b)}^* - \overline{\hat{P}}_s^*\right)^2$$

where B is the number of bootstrap samples (1,000). The variance of $\hat{\alpha}^*$ and $\hat{\beta}^*$ was estimated similarly. One method of calculating an escapement goal range is to calculate the range of $0.8(\overline{\hat{P}}_s^*)$, to $1.6(\overline{\hat{P}}_s^*)$, following methodology in Eggers (1993), whereby he calculated optimum escapement and yields over a wide range of management scenarios.

Table 50.–Estimated stock-recruitment parameters and statistics associated with the three models based upon alternate assumptions concerning the proportion of Klukshu origin chinook salmon in the U.S. Alsek fishery. These estimates are from the original data sets and are uncorrected for measurement error.

Stock-recruitment relationship statistic	**100% assumption** concerning Klukshu origin chinook in U.S. Alsek fishery	**55% assumption** concerning Klukshu origin chinook in U.S. Alsek fishery	**30% assumption** concerning Klukshu origin chinook in U.S. Alsek fishery
Alpha	8.615	7.856	7.435
Beta	0.00084	0.00083	0.00081
Number of data pairs used	16	16	16
Replacement escapement	2,553	2,498	2,464
Maximum recruitment escapement	1,186	1,212	1,228
Optimum escapement (MSY_{esc})	893	890	887
Estimated maximum yield (MSY)	2,729	2,464	2,316

Table 51.–Spawner-recruit data sets used to estimate optimum escapement of chinook salmon in the Klukshu River system. Each of the three data sets has an alternate assumption concerning the proportion of annual U.S. Alsek fishery harvests that are of Klukshu origin: 100%, 55%, and 30%. These three data sets were used for bootstrap analysis to estimate bias and variance in optimum escapement estimates.

Year	**100% U.S. Alsek harvest assumption**		**55% U.S. Alsek harvest assumption**		**30% U.S. Alsek harvest assumption**	
	Escapement	Recruits	Escapement	Recruits	Escapement	Recruits
1976	1,064	2,404	1,064	2,147	1,064	2,005
1977	2,698	2,489	2,698	2,275	2,698	2,156
1978	2,530	3,457	2,530	3,358	2,530	3,302
1979	3,104	1,563	3,104	1,526	3,104	1,506
1980	2,487	1,550	2,487	1,475	2,487	1,433
1981	1,963	3,553	1,963	3,350	1,963	3,238
1982	1,969	3,804	1,969	3,577	1,969	3,450
1983	2,237	2,307	2,237	2,244	2,237	2,209
1984	1,572	2,155	1,572	2,059	1,572	2,006
1985	1,283	3,583	1,283	3,475	1,283	3,415
1986	2,607	2,516	2,607	2,426	2,607	2,376
1987	2,491	2,107	2,491	2,034	2,491	1,994
1988	1,994	3,564	1,994	3,395	1,994	3,301
1989	2,202	3,233	2,202	3,048	2,202	2,945
1990	1,698	9,207	1,698	8,637	1,698	8,320
1991	2,223	4,514	2,223	4,156	2,223	3,958
Averages	2,133	3,250	2,133	3,074	2,133	2,976

The mean bootstrap estimates of $\overline{\hat{P}}_S^*$ for Klukshu River chinook salmon were 916 for the 100% assumption, 911 for the 55% assumption and 907 for the 30% assumption (Table 52). This estimate of P_S compares favorably to the regression estimates of 893, 890 and 887, respectively, in Table 49, meaning estimated bias is less than 3%. Coefficients of variation associated with the three mean bootstrap estimates of optimum escapement range from 14.9% to 15.6%, indicating that estimates are relatively precise, probably due in large part to the precision of the estimated spawners and recruits (Figure 10). These results would indicate a point estimate of about 900 fish and, based upon the methods of Eggers (1993), a biological escapement goal range of 750–1,500 spawners per year.

MARKOVIAN TABULATION OF SPAWNERS AND TOTAL RETURNS

The indicated optimum escapement from the above analysis of about 900 to 920 spawners was below the lowest observed escapement of 1,064 in 1976, as was the lower end of the estimated range (750 spawners). The upper end of the indicated optimum range (1,500 spawners) was above two of the observed escapements. Because of the risk involved in managing for an escapement below the range of observed escapements, we tabulated the probabilities of total return size from the number of spawners in 500-spawner increments, following a Markovian approach (Hilborn and Walters 1992; Chapter 7), coupled with visual examination of the spawner-recruit graph(s).

From the tabulated probabilities, it is indicated that surplus production was observed only when the spawning stock size was below 2,500 fish and that, as spawning stock size increases, the frequency of low returns increases (Table 53). For example, the estimated average surplus production in total returns—when spawners were between 1,001 and 1,500—was about 1,500 (30% U.S. gillnet) to 1,600 spawners (55% U.S. gillnet). Surplus production was estimated at about 2,200 (30% U.S. gillnet) to 2,400 (55% U.S. gillnet) when parent-year spawners were between 1,501 and 2,000. Four out of five spawning stocks between 1,501 and 2,000 produced total returns greater than 3,000 fish, and all five were above replacement. In contrast, only two of five spawning stocks between 2,001 and 2,500 produced returns greater than 3,000 fish, and three of five were at or below replacement.

Inspection of the observed total returns versus spawners in Figure 10 (with 55% of U.S. gillnet harvests) was used to finetune a management range. All escapements fewer than 2,300 spawners have provided surplus production in 10 observed total returns, and escapements between 1,100 and 2,300 have produced the largest total returns. In contrast, five of the six escapements ≥2,480 spawners have produced returns below replacement and, on average, have produced the lowest total returns in the database.

Based upon these results, we believe it may be prudent to set the biological escapement goal range at 1,100 to 2,300 chinook salmon spawners in the Klukshu River system for the time being. This range has produced the largest returns in the past and will provide an opportunity for harvest to Canadian and U.S. fishers.

If this range of 1,100 to 2,300 is managed for, it will provide us with additional experience for evaluating escapements in the range of 1,000 to 1,500, where only two past escapements have occurred. The returns from the 1992 escapement of 1,243 (not complete until 1999) will likely produce one of the higher returns to date, as it has produced the third highest number of age-1.2 fish (864 fish—with 55% of U.S. gillnet harvest), behind only 1,416 age-1.2 fish for the 1990 brood and 1,260 for the 1973 brood, the two broods with the largest estimated returns in the database (Table 54). Observed returns from escapements above 1,500 spawners are covered: we have estimated returns from 14 escapements between 1,572 and 3,104 and, in addition, the escapements in 1993–1996 were all between 3,200 and 5,400 (Table 54; Figure 11–upper panel). If the past trends of decreasing run size with escapements of over 2,500 continue, returns from some of these escapements may, without

Table 52.–Estimates of selected spawner-recruit parameters (alphas and betas; MSY escapements [MSY_{esc}]) and associated precision for bootstrap data sets used to estimate MSY_{esc} of chinook salmon in the Klukshu River. Three data sets were used, the first assuming 100% of U.S. Alsek harvests were of Klukshu River origin, the second 55% and the third 30%.

	100% U.S. harvest assumption			55% U.S. harvest assumption			30% U.S. harvest assumption		
Statistic	MSY_{esc}	Alpha	Beta	MSY_{esc}	Alpha	Beta	MSY_{esc}	Alpha	Beta
Point estimates	893	8.62	0.00084	890	7.86	0.00083	887	7.44	0.00081
Mean	916	9.52	0.000841	911	8.68	0.000823	907	8.21	0.000812
SD	143	4.84	0.000203	138	4.37	0.000202	135	4.12	0.000202
CV	15.6%	50.8%	24.1%	15.2%	50.4%	24.5%	14.9%	50.2%	24.8%
Median	900	8.35	0.000835	890	7.63	0.000816	890	7.22	0.000803
Lower 95%	710	3.82	0.000451	720	3.46	0.000432	720	3.28	0.000425
Upper 95%	1,220	21.37	0.001236	1,200	19.27	0.001222	1,190	18.53	0.001211
Minimum	620	2.12	0.000170	630	1.93	0.000161	630	1.83	0.000155
Maximum	2,470	38.64	0.001512	2,450	35.22	0.001482	2,440	33.33	0.001464
Number of years	16			16			16		

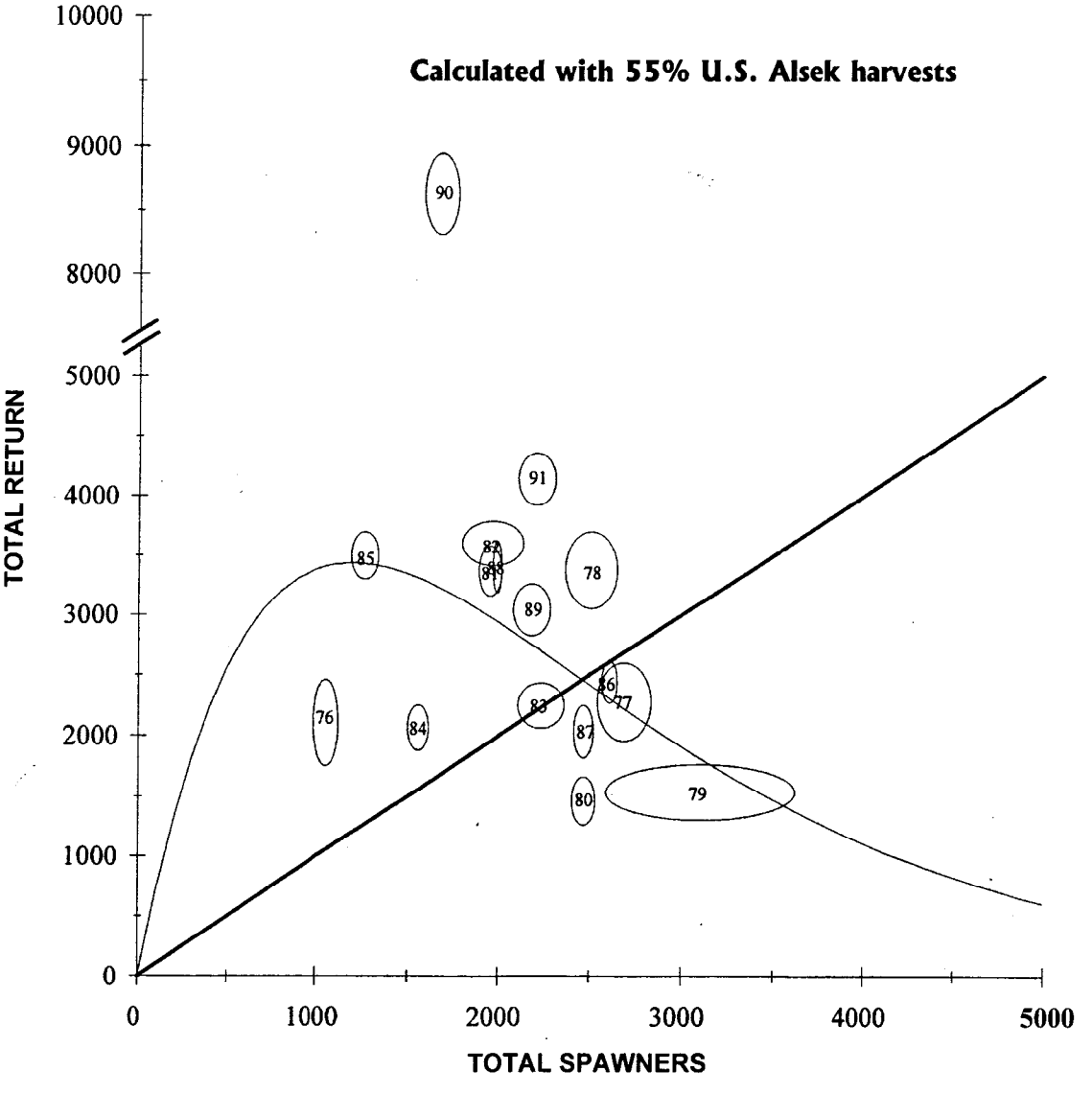

Figure 10.–Estimated spawner-recruit relationship for Klukshu River chinook salmon, 1976–1991 brood years, with estimated 95% confidence intervals for spawners and returns shown around point estimates.

Table 53.–Probability of recruitment for Klukshu River chinook salmon.

PANEL A: TOTAL RETURNS ESTIMATED WITH 30% OF U.S. ALSEK HARVEST INCLUDED

Total return From:	To:	Spawning stock 501–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–3,000	3,001–3,500	Total
8,501	9,000	0	0	0	0	0	0	0
8,001	8,500	0	0	0.2	0	0	0	0.1
7,501	8,000	0	0	0	0	0	0	0
7,001	7,500	0	0	0	0	0	0	0
6,501	7,000	0	0	0	0	0	0	0
6,001	6,500	0	0	0	0	0	0	0
5,501	6,000	0	0	0	0	0	0	0
5,001	5,500	0	0	0	0	0	0	0
4,501	5,000	0	0	0	0	0	0	0
4,001	4,500	0	0	0	0	0	0	0.1
3,501	4,000	0	0	0	0.2	0	0	0.1
3,001	3,500	0	0.5	0.6	0.2	0.3	0	0.3
2,501	3,000	0	0	0	0	0	0	0
2,001	2,500	0	0.5	0.2	0.2	0.7	0	0.4
1,501	2,000	0	0	0	0.2	0	1.0	0.1
1,001	1,500	0	0	0	0.2	0	0	0.1
No. of points		0	2	5	5	3	1	16
Avg. spawners			1,174	1,839	2,328	2,612	3,104	2,133
Avg. total return			2,710	4,063	2,508	2,612	1,506	2,976
Surplus yield			1,536	2,224	180	0	-1,598	843

PANEL B: TOTAL RETURNS ESTIMATED WITH 55% OF U.S. ALSEK HARVEST INCLUDED

Total return From:	To:	Spawning stock 501–1,000	1,001–1,500	1,501–2,000	2,001–2,500	2,501–3,000	3,001–3,500	Total
8,501	9,000	0	0	0.2	0	0	0	0.1
8,001	8,500	0	0	0	0	0	0	0
7,501	8,000	0	0	0	0	0	0	0
7,001	7,500	0	0	0	0	0	0	0
6,501	7,000	0	0	0	0	0	0	0
6,001	6,500	0	0	0	0	0	0	0
5,501	6,000	0	0	0	0	0	0	0
5,001	5,500	0	0	0	0	0	0	0
4,501	5,000	0	0	0	0	0	0	0
4,001	4,500	0	0	0	0.2	0	0	0.1
3,501	4,000	0	0	0.2	0	0	0	0.1
3,001	3,500	0	0.5	0.4	0.2	0.3	0	0.3
2,501	3,000	0	0	0	0	0	0	0
2,001	2,500	0	0.5	0.2	0.4	0.7	0	0.4
1,501	2,000	0	0	0	0	0	1.0	0.1
1,001	1,500	0	0	0	0.2	0	0	0.1
No. of points		0	2	5	5	3	1	16
Avg. spawners			1,174	1,839	2,328	2,612	3,104	2,133
Avg. total return			2,811	4,204	2,591	2,686	1,526	3,074
Surplus yield			1,638	2,364	263	75	-1,578	941

Table 54.–Spawner-recruit table for Klukshu River chinook salmon calculated for 55% of U.S. Alsek harvests, by individual age-class.

Brood year	Brood year escapement	AGE-CLASS (European top row, Gilbert-Rich bottom row)										Estimated total return
		1.1 3(2)	0.3 4(1)	1.2 4(2)	0.4 5(1)	1.3 5(2)	2.2 5(3)	1.4 6(2)	2.3 6(3)	1.5 7(2)	2.4 7(3)	
1971	???	0	0	0	0	540	0	1,220	0	0	0	1,760
1972	???	0	20	127	0	1,447	0	1,394	0	0	0	2,988
1973	???	0	0	1,260	25	2,406	0	2,647	0	0	0	6,337
1974	???	48	0	563	135	2,820	0	2,218	0	11	67	5,862
1975	???	0	135	396	44	1,171	0	1,348	34	4	0	3,132
1976	1,064	0	0	85	34	840	0	1,188	0	0	0	2,147
1977	2,698	0	0	331	0	1,209	0	685	23	0	28	2,275
1978	2,530	0	4	404	0	1,933	23	934	59	0	0	3,358
1979	3,104	29	0	80	0	744	0	673	0	0	0	1,526
1980	2,487	2	0	93	0	843	0	519	2	0	16	1,475
1981	1,963	31	0	171	2	2,024	0	1,104	8	0	10	3,350
1982	1,969	16	217	307	2	1,712	0	1,259	57	0	6	3,577
1983	2,237	2	0	204	0	674	18	1,306	32	0	9	2,244
1984	1,572	4	0	313	0	870	6	725	53	1	87	2,059
1985	1,283	10	0	522	0	1,281	2	1,593	61	0	4	3,475
1986	2,607	0	0	260	2	1,256	0	881	10	0	17	2,426
1987	2,491	4	1	79	30	415	31	1,328	96	19	33	2,034
1988	1,994	9	15	219	1	1,673	0	1,457	19	2	0	3,395
1989	2,202	48	1	420	0	1,519	48	989	17	5	0	3,048
1990	1,698	155	15	1,416	1	5,207	0	1,842	0			8,636
1991	2,223	11	8	553	9	1,812	18					2,410
1992	1,243	22	2	846								871
1993	3,221	35										35
1994	3,620											
1995	5,397											
1996	3,382											
Statistics for 1976–1990 brood years:												
Average	2,127	21		327	5	1,480	9	1,099	29		15	3,002
Minimum	1,064	0		79	0	415	0	519	0		0	1,475
Maximum	3,104	155		1,416	34	5,207	48	1,842	96		87	8,636

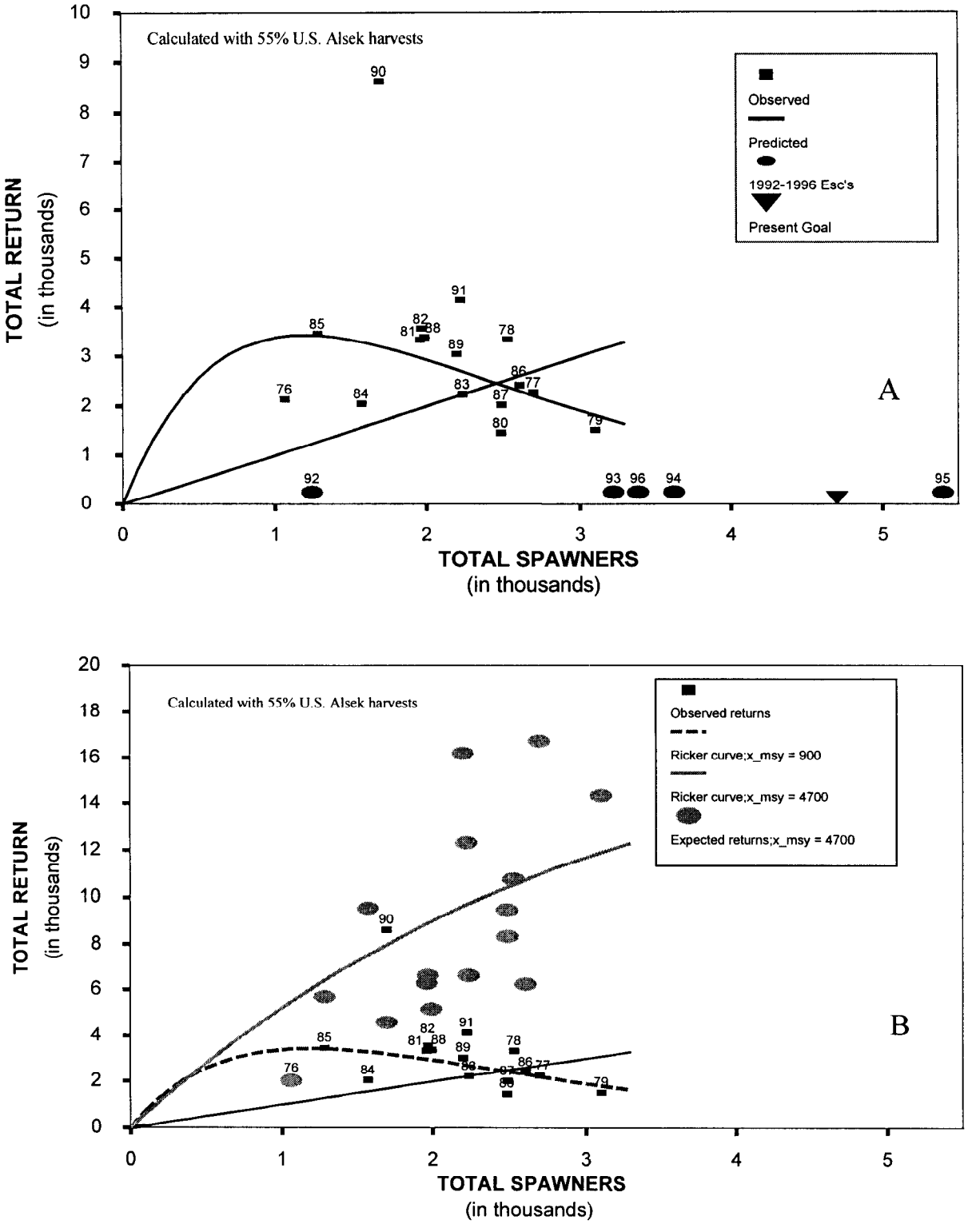

Figure 11.–Spawner-recruit graphs for Klukshu River chinook salmon with observed data, present goal, 1992–1996 escapements, and simulated data for optimum escapement of 4,700.

any change in management, produce escapements in the lower portion of the recommended range.

MINIMIZED LOSS APPROACH

We used methodology of Geiger and Koenings (1991) to determine if a biological escapement goal range of 1,100 to 2,300 spawners is appropriate from an expected loss approach. This methodology utilizes the existing spawner-recruit history, coupled with informative guesses as to what the correct model, i.e., the optimum escapement, ought to be by selecting a range of α and β values in a modified Ricker model. Additionally, prior probabilities can be attached to each α and each β. The prior probabilities and Klukshu spawner-recruit histories are used to construct posterior probabilities for each model. The consequences of choosing an escapement goal are modeled with a loss function, and the expected losses are calculated with the posterior probabilities. Geiger and Koenings recommended using the escapement goal with the lowest expected loss, regardless of which model seems most likely to be correct.

Using notation in Geiger and Koenings (1991), the modified Ricker model form was

$$y_t = \alpha x_t \, exp(-\beta x_t) \, exp(\varepsilon_t)$$

where x_t is spawners in year t, y_t is recruits and exp (ε) represents a random factor describing process error, and α and β represent the parameters of the system. In this case, ε is assumed to be normally distributed with a mean of zero and constant variance, ϕ^2 (i.e., normally distributed natural log residuals in returns), and is assumed that each ε is independently generated. The parameter ϕ is called the process error parameter. We let yield be defined to be $z_t = y_t - x_t$. The optimum is found by solving

$$\frac{dE(z|x)}{dx} = 0$$

to obtain

$$x' = \frac{\alpha \exp(-\beta x' + \phi^2/2) - 1}{\alpha\beta \exp(-\beta x' + \phi^2/2)} = \beta^{-1}\left[1 - \alpha^{-1}\exp(\beta x' - \phi^2/2)\right]$$

where x' is optimum escapement or x_msy, analogous to P_S above.

We chose a wide range of α and β parameters so as to not limit the range of reasonable solutions. We chose five values of α, from 4 to 8, and 16 values of β, from 0.005 to 0.00013, which resulted in a broad range of potential x_msy values ranging from 190 to 4,600 for α = 4 and from 190 to 5,900 for α = 8. Note that for the observed spawner-recruit data, α was estimated between 7 and 8 and β between 0.00081 and 0.00083 for the data sets with 30% and 55% U.S. Alsek gillnet harvest included. We attached the same prior probability to each α and β, so essentially each model was weighted equally before inclusion of the observed spawner-recruit history.

Results showed that large losses would likely occur when escapements were below 500 to 700 spawners or above 2,000 to 2,500 spawners, depending on the value of α; expected losses are very high if more than 3,500 spawners (Figure 12). Closer inspection of the graph shows that expected losses were minimized for x_msy values of about 850 to 1,300 spawners, depending on the value of α (Figure 13). On the left side, expected losses climb rapidly below values of 500 to 700 spawners, with the caveat that we have no experience with spawners below 1,064. On the right side, expected losses clearly climb rapidly above 2,000 spawners for values of α between 4 and 6 and climb sooner for values of α for 7 and 8. The posterior probabilities of α being 5 or 6 were higher than for the other three values of α. In conclusion, we believe this analysis indicates that expected losses will not be substantial in the range of 1,100 to 2,300 spawners, but that losses will likely be less when spawners are held at the lower and middle portions of this range, i.e., from about 1,100 to 1,700 spawners.

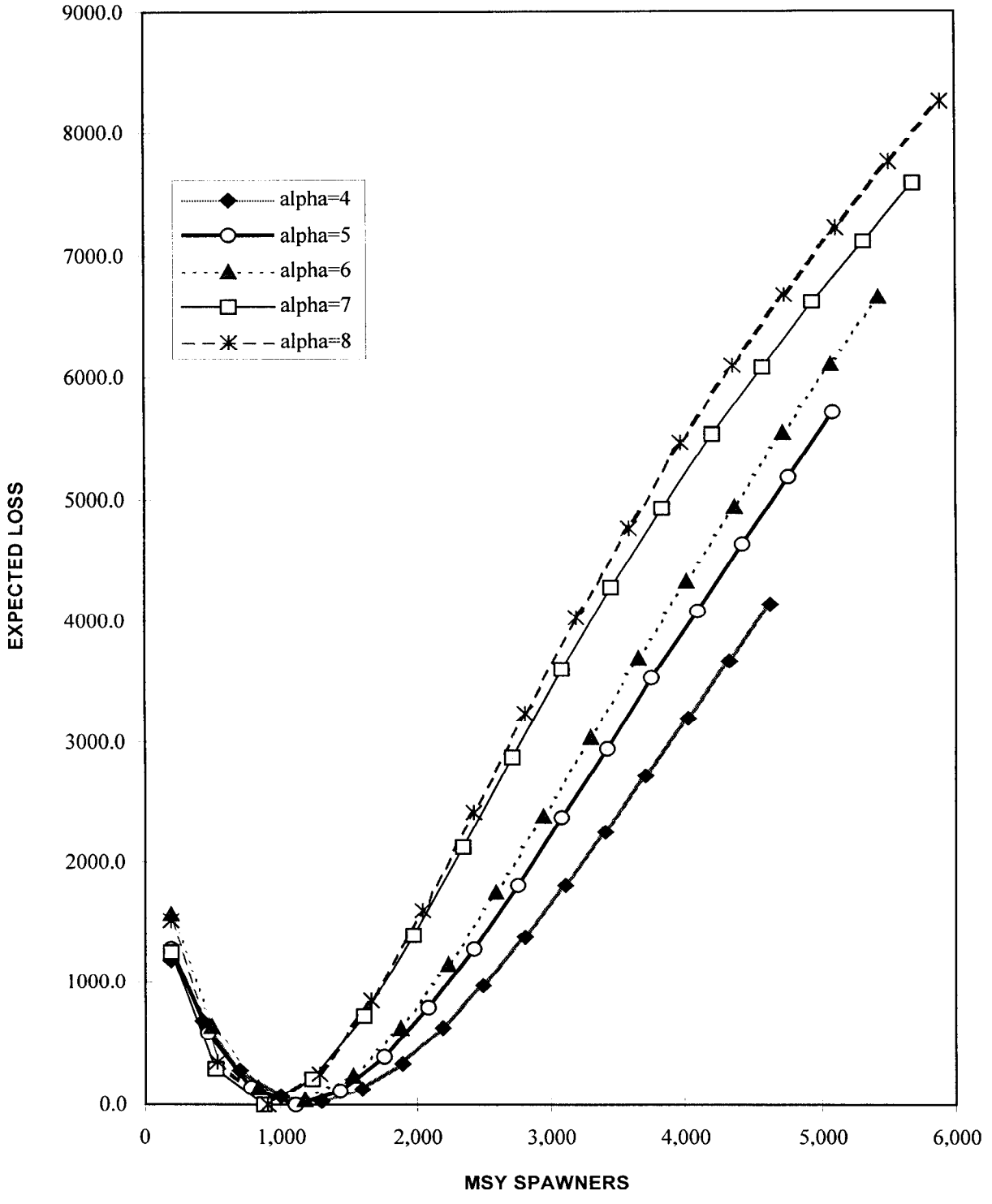

Figure 12.–Expected loss functions for Klukshu River chinook salmon with potential optimum escapements from about 200 to 6,000 spawners.

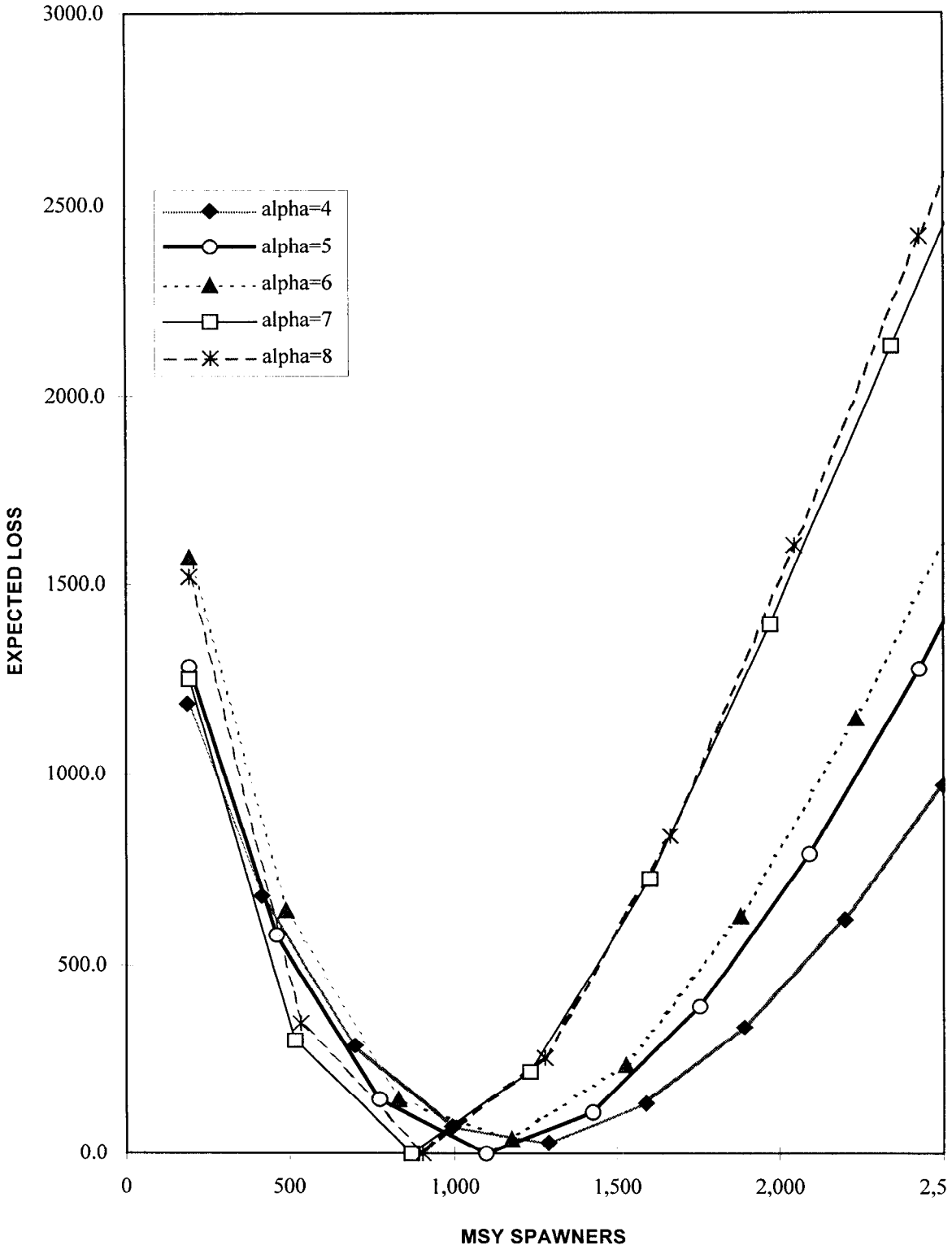

Figure 13.–Expected loss functions for Klukshu River chinook salmon with potential optimum escapements from about 200 to 2,500 spawners.

DISCUSSION

The spawner-recruit database for the Klukshu River chinook salmon stock is one of the best for this species along the eastern Pacific coast, in terms of precision of estimates. One of the biggest obstacles in estimating spawner-recruit parameters is imprecision in estimating the number of spawners and subsequent estimates of recruitment (Walters and Ludwig 1981; Ludwig and Walters 1981). This is not a problem with the Klukshu chinook database, judging from the relatively small 95% confidence intervals around estimates of spawners and returns (Figure 10). Such precision is the result of most (over 75%) of the returns being enumerated through the Klukshu weir and of relatively good age composition samples. Another factor in determining spawner-recruit parameters is the requirement of a relatively wide range of escapements in the database (Ludwig and Walters 1981; Hilborn and Walters 1992, Chapter 7). This is true, but simulated and observed data sets show that the observations which have the largest impact in estimation of spawner-recruit parameters are those from the right-hand side (from large escapements), preferably several observations at 3–5 times the estimated optimum. The range of Klukshu escapements with estimated returns to date is threefold (1,064–3,104) at present and will be fivefold by the year 2001, when the 1995 brood has returned from over 5,000 spawners (see Figure 11–upper panel). Hence, we believe the right-hand side of the graph has been covered.

It is most difficult to estimate spawner-recruit parameters for a severely overexploited population (Walters and Ludwig 1981, Hilborn and Starr 1984). This is not the case for Klukshu River nor Alsek River chinook salmon. Sustainable yields have been ongoing since the turn of the century. Management has been very conservative since the late 1970s. Harvest rates on the Klukshu River stock have been rather modest since 1976, averaging 21% (30% U.S. gillnet) or 25% (55% U.S. gillnet), but 31% at most (100% U.S. gillnet; Table 55). Over the last 16 years (1981–1996), harvest rates have averaged between 19% and 25%. This is a very low harvest rate for spring stocks of chinook salmon up and down the coast (CTC 1996) and would certainly indicate this stock is not overexploited.

It is clear that the previous escapement goal of 4,700 spawners in the Klukshu River is too high. In Figure 11(lower panel) we simulated what a spawner-recruit relationship should look like, assuming that the true optimum escapement is 4,700 spawners and the variation in returns was proportional to that observed for the 1976–1991 brood returns on the Klukshu. These simulated returns bear little resemblance to observed returns for spawning stock sizes ≥2,000 fish. It is also clear that a biological escapement goal range is preferred over a single point estimate, in that the variation in natural survival will exceed the ability to determine any substantive difference between returns from, for example, 1,200 to 1,600 spawners.

The computer data files and analysis programs from which our data were generated appear in Table 56 at the end of this report.

RECOMMENDATIONS

We believe that preserving long-term stock assessment programs should continue to be one of the highest priorities for the Alaska Department of Fish and Game, the Canadian Department of Fisheries and Oceans, and the Pacific Salmon Commission. These types of programs provide information on the basic biology of the resource which is often poorly understood due to the lack of long-term programs coastwide. These programs also provide a continuing time series of data which can be used to understand the causes of abundance fluctuations, allow for comparisons of year-to-year abundance, provide a basis for evaluating status of the resource, and help improve management. Because of the 3 to 7 year life span of chinook salmon, many years of data are necessary to monitor spawning abundance and subsequent returns of a few cohorts, and omission of a single year of data can add uncertainty to an otherwise valid analysis.

We recommend that annual enumeration of chinook salmon escapements in the Klukshu River by weir and enumeration of chinook salmon

Table 55.–Harvest rates for Klukshu River chinook salmon, calculated for 30%, 55% and 100% of the U.S. Alsek harvests.

		30% of U.S. Alsek harvest				55% of U.S. Alsek harvest				100% of U.S. Alsek harvest			
Calendar year	Klukshu escapement	Klukshu total run	U.S. harvest rate (%)	Canadian harvest rate (%)	Total harvest rate (%)	Klukshu total run	U.S. harvest rate (%)	Canadian harvest rate (%)	Total harvest rate (%)	Klukshu total run	U.S. harvest rate (%)	Canadian harvest rate (%)	Total harvest rate (%)
1976	1,064	1,482	10.6	17.6	28.2	1,613	17.9	16.1	34.0	1,849	28.4	14.1	42.5
1977	2,698	3,639	11.7	14.2	25.9	3,994	19.6	12.9	32.5	4,633	30.6	11.1	41.8
1978	2,530	3,778	19.4	13.6	33.0	4,388	30.6	11.7	42.3	5,486	44.5	9.4	53.9
1979	3,104	5,481	14.3	29.1	43.4	6,132	23.4	26.0	49.4	7,304	35.7	21.8	57.5
1980	2,487	3,160	13.7	7.6	21.3	3,519	22.5	6.8	29.3	4,167	34.5	5.8	40.3
1981	1,963	2,461	9.9	10.4	20.2	2,664	16.7	9.6	26.3	3,029	26.8	8.4	35.2
1982	1,969	2,683	6.9	19.7	26.6	2,837	12.0	18.6	30.6	3,116	19.9	16.9	36.8
1983	2,237	2,715	1.4	16.2	17.6	2,746	2.5	16.1	18.5	2,802	4.4	15.7	20.2
1984	1,572	1,879	0.7	15.6	16.3	1,890	1.3	15.5	16.8	1,911	2.4	15.3	17.7
1985	1,283	1,646	4.2	17.9	22.0	1,703	7.4	17.3	24.7	1,806	12.7	16.3	29.0
1986	2,607	2,948	5.1	6.4	11.6	3,074	9.0	6.2	15.2	3,300	15.2	5.8	21.0
1987	2,491	2,956	3.8	11.9	15.7	3,050	6.7	11.6	18.3	3,218	11.6	11.0	22.6
1988	1,994	2,282	3.1	9.5	12.6	2,341	5.5	9.3	14.8	2,447	9.6	8.9	18.5
1989	2,202	2,681	2.8	14.4	17.1	2,743	5.0	14.0	19.0	2,855	8.7	13.5	22.2
1990	1,698	2,292	2.1	23.1	25.3	2,333	3.8	22.7	26.6	2,406	6.8	22.0	28.8
1991	2,223	3,055	1.4	25.0	26.4	3,090	2.5	24.7	27.3	3,154	4.5	24.2	28.7
1992	1,243	1,574	6.0	12.7	18.7	1,653	10.5	12.1	22.6	1,795	17.6	11.1	28.7
1993	3,221	3,607	2.8	7.4	10.2	3,691	5.0	7.2	12.2	3,843	8.8	6.9	15.7
1994	3,620	4,314	6.2	9.7	15.9	4,538	10.8	9.2	20.0	4,941	18.1	8.5	26.6
1995	5,397	6,619	3.3	14.9	18.1	6,800	5.8	14.5	20.3	7,124	10.1	13.8	23.9
1996	3,382	4,363	5.7	16.8	22.4	4,569	9.9	16.0	25.9	4,938	16.6	14.8	31.5
Averages:													
1976–1996	2,428	3,124	6.4	14.9	21.4	3,303	10.9	14.2	25.1	3,625	17.5	13.1	30.6
1976–1980	2,377	3,508	13.9	16.4	30.3	3,929	22.8	14.7	37.5	4,688	34.7	12.4	47.2
1981–1996	2,444	3,005	4.1	14.5	18.6	3,108	7.2	14.0	21.2	3,293	12.1	13.3	25.4

escapements in the Blanchard, Klukshu, and Takhanne rivers and in Goat Creek by aerial surveys continue in order to estimate or index annual escapement abundance of the Alsek River system stock of chinook salmon. Age, sex, and size composition sampling of the Klukshu River escapement of chinook salmon should continue as well with annual sample sizes (aged) of approximately 500 fish. Additionally, we recommend that U.S. and Canadian fishery harvests in the Alsek River continue to be monitored, not only to document catches, but to document the age, sex, and size composition of these harvests. We recommend that target sample sizes (aged) of 300–400 chinook salmon each be used for annual monitoring of the U.S. and the Canadian fishery harvests.

We recommend that mark-recapture studies of the Alsek River system chinook salmon stock be conducted during each of the 1997–1999 seasons. Marking of chinook salmon in the U.S. portion of the Alsek River with recovery efforts being focused at the Klukshu River weir can provide such estimates at minimal cost. This would directly address two scientific issues: (1) the magnitude of the total escapement (and total run) of chinook salmon in the Alsek River system; and (2) the proportion of total harvest in the U.S. Alsek fishery that is of Klukshu River origin. It may be advisable, but cost-prohibitive, to augment this basic program with a radio-tagging study to identify other significant spawning aggregations of chinook salmon in the Alsek River drainage.

We recommend that the escapement goal for the Klukshu stock of chinook salmon be formally changed to 1,100 to 2,300 spawners per year in the Klukshu River system (Klukshu River weir count minus anticipated harvest in the aboriginal fishery above the weir) to conform to our current understanding of the MSY escapement level for this stock of chinook salmon. We recommend that this range be adopted to guide U.S. and Canadian fisheries management. This range of escapements should provide for sustained yield fisheries near the maximum potential of the Klukshu River system stock of chinook salmon. We recommend that both the Alaska Department of Fish and Game and the Canadian Department of Fisheries and Oceans formally adopt the revised biological escapement goal range of 1,100 to 2,300 spawners per year in the Klukshu River in lieu of the existing 4,700 chinook salmon spawners, and that both countries use this revised escapement goal for management of fisheries during the years 1998–2001.

We recommend that this escapement goal range be reexamined in 2001. Returns from the 1991–1995 Klukshu River escapements, which ranged from 1,243 in 1992 to 5,397 in 1995, will all be virtually complete at that time (see Figure 11). If our recommendation concerning research on the proportion of the overall chinook salmon escapement represented by the Klukshu River escapement is followed up on, at least three years of estimated total escapement in the Alsek will be available by fall of 2001. A systemwide escapement goal may be able to be developed at that time, recognizing that Klukshu weir counts will likely remain the primary indexing tool for escapement. If not, the spawner-recruit relationship for the Klukshu River stock will be further improved with additional completed brood years and additional management tools such as timing of upper Tatshenshini stocks in the lower river and the fraction of escapement in the Alsek drainage, etc. This information will provide the framework for improved management and utilization of this chinook salmon resource.

LITERATURE CITED

CTC (Chinook Technical Committee). 1994. 1993 annual report. Pacific Salmon Commission, Report TCCHINOOK (94)-1. Vancouver, British Columbia, Canada.

CTC (Chinook Technical Committee). 1996. 1994 annual report. Pacific Salmon Commission, Report TCCHINOOK (96)-1. Vancouver, British Columbia, Canada.

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

Eggers, D. M. 1993. Robust harvest policies for Pacific salmon fisheries. In Kruse et al., editors. Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska

Sea Grant Program Report No. 93-02, University of Alaska Fairbanks, Fairbanks.

Geiger, H. J. and J. P. Koenings. 1991. Escapement goals for sockeye salmon with informative prior probabilities based on habitat considerations. Fisheries Research 11:239-256.

Hilborn, R. 1985. Simplified calculation of optimum spawning stock size from Ricker's stock recruitment curve. Canadian Journal of Fisheries and Aquatic Sciences 42:1833-1834.

Hilborn, R. and P. Starr. 1984. Making stock recruitment analysis work. Pages 227-244 in P.E.K. Symons and M. Waldichuk, editors. Proceedings of the workshop on stream indexing for salmon escapement estimation, Vancouver, British Columbia, 2–3 February 1984. Canadian Technical Report Fisheries and Aquatic Sciences 1326.

Hilborn, R. and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

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

Ludwig, D. and C .J. Walters. 1981. Measurement errors and uncertainty in parameter estimates for stock and recruitment. Canadian Journal of Fisheries and Aquatic Sciences 38:711-720.

McPherson, S. A. 1990. An inseason management system for sockeye salmon returns to Lynn Canal, Southeast Alaska. Master's thesis, University of Alaska Fairbanks, Fairbanks.

Pacific Salmon Commission (PSC). 1991. Escapement goals for chinook salmon in the Alsek, Taku, and Stikine rivers. Transboundary Technical Committee of the Pacific Salmon Commission, Vancouver, British Columbia, Canada. Report TCTR (91)-4.

Pacific Salmon Commission (PSC). 1994. Preliminary estimates of transboundary river salmon escapement and a review of joint enhancement activities, 1994. Transboundary Technical Committee of the Pacific Salmon Commission, Vancouver, British Columbia, Canada.

Ricker, W. E. 1954. Stock and recruitment. Journal of Fisheries Research Board of Canada 11(5):559-623.

Ricker, W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada No. 191.

Walters, C. J. and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Canadian Journal of Fisheries and Aquatic Sciences 38:704-710.

Wu, C.-F., J. 1986. Jackknife, bootstrap, and other sampling methods in regression analysis. Annals of Statistics 14(4):1261-1350.

Table 56.–Computer files used to create this manuscript.

FILE NAME	DESCRIPTION
ALSEKSM.XLS	Excel (Office 97) workbook with spreadsheets of (1) all abundance and age composition data for harvests and escapements and brood year returns; (2) sampling effort for age composition data; (3) estimates of precision; (4) annual production tables; (5) coded wire tag sampling in Canada; (6) chi-square tests and (7) probability of recruitment table.
BHEFFORT.XLS	Excel (Office 97) workbook with catch, effort and hours fished for the U.S. Alsek set gillnet fishery, 1961-1995.
KLUKBAYS.XLS	Excel (Office 97) workbook with Baysian analysis for Klukshu River chinook salmon.