Fishery Data Series No. 99-29

Abundance of Coho Salmon in the Chilkat River in 1998

by

Randolph P. Ericksen

October 1999

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

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

Spell out year, month, and week.

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

The abundance of coho salmon *Oncorhynchus kisutch* that returned to the Chilkat River in 1998 was estimated using a mark-recapture experiment. Fish were marked in the lower Chilkat River with individually numbered solid-core spaghetti tags and batch marks. Fish were later sampled upriver near spawning grounds to recover tags and estimate marking fractions.

Eight hundred twenty-nine (829) coho salmon ≥ 500 mm mid eye to tail fork (MEF) were marked in the lower Chilkat River between August 8 and October 13, 1998 in fish wheels and drift gillnets. We examined 1,526 coho salmon ≥ 500 mm MEF on spawning areas of the Chilkat River drainage, and 27 of these were marked. A Darroch estimator was used to estimate that 37,132 (SE = 7,432) coho salmon ≥ 500 mm immigrated into the Chilkat River during 1998. We estimated that 72.5% (SE = 2.3%) of these fish were age 1.1 (1995 brood year), and 27.5% age 2.1 (1994 brood year). Most (55.6%, SE = 1.3%) were males.

Key words: mark-recapture, Darroch estimate, escapement, age composition, sex composition, coho salmon, *Oncorhynchus kisutch*, Chilkat River, Haines, Southeast Alaska.

INTRODUCTION

The purpose of this study was to monitor the escapement of coho salmon *Oncorhynchus kisutch* returning to the Chilkat River during 1998. The long-term goal of this study is to develop maximum harvest guidelines for this stock in accordance with sustained yield management.

The freshwater coho salmon fishery in Haines provides a small but important component of the local economy. In 1988, anglers fishing in Haines and Skagway for coho salmon spent an estimated $181,000 (Jones and Stokes 1991). This fishery operates late in the year when other fisheries have finished and is popular both with local and non-local anglers. Ninety percent (90%) of the anglers fishing in freshwater during 1985 were from out of town (Bethers 1986). The Chilkat River produces most of the coho salmon harvested in Haines area sport fisheries and supports one of the largest freshwater coho fisheries in the Southeast region, with an average annual harvest of about 1,000 coho salmon (Mills 1979–1994, Howe et al. 1995–1998). This stock also contributes a significant number of fish to the commercial troll, gillnet and seine fisheries in northern Southeast Alaska (Elliott and Kuntz 1988, Shaul et al. 1991).

The Chilkat River is a large glacial system that originates in British Columbia, Canada, flows through rugged dissected mountainous terrain, and terminates in Chilkat Inlet near Haines, Alaska (Figure 1). The mainstem and major tributaries comprise approximately 350 km of river channel in a watershed covering about 1,600 km² (Bugliosi 1988).

The Chilkat River is the third or fourth largest producer of coho salmon in Southeast Alaska (Scott McPherson, Division of Sport Fish, Douglas personal communication). The escapement of coho salmon to the Chilkat River drainage was estimated for one year (1990) at 80,700 fish (90% CI = 70,000 – 95,600; Dangel et al. *Unpublished*). Research conducted during the 1980s on coho salmon stocks in Lynn Canal (including the Chilkat River), suggest that these stocks have been subjected to very high (over 85%) exploitation rates (Elliott and Kuntz 1988, Shaul et al. 1991).

The current management program for Chilkat River coho salmon relies on postseason monitoring of escapements by an “index system,” where survey counts are conducted on four streams: Clear Creek, Spring Creek, Tahini River, and Kelsall River (Figure 1). The number of adult coho is counted on a weekly basis during peak spawning. The peak number counted for each stream is used as the index count for that year. More research is needed to determine whether these index counts reflect abundance trends in the Chilkat drainage. Research objectives in 1998 were:

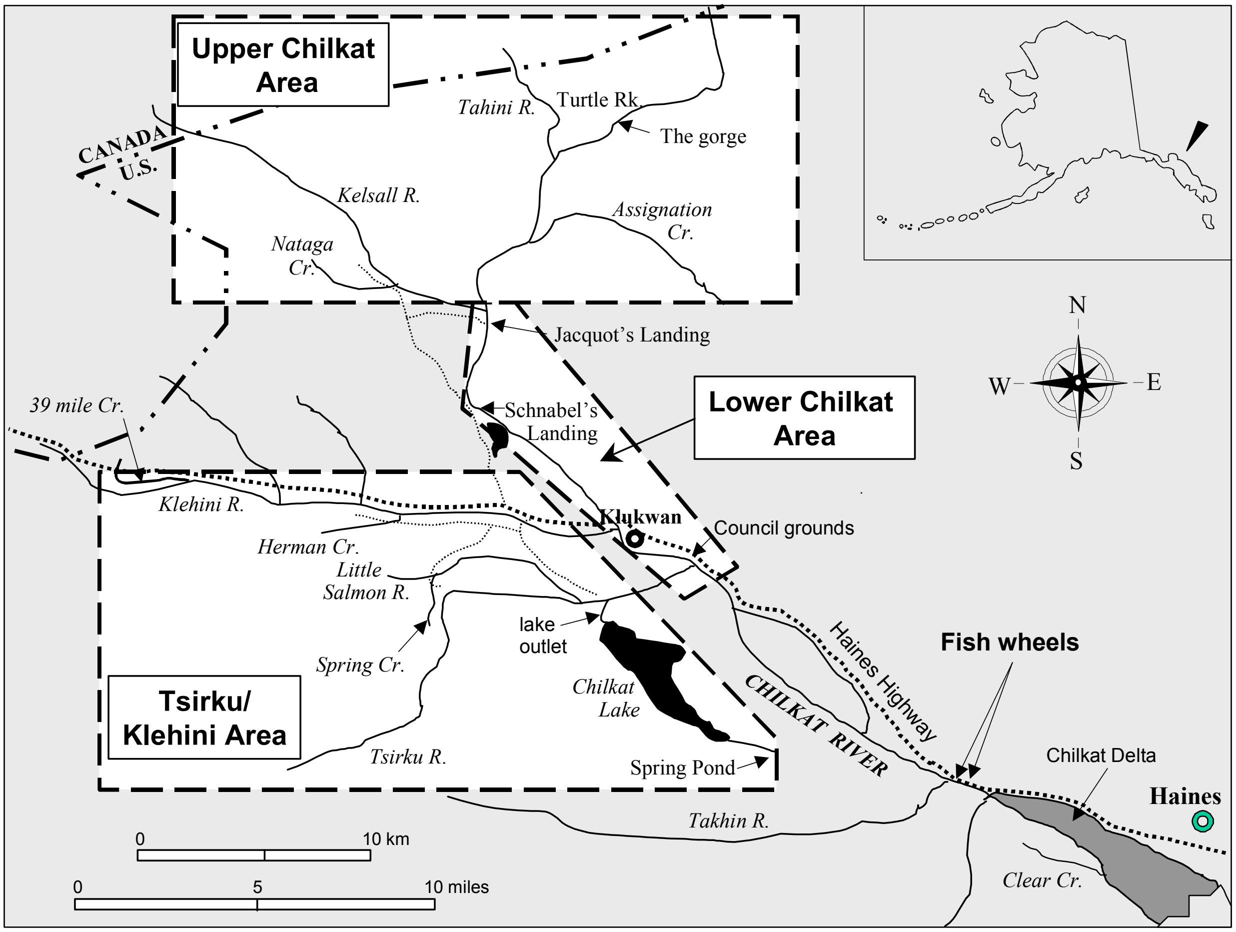


Figure 1.–Location of sampling sites and the three geographical areas of spawning ground recovery sites in the Chilkat River drainage, northern Southeast Alaska, during 1998.

1. to estimate the 1998 immigration of coho salmon into the Chilkat River; and
2. to estimate the age and sex composition of the escapement of coho salmon in the Chilkat River.

METHODS

INRIVER ABUNDANCE

We used a mark-recapture experiment to estimate the number of coho salmon returning to the Chilkat River in 1998. Marks were applied to coho salmon captured in the lower Chilkat River with fish wheels and drift gillnets from August 9 through October 16, between the area adjacent to Haines Highway miles 8 and 9 (Figure 1). Coho salmon were marked with a uniquely numbered solid-core spaghetti tag and a dorsal finclip prior to release. Fish were examined for marks on spawning tributaries of the Chilkat River between October 2 and November 18. The marked to unmarked ratio obtained from tributaries sampled was used to estimate abundance.

Lower River Marking

ADF&G Commercial Fisheries Division (CF) personnel installed two 3-basket aluminum fish wheels in early June to monitor escapement of sockeye salmon *O. nerka* to the Chilkat River.

The Division of Sport Fish provided funding for the fish wheels, beginning September 16, to tag coho salmon. One fish wheel operated adjacent to the Haines Highway near highway mile 9 from June 9 through October 13, and another about 300 m downstream of the first, from June 8 through October 2. The fish wheels were operated continuously except for maintenance until low river levels rendered them inoperable near the end of the season. The wheels were located along the east bank of the river where the main flow was constrained primarily to one side of the floodplain. Water depth (cm), and temperature (°C) were recorded each morning near highway mile 8.

Gillnets were used to capture coho salmon later in the year when dropping river levels stopped the fish wheels. A 7.6-m-long and 1.0-m-deep (25 ft × 3 ft) gillnet with 13.3-cm (5.25-in) stretched mesh was drifted in the lower Chilkat River from October 6 through 16, 1998. Fishing effort varied from day to day, depending on crew availability, but was generally conducted each day between 0900 and 1600 hours. Fishing was conducted from an 18-ft boat along a 0.8-km-long stretch of river adjacent to the Haines Highway mile 9 and 9.5. The active channel of the river used was about 10 m wide and 1 to 2 m deep. Personnel recorded the number of fish caught by species, the time that the net was fully set, and the time the net was pulled completely out of the water.

Coho salmon captured in good condition were measured (MEF), sexed, and marked with a uniquely numbered solid-core spaghetti tag sewn at the posterior end of the dorsal fin through the pterygiophores, and by clipping the last 4 rays of the dorsal fin (about ¼ inch above the back), prior to release. Beginning August 23, coho salmon were also given a tertiary mark (alternating clips to the left and right ventral fin or axillary appendage) to allow the abundance estimate to be stratified over time in the event of significant tag loss.

Spawning Ground Recovery

Thirteen (13) spawning tributaries were sampled for marks by two teams of two people from October 2 to November 18. These tributaries were later classified into three distinct areas based on geographical location and the timing of coho salmon into these systems (Figure 1). The Upper Chilkat area was sampled October 2 to November 3. The Tsirku/Klehini area was sampled October 13 to November 18. The Lower Chilkat area was sampled October 15 to November 17. Coho salmon were captured with gillnets, seine nets, dip nets, and bare hands. All coho salmon were examined for marks, measured for length (MEF in mm), and sexed. Double sampling was prevented by punching a hole in the lower edge of the left operculum of all fish sampled during recovery efforts.

Petersen or Darroch models for closed populations (Seber 1982) were used to estimate abundance, depending on whether stratification by time of marking and/or recapture area was needed. The six assumptions of a Petersen mark-recapture experiment are: (a) that every fish has an equal probability of being marked during event 1, or that every fish has an equal probability of being captured in event 2, or that marked fish mix completely with unmarked fish; (b) that recruitment and "death" (emigration) do not both occur between sampling events; (c) that marking does not affect catchability (or mortality) of the fish; (d) fish do not lose marks between sample events; (e) all recovered marks are reported; and (f) that double sampling does not occur (Seber 1982).

The validity of assumption (a) was tested through a series of hypothesis tests ($\alpha = 0.10$). First, the possibility of selective sampling was investigated because assumption (a) could be violated if the sampling rate varied by size (or sex) of the fish. The hypothesis that fish of different sizes were captured with equal probability was tested with a Kolmogorov-Smirnov (K-S) 2-sample test comparing the size distribution of marked fish with those recaptured. Sex selective sampling was tested using a 2×2 contingency table comparing the number of males and females caught in the lower river and never recaptured, with those recaptured on the spawning grounds. If selective sampling was apparent the abundance estimate could be stratified by age and/or by sex. Next, a 3×2 contingency table (chi-square statistic) was used to test the hypothesis that fish marked during three marking periods were recaptured at the same rate. Finally, a 2×3 contingency table was used to test the hypothesis that fish sampled at the three spawning tributaries were marked at the same rate. If either of these last two hypotheses were accepted, a simple Petersen model was used to estimate abundance; otherwise a Darroch estimator was used. If a Darroch model was needed, temporal or geographical strata were pooled to find admissible (non-negative) estimates, reduce the number of parameters, and increase precision while finding no evidence of lack of fit (Arnason et al. 1990). Two main points were considered when pooling strata: the similarity of the fractions of fish marked (for recovery strata), and the similarity of recovery fractions (for marking strata). Pooling of neighboring strata (temporal periods, or adjoining or adjacent stream reaches) was also considered in order to remove redundancy and to develop an intuitive basis for pooling. The remaining assumptions are considered in the Discussion section.

AGE AND SEX COMPOSITION OF THE ESCAPEMENT

All coho salmon caught in the lower river and all live and dead coho encountered on the spawning grounds were sampled, whenever possible, for length and sex. In addition, every other coho salmon sampled in the lower river was systematically sampled for scales (for age determination). Four scales were removed from the left side of each sampled fish (right side if left-side scales were regenerated), along a line 2 to 4 scale rows above the lateral line between the posterior insertion of the dorsal fin and anterior insertion of the anal fin. Ages were determined from patterns of circuli according to protocols in Mosher (1968).

Sex and length compositions were tabulated separately for fish in the lower river and in each escapement sampling area. Age composition, mean length-at-age, and their variances were calculated using standard normal statistics.

Size and sex selectivity was determined by comparing the numbers of coho salmon by size and sex captured in the lower river and spawning ground samples with contingency table analysis (α = 0.10). Age (or sex) composition of the escapement was obtained from pooled samples when no selectivity was found, or from separate unbiased samples as appropriate. Proportions by age (or proportions by sex) were estimated by

$$\hat{p}_i = \frac{n_i}{n} \qquad (1)$$

$$var[\hat{p}_i] = \frac{\hat{p}_i\ (1-\hat{p}_i)}{n-1} \qquad (2)$$

where p_i is the proportion in the population in age/sex group i, n_i is the number in the sample belonging to group i, and n is the number in the sample that are successfully aged (or sexed).

RESULTS

INRIVER ABUNDANCE

We captured 1,100 coho salmon in the lower Chilkat River with fish wheels and drift gillnets between August 8 and October 16, 1998 (Figure 2). Of the 1,100 fish captured, 1,067 were marked and released (Table 1). Twenty-four (24) coho salmon escaped prior to being marked, 6 were found dead, one was too small to tag, one was too lethargic to tag, and one was missing its adipose fin and was sacrificed to obtain the coded wire tag (tagged as a smolt in the Berners River).

Capture rates of coho salmon peaked on September 29. The mean date of migratory timing (weighted mean, Mundy 1984) in the lower river was September 25 (Figure 3).

We examined 1,583 coho salmon on the spawning grounds for marks (Table 2). Twenty-seven (27) marked fish were recovered (Table 2). None of the marked fish had lost their tags. Tagged fish were recaptured 25 to 59 days (mean = 43 days, SE = 2 days) after being marked in the lower river. Very few fish sampled on the spawning grounds, and no marked fish, were recaptured which were <500 mm (MEF) in length. Therefore, all fish <500 mm were excluded from the experiment. Thus, a total of 829 coho salmon ≥ 500 mm in length were marked, and 1,526 were sampled on the spawning grounds for marks (Table 3).

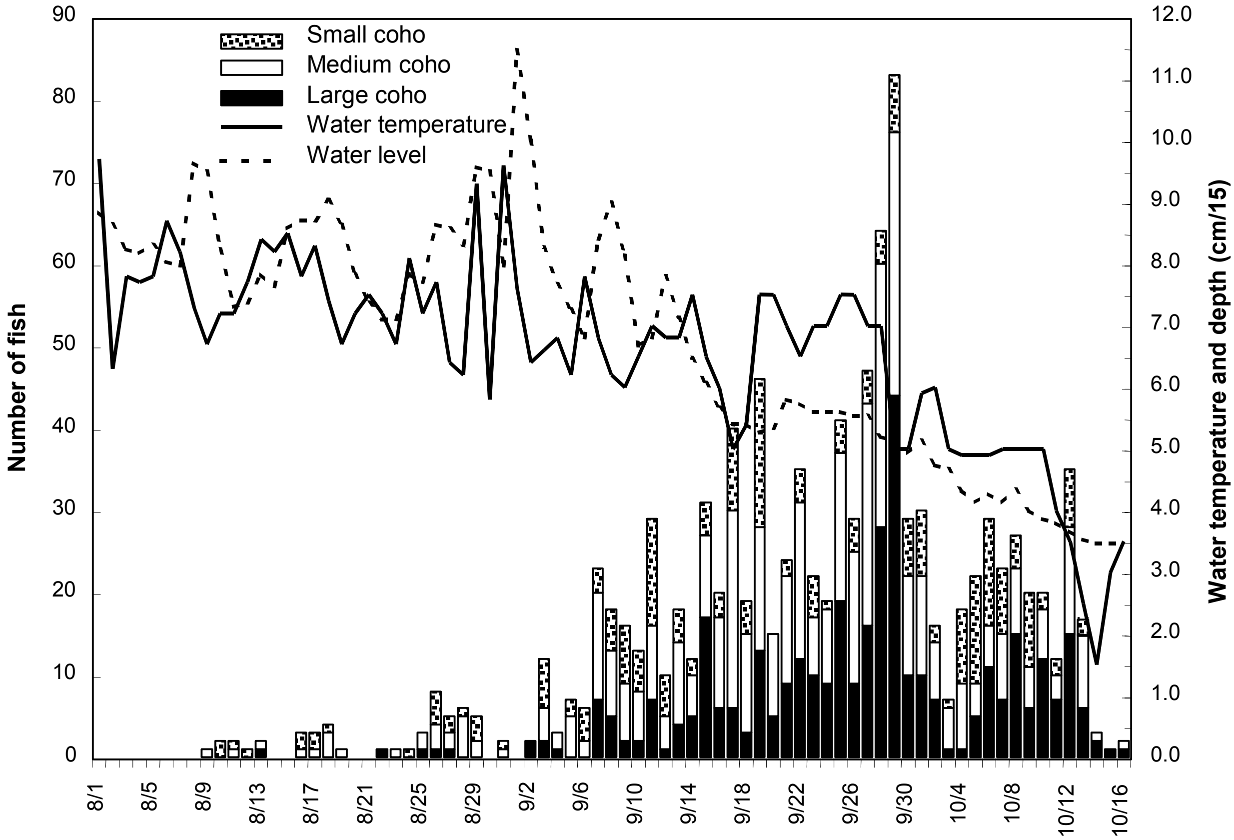


Figure 2.–Daily catch of small (<500 mm), medium (500–650 mm), and large (>650 mm) coho salmon, water temperature (^oC) and depth (cm/15) in the lower Chilkat River, August 1 through October 16, 1998.

The cumulative distribution function (CDF) of lengths of coho salmon ≥ 500 mm marked in the lower Chilkat River was not significantly different from the CDF of tagged coho salmon recaptured on the spawning grounds (K-S test, d_{max} = 0.235, P = 0.112, Figure 4, top). This result suggests the second sampling event was not size-selective. In addition, males and females marked in the lower river were equally likely to be recaptured (χ^2 = 0.003, df = 1, P = 0.959). Thus, the second sampling event was not sex-selective, and it was not necessary to stratify the estimate by size or sex.

Spawning ground sampling was not uniform over time, as recovery rates were greater for fish marked early in the immigration (Table 3). Fish marked during three marking periods (8/9–9/14, 9/15–9/24, and 9/25–10/16) were recaptured at significantly different rates (χ^2 = 7.05, df = 2, P = 0.030). In addition, the probability of capturing a marked coho salmon in the three spawning areas was significantly different (χ^2 = 4.65, df = 2, P = 0.098). Therefore, a Darroch estimator was used to estimate abundance.

Partial pooling of the strata was necessary because inadmissible estimates (at least one estimated probability of capture and stratum abundance <0) were obtained when we applied the Darroch model to the original 6 marking strata and 13 recovery strata. The data for coho salmon ≥ 500 mm were pooled into three temporal marking periods and three spawning areas to estimate abundance (Table 4). An estimated 37,132 (SE = 7,432) coho salmon ≥500 mm immigrated to the Chilkat River drainage in 1998 (Table 5). Individual stratum estimates

Table 1.–Number of coho salmon marked in the lower Chilkat River by time period and size, August 9 through October 16, 1998. Fish were classified by length (MEF): 0-ocean coho salmon < 400 mm; "small" 1-ocean = 400–499 mm; medium = 500–650 mm; and large > 650 mm.

	Fish wheels				Drift gillnet			Combined			
	Small				Small			Small			
Date	0-ocean	1-ocean	Medium	Large	1-ocean	Medium	Large	0-ocean	1-ocean	Medium	Large
08/09-08/10	0	2	1	0				0	2	1	0
08/11-08/15	0	2	2	1				0	2	2	1
08/16-08/20	0	5	6	0				0	5	6	0
08/21-08/25	0	1	3	2				0	1	3	2
08/26-08/30	0	10	12	2				0	10	12	2
08/31-09/04	5	2	7	6				5	2	7	6
09/05-09/09	11	10	35	16				11	10	35	16
09/10-09/14	16	13	33	19				16	13	33	19
09/15-09/19	27	12	71	46				27	12	71	46
09/20-09/24	11	1	58	45				11	1	58	45
09/25-09/29	17	6	125	116				17	6	125	116
09/30-10/04	27	0	44	29				27	0	44	29
10/05-10/09	46	1	29	32	0	1	12	46	1	30	44
10/10-10/16	12	0	27	27	1	5	17	12	1	32	44
	172	65	453	341	1	6	29	172	66	459	370

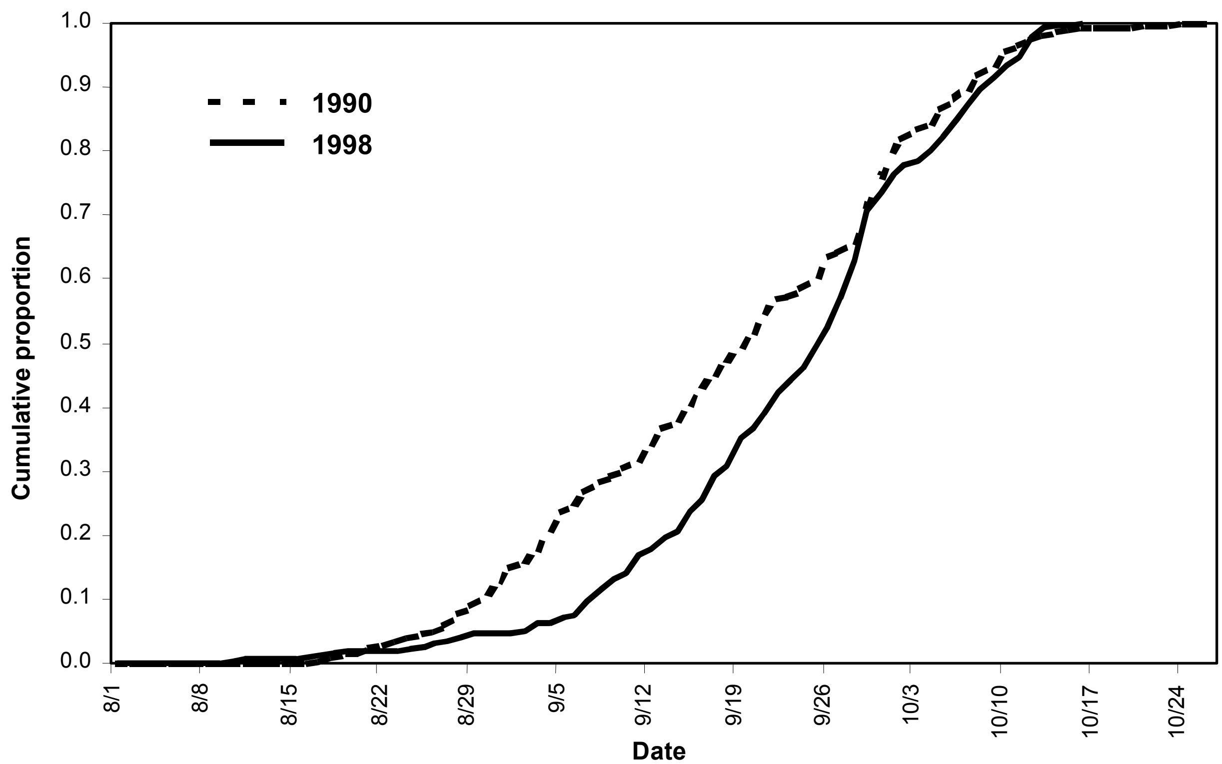


Figure 3.–Cumulative proportion of coho salmon captured in the lower Chilkat River during 1990 and 1998 (1990 data from Dangel et al. *Unpublished*).

Table 2.–Number of coho salmon inspected for marks and number of marked fish recaptured during tag recovery surveys in the Chilkat River, by location, size, and sex, 1998. Fish were classified by length (MEF): 0-ocean coho salmon < 400 mm; "small" 1-ocean = 400–499 mm; medium = 500–650 mm; and large > 650 mm.

		No. of days sam-	Number inspected								Number marked				
			Small												
			0-ocean	1-ocean		Medium		Large			Medium		Large		
Site	Dates	pled	M	M	F	M	F	M	F	Total	M	F	M	F	Total
						UPPER CHILKAT AREA									
Assignation Cr.	10/02–10/22	3	0	1	1	11	3	12	6	34	0	0	0	0	0
Tahini River	10/02–11/06	17	0	14	0	82	92	175	123	486	0	3	1	2	6
Kelsall River	10/07–10/29	5	1	2	0	17	24	40	17	101	1	0	0	0	1
Chilkat River	10/12–10/30	4	0	0	0	14	15	13	8	50	0	1	0	0	1
Nataga Creek	10/29–11/03	2	0	1	0	5	4	3	1	14	0	0	0	0	0
Subtotal		31	1	18	1	129	138	243	155	685	1	4	1	2	8
						TSIRKU/KLEHINI AREA									
Spring Creek	10/13–11/13	12	0	10	3	81	98	60	48	300	0	4	3	1	8
Chilkat Lake	10/19–11/04	4	6	0	0	7	21	24	19	77	0	0	0	0	0
Herman Creek	10/28–11/18	4	1	8	0	34	39	39	12	133	1	0	0	0	1
39 Mile Creek	10/29–11/12	3	0	0	1	8	4	8	5	26	0	0	0	0	0
Little Salmon R.	11/04–11/06	2	0	0	0	7	10	10	7	34	0	0	0	0	0
Subtotal		25	7	18	4	137	172	141	91	570	1	4	3	1	9
						LOWER CHILKAT AREA									
20–22 Mile	10/15–11/10	2	0	0	0	1	3	3	0	7	0	1	0	0	1
Schnabel's Lndg.	10/30–10/30	1	0	0	0	0	1	1	1	3	0	0	0	0	0
Jacquot's Lndg.	11/12–11/17	4	1	7	0	62	40	131	77	318	1	2	4	2	9
Subtotal		7	1	7	0	63	44	135	78	328	1	3	4	2	10
Total		63	9	43	5	329	354	519	324	1,583	3	11	8	5	27

were very imprecise (Table 5) because of small sample sizes. The estimate is germane to the time of tagging in the lower river, since an unquantified removal occurs (due to natural mortality and inriver subsistence and sport fishery harvests) between the two sampling events.

Age and Sex Composition of the Escapement

We sampled 546 coho salmon for age (scales), length, and sex in the lower Chilkat River during 1998; 498 of these were successfully aged (Table 6). Nearly all of the 0-ocean jacks (age 1.0 and 2.0) were <400 mm in length (Figure 5).

Coho salmon ≥ 500 mm captured in fish wheels were significantly smaller than those captured on the spawning grounds (K-S test, d_{max} = 0.121, P <0.001, Figure 4, bottom). Also, the proportion of females ≥500 mm marked in the lower river (55%) was significantly greater than the proportion examined on the spawning grounds (44%, χ^2 = 24.08, df = 1, P < 0.001). These results, in conjunction with prior tests showing the second sampling event not to be size/sex selective, suggest that the first sampling event was selective for smaller fish and for females ≥500 mm. Therefore, samples from the first event (Table 6) do not provide unbiased estimates of the sex composition of the escapement.

We sampled 1,526 coho salmon ≥500 mm for size and sex from the three spawning areas during 1998 (Table 7). Coho salmon sampled on the spawning areas were significantly different in size (χ^2 = 61.67, df = 4, P < 0.001, Figure 6). In addition, sex ratios were significantly different between the spawning areas (χ^2 = 9.02, df = 2, P = 0.011). Thus, samples from each area were weighted by the abundance estimate for that area

Table 3.–Number of marked coho salmon ≥500 mm released in the lower Chilkat River and recaptured by marking period and recovery site, and examined for marks at each recovery location, 1998.

			UPPER CHILKAT AREA					TSIRKU/KLEHINI AREA					LOWER CHILKAT AREA		
Marking stratum	No. marked	Fraction recovered	Assignation Creek	Tahini River	Kelsall River	Main-stem	Nataga Creek	Spring Pond	Chilkat Lake	Herman Creek	39-mile Creek	Little Salmon River	20–22 Mile	Schnabel's Landing	Jacquot's Landing
08/09–09/04	42	0.071	0	3	0	0	0	0	0	0	0	0	0	0	0
09/05–09/14	103	0.058	0	1	1	1	0	3	0	0	0	0	0	0	0
09/15–09/19	117	0.034	0	2	0	0	0	0	0	1	0	0	0	0	1
09/20–09/24	103	0.049	0	0	0	0	0	4	0	0	0	0	0	0	1
09/25–09/29	241	0.029	0	0	0	0	0	1	0	0	0	0	0	0	6
09/30–10/16	223	0.009	0	0	0	0	0	0	0	0	0	0	1	0	1
Examined for marks			32	472	98	50	13	287	71	124	25	34	7	3	310
Fraction marked			0.000	0.013	0.010	0.020	0.000	0.028	0.000	0.008	0.000	0.000	0.143	0.000	0.029

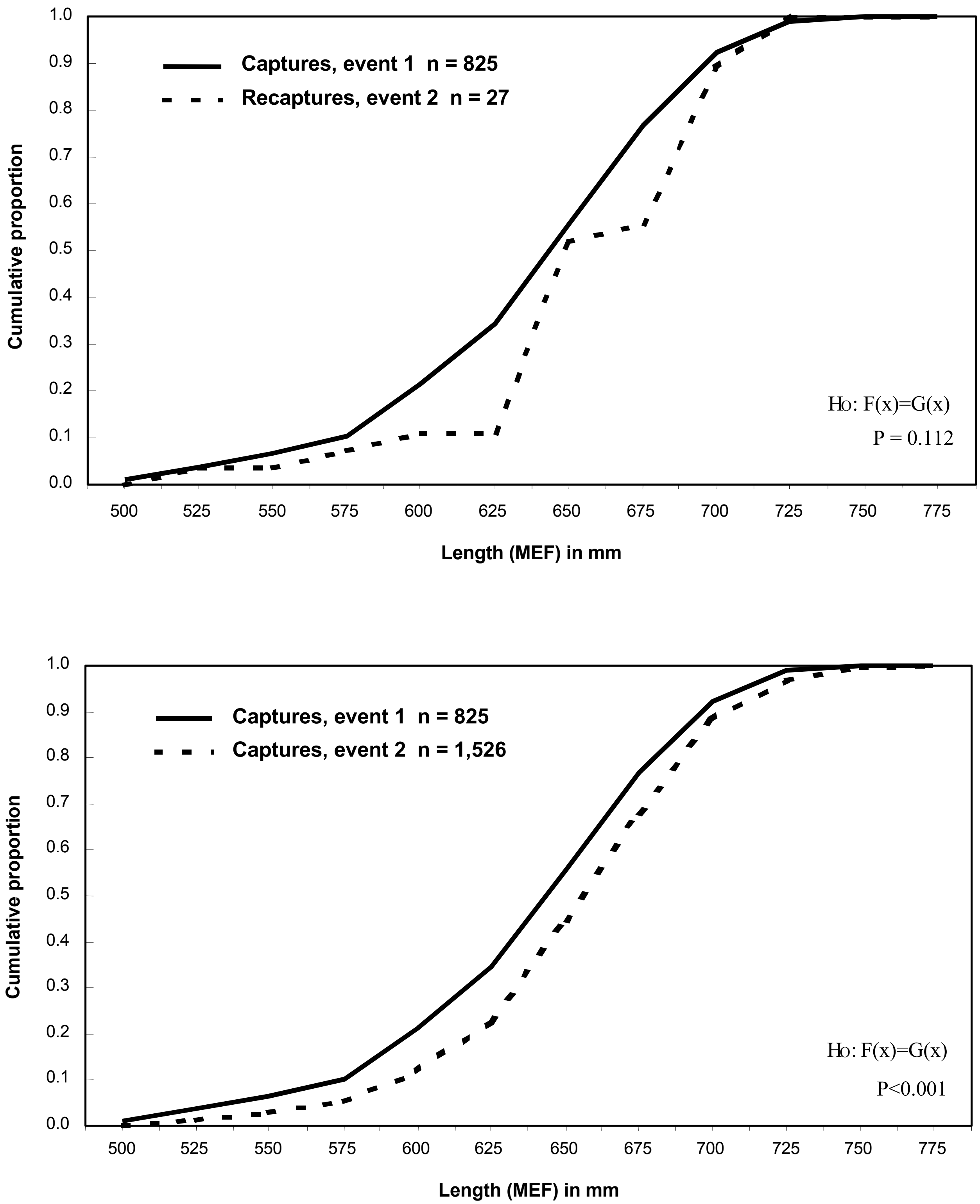


Figure 4.–Cumulative distribution function (CDF) of lengths (MEF) of coho salmon ≥ 500 mm marked in the lower Chilkat River versus lengths of marked fish recaptured on the spawning grounds (top) and versus lengths of large fish examined for marks on the spawning grounds (bottom), 1998.

Table 4.–Pooled numbers of coho salmon ≥ 500 mm marked by stratum, recovered by marking stratum and recovery area, and examined for marks by recovery area in the Chilkat River drainage, 1998.

Marking stratum	No. marked	Fraction recovered	**Upper Chilkat**	**Tsirku/ Klehini**	**Lower Chilkat**
08/09-09/14	145	0.062	6	3	0
09/15-09/24	220	0.041	2	5	2
09/25-10/16	464	0.019	0	1	8
Examined for marks			665	541	320
Fraction marked			0.012	0.017	0.031

Table 5.–Estimated abundance of coho salmon ≥500 mm, by marking stratum and recovery area, immigrating to the Chilkat River in 1998.

Stratum description	Abundance	SE[a]
Marking stratum		
08/09–09/14	13,899	7,820
09/15–09/24	9,885	13,472
09/25–10/16	13,348	9,480
Recovery area		
Upper Chilkat	11,135	10,786
Tsirku/Klehini	8,031	14,096
Lower Chilkat	17,966	6,737
All areas	**37,132**	**7,432**

[a] SE estimated using Plante's maximum likelihood estimator (Arnason et al. 1996) for marking strata and Darroch's moment estimator (Seber 1982) for recovery strata.

to estimate the sex composition of the escapement. However, the resulting estimates (42.2% females, 57.8% males) were not significantly different from estimates obtained by simply pooling the spawning ground samples (Table 7). In addition, the weighted estimates were imprecise because of the large uncertainty in stratum abundance estimates. Thus, the pooled spawning ground samples were used to estimate sex composition of the escapement of fish ≥ 500 mm, at 44.4% females (SE = 1.3%) and 55.6% males (SE = 1.3%).

Age composition of coho salmon ≥500 mm sampled in the lower river did not vary significantly with sex ($\chi^2 = 0.421$, df = 1, P = 0.517), but did so with size (K-S test, $d_{max} = 0.207$, P = 0.003, Figure 7). Because the first sampling event was size selective, it was likely selective also for age. Unbiased point estimates of the age composition of coho salmon ≥ 500 mm were obtained by stratifying age composition data by length for each area and weighting according to the estimated abundance for each area. The resulting estimates of 69.3% age 1.1, and 30.7% age 2.1 were not significantly different from estimates obtained from the lower river samples, and variances could not be estimated for the unbiased age composition. Therefore, we used the lower river samples (Table 6) to estimate that 72.5% (SE = 2.3%) of coho salmon ≥ 500 mm which immigrated into the Chilkat River were age 1.1, and 27.5% (SE = 2.3%) were age 2.1.

A list of computer files used in this analysis is found in Appendix A1.

DISCUSSION

The assumptions for a Petersen mark-recapture experiment are generalized for the Darroch estimate of abundance (Arnason et al. 1996, Seber 1982): (a) every fish present during the marking event has a non-zero probability of recovery in one of the final strata, and all fish in the final strata were also present in one of the initial strata [in salmon runs, closure is achieved by ensuring that sampling starts at the beginning of the run and that sampling continues until all animals have completed spawning]; (b) fish retain their marks and are correctly identified as marked or unmarked and, if marked, by initial stratum; (c) all fish in a given final stratum, whether marked or unmarked, have the same probability of being sampled; and (d) all marked and unmarked fish within a given marking stratum have the same probability of moving between strata.

Fish wheels were operational in early June, long before the first coho salmon was captured on August 9, and continued late into the season. However, low water stopped the last wheel on October 13 while 10–20 coho salmon per day were still being caught. We continued to capture small numbers of coho salmon with a drift gillnet

Table 6.–Estimated age, sex, and length composition of all sizes of coho salmon captured in fish wheels and gillnets in the lower Chilkat River, 1998.

	Brood year and age class					
	1996	1995	1995	1994	**Total**	**Total**
	1.0	2.0	1.1	2.1	**aged**	**sampled**[a]
Females						
Sample size	0	0	169	60	229	251
Percent			73.8	26.2		46.0
SE			2.9	2.9		2.1
Mean length (mm)			621	642		
SE			5	7		
Males						
Sample size	9	62	141	57	269	295
Percent	3.4	23.0	52.4	21.2		54.0
SE	1.1	2.6	3.1	2.5		2.1
Mean length (mm)	318	340	612	628		
SE	10	7	8	14		
All fish						
Sample size	9	62	310	117	498	546
Percent	1.8	12.5	62.2	23.5		
SE	0.6	1.5	2.2	1.9		
Mean length (mm)	318	340	617	635		
SE	10	7	4	8		
All fish ≥ 500 mm						
Sample size			282	107	389	427
Percent			72.5	27.5		
SE			2.3	2.3		
Mean length (mm)			635	657		
SE			3	5		

[a] Total number sampled for age in the lower river, including fish not assigned an age.

Table 7.–Number of coho salmon ≥ 500 mm sampled by length (MEF), sex, and estimated sex composition by area in the Chilkat River drainage, 1998.

	Lower Chilkat		**Tsirku/Klehini**		**Upper Chilkat**		**Pooled**	
Length (mm)	Female	Male	Female	Male	Female	Male	Female	Male
500–625	15	36	87	83	57	68	159	187
626–675	62	72	133	121	157	145	352	338
676–775	45	90	43	74	79	159	167	323
Total	122	198	263	278	293	372	678	848
Percent	38.1	61.9	48.6	51.4	44.1	55.9	44.4	55.6
SE	2.7	2.7	2.2	2.2	1.9	1.9	1.3	1.3

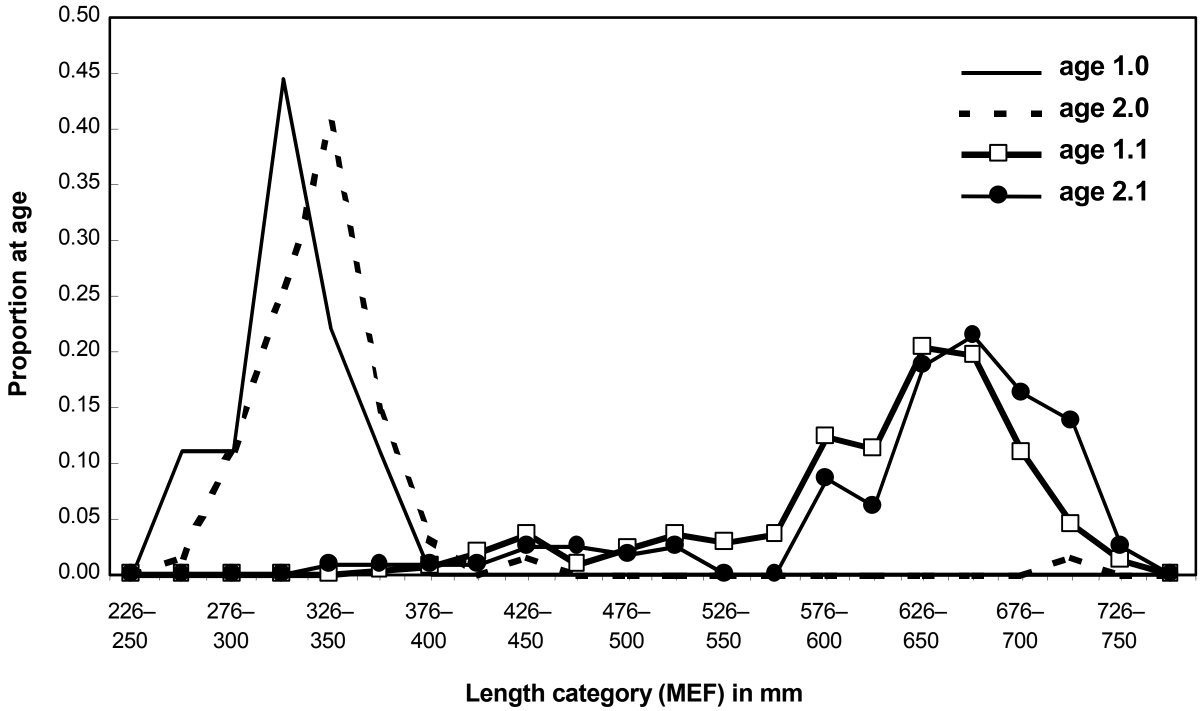


Figure 5.–Length at age for coho salmon sampled in the lower Chilkat River, 1998.

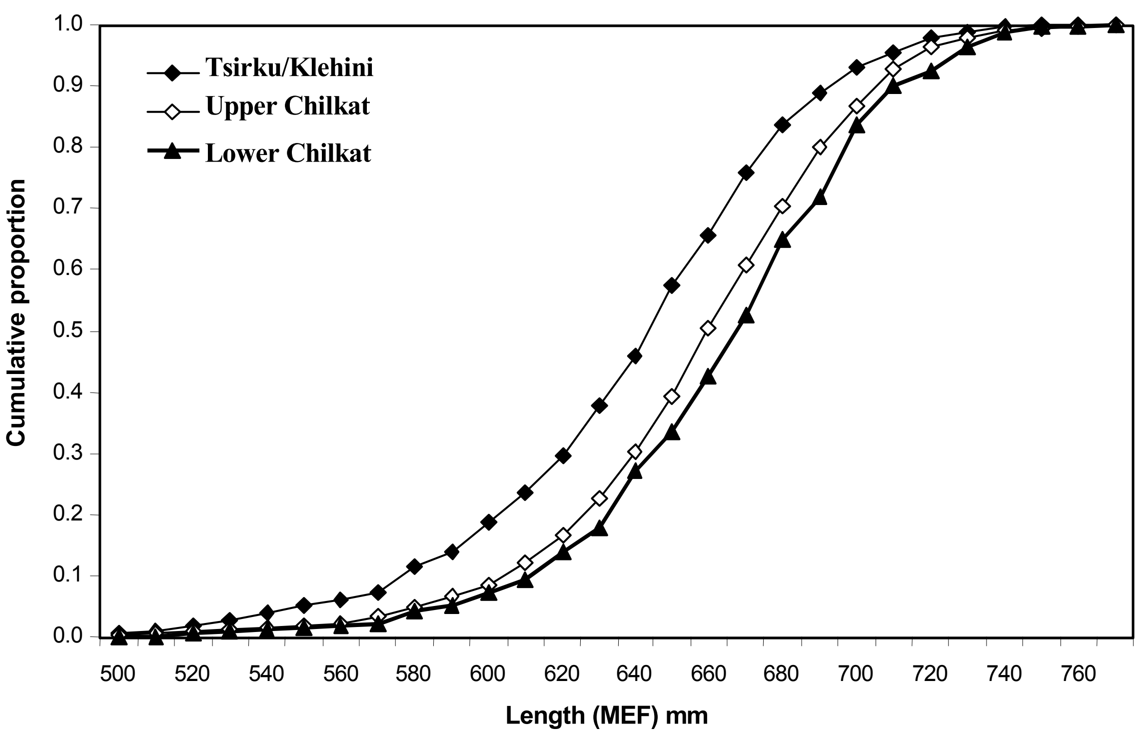


Figure 6.–Length comparison of coho salmon ≥ 500 mm sampled on the three spawning areas of the Chilkat River drainage during 1998. (Fish sampled in the Tsirku/Klehini area tended to be smaller.)

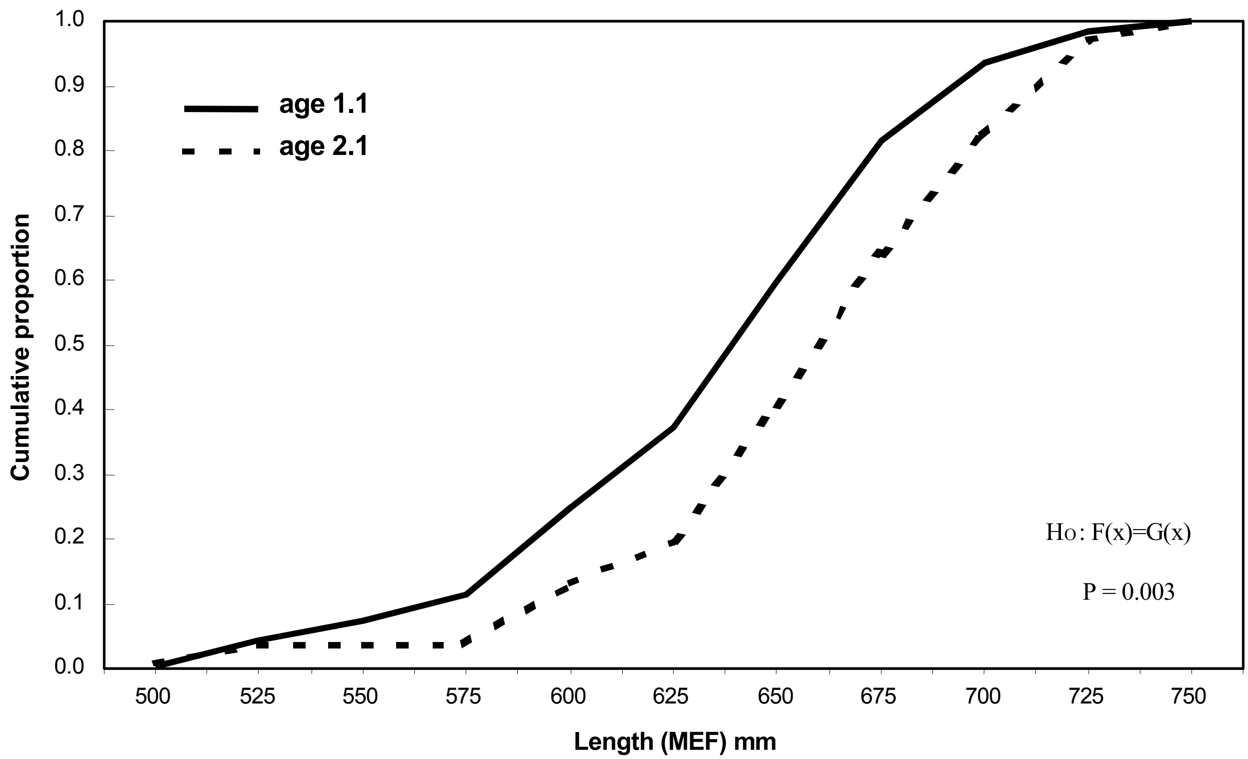


Figure 7.–Cumulative distribution function (CDF) of lengths (MEF) of age 1.1 versus age 2.1 coho salmon ≥ 500 mm scale sampled in the lower Chilkat River, 1998. (Age 2.1 fish were significantly larger.)

through October 16 (Figure 2). Fewer than 2% of the coho salmon were captured after October 13 in 1990 (Figure 3). Thus, we believe that we tagged essentially throughout the entire emigration.

We were not successful in sampling spawning fish until they had all completed spawning. We sampled 104 coho salmon at Jacquot's Landing on November 17 (the next to last day of sampling). This was the largest number of fish sampled for any area on any day during 1998. Only 8 of these fish were classified as spawned out, and 7 as bright/turning (pre-spawning condition). The following day a snowstorm prevented further access to this site. Clearly, we could have sampled many more fish if we had been able to access this area later in the season. However, we did recover fish that had been marked relatively late in the emigration, indicating that any bias due to a failure of assumption (a) was small. In addition, we excluded fish less than 500 mm from the experiment because these fish had virtually no probability of being sampled on the spawning grounds.

Coho salmon have been known to back out of some rivers after being tagged (Eiler et al. *In press*, Jones et al. *In prep*.). This can lead to a failure of assumption (a) if these fish are caught in fisheries downstream or ultimately spawn in another drainage. Other studies have shown that backing out does not occur if the marking site is far enough upstream (Vincent-Lang et al. 1993, Scott Kelley, Commercial Fisheries Division, Douglas, personal communication). We had no evidence of coho salmon backing out of the Chilkat River after being marked. The marking site is located several miles above the intertidal zone and no tags were recovered in the commercial drift gillnet fishery operating in Chilkat Inlet. However, this study should include radio tagging if it is done again.

We did not recover any marked fish with missing tags. A dorsal finclip and a tertiary clip would have identified marked fish in the event that a tag had been lost. The solid-core spaghetti tags used in this experiment held much better than the standard spaghetti tags used in 1990 (where they experienced >20% tag loss). Thus, assumption (b) was met.

The tags used in this study were light blue. They were easy to see in the clear water, and that may have tempted crew members to target marked fish. However, crews sampling on the spawning grounds were instructed not to target marked over unmarked fish (or vice versa), so we do not believe there was a significant failure of assumption (c) from targeting marked fish. I recommend future studies experiment with gray tags and black tags. Gray tags work well for chinook salmon in glacial water and provide less contrast than blue tags. However, black tags may blend in better with the dark coloration along the dorsal region of spawning coho salmon.

Size- or sex-selective sampling during the second sampling event could also violate assumption (c). Our tests indicate that the second sampling event was not selective for fish >500 mm in length. However, because of the low number of marked fish recaptured (27), the power of our test is low. Further, the plot of marked versus recaptured fish (Figure 4, top) is not convincing. To examine this possibility, I further stratified the Darroch estimate by medium (500–650 mm) and large (>650 mm) fish. The resulting estimate (38,193, SE = 5,298) was not significantly different from the original estimate (37,132, SE = 7,432). Thus, any size-selective sampling during the second sampling event was functionally insignificant.

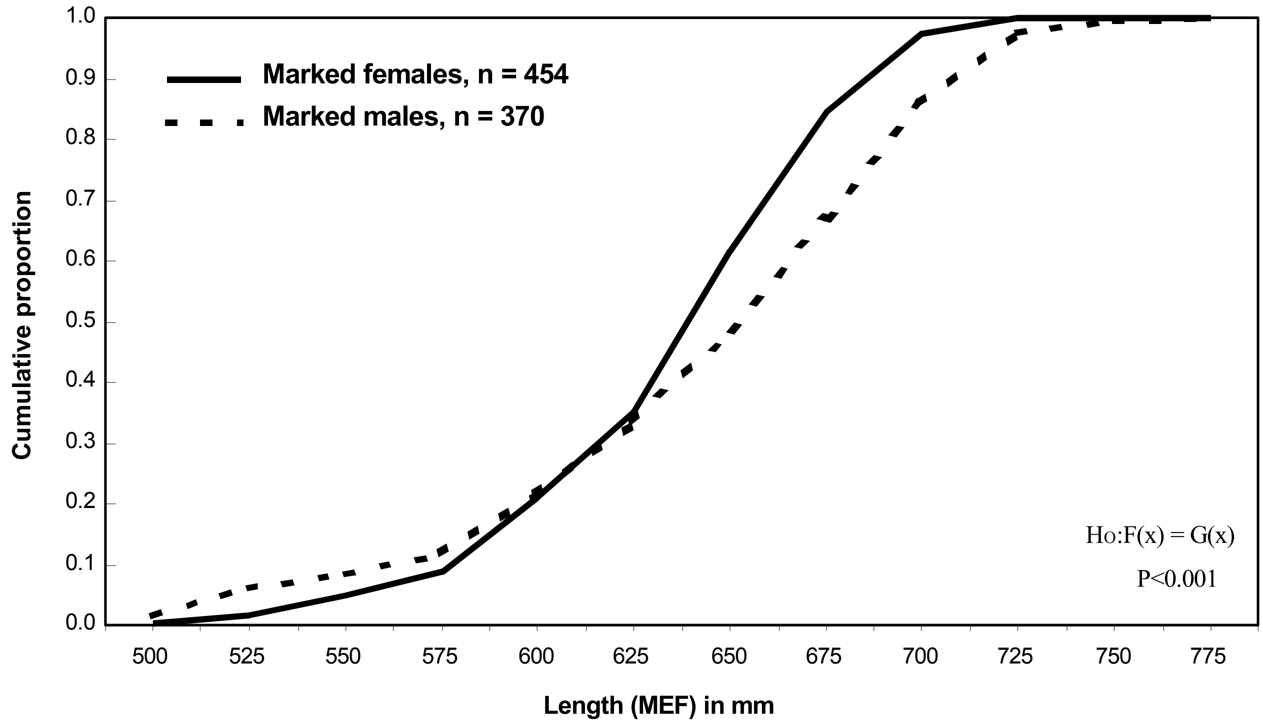
We had no way to test for a violation of assumption (d). However, we have no reason to believe that marked fish migrated differently than unmarked fish.

Our results indicate that fish wheels were selective for smaller coho salmon. Because fish wheels operate next to the riverbank, they may miss larger fish migrating upstream in mid-channel. Smaller fish may travel out of the main current, along the river bank where they are more likely to be captured in fish wheels. This may also explain why fish wheels tended to be selective for females. Females and males (≥500 mm) differed significantly in size during both the marking event (K-S test, $d_{max} = 0.121$, $P < 0.001$, Figure 8, top), and on the spawning grounds (K-S test, $d_{max} = 0.175$, $P < 0.001$, Figure 8, bottom). Females tended to be larger in the smaller sizes and smaller in the larger sizes. Because the larger fish tended to be males and fish wheels selected for smaller fish, the fish wheels tended to catch a higher proportion of female fish.

Whereas sex was estimated with some uncertainty during the marking event, this does not explain the higher proportion of females reported in the fish wheels. Three of 27 tagged fish recaptured on the spawning grounds were sexed incorrectly during the marking event (sexual dimorphism is more evident on the spawning grounds). However, 2 of these 3 were incorrectly classified as males during the marking event. Therefore, sex ratios would be biased toward males during the marking event if this were a result of incorrect sexing at the fish wheels.

Our estimates of age and sex composition are biased by a small amount; however, the reported estimates did not differ significantly from the unbiased (weighted) estimates. Because the bias was negligible and we could not estimate variance for the weighted samples, we used the unweighted samples to estimate age and sex composition of the escapement.

Coho salmon ≥ 500 mm captured in the lower river early in the season tended to be smaller than those captured later in the season (Figure 9). This may be a result of the commercial drift gillnet fishery. Early in the season, larger coho salmon may have been caught in the fishery while smaller fish may have escaped through the mesh. The upper end of Lynn Canal (15A) was closed to commercial fishing after September 15, and the remainder of the district closed after September 23. Thus, larger coho salmon were more likely to escape into the drainage later in the season. Another explanation is that later run fish have spent a longer period of time at sea and thus have additional time to grow.



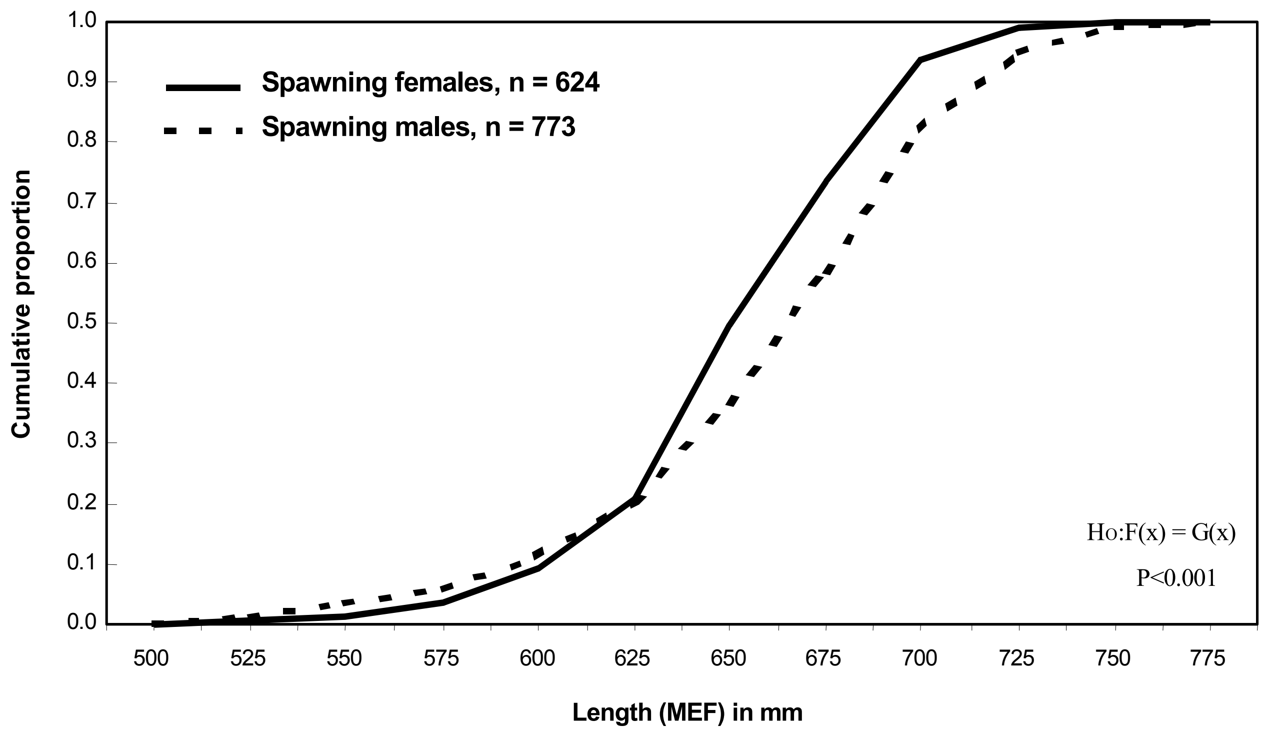


Figure 8.–Cumulative distribution function (CDF) of lengths (MEF) of female versus lengths of male coho salmon ≥500 mm marked in the lower Chilkat River (top), and examined for marks on the spawning grounds (bottom), 1998. Females tended to be larger than males within smaller size ranges but smaller than males at larger size ranges.

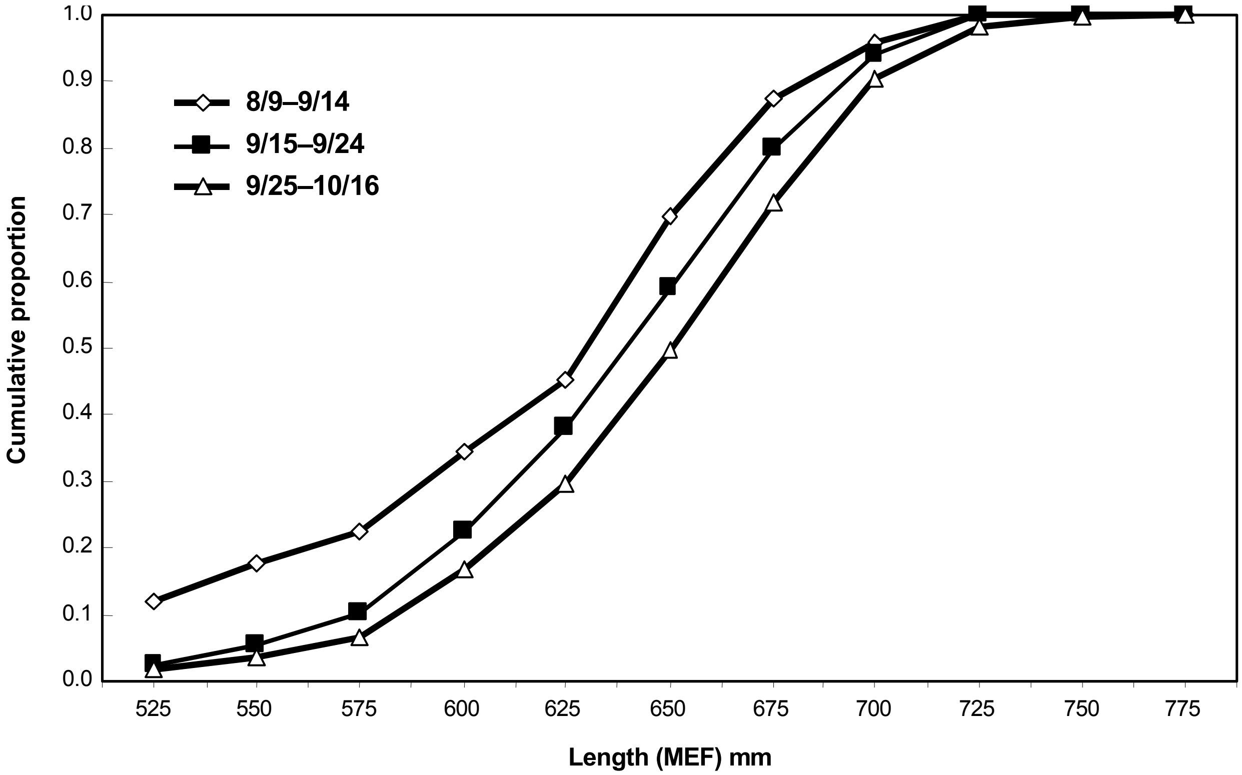


Figure 9.–Length comparison of coho salmon ≥ 500 mm marked during three different marking periods in the lower Chilkat River during 1998. Smaller fish tended to be caught earlier in the season.

The immigration timing of coho salmon through the lower Chilkat River was about one week later than observed in 1990 (Figure 3). The mean date of migratory timing was September 25. In contrast, the mean date for 1990 was September 19. However, the fish wheel coho salmon catch peaked on the same day (September 29) in both years. The immigration timing of coho salmon into the Taku River is typically earlier than that of the Chilkat River, and was also about one week later than average in 1998 (Richard Yanusz, Division of Sport Fish, Douglas personal communication). However, the immigration of chinook salmon into the Chilkat River was about one week early in 1998 (Ericksen 1999).

Our results indicate that coho salmon entering the river early in the season were headed toward the Upper Chilkat area. This result is consistent with work done in 1990 (Dangel et al. *Unpublished*). They found that early migrating fish were bound for spawning areas in the Tahini and Assignation Rivers (included in the Upper Chilkat area). In addition, we found that later fish were headed for the Lower Chilkat area. This area consists of sections of the Chilkat River immediately downstream of confluence with other major rivers. These areas probably provide good sources of upwelling groundwater, which are relatively warm and provide good spawning habitat late in the year.

The 1998 immigration of 37,132 (SE = 7,432) is less than half the abundance estimated in 1990 (80,700, SE = 9,984). Although their estimate was for all coho salmon ≥350 mm, these results are consistent with peak counts of coho salmon on the index spawning tributaries for those years (Table 8). The proportion of fish counted during 1990 (0.0372) and 1998 (0.0388) was very close. This limited sampling supports our index counts. Additional studies are needed to better validate these escapement indices.

Table 8.–Peak number of coho salmon counted in spawning index tributaries of the Chilkat River, 1987–1998, compared to mark-recapture estimates for the entire drainage in 1990 and 1998.

	Peak survey counts					**M-R**		
	Spring Creek	Kelsall River	Tahini River	Clear Creek	Total	**estimate**	**SE**	**Ratio**
1987	84	184	696	23	987			
1988	83	152	539	35	809			
1989	48	182	981	134	1,345			
1990	79	328	2,448	150	3,005	80,700	9,984	0.0372
1991	176	392	1,707	135	2,410			
1992	174	266	1,077	700	2,217			
1993	95	115	947	460	1,617			
1994	398	440	4,419	381	5,638			
1995	253	178	1,029	177	1,637			
1996	180	157	381	290	1,008			
1997	204	129	643	250	1,226			
1998	264	262	638	275	1,439	37,132	7,432	0.0388
Average	170	232	1,292	251	1,945	58,916		0.0380

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APPENDIX A

Appendix A1.– Computer data files used in the analysis of this report.

FILE NAME	DESCRIPTION
98COHOTAGS.XLS	Excel workbook containing all coho salmon and water data collected from the lower Chilkat River during 1998.
98COHOSPWN.XLS	Excel workbook containing coho salmon data collected from the spawning ground recoveries during 1998.
KATAGE-COMP.XLS	Excel workbook used to estimate age and sex composition of Chilkat River coho salmon during 1998