Fishery Data Series No. 10-60

Production and Escapement of Coho Salmon from the Chilkat River, 2006-2007

by

Brian W. Elliott

September 2010

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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ABSTRACT

The purpose of this study was to conduct a full stock assessment of Chilkat River coho salmon Oncorhynchus kisutch. Coho salmon smolt were captured in the Chilkat River during spring 2006, marked with an adipose finclip and a coded wire tag (CWT), and sampled for age, weight, and length. In 2007, adult coho salmon were sampled for CWTs in sport and commercial fishery harvests throughout Southeast Alaska, and in the Chilkat River, to estimate the marked fraction. The 2007 escapement to the Chilkat River was estimated by expanding peak survey counts.

An estimated 883,230 (SE = 136,074) coho salmon smolt emigrated from the Chilkat River in 2006. Most (93.0%, SE = 1.4%) of the smolt emigrating were age-1. In 2007, the total (non-jack) return of Chilkat River coho salmon was estimated at 37,547 (SE = 5,027), of which 12,142 (SE = 1,585) were harvested in marine fisheries, 635 (SE = 149) were harvested inriver, and 24,770 (SE = 4,769) escaped into the Chilkat River. Most (63.2%) of the harvest occurred in the commercial troll fishery (8,078, SE = 1,308). The majority of the escapement was age-1.1 (2004 brood year, 68.4%, SE = 2.2%), and male (57.7%, SE = 2.5%). The marine survival rate (smolt-to-adult) was estimated at 4.3% (SE = 0.9%) and marine exploitation rate at 32.3% (SE = 5.0%) for this stock.

Key words: abundance, escapement, coded wire tag, harvest, contribution, subsistence fishery, recreational fishery, troll fishery, drift gillnet fishery, seine fishery, age composition, size composition, sex composition, length-at-age, marine survival, exploitation rate, coho salmon, Oncorhynchus kisutch, Chilkat River, Haines, Southeast Alaska

INTRODUCTION

The purpose of this study was to conduct a full stock assessment of Chilkat River coho salmon *Oncorhynchus kisutch*. The long-term goal of this study is to gather information needed to manage harvests in accordance with sustained yield principles.

The Chilkat River produces annual adult returns of 100,000 to 300,000 coho salmon, making it one of the largest in Southeast Alaska. Research conducted during the 1980s on coho salmon stocks in Lynn Canal (including the Chilkat River) concluded that these stocks have, at times, been subjected to very high (over 85%) exploitation rates (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 2,600 km² (Bugliosi 1988).

The economic impact of sport fishing in Southeast Alaska is considerable and constitutes a significant component of the overall economy for both Southeast Alaska and the Haines/Skagway management area, as indicated by recent studies. Overall in 2007, anglers spent $274 million in Southeast Alaska, including $175 million by non-resident anglers. Nonresident anglers fishing in Southeast Alaska spent an average of $403.94 per day on sport fishing activities (all types combined) in 2007, while residents spent an average of $102.54 per day of fishing (Southwick Associates Inc. et al. 2008). The freshwater coho salmon fishery in Haines provides a small but important component of the local economy and sport fishery in Southeast Alaska. In 1988, anglers fishing in Haines and Skagway for coho salmon spent an estimated $181,000 (Stokes 1991). This fishery operates late in the year when other fisheries have finished and is popular with local and non-local anglers. In 2007, 79.5% of anglers who fished in freshwater areas of Haines were nonresidents (Jennings et al. 2010), and while they may spend less than the average for Southeast Alaska, their economic impact in Haines is significant.

The Chilkat River produces most of the coho salmon harvested in the Haines management area and supports one of the largest freshwater coho fisheries in Southeast Alaska; annual harvests have averaged about 1,800 coho salmon over recent years (Howe et al. 2001; Jennings et al. 2004, 2006a-b, 2007, 2009 a-b; Walker et al. 2003). This stock also contributes a significant number (more than 60,000 per year) of fish to the commercial troll, gillnet, and seine fisheries in northern Southeast Alaska (Elliott and Kuntz 1988; Shaul et

al. 1991; Ericksen 2001–2003; Ericksen and Chapell 2005; Elliott 2009).

The current management program for Chilkat River coho salmon relies on monitoring of escapement on 4 index streams: Clear Creek, Spring Creek, Tahini River, and Kelsall River (Figure 1). Alaska Department of Fish and Game (ADF&G) personnel survey the index streams by foot or boat on a weekly basis in October during peak spawning, and count all observed coho salmon. In order to establish a peak count, the highest index count is preceded and followed by lower counts. The peak number counted for each stream was used as the index count for that year. Peak survey count estimation has been performed consistently since 1987.

The escapement of coho salmon to the Chilkat River drainage has also been estimated by mark-recapture experiments in 5 years (1990, 1998, 2002, 2003, and 2005), and ranged from 38,589 (SE=4,625) in 2005 to 205,429 (SE=31,165) in 2002. (Table 1, Ericksen 2006).

This was the eighth consecutive year in this study designed to monitor the cycle of smolt production and subsequent adult return of Chilkat River coho salmon. Between 1999 and 2005, 750,000–3,000,000 smolt emigrated from the Chilkat River and contributed 40,000–132,000 adults to commercial, sport, and subsistence fisheries (Ericksen 2001; 2003, 2006; Ericksen and Chapell 2005; Elliott 2009). Research objectives for this study were to:

1. estimate the number of coho salmon smolt leaving the Chilkat River in 2006;
2. estimate the age composition of coho salmon smolt leaving the Chilkat River in 2006;
3. estimate the escapement of coho salmon to the Chilkat River in 2007;
4. estimate the age, sex and length composition of adult (ocean age-1) coho salmon entering the Chilkat River in 2007; and
5. estimate the marine harvest of Chilkat River coho salmon in 2007.

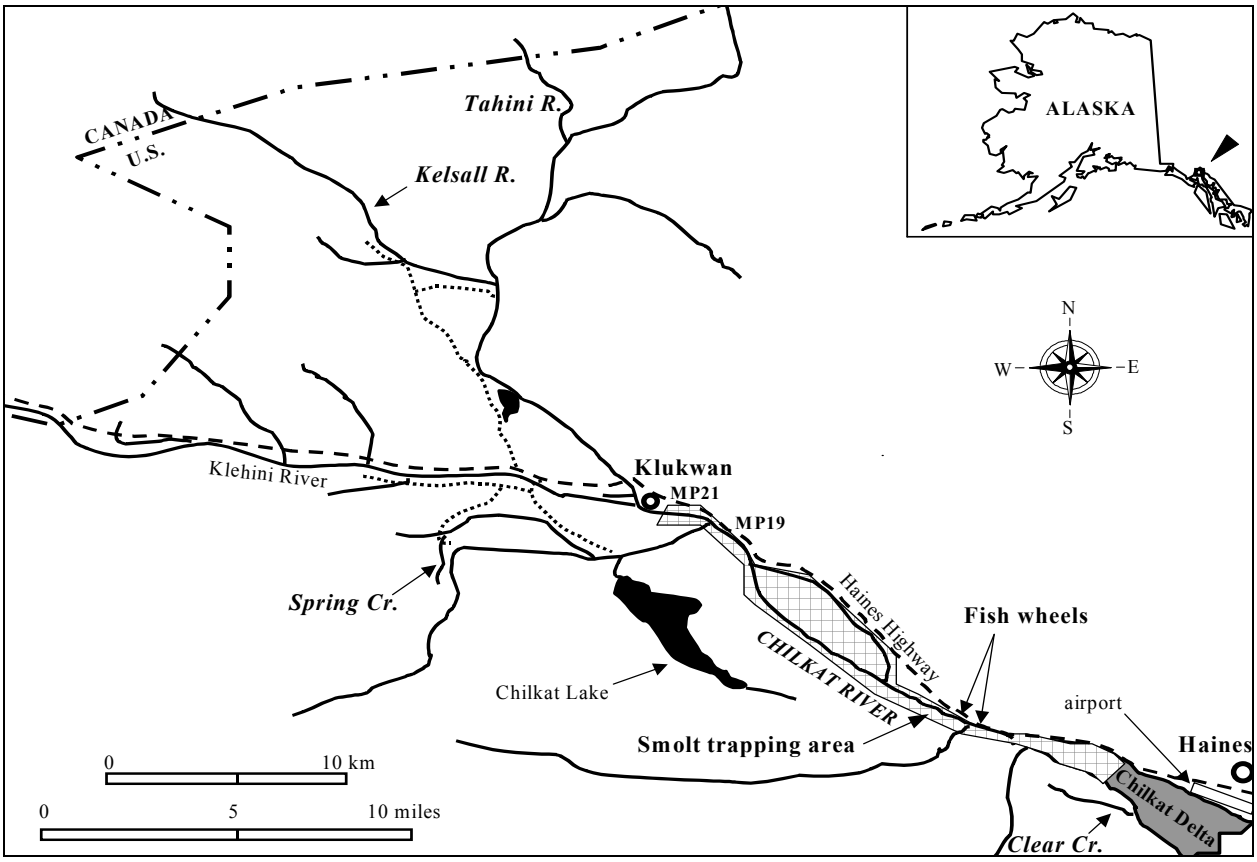

Figure 1.–The Chilkat River drainage, showing location of sampling sites.

Table 1.–Peak survey counts and estimated escapement of coho salmon to the Chilkat River, 1987–2007. Escapement estimates in bold were estimated directly through mark-recapture studies (inriver abundance minus inriver harvest). All others were expanded from the combined peak surveys.

	Peak surveys					Estimated escapement		
	Spring Creek	Kelsall River	Tahini River	Clear Creek	Combined (C_t)	($\hat{N}$)	SE ($\hat{N}$)	Estimation method
1987	99	197	792	25	1,113	37,432	7,202	expanded survey
1988	87	160	590	40	877	29,495	5,675	expanded survey
1989	57	190	1,064	141	1,452	48,833	9,395	expanded survey
1990	88	379	2,766	150	3,383	**79,807**	**9,980**	**mark-recapture**
1991	176	417	1,785	135	2,513	84,517	16,260	expanded survey
1992	183	281	1,143	700	2,307	77,588	14,927	expanded survey
1993	101	129	1,041	460	1,731	58,217	11,200	expanded survey
1994	451	440	4,482	408	5,781	194,425	37,405	expanded survey
1995	268	197	1,033	189	1,687	56,737	10,916	expanded survey
1996	204	179	412	315	1,110	37,331	7,182	expanded survey
1997	227	133	684	250	1,294	43,519	8,373	expanded survey
1998	271	265	649	275	1,460	**50,758**	**10,698**	**mark-recapture**
1999	335	207	962	195	1,699	57,140	10,993	expanded survey
2000	305	571	1,324	435	2,635	88,620	17,050	expanded survey
2001	450	225	1,272	1,285	3,232	108,698	20,912	expanded survey
2002	1,328	440	2,582	1,310	5,660	**205,429**	**31,165**	**mark-recapture**
2003	500	356	1,419	1,675	3,950	**134,340**	**15,070**	**mark-recapture**
2004	564	170	827	445	2,006	67,465	12,980	expanded survey
2005	221	42	219	495	977	**38,589**	**4,625**	**mark-recapture**
2006	503	220	761	915	2,399	80,683	15,523	expanded survey
2007	55	51	415	237	758	25,493	4,905	expanded survey
Mean	308	250	1,249	480	2,287	76,434	14,797	

METHODS

During the spring of 2006, coho salmon smolt were captured in main channels of the Chilkat River and marked with an adipose finclip and a coded wire tag (CWT). In 2007, adult coho salmon were sampled for CWTs in sport and commercial fisheries harvests throughout Southeast Alaska and in the Chilkat River to estimate the adipose finclip mark fraction (θ_{smolt} or θ_s) used to estimate abundance of the 2006 coho smolt emigration. The fraction of adipose-finclipped adult coho salmon sampled in the Chilkat River containing valid CWTs (θ_{marine} or θ_m) was used to estimate marine harvest of adult coho salmon in sampled fisheries in 2007.

SMOLT CAPTURE, SAMPLING, AND MARKING

Smolt were captured in the main channels of the Chilkat River from the Haines airport (Haines Highway milepost [MP] 4) upstream to approximately MP 21 during spring 2006 (Figure 1). Two 2-person crews fished an average of 100 G-40 minnow traps per day between April 9 and May 30. Traps were baited with disinfected salmon roe and checked at least once per day. Crew members immediately released coho salmon obviously less than 75 mm FL and non-target species at the capture site. The weekly peak catch, as measured by coho smolt per minnow trap (CPUE), was determined. Remaining fish were transported to holding pens for processing at the tagging site, located on the bank of the Chilkat River adjacent to MP 19. Water depth (cm) and temperature (°C) were recorded each morning near the tagging site.

ADF&G Division of Commercial Fisheries (CF), as part of a sockeye salmon smolt estimation project, also captured coho salmon smolt emigrating from Chilkat Lake. A portion of captured fish were sampled for age, weight, and length, and data was compared to coho salmon captured in the Chilkat River to detect any differences in estimated age composition or average size.

Preceding tagging, coho salmon smolt were sorted into 3 size classes: small (75-84 mm FL), medium

(85-99 mm FL), and large (≥100 mm FL). All healthy coho salmon smolt ≥75 mm FL were marked with an adipose finclip and given a CWT following the methods in Koerner (1977). Fish were first tranquilized in a solution of tricain-methane sulfonate (MS 222) buffered with sodium bicarbonate.

Spring 2006 was the first year when Chilkat River juvenile coho salmon were differentially marked by size class. During April 9 - May 3, large fish were marked with tag code 04-08-15, and small and medium fish were marked with tag code 04-10-29. During May 5-29, small fish were marked with tag code 04-08-30, while medium and large fish were marked with tag code 04-10-15. Because the size threshold used to assign size classes to tag codes was changed from 85 mm FL to 100 mm FL starting on May 5, and a new tag code was not started for the larger size concurrently, the size class analysis was confounded and a size-stratified smolt abundance estimate could not be calculated.

In an experimental analysis, statistical methods outlined in Weller et al. (2005) and discussed in Appendix B, were used to test for size-based differences.

All marked coho salmon smolt were held overnight to check for 24-hour tag retention and handling-induced mortality. The following morning, 100 fish from the previous day's marking effort were checked for the retention of CWTs. If tag retention was 98/100 or greater, mortalities were counted and all live fish from that batch were released. If tag retention was less than 98/100, then every smolt presumed to contain a CWT was checked for tag retention and those that tested negative were re-tagged. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were compiled and submitted to the CF Mark, Tag, and Age Laboratory in Juneau at the completion of the field season.

Every 60th coho salmon smolt tagged was measured to the nearest mm FL, weighed to the nearest gram, and 12 to 15 scales were collected for age analysis using methods outlined by Scarnecchia (1979). Scales were mounted individually between two 25 mm × 75 mm glass slides and viewed through a microfiche reader at 70× magnification. Age was estimated once for each fish and reported in European notation.

LOWER RIVER ADULT SAMPLING

Returning coho salmon were captured in fish wheels operating adjacent to MP 9 (Figure 1) during 2007. CF personnel installed two 3-basket aluminum fish wheels in early June to estimate escapement of coho, sockeye *O. nerka*, Chinook *O. tshawytscha*, and chum salmon *O. keta*, to the Chilkat River. One fish wheel operated adjacent to MP 9, and the other about 300 m downstream of the first. The fish wheels were operated continuously from June 8 through October 9, except for maintenance. 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 MP 8.

Every captured coho salmon was inspected for missing adipose fins and sampled for sex determination and length (measured to the nearest 5 mm MEF).Coho salmon ≥350mm MEF were assumed to be adults, for preliminary estimates of the marked fraction (θ_s). Every third coho salmon was systematically sampled for scales. Five scales were removed from the left side of the fish, 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 estimated according to methods in Mosher (1968).

Fish wheel personnel retained heads from all coho salmon with missing adipose fins, and a plastic cinch strap with a unique number was inserted through the jaw of the head. Heads and CWT recovery data were sent to the CF Mark, Tag, and Age Laboratory in Juneau where any tags present were removed and decoded; corresponding information was entered into the tag lab database.

SMOLT ABUNDANCE

A two-event mark-recapture experiment was used to estimate the abundance of coho salmon smolt ($\hat{N}_s$) emigrating from Chilkat River in 2006. The number of smolt marked during spring 2006 defined the first sampling event. Sampling returning adults for missing adipose fins during fall 2007 defined the second sampling event.

The number of emigrating coho salmon smolt was estimated using the Chapman's modified Petersen estimator for a closed population (Seber 1982):

$$\hat{N}_s = \frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1 \quad (1a)$$

$$\text{var}[\hat{N}_s] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \quad (1b)$$

where n_1 is the number of smolt marked in the spring of 2006, n_2 is the number of age-1.1 and -2.1 coho salmon captured in the Chilkat River fish wheels in 2007, and m_2 is the subset of n_2 that had been marked with an adipose finclip as coho smolt in 2006. The marked fraction θ_s was calculated as m_2/n_2. Standard error for θ_s was calculated using standard methods for variance of proportions, because m_2 and n_2 were measured with certainty:

$$\text{var}[\theta_s] = \frac{\theta_s(1-\theta_s)}{(n_2-1)}. \quad (1c)$$

The validity of the Petersen mark-recapture experiment rests on several assumptions: (a) that every fish has an equal probability of being marked during event 1, 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) that fish do not lose marks between sample events; (e) that all recovered marks are reported; and (f) that double sampling does not occur (Seber 1982).

Tagging smolt groups according to size allows for testing of assumption (a), which is violated by either different marking probabilities during event 1 or different capture probabilities in event 2. If significant differences in event 1 or 2 capture probability by size class are detected, an unbiased size-stratified smolt abundance estimator, based on Chapman's modification of the Peterson estimator (Appendix B; Seber 1982; Weller et al. 2005) could be used.

ADULT HARVEST

In 2007, harvest of coho salmon originating from the Chilkat River was estimated by sampling for CWTs in commercial and recreational marine fisheries, and in the Chilkat River recreational fishery. To account for tag loss, the marked fraction relevant to the marine environment was calculated as θ_m = number of CWTs successfully decoded/n_2.The parameter θ_m is a subset of the ratio of adipose-clipped fish observed (θ_s), and variance was calculated similarly to equation (1c).

The CF port sampling program sampled landings from commercial drift gillnet, set gillnet, purse seine, and troll fisheries throughout Southeast Alaska and Yakutat. During summer and early fall, samplers were stationed at processors in Ketchikan, Craig, Wrangell, Petersburg, Sitka, Pelican, Port Alexander, Elfin Cove, Excursion Inlet, and Juneau. The sample goal was to inspect at least 20% of the total catch of Chinook and coho salmon for missing adipose fins. Heads from fish missing their adipose fin were sent to the CF Mark, Tag, and Age Laboratory in Juneau on a weekly basis where CWTs were removed and decoded, and the resulting information compiled. The annual CF port sampling manual (ADF&G *Unpublished*) provides a detailed explanation of commercial catch sampling procedures and logistics.

Methods used by ADF&G Division of Sport Fish (SF) creel surveys to sample recreational fisheries in Southeast Alaska are described in Hubartt et al. (1997). There were no Chilkat River coho salmon CWTs recovered from sport fisheries in 2007, however, so creel survey sampling data were not used in this report.

Because there was no consistent sampling in the Haines area, the estimated harvests of Chilkat River coho salmon in the Haines marine and Chilkat River sport fisheries came from the Statewide Harvest Survey (SWHS) produced by SF. SWHS estimates in all streams and tributaries within the Chilkat River drainage were summed to estimate the total inriver coho salmon harvest. Haines area marine sport fishery estimates were restricted to SWHS locations near the terminus of the Chilkat River, and all coho salmon harvested within these locations were assumed to be of Chilkat River origin.

Because several fisheries exploit coho salmon over several months, the 2007 harvest was estimated over several strata, each a combination of time, area, and type of fishery. Sampling data from the commercial troll fishery were stratified by fishing period and quadrant. Statistics from drift gillnet fisheries were stratified by week and district.

Data from the port sampling program were used to estimate the commercial harvest of coho salmon bound for the Chilkat River $\hat{r}_i$ and its variance (by stratum) using the procedures in Bernard and Clark (1996). Estimates of harvest were summed across strata and across fisheries to obtain an estimate of the total $\hat{T}$:

$$\hat{T} = \sum_i \hat{r}_i \tag{2a}$$

$$\mathrm{v}[\hat{T}] = \sum_i \mathrm{v}[\hat{r}_i] \tag{2b}$$

Variance was estimated as the sum of variances across strata because sampling was independent across strata and fisheries.

The mean date of harvest for a commercial fishery was estimated as (Mundy 1982):

$$\hat{\bar{d}} = \sum_{d=1}^{n} d\hat{P}_d \tag{3}$$

where $\hat{P}_d$ is the estimated proportion of harvest on day *d*:

$$\hat{P}_d = \frac{\hat{H}_d}{\sum_d H_d} \tag{4}$$

where $\hat{H}_d$ is the estimated number of Chilkat River coho salmon harvested on day *d*.

ADULT ESCAPEMENT

The 2007 coho salmon escapement to the Chilkat River was estimated by expanding the combined peak survey counts on 4 index spawning tributaries. The surveys were repeated weekly during the peak spawning period of October 1 to October 31. One surveyor had conducted most surveys since inception to ensure that the peak survey counts captured trends in relative spawning abundance. A different surveyor started conducting surveys in 2006.The 5 mark-recapture studies validated that the peak survey counts are a good relative measure of coho escapement to the Chilkat River (Ericksen 2006).

Expansion for Peak Survey Counts

The ratio ($\hat{\pi}_i$) of abundance to peak survey counts for spawning Chilkat coho salmon in year *i* was:

$$\hat{\pi}_i = \hat{N}_i / C_i \tag{5a}$$

$$\mathrm{v}(\hat{\pi}_i) = \mathrm{v}(\hat{N}_i) / C_i^2 \tag{5b}$$

where $\hat{N}_i$ was the mark-recapture escapement estimate of coho salmon (inriver abundance minus inriver harvest) and C_i was the total of peak survey counts for that year.

The mean ratio $(\bar{\pi})$ from the 5 years with mark-recapture estimates was used to expand peak survey counts in years *t* without such estimates:

$$\hat{N}_t = \bar{\pi}\ C_t \tag{6a}$$

$$\mathrm{v}(\hat{N}_t) = C_t^2\ \mathrm{v}(\pi) \tag{6b}$$

where

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \hat{\pi}_y}{k} \tag{7a}$$

Note that the variance of year *t*, $v(\pi)$, instead of average mark-recapture variance, $v(\bar{\pi})$, was used in equation 6b to capture the expected year-to-year variability in the expansion factor, while simultaneously accounting for measurement error from the mark-recapture experiments.

Estimating variance of the expansion of index counts also needs to reflect these 2 sources of variability for the prediction of π, represented by (π_p).The variance expression has 2 components, which reflect an estimate of process error and measurement error:

$$\hat{var}(\pi_p) = \hat{var}(\pi) + \hat{var}(\bar{\pi}) \tag{7b}$$

The term $\hat{\mathrm{var}}(\pi)$ represents process error, i.e., error that is present through environmental variability or the population dynamics process. The term $\hat{\mathrm{var}}(\bar{\pi})$ represents the inter-annual uncertainty in predicting $\hat{\pi}$, or measurement error, which declines with every subsequent mark-recapture estimate of $\hat{\pi}$.

Expanding these 2 terms into variance terms that can be estimated yields the expressions:

$$\hat{var}(\hat{\pi}) = \frac{\sum_{y=1}^{k} (\hat{\pi}_y - \bar{\pi})^2}{k-1} \tag{7c}$$

and,

$$\hat{var}(\bar{\pi}) = \frac{\sum_{y=1}^{k}(\hat{\pi}_y - \bar{\pi})^2}{k(k-1)} \quad (7d)$$

Estimates of $var(\hat{\pi})$ and $var(\bar{\pi})$ were performed through a parametric bootstrap technique with 1,000,000 iterations as described in Efron and Tibshirani (1993). A bootstrap sample of size k is drawn from the k values of the individual estimates of $\hat{\pi}_y$ to produce a set of values represented by $\hat{\pi}_{y(b)}$. The bootstrap mean, $\bar{\pi}_{(b)}$, of these values is used to estimate $var(\hat{\pi})$ using these relationships:

$$\hat{var}_B(\hat{\pi}) = \frac{\sum_{b=1}^{B}(\hat{\pi}_{(b)} - \overline{\hat{\pi}_{(b)}})^2}{B-1} \quad (7e)$$

where

$$\overline{\hat{\pi}_{(b)}} = \frac{\sum_{b=1}^{B}\hat{\pi}_{(b)}}{B} \quad (7f)$$

Calculating $var_B(\bar{\pi})$ uses equations 7e and 7f by substituting appropriate terms. The overall variance of expansion factor prediction combined the bootstrap estimates, with the average of estimated variance of the individual expansion terms $\hat{\pi}_y$, to yield the result:

$$\hat{var}(\pi_p) = \hat{var}_B(\hat{\pi}) - \frac{\sum_{y=1}^{k}\hat{\text{var}}(\hat{\pi}_y)}{k} + \hat{var}_B(\bar{\pi}) \quad (7g)$$

AGE, SEX, AND SIZE COMPOSITIONS

Age composition of coho salmon smolt in 2006 and age and sex compositions of adults in 2007 were estimated from systematically drawn samples as described above. Standard sample summary statistics were used to calculate estimates of mean length- and mean weight-at-age and their variances (Cochran 1977). Proportions in the age (or sex) compositions and their variances were estimated as:

$$\hat{p}_a = \frac{n_a}{n} \quad (8a)$$

$$\text{v}[\hat{p}_a] = \frac{\hat{p}_a\ (1-\hat{p}_a)}{n-1} \quad (8b)$$

where n is the number of successfully aged (or sexed) fish and n_a is the subset of n determined to be age (or sex) a.

The abundance of sex x coho salmon in the escapement was estimated as:

$$\hat{N}_x = \hat{N}_e\ \hat{p}_x \quad (9a)$$

$$\text{v}[\hat{N}_x] = \text{v}[\hat{p}_x]\hat{N}_e^{\,2} + \text{v}[\hat{N}_e]\hat{p}_x^{\,2} - \text{v}[\hat{p}_x]\text{v}[\hat{N}_e] \quad (9b)$$

where $\hat{N}_e$ is the estimated escapement of coho salmon in 2007. The abundance of age a coho salmon by sex in the escapement $\hat{N}_{x,a}$ was estimated by substituting $\hat{N}_x$ and $\hat{p}_{x,a}$ for $\hat{N}_e$ and $\hat{p}_x$ in equations 9a and 9b.

RUN SIZE, EXPLOITATION RATE, AND MARINE SURVIVAL

In 2007, the Chilkat River coho salmon return (harvest plus escapement) was estimated as:

$$\hat{N}_R = \hat{T} + \hat{N}_e \quad (10a)$$

$$\text{v}\left[\hat{N}_R\right] = \text{v}\left[\hat{T}\right] + \text{v}\left[\hat{N}_e\right] \quad (10b)$$

The fraction of the run harvested (the exploitation rate) was calculated as:

$$\hat{E} = \frac{\hat{T}}{\hat{N}_R} \quad (11a)$$

$$\text{v}[\hat{E}] \approx \frac{\text{v}[\hat{T}]\hat{N}_e^2}{\hat{N}_R^4} + \frac{\text{v}[\hat{N}_e]\hat{T}^2}{\hat{N}_R^4} \quad (11b)$$

where the variance is an approximation from the delta method (Seber 1982).

The estimated marine survival rate (smolt-to-adult) and the delta method approximation of its variance were calculated as:

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \quad (12a)$$

$$\text{v}[\hat{S}] \approx \hat{S}^2\left[\frac{\text{v}[\hat{N}_R]}{\hat{N}_R^2} + \frac{\text{v}[\hat{N}_s]}{\hat{N}_s^2}\right] \quad (12b)$$

RESULTS

2006 SMOLT TAGGING, AGE AND SIZE

In spring 2006, 22,194 coho salmon smolt ≥75 mm FL were marked with an adipose finclip and a CWT (Table 2). Twenty-six (26) of these died and 19 lost their tags within 24 hours of tagging, leaving a total marked population of 22,149. In addition, 5,075 Chinook salmon were captured (Table 3).

Spring 2006 was relatively clear and cold; subsequently peak catches of coho salmon were much later than average. After large initial catches (April 8-9), the daily catch of coho salmon peaked on May 22 (Figure 2). The average weekly CPUE peaked May 14-20, when coho smolt per minnow trap was 7.0 fish (Table 3).

Three hundred seventy four (374) coho salmon smolt ≥75 mm were sampled from the Chilkat River for age, weight and length during spring 2006 (Table 4). Of the 371 scale samples successfully aged, age-1. fish dominated the Chilkat River smolt emigration (93.0%, SE = 1.4%). Coho salmon smolt weighed 6.3 g (SE = 2.2 g) and averaged 85.6 mm FL (SE = 9.4 mm; Table 4).

ADF&G CF personnel captured 4,796 coho salmon smolt emigrating out of Chilkat Lake between May 18 and July 5, 2006 (Table 3). A total of 97 were sampled for age, weight, and length, and 93 of those samples were successfully aged (Table 4). These smolt were significantly older than those sampled from the Chilkat River (26.9% vs. 7.0% age 2; χ^2 = 14.1, df = 1, P =0.0002). Those sampled at Chilkat Lake were also larger on average (106.3 mm, 12.3 g) than those sampled from the Chilkat River (85.6 mm, 6.3 g).

Table 2.–Summary of coded wire tagging data in the Chilkat River drainage during spring 2006.

Tag code	Species	Last date	Tagged	24h morts	Marked	Shed tags	Valid CWTs
040829	coho	5/4/2006	9,329	3	9,326	19	9,307
040830	coho	5/30/2006	7,290	13	7,277	0	7,277
041015	coho	5/30/2006	5,575	10	5,565	0	5,565
Total			22,194	26	22,168	19	22,149

Table 3.–Number of traps checked and smolt caught, tagged, and released in the Chilkat River by time period, April 9 through May 30, 2006 and captured at Chilkat Lake outlet, May 14 through July 8, 2006.

		Chilkat River				
		Number released with valid tags		CPUE[a]		Chilkat Lake[b]
Dates	Traps checked	Coho	Chinook	Coho	Chinook	Coho catch
4/9 - 4/15	792	3,274	1,368	4.1	1.7	
4/16 - 4/22	692	2,342	922	3.4	1.3	
4/23 - 4/29	678	2,789	1,093	4.1	1.6	
4/30 - 5/6	684	2,035	686	3.0	1.0	
5/7 - 5/13	660	2,610	469	4.0	0.7	
5/14 - 5/20	649	4,545	439	7.0	0.7	94
5/21 - 5/27	653	3,463	44	5.3	0.1	892
5/28 - 6/3	196	1,091	54	5.6	0.3	3,289
6/4 - 6/10						449
6/11 - 6/17						30
6/18 - 6/24						15
6/25 - 7/1						2
7/2 - 7/8						25
Total	5,004	22,149	5,075	4.4	1.0	4,796

[a] Catch of smolt per trap day.

[b] ADF&G Division of Commercial Fisheries personnel operated a smolt trap on the outlet of Chilkat Lake to monitor the emigration of sockeye salmon smolt. They counted and sampled coho salmon smolt.

Table 4.–Estimated age and size composition of coho salmon smolt ≥75 mm FL marked in the Chilkat River and sampled at Chilkat Lake, 2006.

		Age-1	Age-2	Total aged	Total sampled
Chilkat River	sample size	345	26	371	374
	percent (SE)	93.0 (1.4)	7.0 (1.4)		
	mean length (SE)	84.0 (7.2)	106.6 (10.0)		85.6 (9.4)
	mean weight (SE)	5.9 (1.6)	11.1 (3.0)		6.3 (2.2)
Chilkat Lake[a]	sample size	68	25	93	97
	percent (SE)	73.1 (4.6)	26.9 (4.6)		
	mean length (SE)	98.8 (7.8)	126.8 (13.5)		106.3 (15.8)
	mean weight (SE)	9.6 (2.0)	19.7 (6.1)		12.3 (5.7)

[a] Coho smolt were sampled at the Chilkat Lake outlet by ADF&G Division of Commercial Fisheries.

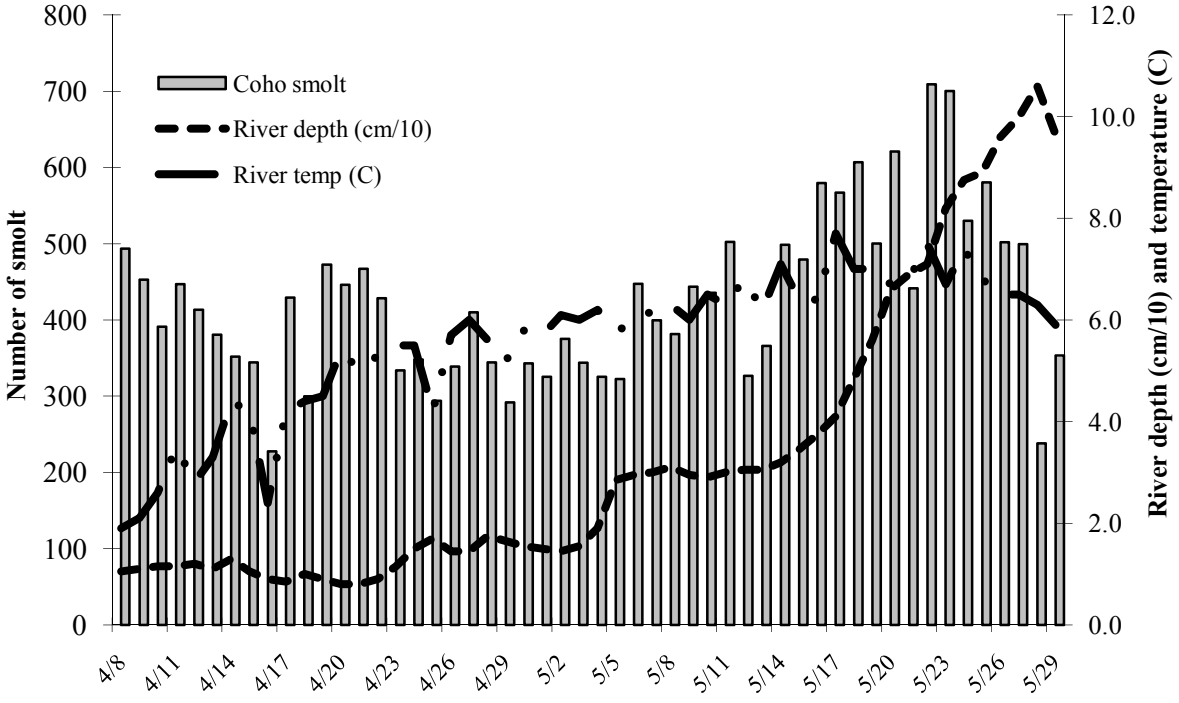

Figure 2.–Catches of coho salmon smolt ≥75 mm, daily water temperature (0C), and depth (cm/10), in the Chilkat River, April 8 through May 29, 2006.

2007 LOWER RIVER ADULT SAMPLING

Between August 6 and October 9, 2007, a total of 1,676 adult coho salmon were captured in the fish wheels (Figure 3), of which 1,640 were examined for missing adipose fins; 1,580 were FL 350mm or greater, and were assumed to be ocean age-1 fish. Thirty-nine (39) fish were missing an adipose fin, and their heads were examined for CWTs (Table 5). Thirty-six (36) contained decodable tags, all of which were released in the Chilkat River in 2006.

Scale samples were collected from 753 coho salmon and 659 were successfully aged. Of these, 97.2% were age-1.1 or -2.1 (ocean age-1; Table 6). Applying the ocean age-1 proportion to all sampled fish, an estimated 1,594 adults sampled for missing adipose fins in 2007 emigrated as smolt during 2006.

SMOLT ABUNDANCE

The 2006 Chilkat River coho salmon smolt abundance estimate was 883,230 (SE = 136,074). This estimate is based on n_1 = 22,149 smolt released in spring 2006, n_2 = 1,594 ocean-age-1 adults sampled from the fish wheels in 2007, and a total of m_2 = 39 marked fish recovered inriver (36 with 2006 Chilkat River tag codes and 3 missing or non-valid tags). The estimated marked fraction θ_s relevant to calculating smolt abundance was 0.025 (SE = 0.0039).

Using chi-square testing, no difference was detected in recovery rates between 2 distinct tagging groups (Table 7).Group 1 was smolt 75-84 mm FL, given tag code 04-08-30, while group 2 was smolt ≥85 mm, and given the code 04-10-15.Overall 7,277 coho salmon smolt were released in group 1, 19 CWTs were recovered in fisheries, and 13 CWTs were recovered in lower Chilkat River sampling, for a total of 32.In group 2, 5,565 coho salmon smolt were released, 22 were recovered in fisheries, and 7 were recovered in lower river sampling for a total of 29.A 2x2 contingency table revealed no difference in recovery rates for these 2 tagging groups (χ^2 = 0.44, df = 1, P =0.51).

The first 2 smolt groups and a third, mixed-sized smolt group, given the tag code 04-08-29, were also compared; 9,307 were released and 52 CWTs were recovered (Table 7). A 2x3 Chi-square test also revealed no difference between the small-sized group, large-sized group, and mixed size group (χ^2 = 1.14, df = 2, P = 0.56).

CODED WIRE TAG RECOVERY

In 2007, 78 CWTs with Chilkat River codes were recovered from coho salmon during the random sampling of commercial marine harvests (Table 8, Appendix A1). Most tags (52) were recovered in the commercial troll fisheries, followed by 26 recoveries in the commercial drift gillnet fisheries (Table 8).There were no CWTs recovered in the inside purse seine fishery or any marine sport fisheries, contrary to prior years. There were also no select recoveries of coho salmon bearing 2006 Chilkat River codes in 2007.

Table 5.–Number of adult coho salmon 350mm FL or greater sampled in the lower Chilkat River for missing adipose fins and coded wire tags, 2007.

Statistical week	Number sampled	Tag code				Total adipose-clips	Proportion marked
		04-08-29	04-08-30	04-10-15	No tag		
32	2	1				1	0.500
33	6					0	0.000
34	31	1		2	1	4	0.129
35	82	1	1			2	0.024
36	141	1	2	1		4	0.028
37	463	4	2			6	0.013
38	242	1	4		1	6	0.025
39	399	4	2	4	1	11	0.028
40	187	3	2			5	0.027
41	27					0	0.000
Total	1,580	16	13	7	3	39	0.025

Table 6.–Combined first and second half stratified estimates for the sampled age/sex composition and length of coho salmon captured in the fish wheels, and estimated escapement in the Chilkat River, 2007.

	Brood year and age class					
	2005 1.0	2004 2.0	2004 1.1	2003 2.1	Total aged	Total sampled[a]
Females						
Sample size		0	179	204	277	692
Percent		0	27 .2	15 .1		42.3
SE			3 .3	3 .6		3.0
Number			6,929	3,847		10,776
SE			1,289	1,086		1,745
Mean length			582	618		
SD			57	50		
Males						
Sample size		18	274	90	382	874
Percent		2 .8	41 .2	13 .7		57.7
SE		4 .0	3 .0	3 .6		2.5
Number		723	10,506	3,488		14,717
SE		727	1,686	1,055		2,096
Mean length		321	526	568		
SD		24	98	95		
All fish[b]						
Sample size		18	453	188	659	1,566
Percent		2 .8	68 .4	28 .8		
SE		4 .0	2 .2	3 .3		
Number		723	17,434	7,335		25,493
SE		727	2,122	1,515		4,905
Mean length		321	548	594		
SD		24	88	79		

[a] Includes fish not assigned an age.

[b] Includes fish with no sex information.

Table 7.–Comparison of coded wire recoveries for 2 classes of coho smolt sizes tagged in the Chilkat River in 2006. Tag codes 040830 and 041015 were used for smolt 75-84 mm and ≥85 mm, respectively; tag code 040829 was used for a mixed-size group. Chi-square tests show no difference in recovery rates between the 3 tagging groups.

Tag code		Chi-square tests of independence		
Tag code 04-08-30 (75-84mm May 5-29)		2 X 2 contingency table		
number tagged (*N1*)	7,277	*N1*	*N2*	
recovered in fisheries	19	7,277	5,565	
recovered in fish wheels	13	32	29	
total recoveries	32			
survival rate 1 (S_1) =	0.0044	X^2 = 0.44, df = 1, P = 0.51		
Tag code 04-10-15 (≥100 mm April 9-May 3 and ≥85 mm May 5-29)				
number tagged (*N2*)	5,565			
recovered in fisheries	22			
recovered in fish wheels	7			
total recoveries	29			
survival rate 2 (S_2) =	0.0052			
survival rate ratio (B) =	1.185			
Tag code 04-08-29 (75-99 mm April 9-May 3)		2 X 3 contingency table		
number tagged	9,307	04-08-30	04-10-15	04-08-29
recovered in fisheries	36	7,277	5,565	9,307
recovered in fish wheels	16	32	29	52
total recoveries	52			
recovery rate	0.0056	X^2 = 1.14, df = 2, P = 0.56		

Table 8.–Random marine recoveries of coded wire tags from Chilkat River coho salmon by tag code, fishery, and gillnet statistical week or troll period, 2007.

Statistical week or troll period	Dates	Tag code 04-08-29	04-08-30	04-10-15	Total
District 115 Gillnet Fishery					
34	8/19 - 8/25		1		1
35	8/26 - 9/1	1			1
36	9/2 - 9/8	1			1
37	9/9 - 9/15	5	1	1	7
38	9/16 - 9/22	6	4	1	11
39	9/23 - 9/29	2			2
40	9/30 - 10/6	2		1	3
	Gillnet subtotal	17	6	3	26
Northwest Quadrant Troll Fishery					
3	7/15 - 7/21	1			1
3	7/22 - 7/28	1			1
3	7/29 - 8/4	1			1
3	8/5 - 8/11	4	1		5
4	8/19 - 8/25	2		2	4
4	8/26 - 9/1	1	3	1	5
4	9/2 - 9/8	2	5	1	8
4	9/9 - 9/15	2	2	7	11
5	9/16 - 9/22	5	1	9	15
Northeast Quadrant Troll Fishery					
4	8/26 - 9/1		1		1
	Troll subtotal	19	13	20	52
Total recoveries		**36**	**19**	**23**	**78**
Valid tags released		9,326	7,277	5,565	22,168
Percent gillnet		47	32	13	33
Percent troll		53	68	87	67

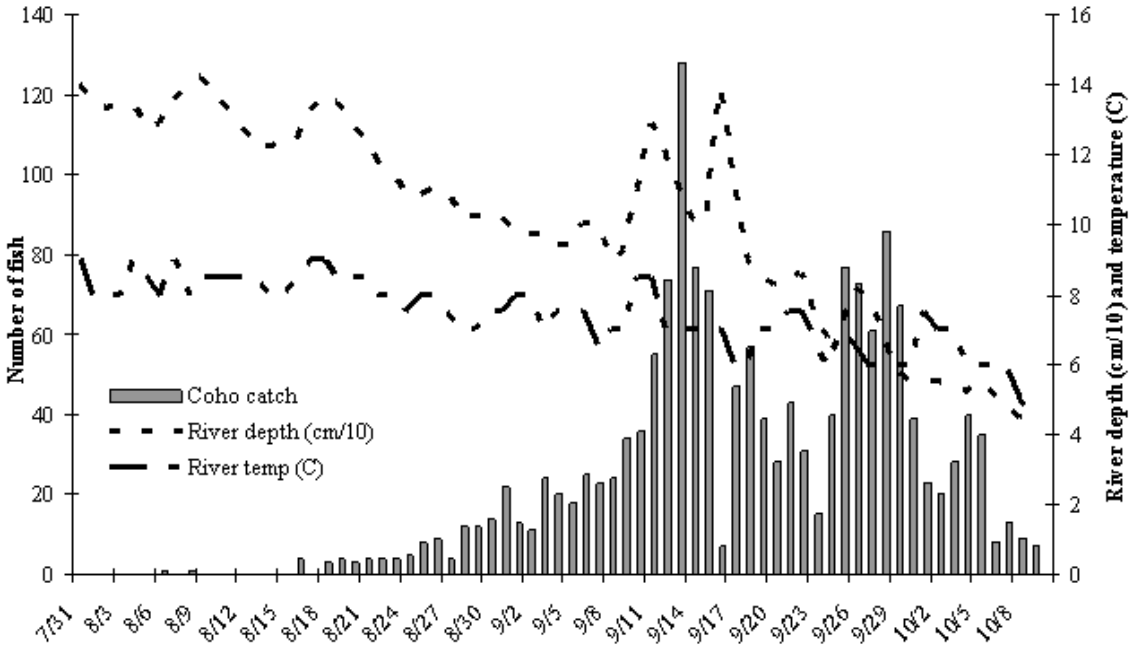

Figure 3.–Fish wheel catch of adult coho salmon, daily water depth (cm/10), and temperature (oC) in the lower Chilkat River, August 1 through October 9, 2007.

Coho salmon bearing Chilkat River tag codes were recovered with comparable relative frequencies in the District 115 (Lynn Canal) drift gillnet fishery from August 19 to October 6, and in the Northwest Quadrant troll fishery from July 15 to September 22 ($\chi^2 = 7.33$, df = 2, P = 0.026, Table 8).

HARVEST

The tagged fraction θ_m, used for estimating marine harvest contributions, was 0.023 (SE = 0.004). This estimate is based on 36 Chilkat River CWTs decoded out of the heads collected from 39 adipose-clipped fish among the 1,594 1-ocean adult coho salmon inspected for marks in the Chilkat River in 2007.

An estimated 12,064 (SE = 1,584) Chilkat River coho salmon were harvested in sampled marine commercial fisheries in 2007 (Table 9). An additional 107 coho salmon were harvested in the Chilkat Inlet and Chilkat River subsistence fisheries, an estimated 540 (SE = 149) in Chilkat River recreational fisheries, and 66 (SE = 45) in Haines marine recreational fisheries, for a total harvest of 12,777 (SE = 1,585, Table 10). Most of the Chilkat harvest (63.2%; 8,078, SE = 1,308) occurred in the commercial troll fisheries, followed by the commercial drift gillnet fisheries (31.2%; 3,986, SE = 893). The remainder of the harvest occurred in the recreational (4.7%) and subsistence (0.8%) fisheries. Harvests in the troll fisheries occurred earlier and over a longer duration, from mid July through September, than in other fisheries due to the migration route from Gulf of Alaska feeding grounds to the Chilkat River (Figures 4 and 5).In contrast, the harvest in the drift gillnet fishery occurred from mid August through the first week of October. The estimated mean date of harvest in the Northwest Quadrant troll fishery was September 3 compared to September 17 for the Lynn Canal drift gillnet fishery.

ESCAPEMENT

A total of 758 coho salmon were counted during peak surveys in the Chilkat River drainage in 2007 (Table 1). Expansion factors for peak survey counts from past years ranged from 23.6 (SE = 2.95) in 1990 to 39.5 (SE = 4.73) in 2005. The mean expansion factor 33.6 (SE = 5.99) was used to estimate that 25,493 (SE = 4,905) coho salmon reached spawning areas in the Chilkat River in 2007 (Table 1).

AGE AND SEX COMPOSITION OF THE ESCAPEMENT

The age composition was significantly different between the first (prior to September 18; the median date of the fish wheel catch) and second half of the immigration ($\chi^2 = 13.6$, df = 1, P = 0.0002). Sex compositions also varied significantly over time for age-1.1 ($\chi^2 = 5.4$, df = 1, P = 0.020) or age–2.1 fish ($\chi^2 = 4.5$, df = 1, P = 0.034). Thus, the samples were temporally stratified to estimate the age and sex composition of the escapement (Appendices A2 and A3). During the first half of the escapement (August 1 – September 17), age-1.1 males comprised 50.0% (SE = 3.9%) of sampled fish, compared with 32.8% (SE = 4.6%) in the second half of the escapement (September 18–October 9).Comparing proportions of brood year 2003 fish, age-2.1 females comprised 9.8% (SE = 5.3%) of the first half sample, and but increased sharply to 20.1% (SE = 5.0%) of the second half sample. Overall, males comprised 57.7% (SE = 2.5%), and age-1.1 fish comprised 68.4% (SE = 2.2%) of the escapement (Table 6).

MARINE EXPLOITATION AND SURVIVAL

The total ocean age-.1 component of the estimated escapement was 24,770 fish (SE = 4,769, Table 11). Assuming all 12,142 fish harvested in marine fisheries and 635 fish harvested in inriver fisheries in 2007 (Tables 9 and 10) were age-.1, the total 2007 run of age-.1 Chilkat River coho salmon was 37,547 fish (SE = 5,027). The estimated marine survival rate for 2006 emigrants was 4.3% (SE = 0.9%). The marine exploitation of this stock was estimated at 32.3% (SE = 5.0%).

Table 9.–Estimated marine harvest in 2007 of adult coho salmon bound for the Chilkat River, by fishery and temporal stratum (troll period or gillnet statistical week).

Fishery	District	Statistical week	Harvest	Var[N]	n	a	a'	t	t'	m	r	SE[r]
NW troll period 3		27-33	299,670	0	88,560	1,389	1,745	1,319	1,318	8	1,142	430
NW troll period 4		34-37	444,549	0	102,290	2,269	2,178	1,684	1,682	28	5,664	1,173
NW troll period 5		38-40	28,923	0	18,804	513	506	415	414	15	1,040	313
NE troll period 4		34-37	8,837	0	1,689	30	30	22	22	1	232	231
		Troll subtotal	781,979	0	211,343	4,201	4,459	3,440	3,436	52	8,078	1,308
Lynn Canal gillnet	115	34	190	0	62	2	2	2	2	1	136	135
Lynn Canal gillnet	115	35	1,102	0	487	21	20	18	18	1	105	105
Lynn Canal gillnet	115	36	2,549	0	1,040	34	34	33	33	1	109	108
Lynn Canal gillnet	115	37	3,163	0	1,450	47	47	46	46	7	677	274
Lynn Canal gillnet	115	38	5,115	0	1,118	30	30	30	30	11	2,231	756
Lynn Canal gillnet	115	39	3,651	0	1,099	43	41	38	38	2	309	221
Lynn Canal gillnet	115	40	1,216	0	386	4	4	3	3	3	419	247
		Gillnet subtotal	16,986	0	5,642	181	178	170	170	26	3,986	893
Total			**798,965**	**0**	**216,985**	**4,382**	**4,637**	**3,610**	**3,606**	**78**	**12,064**	**1,584**

Table 10.–Total (marine and freshwater) harvest and estimated Chilkat River harvest of coho salmon in Alaska fisheries, by fishery and area, 2007.

		Coho salmon harvest			Harvest, %	
Fishery	Area	Total	Chilkat	SE	Fishery	Chilkat
Drift gillnet	District 115	16,986	3,986	893	23.5	31.2
	Subtotal	16,986	3,986	893	23.5	31.2
U.S. troll fishery	NW Quadrant	773,142	7,846	1,288	1.0	61.4
	NE Quadrant	8,837	232	231	2.6	1.8
	Subtotal	781,979	8,078	1,308	1.0	63.2
Recreational	Haines marine[a]	408	66	45	16.2	0.5
	Chilkat River[a]	540	540	149	100.0	4.3
	Subtotal	948	606	149	63.9	4.7
Subsistence	Chilkat Inlet[b]	12	12	0	100.0	0.1
	Chilkat River[b]	95	95	0	100.0	0.8
	Subtotal	107	107	0	100.0	0.8
Total		**800,020**	**12,777**	**1,585**	**1.6**	**100.0**

[a] These estimates came from the Statewide Harvest Survey.

[b] Subsistence harvests as reported on returned permits.

Table 11.–Estimated stock assessment parameters for coho salmon that emigrated from the Chilkat River in 2006.

Parameter	Estimate	SE
2006 smolt emigration	883,230	136,074
2007 marine harvest	12,142	1,585
2007 inriver harvest[a]	635	149
2007 1-ocean age escapement[b]	24,770	4,769
Total 2007 return	37,547	5,027
Marine exploitation rate	32.3%	5.0%
Marine survival	4.3%	0.9%

[a] Includes Haines marine recreational and Chilkat Inlet subsistence harvest estimates from the Statewide Harvest Survey.

[b] Total escapement excluding age 1.0 and 2.0 coho salmon.

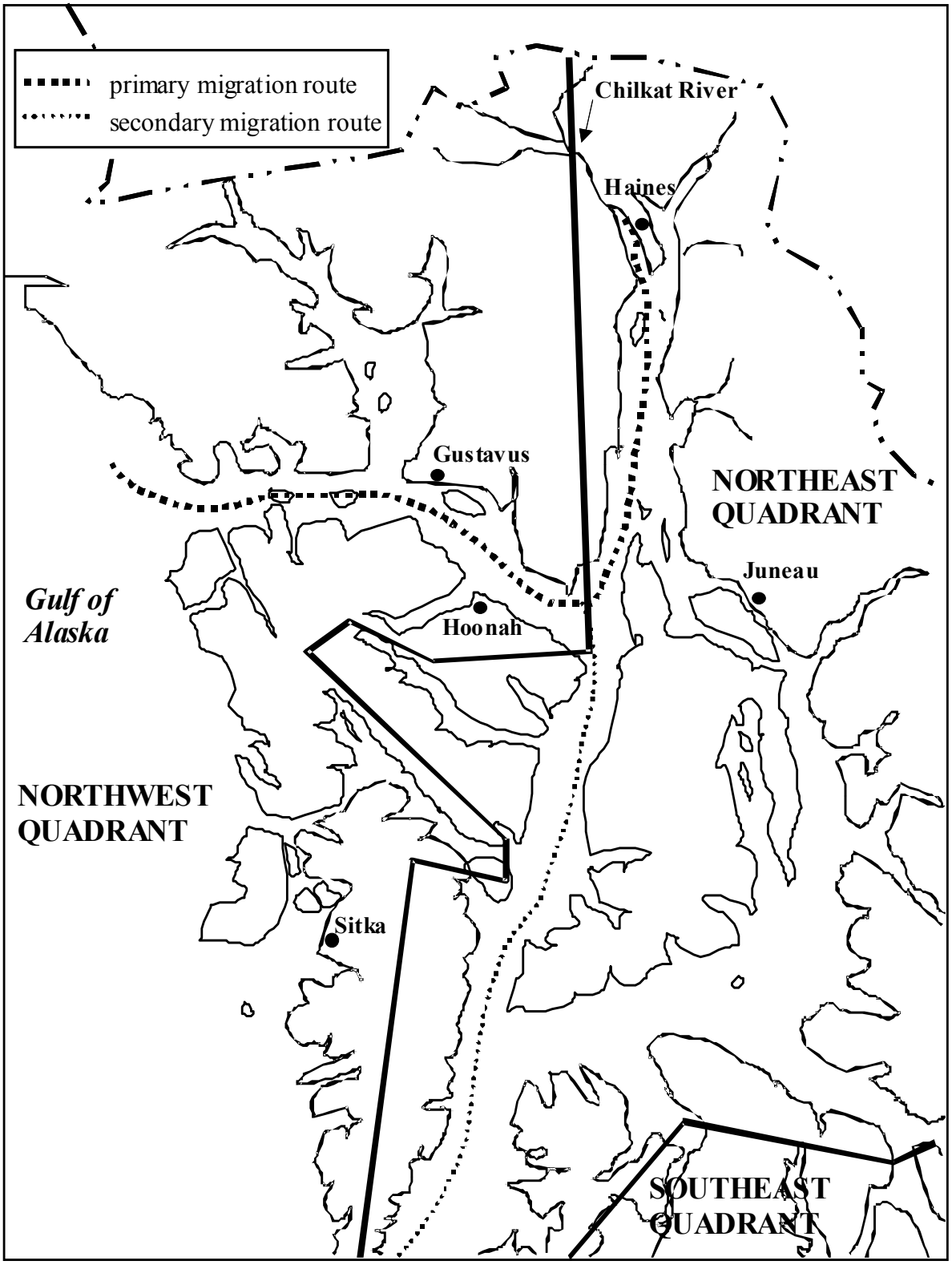

Figure 4.–Commercial troll quadrants and migration routes of Chilkat River coho salmon through northern Southeast Alaska.

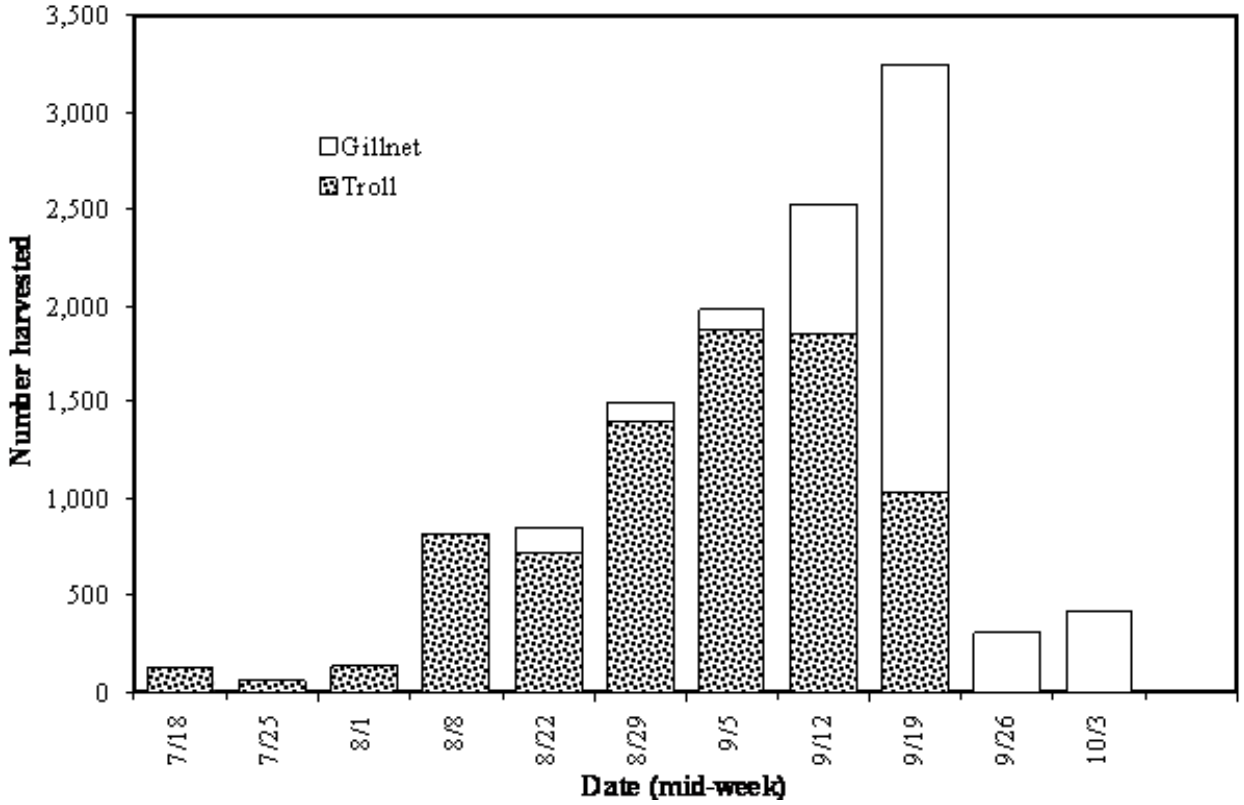

Figure 5.–Estimated marine harvests of coho salmon bound for the Chilkat River, by fishery and statistical week, 2007. Weekly estimates of harvest in the troll (period) and marine sport fisheries (bi-week) are approximated.

DATA FILES

Data collected during this study (Appendix A4) have been archived in ADF&G offices in Haines, Douglas, and Anchorage.

DISCUSSION

The estimate of smolt abundance satisfies the several mark-recapture assumptions discussed above. Attempts were made to ensure every smolt had an equal chance of being marked. Although smolt were still being captured when trapping ceased on May 30, catch rates were declining from the peak in mid-May (Table 3).Therefore, the majority of the emigration was probably sampled. In addition, sampling effort for adults in the fish wheels (to estimate the marked fraction) was relatively constant over time, tending to equalize probability of capture during the second sampling event. Comparing CWT recovery rates for different coho salmon smolt size categories (Table 7) reveals no significant difference between groups, and strengthens the assertion that fish were marked and sampled with equal probability (assumption a).

Although the population in this experiment was not closed to losses from mortality, it was closed to recruitment (assumption b) because salmon return to their natal stream to spawn. There have been rare instances when coho salmon with Berners River tags have been recovered in the Chilkat River, or when juvenile coho salmon containing Chilkat River tags have been captured in other drainages, but these irregular events are considered negligible. Because different capture gear was used during the first and second sampling events, it is unlikely that marking affected the catchability of adults (assumption c). Other studies have shown that marked coho smolt do not suffer significantly higher mortality than unmarked fish (Elliott and Sterritt 1990; Vincent-Lang 1993). Because all fish had secondary marks (adipose finclips) that were not lost, assumption (d) was satisfied. Personnel sampling the fish wheels were able to examine 97.9% of captured fish (1,640 examined out of 1,676 captured) for missing adipose fins - fish that

were not examined either escaped or were overlooked. Once examined, fish were marked to prevent re-sampling; thus it was impossible that fish were sampled more than once. Similarly, it is unlikely that fish were examined for missing adipose fins more than once, thus assumption (e) was robust.

Although freshwater age-2. fish represented approximately 7% of the smolt emigration, they represented nearly 29% of the adult escapement. One possible explanation for this difference is that age-2. smolt had better marine survival than age-1. fish. A second explanation is that the minnow traps were biased toward smaller fish because the limited diameter of the G-40 minnow trap entrance tunnel excluded the largest coho salmon smolt. This phenomenon was investigated on the Unuk River in response to differential marking and survival rates between large and small smolt (Weller et al. 2005). That study concluded that minnow trap design could result in smolt estimates that were biased low by as much as 20%. A third explanation is that coho salmon smolt emigrating from Chilkat Lake were under-represented in event 1. Results from smolt sampling by CF at Chilkat Lake in 2006 indicated that age-2. fish represented 27% of the population, which is much closer to the proportion in the adult escapement (Tables 4 and 6). In future years of the Chilkat River coho salmon smolt study, small (<85mm) and medium/large (≥85mm) fish will continue to be marked with distinct tag codes, to investigate marking or survival rate differences by size class.

Because it is sometimes difficult to identify the sex of ocean-phase fish by visual observation, the sex ratio of samples at the fish wheels may be inaccurate. Ericksen (2006) examined 62 coho salmon that were sampled at the fish wheels then recaptured and sexed on the spawning grounds. Assuming that sex determination is more reliable on the spawning grounds than in the lower river, 8 of 62 fish were incorrectly identified as females, and 6 out of 62 were incorrectly identified as males at the fish wheels. In mark-recapture years, sex compositions determined in the second sampling event can be used to accurately estimate proportions at age of males and females.

The 2007 total escapement estimate of coho salmon (including jacks) to the Chilkat River (25,493, SE = 4,905) was the lowest since abundance estimation began on the Chilkat River drainage in 1987 (Table 1).Marine exploitation (32.3%, SE = 5.0%) was also below average and does not explain low abundance. A more likely explanation is a low smolt emigration (883,230, SE = 136,074) combined with the lowest marine survival estimate (4.3%, SE = 0.9%) since the CWT project began in 1999 (Table 12).

The median date of coho salmon immigration at the Chilkat River fish wheels in 2007 (September 18) matched the 1997-2006 average (September 19, Figure 6).

Daily fish wheel catches in the lower Chilkat River were highly variable, as evidenced by the 2 highest catches occurring 15 days apart, on September 13 (128 captures) and September 28 (86 captures, Figure 3).The estimated total fish wheel catch of 1-ocean coho salmon in 2007 (1,594) was 63% of the 1997-2006 average of 2,547 1-ocean coho salmon. Before 1997, operation of the Chilkat River fish wheels ended around September 15th, which makes comparisons difficult.

Because the number of stocks present decreases with proximity to natal streams, the percentage of Chilkat River coho salmon in the fishery harvest increased as with proximity to the Chilkat River. The estimated harvest of Chilkat River fish was greatest in the Northwest Quadrant troll fishery (7,846, SE = 1,288), but those fish represented only 1.0% of the total harvest in that fishery (Table 10). The second largest harvest occurred in the Lynn Canal drift gillnet fishery (3,986, SE = 893) where Chilkat River fish represented 23.5% of the total harvest.

The fact that there was no difference in recovery rates between the District 115 gillnet fishery or the Northwest Quadrant troll fishery indicates that tagged fish mixed well in the ocean environment. The combined troll (67%) and gillnet (33%) fisheries comprised 100% of all Chilkat tag recoveries.

Table 12.–Estimates of Chilkat River coho salmon smolt and adult production, 2000-2007.

Return year	2000[a]	2001[b]	2002[c]	2003[d]	2004[e]	2005[f]	2006[g]	2007	Average
Number CWT smolt (t-1)	25,915	25,016	36,114	25,296	24,563	17,276	26,342	22,149	25,334
Smolt theta (θ_s)	0.020	0.021	0.012	0.015	0.012	0.021	0.014	0.024	0.018
Smolt estimate	1,237,056	1,185,804	2,970,458	1,696,212	1,938,322	776,934	1,807,837	883,230	1,561,982
SE	219,715	164,121	377,695	190,330	401,419	147,738	217,352	136,074	231,805
Marine theta (θ_m)	0.019	0.020	0.012	0.015	0.010	0.020	0.013	0.023	0.016
Marine harvest	39,546	45,658	110,105	83,302	128,466	29,518	70,813	12,142	64,944
SE	3,745	7,194	10,355	6,956	19,882	3,483	7,632	1,585	7,604
Inriver harvest	853	2,176	3,888	2,932	3,169	1,453	2,082	635	2,149
SE	221	451	742	497	661	293	293	149	413
Age x.1 escapement	84,843	107,697	204,805	133,045	67,053	34,721	79,050	24,770	91,998
SE	16,330	20,720	31,071	14,926	12,901	4,175	15,210	4,769	15,013
Total return	125,242	155,531	318,798	219,279	198,688	65,692	151,945	37,547	159,090
SE	16,755	21,938	32,759	16,474	23,710	5,445	17,020	5,027	17,391
Marine exploitation	0.32	0.29	0.35	0.38	0.65	0.45	0.47	0.32	0.40
SE	0.05	0.05	0.04	0.03	0.05	0.04	0.05	0.05	0.05
Marine survival	0.10	0.13	0.11	0.13	0.10	0.08	0.08	0.04	0.10
SE	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.02

[a] From Ericksen 2001.
[b] From Ericksen 2002.
[c] From Ericksen 2003.
[d] From Ericksen and Chapell 2005.
[e] From Ericksen and Chapell 2006.
[f] From Ericksen 2006.
[g] From Elliott 2009.

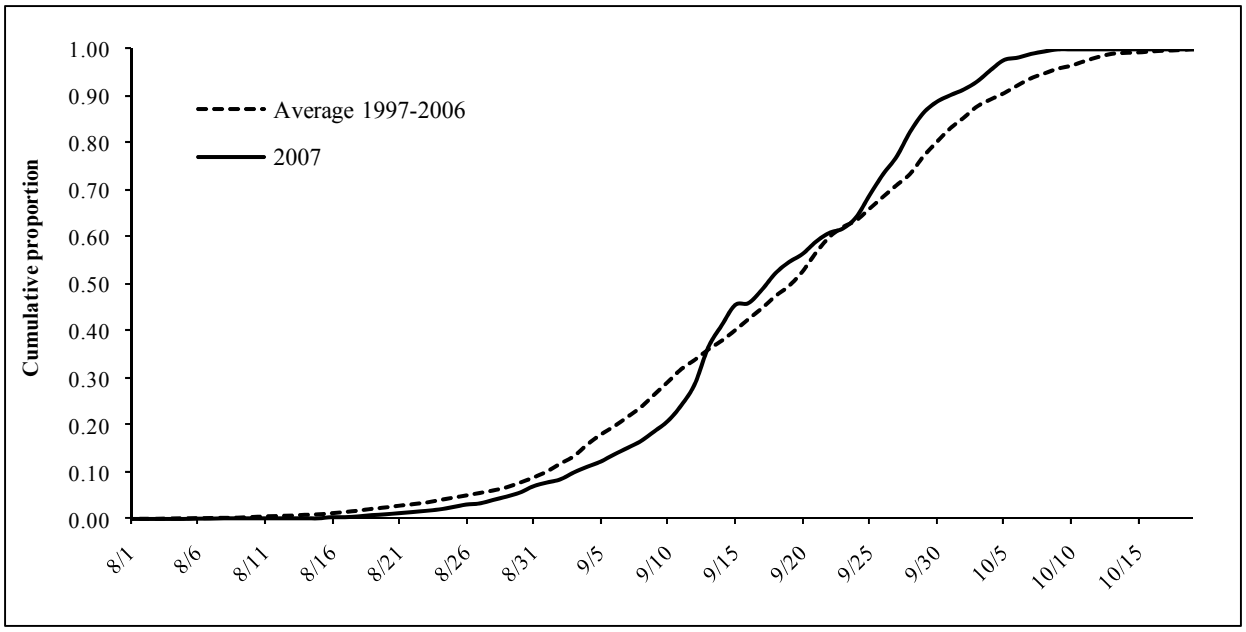

Figure 6.–Cumulative proportion of adult coho salmon captured in Chilkat River fish wheels during 2007 compared to the mean cumulative proportion of 1997–2006.

There is increasing evidence that smolt occasionally migrate through salt water then enter another freshwater drainage to rear for a period of time. One juvenile coho salmon with a Chilkat River tag code was captured moving upstream into Auke Creek near Juneau (Ericksen and Chapell 2005). This was the first time that a juvenile Chilkat River fish was captured migrating upstream into another freshwater drainage in the fall. However, smolt with Chilkat River tag codes have been recovered from other freshwater drainages with Chilkat River codes. One coho salmon smolt with a 2001 Chilkat River tag code was sampled as it emigrated from Jordan Creek near Juneau in 2002 (Ericksen 2003). Two smolt were recaptured in the Berners River in 2000 with 1999 codes (Ericksen 2001).

Adult coho salmon have also been recovered in the Chilkat River fish wheels with tags from other drainages (Ericksen 1999; Ericksen and Chapell 2005). These fish may have originated from the Chilkat River and reared in other drainages. An example of this occurred in 2007, when a returning adipose-clipped adult coho salmon captured in the Chilkat River fish wheels had a Berners River coded wire tag, released in 2006.This fish could either have strayed as an adult or more likely was of Chilkat River origin, and reared for some period of time in the Berners River where it was captured and tagged.

The harvest estimate of Chilkat River coho salmon in 2007 represents minimum total harvest because not all fisheries were sampled, and some were not sampled at rates sufficient to detect small harvests. Some marine sport fishery sites (including Pelican, Prince William Sound, and Cook Inlet) were not sampled for CWTs, so stock contribution to these fisheries cannot be estimated. Furthermore, harvest contributions of Chilkat River coho salmon cannot be determined from tags recovered in mixed district fisheries.

Expansions of harvest for Chilkat coho salmon are based on harvests for a particular district (Table 9). Uncertainties of total harvest quantities for individual districts preclude estimation of Chilkat River coho salmon harvest, and underestimate total harvest.

The marine exploitation rate of Chilkat River coho salmon in 2007 (32.3%, SE = 5.0%) was below average and comparable to return year 2000. However, total return in 2000 was 125,242 fish, over 3 times larger than in 2007 (Figure 7). Return year 2007 is an example of the weak relationship between exploitation and total return.

In fact, both data appear variable and unrelated (Table 12). In 2004, for example, the total return estimate was an above-average 198,688, and the exploitation rate was 64.7%, approximately 61% higher than the 8-year average.

Estimated marine survival (4.3%, SE = 0.9%) and estimated total return (37,547, SE = 5,027) were the lowest since the coho salmon CWT project began in 1999 (Table 12). The poor marine survival was a factor; however a low smolt estimate in 2006 is largely responsible for this precipitous decline. From 2000-2006, marine survival was relatively stable (average 10.6%, SE = 1.9%), and survival has been poorly correlated with total return.

The total return of Chilkat River coho salmon is primarily dependent on the abundance of the smolt emigration (Figure 8). In 2002, for example, when marine survival was average (10.7%), the estimated return of 318,798 coho salmon was 100% higher than the 2000-2007 average (Table 12), due to the large smolt emigration (2,970,458 fish) in 2001. In contrast, marine survival was estimated at an above-average 13.1% for return year 2001, but the smolt outmigration in 2000 was below average at 1,185,804, resulting in a below average total return estimate of 155,531 (Figure 7, Table 12). Linear regression of smolt emigration on total return yields an R^2 value of 0.97 (Figure 8). The abundance of the previous year's smolt emigration estimate, as measured by spring trapping CPUE, could be a useful predictor of return for Chilkat River coho salmon.

Production of Chilkat River coho salmon smolt is limited by the amount of rearing habitat (Ericksen and Fleischman 2006), which would indicate some degree of density dependence; however there is a weak relationship between smolt estimates and average fish size (Table 13, 44% negatively correlated). Average fish size is also not related to marine survival. Thomas Fulton, among others in the early 20th century, developed a method to measure the robustness of fish populations, called the K factor ($K = (\text{weight}/\text{length}^3) \times 10^5$), as an indicator of fish condition (Fulton 1902; Ricker 1975). The smolt estimate data, average K factor, and resulting marine survival were examined for Chilkat coho salmon (Table 13, Figure 9). The insignificant slope ($p = 0.70$) and poor fit ($R^2 = 0.027$) of the regression line show that smolt size has little affect on marine survival.

Similarly, the relationship between smolt emigration abundance and marine survival does not appear to be strong for Chilkat River coho salmon (Figure 10). Regression of survival on smolt abundance produces a line with an insignificant slope ($p = 0.39$) and the data is only 36% correlated. When examining the marine survival to smolt abundance relationship among all Southeast Alaska coho salmon indicator stocks, including Auke Creek, Berners River, Chilkat River, Taku River, Ford Arm Lake, Hugh Smith Lake, Chuck Creek, and Nakwasina River, the data is 14% correlated (Shaul et al. 2008). This weak relationship for the Chilkat River stock and other Southeast Alaska stocks could indicate that marine survival is more driven by ocean rearing conditions than freshwater abundance of rearing juvenile fish.

A predictor of marine survival that may be useful for making inseason fishery management decisions, such as the Chilkat River sport bag limits for coho salmon, is the CWT recovery rate from commercial troll fisheries (Table 14, Figure 11). Examining recovery rates from 2000-2007 for Chilkat River coho salmon reveals that marine recovery and marine survival are 85% positively correlated; i.e. in years with an above average marine recovery rate, marine survival is also above average. Because marine CWT interceptions largely occur before the escapement of Chilkat River coho salmon, and the recovery rate is based on known quantities (smolt released with tags and CWTs recovered), assessing this relationship can help predict marine survival and, after adding the in-season marking fraction θ_m, can be a useful predictor of return strength (Figure 12).

The forecasting model creates 2 estimated parameters, one for the CWT recovery rate from the troll fishery represented by ρ, and the other is for the marine theta, represented by ϕ. Non-linear regression using the least squares method produces estimates for ρ and ϕ, including the residual term ε representing additive error from the model:

$$\text{Estimated return} = \rho(\text{troll CWT \%}) - \phi(\theta_m) + \varepsilon$$

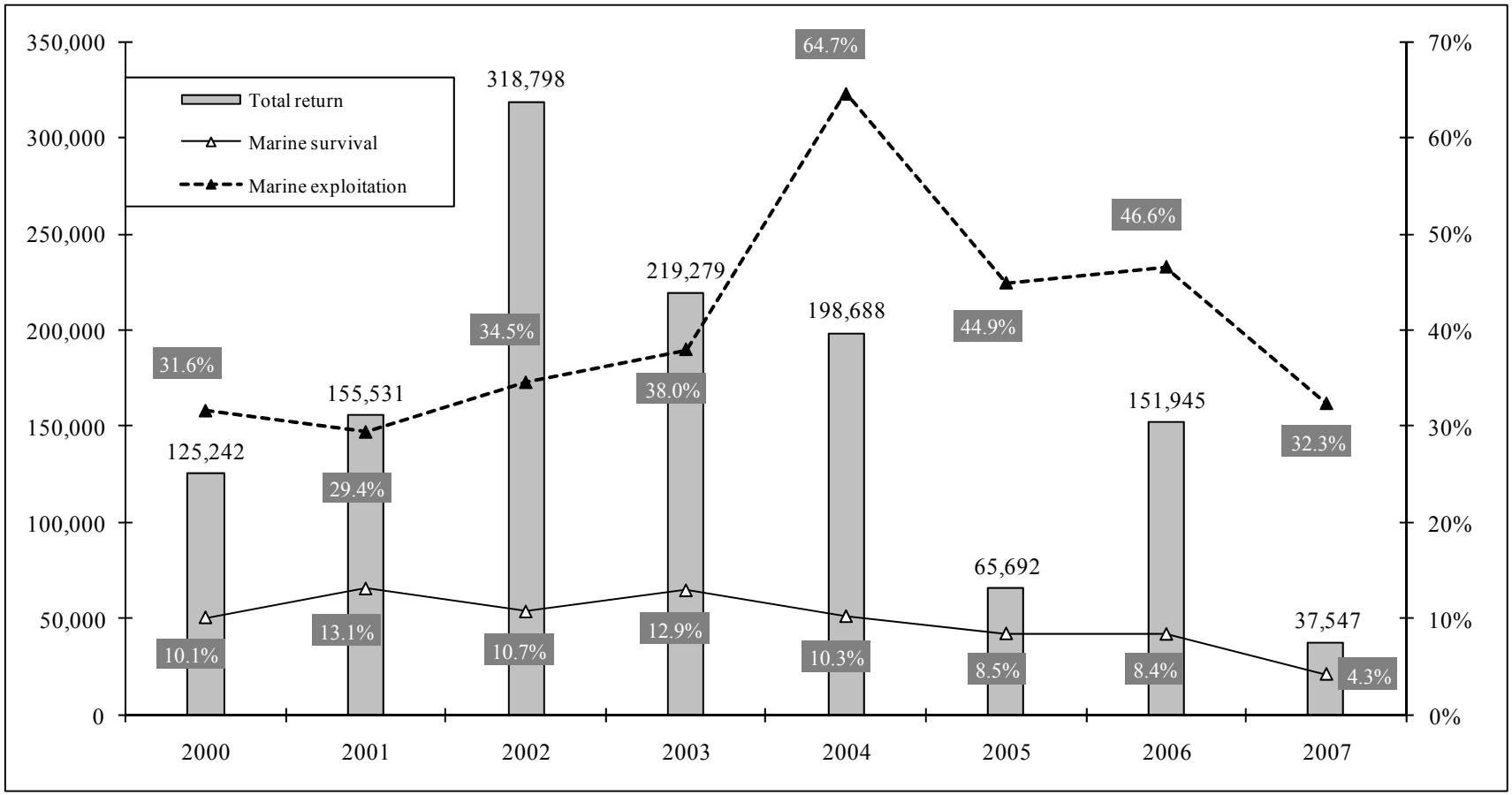

Figure 7.–Estimated total return, marine survival, and marine exploitation rate of Chilkat River coho salmon, 2000-2007.

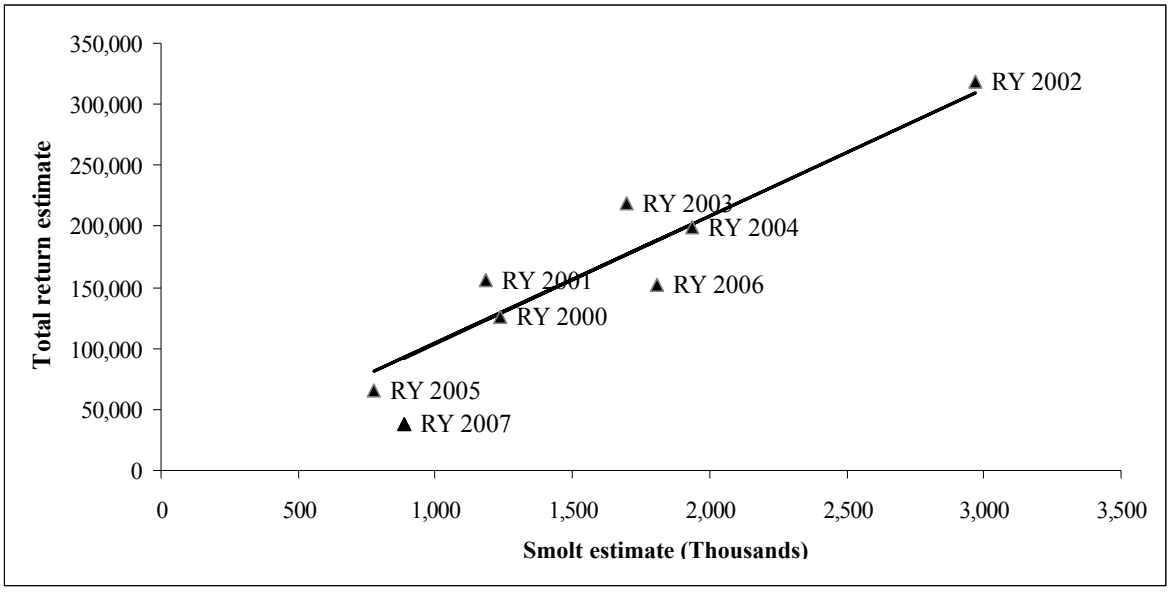

Figure 8.–Estimated smolt emigration and resulting total return of Chilkat River coho salmon, 2000-2007. Linear regression results in an R^2 value of 0.97 and a significant slope with a p value of 1.23E-06.

Table 13.–Smolt estimate, average smolt sizes, and marine survival for Chilkat River coho salmon, 1999-2006.

		Age 1.	Age 1.	Age 1.	Age 2.	Age 2.	Age 2.		
Smolt year	Smolt estimate	*n*	length	weight	*n*	length	weight	All ages K factor	Marine survival
1999	1,237,056	236	80.0	5.4	46	101.0	10.3	1.046	0.101
2000	1,185,804	184	86.3	6.5	22	102.0	10.4	1.008	0.131
2001	2,970,458	379	85.0	6.4	58	101.0	7.1	0.995	0.107
2002	1,696,212	266	83.0	6.0	61	96.0	8.8	1.039	0.129
2003	1,938,322	315	85.0	6.2	22	104.0	10.9	1.007	0.103
2004	776,934	203	83.5	6.1	15	102.1	10.9	1.046	0.084
2005	1,807,837	398	83.0	5.9	38	105.0	11.2	1.026	0.084
2006	883,230	345	84.0	5.9	26	106.6	11.1	0.999	0.044

Table 14.–Chilkat River coho salmon marine coded wire tags released and recovered, 2000-2007.

Year	Smolt tagged (*t*-1)	Marine theta	Marine coded wire tags	Marine recovery rate	Marine survival	Adult return
2000	25,915	1.89%	265	1.02%	10.1%	125,242
2001	25,016	2.03%	251	1.00%	13.1%	155,531
2002	36,114	1.22%	329	0.91%	10.7%	318,798
2003	25,296	1.47%	424	1.68%	12.9%	219,279
2004	24,563	1.04%	254	1.03%	10.3%	198,688
2005	17,276	1.97%	142	0.82%	8.5%	65,546
2006	26,342	1.31%	217	0.82%	8.4%	151,945
2007	22,149	2.28%	78	0.35%	4.3%	37,547
Average	25,334	1.65%	245	0.96%	9.8%	159,072

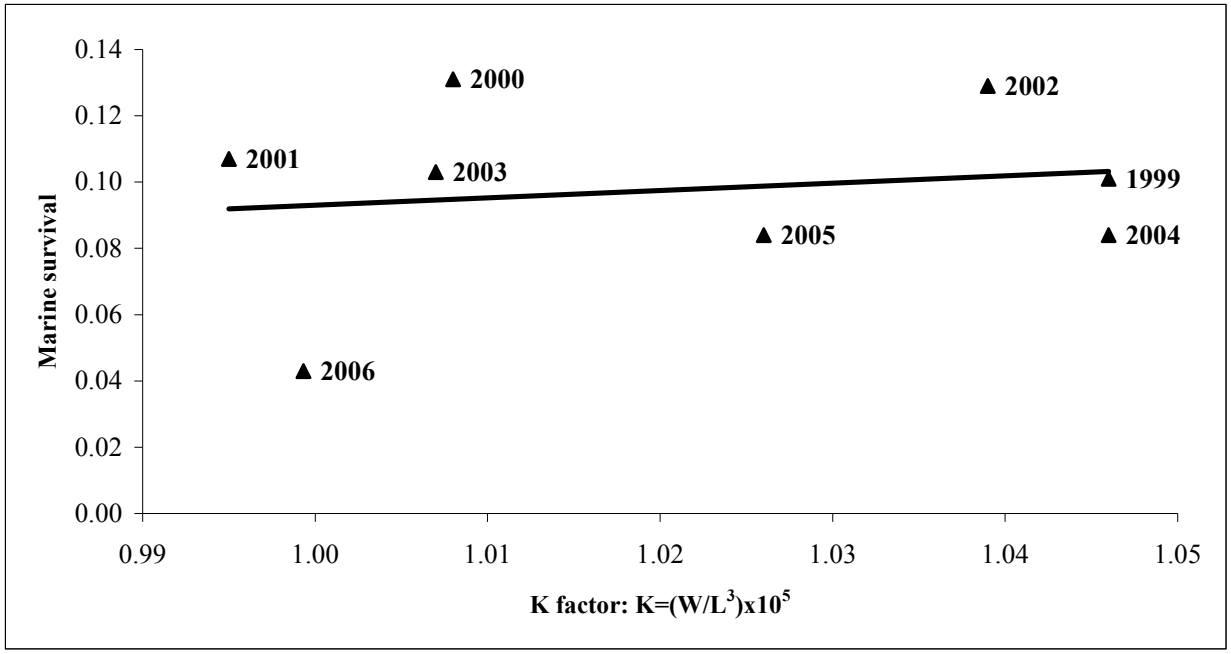

Figure 9.–Estimated smolt sizes as expressed by the K factor and resulting marine survival for Chilkat River coho salmon, smolt years 1999-2006. The data is unrelated as evidenced by an R^2 **value of 0.027 and** an insignificant slope with p value of 0.70.

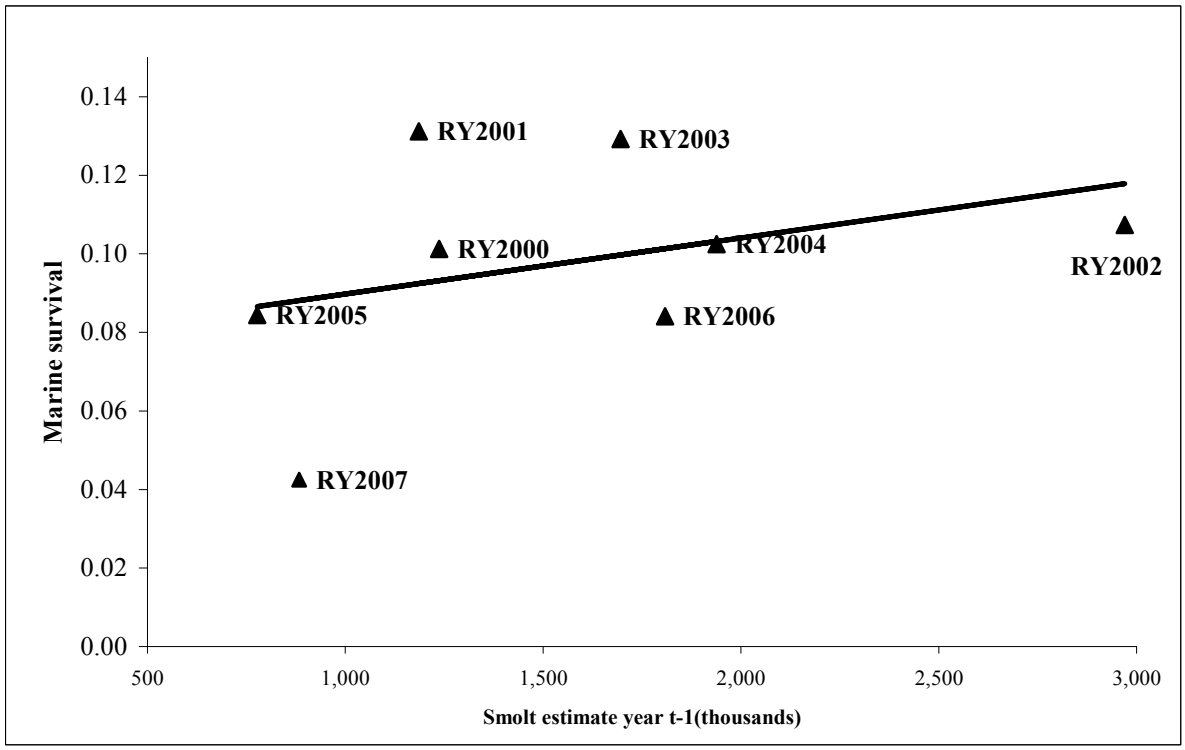

Figure 10.–Observed smolt outmigration estimates and observed and predicted marine survival for Chilkat River coho salmon, return years 2000-2007. Predicted marine survival has an insignificant slope with p value of 0.39, and the data is 36% correlated.

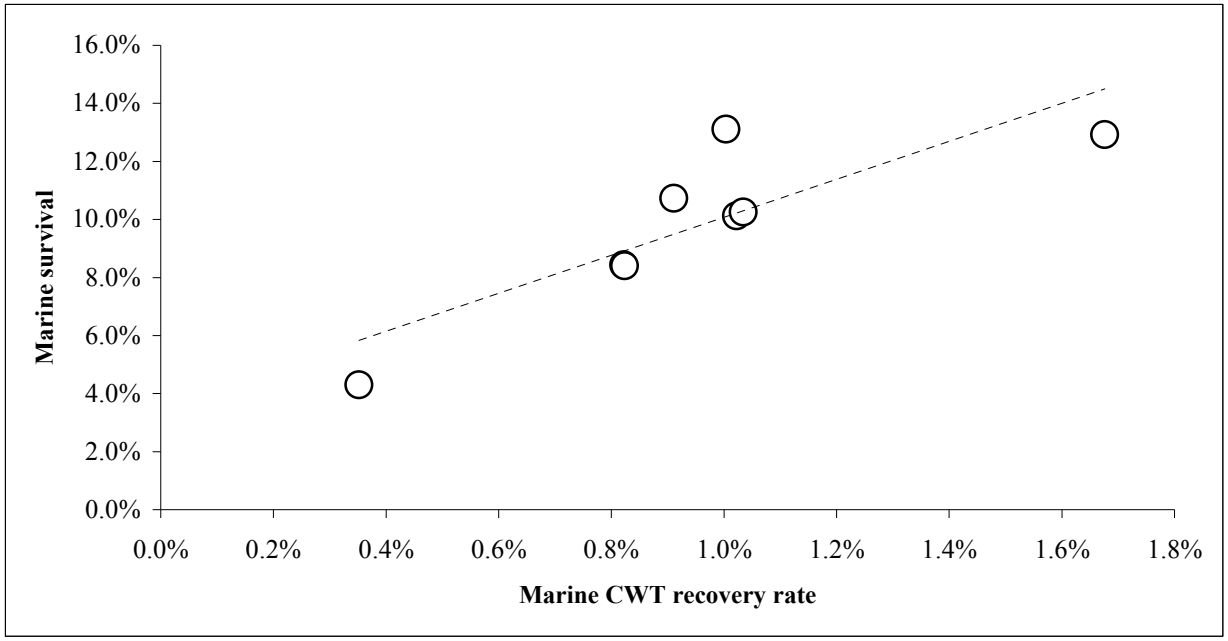

Figure 11.–Marine coded wire tag recovery rate and marine survival for Chilkat River coho salmon, 2000-2007. The data are 85% correlated and linear regression results in an R2 value of 0.97.

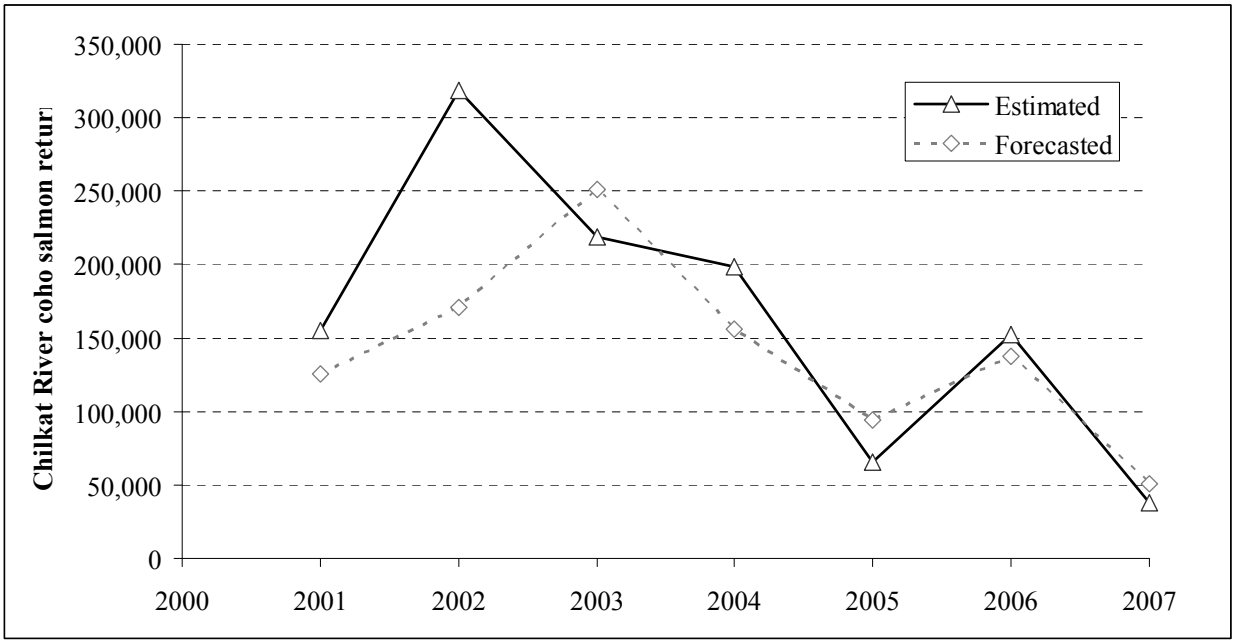

Figure 12.–Inseason forecasted returns and postseason estimated returns of Chilkat River coho salmon, 2001-2007. The number of coded wire tags released in year t-1, average marine theta, and the marine coded wire tag recovery rate are used to generate the forecasted total. Average forecast error for return years 2001-2007 is 27.2%.

Most troll fishery interceptions occur by the end of statistical week 38, which coincides with September 15-21. That time frame is also the median date of the Chilkat River fish wheel catch, when marine theta can be reasonably estimated. Using the total CWTs released in year *t*-1, marine theta, and the marine CWT recovery rate produces inseason forecasted return totals with a forecasting error of less than 25% in 5 of the 8 years examined. Return year 2002 was one anomaly, as the return was the highest recorded and exceeded expectations (Table 12, Figure 12). Prior forecasts of coho salmon return have used CWTs released with average marine survival and average marine exploitation rates; using inseason marine CWT recovery rates allows for more accurate forecasting while utilizing contemporary data. As more data are collected in subsequent years, this forecasting tool will be developed further and should continue to be studied, to predict overall return and escapement of coho salmon to the Chilkat River.

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APPENDIX A

Appendix A1.–Random and select recoveries of coded wire tagged Chilkat River coho salmon in 2007.

Head number	Tag code	Gear	Port	Recovery date	Stat. week	Quad-rant	Dist.	Sub-dist.	Length
RANDOM RECOVERIES									
540572	40830	Gillnet	Excursion Inlet	8/23/2007	34	NE	115		
540644	40829	Gillnet	Excursion Inlet	8/30/2007	35	NE	115		630
320617	40829	Gillnet	Juneau	9/4/2007	36	NE	115		595
320675	40829	Gillnet	Juneau	9/11/2007	37	NE	115		600
320674	40829	Gillnet	Juneau	9/11/2007	37	NE	115		634
266589	41135	Gillnet	Juneau	9/11/2007	37	NE	115		720
320677	40829	Gillnet	Juneau	9/12/2007	37	NE	111		640
320695	40829	Gillnet	Juneau	9/12/2007	37	NE	115		550
324105	40829	Gillnet	Juneau	9/14/2007	37	NE	115		525
324106	40830	Gillnet	Juneau	9/14/2007	37	NE	115		568
324120	40829	Gillnet	Juneau	9/18/2007	38	NE	115		615
324113	40829	Gillnet	Juneau	9/18/2007	38	NE	115		675
324118	40830	Gillnet	Juneau	9/18/2007	38	NE	115		605
324114	40830	Gillnet	Juneau	9/18/2007	38	NE	115		615
324182	40829	Gillnet	Juneau	9/20/2007	38	NE	115		605
324168	40829	Gillnet	Juneau	9/20/2007	38	NE	115		695
324122	40829	Gillnet	Juneau	9/20/2007	38	NE			630
324164	40829	Gillnet	Juneau	9/20/2007	38	NE			655
324176	40830	Gillnet	Juneau	9/20/2007	38	NE	115		610
324126	40830	Gillnet	Juneau	9/20/2007	38	NE			580
324137	41015	Gillnet	Juneau	9/20/2007	38	NE			560
540170	40829	Gillnet	Juneau	9/27/2007	39	NE	115		605
540189	40829	Gillnet	Juneau	9/27/2007	39	NE	115		630
540116	40829	Gillnet	Juneau	10/4/2007	40	NE	115		655
540114	40829	Gillnet	Juneau	10/4/2007	40	NE	115		660
540115	41015	Gillnet	Juneau	10/4/2007	40	NE	115		635
51859	40829	Troll	Pelican	7/20/2007	29	NW			535
58274	40829	Troll	Pelican	7/26/2007	30	NW	114	21	485
58362	40829	Troll	Pelican	8/1/2007	31	NW	116	11	500
58422	40829	Troll	Pelican	8/7/2007	32	NW			485
519779	40829	Troll	Yakutat	8/9/2007	32	NW	181	60	535
58481	40829	Troll	Pelican	8/9/2007	32	NW			510
327969	40829	Troll	Sitka	8/11/2007	32	NW	113	61	550
58466	40830	Troll	Pelican	8/11/2007	32	NW	113	91	525
96526	40829	Troll	Hoonah	8/19/2007	34	NW	113	91	636
349093	41015	Troll	Sitka	8/22/2007	34	NW	113	71	525
327878	41015	Troll	Sitka	8/22/2007	34	NW			500
540586	40829	Troll	Excursion Inlet	8/24/2007	34	NW			450
58681	40830	Troll	Pelican	8/27/2007	35	NW			505
349544	40829	Troll	Sitka	8/28/2007	35	NW			620
349596	40830	Troll	Sitka	8/28/2007	35	NW	113	31	530
96477	40830	Troll	Hoonah	8/29/2007	35	NE	112	16	505
58741	40830	Troll	Pelican	8/30/2007	35	NW			520
540646	41015	Troll	Excursion Inlet	8/30/2007	35	NW			540
525935	40830	Troll	Yakutat	9/3/2007	36	NW	189	30	580
529630	40829	Troll	Excursion Inlet	9/4/2007	36	NW	114	25	610
96673	40829	Troll	Hoonah	9/4/2007	36	NW			580
525975	40830	Troll	Yakutat	9/4/2007	36	NW			505
525965	40830	Troll	Yakutat	9/4/2007	36	NW			610
96724	40830	Troll	Hoonah	9/4/2007	36	NW			625
96718	41015	Troll	Hoonah	9/4/2007	36	NW			642
529643	40830	Troll	Excursion Inlet	9/5/2007	36	NW			545
96744	40829	Troll	Hoonah	9/10/2007	37	NW	114	21	620
58912	41015	Troll	Pelican	9/10/2007	37	NW	114	21	540

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Head number	Tag code	Gear	Port	Recovery date	Stat. week	Quad-rant	Dist.	Sub-dist.	Length
96743	41015	Troll	Hoonah	9/10/2007	37	NW	114	21	608
58876	41015	Troll	Pelican	9/10/2007	37	NW	154		600
58931	41015	Troll	Pelican	9/11/2007	37	NW			540
325191	40830	Troll	Ketchikan	9/12/2007	37	NW	113	71	
96876	40829	Troll	Hoonah	9/13/2007	37	NW			586
350302	40830	Troll	Sitka	9/14/2007	37	NW	113	91	475
58982	41015	Troll	Pelican	9/14/2007	37	NW	113	91	600
58966	41015	Troll	Pelican	9/14/2007	37	NW			590
541036	41015	Troll	Pelican	9/15/2007	37	NW	113	91	690
96891	40829	Troll	Hoonah	9/17/2007	38	NW	114		656
54057	40829	Troll	Hoonah	9/18/2007	38	NW			587
54055	41015	Troll	Hoonah	9/18/2007	38	NW			576
96966	40829	Troll	Hoonah	9/20/2007	38	NW	114	25	536
96970	40829	Troll	Hoonah	9/20/2007	38	NW	114	25	563
96925	40830	Troll	Hoonah	9/20/2007	38	NW	114	21	558
350917	41015	Troll	Sitka	9/20/2007	38	NW			530
350936	41015	Troll	Sitka	9/20/2007	38	NW			565
350918	41015	Troll	Sitka	9/20/2007	38	NW			690
350664	40829	Troll	Sitka	9/21/2007	38	NW	114	25	620
541118	41015	Troll	Pelican	9/21/2007	38	NW	113	91	580
541117	41015	Troll	Pelican	9/21/2007	38	NW	113	91	665
350669	41015	Troll	Sitka	9/21/2007	38	NW	113		570
54077	41015	Troll	Hoonah	9/21/2007	38	NW	113		699
541125	41015	Troll	Pelican	9/21/2007	38	NW			640
252492	40829	Fish Wheels	Chilkat River	8/6/2007	32	NE	115	32	390
252493	41015	Fish Wheels	Chilkat River	8/19/2007	34	NE	115	32	520
252495	40829	Fish Wheels	Chilkat River	8/24/2007	34	NE	115	32	440
252496	41015	Fish Wheels	Chilkat River	8/24/2007	34	NE	115	32	400
252497	40829	Fish Wheels	Chilkat River	8/29/2007	35	NE	115	32	325
252498	40830	Fish Wheels	Chilkat River	8/30/2007	35	NE	115	32	365
252499	41015	Fish Wheels	Chilkat River	9/2/2007	36	NE	115	32	425
252500	40830	Fish Wheels	Chilkat River	9/5/2007	36	NE	115	32	490
56753	40829	Fish Wheels	Chilkat River	9/6/2007	36	NE	115	32	640
56754	40830	Fish Wheels	Chilkat River	9/7/2007	36	NE	115	32	545
56755	40830	Fish Wheels	Chilkat River	9/11/2007	37	NE	115	32	520
56756	40830	Fish Wheels	Chilkat River	9/12/2007	37	NE	115	32	590
56757	40829	Fish Wheels	Chilkat River	9/13/2007	37	NE	115	32	435
56758	40829	Fish Wheels	Chilkat River	9/14/2007	37	NE	115	32	500
56759	40829	Fish Wheels	Chilkat River	9/14/2007	37	NE	115	32	505
56760	40829	Fish Wheels	Chilkat River	9/15/2007	37	NE	115	32	505
56761	40830	Fish Wheels	Chilkat River	9/18/2007	38	NE	115	32	600
56762	40830	Fish Wheels	Chilkat River	9/18/2007	38	NE	115	32	635
56764	40830	Fish Wheels	Chilkat River	9/20/2007	38	NE	115	32	450
56765	40829	Fish Wheels	Chilkat River	9/21/2007	38	NE	115	32	660
56766	40830	Fish Wheels	Chilkat River	9/22/2007	38	NE	115	32	530
56767	40829	Fish Wheels	Chilkat River	9/26/2007	39	NE	115	32	535
56768	40829	Fish Wheels	Chilkat River	9/26/2007	39	NE	115	32	550
56775	40829	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	485
56773	40829	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	530
56774	40830	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	630
56772	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	535
56769	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	595
56771	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	595

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Head number	Tag code	Gear	Port	Recovery date	Stat. week	Quad-rant	Dist.	Sub-dist.	Length
56777	40830	Fish Wheels	Chilkat River	9/29/2007	39	NE	115	32	590
56776	41015	Fish Wheels	Chilkat River	9/29/2007	39	NE	115	32	665
56778	40830	Fish Wheels	Chilkat River	10/1/2007	40	NE	115	32	540
56780	40829	Fish Wheels	Chilkat River	10/4/2007	40	NE	115	32	655
56779	40830	Fish Wheels	Chilkat River	10/4/2007	40	NE	115	32	640
56781	40829	Fish Wheels	Chilkat River	10/5/2007	40	NE	115	32	580
56782	40829	Fish Wheels	Chilkat River	10/5/2007	40	NE	115	32	605
252492	40829	Fish Wheels	Chilkat River	8/6/2007	32	NE	115	32	390
252495	40829	Fish Wheels	Chilkat River	8/24/2007	34	NE	115	32	440
252497	40829	Fish Wheels	Chilkat River	8/29/2007	35	NE	115	32	325
56753	40829	Fish Wheels	Chilkat River	9/6/2007	36	NE	115	32	640
56757	40829	Fish Wheels	Chilkat River	9/13/2007	37	NE	115	32	435
56758	40829	Fish Wheels	Chilkat River	9/14/2007	37	NE	115	32	500
56759	40829	Fish Wheels	Chilkat River	9/14/2007	37	NE	115	32	505
56760	40829	Fish Wheels	Chilkat River	9/15/2007	37	NE	115	32	505
56765	40829	Fish Wheels	Chilkat River	9/21/2007	38	NE	115	32	660
56767	40829	Fish Wheels	Chilkat River	9/26/2007	39	NE	115	32	535
56768	40829	Fish Wheels	Chilkat River	9/26/2007	39	NE	115	32	550
56775	40829	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	485
56773	40829	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	530
56780	40829	Fish Wheels	Chilkat River	10/4/2007	40	NE	115	32	655
56781	40829	Fish Wheels	Chilkat River	10/5/2007	40	NE	115	32	580
56782	40829	Fish Wheels	Chilkat River	10/5/2007	40	NE	115	32	605
252498	40830	Fish Wheels	Chilkat River	8/30/2007	35	NE	115	32	365
252500	40830	Fish Wheels	Chilkat River	9/5/2007	36	NE	115	32	490
56754	40830	Fish Wheels	Chilkat River	9/7/2007	36	NE	115	32	545
56755	40830	Fish Wheels	Chilkat River	9/11/2007	37	NE	115	32	520
56756	40830	Fish Wheels	Chilkat River	9/12/2007	37	NE	115	32	590
56761	40830	Fish Wheels	Chilkat River	9/18/2007	38	NE	115	32	600
56762	40830	Fish Wheels	Chilkat River	9/18/2007	38	NE	115	32	635
56764	40830	Fish Wheels	Chilkat River	9/20/2007	38	NE	115	32	450
56766	40830	Fish Wheels	Chilkat River	9/22/2007	38	NE	115	32	530
56774	40830	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	630
56777	40830	Fish Wheels	Chilkat River	9/29/2007	39	NE	115	32	590
56778	40830	Fish Wheels	Chilkat River	10/1/2007	40	NE	115	32	540
56779	40830	Fish Wheels	Chilkat River	10/4/2007	40	NE	115	32	640
252493	41015	Fish Wheels	Chilkat River	8/19/2007	34	NE	115	32	520
252496	41015	Fish Wheels	Chilkat River	8/24/2007	34	NE	115	32	400
252499	41015	Fish Wheels	Chilkat River	9/2/2007	36	NE	115	32	425
56772	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	535
56769	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	595
56771	41015	Fish Wheels	Chilkat River	9/27/2007	39	NE	115	32	595
56776	41015	Fish Wheels	Chilkat River	9/29/2007	39	NE	115	32	665

Appendix A2.– Age, sex, and length composition of coho salmon sampled at the Chilkat River fish wheels, and estimated escapement in the first of two time strata, August 1 – September 17, 2007.

	Brood year and age class					
	2005	2004	2004	2003		
	1.0	2.0	1.1	2.1	**Total aged**	**Total sampled**[a]
Females						
Sample size	0	90	33		123	302
Percent	0	26 .8	9 .8			40.5
SE		4 .7	5 .3			4.4
Number	0	3,335	1,223			4,558
SE		901	717			1,165
Mean length		581	610			
SD		59	60			
Males						
Sample size	1	168	44		213	443
Percent	0 .3	50 .0	13 .1			59.5
SE	0	3 .9	5 .1			3.4
Number	37	6,226	1,631			7,893
SE	7	1,349	736			1,553
Mean length	310	497	529			
SD		95	101			
All fish[b]						
Sample size	1	258	77		336	745
Percent	0 .3	76 .8	22 .9			47.6
SE	0	2 .6	4 .8			1.8
Number	37	9,561	2,853			12,451
SE	7	1,622	1,027			2,396
Mean length	310	527	563			
SD	0	93	94			

[a]Includes fish not assigned an age.

[b]Includes fish with no sex information

Appendix A3.– Age, sex, and length composition of coho salmon sampled at the Chilkat River fish wheels and estimated escapement in the second of 2 time strata, September 18-October 9, 2007.

	Brood year and age class					
	2005	2004	2004	2003		
	1.0	2.0	1.1	2.1	**Total aged**	**Total sampled**[a]
Females						
Sample size			89	65	154	390
Percent			27.6	20.1		47.5
SE			4.8	5.0		4.0
Number			3,594	2,625		6,218
SE			922	816		1,299
Mean length			582	622		
SD			109	45		
Males						
Sample size		17	106	46	169	431
Percent		5.3	32.8	14.2		52.5
SE		0.6	4.6	5.2		3.9
Number		686	4,280	1,857		6,824
SE		727	1,011	756		1,407
Mean length		322	573	605		
SD		25	84	74		
All fish[b]						
Sample size		17	195	111	323	821
Percent		5.3	60.4	34.4		52.4
SE		0.6	3.5	4.5		1.7
Number		686	7,874	4,482		13,042
SE		727	1,368	1,113		2,509
Mean length		322	577	615		
SD		25	72	59		

[a]Includes fish not assigned an age.

[b]Includes fish with no sex information

Appendix A4.–Computer files used in the analysis of data for this report.

FILE NAME	DESCRIPTION
06trapsum.xls	Excel workbook containing 2006 Chilkat River coho salmon smolt trapping and coded wire tagging data.
Smoltawl2006.xls	Excel workbook containing 2006 Chilkat River coho salmon smolt age-weight-length data.
07FWCoho.xls	Excel workbook containing 2007 Chilkat River fish wheel coho salmon catch, marking, and age-length sample data.
Allcwtrecoveries2007.xls	Excel workbook containing recovery data and harvest estimates of Chilkat River coho salmon tagged as smolt during 2006.

APPENDIX B

Appendix B1.–An alternate smolt abundance estimator using two tagging groups and differential recovery rates.

Coded wire tagging coho salmon smolt in different size groups allows for testing of mark-recapture assumption [a], i.e., that every fish has an equal probability of being marked during event 1, that every fish has an equal probability of being captured in event 2, or that marked fish mix completely with unmarked fish. In the event that chi-square tests indicate unequal probabilities of tagging in event 1 or capture in event 2, an alternate Peterson mark-recapture model will be used for a 2-group population.

A population divided into 2 groups labeled (1) and (2), Peterson's mark-recapture model can be expanded into:

$$N_1 + N_2 = \left(N_1\alpha_1 + N_2\alpha_2\right)\frac{N_1\alpha_1 S_1 B_1 + N_2\alpha_2 S_2 B_2 + N_1\left(1-\alpha_1\right)S_1 B_1 + N_2\left(1-\alpha_2\right)S_2 B_2}{N_1\alpha_1 S_1 B_1 + N_2\alpha_2 S_2 B_2} \qquad \text{(B.1)}$$

In the above equation, N is abundance, α_i is the capture probability in event 1 for each group, S_i the survival rate for each group, and β_i the capture probability for each group.

If one or both capture probability parameters, α_i or β_i, are equal, then the above equation reduces to a more simplified version. Consider the case when $\beta_1 = \beta_2$, the abundance estimator reduces to:

$$N_1 + N_2 = \left(N_1\alpha_1 + N_2\alpha_2\right)\frac{N_1\alpha_1 S_1 + N_2\alpha_2 S_2 + N_1\left(1-\alpha_1\right)S_1 + N_2\left(1-\alpha_2\right)S_2}{N_1\alpha_1 S_1 + N_2\alpha_2 S_2} \qquad \text{(B.2)}$$

If the relationship between α_i parameters is expressed as $A = \alpha_2 / \alpha_1$ and the relationship between S_i parameters is expressed as $B = S_2 / S_1$, equation (B.2) reduces further to:

$$N_1 + N_2 = \frac{\left(N_1 + AN_2\right)\left(N_1 + BN_2\right)}{N_1 + ABN_2} \qquad \text{(B.3)}$$

It is important to note that equation (B.3) is only true if $A = 1$ (i.e. $\alpha_2 = \alpha_1$) OR if $B = 1$ ($S_2 = S_1$).If both A and B are not equal to 1, the above relationship does not hold and an unbiased estimator of abundance cannot be produced. If it is determined that there are both unequal marking probabilities (event 1) and unequal capture or survival probabilities (event 2), Peterson's model can be adjusted to produced an unbiased estimate of smolt abundance. Consider Chapman's modification of the standard Peterson model with two tagging groups, labeled group 1 and group 2:

$$\hat{N} = \frac{\left(N1_1 + N1_2 + 1\right)\left(N2 + 1\right)}{\left(M2_1 + M2_2 + 1\right)} \qquad \text{(B.4)}$$

-continued-

Where $N1_1$ and $N1_2$ are the number marked in groups 1 and 2, $N2$ is the number inspected for marks in the second event, and $M2_1$ and $M2_2$ are the amount of marks recovered from groups 1 and 2.Consider the case where $A > 1$ and $S > 1$, that is, group 2 had both a higher marking probability and capture probability. This would create a negative bias in the estimator and $N > \hat{N}$ .Adjusting Chapman's modification for this tagging bias results in a new, unbiased estimator:

$$\hat{N}^* = \frac{\left(\hat{A}N1_1 + N1_2 + 1\right)\left(N2 + 1\right)}{\hat{A}M2_1 + M2_2 + 1} - 1 \qquad \text{B.5)}$$

Using the scaler $\hat{A}$, i.e. the ratio of marking rates of the 2 groups, essentially forces the 2 groups to have the same marking probability, and therefore the expected value of equation (B.5) equals N as a result.

Retention rates for coded wire tagged fish are rarely 100%; adipose-clipped fish sometime do not contain valid CWTs as tags are shed during freshwater or marine rearing. Also occasionally heads are lost from adipose-clipped fish before they can become decoded. Because of this, a new parameter $\hat{\pi}$ can be used to adjust for adipose-clipped fish with no tag information ($M2_U$), which is the observed ratio of tags recovered from group 1 divided by group 2.Basically the observed recovery rate is extrapolated for fish marked in the first event (as indicated by an adipose finclip) that contain no tag information:

$$\hat{N}^* = \frac{\left(\hat{A}N1_1 + N1_2 + 1\right)\left(N2 + 1\right)}{\hat{A}\left(M2_1 + \left(\hat{\pi}\right)M2_U\right) + M2_2 + \left(1 - \hat{\pi}\right)M2_U + 1} - 1 \qquad \text{(B.6)}$$

In the event that all observed adipose-clipped fish contain valid coded wire tags, the term $M2_U$ is zero and equation (B.6) is identical to equation (B.5).

Variance and relative bias in the modified estimator can be estimated through bootstrapping techniques outlined in Efron and Tibshirani (1993).