Fishery Data Series No. 12-56

Production of Coho Salmon from the 2009 Smolt Emigration from Chuck Creek in Southeast Alaska

by

Steven J. McCurdy

October 2012

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

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
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

FISHERY DATA SERIES NO. 12-56

PRODUCTION OF COHO SALMON FROM THE 2009 SMOLT EMIGRATION FROM CHUCK CREEK IN SOUTHEAST ALASKA

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ABSTRACT

The primary purpose of this study was to estimate smolt production, marine survival, exploitation rates, and escapements of coho salmon (*Oncorhynchus kisutch*) from the 2009 smolt emigration from the Chuck Creek watershed in Southeast Alaska. Additional objectives were to determine if smolt size and the date of smolt emigration influenced survival and age-at-maturity. Emigrating coho smolt were captured at a weir during the spring of 2009, tagged with a sequentially numbered coded wire tag (CWT), and marked by removing their adipose fin. Commercial and sport fisheries were sampled for coho salmon bearing CWTs in 2010. Escapements were counted through a weir at Chuck Creek in 2009 and 2010, and coho salmon were examined for missing adipose fins and the presence of CWTs.

A total of 21,007 coho salmon smolt were tagged and released alive between April 19 and June 7, 2009. In 2010, 281 random recoveries of coho salmon bearing CWTs of Chuck Creek origin were recovered in sampled marine fisheries, yielding an estimated marine harvest of 827 fish (SE = 44). A total of 726 jacks and 814 adults escaped marine fisheries and returned to Chuck Creek from the 2009 smolt emigration. An estimated 22,651 (SE = 158) coho salmon smolt emigrated from Chuck Creek in 2009. Marine survival to adult of the 2009 smolt emigration was estimated at 7.2% (SE = 0.2%), and the exploitation rate in marine fisheries was estimated at 50.4% (SE = 1.3%).

Key words: coho salmon, *Oncorhynchus kisutch*, Chuck Creek, Warm Chuck, Heceta Island, Southeast Alaska, mark-recapture, coded wire tag, recreational fishery, troll fishery, seine fishery, smolt production, marine survival, exploitation rate, escapement, weir, jack.

INTRODUCTION

Harvest of wild coho salmon (*Oncorhynchus kisutch*) in Southeast Alaska is important to numerous commercial, sport, and subsistence users (Shaul et al. 2003; Halupka et al. 2000; Thedinga and Koski 1984). Wild coho salmon stocks are widely distributed in Southeast Alaska and are believed to be present in over 2,500 streams (Shaul et al. 2003). The Alaska Department of Fish and Game (ADF&G) maintains a stock assessment program in Southeast Alaska to better understand and manage coho salmon stocks in the region. ADF&G's stock assessment program includes monitoring a number of key coho salmon stocks in Southeast Alaska where juvenile coho are tagged with coded wire tags (CWTs). Systematically sampling escapements and harvest in fisheries for coho salmon with CWTs allows for estimates of total smolt production, as well as marine survival, exploitation (harvest) rates, and contributions to various fisheries from the monitored stocks. Data collected from the stock assessment program helps managers assess the effectiveness of regulations to ensure sustained yield of these and neighboring stocks of coho salmon.

Chuck Creek was selected to be part of the coho salmon stock assessment program in 2001 to fill the geographical gap in coverage in Southeast Alaska for the southern outside coast. The Chuck Creek watershed is located on Heceta Island (Figure 1), about 35 km northwest of the town of Craig, and it is believed to produce between 850 and 3,000 adult coho salmon annually (Shaul et al. 1991; McCurdy 2005, 2006a-b, 2008, 2009, 2010a-b). Prior to this study, an adult salmon weir was operated successfully on Chuck Creek in 1950 (Edgington et al. 1981) as well as 1982, 1983 and 1985 (Shaul et al. 1991). Also, presmolt juvenile coho salmon from Chuck Creek were marked with CWTs in the early 1980s to enable estimates of survival, fishery contributions, and exploitation rates (Shaul et al. 1991). Recoveries of coho salmon with CWTs in commercial fisheries in the 1980s indicated that the Chuck Creek stock has an ocean distribution and exploitation pattern similar to that of coho salmon from the Klakas River (Shaul et al. 1991), and the Klawock River (ADF&G's Mark, Tag and Age Laboratory, or Tag Lab, database), both on nearby Prince of Wales Island.

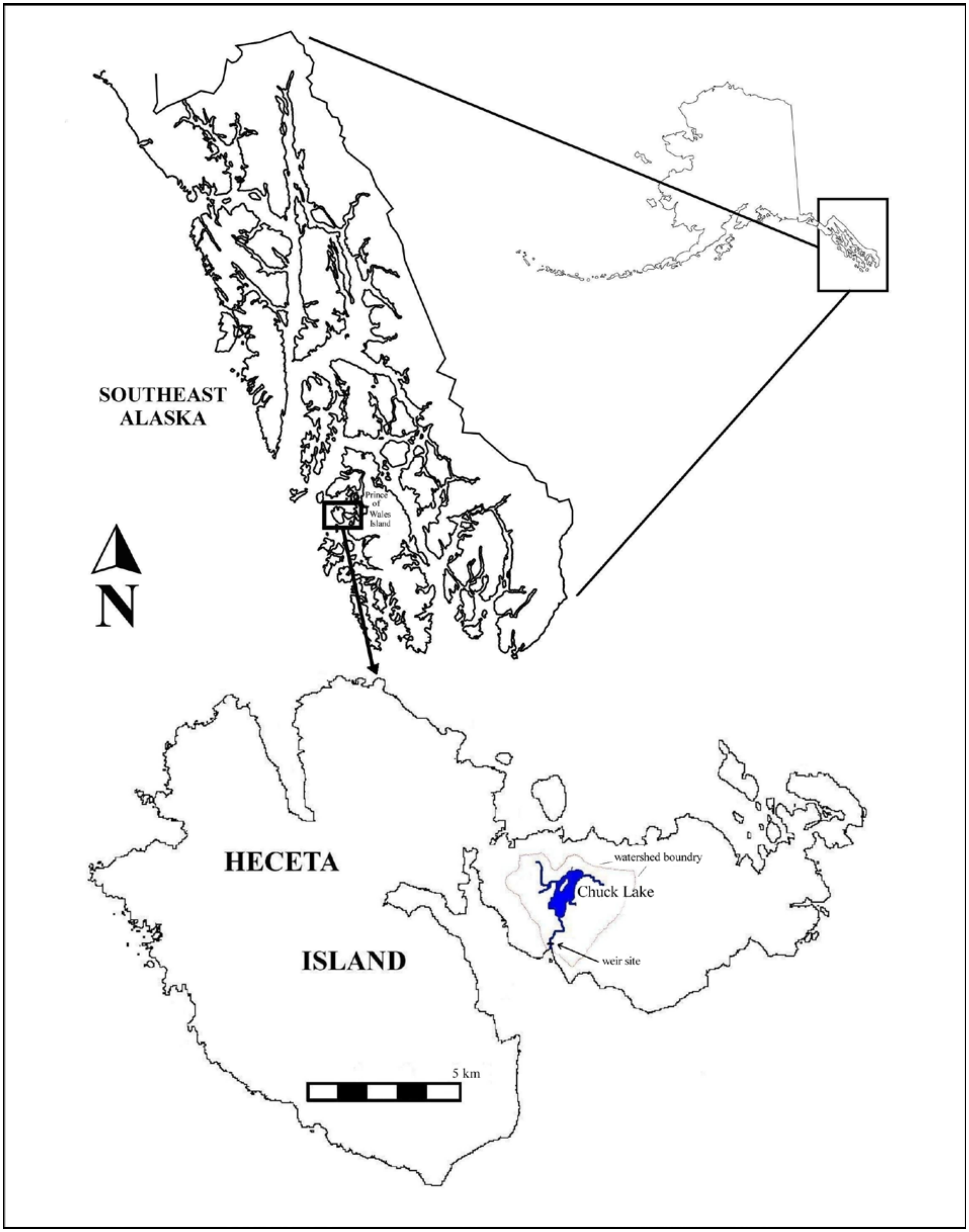

Figure 1.–Location of Heceta Island and the Chuck Creek watershed.

The Chuck Creek watershed drains an area of approximately 750 ha (1,853 acres), and contains Chuck Lake that has a surface area of approximately 63 ha (155 acres). Chuck Lake drains to the south into Warm Chuck Inlet by way of the 1.5 km long outlet stream, Chuck Creek. Four separate tributary streams to the lake contain spawning and rearing habitat for anadromous fish. The watershed is generally low gradient and the highest point of elevation in the drainage is 169 m (553 ft) above sea level. The geology of the watershed is predominately Karst (formed on carbonated bedrock, mostly limestone) and there are numerous springs and ground water sources present, indicating a well-developed subsurface drainage pattern typically associated with Karst geology (Baichtal and Swanston 1996). The watershed land cover is 89.4% forested, and the remainder is water (9.8%) and nonforested land (0.5%, predominantly muskeg; ADF&G 2004). Approximately 81% of the forested land in the watershed was logged in the 1970s and 1980s, at which time extensive timber harvest occurred in riparian areas and along the lakeshore. A vast network of logging roads (approximately 12.8 km) is present throughout the watershed. The watershed contains numerous beaver dams and ponds, and vegetation in the riparian area is significantly influenced by beaver (*Castor canadensis*) activity. In addition to coho salmon, Chuck Creek contains sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Dolly Varden (*Salvelinus malma*), steelhead (*O. mykiss*), and cutthroat trout (*O. clarki*), as well as three-spine stickleback (*Gasterosteus aculeatus*) and coastrange sculpin (*Cottus aleuticus*).

OBJECTIVES

Objectives of this study were:

1. estimate the number of coho salmon smolt emigrating from Chuck Creek in 2009;
2. estimate the age composition, and mean length and weight of coho salmon smolt captured emigrating from Chuck Creek in 2009;
3. count the escapement of coho salmon returning to Chuck Creek from the 2009 smolt emigration;
4. estimate the age and sex composition, and mean length-at-age of the escapement of coho salmon to Chuck Creek from the 2009 smolt emigration;
5. estimate the marine harvest of coho salmon from Chuck Creek in 2010 via recovery of CWTs; and
6. investigate the relationship between coho salmon smolt size and emigration date, and survival and age-at-maturity.

Although not an objective of this study, all other adult and juvenile salmonids of other species (other than young-of-the-year fry) were counted through the adult weir and smolt weir, respectively, and are reported here.

An added benefit of this study is the monitoring of coho salmon production over time with the possibility of identifying factors that affect coho salmon production. Factors that could influence smolt production include escapement magnitudes, abiotic factors, and anthropomorphic changes to the watershed (such as large scale timber harvesting and road building).

METHODS

A mark-recapture (m-r) experiment was used to estimate smolt abundance. Chuck Creek coho salmon were marked and recaptured with the use of weirs as they migrated from (emigrated) and returned to the watershed. Coho salmon smolt were captured as they were emigrating from Chuck Creek in the spring of 2009. Captured smolt were injected with a CWT and had their adipose fin removed. Adult coho salmon were sampled in the harvest of commercial and sport fisheries in 2010 for the presence of CWTs. The escapement of mature coho salmon was monitored through a weir on Chuck Creek in 2009 and 2010, and fish were inspected for missing adipose fins and CWTs to determine the fraction missing adipose fins (θ), and the fraction containing CWTs (θ_{CWT}). Unless otherwise defined in this report, the term "marked" is used to describe a fish with its adipose fin removed, and the term "tagged" is used to describe a fish containing a CWT. The marked fraction (θ) and tagged fraction (θ_{CWT}) could differ as smolt marked with an adipose fin clip may not retain their CWT. The marked fraction of mature fish was used in estimating smolt abundance (as no mature fish that had their adipose fin removed from anywhere other than Chuck Creek would be expected to return to Chuck Creek), and the tagged fraction of adult fish was used for estimating harvest in marine fisheries (as only the unique CWT code could distinguish Chuck Creek fish from other stocks of marked fish that are present in the marine harvest). Harvest of coho salmon in marine waters of Southeast Alaska is limited to adult fish that have spent 1 winter in the marine environment. The term "adult" is used to describe coho salmon that mature and return to spawn the year following their emigration from fresh water (noted as age x.1 fish), and the term "jack" is used to describe male coho salmon that mature and return to spawn in the same year as their emigration from fresh water (noted as age x.0 fish). The term "mature" refers to all coho salmon (both jack and adult) that are sexually mature and returning to spawn.

SMOLT CAPTURE AND CODED WIRE TAGGING

Coho salmon smolt were captured in the spring of 2009 as they were emigrating from the Chuck Creek watershed using a weir and "trough" trap (Figure 2) similar to that described by Elliott (1992). The weir and trough trap were constructed on Chuck Creek at the site of a blown-out beaver dam located approximately 500 m upstream from salt water. The opening in the beaver dam was repaired using rough-cut lumber planks to reestablish the dam (and the resulting pond) and to raise the water level upstream of the dam approximately 1 m. A "V" shaped, perforated, plastic fence (the weir) upstream of the dam extended from both banks and funneled emigrating smolt to the entrance of the trough located on the top of the rebuilt dam. The fence was constructed using two 15 m rolls of 1.5 m wide, 5 mm mesh, rigid plastic fence, held in place with iron pipe pounded into the substrate. The bottom 30 cm of the fence was folded facing upstream on the bottom of the stream and weighted down with rocks and sand bags to seal any openings large enough for fish passage. The top of the fence extended above the water surface. The trough was prefabricated out of aluminum and was approximately 2.4 m long and 30 cm wide. Flexible sewer hose (10 cm diameter) was attached to the downstream end of the trough to funnel fish into a live box located just downstream of the beaver dam. The live box was prefabricated aluminum and had perforated aluminum on one side to allow for water flow. The trap was fished continuously from April 19 to June 7.

Figure 2.–View of Chuck Creek smolt weir looking upstream. Note that the hose from end of trough to the live box is not pictured in the photo (not installed).

Captured fish were removed from the live box several times a day and sorted by species. The trap was checked at dawn, midday, dusk and after dark, at a minimum, and more frequently when fish were migrating. The time the trap was checked and the number of fish captured since the previous check were recorded. All noncoho salmon species, other than young-of-the-year salmonid fry, which could freely pass through the trap fence and perforated live box wall, were counted and released at the trap site. Juvenile coho salmon <70 mm FL that did not have the bright coloration associated with smoltification were released untagged, as it was assumed they would not smolt until the following year (Magnus et al. 2006; note: it has been extremely rare to capture any age-1 or older coho juveniles <70 mm FL at Chuck Creek since smolt tagging began in 2002). Coho salmon smolt were counted and sorted into 3 size categories (*small* smolt ≤100 mm FL, *large* smolt > 100 <130 mm FL, and *extra large* smolt ≥130 mm FL). All captured coho salmon smolt were anesthetized with a solution of tricain-methane-sulfonate (MS-222), had a 1.1 mm, sequentially numbered CWT injected into their snout, and had their adipose fin removed. All coho salmon smolt were tagged daily, regardless of the number captured. Tagging occurred in the afternoon; fish captured after 5:00 pm were held to tag the following day. Each day, before tagging the first fish and after tagging the last fish in each size category, 1 tag would be ejected from the machine and the unique sequential number on the tag would be read and recorded. Subsequently recovered tagged fish could then be associated with a size category and date of emigration from the unique sequential number on their respective CWT. Northwest Marine Technology Mark IV tagging machines[1] were used for tagging. Tag placement was checked at the beginning of tagging operations, and periodically throughout the operation using methods suggested in Koerner (1977). Short-term (several hours) CWT loss and mortality due to the handling and tagging procedure was evaluated by holding fish until dusk on the day they were tagged, at which time they were inspected for mortalities and the presence of a CWT using a metal (tag) detector, then released downstream of the trap. Tag retention procedures required that a random sample of at least 100 fish have a retention rate of 98% or greater. If the sample had less than 98% retention of CWTs, then the entire batch of fish being held was checked for the presence of CWTs and fish missing tags were retagged. The number of fish tagged, the number of mortalities following tagging, and the number of fish that had shed their tags was recorded and the information submitted (along with a sample of the coded wire used) to the Tag Lab in Juneau at the end of field operations. The tags used in 2009 contained the codes 04-16-85, 04-19-92 and 04-21-65 plus a unique sequential number. Water temperatures were recorded hourly with the use of an Onset Computer Corporation WTA08 Optic Stow Away data logger placed in the stream at the weir site.

ESTIMATION OF SMOLT ABUNDANCE

A two-event m-r experiment for a closed population was used to estimate the abundance of coho salmon smolt emigrating from the Chuck Creek watershed in 2009. Event 1 consisted of marking captured coho salmon smolt by removing their adipose fin in 2009. Event 2 consisted of sampling returning mature coho salmon in 2009 (jacks) and 2010 (adults) to determine the marked fraction for the watershed.

The abundance of coho salmon smolt emigrating from Chuck Creek in 2009 was estimated using Chapman's modification of the Petersen estimator for a closed population (Seber 1982):

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

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

where n_1 was the number of smolt marked in 2009 by removing their adipose fin, n_2 was the number of returning coho salmon inspected for marks in 2009 (jacks only) and 2010 (adults only), and m_2 was the subset of n_2 missing their adipose fins.

The conditions for an accurate estimate of smolt abundance using this methodology were: (1) all fish had an equal probability of being marked in event 1, *or* all fish had an equal probability of being inspected for marks in event 2 (requiring that marked and unmarked fish survive at the same rate), *or* marked fish mixed completely with unmarked fish in the population between events (also

[1] This and subsequent product names are included for a complete description of the process and do not constitute product endorsement.

requiring equal survival rates between marked and unmarked fish); (2) there was no recruitment to the population between events; (3) marking did not affect catchability of fish; (4) fish did not lose their marks between events; and (5) all marks were reported on recovery in event 2.

Physiological and life history traits of coho salmon, along with design of this experiment, allow for discounting concerns over several of these conditions. Because almost all coho salmon return to their natal stream to spawn (Quinn 2005; Sandercock 1991), the possibility of any fish recruiting into the population (strays from hatcheries or other watersheds) is thought to have been at such a low level as to not significantly affect the population estimate (condition 2); all immigrating fish in the escapement were obligated to pass through the salmon weir when returning to spawn, so catchability in event 2 was unaffected by marking (condition 3); adipose fins do not regenerate when completely removed (condition 4), and missing adipose fins were easy to note when examining the captured fish (condition 5).

Because smolt capture and marking in this study did not occur for the entire duration of the emigration, all smolt did not have an equal probability of being marked in event 1 (condition 1). Removal of adipose fins has been shown to have no significant effect on mortality (condition 1; Vincent-Lang 1993), but smolt emigration date has been shown to affect survival to maturity of coho salmon smolt in other studies (Bilton et al. 1982; Lum 2003) and in past years in this study (McCurdy 2006a-b, 2007, 2009, 2010a-b). Thus, it is likely that marked and unmarked fish did not survive at the same rate, and almost assures that condition 1 was violated in this study. However, the impact of this violation on the abundance estimate was low, as shown in the Discussion section below.

ESTIMATION OF SMOLT AGE, WEIGHT AND LENGTH

A sample of the emigrating coho salmon smolt was obtained by systematically sampling every 40th fish as they were tagged. Each sampled fish was measured to the nearest 1 mm FL, weighed to the nearest 0.1 gram, and had a scale sample taken for age estimation. Scale samples were taken from the preferred area as described by Scarnecchia (1979), and mounted between two 25 mm x 75 mm microscope slides. Slides and scale samples were labeled to match corresponding recorded length and weight data. Scale samples were viewed at magnification and ages recorded in European notation (where the number of winters in fresh water after hatching and the number of years in salt water are separated by a period per Groot and Margolis 1991). Ages were determined 1 time by 1 reader. Standard sample summary statistics were used to calculate estimates of mean length and weight and its variance (Thompson 2002).

ESTIMATION OF MARINE HARVEST

Estimates of the harvest of coho salmon originating from Chuck Creek and variances were derived from fish sampled from harvest in commercial and recreational sport fisheries using standard methods (Bernard and Clark 1996). Because several fisheries exploited coho salmon bound for Chuck Creek over several months in 2010, harvest was estimated over several strata, each a combination of time, area, and type of fishery. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant (Appendix A1). Statistics from the purse seine fishery were stratified by week and fishing district. Statistics from the sport fishery were stratified by 2-week increments. Hubartt and Jaenicke (2004) present details for sampling sport fisheries. Sampling of commercial fisheries in Southeast Alaska involves samplers stationed at fish processors throughout Southeast Alaska that attempt to sample 20% of the commercial coho salmon harvest for missing adipose fins. Databases from the Pacific States Marine Fisheries Commission (PSMFC) were also queried for any reported recoveries of coho salmon containing CWTs from Chuck Creek in Canadian fisheries.

Estimates of the 2010 harvest r_{ij} of Chuck Creek coho salmon from the entire 2009 smolt emigration j to 1 fishery stratum i were calculated:

$$\hat{r}_{ij} = \hat{H}_i \left(\frac{m_{ij}}{\lambda_i n_i} \right) \hat{\theta}_j^{-1} \tag{3}$$

where H_i is the estimated harvest in stratum i, θ_j is the fraction of adult Chuck Creek coho salmon j possessing CWTs (the portion of the adult escapement sampled found to have CWTs), n_i is the subset of H_i examined for missing adipose fins, m_{ij} is the number of decoded CWTs recovered from the Chuck Creek stock j in stratum i, and $\lambda_i = (a_i' \, t_i') / (a_i \, t_i)$ is the decoding rate for CWTs from recovered salmon (a_i is the number of adipose-finclipped fish in the sample from stratum i, a_i' is the subset of a_i for which heads reach the Tag Lab, t_i is the subset of a_i' with CWTs detected, and t_i' is the subset of t_i with CWTs decoded). Estimates of harvest were summed across strata and fisheries to obtain an estimate of the total harvest $T = \sum \hat{r}_{ij}$. Because sampling was independent across strata and across fisheries the variance of the total harvest was estimated by summing the variances across strata. See Bernard and Clark (1996) for further details.

ESTIMATES OF ESCAPEMENTS

An aluminum bipod and picket weir (Figure 3) was installed across the lower end of Chuck Creek (approximately 500 m from salt water) and operated from August 18 to October 13 in 2009 (McCurdy 2010b), and from August 16 to October 11 in 2010. Pickets were 18 mm in diameter and were spaced at a maximum gap of 31 mm. The bottom and sides of the weir were sealed with sandbags and the weir was monitored continuously. A 2.4 m^2 trap was built into the weir to capture and hold all migrating salmon. All migrating salmon had to enter the trap to pass upstream. Personal observations of the author and field crews since the project began in 2001 have shown that the vast majority of coho salmon, upon entering the stream, arrive at the weir within a few hours, and enter the cage in under an hour upon arriving at the weir (usually within minutes). Using these methods, it appeared that capture at the weir was an excellent indicator of return date to the stream.

All migrating mature salmon were identified and counted by species and date as they passed the weir. All coho salmon were counted by life history type (adult or jack) and examined for missing adipose fins. Life history type was assumed to be accurately determined for each fish enumerated at the weir. Fish that were 450 mm MEF or larger were considered adults, and those less than 380 mm in length were considered jacks; any fish between 380 mm and 450 mm in length had a scale sample taken to verify ocean age. In the previous 9 years of monitoring the escapement of coho salmon at Chuck Creek, all fish between 380 mm and 450 mm in length had a scale sample taken to verify ocean age; the largest jack was 395 mm MEF, and the smallest adult was 390 mm MEF (McCurdy 2010b).

Figure 3.–View of Chuck Creek adult salmon weir and cage looking downstream.

Coho salmon were systematically sampled throughout the entire migration for age, sex, and length (ASL). In 2009 every 4th adult coho and every 3rd jack coho salmon encountered at the weir was sampled, and in 2010 every 4th adult and jack coho salmon was sampled. In both years fish length was measured to the nearest 5 mm MEF, and sex was estimated by external characteristics. All sampled coho salmon missing an adipose fin were also examined for CWTs using a magnetometer (hand held CWT detector from Northwest Marine Technology, Inc.). If a sampled jack was missing its adipose fin it was sacrificed for retrieval of its CWT. Total escapement was the number of coho salmon counted through the weir. These numbers were divided into the number of jacks and the number of adults.

The estimated proportion of the adult and jack migrations that belong to each age or sex group was:

$$\hat{p}_a = \frac{n_a}{n} \tag{4}$$

$$var[\hat{p}_a] = \left(1 - \frac{n}{N}\right) \frac{\hat{p}_a(1 - \hat{p}_a)}{n - 1} \tag{5}$$

where n is the number of fish successfully aged (or sexed), n_a is the number from this sample that belong to age (or sex) group a, and N is the total migration (weir count). Abundance of age or sex group ($\hat{N}_a$) was estimated:

$$\hat{N}_a = \hat{p}_a N \tag{6}$$

$$var(\hat{N}_a) = N^2 var(\hat{p}_a) \tag{7}$$

Standard sample summary statistics were used to calculate estimates of mean length-at-age and its variance (Thompson 2002).

ESTIMATES OF TOTAL RETURN, EXPLOITATION RATE, AND MARINE SURVIVAL

The total adult return (i.e., harvest and escapement) of the coho salmon bound for Chuck Creek in 2009 and its variance was calculated by summing estimates of total harvest (T) and the adult escapement (N_e):

$$\hat{N}_R = \hat{T} + N_e \tag{8}$$

$$\text{var}[\hat{N}_R] = \text{var}[\hat{T}] \tag{9}$$

where $\text{var}[N_e]$ was not added into equation (9) because it is 0. The estimate of the adult exploitation rate was calculated:

$$\hat{E} = \frac{\hat{T}}{\hat{N}_R} \tag{10}$$

$$\text{var}[\hat{E}] \approx \frac{\text{var}[\hat{T}] N_e^2}{\hat{N}_R^4} \tag{11}$$

where the variance was approximated with the delta method (Seber 1982), recalling that $\text{var}[N_e] = 0$. Smolt-to-adult survival rate was estimated as:

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \tag{12}$$

$$\text{var}[\hat{S}] \approx \hat{S}^2 \left[\frac{\text{var}[\hat{N}_R]}{\hat{N}_R^2} + \frac{\text{var}[\hat{N}_s]}{\hat{N}_s^2} \right] \tag{13}$$

where N_s is the smolt abundance estimate from equation (1) and the variance was approximated with the delta method.

When comparing the relationship of smolt size and emigration date, the data were examined to see if it was normally distributed and had equal variance, indicating parametric data, which could be analyzed using a simple linear regression model; if not, the data were analyzed using Spearman's rank correlation coefficient test for nonparametric data (Hollander and Wolfe 1973).

RESULTS

SMOLT EMIGRATION IN 2009

A total of 21,045 coho salmon smolt were captured and tagged emigrating from Chuck Creek between April 19 and June 7, 2009. Twenty fish died after tagging, and an estimated 18 fish lost their tag before being released, leaving a total of 21,025 smolt released with adipose fin clips and 21,007 released with valid CWTs in 2009 (10,295 fish ≤100 mm; 10,496 fish > 100 mm FL <130 mm FL; and 216 fish ≥130 mm FL; Appendix A2). Emigrating coho salmon smolt were first captured in the trough trap on April 20 (Appendix A3), and catches built rapidly starting in early May (Figure 4), with 83% of the entire emigration (including uncaptured smolt) captured during the 21-day period from May 3 to May 23 (Appendix A3). Two peaks in the emigration occurred, with 40% of the emigration captured during an 8-day period starting May 4 and a second peak starting on May 16, when another 25% of the emigration was captured over a 5-day period (Figure 4).

A sample of 527 coho salmon smolt was collected for age, length and weight estimation (Table 1). Age could not be estimated on 6 fish because of regenerated scale samples. Age-1 coho constituted 91.2% (SE = 1.2%) of the sample and averaged 101 mm FL (SE = 0.5) and 9.9 g (SE = 0.2). Age-2 coho smolt constituted 8.8% (SE = 1.2%) of the sample and averaged 121 mm FL (SE = 1.3) and 16.6 g (SE = 0.7) (Table 1, Figure 5). Because smolt lengths sampled on different days throughout the emigration had high and unequal variance (nonparametric data, Figure 5), Spearman's rank correlation coefficient rho test (Hollander and Wolfe 1973) was used to test for relationships between smolt emigration date and length. There was a weak negative correlation between smolt length and emigration date (ρ = -0.08, P = 0.05, n = 527). The smolt in the *extra-large* size category tended to emigrate earlier than the smolt from the two smaller size classes (Figure 4, Appendix A2). Be aware that captured coho salmon smolt that emigrated later in the spring would have been growing in fresh water during the sampling time period of almost 2 months.

Surviving fish from the 2009 smolt emigration returned to Chuck Creek in both 2009 (as jacks) and in 2010 (as adults), and returning fish were examined for a missing adipose fin to determine the marked fraction (θ). In the 2009 escapement, 656 of 696 jacks examined (θ = 0.943) were missing adipose fins. In the 2010 escapement, 727 of 794 adults examined (θ = 0.916) were missing their adipose fin. These two marked fractions were significantly different (χ^2 = 4.0, df = 1, P = 0.04). Pooling both escapement samples (1,383 marks in 1,490 inspected) yielded an estimate of θ = 0.928 (SE = 0.067) for the fraction of the 2009 smolt emigration marked. An estimated 22,651 (SE = 158) coho salmon smolt emigrated from Chuck Creek in 2009 (n_1 = 21,025, n_2 = 1,489, m_2 = 1,382).

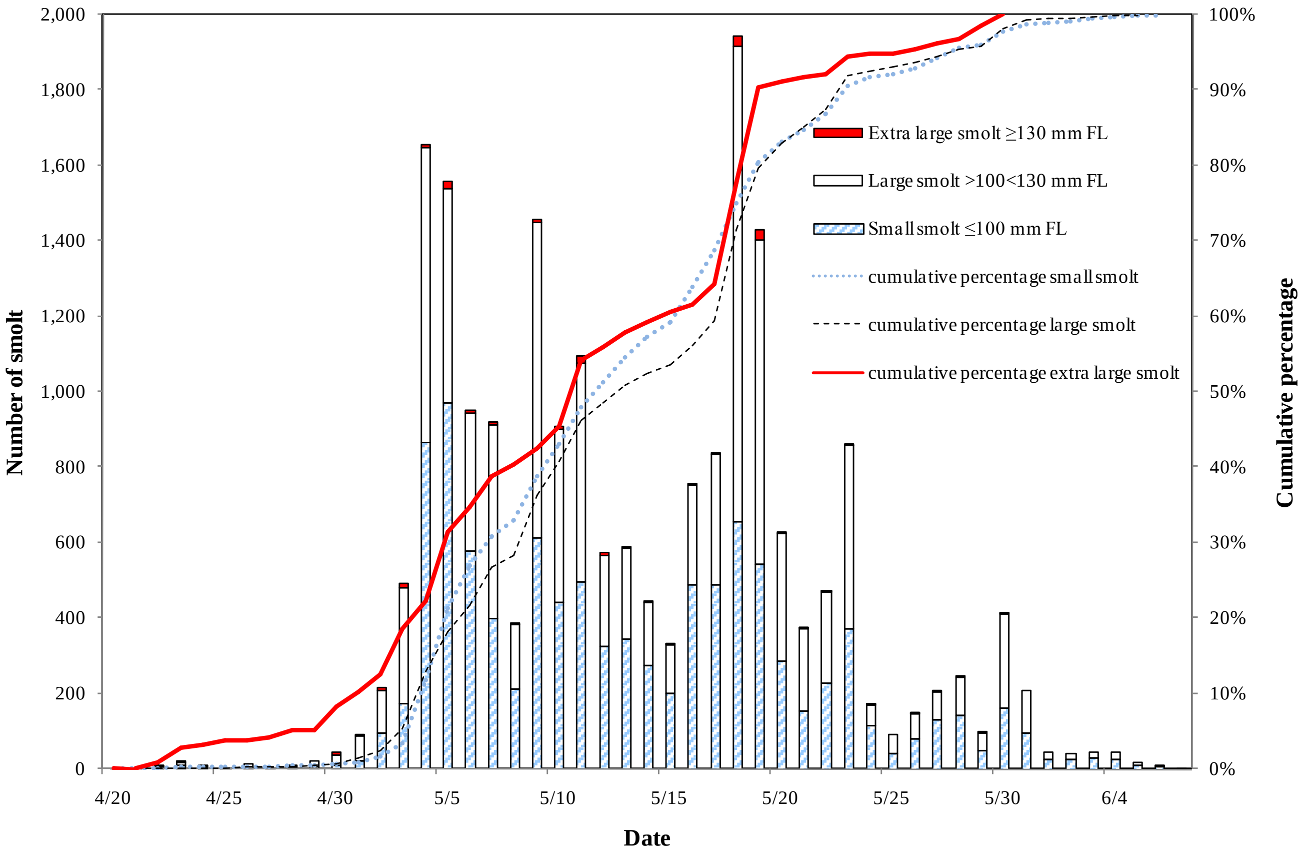

Figure 4.–Daily catch and cumulative percentage of the coho salmon smolt emigration passing the Chuck Creek weir in 2009. Note that fish capture is for the 24-hour period from 5:00 pm the previous day.

Table 1.–Estimated age composition, and mean length- and weight-at-age of emigrating coho salmon smolt captured at Chuck Creek in 2009.

	Age 1	Age 2	All smolt[a]
Sample size	475	46	527
Estimated composition, %	91.2	8.8	100
SE composition, %	1.2	1.2	ND
Mean length (mm)	101.1	120.8	102.9
SE mean length	0.5	1.3	0.5
Mean weight (g)	9.9	16.6	10.5
SE mean weight	0.2	0.7	0.2

[a] Includes smolt that were not successfully aged due to regenerated scales.

ESCAPEMENT ENUMERATION AND SAMPLING

2009 Jack Escapement

A total of 726 jack coho salmon were counted through the weir between August 18 and October 13, 2009 (McCurdy 2010b). Of the total jack escapement, 30 fish were passed upstream before they could be examined for the presence or absence of an adipose fin, and of the remaining 696 fish, 656 were missing their adipose fin ($\theta = 0.943$). A sample of 224 CWT-tagged jacks was collected in 2009. Of the recovered tagged jacks, 1 had been tagged as a *small* smolt in 2008 (but did not emigrate until the spring of 2009), and all the remaining fish were tagged as smolt in 2009. McCurdy (2010b) provides further details on the 2009 escapement of coho salmon to Chuck Creek.

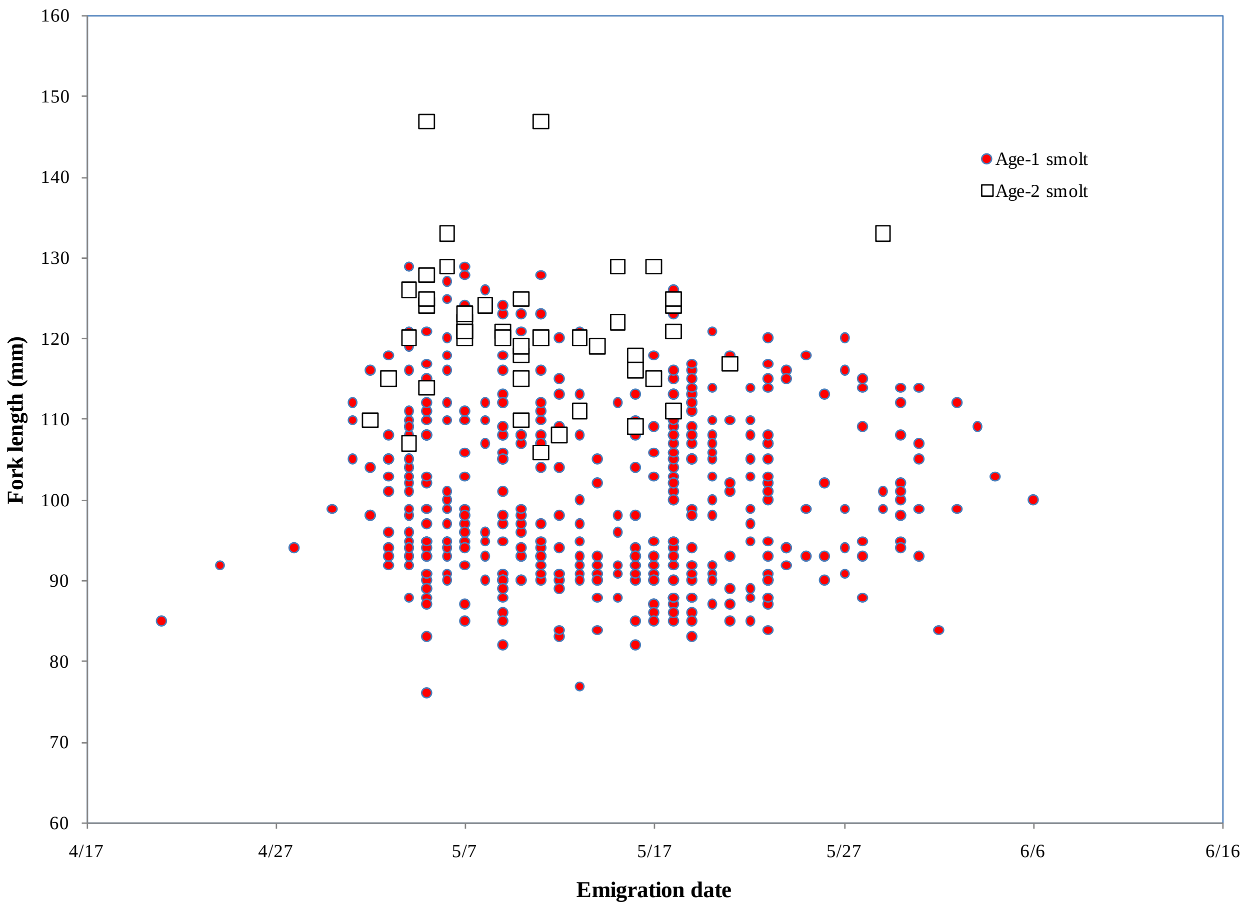

Figure 5.–Date of smolt emigration plotted vs. smolt fork length of systematically sampled coho salmon smolt from the 2009 Chuck Creek smolt emigration.

2010 Escapement

In 2010, a total of 814 adult and 470 jack coho salmon were counted past the weir on Chuck Creek between August 16 and October 11 (Appendix A4). Life history type (adult, jack) was assumed to be accurately determined on all mature fish in the 2010 escapement. The largest jack measured 410 mm MEF, and the smallest adult measured 380 mm MEF (Table 2, Figure 6). All of the jack coho salmon were from the 2010 smolt emigration.

The 2010 coho salmon escapement started at the average time in late August then built rapidly, such that 50% of the escapement had entered the stream several days earlier than the average of previous years (Figure 7). Immigration into the stream slowed for a 2-week period in mid September (concurrent with very low water levels) before increasing again on September 24 when rain caused the stream levels to rise. A small number of mature coho salmon likely entered Chuck Creek after the weir was dismantled on October 11; however this number is likely a very small percentage of the total return as past weir operations have shown few fish return after this date (McCurdy 2005).

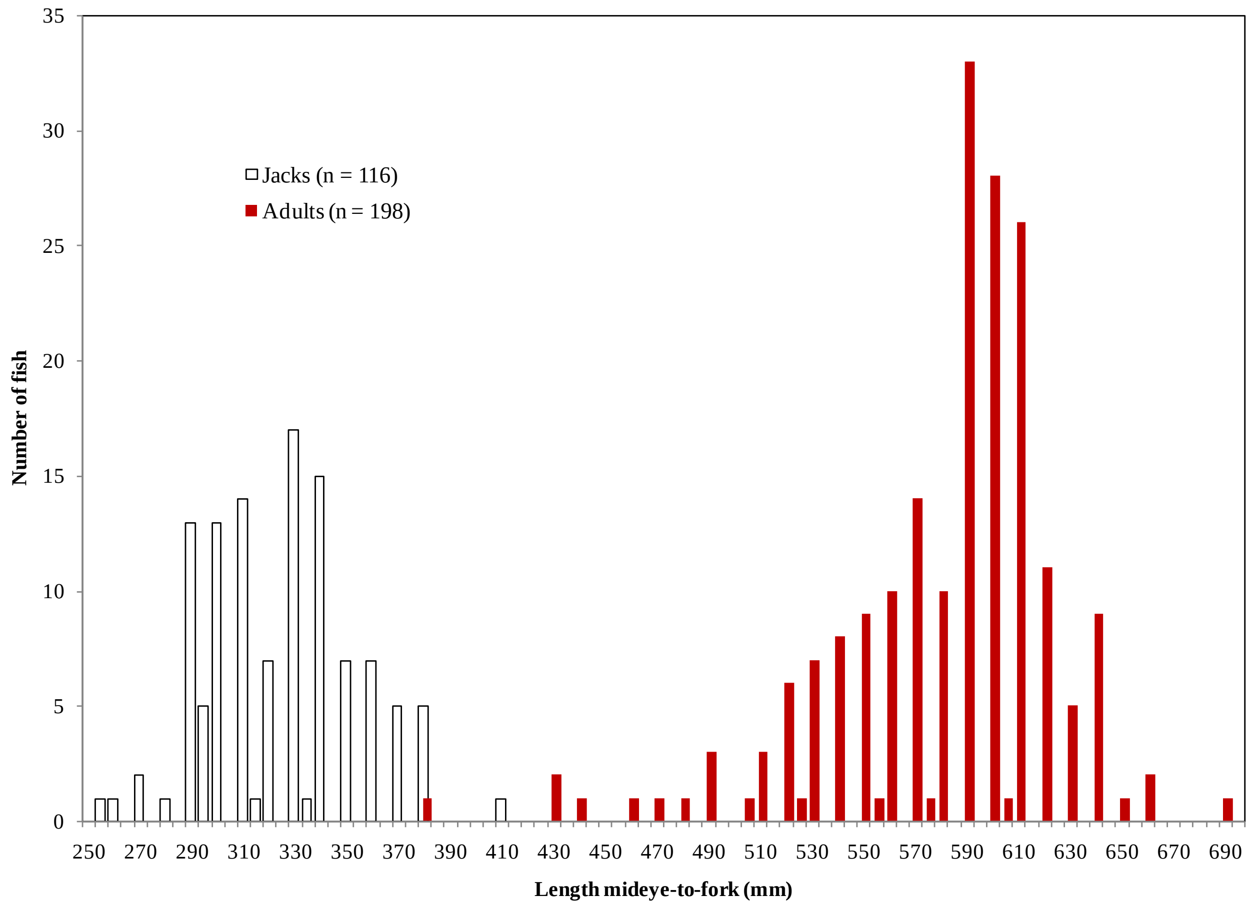

Figure 6.–Length frequency of the coho salmon escapement sampled at the Chuck Creek weir in 2010, by ocean age.

Table 2.–Estimated age composition, and mean length-at-age and -sex of the 2010 Chuck Creek coho salmon escapement.

	Age 1.0	Age 2.0	All jacks[a]	Age 1.1	Age 2.1	All adults[a]
Females						
Sample size	ND	ND	ND	81	1	89
Percent	ND	ND	ND	98.8	1.2	100
SE percent	ND	ND	ND	1.1	1.1	ND
Mean length[b] (mm)	ND	ND	ND	590	610	590
SE mean length	ND	ND	ND	2	ND	2
Minimum length (mm)	ND	ND	ND	520	610	510
Maximum length (mm)	ND	ND	ND	670	610	670
Males						
Sample size	87	19	116	101	1	109
Percent	82.1	17.9	100	99.0	1.0	100
SE percent	3.3	3.3	ND	0.9	0.9	ND
Mean length[b] (mm)	322	332	324	572	540	572
SE mean length	3	5	2	5	ND	4
Minimum length (mm)	255	290	255	380	540	380
Maximum length (mm)	410	380	410	690	540	690
All fish						
Sample size	87	19	116	182	2	198
Percent	82.1	17.9	100	98.9	1.1	100
SE percent	3.3	3.3	ND	0.7	0.7	ND
Mean length[b] (mm)	322	332	324	580	575	580
SE mean length	3	5	2	3	35	3
Minimum length (mm)	255	290	255	380	540	380
Maximum length (mm)	410	380	410	690	610	690

[a] Includes fish that were sampled for sex and length, but the freshwater age could not be estimated.

[b] Length is mid-eye-fork.

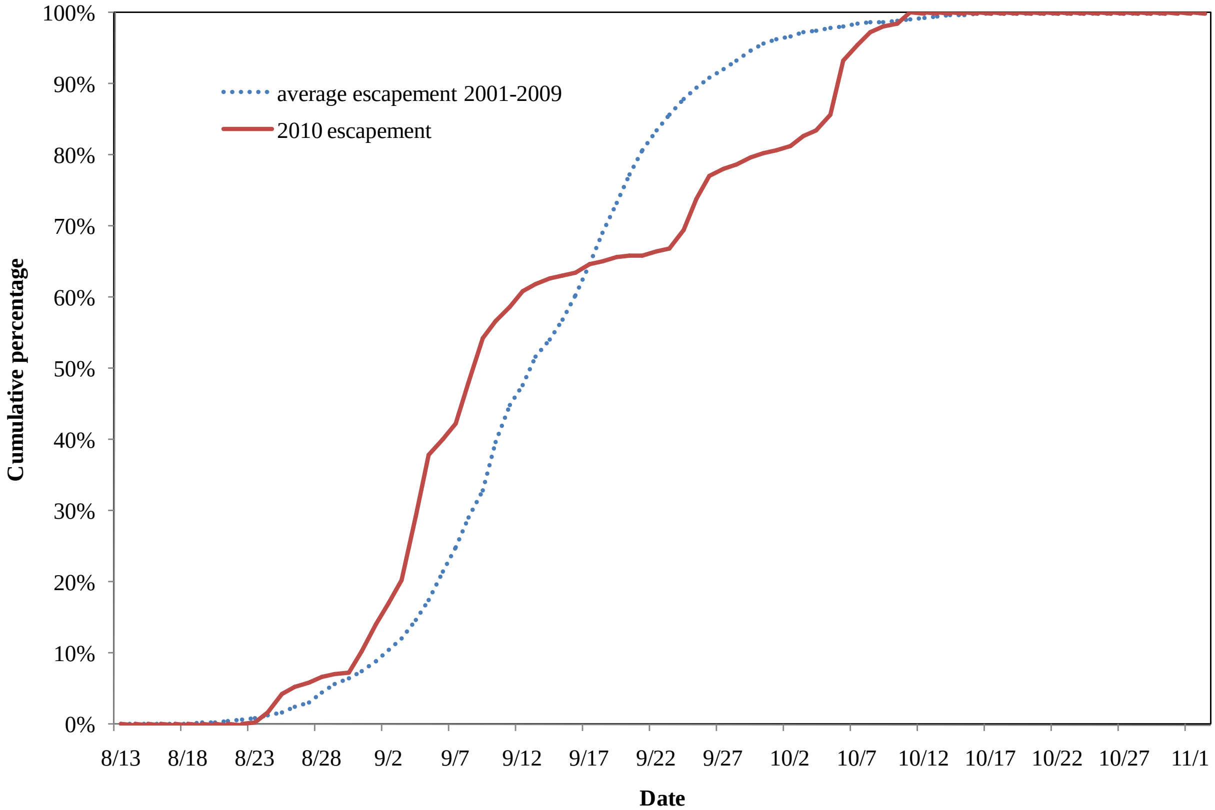

Figure 7.–Cumulative percentage of annual escapement of mature coho salmon (jack and adults combined) passed through the Chuck Creek weir, 2001–2010.

A total of 4,889 adult sockeye salmon, 33 jack sockeye salmon (males <400 mm MEF), 11 chum salmon, 19,001 pink salmon, and 1 steelhead trout were also counted through the weir from August 16 to October 11, 2010 (Appendix A5). Escapements were larger than weir counts for all salmon species as an unknown number of sockeye and pink salmon passed upstream of the weir site before weir installation on August 16, and a number of pink and chum salmon spawned downstream of the weir site (personal observations). Although no Dolly Varden were captured in the weir cage, some were observed passing between the weir pickets by the crew. The one steelhead captured was less than 400 mm FL and showed no external characteristics that allowed for sex determination (i.e. appeared to be immature), and appeared to have recently entered the stream from the marine environment (bright silver coloration and sea lice were present). A prespawn die off of several thousand pink salmon and approximately 40 adult coho salmon occurred in the outlet stream between September 16 and September 24. Mortality only occurred in the lower half of the outlet stream and did not affect fish in the lake or tributaries. The die off occurred near the end of a very low water event (between September 7 and September 23 - less than 8 mm of rain fell in the watershed), and ended when rain on September 24 caused water levels to rise.

MARINE SAMPLING FOR CWTS AND ESTIMATES OF HARVEST, RETURN, AND MARINE SURVIVAL

The estimated tagged fraction (θ_{CWT}) of adult coho salmon used to estimate marine harvest in this study was the same as the marked fraction of the adult escapement missing adipose fins ($\theta = 0.916$), as all adult coho salmon systematically sampled at the weir in the 2010 escapement that were missing an adipose fin (n = 186) also tested positive for the presence of a CWT (thus all adults missing an adipose fin were assumed to have retained their CWT).

A total of 310 adult coho salmon tagged as smolt emigrating from Chuck Creek in 2009 were recovered in creel and port sampling programs that sampled marine fisheries in Alaska in 2010. An additional 2 fish were recovered in sampled Canadian fisheries. Of the 310 marine recoveries of coded wire tagged coho salmon from Chuck Creek in Alaskan waters, 279 were random samples that were useful for estimating marine harvest in various fisheries (Appendix A6). The greatest number (221) of the random CWT recoveries of Chuck Creek coho was in the troll fishery, and the remainder were in the sport fishery (36) and the seine fishery (22). There were also 18 random recoveries in marine fisheries where the fishing area, fishery or time period were not designated, and 12 nonrandom recoveries. One additional fish was recovered at Hidden Falls on the northwest coast of Baranof Island during the terminal troll fishery for hatchery Chinook salmon (*O. tshawytscha*). This fish was added to the harvest estimate, but because of the unusual behavior demonstrated by this fish (a location and time where and when Chuck Creek fish are rarely observed), the recovery was not expanded to include additional Chuck Creek harvest in this strata. Of the random troll recoveries, 146 were recovered in the SW quadrant, 42 in the NW quadrant, 20 in the SE quadrant, and 13 in the NE quadrant (Appendix A1). Purse seine recoveries were in fishing District 104. Sport recoveries were from the ports of Craig/Klawock and Sitka.

Of the Canadian recoveries, 1 fish each were recovered in the troll and sport fisheries, and both were useful for estimating harvesting. The commercial troll recovery was a random sample that could be expanded to estimate harvest in the unsampled portion of the harvest. The fish recovered in the sport harvest was a voluntary recovery. Harvest of CWT-marked salmon in Canadian sport fisheries is estimated using an "awareness factor" that is based on the voluntary recovery of heads from adipose-finclipped salmon, and on extrapolations of data from previous years according to protocols established by the Chinook Technical Committee of the Pacific Salmon Commission. More details on the Canadian recoveries are available from the PSMFC Regional Mark Information System (RMIS) database.

An estimated 817 (SE = 44) coho salmon originating from Chuck Creek were harvested in marine commercial and sport fisheries in Alaskan waters in 2010 (Tables 3 and 4; Appendix A6; Figure 8). The commercial troll fishery harvested an estimated 658 fish, or 80.5% of the Alaskan harvest. The purse seine fishery harvested an estimated 110 fish (13.5% of the Alaskan harvest), and the sport fishery harvested an estimated 49 fish, or 6.0% of the Alaskan harvest. Harvested fish were sampled from June 21 to September 20. In Canadian waters, the troll fishery harvested an estimated 4 fish and the sport fishery harvested an estimated 6 fish.

Table 3.–Estimated harvest, exploitation rate, and total return of Chuck Creek coho salmon in 2010.

Fishery	Area	Estimated harvest	(SE)	Percent of harvest	Exploitation rate	(SE), %
Alaska troll	NE Quadrant	49	(11)	5.9	3.0	(0.3)
	NW Quadrant	167	(22)	20.2	10.2	(0.7)
	SE Quadrant	79	(15)	9.6	4.8	(0.5)
	SW Quadrant	363	(24)	43.9	22.1	(0.7)
	Subtotal	658	(38)	79.6	40.1	(1.1)
Alaska seine	District 104	110	(22)	13.3	6.7	(0.7)
	Subtotal	110	(22)	13.3	6.7	(0.7)
Alaska sport	Craig/Klawock	35	(2)	4.2	2.1	(0.1)
	Sitka	14	(6)	1.7	0.9	(0.2)
	Sbtotal	49	(7)	5.9	3.0	(0.2)
Canada troll	North B. C.	4	(4)	0.5	0.2	(0.1)
Canada sport	North B. C.	6	NA	0.7	0.4	NA
	Subtotal	10	(4)	1.2	0.6	(0.1)
Total harvest		827	(44)	100.0	50.4	(1.3)
Escapement		814	(0)		49.6	
Total return		1,641	(44)		100.0	

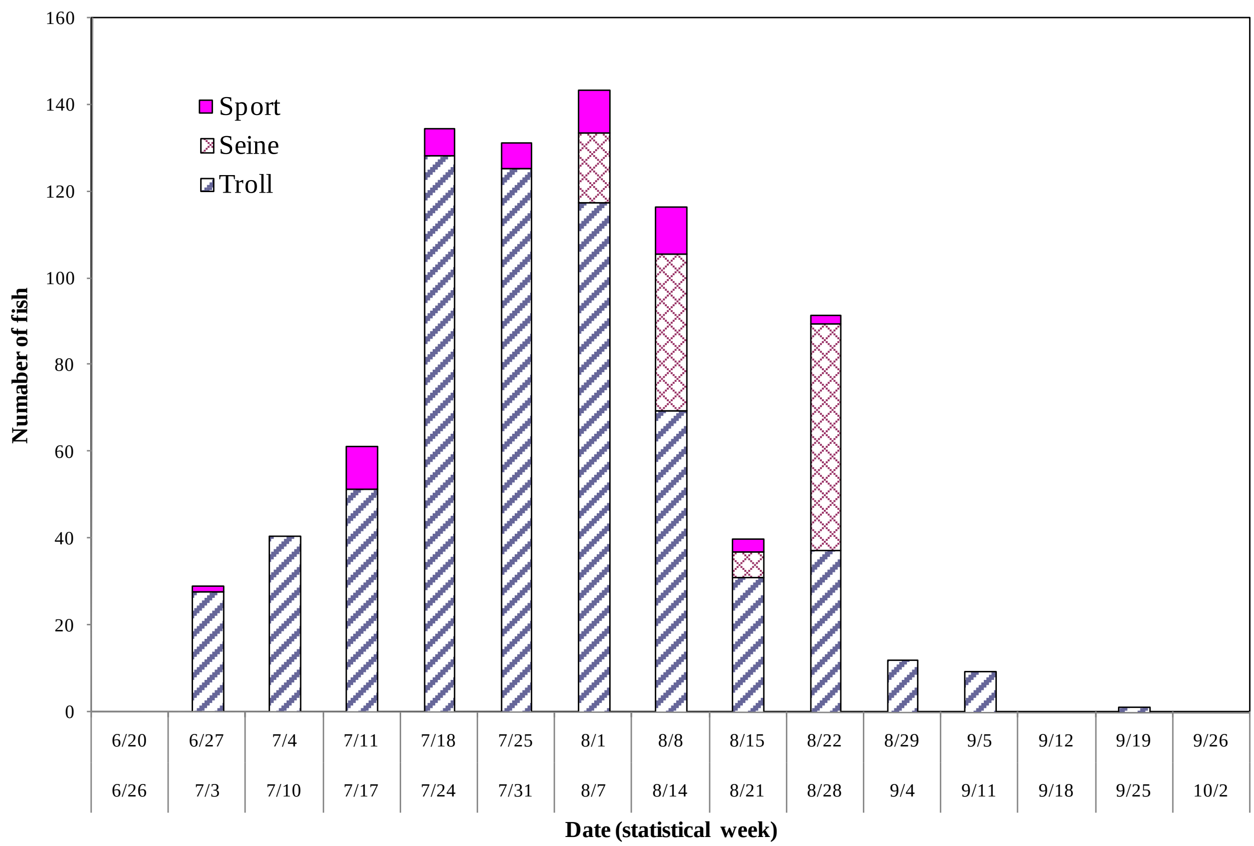

Figure 8.–Estimated marine harvest in Alaskan waters of coho salmon bound for Chuck Creek by fishery and statistical week in 2010.

The total return of Chuck Creek adult coho salmon was estimated at 1,641 fish (SE = 44) in 2010. Marine survival to adult of the 2009 smolt emigration was estimated at 7.2% (SE = 0.2%), and the exploitation rate in marine fisheries was estimated at 50.4% (SE = 1.3%). An additional 726 fish, or 3.2% (SE = 0.02%) of the estimated 22,651 smolt that emigrated in 2009 survived to return as jacks in the same year as their emigration.

SMOLT SIZE AND EMIGRATION DATE EFFECTS ON RECOVERY RATES

All smolt captured in 2009 were tagged with a unique, sequentially numbered CWT that identified their date of emigration (date of capture) and their inclusion into 1 of 3 size categories (*small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL, Appendix A2). Subsequently, 562 of these uniquely-tagged fish were recovered (Appendix A2) as either adults in the 2010 escapement (27 fish), or marine fisheries in 2010 (312 fish), or as jacks in the 2009 escapement (223 fish). The recovery rates between the two life history types (jacks or adults) are not directly comparable as tagged jacks were sampled at a rate of 32.6% (= 223/684), and tagged adults at 22.6% (= 339/1,502). Analysis of the data is complicated by the fact that not all the sequential numbers were readable. All tag codes from the recovered fish were successfully decoded, but on 74 of the tags (39 adults and 35 jacks) one or more crucial digits of the sequential number were not readable. Thus the exact day of emigration and smolt size class were determined on a sample of 488 fish. The problem with the unreadable sequential numbers appeared to be caused by the tagging machine "scratching" the tag when injected, and occurred between May 2 and May 9 on a portion of those tags (72 of the 74 unreadable tags occurred then).

The tags with the unreadable sequential number still proved useful in analyzing smolt survival as a function of emigration date. Although the exact day of emigration could not be determined on these samples, the tag code and the digits in the sequential number that were readable allowed the date of every recovered fish to be determined within a fairly short range of days (Appendix A2). Thus, the entire sample of 562 recovered tags is an unbiased sample of surviving smolt (in relation to emigration date) when the samples are grouped appropriately.

The smolt size class cannot be determined on any of the 74 unreadable tags, so the sample of readable tags is likely biased (in relationship to the true proportions of surviving tagged smolt by size class) by some unknown amount. However the bias may be small. First, the "scratching" of the tag occurred internally in the tagging machine, and was not affected by the size of the individual smolt being tagged. In addition, during the time period when the unreadable tags occurred (May 2–9), *all* the tags were marred and difficult to read; some were just a little worse (one digit unreadable) than others. This suggests that the occurrence of the unreadable tags may have occurred randomly (i.e., did not occur with just 1 size class of smolt on 1 day). This theory is also supported by the fact that from May 2 to 9, the readable tags recovered (= 158 tags) came on all days and from all the *small* and *large* size classes (Appendix A2; note that only 3 to 20 *extra large* smolt were tagged daily during this time period, so no recoveries from some days is not unexpected for this size class). Also, the sample of unreadable tags is relatively small (only 13% of all recovered surviving fish). Thus, with caution, it might be assumed that the readable samples obtained are a relatively good representation of all the surviving tagged smolt by size class.

Table 4.–Estimated harvest, escapement, total return, and exploitation rate of adult coho salmon from Chuck Creek in years with returning coded wire tagged fish.

	Harvest								
Return year	Alaska troll	Alaska seine	Alaska gillnet	Alaska sport	Canadian harvest[a]	Total harvest	Escapement	Total adult return	Exploitation rate, %
1982[b]	1,320	418	ND	ND	ND	1,738	1,017	2,755	63.1
1983[b]	551	618	ND	ND	ND	1,169	1,238	2,407	48.6
1985[b]	1,906	975	ND	ND	ND	2,881	956	3,837	75.1
2003[c]	539	252	ND	83	ND	874	614	1,488	58.7
2004[d]	725	179	ND	76	ND	980	606	1,586	61.8
2005[e]	652	232	ND	120	ND	1,004	646	1,650	60.8
2006[f]	401	32	ND	8	7	448	409	857	52.3
2007[g]	577	116	ND	29	60	782	425	1,207	64.8
2008[h]	389	146	17	8	5	565	309	874	64.6
2009[i]	996	292	3	16	0	1,307	776	2,083	62.7
2010	658	110	0	49	10	827	814	1,641	50.4

[a] Includes all Canadian marine fisheries (commercial troll, seine, gillnet and sport).
[b] Estimates from Shaul et al. 1991b).
[c] Estimates from McCurdy 2005).
[d] Estimates from McCurdy 2006a).
[e] Estimates from McCurdy 2006b).
[f] Estimates from McCurdy 2008).
[g] Estimates from McCurdy 2009).
[h] Estimates from McCurdy 2010a).
[i] Estimates from McCurdy 2010b).

Of the 188 sampled jacks where smolt size could be determined, *small* smolt were recovered at a rate of 0.64% (= 66/10,295), *large* smolt were recovered at a rate of 1.09% (= 114/10,496), and *extra large* smolt were recovered as jacks at a rate of 3.70% (8/216; Table 5). These were significantly different recovery rates (χ^2 = 31.0, df = 2, P < 0.001). Of the 300 adult recoveries where smolt size was determined, *small* smolt were recovered as adults at a rate of 1.39% (= 143/10,295), *large* smolt were recovered at a rate of 1.48% (= 155/10,496) and *extra large* smolt were recovered at a rate of 0.93% (= 2/216; Table 5). These were not significantly different recovery rates (χ^2 = 0.7, df = 2, P = 0.7). Pairwise comparisons of the recovery rate of the three smolt size classes were significantly different for all comparisons to the jack stage, but none of the comparisons were significant to the adult stage (Tables 5 and 6).

Table 5.–The number of coho salmon smolt coded wire tagged by size class and emigration time period from the 2009 Chuck Creek smolt emigration and their subsequent recovery rate as mature fish in marine fisheries and escapement sampling programs.

	Early	Late	Total
	(April 19–May 13)	(May 14–June 7)	
Number of smolt tagged			
Small	5,617	4,678	10,295
Large	5,333	5,163	10,496
Extra large	125	91	216
Total	11,075	9,932	21,007
Jack recovery rate			
Small smolt, %	**0.94**	0.28	0.64
Large smolt, %	**1.26**	0.91	1.09
Extra large smolt, %	**4.00**	3.30	3.70
All smolt combined, %	1.44	0.63	1.06
Adult recovery rate			
Small smolt, %	**1.37**	1.41	1.39
Large smolt, %	**1.33**	1.63	1.48
Extra large smolt, %	**0.80**	1.10	0.93
All smolt combined, %	1.69	1.52	1.61
Overall recovery rate			
Small smolt, %	**2.31**	1.69	2.03
Large smolt, %	**2.59**	2.54	2.56
Extra large smolt, %	**4.80**	4.40	4.63
All smolt combined, %	3.13	2.15	2.67

Note: Bold values are less than or equal to true values due to the inability to determine size class on a sample of 35 jack recoveries and 39 adult recoveries. *Small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL.

Recovery rates of surviving mature fish were compared by dividing the smolt emigration into 2 time periods (*early* and *late*). The *early* period ended on the date that the cumulative total of tagged smolt reached 50%. Thus, the early period ran from April 19 through May 13 (smolt tagged = 11,075; subsequent recoveries = 160 jacks and 187 adults), and the *late* period ran from May 14 through June 7 (smolt tagged = 9,932; recoveries = 63 jacks and 151 adults). Note that 1 of the 562 recovered fish (an adult recovery) is excluded from this analysis as it could have come from either the *early* or *late* time period. Fish that emigrated during the *early* period were recovered at a significantly higher rate as both jacks (χ^2 = 32.7, df = 1, P < 0.0001) and overall (jacks and adults combined χ^2 = 19.3, df = 1, P < 0.0001) than fish that migrated during the *late* period, but not as adults (χ^2 = 0.9, df = 1, P = 0.3) (Tables 5 and 6).

Table 6.–Summary of significance tests of the recovery rate of coded wire tagged coho salmon smolt from the 2009 Chuck Creek smolt emigration by smolt category (smolt size and emigration time period).

Smolt categories tested		Recoveries of tagged smolt as:					
		Jacks		Adults		Overall	
		$\chi 2$	P-value	$\chi 2$	P-value	$\chi 2$	P-value
	Early vs. *late*	32.7	**<0.0001**	0.9	0.3	19.3	**<0.0001**
	Small vs. *large*	12.0	**0.0005**	0.3	0.6	6.6	**0.01**
	Small vs. *extra large*	28.4	**<0.0001**	0.3	0.6	7.0	**0.008**
	Large vs. *extra large*	12.9	**0.0003**	0.4	0.5	3.6	0.06
Early only	*Small* vs. *large*	2.5	0.1	0.0	0.9	0.9	0.4
	Small vs. *extra large*	11.4	**0.001**	0.3	0.6	3.3	0.07
	Large vs. *extra large*	7.1	**0.008**	0.3	0.6	2.3	0.13
Late only	*Small* vs. *large*	16.2	**<0.0001**	0.8	0.4	8.5	**0.004**
	Small vs. *extra large*	24.3	**<0.0001**	0.1	0.8	3.8	**0.05**
	Large vs. *extra large*	5.4	**0.02**	0.2	0.7	1.2	0.3

Note: bold P-values indicate significant tests. *Small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL. *Early* period is April 19-May 13, and *late* period is May 14-June 7.

DISCUSSION

SMOLT EMIGRATION

The timing of the 2009 smolt emigration of coho salmon from Chuck Creek was slightly earlier than the previous 3 years, but about average for this stock when compared to all years that smolt were captured with a weir in this study (since 2003, Figure 9). Additionally, the portion of the entire smolt emigration that was captured was the highest of any year of operation (Figure 9). This occurred despite consistent capture methods in all years, indicating that in 2009 a larger portion of the emigration occurred during the time of weir operations (late April–early June) than in any of the previous years.

Photoperiod is thought to be the primary cue that dictates the time of ocean entry by juvenile salmonids (Groot 1982; Holtby et al. 1989; Quinn 2005; Wedemeyer et al. 1980; Spence and Hall 2010), although proximate stimuli that can trigger emigration can include water temperature (Holtby et al. 1989) and stream flows (Thedinga and Koski 1984). It appears that water temperature does affect emigration timing in this stock of coho salmon. Years with relatively higher water temperatures in late April–early May had a larger portion of smolt emigrating earlier in the spring than years with cooler temperatures (Figure 9).

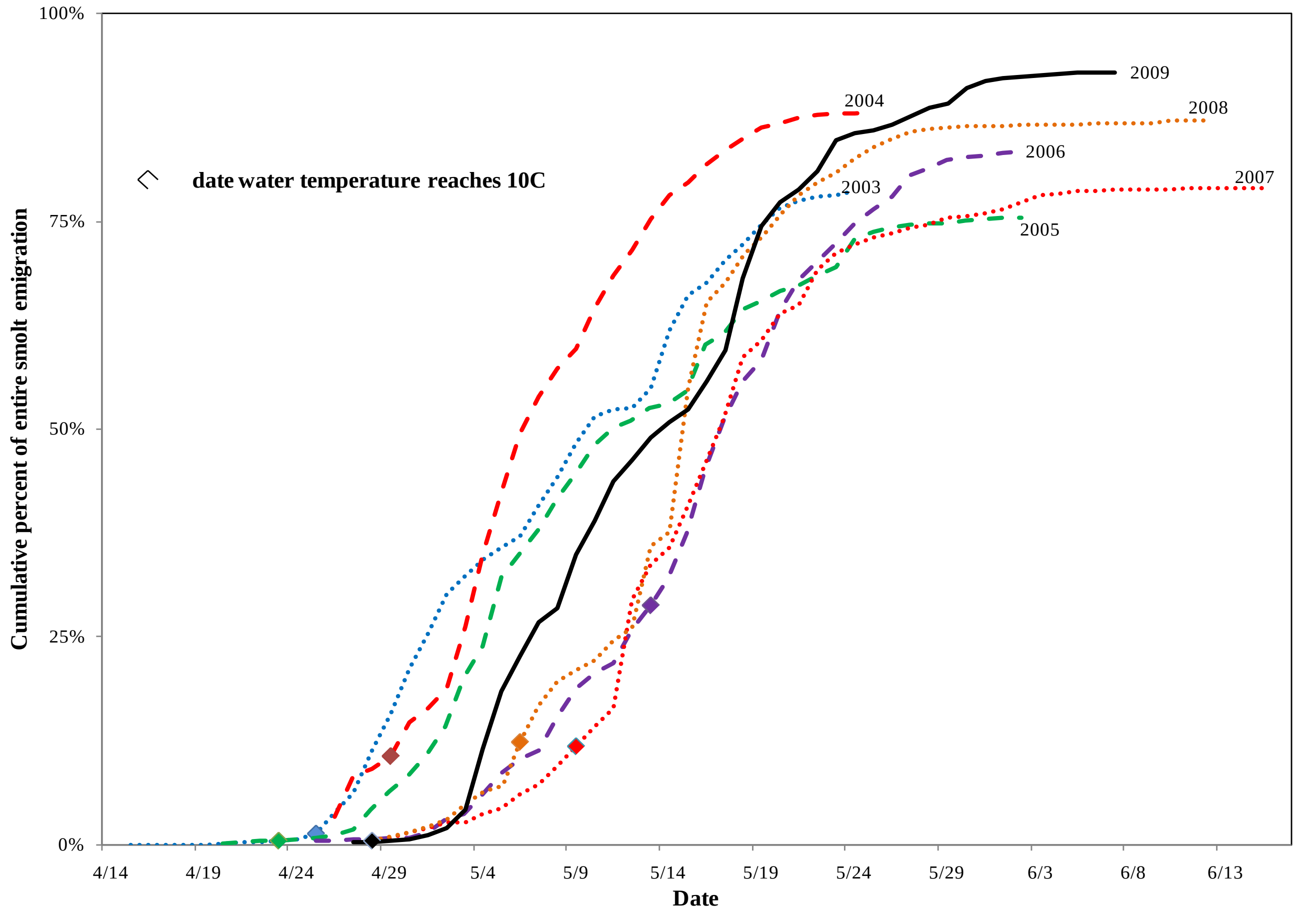

Figure 9.–Cumulative percentage of annual coho salmon smolt emigrations counted past the Chuck Creek weir and the date that the water temperature first reached 10ºC, 2003–2009.

Smolt size has also been shown to affect timing of emigration of coho salmon smolt in this and in other studies of wild coho salmon (McCurdy 2010a-b; Irvine and Ward 1989; Lum 2003; Quinn and Peterson 1996; Thedinga and Koski 1984; but see Holtby et al. 1989), with larger smolt emigrating earlier. Although the effect of smolt size in relation to emigration timing of the 2009 emigration was much weaker (ρ = -0.08) than previous emigrations in this study, larger coho salmon smolt tended to emigrate earlier than smaller fish. With the exception of the extra large smolt emigrating earlier than the other size classes (Figure 4), all sizes of smolt began emigrating in large numbers very quickly in early May and it seems reasonable to assume this was triggered by warming water temperature. Smolt size may have a larger influence on emigration timing in years with more gradually increasing water temperatures in the spring.

MARINE SURVIVAL

Survival to maturity of coho salmon smolt has been shown to be a function of smolt size and/or emigration date (Bilton et al. 1982; Mathews and Ishida 1989; Hagar and Noble 1976; Holtby et al. 1990; Lum 2003). Smolt size and/or emigration date has also been shown to affect age-at-maturity of male coho salmon in studies of hatchery coho salmon (Hagar and Noble 1976; Bilton et al. 1982; Vøllestad et al. 2004) and wild coho salmon (Lum 2003). Larger smolt that are released or emigrate earlier have been shown to produce more jacks than smaller smolt that are released or emigrate later (Bilton et al. 1982; Lum 2003). In addition, studies point to freshwater processes, rather than marine processes, being the dominant forces affecting the frequency of jacks in coho populations (Koseki and Fleming 2006, 2007; Vøllestad et al. 2004), indicating that at the time smolt emigrate, the life history type (jack or adult) of the emigrants has been largely determined.

Differences in survival and propensity to mature as jacks were examined for tagged fish in this study by dividing the data for tagged smolt into size groups and emigration time periods, and then comparing the subsequent recovery rates as mature fish. It was assumed that all recoveries represented a sample of surviving fish that was unbiased in regards to the two time periods, and that bias in the smolt size class sample was likely small. Thus differences in the overall recovery rates (both jacks and adults combined) from the different smolt groups could be attributed to differences in survival rates. Note that when recovery data of jacks and adults is examined separately, any difference in recovery rates between the smolt groups of interest can be attributed to differences in survival rates and/or differences in the proportion of the smolt group "predetermined" to return as either jacks or adults.

Smolt emigration date was related to the survival of marked fish in this study. Fish that emigrated during the *early* period survived at a significantly higher rate overall than fish that migrated during the *late* period (Tables 5 and 6).

Smolt size also appeared to be related to the survival of marked fish in this study as *large* and *extra large* smolt were recovered at maturity (jacks and adults combined) at significantly higher rates than were *small* smolt, and this difference was due almost entirely to the larger smolt being recovered at a higher rate as jacks than were *small* smolt (Tables 5 and 6). These results are consistent with the findings of the last 3 years at Chuck Creek where larger smolt survived at a significantly higher rate than smaller smolt (McCurdy 2009, 2010a-b), but this year's results need to be viewed with caution because smolt size could not be determined for 74 (13%) of the recovered fish. Note that for no significant difference in survival rates between *small* and larger smolt to have occurred for the entire sample of 562 recovered fish, a much higher percentage of the 74 unreadable tags would have to be *small* smolt than the percentage of *small* smolt in the sample of 488 readable tags (i.e., at least 58% vs. the 43% of small smolt in the readable tags). Also note that if the period May 2–9 (the period when the unreadable tags occurred) is excluded from the analysis, then the *extra large* and *large* smolt survival rates are still significantly higher than *small* smolt (survival = 5.5%, 2.8%, and 2.1% respectfully; $\chi^2 = 11.4$, df = 2, P = 0.003).

Smolt were recovered at a significantly higher rate as jacks from the *early* emigration period, but there was very little difference in the adult recovery rate between the *early* and *late* time periods. It seems reasonable to assume that smolt from the earlier emigration period contained a higher portion of "predetermined" jacks than the later emigrating smolt. Similarly, the assumption could be made that smolt from the larger size classes contained a higher portion of "predetermined" jacks than the smaller smolt size classes, as smolt from the larger size classes were recovered at significantly higher rates as jacks, but not as adults. However any assumptions involving smolt size affects on recovery rates in this study need to be made with caution because of the unknown smolt size classes of the 74 unreadable recovered tags.

SMOLT ABUNDANCE

The smolt weir appeared to be operational and virtually 100% effective at capturing coho salmon smolt prior to significant emigration in 2009 (Appendix A3, Figure 4). However, an estimated 7.2% of the escapement from the 2009 smolt emigration was unmarked. It seems reasonable to assume that the majority of these unmarked fish emigrated after the smolt weir was removed on June 7. Therefore, it appears that all coho salmon smolt did not have an equal probability of being marked in this study.

The unequal probability of marking noted above would bias the smolt abundance estimate if the marked and unmarked fish survived at different rates. Differences in survival rates between marked and unmarked smolt in this study cannot be tested for, but comparisons of survival rates between different tagged groups of fish is discussed above. Also, a simple simulation (used in past Chuck Creek studies) to estimate potential bias in the smolt abundance estimate as related to different survival rates between marked and unmarked smolt can be conducted.

Whether the survival rate of marked and unmarked smolt varied greatly from each other in this study is unknown, but it is unlikely that they survived at the same rate. Emigration date negatively affected survival of marked fish in this study and smolt size also decreased with emigration date (a factor identified as affecting smolt survival in other studies as cited above). Also, in past years at Chuck Creek the survival rate of marked fish has been a function of emigration date (McCurdy 2006a-b, 2008–2010). However, a model used to estimate potential bias in smolt abundance estimates in those years demonstrated that it would take a very large difference in the survival rate between marked and unmarked fish to greatly bias the smolt abundance estimates.

By applying the same model (Appendix A7) to the 2009 smolt emigration, potential bias in the abundance estimate can be estimated by conducting simulations where *unmarked* fish survive to maturity (to either jack or adult) at a rate different than the 10.4% survival rate of *marked* fish estimated in this study. If *unmarked* fish survive at 13.0% (a rate 25% higher than the rate of 10.4% for marked fish), then the smolt abundance estimate in this report (22,651) would be biased by 1.0% (and the calculated abundance would be 22,418). Similarly, if the actual survival rate for unmarked fish was 7.8% (25% lower than for marked fish) the smolt abundance estimate would be biased by -3.0% (and the calculated abundance would be 23,346). These simulations suggest it would require a large difference in survival rates between marked and unmarked fish to greatly bias the smolt abundance estimate.

MARINE HARVEST

The estimated marine harvest of 827 Chuck Creek coho salmon was close to the annual average for this stock (for years with returning CWT-tagged fish; Table 4) despite the lowest exploitation rate to date. Almost all harvest occurred in districts along the outside coast (Appendices A1 and A6), and this is the normal geographical distribution of the harvest for this stock. However, a larger portion of the troll harvest came from farther off shore (in District 152; where 28% of recorded troll recoveries were harvested) than in any previous year (average of 5% for 2003–2009). This is consistent with anecdotal information provided by commercial trollers fishing out of Craig, who said that coho salmon were holding several miles off shore for a large portion of July and August, and they had difficulty finding any fish in closer. This would also explain the relatively low exploitation rate of Chuck Creek coho salmon by the seine fleet, who fish closer to shore (Districts 103 and 104).

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Jazmine Alibozek, Jason McGinley, Becky Wilson and Larry Derby all helped collect data in the field. Sarah Power provided biometric support for this study and reviewed and provided comments on a draft of this report. Stacey Poulson formatted the manuscript for publication.

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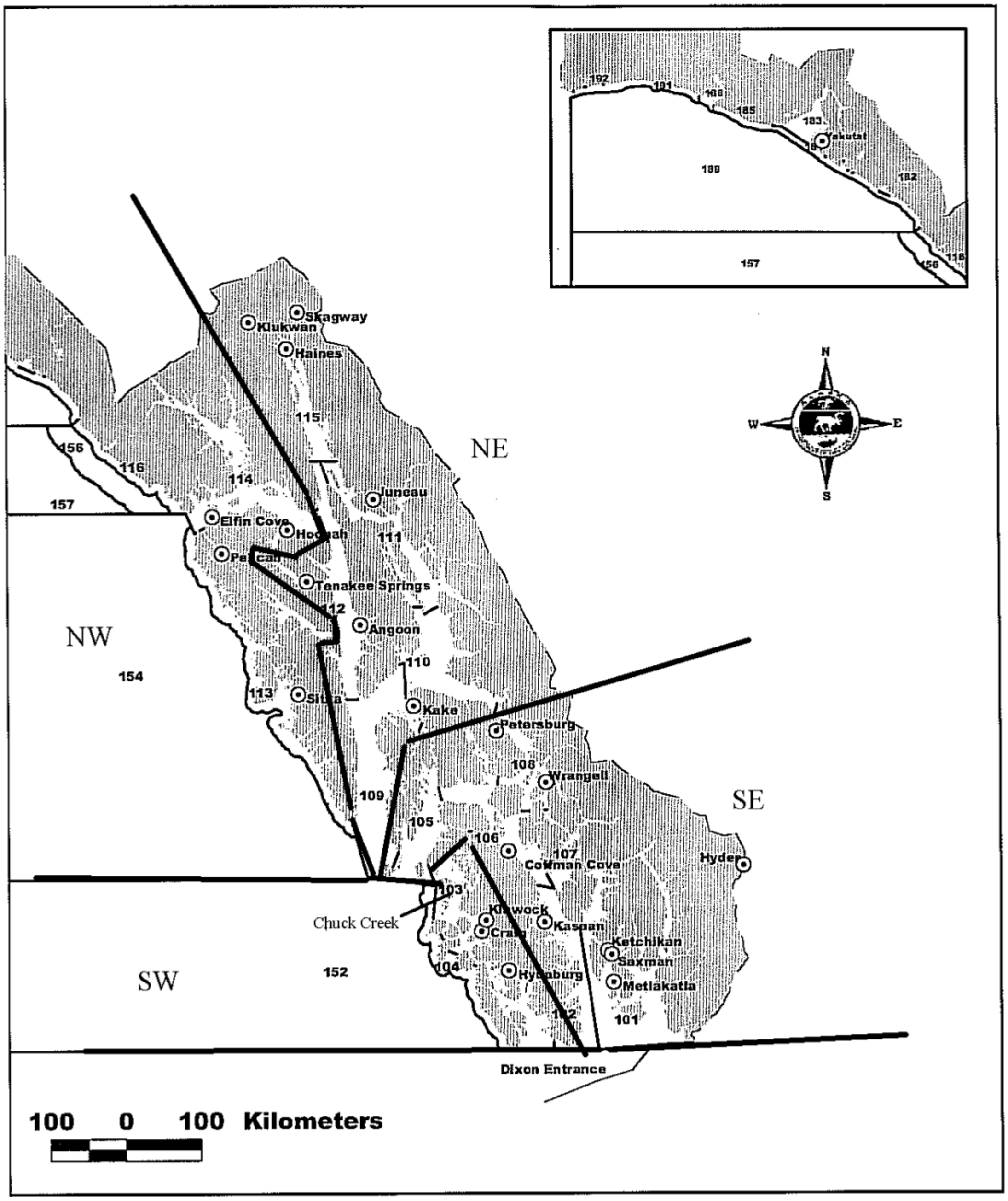
APPENDIX A: MAPS AND DATA

Appendix A1.–Map of Southeast Alaska commercial fishing districts and troll quadrants.



Appendix A2.–Number of coho salmon tagged and released with coded wire tags by date and size class from the 2009 Chuck Creek smolt emigration, and subsequent recoveries as mature fish in marine fisheries (in 2010) and escapement sampling (in 2009 and 2010).

		Number of smolt released with CWTs				Number smolt recovered as jacks			Number smolt recovered as adults		
Date	Tag code	*Small*	*Large*	*Extra large*	Total	*Small*	*Large*	*Extra large*	*Small*	*Large*	*Extra large*
4/20	041685	1	0	0	1	0	0	0	0	0	0
4/21	041685	2	2	0	4	0	0	0	0	0	0
4/22	041685	7	4	2	13	0	0	0	0	0	0
4/23	041685	12	6	4	22	0	0	0	0	0	0
4/24	041685	5	5	1	11	0	0	0	0	0	0
4/25	041685	3	1	1	5	0	0	1	1	0	0
4/26	041685	7	10	0	17	ND	0	0	0	0	0
4/27	041685	1	3	1	5	ND	0	0	0	0	0
4/28	041685	4	7	2	13	ND	1	0	0	0	0
4/29	041685	7	15	0	22	ND	1	0	0	0	0
4/30	041685	13	26	7	46	1	0	0	2	0	0
5/1	041685	22	67	4	93	ND	0	0	0	1	0
5/2	041685	96	115	5	216	3	4	0	3	1	0
5/3	041685	174	307	13	494	2	0	0	0	1	0
5/4	041685	867	782	8	1,657	5	12	0	8	7	0
5/5	041685	972	568	20	1,560	8	8	0	12	5	0
5/6	041685	581	364	7	952	5	9	1	7	10	0
5/7	041685	399	516	9	924	2	7	ND	3	2	0
5/8	041685	213	174	3	390	5	2	1	2	4	0

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Date	Tag code	Number of smolt released with CWTs				Number of smolt recovered as jacks			Number of smolt recovered as adults		
		Small	*Large*	*Extra large*	Total	*Small*	*Large*	*Extra large*	*Small*	*Large*	*Extra large*
5/9	041685	614	839	5	1,458	4	5	0	6	4	0
5/10	041992	444	459	6	909	3	5	0	7	4	0
5/11	041992	497	581	19	1,097	9	7	1	12	16	1
5/12	041992	328	242	4	574	4	3	0	5	7	0
5/13	041992	348	240	4	592	2	3	1	9	9	0
5/14	041992	275	170	3	448	5	2	0	6	5	0
5/15	041992	201	132	3	336	0	0	0	2	1	0
5/16	041992	491	264	2	757	2	3	0	5	1	0
5/17	041992	489	346	6	841	1	ND	0	5	1	0
5/18	041992	657	1,260	29	1,946	1	9	2	3	9	1
5/19	041992	545	861	27	1,433	1	11	1	9	25	0
5/20	042165	286	342	2	630	1	6	0	9	7	0
5/21	042165	157	221	1	379	0	3	0	2	4	0
5/22	042165	229	244	1	474	0	5	0	2	5	0
5/23	042165	375	485	5	865	0	4	0	9	9	0
5/24	042165	116	58	1	175	0	0	0	1	ND	0
5/25	042165	43	50	0	93	0	0	0	1	4	0
5/26	042165	83	68	1	152	0	0	0	3	ND	0
5/27	042165	134	74	2	210	1	1	0	2	1	0

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		Number of smolt released with CWTs				Number of smolt recovered as jacks			Number of smolt recovered as adults		
Date	Tag code	*Small*	*Large*	*Extra large*	Total	*Smal*	*Large*	*Extra large*	*Small*	*Large*	*Extra large*
5/28	042165	144	103	1	248	1	ND	0	3	1	0
5/29	042165	52	45	4	101	0	0	0	0	0	0
5/30	042165	164	251	3	418	0	2	0	2	7	0
5/31	042165	97	113	0	210	0	1	0	1	2	0
6/1	042165	29	18	0	47	0	0	0	1	1	0
6/2	042165	29	14	0	43	0	0	0	0	0	0
6/3	042165	30	15	0	45	0	0	0	0	0	0
6/4	042165	29	18	0	47	0	0	0	0	1	0
6/5	042165	11	8	0	19	0	0	0	0	0	0
6/6	042165	10	3	0	13	0	0	0	0	0	0
6/7	042165	2	0	0	2	0	0	0	0	0	0
Total		10,295	10,496	216	21,007	66	114	8	143	155	2

Note: CWT = coded wire tag. An additional 35 jacks and 39 adults were recovered where the size class of the smolt or the exact day of emigration could not be determined due to unreadable digits in the sequential CWT number. The dates of emigration of these fish could be narrowed down to the following: for adult recoveries; 18 smolt from May 2 to 6; 4 smolt from May 2 to 9; 15 smolt from May 6 to 9; 1 smolt from May 12 to 13; and 1 smolt from May 10 to 18. For jack recoveries: 16 smolt from May 2 to 6; and 19 smolt from May 6 to 9.

Appendix A3.–Daily number of coho salmon smolt and other downstream migrating fish captured at the smolt weir on Chuck Creek in 2009.

	Coho	Sockeye	Dolly Varden		Cutthroat		Steelhead	
Date	Smolt	Smolt	Adults[a]	Juveniles[b]	Adults[a]	Juveniles[b]	Juveniles[c]	Sculpin
4/19	0	0	0	0	0	0	0	0
4/20	2	0	10	0	0	0	0	103
4/21	4	1	5	0	0	2	0	202
4/22	14	1	20	0	0	3	0	92
4/23	20	24	28	0	0	2	0	115
4/24	11	39	23	0	0	2	0	147
4/25	9	26	41	0	0	1	0	162
4/26	15	81	29	0	0	0	0	97
4/27	3	31	30	0	0	0	0	154
4/28	23	140	34	0	2	0	0	160
4/29	45	258	27	1	1	0	0	128
4/30	101	495	48	2	0	0	0	149
5/1	223	739	44	1	0	0	0	101
5/2	419	622	54	3	0	1	0	28
5/3	123	338	6	0	0	0	0	38
5/4	2,247	1,051	5	2	0	0	0	15
5/5	1,144	403	5	4	0	0	0	20
5/6	854	675	4	1	0	0	0	19
5/7	900	457	2	1	0	0	0	16
5/8	644	135	0	0	0	0	0	9
5/9	1,402	660	5	14	0	0	0	14
5/10	1,009	709	23	1	0	0	0	36
5/11	907	450	10	2	0	0	0	17
5/12	443	228	15	5	0	1	0	25
5/13	683	388	3	7	0	0	0	80
5/14	380	232	0	3	0	0	0	29
5/15	271	162	11	8	0	0	0	113
5/16	862	299	135	17	0	0	0	81

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	Coho	Sockeye	Dolly Varden		Cutthroat		Steelhead	
Date	Smolt	Smolt	Adults[a]	Juveniles[b]	Adults[a]	Juveniles[b]	Juveniles[c]	Sculpin
5/17	758	724	18	13	0	2	0	75
5/18	3,018	1,464	30	36	0	3	1	8
5/19	605	454	71	7	0	0	0	99
5/20	402	371	4	2	0	0	0	76
5/21	401	197	0	0	0	0	0	33
5/22	642	302	0	13	0	0	0	24
5/23	730	359	4	3	0	0	0	18
5/24	110	83	0	4	0	0	0	37
5/25	98	66	3	2	0	0	0	28
5/26	147	39	5	0	0	0	0	35
5/27	365	206	3	1	0	0	0	38
5/28	123	74	9	0	0	0	1	22
5/29	100	139	19	42	0	1	5	41
5/30	445	149	5	8	0	2	1	35
5/31	143	69	1	9	0	0	1	35
6/1	38	31	1	5	0	0	2	49
6/2	57	30	5	10	0	0	1	42
6/3	28	3	5	6	0	0	0	87
6/4	48	0	0	0	0	0	0	87
6/5	15	0	0	0	0	0	0	44
6/6	14	0	0	0	0	1	2	63
6/7	0	0	0	0	0	0	0	28
Total	21,045	13,404	800	233	3	21	14	3,154

[a] Fish ≥175mm FL.

[b] Fish <175mm FL.

[c] All fish sexually immature. Includes both fish that appear to be smolt and nonsmolt.

Appendix A4.–Daily escapement counts of mature coho salmon passed through the weir on Chuck Creek, by life history type and marked status in 2010.

	Adult coho (age x.1)				Jack coho (age x.0)			
Date	Marked	Unmarked	Unknown	Total	Marked	Unmarked	Unknown[a]	Total
8/16	0	0	0	0	0	0	0	0
8/17	0	0	0	0	0	0	0	0
8/18	0	0	0	0	0	0	0	0
8/19	0	0	0	0	0	0	0	0
8/20	0	0	0	0	0	0	0	0
8/21	0	0	0	0	0	0	0	0
8/22	0	0	0	0	0	0	0	0
8/23	2	1	0	3	0	2	0	2
8/24	13	1	0	14	0	3	0	3
8/25	31	2	0	33	0	1	0	1
8/26	6	0	0	6	0	4	1	5
8/27	3	2	0	5	0	4	0	4
8/28	6	0	0	6	0	4	0	4
8/29	3	0	0	3	0	3	0	3
8/30	0	0	0	0	0	3	0	3
8/31	26	2	0	28	0	9	0	9
9/1	27	0	0	27	0	20	1	21
9/2	25	0	0	25	0	14	0	14
9/3	27	2	0	29	0	12	0	12
9/4	93	6	0	99	0	17	0	17
9/5	56	4	0	60	0	50	0	50
9/6	21	1	0	22	0	8	0	8
9/7	17	2	0	19	0	7	0	7
9/8	36	7	0	43	0	32	0	32
9/9	36	2	0	38	0	41	0	41
9/10	14	4	0	18	0	14	0	14
9/11	13	0	0	13	0	13	0	13

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Date	Adult coho (age x.1)				Jack coho (age x.0)			
	Marked	Unmarked	Unknown	Total	Marked	Unmarked	Unknown	Total
9/12	4	0	0	4	0	23	0	23
9/13	4	0	0	4	0	9	0	9
9/14	3	0	0	3	0	7	0	7
9/15	1	0	0	1	0	5	0	5
9/16	0	0	0	0	0	6	0	6
9/17	1	0	0	1	0	14	0	14
9/18	1	0	0	1	0	4	0	4
9/19	0	0	0	0	0	8	0	8
9/20	0	0	0	0	0	2	0	2
9/21	0	0	0	0	0	0	0	0
9/22	1	0	0	1	0	7	0	7
9/23	0	0	0	0	0	4	0	4
9/24	5	0	0	5	0	29	0	29
9/25	33	0	0	33	0	23	0	23
9/26	24	4	0	28	0	15	0	15
9/27	3	3	0	6	0	5	0	5
9/28	5	2	0	7	0	2	0	2
9/29	5	3	0	8	0	5	0	5
9/30	3	0	0	3	0	3	0	3
10/1	2	1	0	3	0	4	0	4
10/2	2	0	0	2	0	5	0	5
10/3	14	0	0	14	0	5	0	5
10/4	7	0	0	7	0	2	0	2
10/5	21	3	0	24	0	4	0	4
10/6	86	7	0	93	0	5	0	5
10/7	21	2	0	23	0	5	0	5
10/8	17	3	0	20	0	4	0	4

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Date	Adult coho (age x.1)				Jack coho (age x.0)			
	Marked	Unmarked	Unknown	Total	Marked	Unmarked	Unknown[a]	Total
10/9	5	2	0	7	0	2	0	2
10/10	4	1	0	5	0	0	0	0
10/11	0	0	20[b]	20	0	0	0	0
Total	727	67	20	814	0	468	2	470

[a] Fish passed upstream before they could be examined for the presence of an adipose fin.

[b] Fish holding downstream of the weir when it was dismantled for the season.

Appendix A5.–Daily escapement counts of sockeye, pink, and chum salmon; and steelhead trout passed through the weir at Chuck Creek in 2010.

Date	Sockeye adults	Sockeye jacks[a]	Pinks	Chum	Steelhead
8/16	27	0	0	0	0
8/17	0	0	2	0	0
8/18	0	0	0	0	0
8/19	2	0	2	0	0
8/20	0	0	0	0	0
8/21	6	0	0	0	0
8/22	6	0	0	0	0
8/23	420	3	38	0	0
8/24	1,356	11	451	0	0
8/25	1,250	4	803	0	0
8/26	701	6	648	0	0
8/27	359	3	927	0	0
8/28	182	0	994	0	0
8/29	60	0	710	0	0
8/30	33	0	354	1	0
8/31	166	0	944	0	0
9/1	33	2	853	0	0
9/2	61	0	1,121	1	0
9/3	59	0	1,235	2	0
9/4	32	0	229	0	0
9/5	37	1	1,657	2	0
9/6	18	1	1,457	1	0
9/7	1	1	237	1	0
9/8	20	0	838	0	0
9/9	7	0	455	0	0
9/10	2	0	225	0	0
9/11	2	0	131	0	0
9/12	3	0	130	0	0
9/13	2	0	287	0	1
9/14	0	0	588	1	0

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Date	Sockeye adults	Sockeye jacks[a]	Pinks	Chum	Steelhead
9/15	4	0	444	0	0
9/16	2	0	974	0	0
9/17	1	0	275	0	0
9/18	1	0	568	0	0
9/19	2	0	55	0	0
9/20	0	0	13	0	0
9/21	0	0	10	0	0
9/22	0	0	22	0	0
9/23	0	0	52	0	0
9/24	19	1	386	0	0
9/25	6	0	174	1	0
9/26	7	0	67	0	0
9/27	0	0	79	0	0
9/28	1	0	55	0	0
9/29	0	0	39	0	0
9/30	0	0	26	0	0
10/1	0	0	18	0	0
10/2	0	0	10	0	0
10/3	0	0	23	0	0
10/4	0	0	22	0	0
10/5	0	0	50	0	0
10/6	1	0	178	0	0
10/7	0	0	53	0	0
10/8	0	0	61	0	0
10/9	0	0	19	1	0
10/10	0	0	12	0	0
10/11	0	0	0	0	0
Total	4,889	33	19,001	11	1

[a] Male fish <400 mm MEF.

Appendix A6.–Estimated marine harvest (ri) of adult coho salmon bound for Chuck Creek in 2010.

						SE ALASKA TROLL FISHERY							
Stat week	Dates (period)	Quad	Harvest	Var(H)	n_i	a_i	a_i'	t_i	t_i'	m_i	r_i	SE(r_i)	RP[r_i]
27–33	6/27–8/14 (3)	NE	71,965	0	23,421	323	293	197	196	12	45	11	48.4%
34–40	8/15–10/2 (4)	NE	60,871	0	19,278	351	348	234	233	1	3	3	165.6%
27–33	6/27-–/14 (3)	NW	459,950	0	132,071	1,640	1,604	1,164	1,161	39	152	21	27.2%
34–40	8/15-–/2 (4)	NW	427,043	0	97,990	2,042	1,998	1,609	1,603	3	15	8	100.9%
27–33	6/27–8/14 (3)	SE	62,766	0	18,514	246	242	176	175	16	61	13	42.1%
34–40	8/15–10/2 (4)	SE	55,294	0	13,751	351	350	290	288	4	18	8	86.3%
27–33	6/27–8/14 (3)	SW	165,592	0	76,573	780	768	437	437	129	309	21	13.4%
34–40	8/15–10/2 (4)	SW	30,639	0	10,773	251	249	149	147	17	54	11	39.4%
	Troll subtotal		1,334,120	0	392,371	5,984	5,852	4,256	4,240	221	657	38	11.3%
						SE ALASKA PURSE SEINE FISHERY							
Stat week	Dates	District	Harvest	Var(H)	n_i	a_i	a_i'	t_i	t_i'	m_i	r_i	SE(r_i)	RP[r_i]
wk 32	8/1–8/7	104	2,141	0	601	7	7	5	5	4	16	7	84.5%
wk 33	8/8–8/14	104	2,329	0	496	11	11	10	10	7	36	12	66.5%
wk 34	8/15–8/21	104	817	0	477	5	5	3	3	3	6	2	77.2%
wk 35	8/22–8/28	104	3,473	0	584	14	14	12	12	8	52	17	63.8%
	Seine subtotal		8,760	0	2,158	37	37	30	30	22	110	22	39.5%
						SE ALASKA SPORT FISHERY							
Biweek	Dates	Area	Harvest	Var(H)	n_i	a_i	a_i'	t_i	t_i'	m_i	r_i	SE(r_i)	RP[r_i]
bw 13	6/21–7/4	Craig/Klawock	912		912	4	4	3	3	1	1	0	57.0%
bw 15	7/19–8/1	Craig/Klawock	1,250		1,250	11	11	7	7	7	8	1	21.7%
bw 16	8/2–8/15	Craig/Klawock	1,244		1,244	26	26	21	21	19	21	1	13.3%

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SE ALASKA SPORT FISHERY (continued)													
Var(*H*)	Var(*H*)	Var(*H*)	Var(*H*)	Var(*H*)									
bw 17	8/16–8/29	Craig/Klawock	451		451	14	14	10	10	5	5	1	25.6%
bw 14	7/5–7/18	Sitka	2,880		907	15	15	10	10	3	10	5	95.5%
bw 15	7/19/–8/1	Sitka	14,646		3,681	42	41	31	31	1	4	4	172.6%
	Sport subtotal		21,383	0	8,445	112	111	82	82	36	49	7	26.2%
NORTHERN BRITISH COLUMBIA MARINE FISHERIES													
Dates	Fishery	Area	Harvest	Var(*H*)	n_i	a_i	a_i'	t_i	t_i'	m_i	r_i	SE(r_i)	RP[r_i]
8/8-9/18	Troll	Northern B.C.	51,866		13,685	272	272	159	155	1	4	4	171.5%
8/1-8/31	Sport	Northern B.C.	ND		ND	ND	ND	ND	ND	1	6	ND	ND
	Canadian subtotal		51,866		13,685	272	272	159	155	2	10	4	171.5%
	TOTAL		1,416,129	0	416,659	6,405	6,272	4,527	4,507	281	826	44	10.5%

Note: n_i = number of fish examined for missing adipose fins**;** a_i = number of adipose-finclipped fish seen; $\boldsymbol{a_i'}$ = number of heads received at the Tag Lab**;** t_i = number of CWTs detected; t_i' = number of CWTs decoded; m_i = number of CWTs with codes from Chuck Creek. Variance is not estimated in the Craig/Klawock sport fishery.

APPENDIX B: ANALYSIS NOTES

Appendix B1.–Model used to estimate potential bias in smolt abundance estimate of 2009 Chuck Creek coho salmon smolt emigration if unmarked fish survived at a different rate than marked fish.

In this study, overall survival (to either jack or adult) of *marked* fish can be estimated to be 10.4% (= [$684_{cwt\ jacks}$ + $745_{cwt\ adult\ esc}$ + $757_{cwt\ harvest}$] / $21{,}025_{cwt\ smolt}$). The *CWT harvest* was estimated by expanding the number of recoveries in sampled fisheries for the fraction of the harvest not examined. The *CWT adult esc* was estimated by expanding the number of recoveries in the sampled adult escapement for the fraction of the adult escapement not examined (745 = 814 x 727/794). The *CWT jacks* was estimated by expanding the number of recoveries in the sampled jack escapement for the fraction of the jack escapement not examined (684 = 726 x 656/696). All other variables are known from weir counts. Thus, smolt abundance at survival rates other than the assumed rate of 10.4% is:

$$\hat{N} = n_{marked} + \left(m_{unmarked} / S_{unmarked}\right)$$

where $\hat{N}$ is the mark-recapture estimate of smolt abundance, n_{marked} is the number of smolt that were marked (21,025), $m_{unmarked}$ is the number of unmarked mature fish (estimated at 181 in this study), and *S* is the fraction of unmarked smolt that survive to maturity (unknown in this study). The number of unmarked mature fish was estimated by summing the weir counts in the escapement ($42_{jacks\ unmarked}$ + $69_{adults\ unmarked}$) and the estimated number in the harvest (= 70, assuming the harvest rate for unmarked fish is the same for marked fish).

APPENDIX C: COMPUTER FILES

Appendix C1.–Computer files used in analysis of data for this report.

File Name	Description
2010 Chuck escapement data.xls	Excel workbook containing 2010 Chuck Creek adult escapement data.
2009 Chuck smolt data.xls	Excel workbook containing 2009 Chuck Creek smolt and coded wire tagging data.
2010 Chuck Harvest data.xls	Excel workbook containing 2010 marine harvest estimations and cwt recoveries.
Chuck Creek water temps 2003–2011	Excel workbook containing water temperatures recorded in Chuck and Roadside creeks.