Fishery Data Series No. 10-75

Production of Coho Salmon from the 2008 Smolt Emigration from Chuck Creek in Southeast Alaska

by

Steven J. McCurdy

November 2010

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

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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. 10-75

PRODUCTION OF COHO SALMON FROM THE 2008 SMOLT EMIGRATION FROM CHUCK CREEK IN SOUTHEAST ALASKA

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November 2010

The report was prepared by Steve McCurdy under awards NA04NMF4380288, and NA06NMF380597 (Alaska Sustainable Salmon Fund projects 45834 and 45954) from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, administered by the Alaska Department of Fish and Game. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration, or the U.S. Department of Commerce.

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This document should be cited as:
McCurdy, S. J. 2010. Production of coho salmon from the 2008 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 10-75, Anchorage

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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 2008 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 to maturity, and/or the date of return to freshwater (of jacks). Emigrating coho smolt were captured at a weir during the spring of 2008, 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 2009. Escapements were counted through a weir at Chuck Creek in 2008 and 2009, and coho salmon were examined for missing adipose fins and the presence of CWTs.

A total of 13,461 coho salmon smolt were tagged and released alive between April 16 and June 12, 2008. In 2009, 311 random recoveries of coho salmon bearing CWTs of Chuck Creek origin were recovered in sampled marine fisheries, yielding an estimated marine harvest of 1,307 fish (SE = 91). A total of 617 jacks and 776 adults escaped marine fisheries and returned to Chuck Creek from the 2008 smolt emigration. An estimated 15,471 (SE = 153) coho salmon smolt emigrated from Chuck Creek in 2008. Marine survival to adult of the 2008 smolt emigration was estimated at 13.5% (SE = 0.6%) and the exploitation rate in marine fisheries was estimated at 62.7% (SE = 1.6%).

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. 2003; McCurdy 2005; 2006a-b; 2008-2010). 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. 2003). 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. 2003). 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. 2003), and the Klawock River (ADF&G's Mark, Tag and Age Laboratory, or Tag Lab, database), both on nearby Prince of Wales Island.

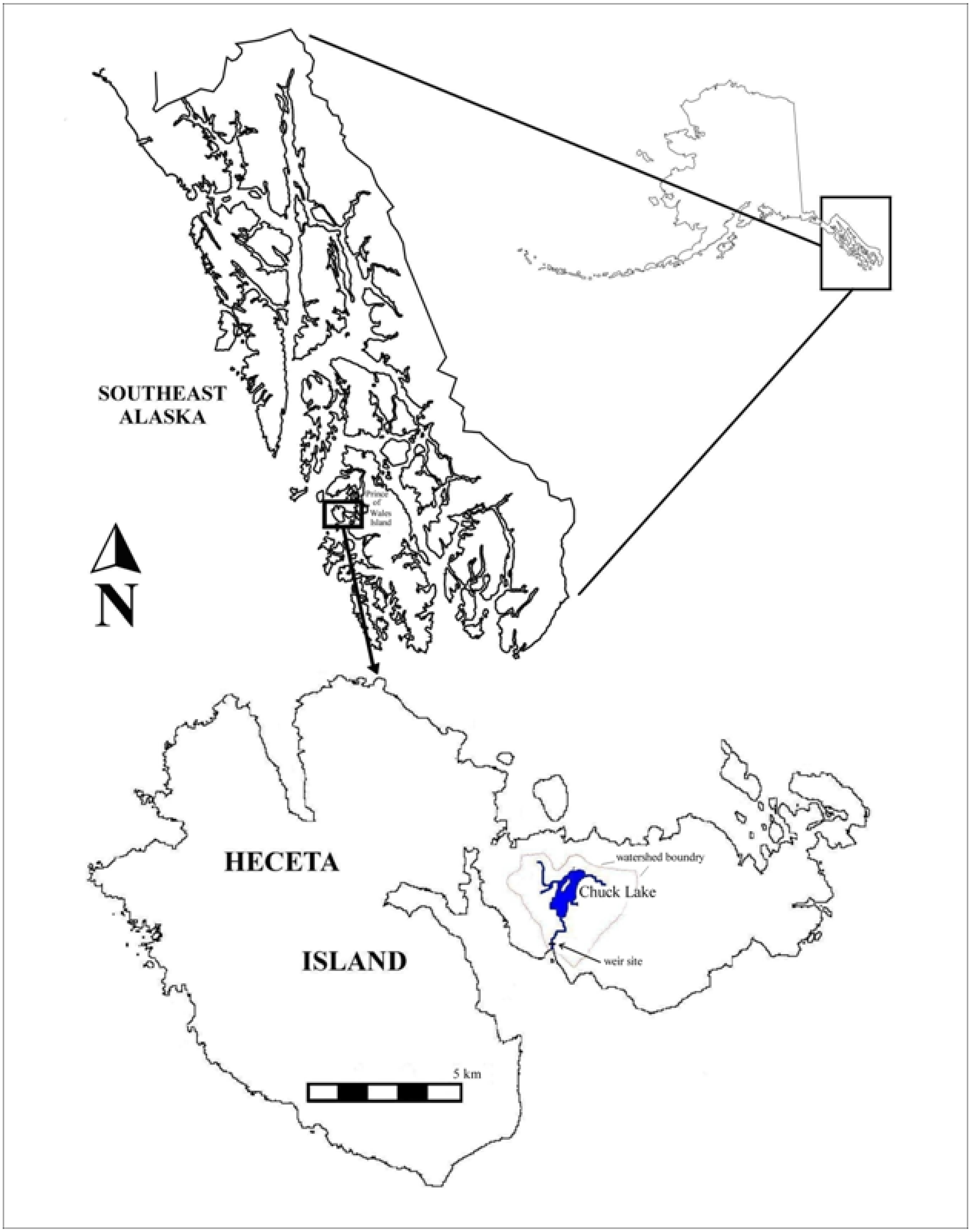

Figure 1.–Location of Heceta Island and the Chuck Creek watershed.

The Chuck Creek watershed drains an area of approximately 750 hectares (1,853 acres), and contains Chuck Lake that has a surface area of approximately 63 hectares (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 with the highest point of elevation in the drainage being 169 meters (553 feet) 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, with the remainder being water (9.8%) and non forested land (0.5%, predominantly muskeg; ADF&G Southeast Habitat Information IMS website). 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 to:

1. estimate the number of coho salmon smolt emigrating from Chuck Creek in 2008;
2. estimate the age composition, and mean length and weight of coho salmon smolt captured emigrating from Chuck Creek in 2008;
3. count the escapement of coho salmon returning to Chuck Creek from the 2008 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 2008 smolt emigration;
5. estimate the marine harvest of coho salmon from Chuck Creek in 2009 via recovery of CWTs;
6. investigate the relationship between coho salmon smolt size and emigration date, and survival to maturity; and
7. investigate the relationship between date of smolt emigration from the watershed and immigration date back to the watershed of age x.0 jacks.

Although not an objective of this study:

1. 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 (immigrated) the watershed. Coho salmon smolt were captured as they were emigrating from Chuck Creek in the spring of 2008. Captured smolt were injected with a CWT and had their adipose fin removed (referred to as “adipose finclipped”). Adult coho salmon were sampled in the harvest of commercial and sport fisheries in 2009 for the presence of CWTs. The escapement of mature coho salmon was monitored through a weir on Chuck Creek in 2008 and 2009 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, and the tagged fraction of adult fish was used for estimating harvest in marine fisheries. Harvest of coho salmon in marine waters of Southeast Alaska is limited to adult fish that have spent one 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), 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). 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 2008 as they were emigrating from the Chuck Creek watershed using a weir and “trough” trap 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 meters 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 meter. 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 16 until June 12.

Captured fish were removed from the live box several times a day and sorted by species. The trap was checked at a minimum at dawn, midday, dusk and after dark, and more frequently when fish were migrating. The time the trap was checked, as well as the number of fish captured since the previous check, was recorded. All non-coho 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 that were <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 that appeared healthy 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. Before tagging the first fish and after tagging the last fish in each size category, on each day, one 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 identified as to their 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 (16 hr) CWT loss and mortality due to the handling and tagging procedure was evaluated by holding all fish overnight, 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 their CWTs, then the entire batch of fish being held overnight was checked for the presence of CWTs and retagged if found missing a tag. The number of fish tagged, the number of overnight 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 2008 contained the codes 04-14-80 and 04-16-84 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 2008. Event 1 consisted of marking captured coho salmon smolt by removing their adipose fin in 2008. Event 2 consisted of sampling returning mature coho salmon in 2008 (jacks) and 2009 (adults) to determine the marked fraction for the watershed.

The abundance of coho salmon smolt emigrating from Chuck Creek in 2008 was estimated using Chapman's modification of the Petersen estimator for a closed population (Seber 1982):

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

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

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

where n_1 was the number of smolt marked in 2008 by removing their adipose fin, n_2 was the number of returning coho salmon inspected for marks in 2008 (jacks only) and 2009 (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 requiring equal survival rates between marked and unmarked fish); (2) there is no recruitment to the population between events; (3) marking does 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 be at such a low level as to not significantly affect the population estimate (condition 2); all immigrating fish in the escapement are obligated to pass through the salmon weir when returning to spawn so catchability in event 2 is unaffected by marking (condition 3); adipose fins do not regenerate when completely removed (condition 4), and missing adipose fins are easy to note when examining the captured fish (condition 5).

Because smolt capture and marking in this study does not occur for the entire duration of the emigration, all smolt do 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; 2008-2010). Thus, it is likely that marked and unmarked fish do not survive at the same rate, and almost assures that condition 1 is violated in this study. However, the impact of this violation on the abundance estimate is 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 coded wire tagged. Each sampled fish was measured to the nearest mm for fork length, 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 freshwater after hatching and the number of years in salt water are separated by a period; Groot and Margolis 1991). Ages were determined one time by one 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 its variance 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 2009, 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 fortnight. Hubartt and Jaenicke (2004) present details of sampling sport fisheries. An ADF&G Division of Commercial Fisheries manuscript[2] describes sampling of commercial fisheries in Southeast Alaska in which samplers stationed at fish processors throughout Southeast Alaska 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 2009 harvest r_{ij} of Chuck Creek coho salmon from the entire 2008 smolt emigration j to one 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 marked fraction of 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 fin clipped 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 was installed across the lower end of Chuck Creek (approximately 500 m from salt water) and operated from August 18 until October 20 in 2008 (McCurdy 2010), and from August 18 until October 13 in 2009. Pickets were 18-mm in diameter and were spaced 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 square 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, 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.

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2 Alaska Department of Fish and Game, Division of Commercial Fisheries, *Unpublished*. Coded wire tag sampling program detailed sampling instructions, commercial fisheries sampling, Located at Alaska Department of Fish and Game, Division of Commercial Fisheries, 802 3rd Street, Douglas, Alaska

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 in length (mideye-to-fork, MEF) or larger were considered adults and those less than 380 mm in length were considered jacks, and any fish between 380 mm and 450 mm in length had a scale sample taken to verify the assumed ocean age. In the previous 8 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 the assumed ocean age, and there has been no overlap in fork length detected between jacks and adults, as the largest jack has been 395 mm in MEF and the smallest adult has been 400 mm in MEF (McCurdy 2010).

Coho salmon were systematically sampled throughout the entire migration for age, sex, and length (ASL). In both 2008 and 2009 every 4th adult coho and every 3rd jack coho salmon encountered at the weir 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 fraction of the adult and jack migrations that belong to each age or sex group is:

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

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

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

$$\hat{E} = \frac{\hat{T}}{\hat{N}_R} \quad (10)$$

$$\mathrm{var}[\hat{E}] \approx \frac{\mathrm{var}[\hat{T}]N_e^2}{\hat{N}_R^4} \quad (11)$$

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

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

$$\mathrm{var}[\hat{S}] \approx \hat{S}^2\left[\frac{\mathrm{var}[\hat{N}_R]}{\hat{N}_R^2} + \frac{\mathrm{var}[\hat{N}_s]}{\hat{N}_s^2}\right] \quad (13)$$

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/or emigration timing to various parameters (i.e. survival to maturity, size at smolt emigration date, size at maturity, return date of jacks etc.) the data was analyzed using a simple linear regression model if the data appeared to be normally distributed and had equal variance (parametric data). Otherwise the data was analyzed using Spearman's rank correlation coefficient test for nonparametric data (Hollander and Wolf 1973). Spearman's test was used to analyze the relationship between smolt size and emigration date as well as the relationship between jack emigration and immigration date (date of capture at the smolt weir to the date of capture at the adult weir).

RESULTS

SMOLT EMIGRATION IN 2008

A total of 13,486 coho salmon smolt were captured emigrating from Chuck Creek between April 16 and June 12, 2008. Of these fish, 12 were sacrificed because they already contained a CWT that needed to be retrieved as part of an age validation study (the fish had been tagged as newly emergent fry in the spring of 2006 - see McCurdy 2010 for details). The remaining 13,474 coho salmon smolt were coded wire tagged and had their adipose fin removed. Thirteen fish died after tagging, leaving a total of 13,461 smolt (9,298 fish $\leq$100 mm; 3,839 fish > 100 mm FL < 130 mm FL; and 324 fish ≥130 mm FL; Appendix A2) that were released with adipose fin clips and valid CWTs in 2008. Emigrating coho salmon smolt were first captured in the trough trap on the night of April 18 (Appendix A3), and peak catches occurred in mid May (Figure 2), with almost 32% of all the coho salmon smolt captured emigrating in one 48-hour period (May 15-16, Appendix A3).

A sample of 330 coho salmon smolt was collected for age, length and weight estimation (Table 1). Age could not be estimated on 4 fish because of regenerated scale samples. Age-1 coho constituted 96.3% (SE = 1.0%) of the sampled and averaged 97 mm FL (SE = 0.5) and 9.0 g (SE = 0.2). Age-2 coho smolt constituted 3.7% (SE = 1.0%) of the sample and averaged 137 mm FL (SE = 4.5) and 24.7 g (SE = 2.5) (Table 1, Figure 3). Because smolt lengths sampled on different days throughout the emigration had high and unequal variance (nonparametric data, Figure 4), 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 ($\rho = -0.2$, $P < 0.0001$, $n = 330$). That is to say smolt that emigrated early in the emigration tended to be larger that smolt that emigrated later, this despite the fact that the coho salmon smolt that left later were certainly growing in freshwater during the sampling time period of almost 2 months. Additionally, smolt in the 2 *larger* size categories tended to emigrate earlier than *small* smolt (Figure 2, Appendix A2). Dividing the time period when smolt were captured (April 17-June 11) into 2 equal time periods, 55% of all the *large* and *extra large* smolt captured emigrated during the *early* period (April 17-May 14), whereas only 38% of all the *small* smolt captured did (Figure 2).

Table 1.–Estimated freshwater age composition, and mean length and weight at age of emigration coho salmon smolt captured at Chuck Creek in 2008.

	Age 1	**Age 2**	**Combined**
Sample size	314	12	326
Estimated composition	96.3%	3.7%	100%
SE composition	1.0%	1.0%	
Mean length (mm)	97	137	99
SE mean length	0.5	4.5	0.7
Mean weight (g)	9.0	24.7	9.6
SE mean weight	0.2	2.5	0.2

Surviving fish from the 2008 smolt emigration returned to Chuck Creek in both 2008 (as jacks) and in 2009 (as adults), and returning fish were examined for a missing adipose fin to determine the marked fraction (θ). In the 2008 escapement, 523 of 616 jacks examined ($\theta = 0.849$) were missing adipose fins. In the 2009 escapement, 688 of 776 adults examined ($\theta = 0.887$) were missing their adipose fin. These 2 marked fractions were significantly different ($\chi^2 = 4.3$, df = 1, $P = 0.04$). Pooling both escapement samples (1,211 marks in 1,392 inspected) yielded an estimate of $\theta = 0.870$ for the fraction of the 2008 smolt emigration marked. An estimated 15,471 (SE = 153) coho salmon smolt emigrated from Chuck Creek in 2008 ($n_1 = 13{,}461$, $n_2 = 1{,}392$, $m_2 = 1{,}211$).

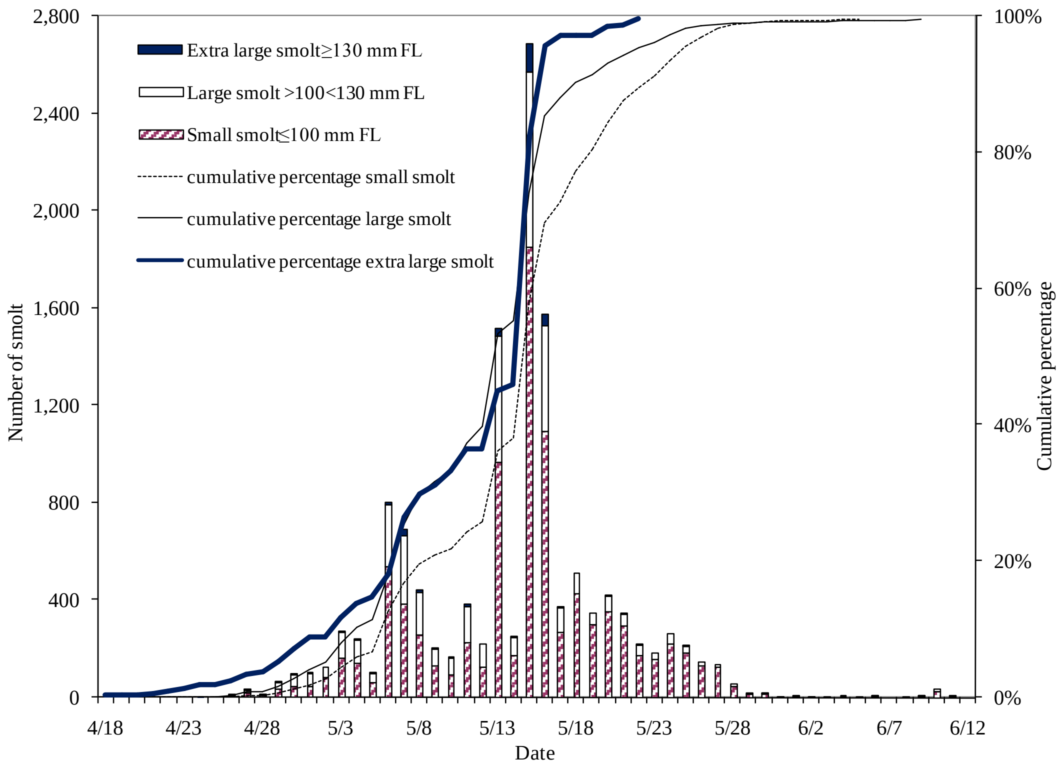


Figure 2.–Daily catch and cumulative percentage of the coho salmon smolt emigration passing the Chuck Creek weir in 2008.

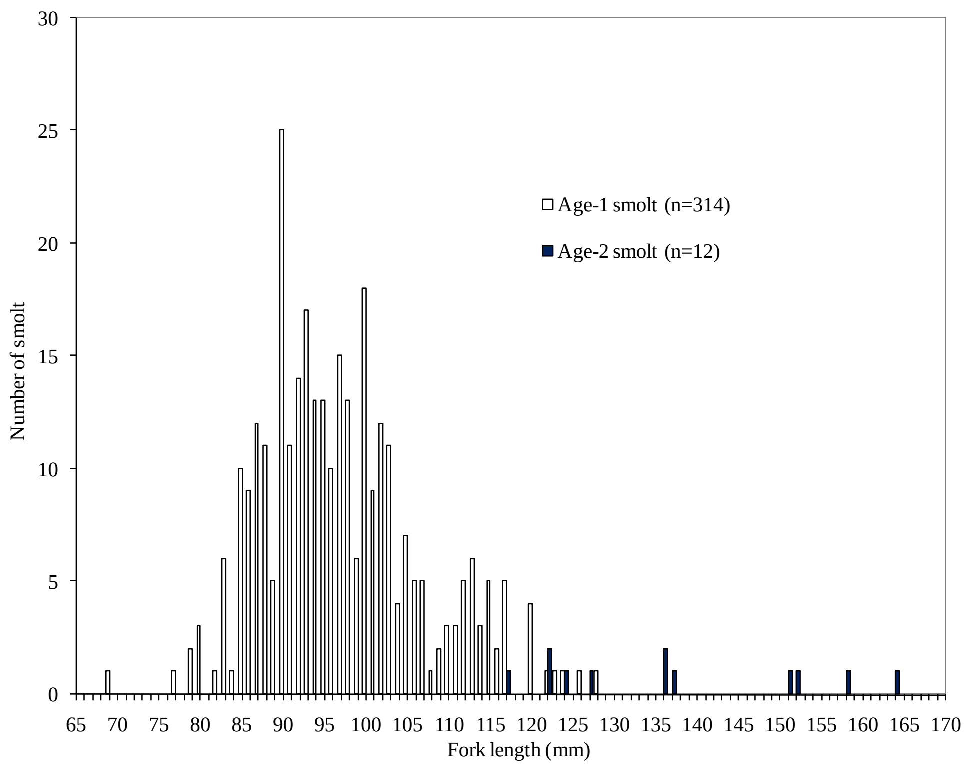


Figure 3.–Length frequency of the coho salmon smolt emigration systematically sampled at Chuck Creek in 2008, by freshwater age.

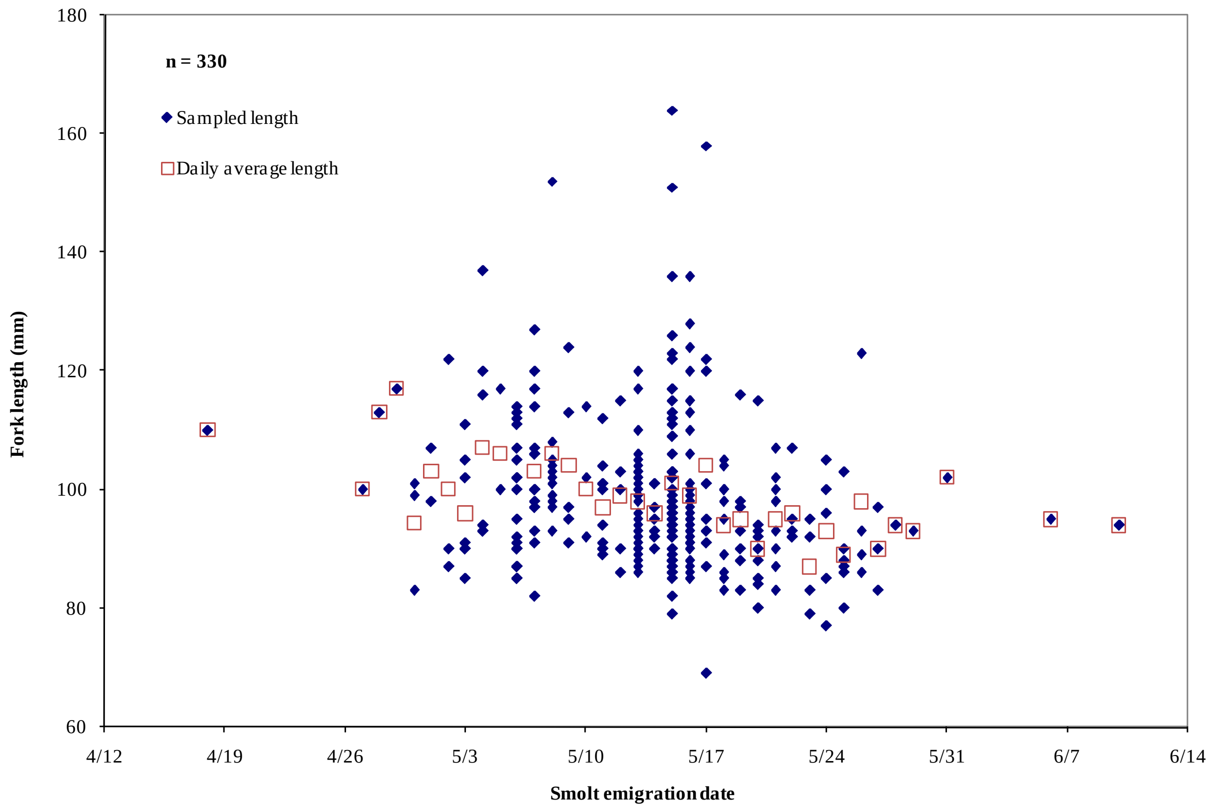


Figure 4.–Date of smolt emigration plotted vs. smolt fork length of systematically sampled coho salmon smolt from the 2008 Chuck Creek smolt emigration.

ESCAPEMENT ENUMERATION AND SAMPLING

2008 Jack Escapement

A total of 617 jack coho salmon were counted through the weir between August 18 and October 20, 2008 (McCurdy 2009). Of the total jack escapement, one fish was passed upstream before it could be examined for the presence or absence of an adipose fin, and of the remaining 616 fish, 523 were missing their adipose fin (θ = 0.849). A sample of 173 coded wired tagged jacks (where the sequential CWT was successfully decoded) was collected in 2008. McCurdy (2010) provides further details on the 2008 escapement of coho salmon to Chuck Creek.

2009 Escapement

In 2009, a total of 776 adult and 726 jack coho salmon were counted past the weir on Chuck Creek between August 18 and October 13 (Appendix A4). Life-history type (adult, jack) was assumed to be accurately determined on all mature fish in the 2009 escapement, as no overlap in length between jacks and adults was detected by aging a random sample of 439 fish (Table 2, Figure 5). In addition, all fish that measured between 380 and 450 mm MEF were sampled for age verification (n = 8, 7 random samples and 1 non-random sample). All of the jack coho salmon were from the 2009 smolt emigration. In the 2009 escapement the largest jack measured

355 mm and the smallest adult measured 390 mm MEF. The temporal pattern of immigration of the escapement was slightly earlier than previous years (Figure 6). A small number of mature coho salmon likely entered Chuck Creek after the weir was dismantled on October 13; 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). In addition a small number of coho likely entered Chuck Creek before the weir was installed on August 18. A freshet on August 16 and 17 resulted in relatively high stream flows on August 17 and 18 (that can be conducive for mature coho salmon to enter freshwater: Holtby et al. 1984; Sandercock 1991). After weir installation on August 18, a stream survey was conducted with snorkel gear from the weir to the lake and 1 adult coho salmon was observed that had entered prior to weir instillation (counted in the data as entering on August 18). It is possible additional coho had also entered, but this number was likely also very small as weir operations at Chuck Creek in past years have shown very few fish entering on or before August 18 (only 5 of a combined 10,963 adult coho counted in weir operations in 1950, 1982, 1983, 1985 and 2001-2008).

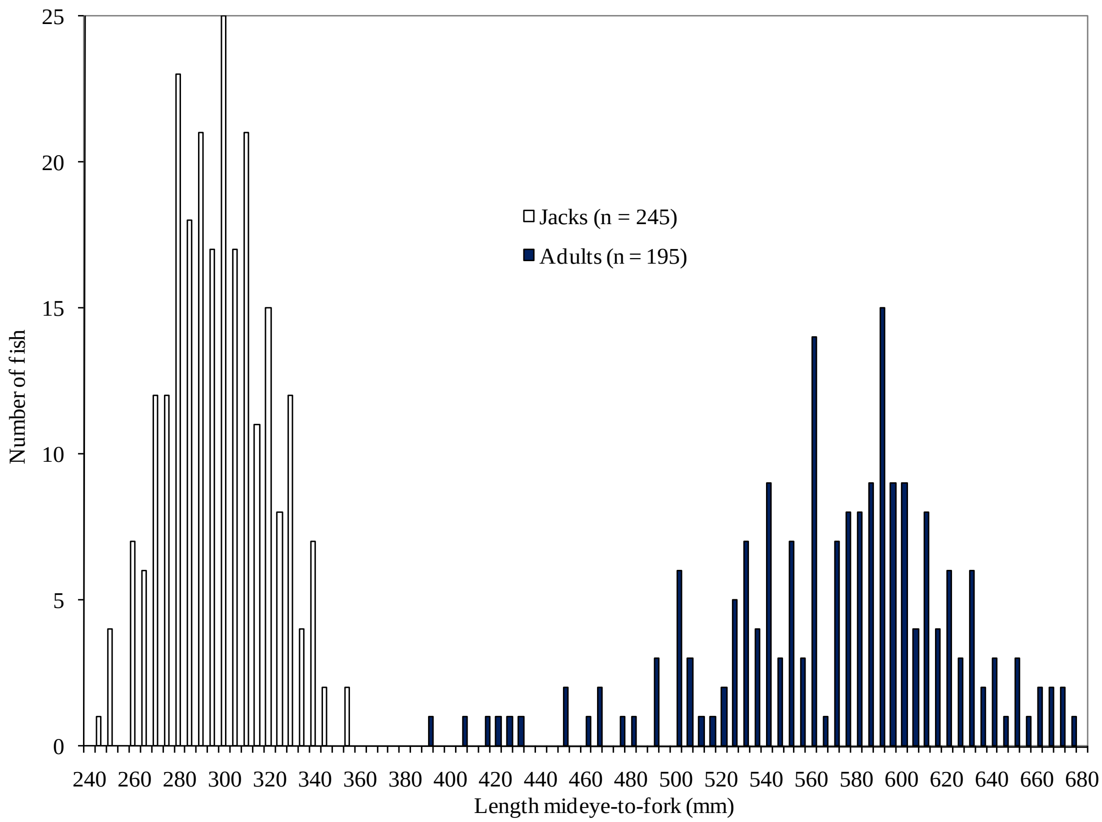


Figure 5.–Length frequency of the coho salmon escapement sampled at the Chuck Creek weir in 2009, by ocean age (every 3rd jack and every 4th adult systematically sampled).

Table 2.– Estimated age composition, and mean length (MEF) at age and sex of the 2009 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				73	6	97
Percent				92.4%	7.6%	100%
SE percent				2.7%	2.7%	
Mean length (mm)				586	595	589
SE mean length				4	10	3
Minimum length (mm)				490	560	490
Maximum length (mm)				675	630	675
Males						
Sample size	178	25	244	80	2	98
Percent	87.7%	12.3%	100%	97.6%	2.4%	100%
SE percent	2.0%	2.0%		1.5%	1.5%	
Mean length (mm)	296	308	298	554	583	550
SE mean length	1	3	1	6	42	5
Minimum length (mm)	245	280	245	405	540	390
Maximum length (mm)	355	345	355	665	625	665
All Fish						
Sample size				153	8	195
Percent				95.0%	5.0%	100%
SE percent				1.5%	1.5%	
Mean length (mm)				569	592	569
SE mean length				4	11	3
Minimum length (mm)				405	540	390
Maximum length (mm)				675	630	675

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

A total of 860 adult sockeye salmon, 58 jack sockeye salmon (males <400 mm MEF), 29 chum salmon, 33,774 pink salmon, 1 Dolly Varden, and 2 steelhead trout were also counted through the weir between August 18 and October 13, 2009 (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 18, and a number of pink and chum salmon spawned downstream of the weir site (personal observations). The crew observed Dolly Varden fitting between the pickets on the weir and it is likely that the weir captured only a small percentage of immigrating Dolly Varden. The 2 steelhead captured were less than 400 mm FL, and showed no external characteristics that allowed for sex determination (i.e. appeared to be immature). One of the steelhead appeared to have recently entered the stream from the marine environment (bright silver coloration).

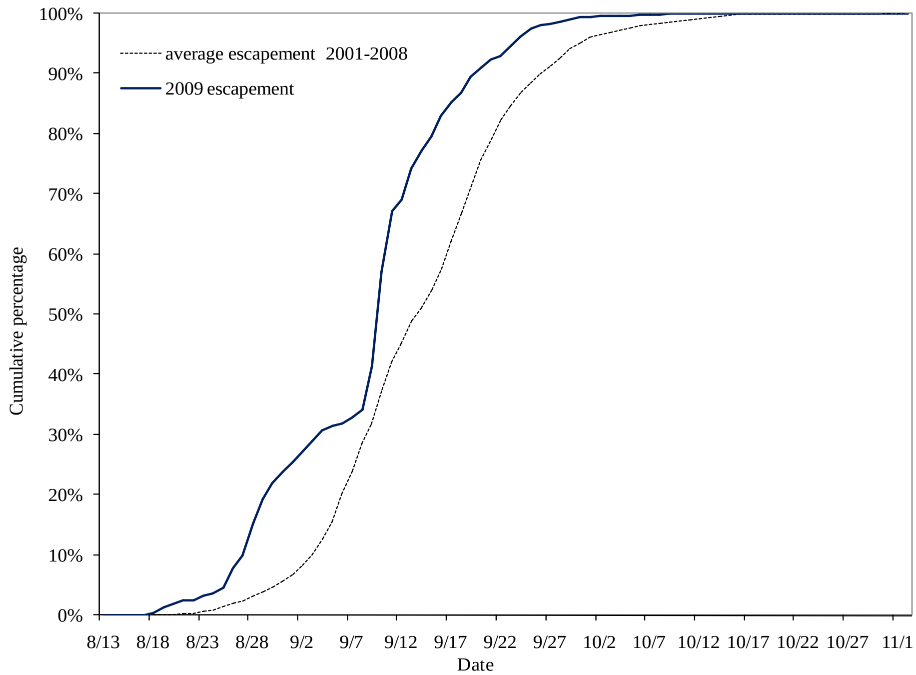


Figure 6.–Cumulative percentage of annual escapement of mature coho salmon (jacks and adults combined) passed through the Chuck Creek weir 2001-2009.

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

The 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 ($\theta = 0.887$), as all adult coho salmon systematically sampled at the weir in the 2009 escapement that were missing an adipose fin (n = 166) also tested positive for the presence of a CWT in their snout (thus all adults missing an adipose fin were assumed to have retained their CWT).

A total of 390 adult coho salmon tagged as smolt emigrating from Chuck Creek in 2008 were recovered in creel and port sampling programs that sampled marine fisheries in Alaska in 2009. No fish were recovered in sampled Canadian fisheries. Of the 390 marine recoveries of coded wire tagged coho salmon from Chuck Creek in Alaskan waters, 311 were random samples that were useful for estimating marine harvest in various fisheries (Appendix A6). The greatest number (273) of the random CWT recoveries of Chuck Creek coho was in the troll fishery and the remainder was in the seine fishery (25), sport fishery (12), and gillnet fishery (1). There were also 53 random recoveries in marine fisheries where the fishing area was not designated, and 21 non-random recoveries. Of the random troll recoveries, 216 were recovered in the SW quadrant, 36 in the NW quadrant, 16 in the SE quadrant, and 5 in the NE quadrant. Purse seine recoveries were in fishing Districts 101, 102, 103 and 104 (Appendix A1). The drift gillnet recovery was in fishing District 101 (in the “Tree Point” area). Sport recoveries were from the ports of Craig/Klawock and Sitka.

An estimated 1,307 (SE = 91) coho salmon originating from Chuck Creek were harvested in marine commercial and sport fisheries in 2009 (Tables 3 and 4; Appendix A6; Figure 7). The commercial troll fishery in Alaska harvested an estimated 996 fish, or 76.2% of the total harvest. The Alaskan purse seine fishery harvested an estimated 292 fish (22.3% of the total harvest), the Alaskan gillnet fishery harvested an estimated 3 fish (or 0.2% of the total harvest), and the Alaskan sport fishery harvested an estimated 16 fish, or 1.2% of the total harvest. Harvested fish were sampled from June 20 to September 17.

The total return of Chuck Creek adult coho salmon was estimated at 2,083 fish (SE = 91) in 2009. Marine survival to adult of the 2008 smolt emigration was estimated at 13.5% (SE = 0.6%) and the exploitation rate in marine fisheries was estimated at 62.7% (SE = 1.6%). An additional 617 fish, or 4.0% (SE = 0.04%) of the estimated 15,471 smolt that emigrated in 2008 survived to return as jacks in the same year as their emigration.

Table 3–Estimated harvest, exploitation rate, and total return of Chuck Creek coho salmon in 2009.

Fishery	Area	Estimated harvest	(SE)	Percent of harvest	Exploitation rate	(SE)
Alaska troll	NE Quadrant	19	(7)	1.5%	0.9%	(0.1%)
	NW Quadrant	130	(18)	9.9%	6.2%	(0.3%)
	SE Quadrant	79	(18)	6.0%	3.8%	(0.3%)
	SW Quadrant	768	(45)	58.8%	36.9%	(0.8%)
	subtotal	996	(53)	76.2%	47.8%	(0.9%)
Alaska gillnet	District 101	3	(2)	0.2%	0.1%	(0.0%)
	subtotal	3	(2)	0.2%	0.1%	(0.0%)
Alaska seine	District 101	5	(4)	0.4%	0.2%	(0.1%)
	District 102	3	(2)	0.4%	0.1%	(0.0%)
	District 103	186	(62)	14.2%	8.9%	(1.1%)
	District 104	98	(41)	7.5%	4.7%	(0.7%)
	subtotal	292	(75)	22.3%	14.0%	(1.3%)
Alaska sport	Craig/Klawock	13	(1)	1.0%	0.6%	(0.0%)
	Sitka	3	(3)	0.4%	0.1%	(0.1%)
	subtotal	16	(3)	1.2%	0.8%	(0.1%)
Total harvest		1,307	(91)	100.0%	62.7%	(1.6%)
Escapement		776	(0)		37.3%	
Total return		2,083	(91)		100.0%	

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				1,738	1,017	2,755	63.1%
1983[b]	551	618				1,169	1,238	2,407	48.6%
1985[b]	1,906	975				2,881	956	3,837	75.1%
2003[c]	539	252		83		874	614	1,488	58.7%
2004[d]	725	179		76		980	606	1,586	61.8%
2005[e]	652	232		120		1,004	646	1,650	60.8%
2006[f]	401	32		8	7	448	409	857	52.3%
2007[g]	577	116		29	60	782	425	1,207	64.8%
2008[h]	389	146	17	8	5	565	309	874	64.6%
2009	996	292	3	16	0	1,307	776	2,083	62.7%

[a]Includes all Canadian marine fisheries (commercial troll, seine, gillnet and sport).
[b]Estimates from Shaul et al. 1991.
[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 2010.

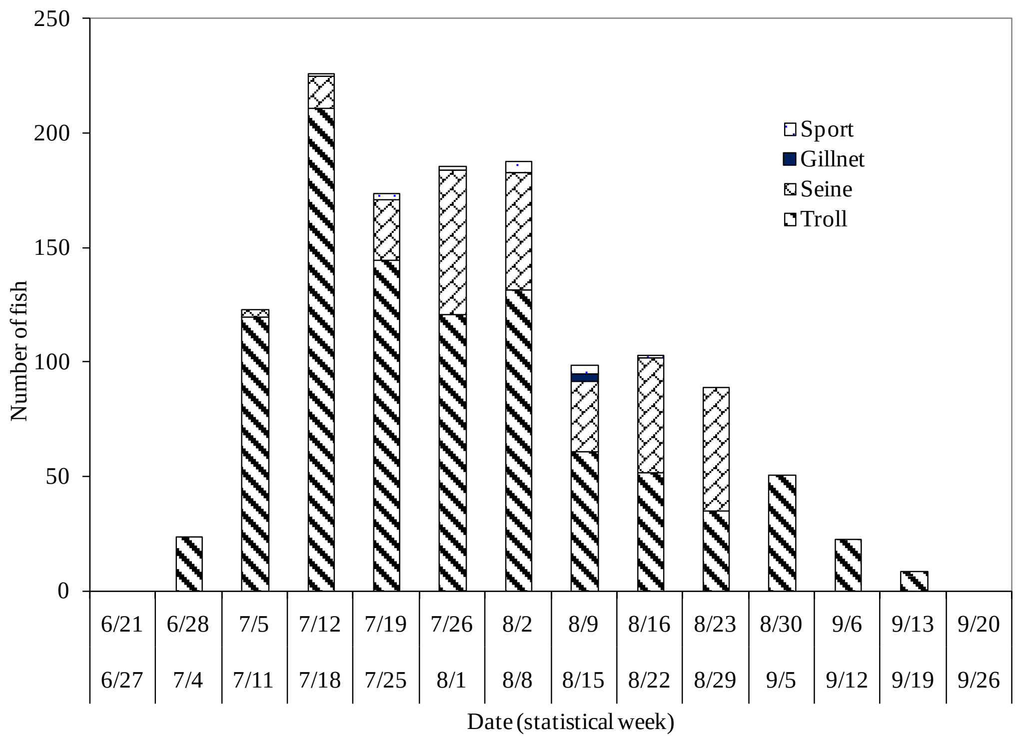


Figure 7.–Estimated marine harvest of coho salmon bound for Chuck Creek by statistical week and fishery in 2009.

Smolt size and emigration date effects on recovery rates, size at maturity and return date

All smolt captured in 2008 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, 564 of these uniquely tagged fish were recovered (Appendices A2) as either adults in the 2009 escapement (5 fish), or marine fisheries in 2009 (386 fish), or as jacks in the 2008 escapement (173 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 33.0% (= 173/524) and tagged adults at 21.2% (= 391/1,847; Appendices A7 and A8).

Of the 173 sampled jacks, *small* smolt were recovered at a rate of 0.92% (= 86/9,298), *large* smolt were recovered at a rate of 1.95% (= 75/3,839), and *extra large* smolt were recovered as jacks at a rate of 3.70% (12/324; Table 5). These were significantly different recovery rates (χ^2 = 38.0, df = 2, P < 0.001). Of the 391 adult recoveries, *small* smolt were recovered as adults at a rate of 2.85% (= 265/9,298), *large* smolt were recovered at a rate of 3.00% (= 115/3,839) and *extra large* smolt were recovered at a rate of 3.40% (= 11/324; Table 5). These were not significantly different recovery rates (χ^2 = 0.5, df = 2, P = 0.8). 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).

Surviving tagged fish from the three smolt size classes kept their size advantage throughout their time spent in the marine environment to both the jack and adult stages. There was a statistically significant difference in the average length of recovered tagged jacks between those that were tagged as *small*, *large* or *extra large* smolt (ANOVA, F = 35.9, df = 2, P < 0.0001; Table 7), as well as those recovered as adult in marine fisheries (ANOVA, F = 10.4, df = 2, P < 0.0001; Table 7).

Recovery rates of surviving mature fish were compared by dividing the smolt emigration into 2 equal emigration time periods (from the date that the first smolt was captured to the date the last smolt was captured). The *early* smolt emigration period ran from April 17 through May 14 (smolt tagged = 5,809; subsequent recoveries = 298), and the *late* period ran from May 15 through June 11 (smolt tagged = 7,665; recoveries = 266). Fish that emigrated during the *early* period were recovered at a significantly higher rate as both jacks (χ^2 = 17.9, df = 1, P < 0.0001) and adults (χ^2 = 8.0, df = 1, P = 0.005) than fish that migrated during the *late* period (Tables 5 and 6, Figure 8). Also there was a significant negative linear relationship between the recovery rate of mature fish and the smolt emigration date (r^2 = 0.21, P = 0.02, for days with at least 100 smolt tagged; Figure 9; note: it seems reasonable to examine the days when sufficient smolt were tagged to make recovering a surviving fish likely. By limiting analysis of the data to days when at least 100 smolt were tagged, the probability of not sampling a surviving fish was ≤0.02; Appendix A7).

The average number of days between tagging and recapture of the 173 jacks was 124 days (SD = 9.2), and the range in time spent in the marine environment was 105 to 157 days. For the *small* smolt only, the average number of days between capture events was 124 days (SD = 8.4), for the *large* smolt the average number of days was 124 (SD = 10.0), and for *extra large* smolt the average number of days was 129 days (SD = 8.8). The number of days at sea was not significantly different between smolt size groups (ANOVA, F = 2.1, df = 2, P = 0.13). The length of the 173 jacks was positively correlated with number of days at sea (days between capture events; R^2 = 0.14, P < 0.0001, Figure 10), with each additional day at sea worth about 1.0 mm in additional length for all 173 jacks.

Table 5.–The number of coho salmon smolt coded wire tagged by size class and emigration time period from the 2008 Chuck Creek smolt emigration and their subsequent recovery rate as mature fish in marine fisheries and escapement sampling programs.

	Early	***Late***	**Total**
	(April 17-May 14)	(May 15-June 11)	
Number of smolt tagged			
Small[a]	3,535	5,763	9,298
Large[a]	2,122	1,717	3,839
Extra large[a]	149	175	324
Total	5,806	7,655	13,461
Jack recovery rate			
Small smolt	1.10%	0.82%	0.92%
Large smolt	2.69%	1.05%	1.95%
Extra large smolt	4.03%	3.43%	3.70%
All smolt combined	1.76%	0.93%	1.29%
Adult recovery rate			
Small smolt	3.17%	2.65%	2.85%
Large smolt	3.77%	2.04%	3.00%
Extra large smolt	2.68%	4.00%	3.40%
All smolt combined	3.38%	2.55%	2.90%
Overall [b] recovery rate			
Small smolt	4.27%	3.47%	3.78%
Large smolt	6.46%	3.09%	4.95%
Extra large smolt	6.71%	7.43%	7.10%
All smolt combined	5.13%	3.47%	4.19%

[a] *Small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL.

[b] Jacks and adults combined.

Table 6.–Summary of significance tests of the recovery rate of coded wire tagged coho salmon smolt from the 2008 Chuck Creek smolt emigration by smolt category (smolt size and emigration time period).

Smolt categories[a] tested		**Recoveries of tagged smolt as:**					
		Jacks		**Adults**		**Overall**	
		χ2	**P-value**	**χ2**	**P-value**	**χ2**	**P-value**
	Early vs. *late*	17.9	**<0.0001**	8.0	**0.005**	22.6	**<0.0001**
	Small vs. *large*	23.8	**<0.0001**	0.2	0.7	9.5	**0.002**
	Small vs. *extra large*	24.0	**<0.0001**	0.3	0.6	9.3	**0.002**
	Large vs. *extra large*	4.5	**0.03**	0.2	0.7	2.8	0.09
Small only	*Early* vs. *late*	2.0	0.2	2.1	0.1	3.9	**0.05**
Large only	*Early* vs. *late*	13.3	**0.0003**	9.8	**0.002**	22.9	**<0.0001**
Extra large only	*Early* vs. *late*	0.1	0.8	0.4	0.5	0.1	0.8
Early only	*Small* vs. *large*	19.9	**<0.0001**	1.5	0.2	13.1	**0.0003**
	Small vs. *extra large*	10.1	**0.001**	0.1	0.7	2.0	0.2
	Large vs. *extra large*	0.9	0.3	0.5	0.5	0.0	0.9
Late only	*Small* vs. *large*	0.8	0.4	2.1	0.2	0.6	0.4
	Small vs. *extra large*	13.1	**0.0003**	1.2	0.3	7.7	**0.006**
	Large vs. *extra large*	7.2	**0.007**	2.8	0.1	8.9	**0.003**

[a] *Small* smolt ≤ 100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥ 130 mm FL. *Early* period is April 17-May 14; *late* period is May 15-June 11.

Table 7.–Sample sizes and average lengths of sampled jack and adult coho salmon from the 2008 Chuck Creek smolt emigration by smolt size class.

	Smolt size class[a]		
	Small	***Large***	***Extra large***
Jacks[b]			
Sample size	86	75	12
Average length (mm)	289	307	338
SD length (mm)	18	23	23
Adults[c]			
Sample size	255	104	11
Average length (mm)	559	581	590
SD length (mm)	46	39	33

[a]*Small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL.

[b]Sampled from the 2008 escapement.

[c]Sampled from marine harvest in 2009.

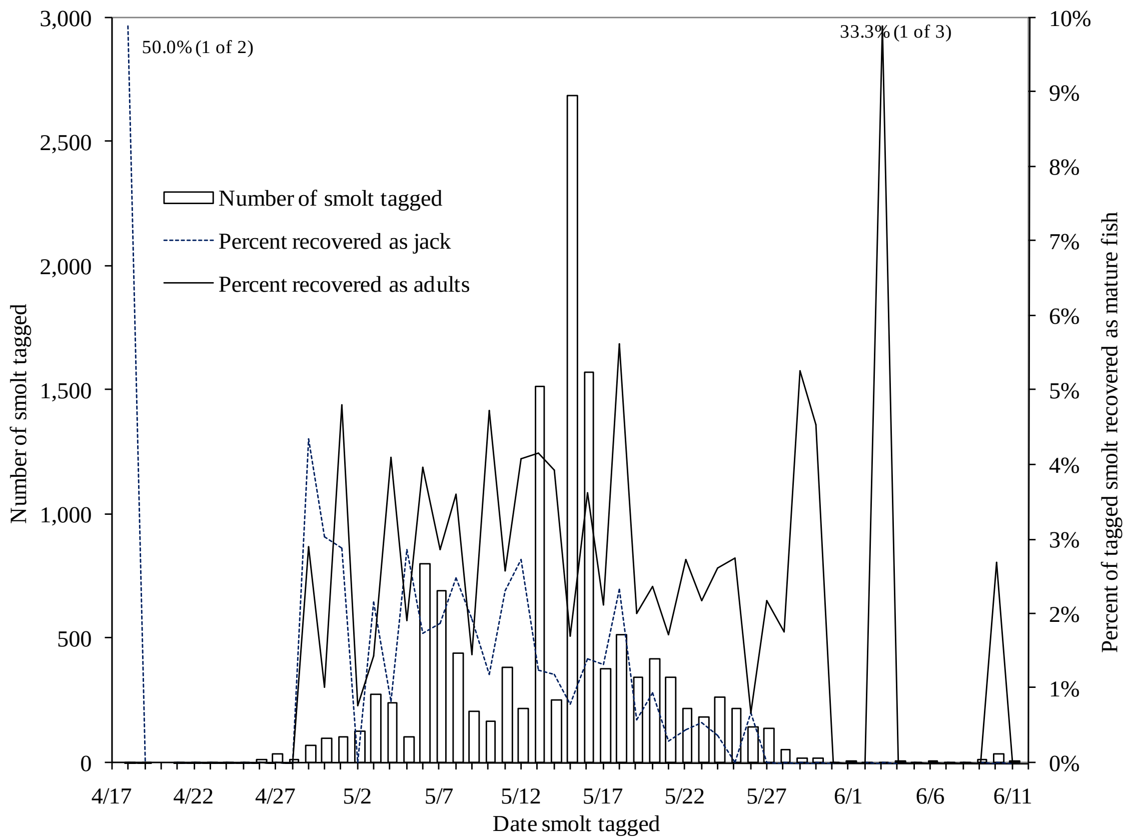


Figure 8.–Number of smolt tagged by date, and their subsequent recovery rate as mature fish sampled in marine fisheries and the escapement from the 2008 Chuck Creek coho salmon smolt emigration. Note that tagged jacks were sampled at a rate of 33.0% and tagged adults at a rate of 21.2%.

Because the assumption of equal variance is not met in the relationship between smolt emigration date and return date of jacks (Figure 11), Spearman's rank correlation coefficient test was used to test for a relationship. The data suggest that there was a weak positive relationship between date of smolt emigration and return date of the 173 jacks sampled ($\rho = 0.17$; $P = 0.03$; note that P-values are not exact in data with ties). That is to say that smolt that emigrated earlier in the emigration and returned as jacks, tended to return earlier.

Adults sampled in the escapement were not sacrificed for retrieval of their coded wire tag so data on time at sea and marine growth of returning fish is not available. However data collected from fish sampled in marine fisheries provides some information concerning growth. The length of the sampled adults (n = 370, as not all fish sampled were measured for length) was positively correlated with number of days at sea (days between sampling events; $R^2 = 0.06$, $P < 0.0001$, Figure 12), with each additional day at sea worth about 0.6 mm in additional length for all 370 adults. Note that the date of sampling in the marine fishery could be up to several days after the date of harvest as fish are usually not sampled until the fish are off loaded in port.

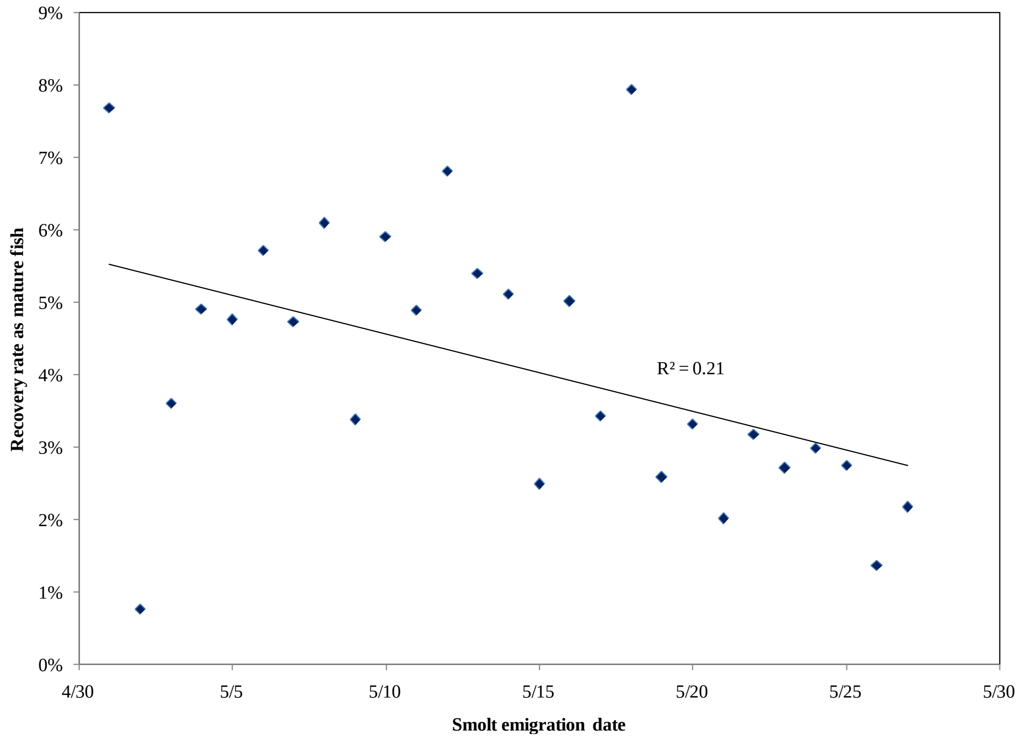


Figure 9.–Date of smolt emigration plotted vs. the recovery rate of all tagged mature fish from the 2008 Chuck Creek smolt emigration (for days with at least 100 smolt tagged).

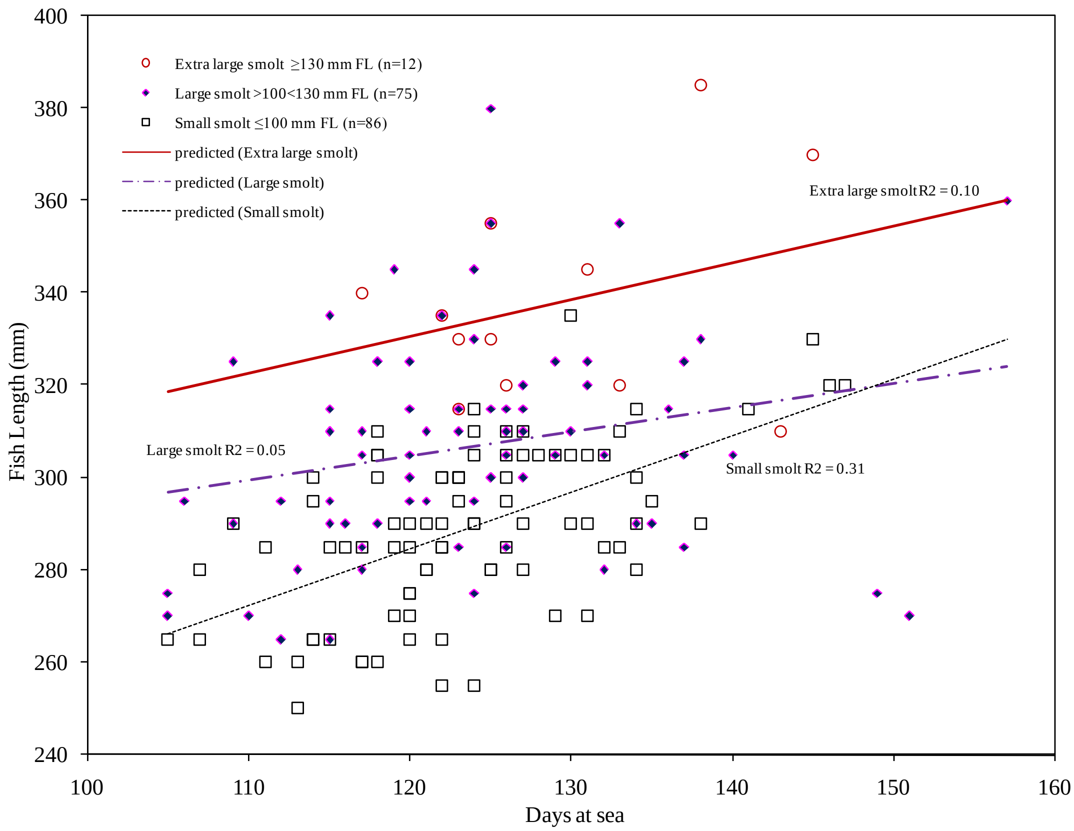


Figure 10.–Length (MEF) of jack coho salmon sampled at the Chuck Creek weir in 2008 plotted vs. days at sea (days between capture as smolt and mature fish).

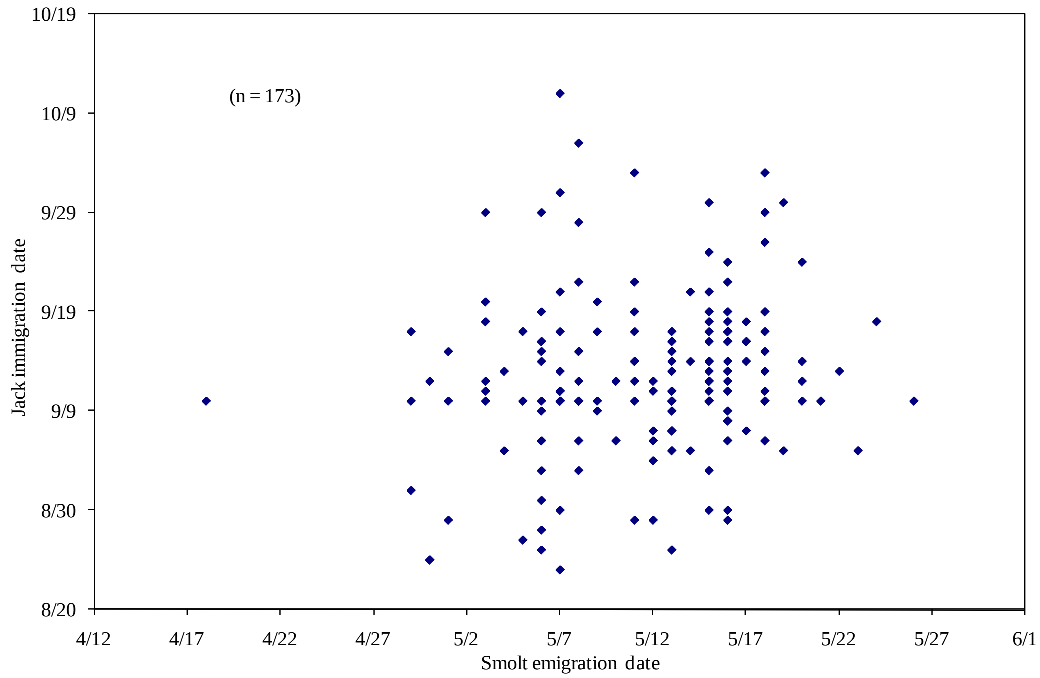


Figure 11.–Date of smolt emigration (capture at weir) plotted by immigration date (capture at weir) of jack coho salmon form the 2008 Chuck Creek smolt emigration.

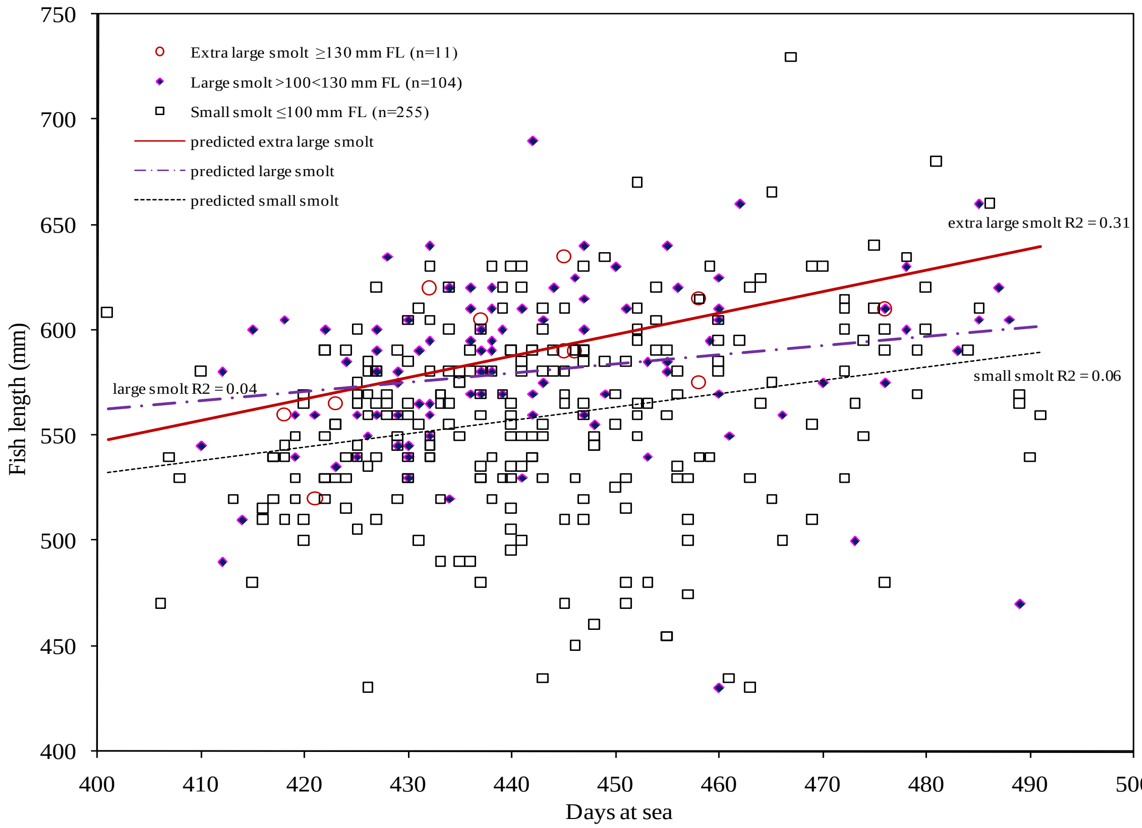


Figure 12.–Length (MEF) of adult Chuck Creek coho salmon sampled in marine fisheries in 2009 plotted vs. days at sea (days between capture as smolt and sampling as mature fish).

DISCUSSION

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 surviving mature fish. It's assumed that all recoveries represent an unbiased sample of surviving fish. Thus differences in the overall recovery rates (both jacks and adults combined) from the different smolt groups can be attributed to differences in survival rates.

Smolt size was 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).

Smolt emigration date was also related to the survival of marked fish in this study. Fish that emigrated during the *early* period survived at a significantly higher rate as both jacks and adults than fish that migrated during the *late* period (Tables 5 and 6, Figure 8). In this study, a higher portion of the *large* and *extra large* smolt emigrated during the *early* period than did *small* smolt (Figure 2). This is consistent with past coho salmon smolt emigrations at Chuck Creek (McCurdy 2009, 2010) and other studies where larger coho salmon smolt tended to emigrate earlier in the wild than smaller fish (Irvine and Ward 1989; Lum 2003; but see Holtby et al. 1989; Quinn and Peterson 1996; Thedinga and Koski 1984). The higher recovery rate of jacks and adults from the *early* time period in this study cannot be explained just by the fact that the *early* period contained a higher proportion of larger smolt, as smolt from each separate size group were recovered at higher rates (as both jacks and adults) from the *early* rather than the *late* emigration period (with the exception of the *extra large* smolt; note that almost 96% of *extra large* smolt emigrated on or before May 16. So comparisons of *early* vs. *late* in this size category may not be appropriate. In addition the sample size of *extra large* smolt was relatively small).

Because the proportions of the smolt size groups differed between emigration period, differences in recovery rates between the two emigration periods was likely influenced by smolt size, and conversely, emigration period likely influenced recovery rates between size groups. The observed differences in recovery rates can be because of different survival rates and/or differences in the proportions of emigrants likely, or "predetermined", to return as jacks or adults. It seems reasonable to assume smolt from the earlier emigration period contained a higher portion of "predetermined" jacks than later migrating smolt, and that a higher portion of the larger smolt were more likely "predetermined" to be jacks than smaller smolt.

In this study, the marine mortality rate (from smolt to maturity) is an estimated 82.5% (= 1 - $[2{,}083_{adults} + 617_{jacks}]/15{,}471_{smolt}$), right at the lower reported range (83.0% to 93.9%) for Chuck Creek coho salmon over the previous 6 years (McCurdy 2010) and within the range reported in the literature for other coho salmon stocks (Sandercock 1991). Other studies have suggested that a significant portion of coho salmon marine mortality occurs shortly after the fish have entered the marine environment (Briscoe et al. 2005; Fisher and Pearcy 1988). Data collected in this study is consistent with this hypothesis. First, there is a strong relationship between the survival rates of jacks and adults from the same smolt emigration cohort for this stock of fish ($R^2 = 0.72$, $P = 0.02$, for emigration years 2002-2008; Figure 13). This relationship would likely be weaker if the majority of the mortality occurred after the time the jacks had returned (given that the population has some intrinsic rate of producing jacks, Quinn 2005). Also, there is a significant correlation between the recovery rates of tagged jacks and tagged adults from the same emigration day in 2008 ($r^2 = 0.92$, for emigration days with at least 100 smolt tagged; Figure 8). This correlation places the mortality forces shared by each return group (jack and adult) from each emigration day at times when the two groups are in close proximity, and prior to complete mixing of the daily tag groups in space and time. It is hard to imagine a natural mortality schedule that leads to such similar tag recovery rates and nearly constant proportion of jacks in the returns from each year's smolt emigration (23% to 32%) that does not require most mortality to occur in the very early marine experience.

Contingency table analysis of the tagged fish (date tagged vs. numbers recovered and numbers not recovered) shows that the recovery probabilities vary significantly by tagging date ($\chi^2 = 83$, df = 26, $P < 0.0001$, for days with at least 100 smolt tagged; Appendix A7). Variation in the recovery rates of mature fish from the daily smolt tagging groups is to be expected, the question is, is this variation due to more than random chance? In this study fish either survive and are recovered, or not, and this suggests a binomial model. Using this model, probabilities of recovering the observed number of recoveries (for the number of fish tagged from each smolt emigration day) can be calculated. The probability of success (recoveries) in each trial was the average recovery probability for the entire data set (= 4.19% or 564/13,461). This test found that on only 2 of the 27 tagging days (7% of days) with at least 100 smolt tagged, the probability was well below $P = 0.001$ of recovering *as few as or as many as* the observed number of recoveries (see Appendix A7). This result (under the binomial model) is not outside of the expected result if a simple binomial process is leading to the observed recovery data (e.g., at most 3 deviant days using a 90% experiment-wise error rate might be expected).

This result is in contrast to the last two smolt emigrations from Chuck Creek when it appeared that a mortality component operating on a near "daily" basis was causing significant daily variation in recovery rates from those smolt emigrations (McCurdy 2009, 2010). Logic suggested that the mortality component that caused this near daily variation in survival rates occurred very near the time after marine entry (prior to complete mixing of the daily tag groups in space and time) and that predation was the most likely cause (McCurdy 2009, 2010). This is not to say whether the cause(s) of mortality that led to the observed *variation* was responsible for much of the overall observed mortality or not, because other mortality forces of significantly greater magnitude could act similarly after smolt from different emigration days have mixed in time and space. The fact that a smolt emigration that did not demonstrate near "daily" variation in survival rates (i.e., the 2008 emigration), and survived at a significantly higher rate (17.5% in 2008) than those emigrations that did not (7.2% in 2006 and 11.4% in 2007), would be consistent with the idea that the mortality regime that caused the high daily variation also caused a large portion of the overall marine mortality.

Although the smolt capture and tagging process cannot be ruled out as causing some of the variation in marine survival in this study, it seems unlikely, as smolt were captured, held, tagged and released at the same time using the same procedures every day. Also, it is worth noting that daily recovery rates were not correlated to the number of smolt emigrating ($r^2 = 0.001$, P = 0.86, for days with at least 100 smolt tagged).

Also, despite larger smolt clearly surviving at a higher rate than smaller smolt, there was no significant correlation in the daily recovery rates to the daily mean length of the smolt (r^2 =0.12, P = 0.08, for days with at least 100 smolt tagged). Smolt size may have played a larger role in survival as the smolt distanced themselves (in place and time) from the point of ocean entry, but this could have occurred after a significant portion of the overall mortality had already occurred (that was not, or was less, size selective). If the majority of mortality occurred soon after ocean entry, then emigration timing may have played a larger role in the survival rate of the 2008 Chuck Creek smolt cohort than smolt size (although both smolt size and emigration timing were related).

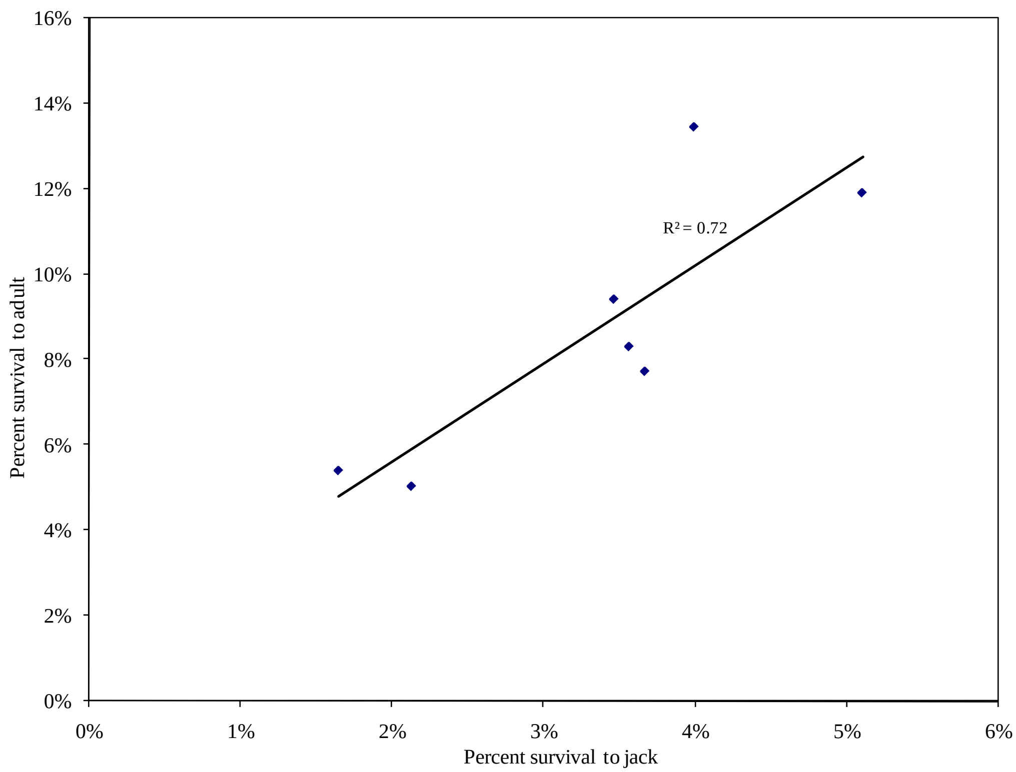


Figure 13.–Marine survival to adult plotted vs. marine survival to jack of Chuck Creek coho salmon from the same smolt emigration; years 2002-2008.

SMOLT ABUNDANCE

The smolt weir appeared to be operational and virtually 100% effective at capturing coho salmon smolt prior to significant emigration in 2008 (Appendix A3, Figure 2). However, an estimated 13.0% of the escapement from the 2008 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 12, 2008. 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.

It is unknown if the survival rate of marked and unmarked smolt varied greatly one way or the other from each other in this study, 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 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 A8) to the 2008 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 17.6% survival rate of *marked* fish estimated in this study. If *unmarked* fish survive at 22.0% (a rate 25% higher than the rate of 17.6% for marked fish), then the smolt abundance estimate in this report (15,471) would be biased by 3.4% (and the actual abundance would be 14,957). Similarly, if the actual survival rate for unmarked fish was 13.2% (25% lower than for marked fish) the smolt abundance estimate would be biased by -3.0% (and actual abundance would be 15,955). 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

Harvest distribution patterns, both geographically and by user group, in Alaskan waters in 2009 were similar to past years (Shaul 1991; McCurdy 2005, 2006a-b, 2008-2010; Table 4). The portion of the 2009 harvest taken by the troll and seine fisheries were slightly higher than their respective annual averages for this stock, while the gillnet and sport fisheries harvested a slightly lower portion than their respective averages (Table 4). Almost all harvest occurred in districts along the outside coast (Appendices A1 and A6), and only 3 tagged fish recovered from the southern inside districts (101 and 102), in the purse seine and gillnet fisheries. The estimated marine harvest of 1,307 Chuck Creek coho salmon and the estimated total run of 2,083 fish were the largest since 2003 (Table 4). The large total run was because of an average smolt emigration coupled with the above average marine survival. The marine exploitation rate of 62.7 % in 2009 was a little above average for years with returning coded wire tagged fish (Table 4).

ACKNOWLEDGMENTS

Jazmine Alibozek, Tim Paul, Becky Wilson, Larry Derby, Don Malherek, and Allen Hoffman all helped collect data in the field. Sue Millard performed the age analysis on all of the coho salmon scales. Sarah Power provided biometric support for this study and reviewed and provided comments on a draft of this report.

REFERENCES CITED

Baichtal, J. F., and D. N. Swanston. 1996. Karst landscapes and associated resources: a resource assessment. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-383, Portland.

Bernard, D. R., and J. E. Clark. 1996. Estimating salmon harvest based on return of coded-wire tags. Canadian Journal of Fisheries and Aquatic Sciences 53:2323-2332.

Bilton, H. T., D. F. Alderdice, and J. T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Canadian Journal of Fisheries and Aquatic Sciences 39:426-447.

Briscoe, R. J., M. D. Adkison, A. Wertheimer, and S. G. Taylor. 2005. Biophysical factors associated with the marine survival of Auke Creek, Alaska, coho salmon. Transactions of the American Fisheries Society 134:817-824.

Edgington, J., R. Larson, and J. Eastwood. 1981. Revised anadromous stream catalog of Southeastern Alaska. Appendix C-District 3. Volume III. Subdistricts 103-80 and 103-90. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report No. 60, Juneau.

Elliott, S. T. 1992. A trough trap for catching coho salmon smolts emigrating from Beaver Ponds. North American Journal of Fisheries Management 12:4:837-840.

Fisher, F. W., and W. G. Pearcy. 1988. Growth of juvenile coho salmon in the ocean off Oregon and Washington, USA, in years of differing coastal upwelling. Canadian Journal of Fisheries and Aquatic Sciences 45:1036-1044.

Groot, C., and L. Margolis, *editors*. 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

Hagar, R. C., and R. E. Noble. 1976. Relation of size at release of hatchery-reared coho salmon to age, size, and sex composition of returning adults. The Progressive Fish Culturist 38:144-147.

Halupka, K. C., M. D. Bryant, M. F. Willson, F. Everest, and H. H. Heinkel, Jr. 2000. Biological characteristics and population status of anadromous salmon in Southeast Alaska. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-468, Portland.

Hollander, M., and D. A. Wolf. 1973. Nonparametric statistical methods. John Wiley & Sons, New York, NY

Holtby, L. B., B. C. Andersen, and R. K. Kadowaki. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 47:2181-2194.

Holtby, L. B., G. F. Hartman, and L. C. Scrivener. 1984. Stream indexing from the perspective of the Carnation Creek experience. Pages 87-111 [*in*] P. Symons and M. Waldichuk, editors. Proceedings of the Workshop on Stream Indexing for Salmon Escapement Estimation, West Vancouver, British Columbia, 2-3 February, 1984. Canadian Technical Report of Fisheries and Aquatic Sciences 1326, Nanaimo, British Columbia.

Holtby, L. B., T. E. McMahon, and J. C. Scrivener. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon (*Oncorhynchus kisutch*) smolts and fry and chum salmon (O. keta) fry from Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1396-1405.

Hubartt, D. J., and M. J. Jaenicke. 2004. Harvest estimates for selected marine sport fisheries in Southeast Alaska during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 04-21, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-21.pdf

Irvine, J. R., and B. R. Ward. 1989. Patterns of timing and size of wild coho salmon (*Oncorhynchus kisutch*) smolts migrating from the Keogh River watershed on Northern Vancouver Island. Canadian Journal of Fisheries and Aquatic Sciences 46:1086-1094.

Koerner, J. F. 1977. The use of the coded wire tag injector under remote field conditions. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 172, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/afrbil.172.pdf

Koseki, Y., and I. Fleming. 2006. Spatio-temporal dynamics of alternative male phenotypes in coho salmon populations in response to ocean environment. Journal of Animal Ecology 75:445-455.

Koseki, Y., and I. Fleming. 2007. Large-scale frequency dynamics of alternative male phenotypes in natural populations of coho salmon (*Oncorhynchus kisutch*): patterns, processes, and implications. Canadian Journal of Fisheries and Aquatic Sciences 64:743-753.

Lum, J. L. 2003. Effects of smolt length and emigration timing on marine survival and age at maturity of wild coho salmon (*Oncorhynchus kisutch*) at Auke Creek, Juneau Alaska. Master of Science Thesis, University of Alaska, Fairbanks, Alaska.

Magnus, D. L., D. Brandenburger, K. F. Crabtree, K. A. Pahlke, and S. A. McPherson. 2006. Juvenile salmon capture and coded wire tagging manual. Alaska Department of Fish and Game, Special Publication No. 06-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/sp06-31.pdf

Mathews, S. B., and Y. Ishida. 1989. Survival, ocean growth, and ocean distribution of differentially timed releases of hatchery coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46:1216-1226.

McCurdy, S. J. 2005. Production of coho salmon from Chuck Creek in Southeast Alaska, 2001-2003. Alaska Department of Fish and Game, Fishery Data Series No. 05-28, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds05-28.pdf

McCurdy, S. J. 2006a. Production of coho salmon from Chuck Creek in Southeast Alaska, 2003-2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-10, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-10.pdf

McCurdy, S. J. 2006b. Production of coho salmon from the 2004 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 06-58, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-58.pdf

McCurdy, S. J. 2008. Production of coho salmon from the 2005 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 08-04, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds08-04.pdf

McCurdy, S. J. 2009. Production of coho salmon from the 2006 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 09-57, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/FDS09-57.pdf

McCurdy, S. J. 2010. Production of coho salmon from the 2007 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 10-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds10-31.pdf

REFERENCES CITED (Continued)

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle.

Quinn, T. P., and N. P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53:1555-1564.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). Pages 397-445 [*in*] Groot, C. and L. Margolis, editors. Pacific salmon life histories. . University of British Columbia Press, Vancouver, Canada.

Scarnecchia, D. L. 1979. Variation of scale characteristics of coho salmon with sampling location on the body. Progressive Fish Culturist 41(3):132-135.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, 2nd edition. Griffin and Company, Ltd. London.

Shaul, L., S. McPherson, E. Jones, and K. Crabtree. 2003. Stock status and escapement goals for coho salmon stocks in Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 03-02, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/sp03-02.pdf

Shaul, L. D., P. L. Gray, and J. F. Koerner. 1991. Coded wire tag estimates of abundance, harvest, and survival rates of selected coho salmon stocks in Southeast Alaska, 1981–1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 91-05, Juneau

Thedinga, J. F., and K. V. Koski. 1984. A stream ecosystem in an old-growth forest in Southeast Alaska Part VI: The production of coho salmon, *Oncorhynchus kisutch*, smolts and adults from Porcupine Creek. Pages 99-108 [*in*] W. R. Meehan, T. R. Merrell, Jr., and T. A. Hanley (*editors*), Fish and Wildlife relationships in old-growth forests: Proceedings of a symposium held in Juneau, Alaska, 12-15 April 1982. American Institute of Fisheries Research Biologists.

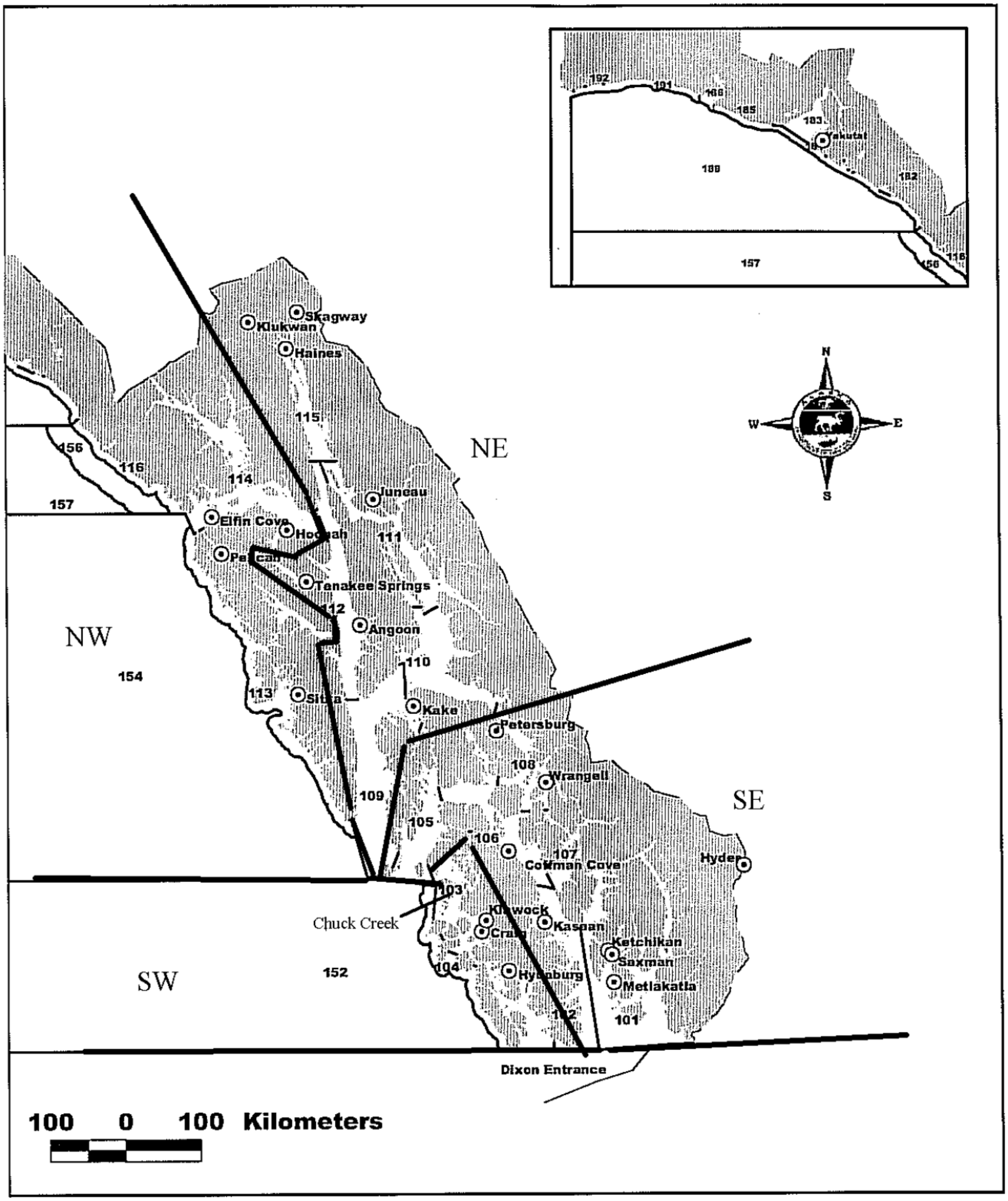
Thompson, S. K. 2002. Sampling, 2nd edition. John Wiley and Sons, New York.

Vincent-Lang, D. 1993. Relative survival of unmarked and fin-clipped coho salmon from Bear Lake, Alaska. The Progressive Fish-Culturist 55(3):141-148.

Vøllestad, L. A., J. Peterson, and T. P. Quinn. 2004. Effects of fresh water and marine growth rates on early maturity in male coho and chinook salmon. Transactions of the American Fisheries Society 133:495-503.

APPENDIX A

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 2008 Chuck Creek smolt emigration, and subsequent recoveries as mature fish in marine fisheries (in 2009) and escapement sampling (in 2008 and 2009).

		Number smolt released with CWTs				Number smolt recovered as jacks			Number smolt recovered as adults		
Date	**Tag code**	***Small*[a]**	***Large*[a]**	***Extra large*[a]**	**Total**	***Small***	***Large***	***Extra large***	***Small***	***Large***	***Extra large***
4/18	041480	1	0	1	2	0	0	1	0	0	0
4/19	041480	0	1	0	1	0	0	0	0	0	0
4/20	041480	0	0	0	0	0	0	0	0	0	0
4/21	041480	0	1	1	2	0	0	0	0	0	0
4/22	041480	1	0	1	2	0	0	0	0	0	0
4/23	041480	0	0	1	1	0	0	0	0	0	0
4/24	041480	0	1	2	3	0	0	0	0	0	0
4/25	041480	0	3	0	3	0	0	0	0	0	0
4/26	041480	4	8	2	14	0	0	0	0	0	0
4/27	041480	19	16	3	38	0	0	0	0	0	0
4/28	041480	8	6	1	15	0	0	0	0	0	0
4/29	041480	36	28	5	69	3	0	0	1	1	0
4/30	041480	50	43	6	99	0	2	1	1	0	0
5/1	041480	49	49	6	104	1	2	0	2	2	1
5/2	041480	85	44	0	129	0	0	0	1	0	0
5/3	041480	162	106	9	277	2	4	0	3	1	0
5/4	041480	144	93	7	244	0	2	0	3	6	1
5/5	041480	65	37	3	105	3	0	0	0	2	0
5/6	041480	540	253	11	804	8	6	0	19	13	0
5/7	041480	389	280	27	696	2	11	0	11	9	0
5/8	041480	258	174	11	443	3	6	2	10	6	0
5/9	041480	133	70	4	207	2	1	1	1	2	0
5/10	041480	93	69	7	169	1	1	0	4	3	1
5/11	041480	230	148	10	388	4	5	0	8	2	0
5/12	041480	126	94	0	220	2	4	0	5	4	0
5/13	041480	966	523	28	1,517	7	12	0	36	26	1
5/14	041480	176	75	3	254	1	1	1	7	3	0
5/15	041480	1,853	718	118	2,689	16	1	4	41	4	1
5/16	041480	1,094	438	43	1,575	12	9	1	35	16	6

-continued-

Date	Tag code	Number smolt released with CWTs				Number smolt recovered as jacks			Number smolt recovered as adults		
		Small[a]	**Large[a]**	**Extra large[a]**	**Total**	**Small**	**Large**	**Extra large**	**Small**	**Large**	**Extra large**
5/17	041480	271	102	5	378	3	1	1	5	3	0
5/18	041684	430	86	0	516	9	3	0	26	3	0
5/19	041684	303	45	0	348	2	0	0	7	0	0
5/20	041684	355	62	4	421	1	3	0	9	1	0
5/21	041684	299	47	1	347	0	1	0	4	2	0
5/22	041684	176	41	3	220	1	0	0	5	1	0
5/23	041684	158	26	0	184	1	0	0	3	1	0
5/24	041684	220	47	0	267	1	0	0	4	3	0
5/25	041684	184	33	1	218	0	0	0	6	0	0
5/26	041684	131	15	0	146	1	0	0	1	0	0
5/27	041684	128	10	0	138	0	0	0	3	0	0
5/28	041684	49	8	0	57	0	0	0	1	0	0
5/29	041684	18	1	0	19	0	0	0	1	0	0
5/30	041684	20	2	0	22	0	0	0	1	0	0
5/31	041684	4	1	0	5	0	0	0	0	0	0
6/1	041684	6	3	0	9	0	0	0	0	0	0
6/2	041684	4	1	0	5	0	0	0	0	0	0
6/3	041684	3	0	0	3	0	0	0	1	0	0
6/4	041684	7	3	0	10	0	0	0	0	0	0
6/5	041684	4	0	0	4	0	0	0	0	0	0
6/6	041684	9	2	0	11	0	0	0	0	0	0
6/7	041684	0	2	0	2	0	0	0	0	0	0
6/8	041684	2	1	0	3	0	0	0	0	0	0
6/9	041684	8	5	0	13	0	0	0	0	0	0
6/10	041684	24	13	0	37	0	0	0	0	1	0
6/11	041684	3	5	0	8	0	0	0	0	0	0
6/12		0	0	0	0	0	0	0	0	0	0
Totals		9,298	3,839	324	13,461	86	75	12	265	115	11

[a] *Small* smolt ≤100 mm FL, *large* smolt > 100 < 130 mm FL, and *extra large* smolt ≥130 mm FL.

Appendix A3.–Daily number of coho salmon smolt and other downstream migrating fish captured at the smolt weir on Chuck Creek in 2008.

Date	Coho smolt	Sockeye smolt	Dolly Varden Adults[a]	Dolly Varden Juveniles[b]	Cutthroat adults[a]	Cutthroat Juveniles[b]	Steelhead Juveniles[c]	Sculpin
4/16	0	0	0	0	0	0	0	0
4/17	0	4	1	0	0	0	0	13
4/18	2	5	3	0	0	0	0	10
4/19	1	5	0	0	0	0	0	2
4/20	0	3	7	0	0	0	0	6
4/21	2	13	2	0	0	0	0	53
4/22	2	14	2	0	0	0	0	86
4/23	1	35	13	0	0	0	0	155
4/24	3	103	30	0	1	0	0	253
4/25	3	39	0	0	0	0	1	83
4/26	14	109	12	2	0	0	0	181
4/27	39	34	29	0	0	0	0	316
4/28	15	109	13	0	0	0	0	145
4/29	70	390	11	0	1	0	0	136
4/30	99	357	5	1	1	0	0	88
5/1	104	351	18	0	0	0	0	182
5/2	129	189	4	5	0	0	0	123
5/3	278	363	2	2	1	1	0	92
5/4	244	741	3	3	0	0	0	58
5/5	106	2,098	4	2	0	0	0	71
5/6	804	4,775	8	5	0	0	0	92
5/7	697	1,543	0	1	1	0	1	35
5/8	443	4,396	22	9	0	0	0	136
5/9	207	725	2	6	0	0	0	68
5/10	170	421	2	2	0	0	0	35
5/11	389	1,968	5	10	0	0	0	41
5/12	220	993	0	3	0	0	0	21
5/13	1,520	6,278	41	36	0	0	0	22
5/14	255	592	45	94	0	0	3	157
5/15	2,697	11,671	24	64	2	1	2	170
5/16	1,580	4,423	1	53	0	0	2	45
5/17	378	1,268	20	21	0	0	2	56
5/18	516	998	3	10	0	0	2	42
5/19	348	807	0	8	0	0	0	63
5/20	422	893	2	1	0	0	0	51
5/21	347	540	2	2	0	0	1	38
5/22	220	161	1	8	0	0	0	97
5/23	184	482	5	12	0	0	0	97
5/24	267	173	0	2	0	0	2	75
5/25	218	206	1	2	0	0	3	36
5/26	146	150	0	1	0	0	7	68
5/27	138	102	1	1	0	0	1	66
5/28	57	16	0	1	0	0	1	47
5/29	19	8	0	0	0	0	0	38

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Date	Coho smolt	Sockeye smolt	Dolly Varden Adults[a]	Dolly Varden Juveniles[b]	Cutthroat adults[a]	Cutthroat Juveniles[b]	Steelhead Juveniles[c]	Sculpin
5/30	22	4	0	0	0	0	0	91
5/31	5	8	0	1	0	0	2	101
6/1	9	5	0	0	0	0	1	30
6/2	5	6	0	0	0	0	0	66
6/3	3	9	0	1	0	0	0	64
6/4	10	7	0	0	0	0	1	52
6/5	4	7	0	0	0	0	0	52
6/6	11	7	0	0	0	0	0	35
6/7	2	4	0	0	0	0	0	21
6/8	3	1	0	0	0	0	1	10
6/9	13	20	0	0	0	0	0	6
6/10	37	7	0	0	0	0	1	41
6/11	8	10	0	1	0	0	0	3
6/12	0	3	0	0	0	0	0	13
Totals	13,486	48,649	344	370	7	2	34	4,234

[a]Fish 175 ≥ mm FL.

[b]Fish 175 < mm FL.

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

Appendix A4.–Daily escapement counts of mature coho salmon passed through the weir on Chuck Creek , by life history type and marked status in 2009.

	Adult coho (age x.1)				Jack coho (age x.0)			
Date	Marked	Unmarked	Unknown	Total	Marked	Unmarked	Unknown[a]	Total
8/18	6	1	0	7	0	0	0	0
8/19	11	1	0	12	0	0	0	0
8/20	9	0	0	9	2	0	0	2
8/21	4	1	0	5	1	0	0	1
8/22	0	0	0	0	2	0	0	2
8/23	6	2	0	8	1	0	1	2
8/24	3	4	0	7	0	0	0	0
8/25	12	0	0	12	2	1	0	3
8/26	38	0	0	38	10	0	0	10
8/27	23	1	0	24	6	1	0	7
8/28	54	7	0	61	20	0	0	20
8/29	40	2	0	42	15	1	1	17
8/30	32	1	0	33	8	0	0	8
8/31	13	1	0	14	13	2	0	15
9/1	8	1	0	9	11	2	0	13
9/2	12	1	0	13	15	0	0	15
9/3	11	0	0	11	15	0	0	15
9/4	11	2	0	13	12	0	2	14
9/5	2	0	0	2	8	0	1	9
9/6	2	0	0	2	5	0	0	5
9/7	3	1	0	4	8	0	0	8
9/8	6	0	0	6	14	0	2	16
9/9	37	1	0	38	65	3	3	71
9/10	79	3	0	82	144	3	5	152
9/11	54	6	0	60	84	2	6	92
9/12	9	2	0	11	18	1	0	19
9/13	40	2	0	42	28	2	3	33
9/14	19	3	0	22	24	0	1	25
9/15	10	0	0	10	23	0	0	23
9/16	22	7	0	29	22	1	0	23
9/17	8	6	0	14	17	3	1	21
9/18	11	1	0	12	9	3	0	12
9/19	23	3	0	26	12	2	0	14
9/20	12	3	0	15	5	2	0	7
9/21	9	3	0	12	6	1	1	8
9/22	3	0	0	3	2	0	3	5
9/23	17	2	0	19	5	2	0	7
9/24	9	8	0	17	5	1	0	6
9/25	15	2	0	17	2	3	0	5
9/26	1	2	0	3	3	0	0	3
9/27	1	1	0	2	2	1	0	3
9/28	1	0	0	1	3	0	0	3
9/29	1	2	0	3	3	0	0	3
9/30	0	1	0	1	1	3	0	4

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	Adult coho (age x.1)				Jack coho (age x.0)			
Date	**Marked**	**Unmarked**	**Unknown**	**Total**	**Marked**	**Unmarked**	**Unknown[a]**	**Total**
10/1	0	1	0	1	1	0	0	1
10/2	0	0	0	0	3	0	0	3
10/3	0	0	0	0	0	0	0	0
10/4	0	0	0	0	0	0	0	0
10/5	0	0	0	0	0	0	0	0
10/6	1	1	0	2	0	0	0	0
10/7	0	0	0	0	1	0	0	1
10/8	0	0	0	0	0	0	0	0
10/9	0	1	0	1	0	0	0	0
10/10	0	0	0	0	0	0	0	0
10/11	0	0	0	0	0	0	0	0
10/12	0	0	0	0	0	0	0	0
10/13	0	1	0	1	0	0	0	0
Total	**688**	**88**	**0**	**776**	**656**	**40**	**30**	**726**

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

Appendix A5.–Daily escapement counts of sockeye, pink, and chum salmon; Dolly Varden; and steelhead trout passed through the weir at Chuck Creek in 2009.

Date	Sockeye adults	Sockeye jacks[a]	Pink	Chum	Dolly Varden	Steelhead
8/18	62	0	57	0	0	1
8/19	41	7	500	0	0	0
8/20	138	6	1,016	1	0	0
8/21	34	2	1,087	0	0	0
8/22	8	1	413	0	0	0
8/23	67	3	552	0	0	0
8/24	63	4	795	0	0	0
8/25	60	4	366	0	0	0
8/26	27	2	229	0	1	0
8/27	46	4	366	0	0	0
8/28	44	4	1,466	1	0	0
8/29	11	3	493	1	0	0
8/30	12	1	483	0	0	0
8/31	11	1	227	1	0	0
9/1	12	0	477	1	0	0
9/2	42	6	1,746	0	0	0
9/3	31	2	1,934	0	0	1
9/4	34	2	1,604	0	0	0
9/5	16	1	1,810	1	0	0
9/6	6	0	1,088	0	0	0
9/7	9	0	4,376	0	0	0
9/8	10	0	3,176	0	0	0
9/9	9	1	615	1	0	0
9/10	8	0	654	3	0	0
9/11	18	1	885	1	0	0
9/12	1	0	139	0	0	0
9/13	12	2	739	0	0	0
9/14	2	1	88	2	0	0
9/15	1	0	48	0	0	0
9/16	0	0	71	1	0	0
9/17	2	0	574	2	0	0
9/18	7	0	452	0	0	0
9/19	2	0	553	2	0	0
9/20	2	0	219	1	0	0
9/21	3	0	862	2	0	0
9/22	3	0	2,275	3	0	0
9/23	1	0	673	2	0	0
9/24	1	0	83	1	0	0
9/25	0	0	41	0	0	0
9/26	2	0	25	1	0	0
9/27	0	0	31	1	0	0
9/28	0	0	14	0	0	0
9/29	0	0	12	0	0	0
9/30	0	0	32	0	0	0
10/1	0	0	39	0	0	0

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Date	Sockeye adults	Sockeye jacks[a]	Pink	Chum	Dolly Varden	Steelhead
10/2	0	0	44	0	0	0
10/3	0	0	27	0	0	0
10/4	0	0	19	0	0	0
10/5	0	0	24	0	0	0
10/6	0	0	43	0	0	0
10/7	0	0	29	0	0	0
10/8	0	0	32	0	0	0
10/9	0	0	42	0	0	0
10/10	2	0	47	0	0	0
10/11	0	0	39	0	0	0
10/12	0	0	31	0	0	0
10/13	0	0	12	0	0	0
Total	860	58	33,774	29	1	2

[a]Male fish <400 mm MEF.

Appendix A6.–Estimated marine harvest (r_i) of adult coho salmon bound for Chuck Creek in 2009.

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	6/28-8/15 (3)	NE	32,670	0	9,444	69	68	45	45	2	8	5	120%
34-40	8/16-10/3 (4)	NE	84,122	0	27,150	432	424	308	307	3	11	5	96%
27-33	6/28-8/15 (3)	NW	524,113	0	166,531	1,863	1,826	1,373	1,371	34	123	18	29%
34-40	8/16-10/3 (4)	NW	399,810	0	137,450	2,147	2,103	1,719	1,715	2	7	4	116%
27-33	6/28-8/15 (3)	SE	99,296	0	23,028	265	264	204	202	14	69	16	47%
34-40	8/16-10/3 (4)	SE	66,588	0	15,666	330	323	266	266	2	10	6	124%
27-33	6/28-8/15 (3)	SW	275,484	0	83,773	891	872	599	597	163	620	42	13%
34-40	8/16-10/3 (4)	SW	89,514	0	37,324	650	631	456	455	53	148	16	22%
	Troll subtotal		1,571,597	0	500,366	6,647	6,511	4,970	4,958	273	996	53	10%

SE ALASKA DRIFT GILLNET 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 33	8/9-8/15	101	4,019	0	1,669	16	16	12	12	1	3	2	156%

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 30	7/19-7/25	101	4,292	0	1,322	19	15	13	13	1	5	4	174%
wk 28	7/5-7/11	102	4,114	0	1,672	25	25	17	17	1	3	2	157%
wk 30	7/19-7/25	103	857	0	85	1	1	1	1	1	11	11	187%
wk 31	7/26-8/1	103	7,589	0	1,337	11	10	8	8	6	42	16	74%
wk 32	8/2-8/8	103	9,312	0	204	1	1	1	1	1	51	51	194%
wk 33	8/9-8/15	103	6,748	0	731	6	6	4	4	3	31	17	108%
wk 34	8/16-8/22	103	9,728	0	805	6	6	5	5	2	27	19	133%
wk 35	8/23-8/29	103	6,614	0	610	3	3	2	2	2	24	17	133%
wk 29	7/12-7/18	104	3,812	0	503	5	3	2	2	1	14	14	189%
wk 30	7/19-7/25	104	8,483	0	1,002	8	8	7	7	1	10	9	185%
wk 31	7/26-8/1	104	21,757	0	1,153	16	16	12	12	1	21	21	191%
wk 34	8/16-8/22	104	12,626	0	2,529	27	27	22	22	4	23	10	89%
wk 35	8/23-8/29	104	10,348	0	389	9	9	6	6	1	30	29	193%
Purse Seine subtotal			106,280	0	12,342	137	130	100	100	25	292	75	50%

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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 14	7/6-7/19	Craig/Klawock	2,175		2,175	7	7	4	4	1	1	0	66%
bw 15	7/20-8/2	Craig/Klawock	3,334		3,334	19	18	14	14	4	5	1	39%
bw 16	8/3-8/16	Craig/Klawock	3,692		3,692	19	19	16	16	5	6	1	30%
bw 17	8/17-8/30	Craig/Klawock	966		966	8	8	6	6	1	1	0	66%
bw 16	8/3-8/16	Sitka	8,546	4,045,548	2,776	27	27	25	25	1	3	3	165%
	Sport subtotal		18,713		12,943	80	79	65	65	12	16	3	39%
TOTAL ALL FISHERIES			1,700,609	4,045,548	527,320	6,880	6,736	5,147	5,135	311	1,307	91	14%

Note: n_i = number of fish examined for missing adipose fins**;** a_i = number of adipose-finclipped fish seen; 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 A7.–Daily number of: smolt tagged, actual and expected recoveries of surviving fish, probability of recovering a tagged fish (P), probably of not recovering a tagged fish (1- P)13,461, χ2 statistic of number of fish recovered vs. not recovered, and the binomial probability of recovery at most the actual number of fish recovered for the 2008 Chuck Creek coho smolt emigration.

	Number of	Number of recoveries					
Date	**smolt tagged**	**Actual**	**Expected[a]**	**P**	**$(1\text{-}P)^{13,461}$**	**χ^2**	**Binomial P**
4/18	2	1	0.1	0.00001	0.91962	10.0	0.99824
4/19	1	0	0.0	0.00000	0.95897	0.0	0.95810
4/20	0						
4/21	2	0	0.1	0.00001	0.91962	0.1	0.91796
4/22	2	0	0.1	0.00001	0.91962	0.1	0.91796
4/23	1	0	0.0	0.00000	0.95897	0.0	0.95810
4/24	3	0	0.1	0.00001	0.88188	0.1	0.87950
4/25	3	0	0.1	0.00001	0.88188	0.1	0.87950
4/26	14	0	0.6	0.00004	0.55622	0.6	0.54924
4/27	38	0	1.6	0.00012	0.20347	1.6	0.19662
4/28	15	0	0.6	0.00005	0.53339	0.6	0.52622
4/29	69	5	2.9	0.00021	0.05550	1.5	0.93090
4/30	99	4	4.1	0.00030	0.01579	0.0	0.59936
5/1	104	8	4.4	0.00032	0.01280	3.0	0.96915
5/2	129	1	5.4	0.00040	0.00449	3.6	0.02657
5/3	277	10	11.6	0.00085	0.00001	0.2	0.38600
5/4	244	12	10.2	0.00075	0.00004	0.3	0.77374
5/5	105	5	4.4	0.00032	0.01228	0.1	0.72224
5/6	804	46	33.7	0.00247	0.00000	4.5	0.98470
5/7	696	33	29.2	0.00214	0.00000	0.5	0.79693
5/8	443	27	18.6	0.00136	0.00000	3.8	0.97815
5/9	207	7	8.7	0.00064	0.00017	0.3	0.35905
5/10	169	10	7.1	0.00052	0.00084	1.2	0.90024
5/11	388	19	16.3	0.00119	0.00000	0.5	0.79821
5/12	220	15	9.2	0.00067	0.00010	3.6	0.97612
5/13	1,517	82	63.6	0.00465	0.00000	5.3	0.99043
5/14	254	13	10.6	0.00078	0.00002	0.5	0.81767
5/15	2,689	67	112.7	0.00825	0.00000	18.5	0.00000
5/16	1,575	79	66.0	0.00483	0.00000	2.6	0.95218
5/17	378	13	15.8	0.00116	0.00000	0.5	0.28281
5/18	516	41	21.6	0.00158	0.00000	17.4	0.99996
5/19	348	9	14.6	0.00107	0.00000	2.1	0.08013
5/20	421	14	17.6	0.00129	0.00000	0.8	0.22713
5/21	347	7	14.5	0.00106	0.00000	3.9	0.02136
5/22	220	7	9.2	0.00067	0.00010	0.5	0.29373
5/23	184	5	7.7	0.00056	0.00045	1.0	0.21344
5/24	267	8	11.2	0.00082	0.00001	0.9	0.21007
5/25	218	6	9.1	0.00067	0.00011	1.1	0.18903
5/26	146	2	6.1	0.00045	0.00220	2.8	0.05338
5/27	138	3	5.8	0.00042	0.00308	1.3	0.16587
5/28	57	1	2.4	0.00017	0.09177	0.8	0.30451
5/29	19	1	0.8	0.00006	0.45108	0.1	0.81186

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Date	Number of smolt tagged	Number of recoveries Actual	Expected[a]	P	$(1-P)^{13,461}$	χ^2	Binomial P
5/30	22	1	0.9	0.00007	0.39780	0.0	0.76519
5/31	5	0	0.2	0.00002	0.81099	0.2	0.80734
6/1	9	0	0.4	0.00003	0.68585	0.4	0.68030
6/2	5	0	0.2	0.00002	0.81099	0.2	0.80734
6/3	3	1	0.1	0.00001	0.88188	6.1	0.99488
6/4	10	0	0.4	0.00003	0.65771	0.4	0.65180
6/5	4	0	0.2	0.00001	0.84570	0.2	0.84265
6/6	11	0	0.5	0.00003	0.63072	0.5	0.62449
6/7	2	0	0.1	0.00001	0.91962	0.1	0.91796
6/8	3	0	0.1	0.00001	0.88188	0.1	0.87950
6/9	13	0	0.5	0.00004	0.58002	0.5	0.57326
6/10	37	1	1.6	0.00011	0.21217	0.2	0.53728
6/11	8	0	0.3	0.00002	0.71520	0.3	0.71005

[a]Expected recoveries are the number of smolt tagged multiplied by the overall recovery rate (4.19% or 13,461/564). Probability of recovering a fish is the expected number of recoveries divided by the total number of smolt tagged (13,461).

Appendix A8.–Model used to estimate potential bias in smolt abundance estimate of 2008 Chuck Creek coho salmon 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 17.6% (= $[524_{cwt\ jacks} + 688_{cwt\ adult\ esc} + 1{,}159_{cwt\ harvest}] / 13{,}461_{cwt\ smolt}$). The *CWT harvest* was estimated by expanding the number of recoveries in sampled fisheries for the fraction of the harvest not examined, and *CWT jacks* was estimated by expanding the number of recoveries in the sampled jack escapement for the fraction of the jack escapement not examined (524 = 617 x 523/616). All other variables are known from weir counts. Thus, smolt abundance at survival rates other than the assumed rate of 17.6% 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 (13,461), $m_{unmarked}$ is the number of unmarked mature fish (estimated at 329 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 ($93_{jacks\ unmarked} + 88_{adults\ unmarked}$) and the estimated number in the harvest (= 148, assuming the harvest rate for unmarked fish is the same for marked fish).

Appendix A9.–Computer files used in the analysis of data for this report.

File Name	Description
09Chuck escapement data.xls	Excel workbook containing 2009 Chuck Creek adult escapement data.
08Chuck smolt data.xls	Excel workbook containing 2008 Chuck Creek smolt and coded wire tagging data.
09Chuck Harvest.xls	Excel workbook containing 2009 marine harvest estimations and cwt recoveries.