Fishery Data Series No. 11-50

Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from Nakwasina River in Southeast Alaska, 2008-2009

by

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and

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October 2011

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2, etc.}$
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 11-50

SMOLT PRODUCTION, ADULT HARVEST, AND SPAWNING ESCAPEMENT OF COHO SALMON FROM NAKWASINA RIVER IN SOUTHEAST ALASKA, 2008-2009

by

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ABSTRACT

In 2008 and 2009, a continuing coded wire tag (CWT) project for coho salmon *Oncorhynchus kisutch* in Nakwasina River near Sitka, Alaska was conducted to supplement a regionwide effort to assess the status of key coho salmon stocks in Southeast Alaska. During spring 2008, 8,708 coho salmon smolt ≥65 mm FL were captured in minnow traps, marked with an adipose finclip, given a CWT, and released. The Chapman modification to the Petersen model was used to estimate smolt abundances at 35,618 in 2008. Beach seines, tangle nets, and hook-and-line gear were used to capture immigrant coho salmon during the autumn of 2009. Using an expansion factor, a bracketed peak count was expanded to estimate instream escapement at 1,453 fish. Harvest of returning Nakwasina River coho in 2009 was estimated at 857, exploitation in marine fisheries was 37.1%, and marine survival was 6.5%. Total run (escapement plus harvest) for all coho bound for Nakwasina River in 2009 was 2,310.

Key words: coho salmon, *Oncorhynchus kisutch*, Nakwasina River, harvest, troll fishery, sport fishery, migratory timing, return, exploitation rate, Jolly-Seber, marine survival, coded wire tag, mark-recapture experiment, spawning escapement, smolt abundance, Southeast Alaska, expansion factor, Petersen.

INTRODUCTION

Coho salmon *Oncorhynchus kisutch* produced by Nakwasina River and thousands of other coastal river systems in Southeast Alaska collectively support the region's mixed stock commercial troll and net fisheries along with freshwater and marine sport fisheries. The Alaska Department of Fish and Game (ADF&G) has conducted comprehensive coded wire tag (CWT) assessment projects on a long-term basis to evaluate the effects of Southeast Alaska fisheries on specific coho stocks native to streams in northern and inside areas of Southeast Alaska (Yanusz et al. 1999), but stock-specific information is more limited for outside, central, and southern areas. In order to represent all geographic areas, projects have been periodically implemented for specific stocks, including the Unuk River in southern inside waters (Jones III et al. 1999; 2001a-b; Weller et al. 2002, 2003, 2006), Slippery Creek in central waters (Beers 1999, 2003), and Chuck Creek in southern outside waters (McCurdy 2005, 2006a-b, 2008). Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and has continued through 2009 (Shaul and Crabtree 1998; Leon Shaul, personal communication, Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas). The Division of Sport Fish also conducted a CWT project to assess fishery impacts to Salmon Lake (near Sitka) coho salmon during the periods of 1983–1990, 1994–1995 (Schmidt 1996), and 2001–2005 (Tydingco et al. 2006, 2008).

Beginning in 1998 and continuing through 2009, the Division of Sport Fish has conducted a coho salmon CWT project in Nakwasina River (Figure 1) to supplement the regionwide effort to assess the status of key coho salmon stocks in central Southeast Alaska (Brookover et al. 2001, 2003; Tydingco 2003, 2005a-b, 2006, 2010; Tydingco and Fowler 2010). Estimated smolt abundance in Nakwasina River between 1998 through 2007 ranged from 22,472 (SE = 1,660) in 2002 to 102,794 (SE = 15,255) in 1998. Estimated harvests of returning adults in 1999–2008 ranged from 604 fish (SE = 109) in 2003 to 1,983 (SE = 354) in 1999 (Table 1).

Table 1.–Numbers of smolt tagged, smolt abundance with resultant escapement, and harvest from the Nakwasina River, 1998–2009.

Year	Smolt tagged	Smolt abundance estimate	Smolt SE	Adult esc	Adult esc SE	Harvest	Harvest SE	Survival	Exploitation	Fraction Tagged (θ)	Stream survey peak count and proportion of escapement estimate
1998	9,980	102,794	15,255	ND	ND	ND	ND	ND	ND	ND	653 (-)
1999	3,971	47,571	6,402	ND	ND	1,983	354	ND	ND	0.10	291 (-)
2000	10,120	45,677	2,669	2,000	261	1,219	213	6.8%	0.38	0.08	419 (0.21)
2001	10,381	43,630	2,660	2,992	510	1,439	155	9.7%	0.33	0.22	753 (0.25)
2002	5,686	22,472	1,660	3,141	661	731	109	9.8%	0.18	0.24	713 (0.23)
2003	15,762	55,424	4,023	2,063	233	604	109	11.9%	0.23	0.23	440 (0.21)
2004	9,771	47,573	3,039	3,867	937	1,645	178	9.9%	0.30	0.29	399 (0.10)[a]
2005	12,989	64,164	3,105	3,539	817	1,804	226	11.2%	0.34	0.21	892 (0.25)
2006	10,644	37,785	2,579	5,698	749	1,416	167	11.1%	0.20	0.20	996 (0.17)
2007	10,633	59,457	4,975	1,000	220	1,013	131	5.3%	0.50	0.27	385 (0.39)
2008	8,708	35,618	3,247	3,610[b]	ND	1,247	174	8.2%	0.26	0.18	839 (-)[b]
2009	ND	ND	ND	1,453[b]	ND	857	121	6.5%	0.37	0.24	338 (-)[b]
Averages	9,877	51,106	4,510	3,038	549	1,269	176	9.0%	0.31	0.20	593 (0.24)

[a] 2004 experienced poor stream survey conditions and subsequently was not used in the development of the expansion factor.

[b] 2008 and 2009 escapement estimates were derived by applying the expansion factor to the peak count.

OBJECTIVES

The objectives of this study were to: (1) estimate the number of coho salmon smolt leaving Nakwasina River in 2008; (2) estimate the marine harvest of coho salmon from Nakwasina River stock in 2009 via recovery of CWTs applied in 2008; (3) estimate spawning escapement in 2009; and (4) define the relationship between the estimated escapement and the peak foot survey count.

ADF&G managers will be able to use the information obtained through this project, in combination with indicator systems, to assess the status of wild coho salmon stocks in Southeast Alaska. This will allow management action resulting in appropriate levels of harvest and opportunity while preserving sustainability. In addition, as future levels of exploitation, escapement, smolt production, or marine survival conditions change, managers will be better prepared to understand the implications of these events and be better equipped to enact effective management strategies. This project will further define the relationship between estimated escapements (as derived from open population mark-recapture experiments) and peak foot survey counts in the Nakwasina River. Expanding peak foot survey counts may provide a cost-effective tool to track yearly escapements in lieu of mark-recapture experiments.

STUDY AREA

Nakwasina River is located on the outer coast of Baranof Island in Southeast Alaska (Figure 1). It is about 13 km long, and the anadromous portion ranges between 6 to 30 m wide and up to 3 m deep. It empties into Nakwasina Sound (57°15'16"W/135°20'41"N) about 23 km north of Sitka. Nakwasina River drains approximately 8,600 square hectares and is one of the larger river systems on Baranof Island. Average daily flow rates between 1976 and 1982 ranged between 100 ft^3/s to 1,200 ft^3/s. Maximum and minimum average daily flows during this time period ranged from a low of 22 ft^3/s to a high of 3,400 ft^3/s. In the 1960s the majority of riparian area in the anadromous portion of Nakwasina River valley was clear-cut to the streambank (Greg Killinger, personal communication, Sitka Ranger District, U.S. Forest Service, Sitka).

Nakwasina River is known locally for its freshwater sport fisheries for coho salmon and Dolly Varden *Salvelinus malma*. Because Nakwasina River is easily accessed by boat and supports one of the largest populations of coho salmon in Sitka Sound, it is one of the few rivers near Sitka that attracts freshwater sport fishing effort for coho salmon. The number of respondents in the Statewide Harvest Survey (SWHS) was not sufficient to produce a viable estimate of coho salmon harvested in Nakwasina Sound, including Nakwasina River (Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007, 2009, 2010a-b; Mills 1985–1994; Walker et al. 2003). However, anecdotal information suggests that the harvest in the freshwaters of Nakwasina River is a couple hundred fish annually.

Since 1980, annual peak foot survey counts have been conducted on Nakwasina River to provide an indication of abundance, which are collectively examined for trends. On average, Nakwasina River peak counts represent the largest of the six Sitka area systems surveyed for coho salmon. Surveys conducted in Nakwasina River from 1980 to 2009 have documented 47 (1987) to 996 (2006) adult coho salmon spawners (Table 2).

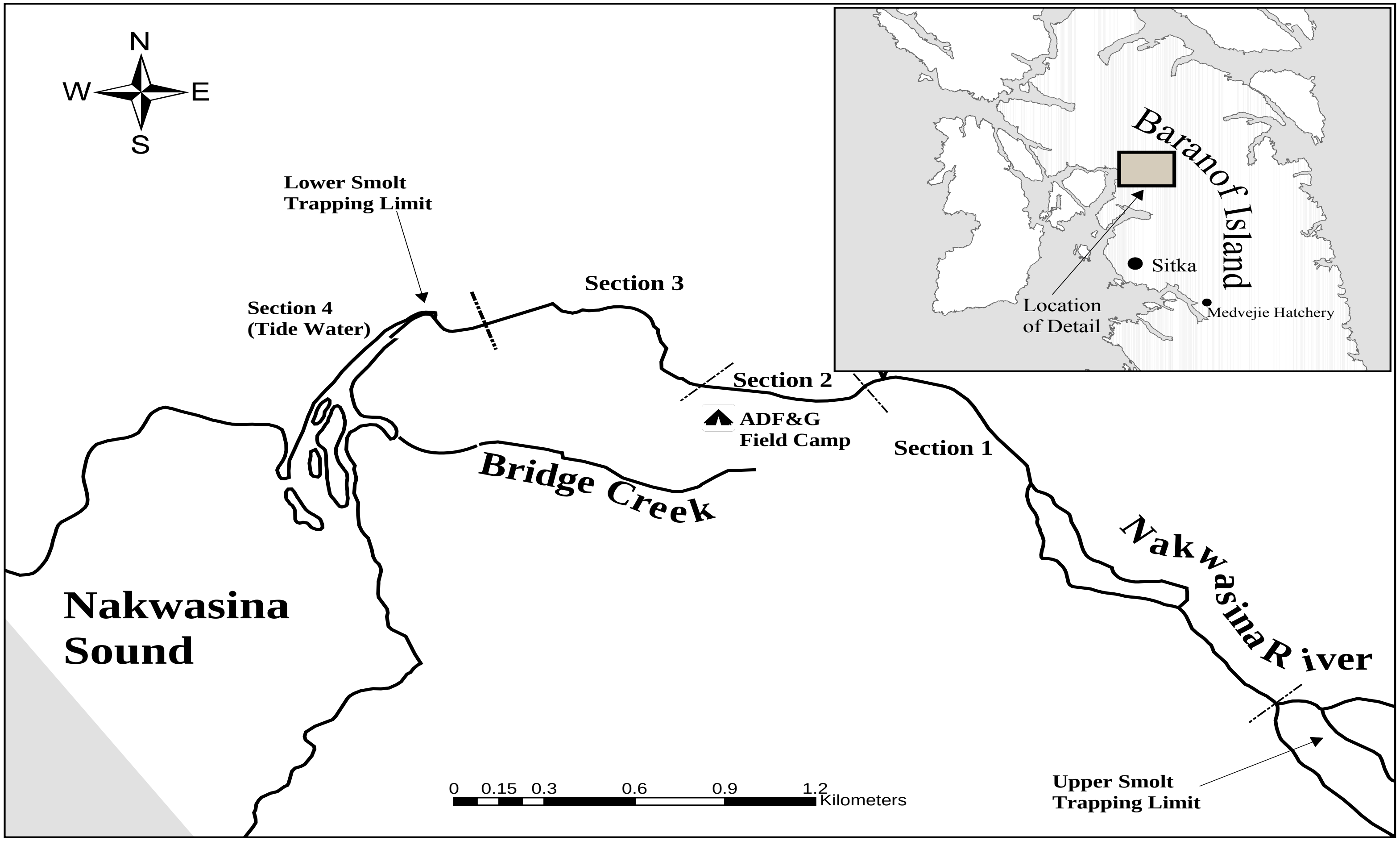

Figure 1.–Map showing Nakwasina River area, including major tributaries and location of ADF&G research sites and stream sections.

Table 2.–Peak escapement counts of coho salmon in the Sitka Area, 1980–2009.

	Sinitsin Creek			St. John Baptist Bay Creek			Starrigavan River			Eagle River			Black River			Nakwasina River		
Year	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho	Survey type	Peak survey date	No. of coho
1980	Foot	30-Sep	39	Foot	9-Oct	26	Foot			Foot	7-Oct	9	Foot	26-Oct	328	Foot	29-Oct	70
1981	Foot	6-Oct	85	Foot	14-Oct	51	Foot	20-Oct	170	Foot	17-Oct	28				Foot	7-Oct	780
1982	Foot	20-Oct	46	Foot			Foot	21-Oct	317									
1983	Foot	27-Sep	31	Foot	13-Oct	20	Foot	6-Oct	45							Foot	14-Oct	217
1984	Foot	10-Oct	160	Foot	10-Oct	154	Foot	10-Oct	385	Foot	16-Oct	7	Helo	3-Oct	425	Foot	17-Oct	715
1985	Foot	15-Oct	144	Foot	8-Oct	109	Foot	11-Oct	193	Foot	9-Sep	61	Helo	7-Oct	1,628	Foot	7-Oct	408
1986	Foot	30-Sep	4	Foot	10-Oct	9	Foot	10-Oct	57	Foot	26-Sep	245	Helo	10-Oct	312	Foot	28-Oct	275
1987	Foot	23-Sep	21	Foot	23-Sep	4	Foot	9-Oct	36	Foot	24-Sep	167	Helo	9-Oct	262	Foot	30-Oct	47
1988	Foot	3-Oct	56	Foot	3-Oct	71	Foot	12-Oct	45	Foot	2-Sep	10	Helo	10-Oct	280	Foot	27-Oct	104
1989	Foot	5-Oct	76	Foot	5-Oct	89	Foot	13-Oct	101	Weir	2-Oct	131	Helo	13-Oct	181	Foot	19-Oct	129
1990	Foot	1-Oct	80	Foot	1-Oct	38	Foot	17-Oct	39	Snorkel	2-Oct	214	Helo	4-Oct	842	Foot	31-Oct	195
1991	Foot	1-Oct	186	Foot	10-Oct	107	Foot	2-Oct	142	Snorkel	17-Oct	454	Helo	17-Oct	690	Foot	25-Oct	621
1992	Foot	23-Sep	265	Foot	14-Oct	110	Foot	12-Oct	241	Snorkel	6-Oct	629	Helo	6-Oct	866	Foot	30-Oct	654
1993	Foot	7-Oct	213	Foot	6-Oct	90	Foot	13-Oct	256	Snorkel	13-Oct	513	Helo	7-Oct	764			
1994	Foot	30-Sep	313	Foot	30-Sep	227	Foot	11-Oct	304	Snorkel	1-Oct	717	Helo	14-Oct	758	Foot	14-Oct	404
1995	Foot	26-Sep	152	Foot	5-Oct	99	Foot	6-Oct	274	Snorkel	5-Oct	336	Helo	27-Sep	1,265	Foot	29-Sep	626
1996	Foot	2-Oct	150	Snorkel	2-Oct	201	Foot	17-Oct	59	Snorkel	30-Sep	488	Helo	30-Sep	385	Foot	30-Oct	553
1997	Foot	29-Sep	90	Snorkel	30-Sep	68	Foot	27-Oct	55	Snorkel	30-Sep	296	Helo	30-Sep	686	Foot	14-Nov	239
1998	Foot	1-Oct	109	Snorkel	9-Oct	57	Foot	8-Oct	123	Snorkel	9-Oct	300	Helo	8-Oct	1,520	Foot	2-Nov	653
1999	Foot	11-Oct	48	Snorkel	29-Oct	27	Snorkel	28-Oct	167				Helo	4-Oct	1,590	Foot	12-Nov	291
2000	Foot	26-Sep	62	Snorkel	26-Oct	32	Snorkel	8-Oct	144	Snorkel	29-Sep	108	Helo	2-Oct	880	Foot	8-Nov	419
2001	Foot	5-Oct	132	Snorkel	4-Oct	80	Foot	3-Oct	133	Snorkel	4-Oct	417	Helo	4-Oct	1,080	Foot	14-Nov	753
2002	Foot	10-Oct	169	Snorkel	2-Oct	100	Foot	10-Oct	227	Snorkel	10-Oct	659	Helo	3-Oct	1,994	Foot	5-Nov	713
2003	Foot	29-Sep	102	Snorkel	30-Sep	91	Foot	2-Oct	95	Snorkel	9-Oct	373	Helo	2-Oct	1,055	Foot	31-Oct	440
2004	Foot	3-Oct	112	Snorkel	1-Oct	80	Foot	2-Oct	143	Snorkel	11-Oct	391	Helo	7-Oct	380	Foot	8-Nov	399
2005	Foot	4-Oct	67	Snorkel	14-Oct	173	Foot	7-Oct	76	Snorkel	14-Oct	460	Helo	6-Oct	106	Foot	7-Nov	892
2006	Foot	1-Oct	152	Snorkel	1-Oct	121	Foot	8-Oct	386	Snorkel	12-Oct	992	Helo	12-Oct	1,100	Foot	6-Nov	996
2007	Foot	4-Oct	39	Snorkel	4-Oct	86	Foot	8-Oct	130	Snorkel	9-Oct	426	Helo	4-Oct	745	Foot	6-Nov	385
2008	Foot	6-Oct	74	Snorkel	6-Oct	128	Foot	9-Oct	96	Snorkel	8-Oct	66	Helo	6-Oct	500	Foot	12-Nov	839
2009	Foot	28-Sep	160	Snorkel	29-Sep	105	Foot	16-Oct	128	Snorkel	7-Oct	393	Helo	8-Oct	747	Foot	9-Nov	338
Mean (1980-2009)			111			88			157			329			79			470
5-yr Mean (2005-2009)			98			123			163			467			64[illegible]			690

METHODS

SMOLT TAGGING AND SAMPLING

The first (tagging) event of the two-event mark-recapture experiment to estimate smolt abundance occurred in the spring of 2008 and the recapture event took place in the fall of 2009. From April 16 to May 21, 2008, between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily in Nakwasina River. Traps were fished 24 hours per day, approximately 6 days per week and checked at least once each day. Traps were set along mainstem banks and in backwater areas of the lower river between the estuary and approximately 6 km upstream. Traps were distributed and redistributed opportunistically to maximize catch by targeting areas of likely rearing habitat, unfished areas, and areas known to produce relatively high catch rates. After the first day of trapping each year, captured fish were examined to determine an appropriate minimum tagging length. Generally, most fish were of a uniform length and exhibited a natural size break between young-of-the-year and age-1. fish. Coho salmon smolt ≥65 mm FL were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden) and small coho fry (<65 mm FL) were counted and released at the capture site.

Every 2–3 days, all live coho salmon smolt were tranquilized with a solution of tricane methane-sulfonate (MS-222)[1] and injected with a CWT. Fish were then marked externally by excising the adipose fin. Tagging and marking followed the methods of Koerner (1977) and Magnus et al. (2006). All tagged fish were held overnight in a net pen to test for mortality, tag retention, and adipose finclip status and released. To test for tag retention, 100 fish were randomly selected and passed through a Northwest Marine Mark IV Portable Sampling Detector™. If tag retention was 98% or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97% or less, all fish were tested for tag retention and those not possessing a tag were retagged. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were recorded on *ADF&G Tagging Summary and Release Information Forms* which were submitted to ADF&G Division of Commercial Fisheries Mark, Tag and Age Laboratory (Tag Lab) in Juneau when fieldwork ended.

Three separate tag codes were used to identify different components of the smolt run. Small smolt (≥65 mm but less than 85 mm FL) were tagged with code 04-16-82, while large smolt (≥85 mm FL) were tagged with code 04-16-81. These tag codes were used to identify potential differential survival based on size at smolting. A third tag code (04-16-83) was used for all fish that were captured in an unnamed tributary to Nakwasina (Figure 1) that is connected only intermittently. This tributary, referred to as "Bridge Creek", empties into salt water approximately ½ km from the outlet of Nakwasina River, except at high tides when the two appear to be connected by a small freshwater passage. This third tag code was used to determine if fish emigrating from this tributary spawn in the mainstem of Nakwasina River and to examine differential survival by location of capture.

Smolt were measured from snout to fork of tail (FL) to the nearest 1 mm, weighed to the nearest 0.1 g, and sampled for scales. Twelve to 15 scales were removed from the preferred area on the left side of the coho salmon smolt (Scarnecchia 1979). Scales were sandwiched between two 1x

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[1] Product names used in the publication are included for scientific completeness but do not constitute product endorsement.

3-in microscope slides and numbered consecutively for each sampled fish. Slides were taped together and the number and length of each fish was written on the frosted portion of the bottom slide according to scale position on the slide. Ages were determined postseason.

INSTREAM MARK-RECAPTURE SAMPLING, CODED WIRE TAG RECOVERY, AND MARINE HARVEST SAMPLING

During the fall of 2009, an open population mark-recapture experiment was conducted in an effort to estimate escapement. This was done in conjunction with CWT recovery efforts that provided information for estimation of smolt abundance with a closed population model.

Sampling occurred during 2- or 3-day periods once each week from September 13 through December 2, 2009. Adult coho salmon were captured using a 3.6 x 22.5-m, 3.75-cm mesh beach seine and a 3.0 x 35-m, 7.5-cm mesh tangle net. Hook-and-line gear was also used to supplement net captures. Carcasses were sampled opportunistically when observed.

The stream was divided into 4 sections (Figure 1). Section 1 extended from river kilometer (rkm) 4.5 downstream to rkm 2.6. The portion of the river upstream of rkm 4.5 was not included because few fish have been observed in this section, and the presence of excessive amounts of woody debris and undercut banks were not conducive to capturing fish. Section 2 extended from rkm 2.6 downstream to rkm 2, and section 3 extended from rkm 2 to rkm 1. Section 4 extended from rkm 1 to tide water. Sampling was concentrated in sections 2 and 3 because the large pools located therein contained the majority of adult coho salmon visible in the river at any given time. These pools enabled effective deployment of the beach seine and tangle net.

All coho captured were examined for presence or absence of their adipose fin (signifying the presence of a CWT). Approximately every other coho salmon missing its adipose fin was sacrificed, and its head was removed and sent to the Tag Lab for dissection and decoding. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent of this combination were measured to the nearest mm FL, tagged with uniquely numbered Floy™ T-Bar anchor tags, given a secondary mark (opercle punch) to permit estimation of tag loss, examined to determine sex and condition, and sampled to collect scales for aging. Tags were inserted 1 cm below the insertion of the dorsal fin on the left side of the fish. Secondary marks were varied weekly to allow for reconstruction of capture histories in the event Floy™ tags were lost between sampling events. Secondary marks included various combinations of opercle punches that consisted of 0.6 cm diameter holes. The condition of each fish was determined from external characteristics using the following convention:

1)	Bright	Ocean bright or nearly ocean bright;
2)	Blush	Some color (primarily blush red);
3)	Dark	Dark color (primarily red);
4)	LPS (live post-spawner)	Spawned out but not yet dead;
5)	Carcass	Dead spawned fish; and,
6)	Mortality	Dead unspawned fish.

For fish captured with a Floy™ tag, the section, gear used, tag number, and condition were recorded and the fish was released. If an opercle punch but no anchor tag was present, the fish was recorded as a valid tag recovery (indicating the tag was shed), retagged, and examined for condition.

All carcasses that could be retrieved were also inspected for marks, recorded, and heads were removed if the adipose fin was missing. Carcasses were slashed on the left side along the midline to prevent resampling.

Sex was determined from external characteristics. Scale samples, consisting of 4 scales from the preferred area near the lateral line on an imaginary line from the insertion of the posterior dorsal fin to the anterior origin of the anal fin (Scarnecchia 1979), were collected and affixed to a gum card in the field. Postseason, scale images were impressed on acetate and ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Moser (1968).

Harvest of coho salmon originating from Nakwasina River was estimated from fish sampled in both commercial and marine sport fisheries. Fisheries personnel with the ADF&G Division of Commercial Fisheries port-sampling program examined commercially caught fish at processing locations and recovered coho salmon with missing adipose fins[2]. Similarly, the Division of Sport Fish employed a creel survey program to examine fish caught in the sport fishery (e.g., see Hubartt et al. 2002). When possible, heads of fish without an adipose fin were removed and sent to the Tag Lab for tag detection and decoding. Because multiple fisheries exploited coho salmon over several months, 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. Statistics from the marine sport fishery were stratified bi-weekly.

FOOT SURVEY COUNTS

Adult coho salmon in Nakwasina River were counted approximately every other week during October and November. Visual counts were conducted by 2 experienced observers either during or 1 day after instream sampling efforts. Only fish positively identified as coho salmon were counted. Counts were conducted between the uppermost portion of the survey area (rkm 7.75) and a pool near the high tide mark at rkm 0.25. Uncontrolled variables included observer abilities, weather conditions, and water clarity. Weather conditions, water clarity, and counts were recorded by stream section.

Bridge Creek was examined opportunistically during the course of sampling to determine if coho salmon used it for spawning or rearing. To date, no coho salmon spawning activity has been observed in Bridge Creek.

ESTIMATES OF SMOLT ABUNDANCE AND SIZE

Chapman's modification of the Petersen estimator (Seber 1982) was used to estimate smolt abundance. Several conditions had to be met for unbiased estimates:

1. there is no recruitment or immigration to the population–only fish that were present in the population during the smolt marking are present in the population of fish inspected for marks as adults;

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[2] For protocol, see Oliver, G. *Unpublished.* Alaska Department of Fish and Game coded wire tag sampling program, detailed sampling instructions, commercial fisheries sampling. Available through Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

2. there is no tagging induced behavior or mortality–tagged fish behave the same as untagged fish after the marking event;
3. fish do not lose their marks and all marks are recognizable;
4. tag codes and release locations can be correctly determined for all adult fish observed with missing adipose fins; and
5. all fish marked as juveniles are smolt.

In addition, at least 1 set of conditions on mortality and sampling must be met. Because significant mortality occurs between sampling events, these conditions must be evaluated and satisfied concurrently. At least 1 of the following sets of conditions must be met:

S1. all fish have an equal probability of being captured and marked during the first event; or

S2. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups and complete mixing of marked and unmarked fish occurs prior to the second event; or

S3. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups and all fish have an equal probability of being captured and inspected for marks during the second event.

When possible, these conditions were evaluated using experimental data, and in some cases by indirect knowledge. Otherwise, they were ensured by exercising control over experimental procedures. Equal survival between tagging groups was evaluated using contingency table analysis to test for lack of independence between tagging group and probability of recovery during adult sampling. Contingency table analysis was also used to test for lack of independence between sampling events and freshwater age.

Estimates of mean smolt length and weight-at-age and their variances were calculated with standard sample summary statistics (Cochran 1977).

ESTIMATE OF HARVEST

The contribution (r_{ij}) of release group j to a fishery stratum i was estimated as:

$$\hat{r}_{ij} = N_i \left[\frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \tag{1}$$

where:

N_i = total harvest in fishery stratum i,
n_i = number of fish inspected in fishery stratum i (the sample),
a_i = number of fish which were missing an adipose fin,
a_i' = number of heads that arrived at the lab,
t_i = number of heads with CWTs detected,
t_i' = number of CWTs that were dissected from heads and decoded,
m_i = number of CWTs with code(s) of interest, and
θ_j = fraction of the cohort tagged with code(s) of interest.

When N_i and θ_j are known without error, an unbiased estimate of the variance of $\hat{r}_{ij}$ can be calculated as shown by Clark and Bernard (1987). However, N_i is estimated with error in sport fisheries, and θ_j is estimated with error on Nakwasina River because wild stocks are tagged. Because of these circumstances, estimates of the variance of $\hat{r}_{ij}$ based on large sample approximations were obtained using the appropriate equations in Bernard and Clark (1996).

The total harvest for a cohort was calculated as the sum of strata estimates:

$$\hat{H} = \sum_i \sum_j \hat{r}_{ij} \tag{2}$$

$$Var\left[\hat{H}\right] = \sum_i \sum_j v\left[\hat{r}_{ij}\right] \tag{3}$$

SPAWNING ESCAPEMENT

Estimate via Jolly-Seber Experiment

A Jolly-Seber (JS) experiment (Seber 1982), using the model described by Schwarz et al. (1993), was conducted in an effort to estimate the escapement of adult (age-.1) coho salmon in Nakwasina River during 2009. A description of this model along with methods and assumptions specific to Nakwasina River are described in Tydingco and Fowler (2010).

Estimate via Expansion of Foot Counts

Spawning escapement in 2009 was estimated by applying an expansion factor to the peak foot count. The expansion factor was derived by comparing open population estimate models to peak foot counts between 2000 and 2007. The expansion factor used for 2009 was 4.3.

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age or sex was estimated by (Cochran 1977):

$$\hat{p}_j = \frac{n_j}{n} \tag{4}$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{5}$$

where:

p_j = the proportion in the population in group j;
n_j = the number in the sample of group j; and
n = sample size.

To reduce bias attributed to inseason changes in age composition, samples were obtained systematically.

ESTIMATES OF TOTAL RUN, EXPLOITATION, AND MARINE SURVIVAL

Estimates of total run (i.e., harvest and escapement) for coho salmon returning to Nakwasina River in 2009 and the associated exploitation rate in commercial and sport fisheries were based on the sum of the estimated harvest and escapement:

$$\hat{N}_R = \hat{H} + \hat{E}\ . \tag{6}$$

The variance of the estimated run was calculated as the sum of the variances for estimated escapement and harvest:

$$Var\,[\hat{N}_R] = Var\,[\hat{H}] + Var\,[\hat{E}] \tag{7}$$

The estimate of exploitation rate and variance were calculated using (Mood et al. 1974):

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \tag{8}$$

$$Var\left[\hat{U}\right] \approx \frac{Var[\hat{H}]\,\hat{E}^2}{\hat{N}_R^4} + \frac{Var[\hat{E}]\,\hat{H}^2}{\hat{N}_R^4}. \tag{9}$$

The estimated survival rate of smolt to adults and variance were calculated using (Mood et al. 1974):

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \tag{10}$$

$$Var[\hat{S}] \approx \hat{S}^2 \left[\frac{Var[\hat{N}_R]}{\hat{N}_R^2} + \frac{Var[\hat{N}_s]}{\hat{N}_s^2} \right]. \tag{11}$$

RESULTS

SMOLT TAGGING, SAMPLING, AND ABUNDANCE

Smolt abundance in 2008 was estimated to be 35,618 (SE = 3,247). Between April 16 to May 21, 2008, 8,733 coho smolt from Nakwasina River and its tributaries were captured and coded-wire-tagged. Overnight tag retention was 100% for all tag codes. A total of 25 overnight mortalities occurred. Adjusting for tag retention and mortalities, the total number of valid tag releases was calculated as 8,708. Of these, 5,988 (68.8%) were small smolt captured in the mainstem of Nakwasina River, while 894 (10.3%) were large smolt (Table 3). The remaining 1,826 (20.9%), were fish ≥65 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina River that were age 1. (those rearing for 1 year in fresh water) comprised 100% of sampled smolt. Fork length averaged 75.2 mm (SE = 0.52) and had SD = 8.47. Average weight was 4.65 g (SE = 0.10) and had SD = 1.62 (Table 4). Average length and weight remained approximately the same throughout the tagging effort. Age-1. fish from Bridge Creek comprised 100% of sampled smolt. Fork length averaged 77.5 mm FL (SE = 1.04) and had SD = 8.65. Average weight was 4.9 g (SE = 0.20 and had SD = 1.67 (Table 4).

The proportions of smolt tagged with each of three tag codes was not significantly different than that observed in the spawning escapement in 2009 (χ^2 = 3.76, P = 0.152, Table 3). Smolt emigrating from Bridge Creek in 2008 appeared to survive at a similar rate compared to the Nakwasina smolt when both large and small size categories were combined (χ^2 = 1.51, P = 0.219, Table 3). The tag groups of large and small Nakwasina River smolt had similar survival based on rates of recovery of tagged adult fish (χ^2 = 0.31, P = 0.581, Table 3).

Table 3.–Numbers and $\chi2$ tests for independence for smolt and adult coho salmon from the Nakwasina River and Bridge Creek, 2000–2009.

Year	≥70 mm[a]	≥85 mm	Bridge Creek	Total	≥70 mm[a]	≥85 mm	Bridge Creek
Spring smolt releases					Percentage of total		
2000	5,446	1,831	3,042	10,319	53%	18%	29%
2001	6,979	1,434	1,986	10,399	67%	14%	19%
2002	3,566	874	1,246	5,686	63%	15%	22%
2003	9,925	2,533	3,304	15,762	63%	16%	21%
2004	5,165	2,692	1,914	9,771	53%	28%	20%
2005	7,158	2,083	3,748	12,989	55%	16%	29%
2006	5,289	2,442	2,913	10,644	50%	23%	27%
2007	7,591	1,071	1,971	10,633	71%	10%	19%
2008	5,988	894	1,826	8,708	69%	10%	21%
Adult escapement recoveries							
2001	75	35	40	150	50%	23%	27%
2002	146	39	15	200	73%	20%	8%
2003	145	28	24	197	74%	14%	12%
2004	180	77	44	301	60%	26%	15%
2005	87	48	37	172	51%	28%	22%
2006	100	21	44	165	61%	13%	27%
2007	33	15	24	72	46%	21%	33%
2008	70	10	10	90	78%	11%	11%
2009	29	6	16	51	57%	12%	31%
Adult fisheries recoveries							
2001	48	22	29	99	48%	22%	29%
2002	27	22	5	54	50%	41%	9%
2003	28	8	14	50	56%	16%	28%
2004	52	22	24	98	53%	22%	24%
2005	45	15	20	80	60%	26%	15%
2006	28	16	37	81	35%	20%	46%
2007	25	20	27	72	35%	28%	38%
2008	50	12	5	67	75%	18%	7%
2009	51	8	16	75	68%	11%	21%
All adults combined							
2001	123	57	69	249	49%	23%	28%
2002	173	61	20	254	68%	24%	8%
2003	173	36	38	247	70%	15%	15%
2004	232	99	68	399	58%	25%	17%
2005	132	63	57	252	60%	26%	15%
2006	128	37	81	246	52%	15%	33%
2007	58	35	51	144	40%	24%	35%
2008	120	22	15	157	76%	14%	10%
2009	80	14	32	126	63%	11%	25%

[a] In 2003, 2007and 2008 smolt ≥65 mm were tagged.

Component 1	Component 2	$\chi2$	P
Nakwasina smolt 2000	All adults 2001	4.63	0.099
Nakwasina smolt 2000	Adult escapement 2001	3.11	0.191
Adult fisheries 2001	Adult escapement 2001	0.21	0.901
Nakwasina Smolt 2001	All adults 2002	36.95	0.000
Nakwasina Smolt 2001	Adult escapement 2002	20.24	0.000
Adult fisheries 2002	Adult escapement 2002	11.46	0.003
Nakwasina Smolt 2002	All adults 2003	7.34	0.026
Nakwasina Smolt 2002	Adult escapement 2003	12.85	0.002
Adult fisheries 2003	Adult escapement 2003	8.34	0.016
Nakwasina smolt 2002	Nakwasina adults 2003	0.84	0.360
Nakwasina smolt 2002	Nakwasina escapement 2003	1.39	0.238
Nakwasina fisheries 2003	Nakwasina escapement 2003	0.76	0.383
Adult fisheries 2004	Adult escapement 2004	5.10	0.078
Nakwasina smolt 2003	Nakwasina adults 2004	23.98	0.000
Nakwasina smolt 2003	Nakwasina escapement 2004	23.65	0.000
Nakwasina smolt 2003	Bridge Creek smolt 2003	3.80	0.051
Nakwasina small smolt 2003	Nakwasina large smolt 2003	19.25	0.000
Nakwasina fisheries 2004	Nakwasina escapement 2004	5.10	0.078
Nakwasina smolt 2004	Nakwasina adults 2005	1.84	0.400
Nakwasina smolt 2004	Nakwasina escapement 2005	0.51	0.775
Nakwasina smolt 2004	Bridge Creek smolt 2004	1.51	0.219
Nakwasina small smolt 2004	Nakwasina large smolt 2004	0.34	0.560
Nakwasina fisheries 2005	Nakwasina escapement 2005	2.46	0.292
Nakwasina smolt 2005	Nakwasina adults 2006	2.03	0.363
Nakwasina smolt 2005	Nakwasina escapement 2006	2.34	0.311
Nakwasina smolt 2005	Bridge Creek smolt 2005	2.03	0.155
Nakwasina small smolt 2005	Nakwasina large smolt 2005	0.00	0.971
Nakwasina fisheries 2006	Nakwasina escapement 2006	14.83	0.001
Nakwasina smolt 2006	Nakwasina adults 2007	6.17	0.046
Nakwasina smolt 2006	Nakwasina escapement 2007	1.30	0.522
Nakwasina smolt 2006	Bridge Creek smolt 2006	4.76	0.029
Nakwasina small smolt 2006	Nakwasina large smolt 2006	1.59	0.207
Nakwasina fisheries 2007	Nakwasina escapement 2007	1.99	0.369
Nakwasina smolt 2007	Nakwasina adults 2008	9.96	0.007
Nakwasina smolt 2007	Nakwasina escapement 2008	3.32	0.191
Nakwasina smolt 2007	Bridge Creek smolt 2007	8.51	0.004
Nakwasina small smolt 2007	Nakwasina large smolt 2007	1.30	0.254
Nakwasina fisheries 2008	Nakwasina escapement 2008	1.85	0.396
Nakwasina smolt 2008	Nakwasina adults 2009	1.80	0.406
Nakwasina smolt 2008	Nakwasina escapement 2009	3.76	0.152
Nakwasina smolt 2008	Bridge Creek smolt 2008	1.51	0.219
Nakwasina small smolt 2008	Nakwasina large smolt 2008	0.31	0.581
Nakwasina fisheries 2009	Nakwasina escapement 2009	1.83	0.400

Table 4.–Estimated fork length, weight, and age of coho salmon smolt from Nakwasina River and Bridge Creek in 2008.

	Nakwasina		Bridge Creek		Combined	
	Age-1.		Age-1.		Age-1.	
Statistic	Length	Weight	Length	Weight	Length	Weight
Mean	75.21	4.65	77.49	4.90	75.68	4.70
Standard error	0.52	0.10	1.04	0.20	0.46	0.09
Sample size	269	269	69	69	338	338

Table 5.–Number of age-1. and age-2. coho salmon smolt and adults from Nakwasina River, 2008–2009.

	Sample year	2009		
	Brood year	2006	2005	Total aged
	Age class	1.1	2.1	
Females	Sample size	40	1	41
	Percent	97.5%	2.4%	
	SE	2.4%	2.4%	
	Mean length	588.6	715.0	
	SE	9.8	-	
Males	Sample size	58	1	59
	Percent	98.3%	1.7%	
	SE	1.7%	1.7%	
	Mean length	540.3	580	
	SE	9.5	-	
All fish	Sample size	98	2	100
	Percent	98.0%	2.0%	
	SE	1.4%	1.4%	
	Mean length	560.0	647.5	
	SE	7.3	67.5	

	Freshwater age			
	1	2	$\chi 2$	*P*-value
Adults 2009	98	2	6.77	0.009
Smolt 2008	337	0		
2009 adult males	58	1	0.07	0.797
2009 adult females	40	1		

INSTREAM CODED WIRE TAG RECOVERY AND AGE-SEX COMPOSITION

The CWT fraction of adult coho salmon sampled in Nakwasina River during 2009 was 0.242. Of the 363 adult coho salmon examined, 88 had an adipose fin clip. Of these, 51 were sacrificed and 100% of those sacrificed contained a valid Nakwasina River or Bridge Creek tag.

The proportion of freshwater age-1. fish in the 2009 sample was 98% (Table 5, Appendix A1). No differences were detected in freshwater age by sex ($\chi^2 = 0.07$, $P = 0.797$).

CONTRIBUTION TO MARINE FISHERIES

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2009 was 857 (SE = 121, Table 6, Figure 2). Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,031,654, Table 6) for the areas in which Nakwasina River fish were recovered. The estimated total contribution to the marine sport fishery was 35 fish. Four percent of Nakwasina coho salmon harvested were caught in the sport fishery, while 95% were caught in the troll fishery. However, relative contributions were higher in sport fisheries (0.13% of the harvest) than troll (0.08% of the harvest). Estimates of freshwater harvest of coho salmon in Nakwasina River based on the Statewide Harvest Survey are not considered reliable because of a low response rate. Anecdotal information suggests that in 2009 a few hundred fish were harvested in the freshwaters of Nakwasina River.

In 2009, 69 CWTs from Nakwasina River and Bridge Creek were randomly recovered from 341,745 coho salmon sampled in commercial and sport fisheries, and 7 additional CWTs were recovered incidentally (Table 6, Appendix A2). Sixty-five coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries. Of the 65 random troll fishery recoveries, 43 were caught in the Northwest Quadrant (Figure 3) between July 11 and September 28. Three coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between July 14 and August 23. One fish was randomly recovered in the commercial seine fishery within the Southeast Quadrant on June 29. Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 566 mm FL (SE = 6.13)and had SD = 49.84.

ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

Although a Jolly-Seber (JS) estimate of abundance was attempted, results were not conclusive because the condition of equal capture probability was not satisfied. A constrained JS model was required to fit the 2009 data, similar to previous years (Tydingco 2003, 2005a-b, 2006, 2010). Several attempts were made to fit the model, using different poolings of adjacent sampling periods when statistics for adjacent periods were similar. The estimates of abundance from the different data configurations consistently provided point estimates of escapement on the order of approximately 1,000 coho salmon. However, all escapement estimates based on the JS model were extremely imprecise, with SEs exceeding the magnitude of the point estimate. As a result, estimates based on the JS model provided no utility except for indicating the order of magnitude of the escapement. Consequently, the expansion factor of 4.3 was applied to the peak foot count of 338 to produce an escapement estimate of 1,453.

Only 21 fish (or 4% of the sample) were captured or recovered in section 1, while in section 2 68.3% were captured or recovered. In section 3, there were 26.5% of the total captures, and 1.2%

were at tidewater (Table 7). In total, 43.5% of the fish inspected for Floy™ tags had either a Floy™ tag or a secondary mark. The probability of capturing a tagged fish was significantly different between river sections (χ^2 = 24.0, P < 0.000, Table 8). The proportions of males and females captured in sections 1, 2, and 3 were significantly different (χ^2 = 10.59 P = 0.014, Table 9). Recapture rates between males and females were significantly different (χ^2 = 10.81 P = 0.001, Table 9). There was not a significant difference between the proportion of males and females captured across gear types (χ^2 = 1.71, P = 0.426, Table 9).

Length distributions of coho salmon captured in Nakwasina River with and without adipose fin clips were not different (Table 10, Figure 4). Fish captured with hook and line gear were smaller than those captured through the use of a seine (D_i = 0.297, P = 0.001).

Table 6.–Estimated harvest of adult Nakwasina River coho salmon in sport and commercial fisheries sampled in 2009.

Period	Dates	Quadrant	Estimated harvest	Inspected	*a*	*a'*	*t*	*t'*	*m*	Expanded harvest (N_1)	SE{N_1}
TROLL FISHERY											
3	6/28–8/15	NW	526,465	166,532	1,864	1,827	1,374	1,372	21	280	67
4	8/16–10/3	NW	397,458	137,450	2,147	2,103	1,719	1,715	43	525	98
4	8/16–10/3	NE	84,115	27,150	432	424	308	307	1	13	13
Subtotal troll fishery			1,008,038	331,132	4,443	4,354	3,401	3,394	65	818	119
PURSE SEINE FISHERY											
27	6/28–7/4	SE	3,584	3,251	38	38	27	27	1	5	4
Subtotal seine fishery			3,584	3,251	38	38	27	27	1	5	4
SPORT FISHERY											
14	7/6–7/19	Sitka	4,584	1,850	9	9	7	7	1	10	10
16	8/3–8/16	Sitka	8,546	2,776	29	27	25	25	1	14	13
17	8/17–8/30	Sitka	6,902	2,736	23	22	20	20	1	11	10
Subtotal sport fishery			20,032	7,362	61	58	52	52	3	35	19
Total all fisheries			1,031,654	341,745	4,542	4,450	3,480	3,473	69	857	121

The average lengths of female and male coho salmon were 595 mm MEF (SE = 3.8, SD = 3.83) and 560 mm MEF (SE = 4.3, SD = 4.26) respectively.

Based on an escapement estimate of 1,453, a marine harvest estimate of 857 (SE = 121), and a smolt abundance estimate of 35,618 (SE = 3,246), the estimated total run in 2009 was 2,310, marine survival was 6.5%, and the exploitation rate was 37.1%. Because escapement was based on an expansion factor, standard errors were not possible for total run, marine survival, and exploitation rate.

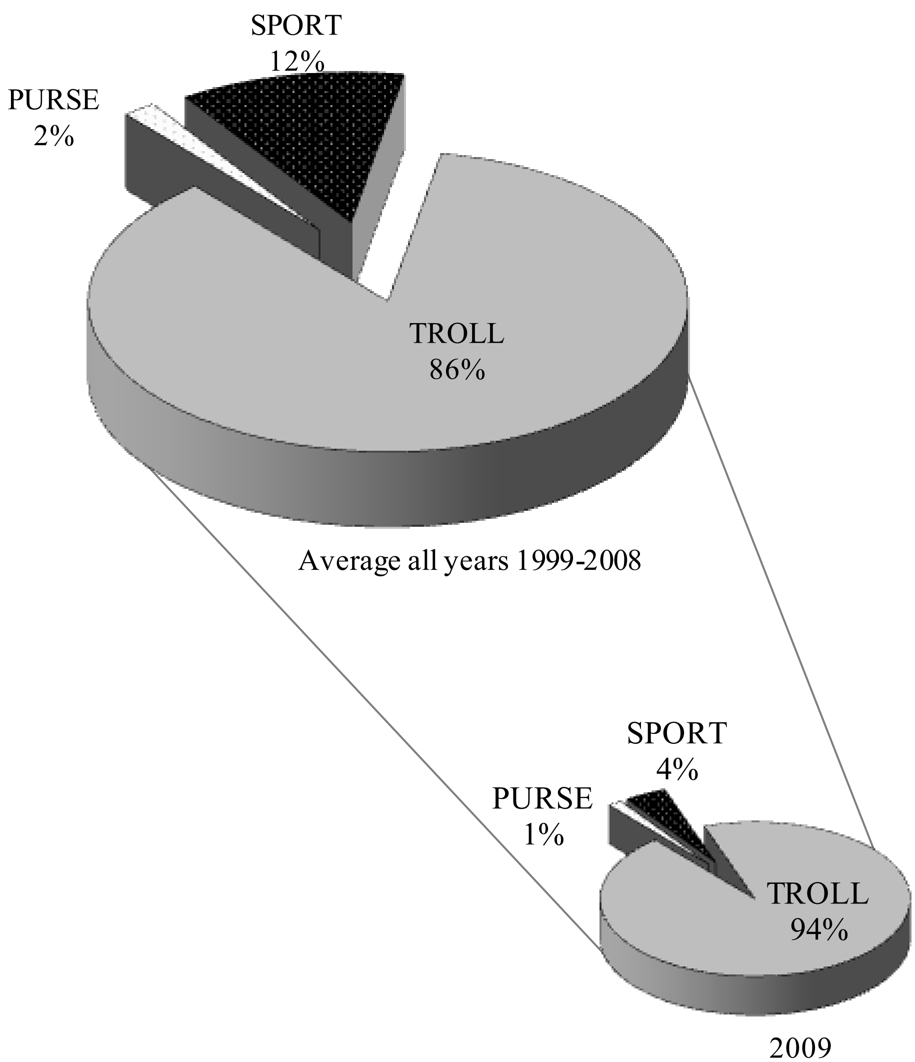

Figure 2.–Portion of Nakwasina coho harvest by fishery between 1999 and 2009 (select recoveries omitted).

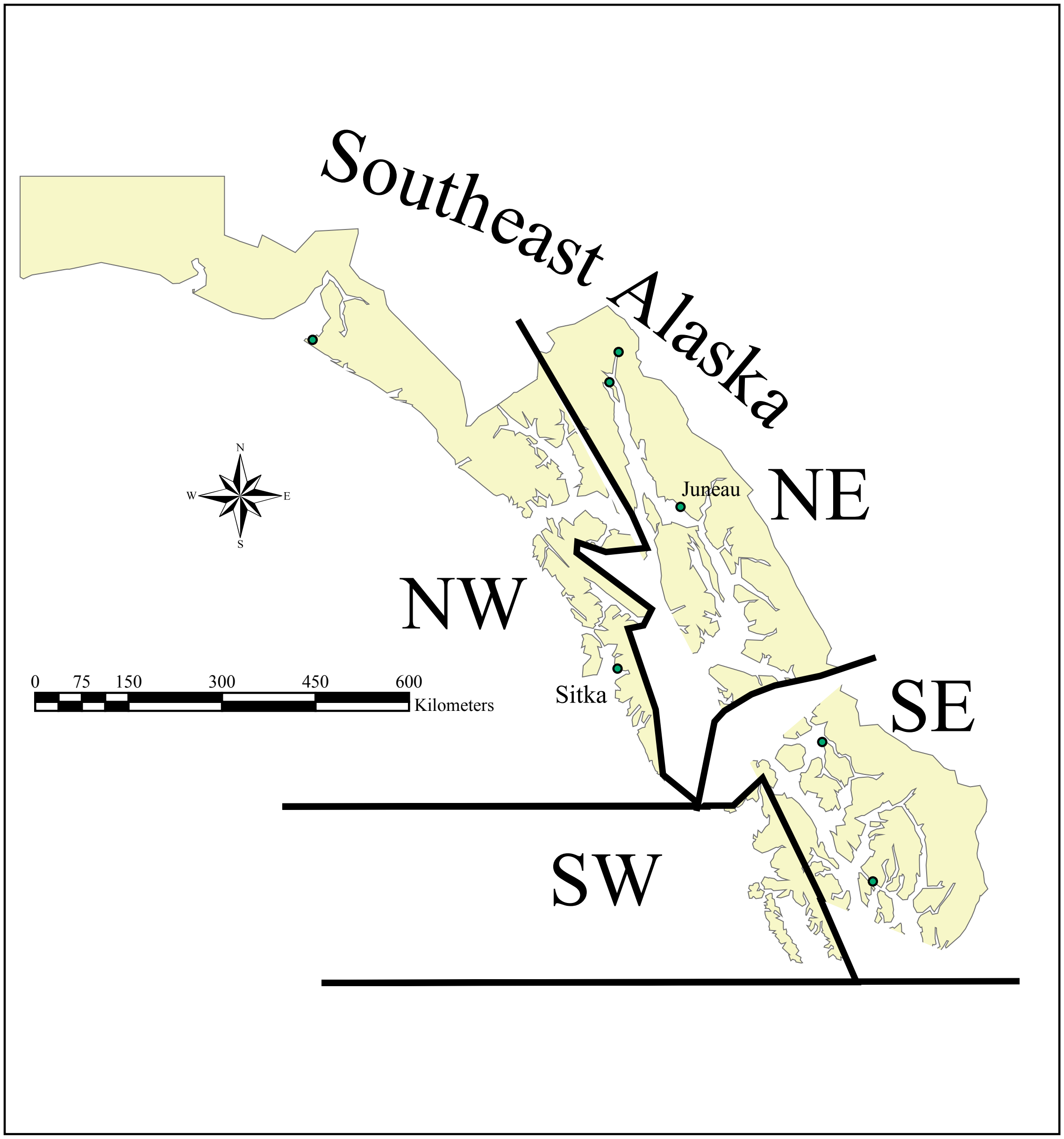

Figure 3.–Map of Southeast Alaska showing the boundaries for coded wire tag quadrants.

Table 7.–Summarized mark-recapture data for Nakwasina River coho salmon, 2009.

Week #	Location	Original captures	Recaptures	Total captures	Proportion (Floy) tagged
36	2	2		2	0.0%
39	2	17		17	0.0%
40	2	10		10	0.0%
	Tidewater	6		6	0.0%
41	2	8		8	0.0%
	3	2		2	0.0%
42	2	12	1	13	7.7%
	3	40		40	0.0%
43	1		1	1	100.0%
	2	50	6	56	10.7%
	3	7	2	9	22.2%
44	2	3		3	0.0%
45	1	5		5	0.0%
	2	54	14	68	20.6%
	3	52	6	58	10.3%
46	2	44	27	71	38.0%
	3	15	11	26	42.3%
47	1	2	3	5	60.0%
	2	12	25	37	67.6%
48	1	6	4	10	40.0%
	2	10	37	47	78.7%
	3	1	2	3	66.7%
49	2	5	19	24	79.2%
Grand total		363	158	521	30.3%

Table 8.–Results of $\chi 2$ tests for differences in tagged rate between river sections for Nakwasina coho salmon in 2009.

Location	Untagged	Tagged	Total	Percent of total captures by location
1	13	8	21	4.0%
2	227	129	356	68.3%
3	117	21	138	26.5%
Tide water	6		6	1.2%
Total	363	158	521	
Sections 1–3	χ 2=	24.00		
	P<	0.000		

Table 9.–Differences in sex composition between capture type, gear, and section for Nakwasina coho salmon in 2009.

Capture	Females	Males	% Males	$\chi 2$	*P*-value
Recapture	91	69	43.1%	10.81	0.001
Captured	150	213	58.7%		
Gear type					
Hook and line	19	31	62.0%	1.71	0.426
Seine	207	238	53.5%		
Tangle net	14	13	48.1%		
Location					
1	10	11	52.4%	10.59	0.014
2	148	209	58.5%		
3	79	60	43.2%		
Tidewater	4	2	33.3%		

Table 10.–Results of Kolmogorov-Smirtov tests for differences between cumulative length frequencies for adult coho salmin in the Nakwasina River, 2009.

Component 1	Component 2	n_1	n_2	D_i	*P*-value
Males	Females	213	150	0.287	<0.000
Hook and line	Seine	50	295	0.297	0.001
Sep 3–Oct 31	Oct 31– Dec 2	157	206	0.205	0.001
Adipose clip	No adipose clip	88	275	0.063	0.946
Section 2	Section 3	227	117	0.186	0.008

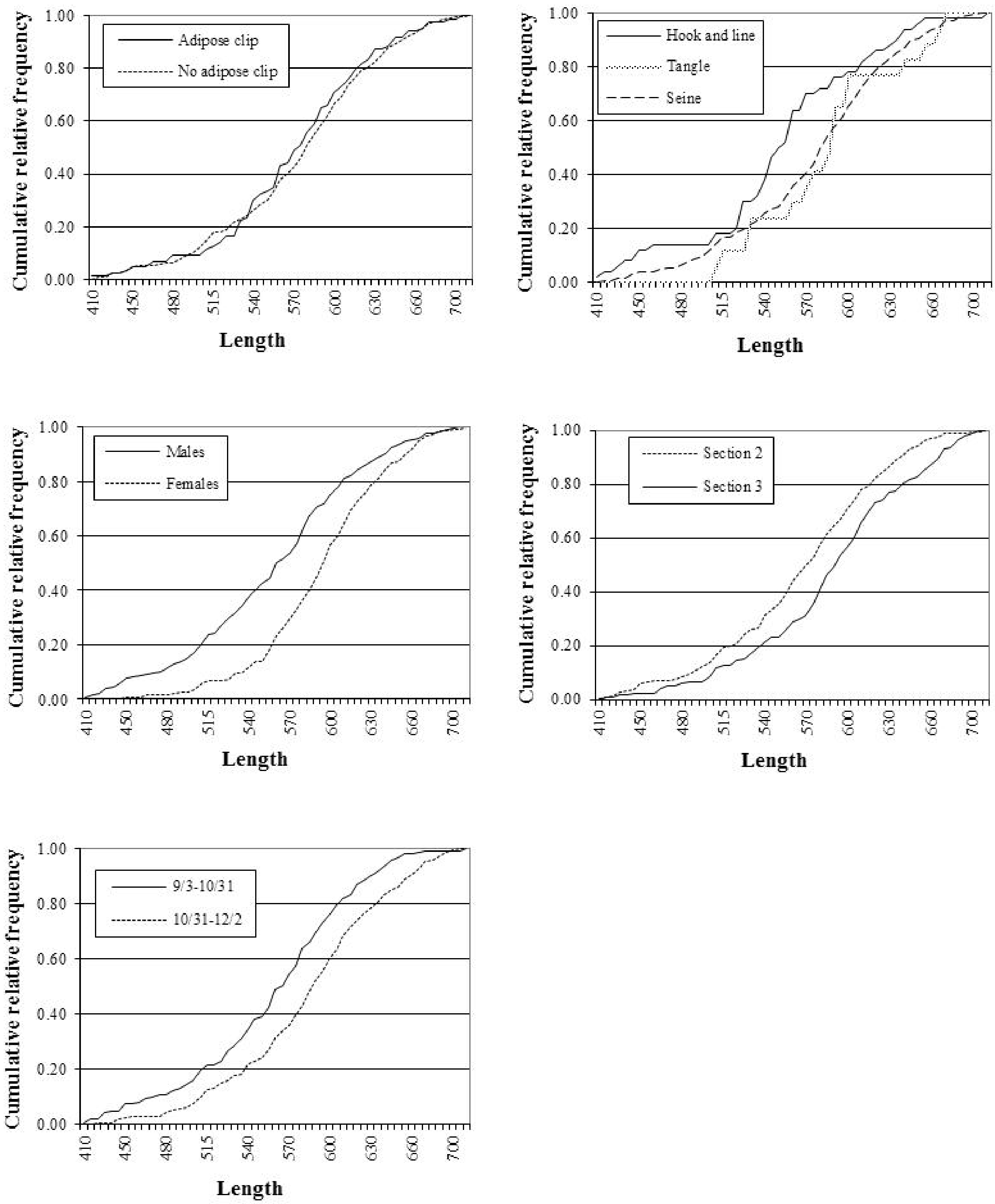

Figure 4.–Cumulative length frequency distributions to test for differences in lengths of captured Nakwasina River coho salmon by sex, adipose fin presence, date, gear type, and area in 2009.

FOOT SURVEY COUNTS

Foot survey counts were conducted on Nakwasina River on 4 occasions in 2009 (Table 11). The peak count was 338, which occurred on November 19th.

Table 11.–Stream counts including number of coho salmon counted, date, survey conditions, and percentage of total escapement estimate represented by daily count in Nakwasina River, 2009.

Date	Count	Conditions	Percent of estimated escapement
8 Oct	103	Visibility normal, water normal	7.1%
1 Nov	313	Visibility normal, water normal	21.5%
19 Nov	338[a]	Visibility normal, water normal	23.3%
18 Nov	191	Visibility normal, water normal	13.1%

[a] Peak count.

DISCUSSION

SMOLT ABUNDANCE AND ADULT HARVEST

The smolt-to-adult survival rates of 6.5% are lower than the 2000–2008 average (9.3%), but comparable to some of the other systems in the region for 2009 (Table 12). Because of the low average smolt-to-adult survival rate in Nakwasina River in 2000–2002 (8.7%), extra care was taken in subsequent years to insure smolt were given an adequate opportunity to recover and smolt naturally. However, survival remained relatively low in 2009, indicating that Nakwasina River coho smolt-to-adult survival rate may tend toward the lower end of the range observed in Southeast Alaska systems.

Table 12.–Smolt-to-adult survival rate for coho salmon indicator streams around Southeast Alaska, 2000–2009.

Stream	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
Auke Creek	18.5	28.3	26.8	25.0	20.2	16.0	20.3	11.9	24.1	15.5	20.7
Chuck Creek				11.9	5.4	9.4	8.3	7.9	5.0	15.6	9.1
Berners River	11.8	11.9	19.0	19.1	17.7	8.4	12.8	7.5	15.8	9.1	13.3
Taku River	8.1	9.1	13.0	8.8	8.3	8.1	9.9	3.3	7.4	7.2	8.3
Ford Arm	12.9	8.4	14.7	17.1	11.9	8.4	10.0	10.3	15.3	7.4	11.6
Hugh Smith Lake	6.8	13.5	14.5	13.7	10.4	9.1	6.9	9.0	10.5	18.2	11.3
Nakwasina River	6.8	9.5	9.8	11.9	9.9	11.2	11.1	5.3	8.2	6.5	9.0
Average	10.8	13.4	16.3	15.4	12.0	10.1	11.3	7.9	12.3	11.4	11.9

Condition 1 for an unbiased estimate of smolt abundance required that there was no recruitment to the marked population. Recruitment to Nakwasina River via straying coho salmon from other systems, while possible, is unlikely to contribute appreciable recruitment to the stock between marking and recovery. Documented coho salmon straying rates vary between populations (Shaul 2010). Straying appears to occur most frequently within hatchery-reared populations and when geographic distance between systems is minimal. However, straying occurrences have been documented over large geographic distances (245 km), and between wild systems. Of the 1,433 marked coho salmon sampled in Nakwasina River between 2000 and 2009, 100% were verified as tag codes originating from Nakwasina River. Likewise, no marked coho salmon originating from Nakwasina River have been recovered in any other system. The presence of stray coho salmon reared at Medvejie hatchery is possible, but unlikely given the geographical distance between the two sites and the lack of Medvejie origin tag recoveries within Nakwasina River. Additionally, few coho salmon from Medvejie hatchery have been recovered in Salmon Lake, which is much closer to the hatchery release area. The presence of stray coho salmon from adjacent wild stocks is also possible and the true proportion of recruitment into Nakwasina River is unknown.

Vincent-Lang (1993) showed that coho salmon smolt marked as in this project and handled competently suffer no detectable mortality from the experience, so condition 2 was likely satisfied. Also, there is no reason to believe that capture rates for adults was influenced by the code on a tag imbedded deep within its cartilage.

It is unlikely that smolt regenerated the clipped adipose fin that identified the fish as containing a tag, so it is likely that condition 3 was satisfied. In conjunction with tag retention and overnight mortality tests, adipose fin clips on smolt were examined. All smolt examined appeared to have good fin clips. Also, all adult coho examined had well defined or a complete absence of an adipose fin.

Although the assumption that complete mixing occurred could not be tested, coho salmon most likely mixed within or across stocks during their extended time (14 months) at sea. In Nakwasina River catches, the fraction of adult coho salmon with marks (missing an adipose fin) did not vary significantly over time ($\chi^2 = 2.94$, $P = 0.086$, Table 13).

No significant difference in smolt-to-adult survival was detected between tagging groups in 2008–2009. No significant difference was detected between tagging groups and their subsequent recovery as adults in both marine harvest and escapement sampling. Based on these results, either S2 or S3 was satisfied and a Petersen-type model was appropriate for estimating smolt abundance in 2008.

ADULT ESCAPEMENT

The attempted JS experiment failed to produce a viable estimate of escapement because of high variance between sampling periods. For this reason, the peak foot count was expanded to estimate escapement.

FOOT SURVEY COUNTS

Nakwasina River is similar to other clearwater streams in the area, and the relationship between the peak observer count and the total escapement is similar to that found in Steep Creek near Juneau, Alaska (20% in Nakwasina River versus 21% in Steep Creek; Jones III and McPherson

1997; McPherson et al. 1996). The ability to count spawning salmon depends on many factors, including the observer, weather, water clarity, canopy cover, pool-to-riffle ratio, the density of fish, the amount of undercut banks, and the ecology, behavior, size, and color of salmon (Jones III 1995).

Table 13.–Proportion of recovered Nakwasina River adult coho salmon observed with and without adipose fin clips, 2009

Date	No clip	Clip observed	Tagged portion
Sep-03	1	1	0.50
Sep-22	2		0.00
Sep-23	11	4	0.27
Sep-29	11	5	0.31
Oct-06	1	2	0.67
Oct-07	4	1	0.20
Oct-08	2		0.00
Oct-13	9	3	0.25
Oct-14	28	12	0.30
Oct-21	22	11	0.33
Oct-22	20	4	0.17
Oct-27	1		0.00
Oct-28		2	1.00
Nov-02	55	14	0.20
Nov-03	24	8	0.25
Nov-06		1	1.00
Nov-07	7	2	0.22
Nov-08	48	11	0.19
Nov-15	1	1	0.50
Nov-16	10	2	0.17
Nov-23	9	2	0.18
Nov-24	5	1	0.17
Dec-02	4	1	0.20
Grand total	275	88	0.24
Sep 3 – Oct 31	112	45	0.29
Nov 1– Dec 2	163	43	0.21
	χ^2 =	2.94	
	P =	0.086	

HARVEST SAMPLING

To assess the adequacy of sampling rates, troll harvests within Southeast Alaska where Nakwasina River coho salmon recovery occurred were examined (Table 14). The sampling rates for troll fisheries in 2009 ranged from 5% (District 116) to 32% (Districts 109). Because not all fisheries were sampled, it is likely that Nakwasina River coho salmon harvest was undetected in some fisheries, which would result in an underestimated total marine harvest. On average, 50% of the harvest of coded wire tagged coho salmon between 1999 and 2009 occurred by August 20, and 90% were recovered by September 14 (Figure 5).

Nakwasina River coho salmon appear to have later run timing than some of the other streams in the Sitka area. Peak stream counts generally occur in late October or early November in the Nakwasina River, up to a month later than the other five index streams in the Sitka area

(Table 2). Additionally tag recoveries in marine fisheries occur later than Salmon Lake (Figure 6) by approximately a month. Anecdotal information suggests that Katlian River, near Sitka, exhibits similar run timing to the Nakwasina River, but most streams follow a return pattern similar to the other five index streams in the area.

Table 14.–Numbers of fish harvested and sampled for coded wire tag recovery for districts in which Nakwasina River coho salmon were recovered in 2009.

District	Fish harvested	Fish sampled	Proportion sampled
102	71,175	16,300	0.229
109	112,608	35,912	0.319
113	646,374	175,674	0.272
114	130,907	14,470	0.111
116	82,878	4,348	0.052
154	20,980	4,047	0.193
189	12,577	2,278	0.181
Total	1,077,499	253,029	0.235

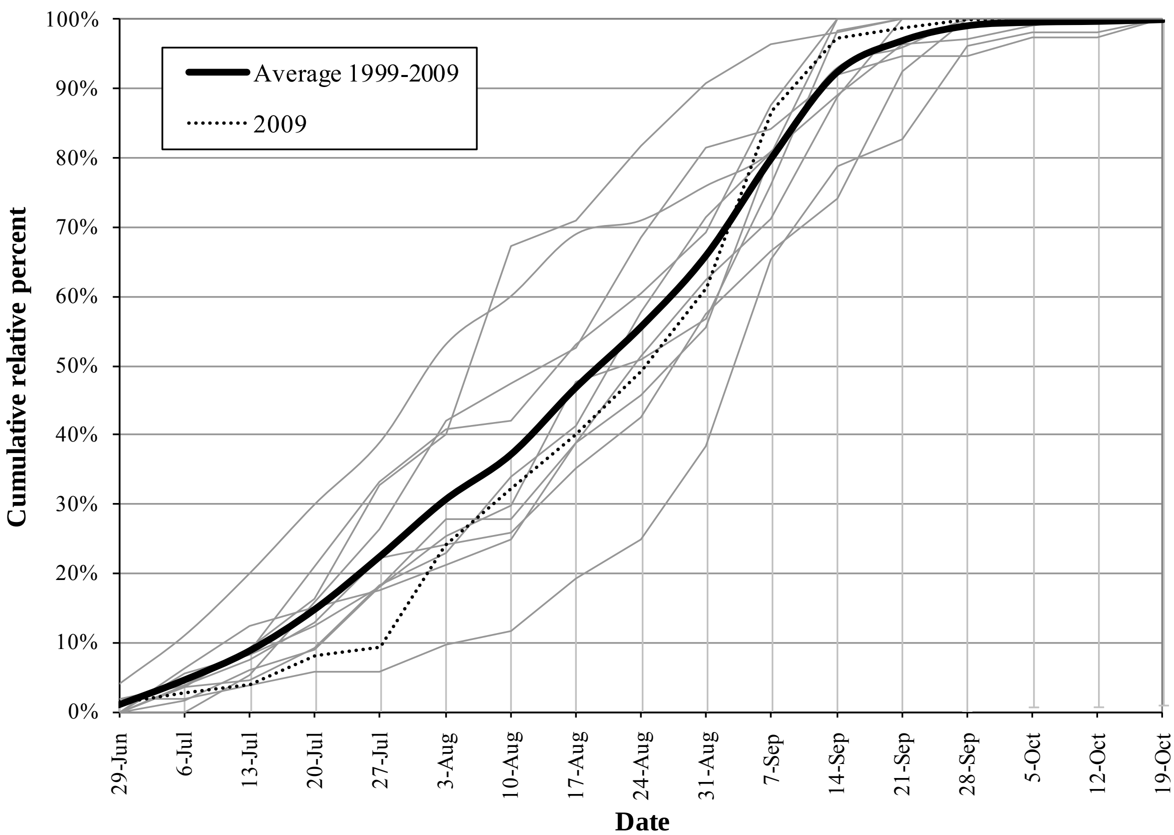

Figure 5.–Cumulative relative percent of Nakwasina River coho salmon coded wire tag returns by date between 1999 and 2009 in marine sport and commercial fisheries.

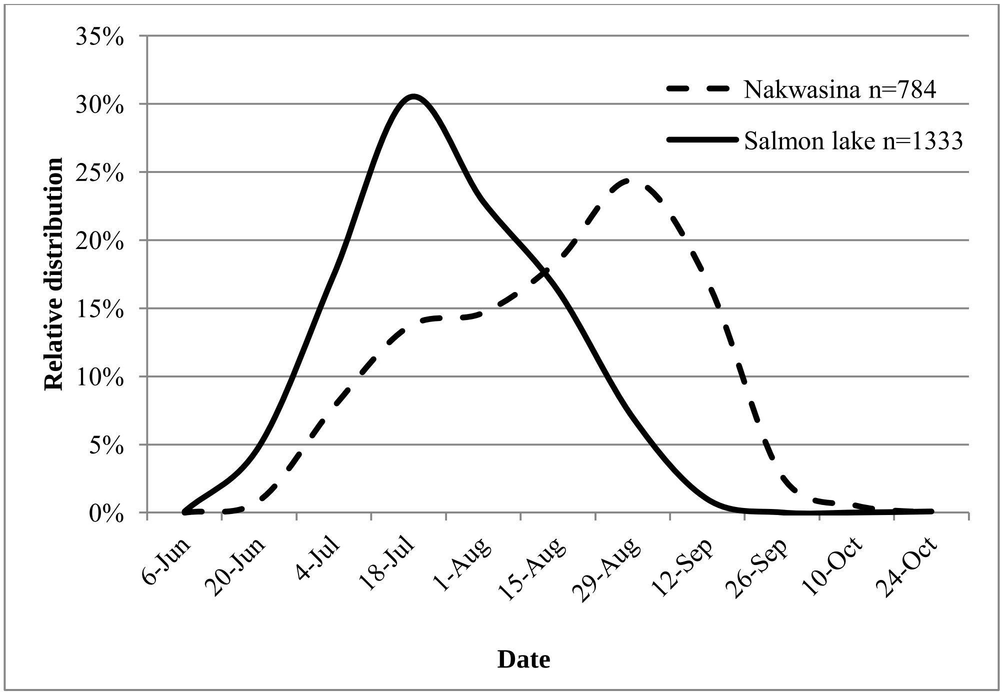

Figure 6.–Relative distribution of coho salmon coded wire tag recoveries by date from the Nakwasina River and Salmon Lake between 1988 and 2009.

EXPANSION FACTOR

As a tool for estimating escapement without the use of a mark-recapture experiment, an expansion factor was developed for the Nakwasina River. Peak counts were compared to escapement for all years that peak counts and escapement were available except 2004, when a peak count was not available due to poor water conditions. During the 7 years compared between 2000 and 2006, estimated escapements ranged between 2,000 and 5,698 fish (Table 1, Figure 7). The resulting expansion factor (as described in Appendix A3) was 4.30 (SE = 0.36).

RECOMMENDATIONS

CONTINUATION OF PROJECT

This project should continue for the estimation of escapement, harvest, smolt abundance, survival, and exploitation. Nakwasina River is the only non-lake system that is used as a full indicator stock in the outside waters of northern Southeast Alaska (Shaul et al. 2008). As such, it is important to the region as an indicator for this specific, non-lake stream habitat. In order to identify trends in abundance, survival and exploitation, a long-term data series is needed. Nakwasina River represents the most complete coho salmon data set in the Sitka area and the continuation of this project would yield the information necessary to establish a biological escapement goal. Additions to the dataset will allow a more comprehensive understanding of variations through time and enable appropriate management action. In addition, the expansion factor that was developed to apply towards Nakwasina River foot surveys will increase in confidence as the dataset grows.

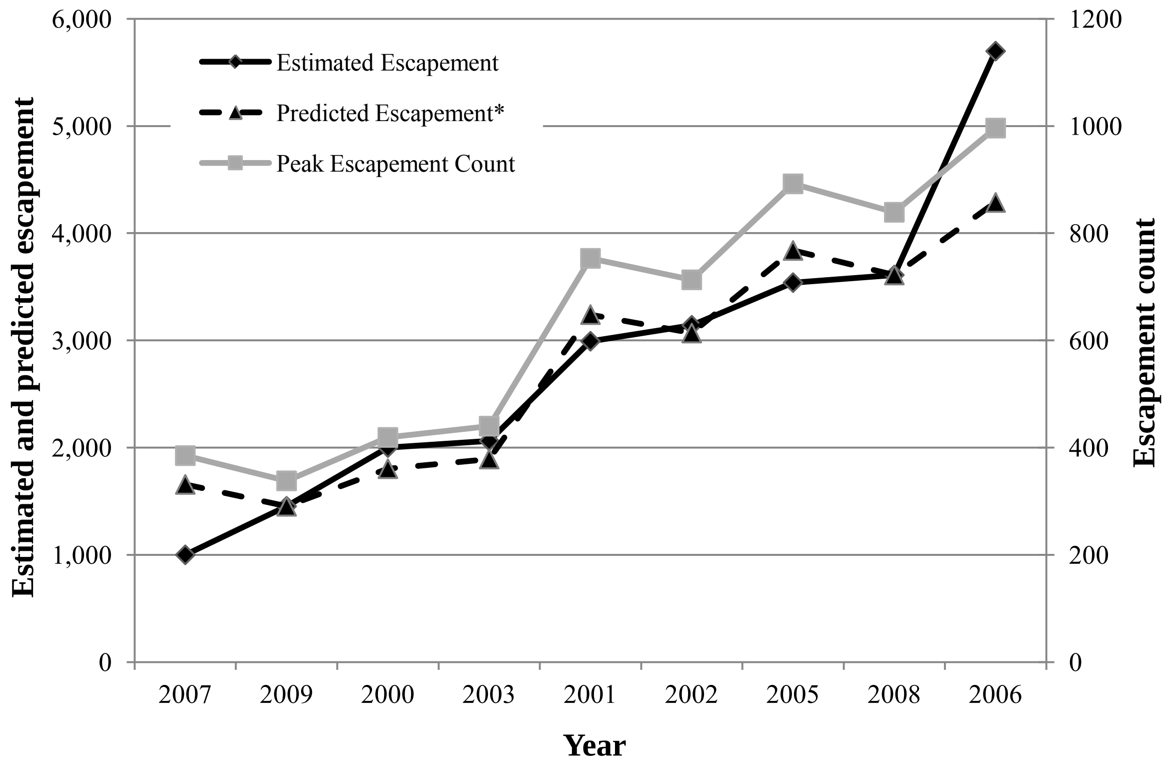

Figure 7.–Estimated escapement, peak counts, and predicted escapement at Nakwasina River, 2000–2009. Predicted escapement was calculated by applying an expansion factor of 4.30 to peak escapement count. In 2008 and 2009 predicted and estimated escapement were based on an expansion of the peak foot count.

DEVELOPMENT OF ADDITIONAL EXPANSION FACTORS

The development of additional expansion factors for the other four coho index streams within the Sitka area may provide the opportunity to estimate trends in abundance and the refinement of escapement goals. Currently, peak counts in the Sitka area are only useful as an index of abundance, but it is unknown how these counts relate to actual escapements. Coho salmon in Southeast Alaska frequently exhibit prolonged run timing during the fall, so the use of open population mark-recapture experiments may be the only way to successfully estimate abundance in these conditions. Comparing peak stream counts on other index systems to an estimated escapement, derived from an open population mark-recapture experiment, would provide an expansion factor that could be used not only to estimate escapement, but would also allow the estimation of escapement for prior years.

TAGGING

In future tagging events, extra care should be taken to ensure that any potential effects of tagging are minimized. Recommendations for future tagging include: 1) releasing smolt in side tributaries with extensive available rearing habitat as opposed to mainstem areas with higher velocities; 2) minimizing transport distances by centralizing the tagging and holding site; 3) returning tagged smolt to locations near their capture site; 4) tagging and sampling all fish within 48 hours of capture to ensure fish are not held for periods greater than 72 hours, including overnight mortality testing; and 5) estimating the true contribution and survival of Bridge Creek smolt in the Nakwasina River adult escapement. This may be accomplished by continuing to operate a weir on Bridge Creek for the duration of the smolt emigration, or by conducting a mark-recapture experiment to estimate the number of smolt in Bridge Creek prior to the migration.

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REFERENCES CITED

Beers, D. E. 1999. Production of coho salmon from Slippery Creek, 1997–1998. Alaska Department of Fish and Game, Fishery Data Series No. 99–46, Anchorage.

Beers, D. E. 2003. Production of coho salmon from Slippery Creek, 2000–2001. Alaska Department of Fish and Game, Fishery Data Series No. 03–08, Anchorage.

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.

Brookover, T. E., P. A. Hansen, and T. A. Tydingco. 2001. Smolt production and adult harvest of coho salmon from the Nakwasina River in Southeast Alaska, 1998–1999. Alaska Department of Fish and Game, Fishery Data Series No. 01–16, Anchorage.

Brookover, T. E., P. A. Hansen, and T. A. Tydingco. 2003. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 1999–2000. Alaska Department of Fish and Game, Fishery Data Series No. 03–25, Anchorage.

Clark, J. E., and D. R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing coded microwire tag recovery from commercial salmon catches in Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 261, Juneau.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

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

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96–32, Anchorage.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95–24, Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97–29 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98–25 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99–41 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01–08, Anchorage.

Hubartt, D. J., M. Jaenicke, and A. E. Bingham. 2002. Harvest estimates for selected marine sport fisheries in Southeast Alaska during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 02–30, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07–40, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09–54, Anchorage.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10–02, Anchorage.

REFERENCES CITED (Continued)

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2008. Alaska Department of Fish and Game, Fishery Data Series No. 10–22, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04–11, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06–34, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06–44, Anchorage.

Jones III, E. L. 1995. Observer variability and bias in estimation of Southeast Alaska pink salmon escapement. Master's thesis. University of Alaska, Fairbanks.

Jones III, E. L., and S. A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97–25, Anchorage.

Jones III, E. L., S. A. McPherson, and A. B. Holm. 1999. Production of coho salmon from the Unuk River, 1997–1998. Alaska Department of Fish and Game, Fishery Data Series No. 99–43, Anchorage.

Jones III, E. L., S. A. McPherson, and A. B. Holm. 2001a. Production of coho salmon from the Unuk River, 1998–1999. Alaska Department of Fish and Game, Fishery Data Series No. 01–10, Anchorage.

Jones III, E. L., J. A. Weller, and A. B. Holm. 2001b. Production of coho salmon from the Unuk River, 1999–2000. Alaska Department of Fish and Game, Fishery Data Series No. 01–14, Anchorage.

Koerner, J. F. 1977. The use of coded wire tag injector under remote field conditions. Alaska Department of fish and Game, Division of Commercial Fisheries, Informational Leaflet No. 172, Juneau.

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.

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.

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.

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.

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.

McPherson, S. A., B. J. Glynn, and E. L. Jones III. 1996. A mark-recapture experiment to estimate the escapement of coho salmon in Steep Creek, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96–31, Anchorage.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1984–1985, Project F-9-17, 26 (SW-I-A), Juneau.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1985–1986, Project F-10-1, 27 (RT-2), Juneau.

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

REFERENCES CITED (Continued)

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90–44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91–58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92–40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93–42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94–28, Anchorage.

Mood, A. M., F. A. Graybill, and D. C. Boes. 1974. Introduction to the theory of statistics, 3rd edition. McGraw-Hill Book Co., New York.

Moser, K. H. 1968. Photographic atlas of sockeye salmon scales. Fishery Bulletin 67(2): 243–279.

Neter, J., W. Wasserman, and M. H. Kutner. 1990. Applied linear statistical models, 3rd edition. Irwin Publishing Company. Homewood, IL.

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

Schmidt, A. E. 1996. Interception of wild Salmon Lake coho salmon by hatchery supported fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 96–26, Anchorage.

Schwartz, C.J., R.J. Bailey, J. Irvine, and F.c. Dalziel. 1993. Estimating salmon escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50:1187–1197.

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

Shaul, L., and K. Crabtree. 1998. Harvests, escapements, migratory patterns, smolt migrations, and survival of coho salmon in Southeast Alaska based on coded wire tagging, 1994–1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 1J98-02, Juneau.

Shaul, L., E. Jones, K. Crabtree, T. Tydingco, S. McCurdy, and B. Elliott. 2008. Coho salmon stock status and escapement goals in Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 08–20, Anchorage.

Shaul, L. D. 2010. Wild and hatchery coded-wire tagged coho salmon recovered as strays in natural spawning escapements in Southeast Alaska, 1976–2007. Alaska Department of Fish and Game, Special Publication No.10-10, Anchorage.

Tydingco, T. 2003. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 2000–2001. Alaska Department of Fish and Game, Fishery Data Series No. 03–19, Anchorage.

Tydingco, T. A. 2005a. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2002–2003. Alaska Department of Fish and Game, Fishery Data Series No. 05–26, Anchorage.

REFERENCES CITED (Continued)

Tydingco, T. A. 2005b. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 2001–2002. Alaska Department of Fish and Game, Fishery Data Series No. 05–04, Anchorage.

Tydingco, T. A. 2006. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2003–2004. Alaska Department of Fish and Game, Fishery Data Series No. 06–66, Anchorage.

Tydingco, T. A. 2010. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2004–2006. Alaska Department of Fish and Game, Fishery Data Series No. 10–21, Anchorage.

Tydingco, T. A., P. A. Fowler. 2010. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2006–2008. Alaska Department of Fish and Game, Fishery Data Series No. 10–44, Anchorage.

Tydingco, T. A., R. E. Chadwick, S. Reifenstuhl, J. Lorrigan, T. Suminski, and D. Reed. 2006. Stock assessment of Salmon Lake sockeye and coho salmon, 2001–2003. Alaska Department of Fish and Game, Fishery Data Series No. 06–35, Anchorage.

Tydingco, T. A., R. E. Chadwick, S. Reifenstuhl, T. Suminski, and D. Reed. 2008. Stock assessment of Salmon Lake coho salmon, 2004–2005. Alaska Department of Fish and Game, Fishery Data Series No. 08–27, Anchorage.

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.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03–05, Anchorage.

Weller, J. A., E. L. Jones III, and A. B. Holm. 2002. Production of coho salmon from the Unuk River, 2000–2001. Alaska Department of Fish and Game, Fishery Data Series 02–29, Anchorage.

Weller, J. L., E. L. Jones III, and A. B. Holm. 2006. Production of coho salmon from the Unuk River, 2003–2004. Alaska Department of Fish and Game, Fishery Data Series No. 06–60, Anchhorage.

Weller, J. L., E. L. Jones III, D. R. Bernard, and A. B. Holm. 2003. Production of coho salmon from the Unuk River, 2001–2002. Alaska Department of Fish and Game, Fishery Data Series No. 03–27, Anchorage.

Yanusz, R. J., S. A. McPherson, and D. R. Bernard. 1999. Production of coho salmon from the Taku River, 1997–1998. Alaska Department of Fish and Game, Fishery Data Series No. 99–34, Anchorage.

APPENDICES

Appendix A.–Brood year, age classes and lengths of coho salmon by year sampled in the Nakwasina River, 2005–2009.

	Brood year	2006	2005	2005	2004	2005	2004	2003	2004	2003	2003	2002	2002	2001
	Sample year	2009		2008		2007			2006				2005	
	Age class	1.1	2.1	1.1	2.1	1.0	1.1	2.1	1.0	2.0	1.1	2.1	1.1	2.1
Females	Sample size	40	1	211	3	-	181	4	-	-	241	7	247	4
	Percent	97.50%	2.44%	98.6%	1.4%	-	97.8%	2.2%	-	-	97.2%	2.8%	98.4%	1.6%
	SE	2.4%	2.4%	0.8%	0.8%	-	1.1%	1.1%	-	-	1.1%	1.1%	0.8%	0.8%
	Mean length	588.6	715	671.8	661.7	-	629.9	662.5	-	-	650.0	663.6	638.7	672.5
	SE	9.8	-	2.3	11.7	-	2.9	10.9	-	-	2.3	20.3	2.2	24.4
Males	Sample size	58	1	259	-	5	180	2	15	1	388	5	373	10
	Percent	98.31%	1.69%	100.0%	-	2.7%	96.3%	1.1%	3.7%	0.2%	94.9%	1.2%	97.4%	2.6%
	SE	1.7%	1.7%	0.0%	-	0.8%	0.8%	0.8%	0.9%	0.2%	1.1%	0.5%	0.8%	0.8%
	Mean length	540.3	580	659.2	-	326.0	605.0	647.5	303.0	320.0	630.0	588.0	622.2	620.0
	SE	9.5	-	3.8	-	8.0	4.4	27.5	10.3	-	3.4	22.7	2.2	24.3
All fish	Sample size	98	2	470	3	5	361	6	15	1	629	12	620	14
	Percent	98.00%	2.00%	99.4%	0.6%	1.3%	97.0%	1.6%	2.3%	0.2%	95.7%	1.8%	97.8%	2.2%
	SE	1.4%	1.4%	0.4%	0.4%		0.7%	0.7%	0.6%	0.2%	0.8%	0.5%	0.6%	0.6%
	Mean length	560.0	647.5	665.5	661.7	326.0	617.5	657.5	303.0	320.0	637.9	632.1	628.8	622.5
	SE	7.3	67.5	2.4	11.7	8.0	2.7	10.4	10.3	-	2.3	18.3	2.2	18.2

Appendix B.–Recoveries of coded wire tags originating from Nakwasina River coho salmon in 2009.

Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
				Random Recoveries					
41683	PURSE	6/29/2009	27	SE	102	20	525	KETCHIKAN	9066198
41682	TROLL	7/11/2009	28	NW	113	71	520	SITKA	9037352
41682	TROLL	7/22/2009	30	NW	113	45	520	SITKA	9037469
41682	TROLL	7/23/2009	30	NW			560	SITKA	9037491
41682	TROLL	7/25/2009	30	NW			550	EXCURSION INLET	9100046
41682	TROLL	7/29/2009	31	NW	114	21	560	PELICAN	9010016
41682	TROLL	8/3/2009	32	NW			505	SITKA	9037576
41681	TROLL	8/4/2009	32	NW			560	EXCURSION INLET	9100064
41682	TROLL	8/4/2009	32	NW	113	45	610	SITKA	9037587
41682	TROLL	8/5/2009	32	NW	113	61	545	SITKA	9037596
41682	TROLL	8/5/2009	32	NW	113	61	550	SITKA	9037596
41682	TROLL	8/6/2009	32	NW	113	61	520	SITKA	9037607
41682	TROLL	8/7/2009	32	NW	113	61	550	SITKA	9037621
41683	TROLL	8/7/2009	32	NW			580	SITKA	9037618
41683	TROLL	8/7/2009	32	NW			585	JUNEAU	9046124
41681	TROLL	8/8/2009	32	NW			605	EXCURSION INLET	9100072
41681	TROLL	8/10/2009	33	NW	113	45	580	SITKA	9037654
41682	TROLL	8/10/2009	33	NW			586	HOONAH	9110092
41683	TROLL	8/10/2009	33	NW	113	71	505	SITKA	9037678
41682	TROLL	8/11/2009	33	NW	113	41	580	SITKA	9037666
41681	TROLL	8/12/2009	33	NW	116		575	JUNEAU	9046126
41682	TROLL	8/13/2009	33	NW			570	SITKA	9037677
41681	TROLL	8/21/2009	34	NW	113	31	605	SITKA	9037765
41682	TROLL	8/21/2009	34	NW			591	HOONAH	9110114
41682	TROLL	8/21/2009	34	NW			858	HOONAH	9110116
41681	TROLL	8/22/2009	34	NW	113	31	560	SITKA	9037753
41682	TROLL	8/22/2009	34	NW	113	31	580	SITKA	9037753
41682	TROLL	8/22/2009	34	NW	113	81	560	SITKA	9037756
41682	TROLL	8/23/2009	35	NW	113	31	585	SITKA	9037807
41682	TROLL	8/23/2009	35	NW	113	31	590	SITKA	9037796
41682	TROLL	8/23/2009	35	NW				SITKA	9037826
41683	TROLL	8/23/2009	35	NW				SITKA	9037826
41683	TROLL	8/25/2009	35	NW	113	91	580	JUNEAU	9046133
41682	TROLL	8/27/2009	35	NW	113		450	SITKA	9037849
41682	TROLL	9/2/2009	36	NW			570	EXCURSION INLET	9100114
41681	TROLL	9/3/2009	36	NW	113		595	SITKA	9037887
41682	TROLL	9/3/2009	36	NW			529	HOONAH	9110151
41682	TROLL	9/4/2009	36	NW	113	81	565	SITKA	9037916
41682	TROLL	9/4/2009	36	NW	113	81	620	SITKA	9037916
41682	TROLL	9/4/2009	36	NW	113		585	SITKA	9037913
41682	TROLL	9/4/2009	36	NW			490	SITKA	9037912
41681	TROLL	9/5/2009	36	NW	113	45	580	SITKA	9037905
41682	TROLL	9/5/2009	36	NW	113	45	550	SITKA	9037905
41682	TROLL	9/6/2009	37	NW	113	71	495	SITKA	9037909
41683	TROLL	9/6/2009	37	NW	113	45	545	SITKA	9037908
41682	TROLL	9/7/2009	37	NW	113	31	535	SITKA	9037937

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Appendix B.–Page 2 of 2.

Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey Site	Sample
Random Recoveries									
41682	TROLL	9/8/2009	37	NW	113	45	490	SITKA	9037953
41682	TROLL	9/8/2009	37	NW	113		560	SITKA	9037940
41682	TROLL	9/8/2009	37	NW	113			SITKA	9037963
41683	TROLL	9/8/2009	37	NW	113	71	550	SITKA	9037956
41683	TROLL	9/8/2009	37	NW	113	71	580	SITKA	9037956
41683	TROLL	9/8/2009	37	NW	113	71	630	SITKA	9037956
41683	TROLL	9/8/2009	37	NW	113		560	SITKA	9037940
41682	TROLL	9/9/2009	37	NE	109		520	SITKA	9037966
41682	TROLL	9/10/2009	37	NW	113	62	540	SITKA	9037982
41682	TROLL	9/10/2009	37	NW	113	62	600	SITKA	9037982
41683	TROLL	9/10/2009	37	NW	189	30	580	YAKUTAT	9146204
41682	TROLL	9/14/2009	38	NW	113	41	565	SITKA	9037992
41683	TROLL	9/14/2009	38	NW	113	41	575	SITKA	9037989
41682	TROLL	9/15/2009	38	NW	113	45	590	SITKA	9038007
41683	TROLL	9/15/2009	38	NW	113	61	590	SITKA	9037997
41682	TROLL	9/16/2009	38	NW	113	61	580	SITKA	9038038
41682	TROLL	9/17/2009	38	NW	113	45	550	SITKA	9038028
41682	TROLL	9/18/2009	38	NW			530	SITKA	9038048
41682	TROLL	9/18/2009	38	NW			600	SITKA	9038048
41682	TROLL	9/28/2009	40	NW	113	93	590	PETERSBURG	9056861
41683	SPORT	7/14/2009	29	NW	113	41	570	SITKA	9035257
41682	SPORT	8/3/2009	32	NW	113	91	560	ELFIN COVE	9025028
41682	SPORT	8/23/2009	35	NW	113	45	570	SITKA	9035381
Select Recoveries									
41682	TROLL	9/8/2009	37	NW	154			SITKA	9039987
41682	TROLL	9/9/2009	37	NW	113	41		SITKA	9039989
41682	TROLL	9/11/2009	37	NW	113	71		KETCHIKAN	9069994
41682	TROLL	9/11/2009	37	NW	113	71		KETCHIKAN	9069994
41682	TROLL	9/11/2009	37	NW	113	71		KETCHIKAN	9069994
41683	TROLL	9/22/2009	39					SITKA	9039986
41682	SPORT	10/12/2009	42	NW	113	41	360	SITKA	9035413

The expansion factor provides a means of predicting escapement in years where only an index count of the escapement is available (i.e., no weir counts or mark-recapture experiments were conducted). The expansion factor is the average over several years of the ratio of the escapement estimate (or weir count) to the index count.

Systems where escapement is known

On systems where escapement can be completely enumerated with weirs or other complete counting methods, the expansion factor is an estimate of the expected value of the "population" of annual expansion factors (π 's) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \pi_y}{k} \tag{1}$$

where $\pi_y = N_y / C_y$ is the observed expansion factor in year *y*, N_y is the known escapement in year *y*, C_y is the index count in year *y*, and *k* is the number of years for which these data are available to calculate an annual expansion factor.

The estimated variance for expansion of index counts needs to reflect two sources of uncertainty for any predicted value of π, (π_p). First is an estimate of the process error (*var*(π); the variation across years in the π's, reflecting, for example, weather or observer-induced effects on how many fish are counted in a survey for a given escapement. Second is the sampling variance of $\bar{\pi}$ (*var*($\bar{\pi}$)), which will decline as we collect more data pairs.

The variance for prediction will be estimated (Neter et al. 1990):

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}) \tag{2}$$

where:

$$v\hat{a}r(\pi) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1} \tag{3}$$

and:

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k(k-1)} \tag{4}$$

such that:

$$v\hat{a}r(\pi_p) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1} + \frac{\sum_{y=1}^{q} (\pi_y - \bar{\pi})^2}{k(k-1)} \tag{5}$$

-continued-

Systems where escapement is estimated

On systems where escapement is estimated, the expansion factor is an estimate of the expected value of the "population" of annual expansion factors (π 's) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \hat{\pi}_y}{k} \qquad (6)$$

where $\hat{\pi}_y = \hat{N}_y / C_y$ is the estimate of the expansion factor in year *y*, $\hat{N}_y$ is the estimated escapement in year *y*, and other terms are as described above.

The variance for prediction will again be estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}) \qquad (7)$$

The estimate of $var(\pi)$ should again reflect only process error. Variation in $\hat{\pi}$ across years, however, represents process error **plus** measurement error within years (e.g. the mark-recapture induced error in escapement estimation) and is described by the relationship (Mood et al. 1974):

$$V(\hat{\pi}) = V[E(\hat{\pi})] + E[V(\hat{\pi})] \qquad (8)$$

This relationship can be rearranged to isolate process error, that is:

$$V[E(\hat{\pi})] = V[\hat{\pi}] - E[V(\hat{\pi})] \qquad (9)$$

An estimate of $var(\pi)$ representing only process error therefore is:

$$v\hat{a}r(\pi) = v\hat{a}r(\hat{\pi}) - \frac{\sum_{y=1}^{k} v\hat{a}r(\hat{\pi}_y)}{k} \qquad (10)$$

Where $v\hat{a}r(\hat{\pi}_y) = v\hat{a}r(\hat{N}_y)/C_y^2$ and $v\hat{a}r(\hat{N}_y)$ is obtained during the experiment when N_y is estimated. We can calculate:

$$v\hat{a}r(\hat{\pi}) = \frac{\sum_{y=1}^{k} (\hat{\pi}_y - \bar{\pi})^2}{k-1} \qquad (11)$$

and we can estimate $var(\bar{\pi})$ similarly to as we did above:

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^{k} (\hat{\pi}_y - \bar{\pi})^2}{k(k-1)} \qquad (12)$$

where both process and measurement errors need to be included.

For large *k* (*k* > 30), equations (11) and (12) provide reasonable parameter estimates, however for small *k* the estimates are imprecise and may result in negative estimates of variance when the results are applied as in equation (7).

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Because k is typically <10, we will estimate $var(\hat{\pi})$ and $var(\overline{\pi})$ using parametric bootstrap techniques Efron and Tibshirani (1993). The sampling distributions for each of the $\hat{\pi}_y$ are modeled using Normal distributions with means $\hat{\pi}_y$ and variances $v\hat{a}r(\hat{\pi}_y)$. At each bootstrap iteration, a bootstrap value $\hat{\pi}_{y(b)}$ is drawn from each of these Normal distributions and the bootstrap value $\hat{\pi}_{(b)}$ is randomly chosen from the k values of $\hat{\pi}_{y(b)}$. Then, a bootstrap sample of size k is drawn from the k values of $\hat{\pi}_{y(b)}$ by sampling with replacement, and the mean of this bootstrap is the bootstrap value $\overline{\pi}_{(b)}$. This procedure is repeated B = 1,000,000 times. We can then estimate $var(\hat{\pi})$ using:

$$v\hat{a}r_B(\hat{\pi}) = \frac{\sum_{b=1}^{B}(\hat{\pi}_{(b)} - \overline{\hat{\pi}_{(b)}})^2}{B-1} \tag{13}$$

where:

$$\overline{\hat{\pi}_{(b)}} = \frac{\sum_{b=1}^{B}\hat{\pi}_{(b)}}{B} \tag{14}$$

And we can calculate $var_B(\overline{\pi})$ using equations (13) and (14) with appropriate substitutions. The variance for prediction is then estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r_B(\hat{\pi}) - \frac{\sum_{y=1}^{k}\text{v}\hat{\text{a}}\text{r}(\hat{\pi}_y)}{k} + v\hat{a}r_B(\overline{\pi}) \tag{15}$$

As the true sampling distributions for the $\hat{\pi}_y$ are typically skewed right, using a Normal distribution to approximate these distributions in the bootstrap process will result in estimates of $var(\hat{\pi})$ and $var(\overline{\pi})$ that are biased slightly high, but simulation studies using values similar to those realized for this application indicated that the bias in equation (15) is < 1%.

Predicting Escapement

In years when an index count (C_p) is available but escapement (N_p) is not known, it can be predicted:

$$\hat{N}_p = \overline{\pi}\, C_p \tag{16}$$

and:

$$v\hat{a}r(\hat{N}_p) = C_p^2 v\hat{a}r(\pi_p) \tag{17}$$

Appendix D.–Data files used to estimate parameters of the Nakwasina River coho salmon population, 2008 through 2009.

Data File[a]	Description
2009AdultCWT_Recoveries.xls	Recovery information from 2009 coded wire tag recoveries in Southeast Alaska.
NakwasinaRiver2009_M-R_and_CWT.xls	Mark, recapture, and coded wire tag recovery information from fish captured in Nakwasina River in 2009.
2009AdultAWL.xls	Age and length information including summary statistics of adult coho captured in Nakwasina River in 2009.
2008SmoltAWLData.xls	2008 smolt raw data including summaries of analyzed data.

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.