Fishery Data Series No. 10-21

Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from Nakwasina River in Southeast Alaska, 2004–2006

by

Troy Tydingco

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska Department of Fish and Game	ADF&G
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)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

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. 10-21

SMOLT PRODUCTION, ADULT HARVEST, AND SPAWNING ESCAPEMENT OF COHO SALMON FROM NAKWASINA RIVER IN SOUTHEAST ALASKA, 2004–2006

by
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ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

In 2004, 2005, and 2006, 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 2004, 9,771 coho salmon smolt ≥70 mm FL were captured in minnow traps, marked with an adipose finclip, given a CWT, and released. During spring 2005, 12,989 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 47,573 in 2004 and 64,164 in 2005. Beach seines, gillnets, and hook and line gear were used to capture immigrant coho salmon during autumn 2005 and 2006. Using Jolly-Seber open population models, the estimated escapements were 3,539 in 2005 and 5,698 in 2006. The peak foot survey counts of 892 in 2005 and 996 in 2006 represented 25.2% and 17.5% of the total estimated escapements. The resulting expansion factors in 2005 and 2006 were 4.0 and 5.7, respectively. Estimated harvests of returning Nakwasina River coho in 2005 and 2006 were 1,801 and 1,416, exploitation rates were 33.7% and 19.8%, and marine survival rates were 11.2% and 11.1%. Estimated total runs (escapement plus harvest) for coho bound for Nakwasina River in 2005 and 2006 were 5,340 and 7,114.

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.

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, and 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. To bridge geographic areas, projects have been implemented more recently for specific stocks, including the Unuk River in southern Southeast (Jones III et al. 1999, 2001; Weller et al. 2002-2003, 2006), Slippery Creek in central Southeast (Beers 1999, 2003), and Chuck Creek (McCurdy 2006) in southern Southeast outside waters. Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and has continued through 2006 (Shaul and Crabtree 1998; Leon Shaul, personal communication, Alaska Department of Fish and Game, Commercial Fisheries Division, Douglas). The Division of Sport Fish also conducted a CWT project to assess fishery impacts to Salmon Lake (near Sitka) coho salmon from 1983 to 1990 and again in 1994–1995 (Schmidt 1996), and 2001–2005 (Tydingco et al. 2006, 2008).

Beginning in 1998 and continuing through 2007, 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. 1999, 2000, 2003; Tydingco 2003, 2005a-b, 2006). Estimated smolt abundance in Nakwasina River from 1998 through 2003 ranged from 22,472 (SE = 1,660) in 2002 to 102,794 (SE = 15,255) in 1998. Estimated harvests of returning adults in 1999–2004 ranged from 604 fish (SE = 109) in 2003 to 1,983 (SE = 354) in 1999 (Table 1).

The objectives of this study were to: (1) estimate the number of coho salmon smolt leaving Nakwasina River in 2004 and 2005; (2) estimate the marine harvests of coho salmon from Nakwasina River stocks in 2005 and 2006 via recovery of CWTs applied in 2004 and 2005; and (3) estimate spawning escapements in 2005 and 2006. As a means to develop a cost-effective way to estimate escapement using foot surveys, an additional task of this project was to define the relationship between the estimated escapements and peak foot survey counts.

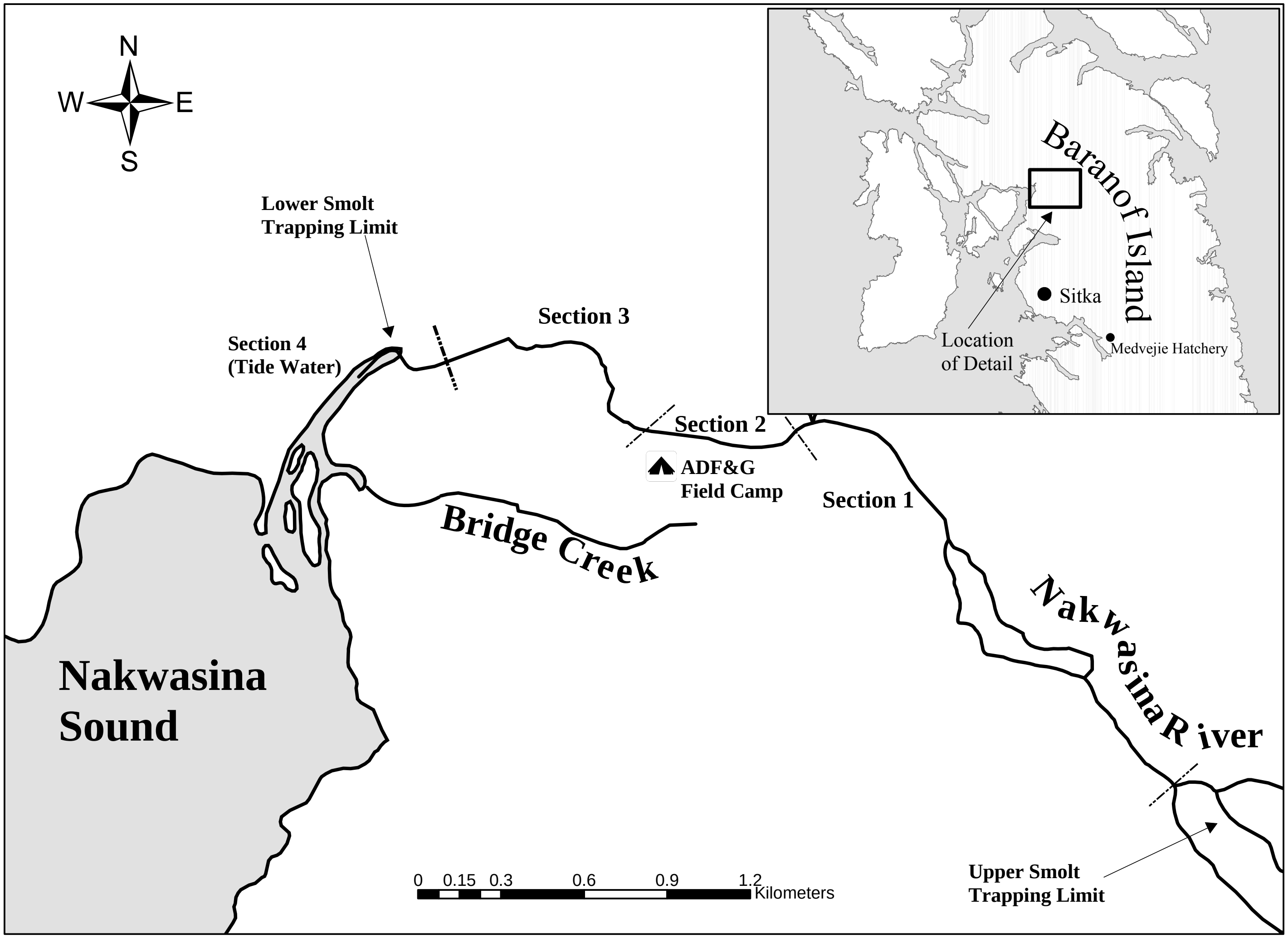

Figure 1.–Map showing Nakwasina River area, including major tributaries and location of ADF&G research sites and stream sections.

Table 1.–Numbers of smolt tagged, smolt abundance with resultant escapement, and harvest from the Nakwasina River 1998–2006.

Year	Smolt tagged	Smolt Abundance Estimate	Smolt SE	Adult Esc	Adult Esc SE	Harvest	Harvest SE	Survival	Exploitation	Theta	Stream survey peak count	Proportion of escapement estimate
1998	9,980	102,794	15,255	-	-	-	-	-	-	-	653	-
1999	3,971	47,571	6,402	-	-	1,983	354	-	-	0.095	291	-
2000	10,120	45,677	2,669	2,000	261	1,219	213	6.80%	0.379	0.082	419	0.21
2001	10,381	43,630	2,660	2,992	510	1,439	155	9.70%	0.325	0.221	753	0.25
2002	5,686	22,472	1,660	3,141	661	731	109	9.80%	0.178	0.237	713	0.23
2003	15,762	55,424	4,023	2,063	233	604	109	11.90%	0.226	0.225	440	0.21
2004	9,771	47,573	3,039	3,867	937	1,645	178	9.90%	0.298	0.286	399	0.10
2005	12,989	64,164	3,105	3,539	817	1,801	226	11.20%	0.337	0.205	892	0.25
2006	10,644	-	-	5,698	749	1,416	167	11.10%	0.198	0.202	996	0.17
Averages	9,923	53,663	4,852	3,329	595	1,355	189	10.06%	0.277	0.194	617	0.20

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 and 30 m wide, and up to 3 m deep. It empties into Nakwasina Sound (57° 15'16.8"W/135° 20'41.5"N) about 23 km north of Sitka. Nakwasina River drains approximately 8,600 ha^2 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 and 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.

Nakwasina River is known locally for its freshwater sport fisheries for coho salmon and Dolly Varden *Salvelinus malma*. As 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. Although the number of respondents was low in the Statewide Harvest Survey (SWHS), estimated annual harvests of coho salmon in Nakwasina Sound, including Nakwasina River, ranged from 0 to 182 fish between 1984 and 2004 (Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007; Mills 1985-1994; Walker et al. 2003). Estimated angler effort expended in Nakwasina Sound and River (for all fish species) ranged from 31 to 891 angler days. Anecdotal information suggests that the harvest in the freshwaters of Nakwasina River may be a couple hundred fish annually.

Since 1980, visual surveys have been conducted by foot on Nakwasina River to provide an indication of trends in the annual abundance of coho salmon. Annual peak counts in Nakwasina River represent the largest of 5 systems surveyed in the Sitka area. Surveys conducted from 1980 to 2006 observed a range of adult coho salmon spawners between 47 (1986) and 996 (2006) (Table 2).

METHODS

SMOLT TAGGING AND SAMPLING

From April 15 to May 19, 2004, and April 14 to May 20, 2005, 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 in 2004 ≥70 mm FL and ≥65 mm FL in 2005 were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden) and small coho fry (<70 mm FL in 2004 and <65 mm FL in 2005) were counted and released onsite.

Every 2–3 days, all live coho salmon smolt were tranquilized with a solution of tricane methane-sulfonate (MS-222) 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 prior to release. To test for tag retention, 100 fish were randomly selected and passed through a Northwest Marine Mark IV Portable Sampling Detector™[1]. If tag retention was 98% or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97% or less, untagged fish 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* that were submitted to ADF&G Commercial Fisheries Division (CFD) 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

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Table 2.–Peak escapement counts of coho salmon in the Sitka area, 1980–2006.

	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	Snorkel	11 Oct	48	Snorkel	29 Oct	27	Snorkel	8 Oct	167				Helo	4 Oct	1,590	Snorkel	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	Snorkel	8 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
Mean (1980–2006)			113			86			162			334			807			464
5-yr mean (200–2006)			120			113			185			575			927			688

smolt (≥70 mm in 2004 and ≥65 mm in 2005 but less than 85 mm FL) were tagged with codes 04-08-66 in 2004 and 04-10-03 in 2005, while large smolt (≥85 mm FL) were tagged with codes 04-08-67 and 04-10-04. These tag codes were used to identify potential differential survival based on size at smolting. A third tag code (04-08-68 in 2004 and 04-10-05 in 2005) was used for all fish ≥65 mm or ≥70 mm 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 and to examine differential survival by location of capture.

Smolt were measured to the nearest 1 mm FL, 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 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

Each fall in 2005 and 2006, an open population mark–recapture experiment was used 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 9 through December 6, 2005, and August 30 through December 11, 2006. 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 gillnet. 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) 7.75 downstream to rkm 4.1. The portion of the river upstream of rkm 7.75 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 4.1 downstream to rkm 3.7, and section 3 extended from rkm 3.7 to rkm 3.4. Section 4 extended from rkm 3.4 to tidewater. Sampling was concentrated in sections 2 and 3 because 2 large pools located there 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 gillnet.

All coho salmon captured were examined for presence or absence of their adipose fin. Initially, every coho salmon lacking an adipose fin was sacrificed, and its head was removed and sent to the Tag Lab for dissection and decoding. After a sufficient number of adipose-clipped individuals had been sacrificed to ensure desired statistical accuracy, sacrifices were reduced to every other coho lacking an adipose fin. This was done to minimize the removal of adult spawners. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent this combination were measured to the nearest mm FL, tagged with uniquely numbered Floy™ T-Bar anchor tag, 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 recaptured 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 and recorded, and heads were removed if the adipose fin was missing. The left side of carcasses was slashed to prevent double sampling.

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 CFD port-sampling program examined commercially-caught fish at processing locations and recovered coho salmon with missing adipose fins (Oliver *Unpublished*). 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 each year. 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.

ESTIMATE OF SMOLT ABUNDANCE AND SIZE

Chapman’s modification of the Petersen estimator (Seber 1982) was used to estimate smolt abundance. Several conditions must 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 marking event are present in the population of fish inspected for marks as adults;
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 one 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 one 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.

These conditions were evaluated, where possible, using experimental data and in some cases by indirect knowledge, or 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 Tag 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 since 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

The escapements of adult (age .1) coho salmon in Nakwasina River were estimated from a Jolly-Seber (JS) experiment (Seber 1982) using the model described by Schwarz et al. (1993). Sub-adult (age .0) coho salmon were much smaller than adults and were ignored. Weekly sampling trips spanning the time of immigration were conducted to mark and recapture adults. Following the work of Sykes and Botsford (1986), repeated recaptures of carcasses "captured" in a decayed condition were not included. Carcasses found were slashed along the left side to prevent double sampling.

In general, escapement (E) is the total number of immigrants (B_i) between the first and last sampling occasion, including fish that enter the system and die between any 2 sampling occasions (i), and fish that enter before the first sampling occasion (B_0) and after the last sampling occasion (B_s): $\hat{E} = \hat{B}_0 + ... + \hat{B}_{s-2} + \hat{B}_{s-1} + B_s$. Because sampling began early in immigration and continued until it was virtually over, $B_0 + B_1$ was estimated from an estimate of abundance just before the second JS sampling event ($\hat{N}_2$) and ignored immigration B_{s+1} and beyond as suggested by Schwarz et al (1993). The resulting (albeit negatively biased) estimator is thus:

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + \ldots + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \tag{4}$$

where $\hat{B}_i$ are JS estimates of the number of fish present at sample time $i+1$ that immigrated between i and $i+1$, $\hat{\phi}_i$ is the survival rate from i to $i+1$, and the factors $\frac{log(\phi_i)}{\phi_i - 1}$ account for fish that enter and die between samples under the assumption that mortality is uniformly distributed between sampling events. The computer program POPAN (Arnason and Schwarz 1995) was used to estimate the JS parameters, and out-of-bounds estimates were constrained to admissible values (Schwarz et al. 1993; Schwarz and Arnason 1996). Variance of escapement was estimated using the delta method and the asymptotic variance and covariances in Schwarz et al. (1993), and expected values of the sampling statistics from POPAN.

Assumptions of the standard (full) JS model (Seber 1982) include:

1. every fish in the population has the same probability of capture in the i^{th} sample;
2. every marked fish has the same probability of surviving from the i^{th} to the $(i+1)^{th}$ sample and being in the population at the time of the $(i+1)^{th}$ sample;
3. every fish caught in the i^{th} sample has the same probability of being returned to the population;
4. marked fish do not lose their marks between sampling events and all marks are reported on recovery; and
5. all samples are instantaneous (sampling time is negligible).

Chi-square goodness-of-fit tests were used to test for homogenous capture and survival probabilities by tagged status (Pollock et al. 1990). The first test is equivalent to the Robson (1969) test for short-term mortality. The second test is reported to be better at detecting heterogeneous survival probabilities (Pollock et al. 1990). The sum of the χ^2 from each test is an overall test statistic for violations of the first 3 assumptions above (equal probability of capture, survival, and return to the population).

The equal probability of capture assumption can also be violated if sampling is size or sex selective. Although differences in the size of adult coho salmon are small, a hypothesis that fish of different sizes were captured with equal probabilities was tested by using Kolmogorov-Smirnov (K-S) 2-sample tests (Conover 1980). Sex-selective sampling was investigated using contingency table analysis with a χ^2 test statistic (Cochran 1977) comparing the number of males and females marked with those recaptured.

Assumptions 3, 4, and 5 were thought to be robust in this experiment. With regard to assumption 3, the only fish that are not returned to the experiment during sampling are those with missing adipose fin, indicating the presence of a coded wire tag. There is no reason to believe the presence or absence of a coded wire tag imbedded deep in cartilage has any effect on adult inriver survival, spawning activity, or the probability that a fish is captured during inriver sampling. With regard to assumption 4, the combination of opercle punch and anchor tag marks and diligent inspection of all fish sampled has been sufficient to ensure that an accurate capture history is recorded for each fish sampled. With regard to assumption 5, the ability to observe multiple recaptures over the course of the experiment indicates that fish persist in the sampling sections across several sampling events, so while sampling events occupy 2–3 days per week, the potential for bias due to sampling not being "instantaneous" is negligible.

AGE AND SEX COMPOSITION

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

$$\hat{p}_j = \frac{n_j}{n} \tag{5}$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{6}$$

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 due 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 2005 and 2006 and the associated exploitation rate in commercial and sport fisheries are based on the sum of the estimated harvest and escapement:

$$\hat{N}_R = \hat{H} + \hat{E} \quad (7)$$

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

$$Var[\hat{N}_R] = Var[\hat{H}] + Var[\hat{E}] \quad (8)$$

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

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \quad (9)$$

$$Var[\hat{U}] \approx \frac{Var[\hat{H}]\hat{E}^2}{\hat{N}_R^4} + \frac{Var[\hat{E}]\hat{H}^2}{\hat{N}_R^4} \quad (10)$$

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

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \quad (11)$$

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

RESULTS

Smolt Tagging, Sampling, and Abundance

2004

Smolt abundance in 2004 was estimated to be 47,573 (SE = 3,039). From April 15 to May 19, 2004, 9,796 coho smolt from Nakwasina River and its tributaries were captured and marked with a CWT. Tag retention was 100.0% with 25 overnight mortalities. This left 9,771 valid tag releases. Of these, 5,165 (52.9%) were small smolt captured in the mainstem of Nakwasina River (Table 3), while 2,692 (27.5%) were large smolt. Twenty percent (19.6%), or 1,914, were fish ≥70 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina River that were age-1. fish (those rearing for one year in fresh water) comprised 98% of sampled smolt and averaged 83.1 mm FL (SE = 0.53) and 5.7 g (SE = 0.13, Table 4). Age-2. coho smolt from mainstem Nakwasina averaged 99.3 mm FL (SE = 2.18) and 9.3 g (SE = 0.79). The combined catch averaged 83.4 mm FL (SE = 0.53) and 5.8 g (SE = 0.13). Average length and weight of captured coho remained approximately the same throughout the tagging effort.

Age-1. fish from Bridge Creek comprised 99% of sampled smolt and averaged 86.3 mm FL (SE = 1.10) and 6.5 g (SE = 0.28, Table 4). One age-2. coho smolt was sampled from Bridge Creek and measured 108 mm and weighed 11.2 g.

The proportions of smolt tagged in 2004 with each of 3 tag codes were not significantly different than that observed in the spawning escapement in 2005 (χ^2 = 0.51, P = 0.775, Table 3). Additionally, no differences were detected when large and small smolt from Nakwasina River were combined and compared to those tagged in Bridge Creek (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 = 0.34, P = 0.560, Table 3). Tagged adults from Bridge Creek were included to estimate smolt abundance because their survival was similar to fish tagged in Nakwasina River.

Table 3.–Numbers and χ2 tests for independence for smolt and adult coho salmon from the Nakwasina River and Bridge Creek, 2000–2006.

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%
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%
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%
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%

Component 1	Component 2	χ2	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
Smolt 2001	All adults 2002	36.95	0.000
Smolt 2001	Adult escapement 2002	20.24	0.000
Adult fisheries 2002	Adult escapement 2002	11.46	0.003
Smolt 2002	All adults 2003	7.34	0.026
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	3.62	0.057
Nakwasina small smolt 2003	Nakwasina large smolt 2003	18.09	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	2.155	0.342
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	1.89	0.169
Nakwasina fisheries 2006	Nakwasina escapement 2006	13.17	0.001

[a] In 2003 and 2005 smolt ≥65 mm were tagged.

Table 4.–Estimated fork length, weight, and age of coho salmon smolt from Nakwasina River and Bridge Creek in 2004 and 2005.

	2004[a]									
	Nakwasina						Bridge Creek			
	Age-1.		Age-2.		Combined		Age-1.		Age-2.	
Statistic	Length[b]	Weight[b]	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Mean	83.13	5.74	99.25	9.25	83.37	5.79	86.34	6.49	108	11.2
SE	0.527	0.125	2.175	0.786	0.533	0.127	1.096	0.280	-	-
Sample size	266	265	4	4	270	269	76	76	1	1
	2005[a]									
	Nakwasina						Bridge Creek			
	Age-1.		Age-2.		Combined		Age-1.		Age-2.	
Statistic	Length[b]	Weight[b]	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Mean	78.57	4.92	108.50	12.75	78.74	4.97	83.52	5.61	-	-
SE	0.509	0.101	3.500	1.950	0.521	0.105	0.762	0.157	-	-
Sample size	347	347	2	2	349	349	145	145	-	-

[a] Minimum tagging size was 70 mm FL in 2004 and 65 mm FL in 2005.

[b] Length measured to the nearest mm FL and weight to the nearest 0.10 g.

2005

Smolt abundance in 2005 was estimated to be 64,164 (SE = 3,105). Between April 14 and May 20, 2005, 13,024 coho smolt from Nakwasina River and its tributaries were captured and marked with a CWT. Tag retention was 99.9% with 30 overnight mortalities. This left 12,989 valid tag releases. Of these, 7,158 (55.1%) were small smolt captured in the mainstem of Nakwasina River, while 2,083 (16.0%) were large smolt (Table 3). Twenty-nine percent (28.9%), or 3,748 were fish ≥65 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina River that were age-1. fish comprised 99% of sampled smolt and averaged 78.6 mm FL (SE = 0.51) and 4.9 g (SE = 0.10, Table 4). Age-2. coho smolt from mainstem Nakwasina averaged 108.5 mm FL (SE = 3.5) and 12.8 g (SE = 1.95). The combined catch averaged 78.7 mm FL (SE = 0.52) and 5.0 g (SE = 0.11). Average length and weight of captured coho remained approximately the same throughout the tagging effort.

Age-1. fish from Bridge Creek comprised 100% of sampled smolt and averaged 83.5 mm FL (SE = 7.6) and 5.6 g (SE = 0.16, Table 4).

The proportions of smolt tagged in 2005 with each of 3 tag codes were not significantly different than that observed in the spawning escapement in 2006 (χ^2 = 2.34, P < 0.311, Table 3). Additionally, no differences were detected when large and small smolt from Nakwasina were combined and compared to those tagged in Bridge Creek (χ^2 = 2.03, P = 0.155, 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 = 1.89, P = 0.169, Table 3). Tagged adults from Bridge Creek were included to estimate smolt abundance because their survival was similar to fish tagged in Nakwasina River.

INSTREAM CODED WIRE TAG RECOVERY AND AGE-SEX COMPOSITION

2005

The CWT marked fraction of adult coho salmon sampled in Nakwasina River during 2005 was 0.205. Of the 921 adult coho salmon examined, 189 had an adipose finclip. Of these, 9 did not contain a coded wire tag and 8 were released alive.

The proportion of freshwater age-1. fish was not significantly different (χ^2 = 0.70, P = 0.404) between smolt sampled in 2004 and adults sampled inriver during 2005 (Table 5, Appendix A1). Both groups were predominately (>97%) freshwater age-1. fish. Additionally, no differences were detected in freshwater age by sex (χ^2 = 0.73, P = 0.394).

2006

The CWT marked fraction of adult coho salmon sampled in Nakwasina River during 2006 was 0.202. Of the 1,634 adult coho salmon examined, 330 had an adipose finclip. Of these, 166 were sacrificed for tag analysis. Of the 166, 165 were successfully decoded and contained a valid Nakwasina River tag. One fish did not contain a coded wire tag. One hundred sixty-four (164) fish were released alive.

The proportion of freshwater age-1. fish was not significantly different (χ^2 = 0.89, P = 0.345) between smolt sampled in 2005 and adults sampled inriver during 2006 (Table 5, Appendix A1). Both groups were predominately (>97%) freshwater age-1. fish. Additionally, no differences were detected in freshwater age by sex (χ^2 = 1.99, P = 0.158).

CONTRIBUTION TO MARINE FISHERIES

2005

The estimated harvest of Nakwasina River coho salmon in randomly sampled marine fisheries in 2005 was 1,796 (SE = 226, Table 6). Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,357,614, Table 6) for the areas in which Nakwasina River fish were recovered. The estimated total contribution to the marine sport fishery by Nakwasina coho was 138 fish. Sport-caught Nakwasina coho salmon comprised 12% (Figure 2) of total harvest of that stock in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.34%) than the troll harvest (0.12%). Estimates of freshwater harvest of coho salmon in Nakwasina River based on the SWHS are not considered reliable because of a low response rate. Anecdotal information, collected from angler

Table 5.–Number of age-1. and age-2. coho salmon smolt and adults, 2004–2006.

		Brood year and age class							
	Sample year	2006					2005		
	Brood year	2004	2003	2003	2002	Total aged	2002	2001	Total aged
	Age class	1.0	2.0	1.1	2.1		1.1	2.1	
Females	Sample size	-	-	241	7	248	247	4	251
	Percent	-	-	97.2%	2.8%		98.4%	1.6%	
	SE	-	-	1.1%	1.1%		0.8%	0.8%	
	Mean length	-	-	650.0	663.6		638.7	672.5	
	SE	-	-	2.3	20.3		2.2	24.4	
Males	Sample size	15	1	388	5	393	373	10	383
	Percent	3.7%	0.2%	94.9%	1.2%		97.4%	2.6%	
	SE	0.9%	0.2%	1.1%	0.5%		0.8%	0.8%	
	Mean length	303.0	320.0	630.0	588.0		622.2	620.0	
	SE	10.3	-	3.4	22.7		2.2	24.3	
All Fish	Sample size	15	1	629	12	641	620	14	634
	Percent	2.3%	0.2%	95.7%	1.8%		97.8%	2.2%	
	SE	0.6%	0.2%	0.8%	0.5%		0.6%	0.6%	
	Mean length	303.0	320.0	637.9	632.1		628.8	622.5	
	SE	10.3	-	2.3	18.3		2.2	18.2	

	Freshwater age[a]			
	1	2	$\chi 2$	P-value
Adults 2005	620	14	0.70	0.4044
Smolt 2004	342	5		
Adults 2006	630	14	0.89	0.3447
Smolt 2005	488	7		
2005 adult males	373	10	0.73	0.3939
2005 adult females	247	4		
2006 adult males	388	5	1.99	0.1584
2006 adult females	241	7		

[a] Differences between χ^2 observations and age class sample sizes are due to unreadability of fresh or saltwater ages.

Table 6.–Estimated harvest of adult Nakwasina River coho salmon in sport and commercial fisheries sampled in 2005 and 2006.

2006											
TROLL FISHERY											
Period	Dates	Quadrant	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
3	6/25–8/12	NE	103,856	28,143	312	308	205	205	1	19	18
3	8/14–9/10	NW	469,803	134,965	1,476	1,413	1,033	1,033	19	344	79
3	8/14–9/10	SE	74,432	24,050	211	202	124	124	2	32	22
4	8/13–9/7	NE	106,264	27,849	333	327	244	244	2	39	27
4	8/13–9/7	NW	405,754	96,590	1,568	1,519	1,270	1,269	32	692	124
Subtotal troll fishery			1,160,109	311,597	3,900	3,769	2,876	2,875	56	1,125	152
SPORT FISHERY											
Bi-week	Dates	Area	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
14	7/14–7/15	SITKA	2,800	1,681	16	16	14	14	1	8	8
15	7/16–7/29	SITKA	10,000	3,250	32	32	23	23	5	77	33
16	7/30–8/12	SITKA	12,385	4,180	37	37	33	33	4	59	29
17	8/13–8/26	SITKA	10,590	4,805	44	44	38	38	5	55	24
18	8/27–9/9	SITKA	4,720	802	21	21	19	19	1	29	29
19	9/10–9/23	SITKA	610	110	2	2	2	2	2	55	38
Subtotal sport fishery			41,105	14,828	152	152	129	129	18	283	70
Total all fisheries			1,201,214	326,425	4,052	3,921	3,005	3,004	74	1,409	167
2005											
TROLL FISHERY											
Period	Dates	Quadrant	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
3	6/26–8/13	NW	646,267	181,111	2,238	2,194	1,614	1,609	19	339	79
4	8/14–9/10	NE	69,947	16,812	238	238	185	185	1	20	20
4	8/14–9/10	NW	405,055	102,640	1,420	1,404	1,131	1,128	22	430	93
4	8/14–9/10	SE	67,343	9,134	119	118	79	79	23	836	180
5	9/11–10/1	NW	127,713	39,415	737	729	571	571	1	16	16
Subtotal troll fishery			1,316,325	349,112	4,752	4,683	3,580	3,572	66	1,642	219
PURSE SEINE FISHERY											
Week	Dates	Quadrant	Estimated Harvest	Inspected	a	a'	t	t'	m	r	SE{r}
34	8/14–8/20	NW	832	500	9	9	5	5	2	16	11
Subtotal seine fishery			832	500	9	9	5	5	2	16	11
SPORT FISHERY											
Bi-week	Dates	Area	Estimated Harvest	Inspected	a	a'	t	t'	m	r	SE{r}
16	8/1–8/14	SITKA	17,411	4,973	101	100	85	85	1	17	17
17	8/15–8/28	SITKA	16,823	5,161	66	65	61	61	5	81	35
18	8/29–9/11	SITKA	6,223	762	10	10	9	9	1	40	39
Subtotal sport fishery			40,457	10,896	177	175	155	155	7	138	56
Total all fisheries			1,357,614	360,508	4,938	4,867	3,740	3,732	75	1,796	226

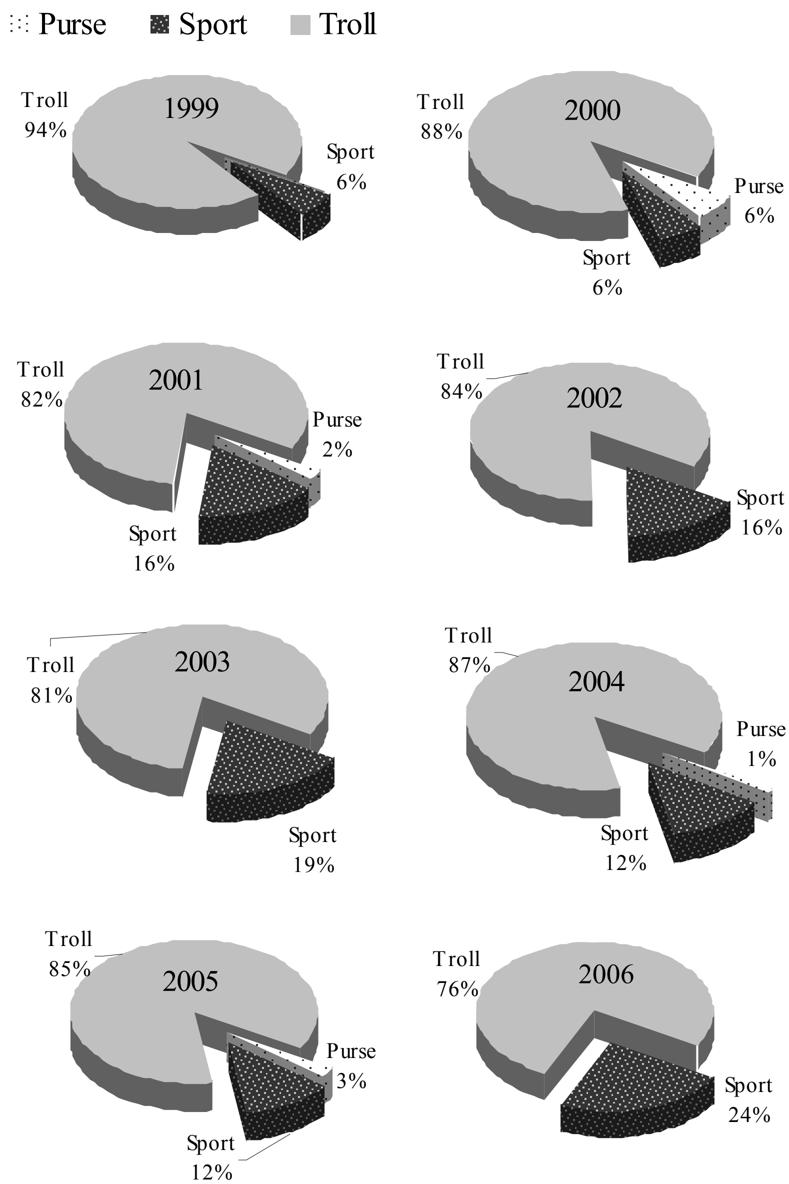

Figure 2.–Portion of Nakwasina coho harvest by fishery, 1999–2006.

reports and observation, suggests that in 2005 a few hundred fish were harvested in the freshwater of Nakwasina River.

In 2005, 77 CWTs from Nakwasina River and Bridge Creek were randomly recovered from 360,508 coho salmon sampled in commercial and sport fisheries and 2 additional CWTs were selectively recovered (Appendix A2). Sixty-six coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries. Of the 66 random troll fishery recoveries with quadrant information 42 were caught in the Northwest Quadrant (Figure 3) of Southeast Alaska between June 26 and October 1, 2005. Seven coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between August 1 and September 11. Two fish were randomly recovered in the commercial seine fishery in the Northwest Quadrant in stat week 34. Two coho salmon bearing CWTs were recovered in the Yakutat

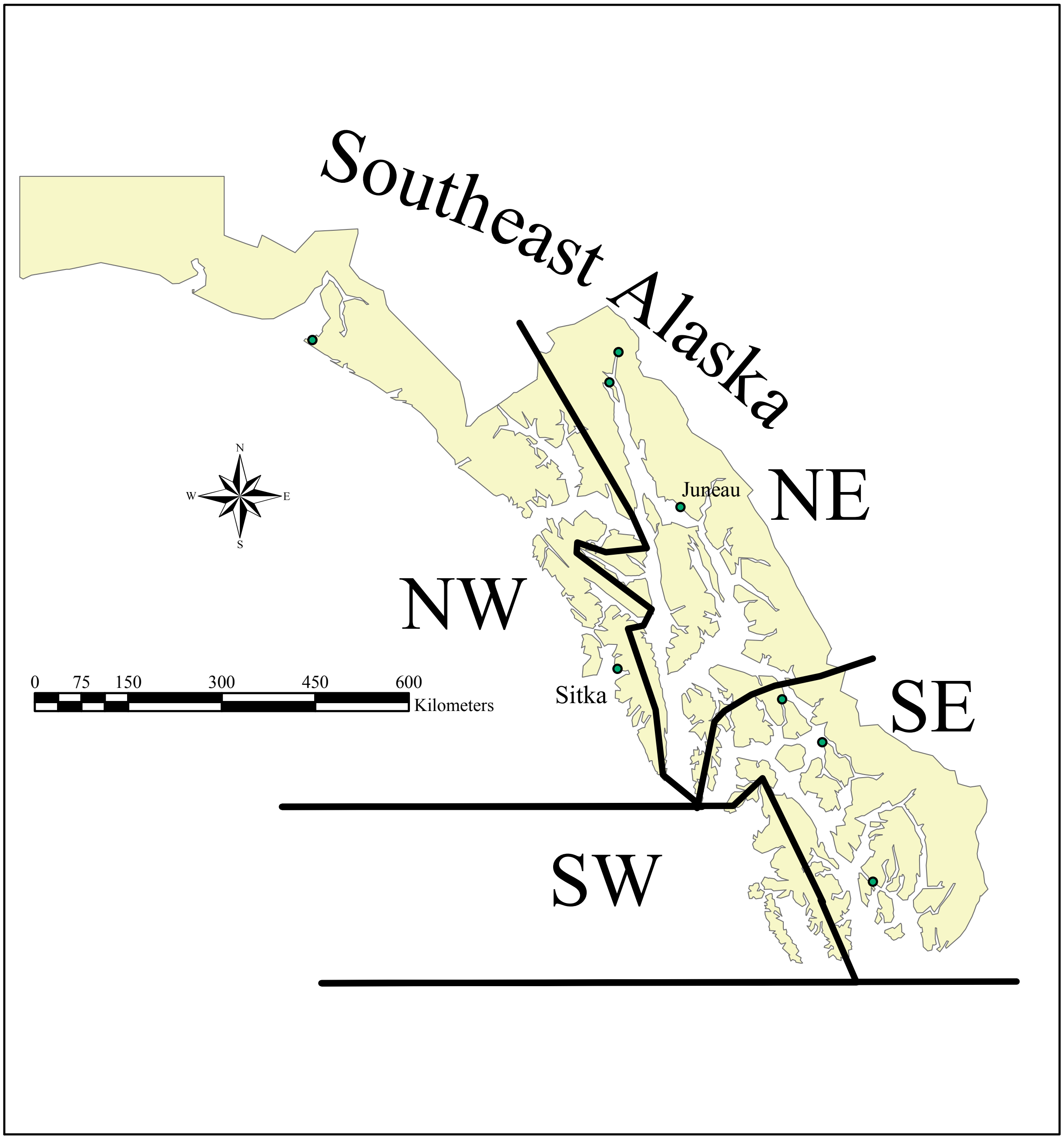

Figure 3.–Map of Southeast Alaska showing the boundaries for CWT quadrants.

sport fishery on September 3, 2005. Although these 2 fish were recovered randomly, the total catch and number samples were not available for that stratum. These 2 fish were not used in expanding harvest, but were added to the total estimated harvest along with one random recovery lacking quadrant data, and 2 selective recoveries making the total estimated harvest 1,801.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 639 mm FL (SE = 5.12).

2006

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2006 was 1,409 (SE = 167, Table 6). In 2006, 74 CWTs from Nakwasina River and Bridge Creek were randomly recovered from 326,425 coho salmon sampled in the commercial and sport fisheries and 5 additional CWTs were selectively recovered (Appendix A2). Fifty-six coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries, and an additional 2 fish were recovered that did not have associated quadrant data. Of the 56 random troll fishery recoveries with quadrant information, all but 5 were caught in the Northwest Quadrant (Figure 3) of Southeast Alaska between June 25 and September 7, 2006. Eighteen coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between July 14 and September 11. The additional 5 selectively recovered fish and 2 fish without quadrant information were added to the harvest estimate to bring the total estimated harvest to 1,416.

Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,201,214, Table 6) for the areas in which Nakwasina River fish were recovered. The estimated total contribution to the marine sport fishery by Nakwasina coho was 283 fish. Sport-caught Nakwasina coho salmon comprised 24% of the harvest of that stock in the sampled marine fisheries (Figure 2), but relative contributions were higher for the sport harvest (0.69%) than the troll harvest (0.10%). Approximately 50% of recovered coded wire tagged coho of Nakwasina origin in marine fisheries are recovered by the third week in August annually (Figure 4). Estimates of freshwater harvest of coho salmon in Nakwasina River based on the SWHS are not considered reliable because of a low response rate. Anecdotal information, collected from angler reports and onsite observation, suggests that in 2006 a few hundred fish were harvested in the freshwater of Nakwasina River.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 683 mm FL (SE = 5.77).

ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

2005

The estimated spawning escapement of coho salmon in Nakwasina River in 2005 was 3,539 fish (SE = 817). Coho salmon were marked and recaptured in all 13 weeks (September 9–December 6) of the study. Altogether, sampling resulted in 1,073 fish captures: 920 unique adults were captured and examined and 153 were recaptures (Table 7, Appendix A3). No recaptured fish lost their numbered tag as evidenced by the operculum punches. A total of 193 fish were sacrificed for their CWTs or died on capture and 1 fish died upon recapture. Most adult coho captured in Nakwasina River in 2005 were captured with either the beach seine or gillnet, while 90 were captured with hook-and-line. Hook-and-line gear was moderately effective at capturing fish, but only when water conditions allowed for sighting fish.

Instream abundance peaked at 2,050 adults in week 45 and declined to 58 fish in week 50 (Table 8). Period-to-period survival rates varied from 0.04 to 1.0 (constrained, Table 8). Two estimates of survival and 5 estimates of recruitment were constrained to yield admissible (realistic) values during the estimation procedure.

Goodness-of-fit tests suggested some potential for capture heterogeneity or handling mortality. Specifically, it appears that fish first captured prior to period 44 and in period 44 were significantly more likely to be seen later in the experiment than fish caught and marked for the first time during period 44. In contrast, fish caught prior to period 45 and in period 45 were significantly less likely to be seen later in the experiment than fish caught and marked for the first time during period 45 (Table 9, component 1). These test results do not indicate a clear pattern in capture heterogeneity or handling mortality.

Nineteen (19.5%) of the sample was captured or recovered in section 1, 56.1% at section 2, 22.9% at section 3, and 1.5% at tidewater (Table 10). In total, 14.3% of the fish inspected for Floy™ tags had either a tag or a secondary mark. The probability of capturing a tagged fish was significantly different in section 1 versus section 2 (χ^2 = 15.9, P < 0.0001) and section 1 versus section 3 (χ^2 = 26.4, P < 0.0001).

Length distributions of adult coho salmon captured in 2005 in Nakwasina River did not appear to be different between capture and

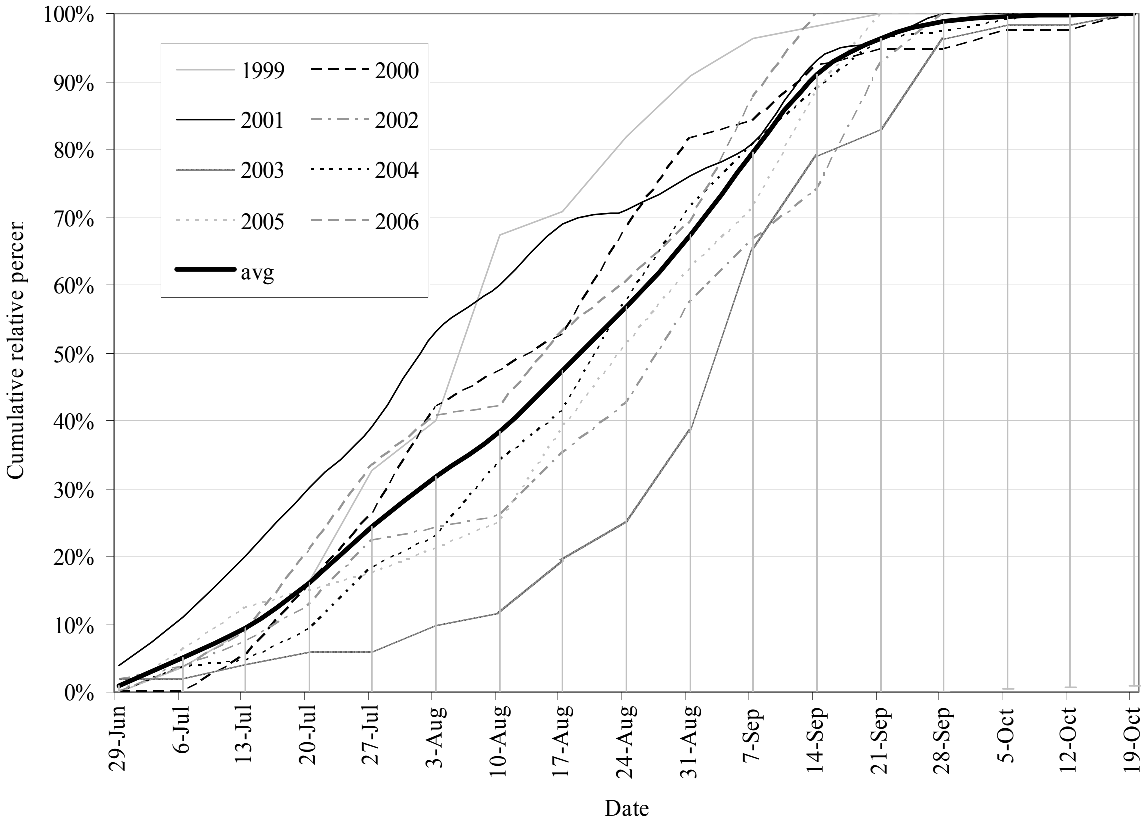

Figure 4.–Cumulative relative percent of Nakwasina River coded wire tag returns by date between 1999 and 2006 in marine sport and commercial fisheries.

recapture or time of capture (Figure 5), but there was a lack of evidence to reject the null hypothesis in some cases (Table 11). The average lengths of female and male coho salmon were 638 mm FL (SE = 1.8) and 621 mm FL (SE = 2.8), respectively. More males than females were caught in sections 1 and 2 (χ^2 = 15.92, P = 0.001, Table 12).

Based on an escapement estimate of 3,539, a coho salmon marine harvest of 1,801 (1,796 plus 2 Yakutat fish, 2 select recoveries and 1 random recovery without quadrant data), and smolt abundance of 47,573, the estimated total run in 2005 was 5,340 (SE = 848) and ocean survival was 11.2% (SE = 2.0%). Total exploitation was estimated to be 33.7% (SE = 5.9%).

2006

The estimated spawning escapement of coho salmon in Nakwasina River was 5,698 fish (SE = 741). Coho salmon were marked and recaptured in all 13 weeks of the study (September 5–December 11). Altogether, sampling resulted in 2,139 fish captures; 1,634 unique adults were captured and examined and 505 were recaptures (Table 7, Appendix A3). No recaptured fish lost its numbered tag as evidenced by the operculum punches. A total of 211 fish were sacrificed for their CWTs or died on capture. Eleven carcasses were sampled. Most adult coho captured in Nakwasina River in 2006 were captured with either the beach seine or gillnet, while 219 were captured with hook-and-line. Hook-and-line gear was moderately effective at capturing fish, but only when water conditions allowed for sighting fish.

Instream abundance peaked at 2,146 adults in week 42 and declined to 34 fish in week 50 (Table 8). Period-to-period survival rates varied from 0.038 to 1.0 (constrained, Table 8). Three estimates of survival and 5 estimates of recruitment were constrained to yield admissible (realistic) values during the estimation procedure.

Goodness-of-fit tests suggested little potential for capture heterogeneity or handling mortality (Table

Table 7.–Summarized mark–recapture data for Nakwasina River coho salmon, 2005 and 2006. Notation follows that in Seber (1982).

	2005				2006			
Week	Number captured	Number marked caught in *mi*	Losses on capture	Subsequently recaptured	Number captured	Number marked caught in *mi*	Losses on capture	Subsequently recaptured
35					1		1	
36					7		2	
37	4				18		6	
38	1		1		18		3	1
39	10		4	4	19		7	2
40	39		11	20	66		12	17
41	55	3	9	11	104	8	11	15
42	54	2	14	12	272	10	37	58
43	134	9	32	24	194	14	23	71
44	153	23	30	20	229	34	25	91
45	132	15	23	21	262	69	19	96
46	173	24	29	29	219	58	17	65
47	206	51	30	10	304	104	18	63
48					217	108	11	20
49	54	13	4	2	175	82	17	6
50	58	13	6		34	18	2	
Total	1,073	155	193	153	2,139	505	211	505

9, component 1). Therefore, the potential for bias from capture or survival heterogeneity was small, and the reported estimate is considered reliable for management purposes.

Ten percent (10.4%) of the sample was captured or recovered in section 1, 45.9% at section 2, 41.9% at section 3, and 1.9% at tidewater (Table 10). In total, 23.6% of the fish inspected for Floy™ tags had a tag. The probability of capturing a tagged fish was not significantly different in sections 1 versus section 2 (χ^2 = 0.66, P < 0.414), but was between sections 1 and 2 combined versus section 3 (χ^2 = 162.57, P < 0.000).

Length distributions of adult coho salmon captured in 2006 in Nakwasina River did not appear to be different between capture and recapture or time of capture (Figure 6), but there was a lack of evidence to reject the null hypothesis in some cases (Table 11). The average lengths of female and male coho salmon were 649.8 mm FL (SE = 1.3) and 632 mm FL (SE = 2.16), respectively. The proportions of males and females captured in sections 1, 2, and 3 were not significantly different (χ^2 = 1.76 P =0.415, Table 12), but recapture rates were significantly different (χ^2 = 5.09 P < 0.024, Table 12).

Based on an escapement estimate of 5,698, a coho salmon marine harvest of 1,416 fish, and smolt abundance of 64,164, the estimated total run in 2006 was 7,107 (SE = 767) and ocean survival was 11.1% (SE = 1.3%). Total exploitation was estimated to be 19.8% (SE = 2.7%).

VISUAL COUNTS

Visual counts were conducted on Nakwasina River on 3 occasions in 2005 and 4 occasions in 2006 (Table 13). In 2005, the peak count was 892 on November 7. In 2006, the peak count was 996 on November 6. Although the peak counts were not bracketed, stream conditions in both 2005 and 2006 precluded an additional count. In subsequent weeks when stream conditions would have allowed an additional count, it was obvious that there were fewer fish. These peak counts represent 25.2% and 17.5% of the estimated escapement respectively.

Table 8.–Jolly-Seber estimates of abundance (N), survival (ϕ), and recruitment (B) of adult coho salmon at Nakwasina River, 2005 and 2006.

Week(s)	Dates	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$
2005							
37–40	9/4–10/1	713	376	1.0000	0.0000	-	-
41	10/2–10/8	697	376	0.9681	0.2739	900	460
42	10/9–10/15	1,566	401	0.9464	0.2571	-	-
43	10/16–10/22	1,468	293	1.0000	0.0000	-	-
44	10/23–10/29	1,436	293	0.7709	0.1986	967	571
45	10/30–11/5	2,050	699	0.4943	0.1263	193	280
46	11/6–11/12	1,196	183	0.8071	0.2623	-	-
47	11/13–11/19	941	304	0.8090	0.6036	459	450
49	11/20–12/3	1,196	906	0.0400	0.0277	10	17
50	12/4–12/10	58	7.54	0.0000	0.0000	-	-
2006							
Week(s)	Dates	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$
35–40	8/27–10/7	1,305	416	1.0000	0.0000	-	-
41	10/8–10/14	1,274	416	0.4310	0.0972	1,601	731
42	10/15–10/21	2,146	768	0.5262	0.0742	998	414
43	10/22–10/28	2,107	223	0.7944	0.0904	-	-
44	10/29–11/4	1,656	170	0.8804	0.0839	-	-
45	11/5–11/11	1,436	159	1.0000	0.0000	527	146
46	11/12–11/18	1,944	126	0.9100	0.1013	-	-
47	11/19–11/25	1,754	183	1.0000	0.0000	-	-
48	11/26–12/2	1,736	183	0.4384	0.1743	93	84
49	12/3–12/9	849	337	0.0380	0.0152	2	6
50	12/10–12/16	34	5.81	0.0000	0.0000	-	-

DISCUSSION

SMOLT ABUNDANCE

The smolt-to-adult survival rates of 11.2% and 11.1% in 2005 and 2006 are higher than the 2000–2004 average (9.4%), but still lower than some of the other systems in the region (Table 14). Because of the low average smolt-to-adult survival rate in Nakwasina River in 2000–2002 (8.7%), extra care was taken in springs of 2004–2005 to insure smolt were given an adequate opportunity to recover and smolt naturally. However, survival remained relatively low in 2005–2006, indicating that Nakwasina River coho smolt-to-adult survival rate may tend toward the lower end of the range observed in Southeast Alaska systems.

Condition 1 of an unbiased estimate of smolt abundance required that there was no recruitment to the population between years. Because almost all wild coho salmon return to their natal streams and sampling only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. The presence of stray coho salmon reared at Medvejie hatchery is possible but unlikely given the geographical distance between the 2 sites. Additionally, no coho salmon from Medvejie hatchery have been recovered in Salmon Lake, which is much closer to the hatchery release area.

Vincent-Lang (1993) has shown that coho salmon smolt marked as in this project and handled competently suffer no detectable mortality from the experience, so condition 2 was 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. For these reasons, the differences in recovery rates were most likely due to natural differences in survival rates.

Table 9.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group in 2005 and 2006. Overall $\chi 2$ are the sum of the individual test statistics.

	2005					
	Component 1[a]			Component 2[b]		
Period	χ^2 τατσ	df	P-value	χ^2 τατσ	df	P-value
42	1.009	1	0.315	--	0	--
43	2.309	1	0.129	3.273	1	0.070
44	3.915	1	0.048	0.101	1	0.751
45	5.168	1	0.023	--	0	--
46	3.441	1	0.064	--	0	--
47	0.348	1	0.555	0.117	1	0.732
49	0.094	1	0.342	0.069	1	0.393
50	0.732	1	0.392	--	0	--
Overall	17.826	8	0.023	3.560	4	0.469
	2006					
	Component 1[a]			Component 2[b]		
Period	χ^2 τατσ	df	P-value	χ^2 τατσ	df	P-value
41	0.085	1	0.770	1.225	1	0.269
42	0.159	1	0.690	0.581	1	0.446
43	1.053	1	0.305	0.043	1	0.836
44	0.480	1	0.488	0.130	1	0.719
45	0.134	1	0.714	0.005	1	0.942
46	1.234	1	0.267	0.067	1	0.796
47	0.385	1	0.535	0.874	1	0.350
49	0.052	1	0.819	0.392	1	0.531
50	0.004	1	0.950	--	0	--
Overall	3.586	9	0.937	3.316	8	0.913

[a] Test for short-term mortality per Robson (1969).

[b] Test for heterogenous survival probabilities per Pollock et al. (1990).

Table 10.–Results of $\chi 2$ tests for differences in tagged rate between river sections for coho salmon in the Nakwasina River, 2005 and 2006.

2005				
Section	Untagged	Tagged	Total	% of total captures by section
1	156	53	209	19.48%
2	521	81	602	56.10%
3	227	19	246	22.93%
Tidewater	16		16	1.49%
Total	920	153	1,073	
Sections 1–3	$\chi 2$=	29.56	P<	0.0000
2006				
Section	Untagged	Tagged	Total	% of total captures by section
1	151	71	222	10.4%
2	639	342	981	45.9%
3	804	92	896	41.9%
Tidewater	40		40	1.87%
Total	1,634	505	2,139	
Sections 1–3	$\chi 2$=	163.57	P<	0.0000

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 finclips on smolt were examined. All smolt examined appeared to have good finclips. Also, all adult coho examined had well defined or a complete absence of an adipose fin.

Although the assumption that complete mixing occurred cannot 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 in either 2005 ($\chi 2$ = 1.67, P = 0.434) or 2006 ($\chi 2$ = 3.087, P = 0.215; Table 15).

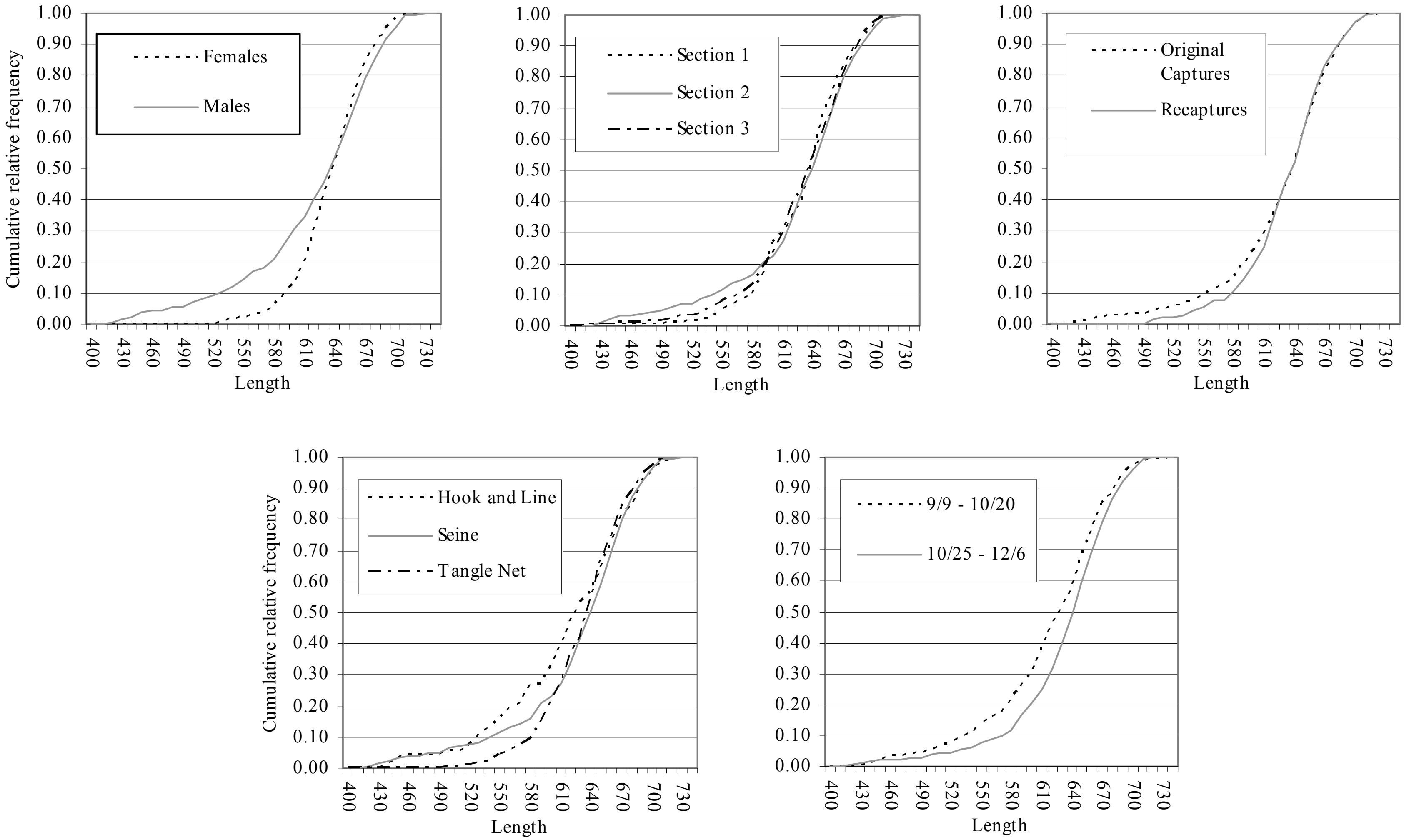

Figure 5.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, location, capture or recapture, gear and time, 2005.

Table 11.–Results of Kolmogorov-Smirnov tests for differences between cumulative length frequencies for adult coho salmon in the Nakwasina River, 2005 and 2006.

			2005			
Component 1	n		Component 2	n	D_i	P-value
Males	548	vs.	Females	371	0.17	<0.000
9 Sep–20 Oct	283	vs.	25 Oct–6 Dec	637	0.15	<0.000
Hook and Line	90	vs.	Seine	529	0.13	0.113
Tangle Net	299	vs.	Seine	529	0.08	0.166
Original Capture	920	vs.	Recapture	140	0.05	0.865
Section 1	156	vs.	Section 3	227	0.07	0.765
Section 1	156	vs.	Section 2	521	0.08	0.354
			2006			
Component 1	n		Component 2	n	D_i	P-value
Males	896	vs.	Females	735	0.16	<0.000
9 Sep–17 Oct	217	vs.	26 Oct–6 Dec	599	0.08	0.393
Hook and Line	219	vs.	Seine	1,410	0.08	0.587
Original Capture	816	vs.	Recapture	252	0.05	0.769
Section 1	150	vs.	Section 3	802	0.09	0.303
Section 1	150	vs.	Section 2	320	0.05	0.929

Table 12.–Differences in sex composition of coho salmon between capture type, gear, and section of Nakwasina River, 2005 and 2006.

			2005		
Capture	Females	Males	% Males	χ^2	P-value
Captured	371	548	59.63%	0.16	0.686
Recaptured	54	86	61.43%		
Gear type					
Hook and line	36	54	60.00%	5.36	0.021
Seine/tangle net	651	586	47.37%		
Section					
1	83	125	60.10%	15.92	0.001
2	217	385	63.95%		
3	124	121	49.39%		
Tidewater	5	11	68.75%		
			2006		
Capture	Females	Males	% Males	χ^2	P-value
Captured	736	897	54.93%	5.09	0.024
Recaptured	198	305	60.64%		
Gear type					
Hook and line	112	126	52.94%	1.18	0.278
Seine/tangle net	822	1,074	56.65%		
Location					
1	96	126	56.76%	1.76	0.415
2	412	568	57.96%		
3	403	491	54.92%		
Tidewater	23	17	42.50%		

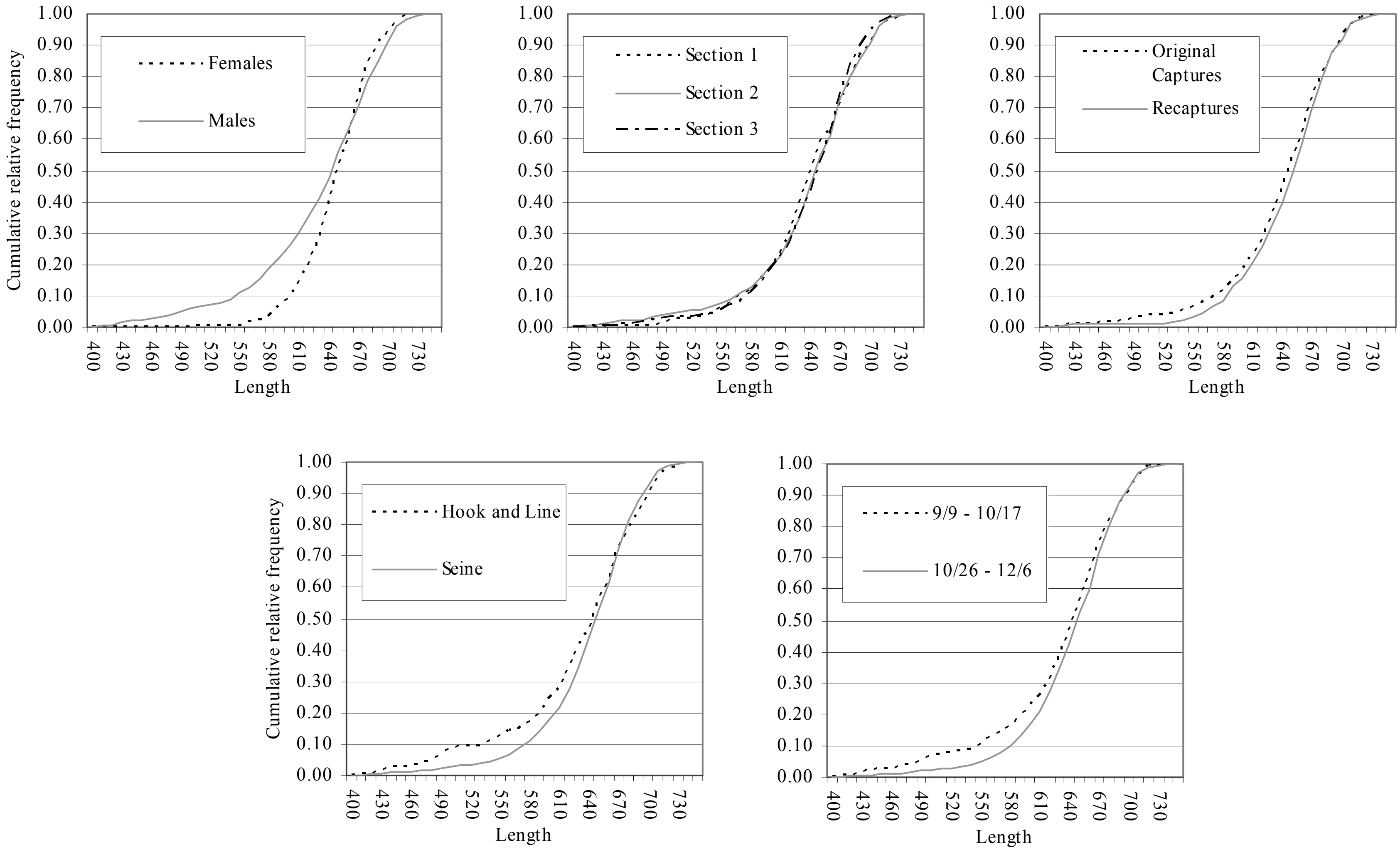

Figure 6.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, location, capture or recapture, gear and time, 2006.

Smolt-to-adult survival rates for smolt tagged in both 2004 and 2005 in the mainstem of Nakwasina River and those tagged in Bridge Creek were not significantly different. No significant differences in smolt-to-adult survival were detected between small and large tagging groups for smolt tagged in 2004 and 2005. Based on these results, we concluded that either S2 or S3 was satisfied and a Petersen-type model was appropriate for estimating abundance of 2004 and 2005 coho smolts from the Nakwasina River.

SPAWNING ESCAPEMENTS IN 2005 AND 2006

During both 2005 and 2006 experiments to estimate spawning escapement, tag loss was low (<1%) and sampling rates were high. Marking did not appear to affect the behavior or movement of fish, as marked fish were observed spawning with or near unmarked fish throughout the study. In 2006, assumptions of the JS experiment were met, and the JS model fit the data. In 2005, diagnostic testing for handling mortality and/or heterogeneity in probability of capture or survival indicated some potential for these problems. The significant test statistics occurred for adjacent sampling periods, and the direction of potential sampling bias was not consistent between these periods. No significant results were detected during later sampling periods where sample sizes for the tests were slightly larger. As no persistent pattern was apparent, it is difficult to draw clear conclusions about the potential for bias resulting from possible sampling problems indicated by the diagnostic tests.

A higher rate of recapture was observed for males than females in 2006. This may have been due to error in determining the sex of fish early in the run. Because the secondary maturation characteristics had not fully developed earlier in the run, it is possible that some fish were misidentified as females. Similar tests from previous years have yielded inconsistent results, with no difference detected between male and female recapture rates in 2000, 2002, and 2005, but a significantly higher apparent recapture rate for females in 2001, and a significantly higher rate for males in 2003 (Brookover et al. 2003; Tydingco 2003, 2005a-b). The lack of pattern

Table 13.–2005 and 2006 stream counts including number of coho counted, date, survey conditions, and percentage of total escapement estimate represented by daily count.

Date	Count	Conditions	% of total escapement
10/7/2005	440	Visibility normal, tide low, water normal	12.4%
10/31/2005	763	Visibility normal, tide low, water normal	21.6%
11/7/2005[a]	892	Visibility normal, tide low, water normal	25.2%
10/11/2006	508	Visibility normal, tide high, water normal	8.9%
10/27/2006	605	Visibility poor, tide low, water normal	10.6%
11/2/2006	871	Visibility poor, tide low, water normal	15.3%
11/6/2006[a]	996	Visibility poor, tide high, water normal	17.5%

[a] Peak count

Table 14.–Smolt-to-adult survival rate for coho indicator streams around Southeast Alaska 2000–2006.

	Return year							
Stream	2000	2001	2002	2003	2004	2005	2006	Average
Auke Creek	18.5	28.3	26.8	25	20.7	16	17.1	21.8
Berners River	12.1	11.9	19	19.1	17.7	8.4	12.8	14.4
Taku River	6.3	8.8	11.1	8.9	8.6	8.1	9.8	8.8
Ford Arm	12.8	8.2	14.7	17	11.9	8.1	9.9	11.8
Hugh Smith Lake	6.6	13.5	14.5	13.7	10.4	9.1	6.7	10.6
Unuk River	3.8	11.4	9.3					8.2
Nakwasina River	6.8	9.5	9.8	11.9	9.9	11.2	11.1	10.0
Slippery Creek			17.5					
Chuck Creek					9.4			
Average	9.6	13.1	15.3	15.9	12.7	10.2	11.2	12.2

Table 15.–Proportion of recovered Nakwasina River adult coho observed with and without adipose finclips, 2005 and 2006.

2005			
Date	Observed without clip	Observed with clip	Tagged portion
9/9/2005	4		
9/13/2005		1	
9/20/2005	2	2	0.50
9/23/2005	5	1	0.17
9/30/2005	23	5	0.18
10/1/2005	8	3	0.27
10/3/2005	43	5	0.10
10/8/2005	1	3	0.75
10/12/2005	3	3	0.50
10/14/2005	40	6	0.13
10/17/2005	57	19	0.25
10/20/2005	36	13	0.27
10/24/2005	18	6	0.25
10/25/2005	39	14	0.26
10/27/2005	42	10	0.19
10/28/2005		1	
11/1/2005	92	22	0.19
11/2/2005	2	1	0.33
11/8/2005	46	14	0.23
11/9/2005	74	15	0.17
11/14/2005	79	16	0.17
11/15/2005	46	14	0.23
11/28/2005	11	1	0.08
11/29/2005	12	4	0.25
11/30/2005	11	2	0.15
12/5/2005	13	1	0.07
12/6/2005	24	7	0.23
Total	731	189	0.205
9 Sep–8 Oct	86	20	
12 Oct–2 Nov	329	95	
8 Nov–6 Dec	316	74	
	χ^2 =	1.67	
	P =	0.434	

2006			
Date	Observed without clip	Observed with clip	Tagged portion
8/30/2006		1	
9/5/2006	7		
9/11/2006	12		
9/15/2006	3	3	0.50
9/18/2006	16	2	0.11
9/26/2006	15	4	0.21
10/1/2006	28	7	0.20
10/2/2006	18	5	0.22
10/3/2006	8		
10/9/2006	65	12	0.16
10/10/2006	15	3	0.17
10/12/2006		1	
10/16/2006	37	9	0.20
10/17/2006	129	33	0.20
10/19/2006	18	6	0.25
10/20/2006	25	5	0.17
10/26/2006	12	7	0.37
10/27/2006	38	12	0.24
10/28/2006	92	19	0.17
11/2/2006	58	24	0.29
11/3/2006	87	26	0.23
11/7/2006	141	36	0.20
11/8/2006	11	5	0.31
11/14/2006	128	33	0.20
11/21/2006	163	37	0.19
11/28/2006	90	19	0.17
12/4/2006	25	5	0.17
12/5/2006	50	13	0.21
12/11/2006	13	3	0.19
Total	1,304	330	0.202
30 Aug–10 Oct	187	37	
12 Oct–2 Nov	409	116	
3 Nov–11 Dec	708	177	
	χ^2 =	3.08	
	P =	0.215	

across years suggests that apparent differences are more likely the result of misclassification than in behavioral differences between males and females that affect probability of recapture. If, during 2006, the probability of capture for females was lower than that for males throughout the experiment, the abundance estimate is biased low.

The fact that the JS estimations were constrained to yield admissible values does not necessarily indicate that violation of some of the assumptions occurred and that the estimation model was inappropriate (Schwarz et al. 1993). However, assumptions that all fish have the same survival rate and that all fish have the same probability of capture during each event are not likely to be satisfied in a field experiment such as this one, so potential for bias in the abundance estimate needs to be considered. Differences were found between the fractions of fish carrying marks in upriver and downriver locations (Table 10), indicating that marked and unmarked fish did not mix completely between sampling events. Lack of complete mixing between events can only be mitigated by application of uniform sampling effort across the study area during each event, ensuring similar probabilities of capture for all fish. While it is unlikely that equal capture probabilities can be uniformly achieved, field efforts to sample proportional to fish abundance across the study area are intended to minimize the potential for bias. It is not expected that the survival rate is uniform across all fish in the experiment between sampling events. "Older" fish are expected to have a lower survival rate between events, particularly later in this experiment. While Seber (1982), as cited by Sykes and Botsford (1986), suggests that JS estimates should be relatively unbiased if mark status and mortality are not correlated, Schwarz et al. (1993) demonstrated with simulation that declines in survival of 20% between successive sampling periods after new fish enter the study area can result in overestimates of abundance on the order of one standard error of the point estimate. However, if "older" fish are also more susceptible to capture due to declining condition, a negative bias can result that may nearly cancel the positive bias resulting from the survival heterogeneity. While it is expected that fish in this experiment tended to experience lower survival later in their tenure in the study area, it is not likely as well correlated or severe as that simulated by Schwarz et al. (1993). If the escapement estimate is biased due to differential mortality, it is biased high and the magnitude of the bias is within one standard error of the estimate.

Although some fish do temporarily emigrate and re-immigrate after being tagged, no data exists to indicate a problem due to fish from other systems temporarily entering the system, being tagged, and then permanently emigrating. Some fish may temporarily emigrate from the study area due to stress associated with handling and tagging and later re-immigrate into the study area. In 2001, a Floy™ tagged fish with fresh herring in its belly was returned by a fisherman that captured the fish in Nakwasina River. This indicates that some fish do temporarily emigrate and re-immigrate after being tagged. The temporary lack of closure is not likely a significant source of bias. Of 140 first recaptures of marked fish in 2005, 41% occurred during the sampling event immediately after the tagging event and 58% occurred during either the first or second event immediately after tagging.

In 2005 and 2006, 10 and 27 fish were tagged at tidewater respectively. Of these, 6 and 16 were recovered. These recovery rates are higher than sections 2 and 3 (Table 16) and therefore indicate that problems associated with tagging mortality near the saltwater/freshwater interface (Vincent-Lang 1993) were not present during this study.

VISUAL 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 (21% in Steep Creek and 20% in Nakwasina River: 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).

HARVEST SAMPLING

To assess the adequacy of sampling rates in the purse seine and gillnet fisheries, troll harvests within Southeast Alaska where Nakwasina River coho salmon recovery occurred were examined (Table 17). The sampling rates in 2005 for troll fisheries in the Northwest Quadrant ranged from 6% (District 105) to 22% (Districts 116). In 2006 sampling rates ranged between 18% in District 105 and 30% in District 189. 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 CWT-marked coho between 1999 and 2006 occurs by August 20, and 90% are recovered by September 14.

Nakwasina River coho appear to have a 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 5 index streams in the Sitka Area (Table 2). Additionally tag recoveries in marine fisheries occur later than Salmon Lake (Figure 7) by approximately a month. Anecdotal information suggests that Katlian River, near Sitka, exhibits a similar run

Table 16.–Numbers of coho salmon recaptured by section of original tagging and section of recapture in Nakwasina River, 2005 and 2006.

	2005			
	Original tag section			
Section of recapture	Upstream 1	Middle section 2	Lower section 3	Tidewater
Upstream 1	12	28	11	2
Middle section 2		51	26	4
Lower section 3		10	9	
Totals	12	89	46	6
Total number of fish tagged	124	418	175	10
Proportion recovered	0.10	0.21	0.26	0.60

	2006			
	Original tag section			
Section of recapture	Upstream 1	Middle section 2	Lower section 3	Tidewater
Upstream 1	14	21	32	2
Middle section 2	1	142	189	9
Lower section 3		19	66	5
Totals	15	182	287	16
Total number of fish tagged	125	562	711	27
Proportion recovered	0.12	0.32	0.40	0.59

timing to the Nakwasina River, but most streams in the area follow a return pattern similar to the other 5 index streams.

Table 17.–Numbers of fish harvested in troll fisheries and sampled for coded wire tags in districts where Nakwasina River coho salmon were recovered, 2005 and 2006.

2005			
District	Fish harvested	Fish sampled	Proportion sampled
105	19,450	1,246	0.06
113	682,744	156,279	0.19
114	147,118	37,123	0.20
116	9,158	2,590	0.22
154	3,820	890	0.19
181	797	374	0.32
189	23,597	6,687	0.22
	886,684	205,189	0.19
2006			
District	Fish harvested	Fish sampled	Proportion sampled
105	9,136	2,071	0.18
109	46,366	13,967	0.23
112	7,144	1,032	0.13
113	309,988	74,272	0.19
114	37,196	6,444	0.15
116	52,686	18,146	0.26
189	8,923	3,788	0.30
	471,439	119,720	0.20

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 wasn't available due to poor water conditions. During the 6 years compared, estimated escapements ranged between 2,000 and 5,698 fish (Table 1, Figure 8). The resulting expansion factor (as estimated according to procedures in Appendix A4) was 4.588 (SE = 0.266).

RECOMMENDATIONS

CONTINUATION OF PROJECT

This project should continue for the estimation of escapement, harvest, smolt abundance, survival, and exploitation. The long-term relationship between exploitation and abundance should be monitored. Stock information from the Nakwasina River represents the most complete coho data set in the Sitka area and is the only non-lake wild stock in the outside waters of Northern Southeast Alaska with this information. Trends in abundance, survival, and exploitation may only be detected in a river with a long-term data set.

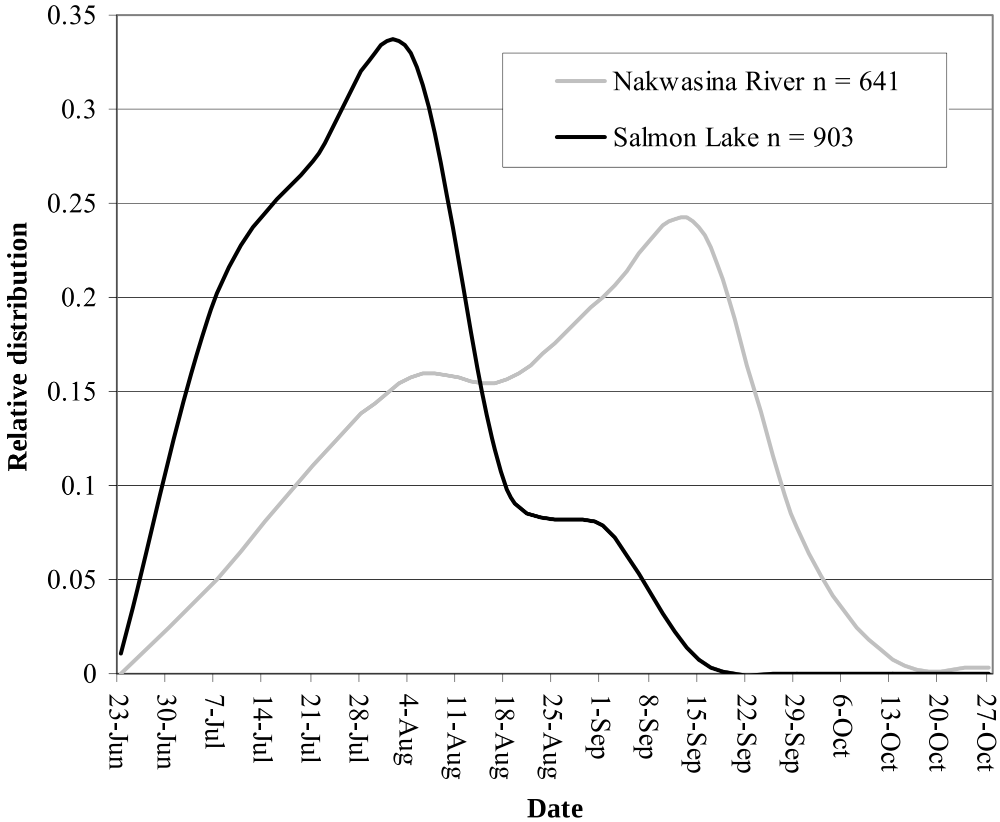

Figure 7.–Relative distribution of coded wire tag recoveries in marine fisheries by date in the Nakwasina River and Salmon Lake between 1988 and 2006.

DEVELOPMENT OF ADDITIONAL EXPANSION FACTORS

As tools for estimating abundance, the development of additional expansion factors in other streams may provide the opportunity to estimate trends in abundance and the refinement of escapement goals. Because coho salmon in Southeast Alaska frequently exhibit prolonged run timing during the fall and the return timing is often correlated with high water events, estimating escapement can be problematic. The use of open-population mark–recapture experiments may be the only way to successfully estimate abundance in these conditions. 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. Comparing peak stream counts on other index systems to an estimated escapement would provide a useful tool for not only predicting escapement when only a stream count is possible, it would also allow the estimation of escapement for prior years. This may provide adequate information for the development of refined escapement goals.

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 adult escapement. This

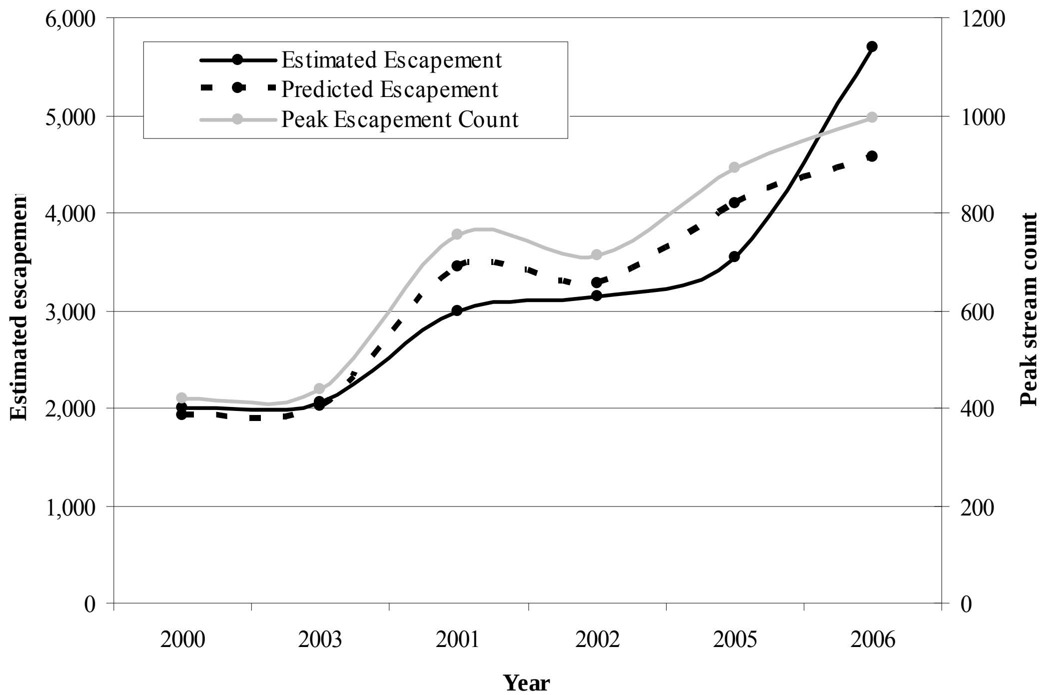

Figure 8.–Estimated escapement, peak counts, and predicted escapement at Nakwasina River, 2000–2006.

may be done by installing a weir on Bridge Creek through the smolting migration and either counting each fish that smolts through the weir or conducting a mark–recapture experiment to estimate the number of smolt in Bridge Creek prior to the smolting migration.

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APPENDIX A

Appendix A1.–Brood year, age classes and lengths of coho salmon by year sampled in the Nakwasina River, 2001–2006.

	Brood year	2004	2003	2003	2002	2002	2001	2002	2001	2000
	Sample year	2006				2005		2004		
	Age class	1.0	2.0	1.1	2.1	1.1	2.1	1.0	1.1	2.1
Females	Sample size	-	-	241	7	247	4	-	332	4
	Percent	-	-	97.2%	2.8%	98.4%	1.6%	-	98.8%	1.2%
	SE	-	-	1.1%	1.1%	0.8%	0.8%	-	0.6%	0.6%
	Mean length	-	-	650.0	663.6	638.7	672.5	-	639.6	615.0
	SE	-	-	2.3	20.3	2.2	24.4	-	2.2	26.8
Males	Sample size	15	1	388	5	373	10	20	488	7
	Percent	3.7%	0.2%	94.9%	1.2%	97.4%	2.6%	3.9%	94.8%	1.4%
	SE	0.9%	0.2%	1.1%	0.5%	0.8%	0.8%	0.9%	1.0%	0.5%
	Mean length	303.0	320.0	630.0	588.0	622.2	620.0	326.5	625.9	636.4
	SE	10.3	-	3.4	22.7	2.2	24.3	5.2	2.6	24.8
All fish	Sample size	15	1	629	12	620	14	20	820	11
	Percent	2.3%	0.2%	95.7%	1.8%	97.8%	2.2%	2.4%	96.4%	1.3%
	SE	0.6%	0.2%	0.8%	0.5%	0.6%	0.6%	0.5%	0.6%	0.4%
	Mean length	303.0	320.0	637.9	632.1	628.8	622.5	326.5	631.5	628.6
	SE	10.3	-	2.3	18.3	2.2	18.2	5.2	1.8	18.0

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	Brood year	2001	2000	2000	1999	2000	1999	1998	1999	1998	1998	1997
	Sample year	2003				2002			2001			
	Age class	1.0	2.0	1.1	2.1	1.0	1.1	2.1	1.0	2.0	1.1	2.1
Females	Sample size	-	-	276	6	-	243	13	-	-	263	5
	Percent	-	-	97.9%	2.1%	-	94.9%	5.1%	-	-	98.1%	1.9%
	SE	-	-	0.9%	0.9%	-	1.4%	1.4%	-	-	0.8%	0 .8%
	Mean length	-	-	634.5	640.0	-	625.8	646.5	-	-	629.9	658.0
	SE	-	-	2.1	17.7	-	2.7	10.6	-	-	2.3	18.3
Males	Sample size	16	5	405	7	2	409	12	4	2	433	14
	Percent	3.7%	1.2%	93.5%	1.6%	0.5%	96.7%	2.8%	0.9%	0.4%	95.6%	3.1%
	SE	0.9%	0.5%	1.2%	0.6%	0.3%	0.9%	0.8%	0.4%	0.3%	1.0%	0.8%
	Mean length	319.4	319.0	613.5	654.3	312.5	607.8	640.8	282.5	352.5	620.8	596.8
	SE	8.4	13.6	2.6	12.8	2.5	3.2	18.1	6.0	27.5	2.8	18.4
All fish	Sample size	16	5	681	13	2	652	25	4	2	696	19
	Percent	2.2%	0.7%	95.2%	1.8%	0.3%	96.0%	3.7%	0.6%	0.3%	96.5%	2.6%
	SE	0.6%	0.3%	0.8%	0.5%	0.2%	0.7%	0.7%	0.3%	0.2%	0.7%	0.6%
	Mean length	319.4	319.0	622.0	647.7	312.5	614.5	643.8	282.5	352.5	624.2	612.9
	SE	8.4	13.6	1.8	10.4	2.5	2.3	10.1	6.0	27.5	2.0	15.5

Appendix A2.–Recoveries of coded wire tags originating from Nakwasina River coho salmon in 2005 and 2006.

Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
2005										
Random Recoveries										
303662	40867	TROLL	9/3/2005	36	NE			525	SITKA	5031324
296851	40865	TROLL	7/9/2005	28	NW	113	31	562	SITKA	5030888
296305	40865	TROLL	7/5/2005	28	NW	113	41	578	SITKA	5030810
296339	40865	TROLL	7/6/2005	28	NW	113		632	SITKA	5030828
296469	40867	TROLL	7/7/2005	28	NW	113	91	552	SITKA	5030855
295085	40867	TROLL	7/5/2005	28	NW			629	HOONAH	5119999
75714	40865	TROLL	7/10/2005	29	NW	113	91	612	PELICAN	5010038
295206	40865	TROLL	7/12/2005	29	NW			613	HOONAH	5110126
269303	40867	TROLL	7/12/2005	29	NW	113	61	602	SITKA	5030912
296577	40867	TROLL	7/12/2005	29	NW	113	31	611	SITKA	5030921
302879	40867	TROLL	7/15/2005	29	NW	113	21	635	SITKA	5030958
302389	40865	TROLL	7/20/2005	30	NW	113	31	620	SITKA	5031006
302444	40866	TROLL	7/22/2005	30	NW	113		660	SITKA	5031016
302127	40865	TROLL	7/24/2005	31	NW	116	12	652	SITKA	5031031
93806	40867	TROLL	7/29/2005	31	NW	113		600	PELICAN	5010086
303310	40865	TROLL	8/3/2005	32	NW	113	21	621	SITKA	5031099
295522	40866	TROLL	7/31/2005	32	NW			626	HOONAH	5110172
302182	40867	TROLL	8/1/2005	32	NW	113	62	642	SITKA	5031081
27460	40865	TROLL	8/8/2005	33	NW	114	21	580	ELFIN COVE	5020196
295633	40866	TROLL	8/10/2005	33	NW			674	HOONAH	5110206
295738	40865	TROLL	8/18/2005	34	NW	113	91	582	HOONAH	5110228
301299	40865	TROLL	8/17/2005	34	NW	113	41	606	SITKA	5031196
303414	40865	TROLL	8/19/2005	34	NW	113		627	SITKA	5031232
288739	40865	TROLL	8/17/2005	34	NW	189	30	661	YAKUTAT	5140143
303499	40866	TROLL	8/20/2005	34	NW	113	31	664	SITKA	5031239
295815	40867	TROLL	8/19/2005	34	NW			568	HOONAH	5110234
303993	40865	TROLL	8/25/2005	35	NW	154		615	SITKA	5031270
27520	40865	TROLL	8/26/2005	35	NW	114	21	620	ELFIN COVE	5020256
301419	40865	TROLL	8/26/2005	35	NW	113	45	685	SITKA	5031274
303505	40866	TROLL	8/22/2005	35	NW	113	35	574	SITKA	5031255
295844	40866	TROLL	8/21/2005	35	NW			634	HOONAH	5110252
303992	40867	TROLL	8/25/2005	35	NW	154		579	SITKA	5031270
27539	40865	TROLL	8/29/2005	36	NW	114	21	615	ELFIN COVE	5020267
269064	40865	TROLL	8/30/2005	36	NW	113	45	631	SITKA	5031295
303561	40865	TROLL	8/29/2005	36	NW	113	31	633	SITKA	5031287
301478	40865	TROLL	8/28/2005	36	NW	113	61	645	SITKA	5031279
269097	40865	TROLL	9/9/2005	37	NW	113	62	635	SITKA	5031334
539584	40865	TROLL	9/6/2005	37	NW	113	91	650	JUNEAU	5040183
24035	40865	TROLL	9/9/2005	37	NW	189	30	663	YAKUTAT	5140220
539856	40865	TROLL	9/6/2005	37	NW	113	91	670	JUNEAU	5040183
27607	40865	TROLL	9/7/2005	37	NW	114	21		ELFIN COVE	5020319
288913	40867	TROLL	9/10/2005	37	NW	189	30	662	YAKUTAT	5140225
288957	40865	TROLL	9/13/2005	38	NW	181	60	612	YAKUTAT	5140247
303705	40865	TROLL	9/11/2005	38	NW	113	31	645	SITKA	5031338
299185	40865	TROLL	9/15/2005	38	NW			668	HOONAH	5110329
299122	40865	TROLL	9/13/2005	38	NW	113	93	672	HOONAH	5110318
242055	40865	TROLL	9/16/2005	38	NW	113	91	672	PELICAN	5010218
276940	40865	TROLL	9/16/2005	38	NW	189	30	677	YAKUTAT	5140268
303764	40865	TROLL	9/13/2005	38	NW	113	45	749	SITKA	5031365
303762	40866	TROLL	9/13/2005	38	NW	113	45	635	SITKA	5031365
303749	40866	TROLL	9/13/2005	38	NW	113	41	670	SITKA	5031361
269123	40866	TROLL	9/13/2005	38	NW			676	SITKA	5031350
288915	40866	TROLL	9/11/2005	38	NW	189	30	745	YAKUTAT	5140229

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Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
Random recoveries										
230988	40867	TROLL	9/13/2005	38	NW	113	91	615	PELICAN	5010206
300806	40867	TROLL	9/16/2005	38	NW	113		663	SITKA	5031372
299190	40867	TROLL	9/15/2005	38	NW			692	HOONAH	5110329
300849	40865	TROLL	9/19/2005	39	NW	113	45	598	SITKA	5031380
539899	40865	TROLL	9/20/2005	39	NW	113	97	637	JUNEAU	5040201
300852	40865	TROLL	9/19/2005	39	NW	113	45	645	SITKA	5031380
300887	40865	TROLL	9/20/2005	39	NW	113		677	SITKA	5031387
300886	40865	TROLL	9/20/2005	39	NW	113		683	SITKA	5031387
539822	40865	TROLL	9/22/2005	39	NW			708	JUNEAU	5040206
539208	40866	TROLL	9/23/2005	39	NW	113	91	590	JUNEAU	5040197
300888	40866	TROLL	9/20/2005	39	NW	113		677	SITKA	5031387
299257	40866	TROLL	9/20/2005	39	NW			720	HOONAH	5110337
90753	40865	PURSE	8/17/2005	34	NW	113		660	EXCURSION INLET	5100140
90752	40866	PURSE	8/17/2005	34	NW	113		541	EXCURSION INLET	5100140
291238	40867	TROLL	8/30/2005	36	SE	105	10	578	CRAIG	5070330
303522	40867	TROLL	8/27/2005	35				654	SITKA	5031280
259801	40867	SPORT	8/10/2005	33	NW	113	41	625	SITKA	5035507
81624	40865	SPORT	8/15/2005	34	NW	113	41	624	SITKA	5035543
81641	40866	SPORT	8/20/2005	34	NW	113	45	695	SITKA	5035562
81625	40867	SPORT	8/15/2005	34	NW	113	41	683	SITKA	5035544
259272	40865	SPORT	8/22/2005	35	NW	113	61	641	SITKA	5035596
81654	40865	SPORT	8/26/2005	35	NW	113	31	693	SITKA	5035577
305510	40865	SPORT	9/3/2005	36	NW	183	10	680	YAKUTAT	5145034
81671	40865	SPORT	9/2/2005	36	NW	113	45	688	SITKA	5035618
305509	40867	SPORT	9/3/2005	36	NW	183	10	710	YAKUTAT	5145033
Select recoveries										
901837	40865	TROLL	9/10/2005	37	NW				SITKA	5039972
259182	40867	SPORT	8/23/2005	35	NW	113	41		SITKA	5035605

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Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
2006										
Random recoveries										
166535	41005	TROLL	7/21/2006	29	NE	109	61	445	PORT ALEXANDER	6080037
166829	41005	TROLL	8/3/2006	31	NE	109	10	520	PORT ALEXANDER	6080071
313809	41003	TROLL	7/12/2006	28	NW	113		580	SITKA	6036661
313910	41003	TROLL	7/18/2006	29	NW	113	21	545	SITKA	6036709
27285	41003	TROLL	7/23/2006	30	NW	116		590	PELICAN	6010077
299584	41003	TROLL	7/27/2006	30	NW	116	11	572	HOONAH	6110124
94443	41003	TROLL	7/31/2006	31	NW			430	PELICAN	6010092
94680	41003	TROLL	8/8/2006	32	NW			575	PELICAN	6010116
314310	41003	TROLL	8/9/2006	32	NW	113	41	625	SITKA	6036853
313914	41004	TROLL	7/18/2006	29	NW	113	45	570	SITKA	6036710
27745	41004	TROLL	7/21/2006	29	NW			580	ELFIN COVE	6020088
314534	41004	TROLL	8/3/2006	31	NW	116	11	540	SITKA	6036811
314540	41004	TROLL	8/4/2006	31	NW			575	SITKA	6036821
94650	41004	TROLL	8/8/2006	32	NW	113	91	570	PELICAN	6010109
299469	41005	TROLL	7/13/2006	28	NW	116	11	610	HOONAH	6110092
299612	41005	TROLL	7/28/2006	30	NW			581	HOONAH	6110132
299629	41005	TROLL	7/28/2006	30	NW			599	HOONAH	6110132
94523	41005	TROLL	7/31/2006	31	NW			545	PELICAN	6010097
94511	41005	TROLL	8/1/2006	31	NW	116	11	585	PELICAN	6010096
299735	41005	TROLL	8/5/2006	31	NW			610	HOONAH	6110174
314311	41005	TROLL	8/9/2006	32	NW	116	11	575	SITKA	6036854
166567	41005	TROLL	7/23/2006	30	SE	105	10	565	PORT ALEXANDER	6080043
278849	41003	TROLL	9/18/2006	38	NE	112		585	JUNEAU	6046209
278850	41005	TROLL	9/18/2006	38	NE	112		680	JUNEAU	6046209
305586	41003	TROLL	8/30/2006	35	NW	189	30	540	YAKUTAT	6140180
315188	41003	TROLL	9/5/2006	36	NW	113		575	SITKA	6037044
321053	41003	TROLL	9/6/2006	36	NW	189	30	565	YAKUTAT	6140192
94946	41003	TROLL	9/8/2006	36	NW			640	PELICAN	6010168
95227	41003	TROLL	9/12/2006	37	NW			660	PELICAN	6010179
95272	41003	TROLL	9/13/2006	37	NW			700	PELICAN	6010182
315643	41003	TROLL	9/14/2006	37	NW	113		525	SITKA	6037088
315645	41003	TROLL	9/15/2006	37	NW	113	62	650	SITKA	6037092
315649	41003	TROLL	9/15/2006	37	NW			605	SITKA	6037093
96425	41003	TROLL	9/16/2006	37	NW			656	HOONAH	6110331
95682	41003	TROLL	9/20/2006	38	NW			645	PELICAN	6010203
317161	41003	TROLL	9/21/2006	38	NW			655	SITKA	6037125
315055	41004	TROLL	8/23/2006	34	NW	113	45	540	SITKA	6036983
316980	41004	TROLL	8/31/2006	35	NW	113		595	SITKA	6037014
94917	41004	TROLL	9/2/2006	35	NW			590	PELICAN	6010158
95621	41004	TROLL	9/16/2006	37	NW			630	PELICAN	6010188
95600	41004	TROLL	9/16/2006	37	NW			660	PELICAN	6010188
317115	41004	TROLL	9/17/2006	38	NW	113	45	625	SITKA	6037102
315039	41005	TROLL	8/22/2006	34	NW	113	45	460	SITKA	6036954
46789	41005	TROLL	8/22/2006	34	NW			590	EXCURSION INLET	6100067
315069	41005	TROLL	8/23/2006	34	NW	113	45	575	SITKA	6036985
315225	41005	TROLL	8/31/2006	35	NW	113	62	575	SITKA	6037016
94892	41005	TROLL	9/1/2006	35	NW			590	PELICAN	6010154
315173	41005	TROLL	9/5/2006	36	NW	113	91	520	SITKA	6037042
315198	41005	TROLL	9/6/2006	36	NW	113	41	570	SITKA	6037051
94997	41005	TROLL	9/12/2006	37	NW	113	91	655	PELICAN	6010177
95220	41005	TROLL	9/12/2006	37	NW	114	21	570	PELICAN	6010178
96275	41005	TROLL	9/12/2006	37	NW			619	HOONAH	6110307
96327	41005	TROLL	9/14/2006	37	NW	114	21	568	HOONAH	6110319
95298	41005	TROLL	9/14/2006	37	NW			585	PELICAN	6010185

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Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
					Random recoveries					
96408	41005	TROLL	9/19/2006	38	NW	116	11	642	HOONAH	6110326
317148	41005	TROLL	9/20/2006	38	NW	113	41	655	SITKA	6037118
315257	41003	TROLL	9/5/2006	36				590	SITKA	6037037
315260	41004	TROLL	9/5/2006	36				630	SITKA	6037037
83328	41003	SPORT	7/24/2006	30	NW	113	41	585	SITKA	6035339
318031	41003	SPORT	7/25/2006	30	NW	113	41	631	SITKA	6035346
318374	41003	SPORT	8/4/2006	31	NW	113	61	590	SITKA	6035421
318067	41003	SPORT	8/22/2006	34	NW	113	45	612	SITKA	6035520
248047	41003	SPORT	8/25/2006	34	NW	113	61	650	SITKA	6035543
318085	41003	SPORT	9/22/2006	38	NW	113	43	635	SITKA	6035568
318367	41004	SPORT	7/28/2006	30	NW	113	45	625	SITKA	6035366
318476	41004	SPORT	7/29/2006	30	NW	113	41	580	SITKA	6035378
319130	41004	SPORT	7/29/2006	30	NW	113	41	630	SITKA	6035383
318352	41005	SPORT	7/15/2006	28	NW	113	61	540	SITKA	6035280
83338	41005	SPORT	7/31/2006	31	NW	113	45	600	SITKA	6035399
318379	41005	SPORT	8/5/2006	31	NW	113	61	540	SITKA	6035425
318493	41005	SPORT	8/13/2006	33	NW	113	71	650	SITKA	6035479
318073	41005	SPORT	8/24/2006	34	NW	113	41	645	SITKA	6035537
83364	41005	SPORT	8/25/2006	34	NW	113	61	620	SITKA	6035540
83367	41005	SPORT	8/26/2006	34	NW	113	45	565	SITKA	6035544
319137	41005	SPORT	9/1/2006	35	NW	113	62	615	SITKA	6035553
318084	41005	SPORT	9/22/2006	38	NW	113	43	660	SITKA	6035568
					Select recoveries					
900990	41004	TROLL	9/23/2006	38	NW	114	21		SITKA	6039982
901116	41005	TROLL	9/11/2006	37	NW				SITKA	6039976
318280	41003	SPORT	8/8/2006	32	NW	113	45		SITKA	6035447
318278	41005	SPORT	8/7/2006	32	NW	113	45		SITKA	6035442
288388	41005	SPORT	9/12/2006	37	NW	113	41		SITKA	6035567

Appendix A3.–Capture and recovery data from the Nakwasina River coho salmon mark–recapture study, 2005 and 2006, by section and date.

Week#	Section	2005 Original captures	2005 Recaptures	2005 Total captures	2005 Proportion (Floy™) tagged	2006 Original captures	2006 Recaptures	2006 Total captures	2006 Proportion (Floy™) tagged
35	2					1		1	0.00
36	2					7		7	0.00
37	2	4		4	0.00	16		16	0.00
	3					2		2	0.00
38	2	1		1	0.00	8		8	0.00
	3					1		1	0.00
	TW					9		9	0.00
39	2	6		6	0.00	12		12	0.00
	3					1		1	0.00
	TW	4		4	0.00	6		6	0.00
40	2	30		30	0.00	27		27	0.00
	3					39		39	0.00
	TW	9		9	0.00				
41	1					9	1	10	0.10
	2	20	2	22	0.09	6	1	7	0.14
	3	32	1	33	0.03	81	6	87	0.07
42	1					22	4	26	0.15
	2	32		32	0.00	53		53	0.00
	3	20	2	22	0.09	165	6	171	0.04
	TW					22		22	0.00
43	1					5		5	0.00
	2	74	7	81	0.09	40	6	46	0.13
	3	51	2	53	0.04	132	8	140	0.06
	TW					3		3	0.00
44	1	8	1	9	0.11	26	9	35	0.26
	2	85	18	103	0.17	38	12	50	0.24
	3	37	4	41	0.10	131	13	144	0.09
45	1					16	6	22	0.27
	2	105	14	119	0.12	107	54	161	0.34
	3	9	1	10	0.10	70	9	79	0.11
	TW	3		3	0.00			0	
46	1	60	15	75	0.20			0	
	2	63	7	70	0.10	105	51	156	0.33
	3	26	2	28	0.07	56	7	63	0.11
47	1	25	16	41	0.39			0	
	2	95	32	127	0.25	75	62	137	0.45
	3	35	3	38	0.08	125	42	167	0.25
48	2					109	108	217	0.50
49	1	29	10	39	0.26	60	34	94	0.36
	2					33	48	81	0.59
	3	12	3	15	0.20			0	
50	1	34	11	45	0.24	13	17	30	0.57
	2	6	1	7	0.14	2		2	0.00
	3	5	1	6	0.17	1	1	2	0.50
Total		920	153	1,073	0.14	1,634	505	2,139	0.24

Appendix A4.–Predicting escapement from index counts using an expansion factor.

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:

$$\overline{\pi} = \frac{\sum_{y=1}^{k} \hat{\pi}_y}{k} \tag{6}$$

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:

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\overline{\pi}) \tag{7}$$

The estimate of *var*(π) 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):

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

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

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

An estimate of *var*(π) representing only process error therefore is:

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

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:

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

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

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

where both process and measurement errors need to be included.

-continued-

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).

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:

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

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 A5.–Data files used to estimate parameters of the Nakwasina River coho population, 2004 through 2006.

Data file[a]	Description
2005-2006_Adult_CWT_Recoveries.xls	Recovery information from 2005–2006 coded wire tag recoveries in Southeast Alaska.
Nakwasina_River_2005-2006_M-R_and_CWT.xls	Mark, recapture, and coded wire tag recovery information from fish captured in Nakwasina River in 2005 and 2006.
2005-2006AdultAWL.xls	Age and length Information including summary statistics of adult coho captured in Nakwasina River in 2005–2006.
2004-2005_smolt_AWL_data.xls	2004 and 2005 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, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.