Fishery Data Series No. 06-66

Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from Nakwasina River in Southeast Alaska, 2003-2004

by

Troy A. Tydingco

December 2006

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska 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

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by
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December 2006

Development and publication of this manuscript were partially financed by the Federal Aid in Sport fish Restoration Act (16 U.S.C.777-777K) under Projects F-10-18 and F-10-20, Job No. S-1-11, and by the Southeast Sustainable Salmon Fund, Project 45051.

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This document should be cited as:
Tydingco, T. A. 2006. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2003-2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-66, Anchorage.

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ABSTRACT

In 1998, a coded wire tag (CWT) project was initiated for coho salmon *Oncorhynchus kisutch* in Nakwasina River near Sitka, Alaska to supplement a continuing regionwide effort to assess the status of key coho salmon stocks in Southeast Alaska. During spring 2003, 15,762 coho salmon smolt ≥65-mm fork length (FL) were captured in minnow traps, marked with an adipose fin clip, given a CWT, and released. A weighted variation of the modified Peterson model was used to estimate smolt abundance in 2003 at 55,424 (SE = 4,023). In fall 2004, beach seines, gillnets, and hook-and-line gear were used to capture immigrant coho salmon. During the course of the experiment, 1,078 coho salmon were examined, 749 were released with Floy™ tags, and 156 were subsequently recaptured. Using a Jolly-Seber model, the estimated escapement was 3,867 (SE = 937). The peak foot survey count of the mainstem river was 399 adult coho salmon, or 10% of the estimated escapement. An estimated 1,645 (SE = 178) coho salmon of Nakwasina River origin were harvested in Southeast Alaska marine fisheries in 2004. The marine sport fishery harvested an estimated 200 fish, or 12.2% of the total harvest, while the commercial fisheries harvested 84% (troll) and 3.8% (seine). The total run (i.e., escapement plus harvest) for all coho salmon bound for Nakwasina River was 5,512, the marine survival rate was 9.9%, and the marine fishery exploitation was 29.8%.

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

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) and Slippery Creek in central Southeast (Beers 1999). Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and has continued through 2004 (Shaul and Crabtree 1998; Leon Shaul, personal communication, Alaska Department of Fish and Game, Commercial Fisheries Division, Douglas). In southern Southeast, Chuck Creek has been included as a coho stock assessment project. 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). The Salmon Lake CWT project was initiated again in 2001 and returns of adults with CWTs are expected through 2005.

Beginning in 1998, Sport Fish Division 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). Estimated smolt abundance from 1998 through 2002 ranged from 22,472 (SE = 1,660) in 2002 to 102,794 (SE = 15,255) in 1998. Estimated harvests of returning adults in 1999–2003 ranged from 604 fish (SE = 110) in 2003 to 1,983 (SE = 605) in 1999 (Table 1).

The objectives of this study were to: (1) estimate the number of coho salmon smolt leaving Nakwasina River in 2003; (2) estimate the marine harvest of coho salmon from Nakwasina River in 2004 via recovery of CWTs applied in 2003; and (3) estimate spawning escapement in 2004. An additional task of this project was to define the relationship between the estimated escapement and peak foot survey count.

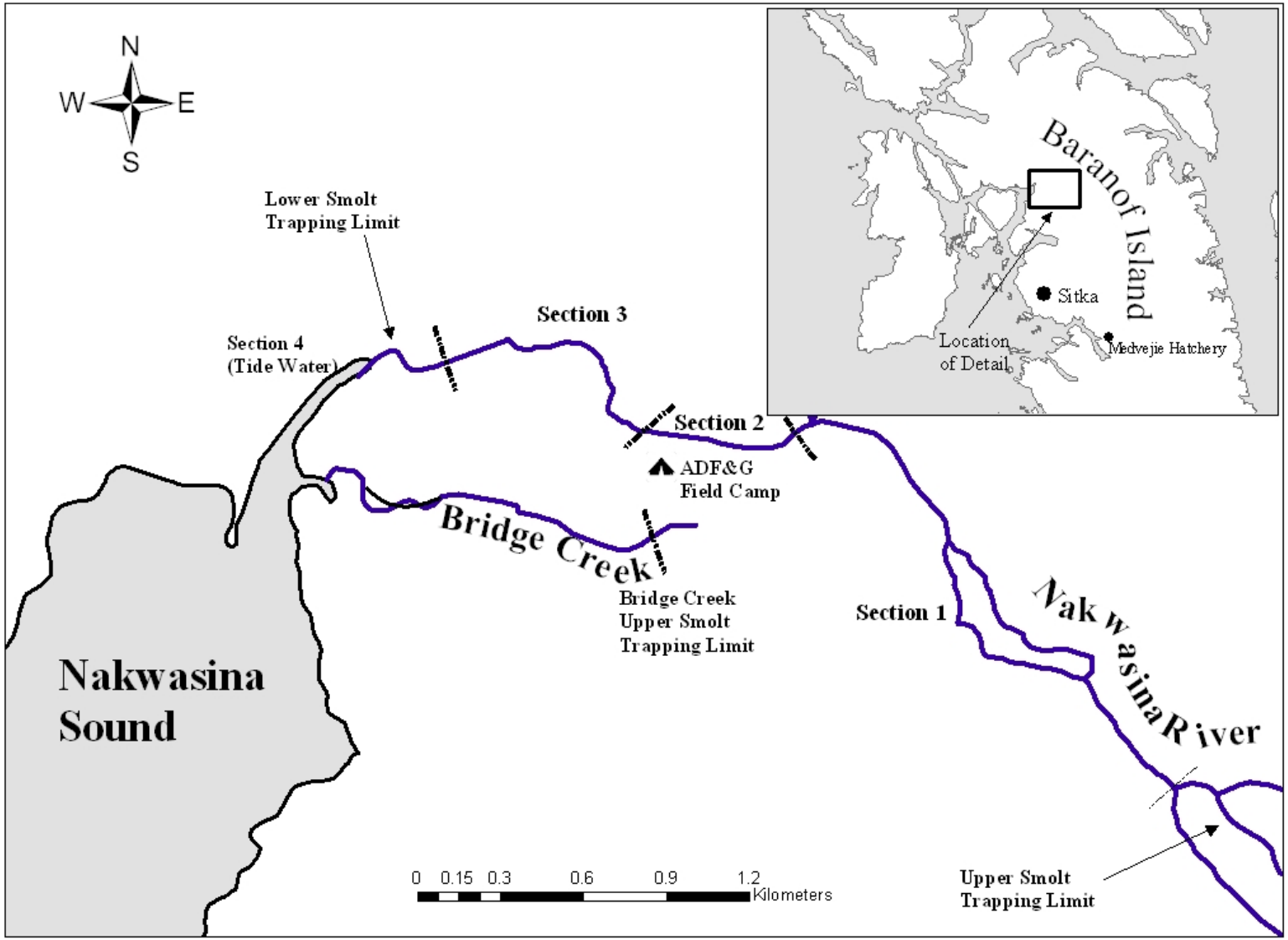

Figure 1.–Map showing Nakwasina River area, including major tributaries and location of ADF&G research sites and stream sections.

Table 1.–Summaries of estimated smolt abundance, harvest, escapement, exploitation, and stream counts in Nakwasina River 1998–2004.

Year	Smolt tagged	Smolt abundance estimate	Smolt SE	Adult escapement	Adult escapement SE	Harvest	Harvest SE	Exploitation	Marked fraction, theta	Stream survey peak count	Proportion of escapement estimate	Estimated marine survival
1998	9,985	102,794	15,255	-	-	-	-	-	-	653	-	
1999	3,971	47,571	6,402	-	-	1,983	605	-	0.095	291	-	
2000	10,228	46,575	2,722	2,000	261	1,219	231	0.37	0.082	419	0.21	6.8
2001	10,381	39,461	3,057	2,992	510	1,439	155	0.325	0.221	753	0.252	9.5
2002	5,286	22,472	1,660	3,141	661	731	109	0.178	0.237	713	0.227	9.8
2003	15,761	55,424	4,023	2,063	233	604	110	0.226	0.203	440	0.213	11.9
2004				3,867	937	1,645	178	29.8	0.286	399	0.970	9.9
Averages	9,269	52,383	5,520	2,813	520	1,270	231	6.18	0.19	524	0.20	9.6

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 square hectares and is one of the larger river systems on Baranof Island. Average daily flow rates between 1976 and 1982 ranged from 100 ft^3/s to 1,200 ft^3/s. Maximum and minimum average daily flows during this time period ranged from a low of 22 ft^3/s to a high of 3,400 ft^3/s.

Nakwasina River is known locally for its freshwater sport fisheries for coho salmon and Dolly Varden (*Salvelinus malma)*. Because Nakwasina River is easily accessed by boat and it 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 2003 and estimated angler effort expended in Nakwasina Sound and River (for all fish species) ranged from 31 to 891 angler days (Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006a,b; Mills 1985-94; Walker et al. 2003).

In the 1960s, the majority of riparian area in the anadromous portion of Nakwasina River valley was clearcut to the streambank (Greg Killinger, personal communication, Sitka Ranger District, U.S. Forest Service, Sitka). Nakwasina River coho salmon are of special concern because of the potential risk of excessive exploitation in combination with the potential negative impacts to the stock from habitat damage due to logging.

Since 1980, visual surveys have been conducted by foot on Nakwasina River to provide an indication of trends in the annual abundance of coho escapement. Annual peak counts in Nakwasina River represent the largest of five systems surveyed annually in the Sitka area. Surveys conducted from 1980 to 2004 have documented 47 (1987) to 753 (2001) adult coho salmon spawners (Table 2).

METHODS

SMOLT TAGGING AND SAMPLING

From April 17 to May 15, 2003, between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily in Nakwasina River. Traps were fished for 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. Coho salmon smolt ≥65 mm FL were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden) and coho fry <65 mm FL were counted and released on site.

Every 2–3 days, all live coho salmon smolt ≥65 mm FL were anesthetized with a solution of tricane methane-sulfonate (MS-222) and injected with a CWT with one of the following codes: 04-08-17, 04-08-18, or 04-08-19. Fish were then marked externally by excising the adipose fin. Tagging and marking followed the methods of Koerner (1977). All tagged fish were held overnight in a net pen to test for mortality, tag retention, and adipose fin clip status and released. 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, all 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* which were submitted to ADF&G Commercial Fisheries Division (CFD) Mark, Tag and Age Laboratory (Tag Lab) in Juneau when fieldwork ended.

[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, 1980–2004.

	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	26-Oct	328	Foot	29-Oct	70
1981	Foot	6-Oct	85	Foot	14-Oct	51	Foot	20-Oct	170	Foot	22-Sep	27				Foot	7-Oct	780
1982	Foot	20-Oct	46	Foot			Foot	21-Oct	317									
1983	Foot	27-Sep	31	Foot	13-Oct	12	Foot	6-Oct	45							Foot	14-Oct	217
1984	Foot	10-Oct	160	Foot	10-Oct	154	Foot	10-Oct	385				Helo	3-Oct	425	Foot	17-Oct	715
1985	Foot	15-Oct	144	Foot	8-Oct	109	Foot	11-Oct	193				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	32	Foot	23-Sep	9	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	Foot	2-Oct	130	Helo	13-Oct	181	Foot	19-Oct	129
1990	Foot	1-Oct	80	Foot	1-Oct	35	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	272	Snorkel	5-Oct	336	Helo	27-Sep	1265	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	25	Snorkel	8-Oct	166				Helo	4-Oct	1,590	Snorkel	12-Nov	291
2000	Foot	26-Sep	48	Snorkel	26-Oct	32	Snorkel	8-Oct	144	snorkel	29-Sep	108	Helo	2-Oct	880	Foot	8-Nov	419
2001	Foot	5-Oct	62	Snorkel	4-Oct	80	Snorkel	8-Oct	430	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-Oct	102	Snorkel	30-Sep	91	Foot	2-Oct	95	snorkel	9-Oct	375	Helo	2-Oct	1,055	Foot	31-Oct	440
2004	Foot	3-Oct	106	Snorkel	1-Oct	52	Foot	2-Oct	121	snorkel	11-Oct	391	Helo	7-Oct	380	Foot	8-Nov	399
Average (1980-2004)			111			79			168			341			826			422
5-yr average (1998-2004)			97			71			203			390			1,078			545

Three separate tag codes were used to identify different components of the smolt run. Small smolt (≥65 mm but less than 85 mm FL) were tagged with code 04-08-17, while large smolt (≥85 mm FL) were tagged with code 04-08-18. These two tag codes were used to identify differential survival based on size at smolting. A third tag code (04-08-19) was used for all fish ≥65 mm that were captured in an unnamed tributary to Nakwasina River (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.

Coho salmon smolt were measured from snout to fork of tail (FL) to the nearest 1 mm, weighed to the nearest 0.1 g, and sampled for scales. Twelve to 15 scales were removed from the preferred area on the left side following procedures described by Scarnecchia (1979). Scales were sandwiched between two 1x3-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.

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

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. Requirements of the open-population experiment demanded more intensive sampling, therefore an open population experimental design was used.

Sampling occurred during 2 or 3-day periods once each week from September 10 through December 8, 2004. 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 four 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 area, 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 tide water. Sampling was concentrated in sections 2 and 3 because two 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. Little sampling occurred below rkm 3.4 in order to avoid potential mortality associated with capturing coho salmon that had recently entered fresh water (Vincent-Lang et al. 1993).

All coho captured were examined for presence or absence of their adipose fin. Between September 10 and December 8, all coho missing adipose fins were sacrificed, their heads removed, and sent to the Tag Lab for dissection and decoding. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent this combination were measured to the nearest mm MEF, tagged with uniquely numbered Floy™ T-bar anchor tags, given a secondary mark (opercle punch) to permit estimation of tag loss, examined to determine sex and condition, and sampled to collect scales for aging. Tags were inserted just posterior of and 1 cm below the dorsal fin on the left side of the fish. Secondary marks included various combinations of opercle punches that consisted of 0.6 cm diameter holes. The condition of each fish was determined from external characteristics using the following convention:

1) Bright: Ocean bright or nearly ocean bright;
2) Blush: Some color (primarily blush red);
3) Dark: Dark color (primarily red);

4) LPS (live post-spawner): Spawned out but not yet dead;
5) Carcass: Dead spawned fish; and,
6) Mortality: Dead unspawned fish.

For fish captured with a Floy™ tag, the location, 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. Heads were removed if the adipose fin was missing. Subsequent sampling of these carcasses was prevented by slashing the left side of the fish. These carcasses were not counted as observations for estimating spawning abundance.

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. Post-season, scale images were impressed on acetate cards and ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Mosher (1968).

Harvest in 2004 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 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 (Hubartt et al. 2001). 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 in 2004, 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 visually on October 11 and again on November 8, 2004. Visual counts were conducted by two experienced observers either during or one 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 smolt marking 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 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.

If survival rates for large and small smolt tagged in Nakwasina River were significantly different such that smolt in either size group survived differently, condition S2 would not be satisfied. Further, if smolt of one group or another were more or less likely to be captured in 2003 than another, condition S1 would not be satisfied, but the experimental design did not provide for evaluation of this. Also, there was no test to evaluate equal tagging probability between Bridge Creek and Nakwasina River smolt.

When one of the above conditions regarding mortality and sampling are met, a modified Petersen estimator is generally used, however when these conditions are violated, no clearly unbiased estimate of smolt abundance can be calculated. The best, albeit biased, estimator for which the potential biases can be described is a weighted variant of Chapman's modification of the Petersen estimator:

$$\hat{N} = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}(R_1 + \hat{\pi}_1 R_3) + (R_2 + \hat{\pi}_2 R_3) + 1} - 1 \qquad (1)$$

where M_i is the number of Nakwasina River smolts marked by size group (1 = small smolt, 2 = large smolt), C is the number of adults inspected for marks, R_i is the number of recaptures by size group (3 = unknown size), A is the ratio of the catchability coefficients for small and large smolt, and π_i is the fraction of adults that were small or large smolts. Smolt tagged in Bridge Creek in 2003 were not used in this estimator, although observed adults were used to estimate the π_i parameters.

The estimate of A is used to adjust for differences in catchability such that $A > 1$ when large smolt are more catchable, and < 1 when larger smolt are less catchable. Because some recaptured fish were not sacrificed to find tags or some marked adults did not contain tags, π_i's were used to assign recaptured fish of unknown pedigree to the appropriate smolt size group. An estimate of π_i is:

$$\hat{\pi}_i = \frac{T_i}{T_1 + T_2 + T_{BC}} \qquad (2)$$

where T_i is the number of tag recoveries representing a smolt size group (i = 1, 2) regardless of how or where they were recovered, and T_{BC} is the number of adults tagged as smolt in Bridge Creek.

The relative catchability of small and large smolt can be described accordingly. If $\hat{p}$ is the estimated fraction of all adults that are of age-1., $\hat{\phi}_1$ is the estimated fraction of smolts in the smaller-size group that were age-1., and $\hat{\phi}_2$ is the estimated fraction of smolts in the larger-size group that were age-1., then an estimate of the ratio of catchability coefficients for larger to smaller smolt is:

$$\hat{A} = \frac{T_2(\hat{\phi}_2 - \hat{p})}{T_1(\hat{p} - \hat{\phi}_1)} \qquad (3)$$

(see Appendix A3 in Tydingco 2005b for derivation of equation 3). From tagging records, $\hat{\phi}_1$ = 333/333 = 1.0 and $\hat{\phi}_2$ = 77/87 = 0.8851. Of the 851 adults sampled for age in Nakwasina River in 2004 (Table 3), 840 were age 1.1, making $\hat{p}$ = 0.9871. Given that T_1 = 232 and T_2 = 99 in 2004, $\hat{A}$ = 3.37. Simulations (see below) indicate

Table 3.–Estimated fork length, weight, and age of coho salmon smolt from Nakwasina River and Bridge Creek in 2003.

	Nakwasina						Bridge Creek			
	Age-1.		Age-2.		Combined		Age-1.		Age-2.	
Statistic	Length*	Weight*	Length	Weight	Length	Weight	Length	Weight	Length	Weight
Mean	77.9	4.9	103.8	10.4	78.6	5.0	78.5	4.7	99	9.2
Standard Error	0.37	0.08	1.84	0.62	0.42	0.09	0.81	0.21		
Sample Size	410	409	10	10	420	419	105	52	1	1
	% age-1. fish in Nakwasina = 98%						% age-1. fish in Bridge Creek = 99%			

*Length measured to the nearest millimeter and weight to the nearest 10th gram.

that this estimated rate is statistically different from 1. Variance and 95% credibility interval (CI_{MCMC}) for the estimator (equation 1) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for $\hat{N}$ and $\hat{A}$ were generated by collecting 100,000 simulated values of $\hat{N}'$ and $\hat{A}'$ which were calculated using equations (1) and (3) from simulated values of equation parameters. Simulated values were modeled from observed data (Appendix A1).

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:

$$\hat{r}_{ij} = N_i \left[\frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \tag{4}$$

where:

N_i = total harvest in fishery stratum i,

n_i = number of fish inspected in fishery stratum i (the sample),

a_i = number of fish which were missing an adipose fin,

a_i' = number of heads that arrived at the lab,

t_i = number of heads with CWTs detected,

t_i' = number of CWTs that were dissected from heads and decoded,

m_i = number of CWTs with code(s) of interest, and

θ_j = fraction of the cohort tagged with code(s) of interest.

When N_i and θ_j are known without error, an unbiased estimate of the variance of $\hat{r}_{ij}$ can be calculated as shown by Clark and Bernard (1987). However, N_i is estimated with error in sport fisheries, and θ_j is estimated with error on Nakwasina River 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:

$$\hat{H} = \sum_i \sum_j \hat{r}_{ij} \tag{5}$$

$$Var\left[\hat{H}\right] = \sum_i \sum_j v\left[\hat{r}_{ij}\right] \tag{6}$$

SPAWNING ESCAPEMENT

The escapement of adult (age-.1) coho salmon in Nakwasina River was 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 midline to prevent re-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 two 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 we began sampling early in immigration and continued until it was virtually over, we estimated $B_0 + B_1$ 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:

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + ... + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \quad (7)$$

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 population analysis 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 and Arnason 1996; Schwarz et al. 1993). 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 ith sample;
2. Every marked fish has the same probability of surviving from the ith 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 ith 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 chi-squares from each test is an overall test statistic for violations of the first three 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 in-river 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 area 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):

$$\hat{p}_j = \frac{n_j}{n} \tag{8}$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{9}$$

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 2004 and the associated exploitation rate in commercial and sport fisheries are based on the sum of the estimated harvest and escapement:

$$\hat{N}_R = \hat{H} + \hat{E}\ . \tag{10}$$

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

$$Var[\hat{N}_R] = Var[\hat{H}] + Var[\hat{E}]. \tag{11}$$

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

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \tag{12}$$

$$Var\left[\hat{U}\right] \approx \frac{Var[\hat{H}]\hat{E}^2}{\hat{N}_R^4} + \frac{Var[\hat{E}]\hat{H}^2}{\hat{N}_R^4}\ . \tag{13}$$

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

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \tag{14}$$

$$Var[\hat{S}] \approx \hat{S}^2\left[\frac{Var[\hat{N}_R]}{\hat{N}_R^2} + \frac{Var[\hat{N}_s]}{\hat{N}_s^2}\right] \tag{15}$$

RESULTS

SMOLT TAGGING, SAMPLING, AND ABUNDANCE IN 2003

Smolt abundance in 2003, based on fish tagged in Nakwasina River, is 55,424 (SE = 4,023; 95% CI_{MCMC} = 48,200-63,940). Between April 17 and May 15, 2003, 15,813 coho smolt from Nakwasina River and its tributaries were captured and tagged. Tag retention was 99.9% with ten overnight mortalities. This left 15,762 valid tag releases. Of these, 9,925 (63%) were small smolt captured in the mainstem of Nakwasina River, while 2,533 (16%) were large smolt. Twenty-one percent (21%), or 3,304, were fish ≥65 mm captured in Bridge Creek.

Smolt captured and sampled in the mainstem of Nakwasina River that were age-1. fish (those rearing for one year in fresh water) comprised 98% and averaged 77.9 mm FL (SE = 0.37) and 4.9 g (SE = 0.08, Table 3). Age-2. coho smolt from the mainstem Nakwasina River averaged 103.8 mm FL (SE = 1.84) and 10.4 g (SE = 0.62). The combined catch averaged 78.6 mm FL (SE = 0.42) and 5.0 g (SE = 0.09). 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 78.5 mm FL (SE = 0.81) and 4.7 g (SE = 0.21, Table 3). One age-2. coho smolt was captured and sampled from Bridge Creek and was 99 mm and weighed 9.2 g.

The proportions of smolt tagged in 2003 with each of three tag codes were significantly different than that observed in the spawning escapement in 2004 (χ^2 = 23.65, P < 0.0001, Table 4). However, no differences were detected when large and small smolt from Nakwasina were combined and compared to those tagged in Bridge Creek (χ^2 = 3.62, P = 0.057, Table 4). The smaller tag group apparently had lower survival based on rates of recovery of tagged adult fish (χ^2 = 18.09,

Table 4.–Numbers and χ^2 tests for independence for smolt and adult coho salmon from Nakwasina River and Bridge Creek, 2000–2004.

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	2533	3,304	15,762	63%	16%	21%
Adult escapement recoveries							
2001	75	35	40	150	50%	23%	27%
2002	146	39	15	200	73%	20%	8%
2003	145	28	24	197	74%	14%	12%
2004	180	77	44	301	60%	26%	15%
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%
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%

Component 1	Component 2	χ^2	p
Smolt 2000	All adults 2001	4.63	0.099
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	5.1	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	5.1	0.078

[a] In 2003 smolt ≥65 mm were tagged.

$P < 0.0001$, Table 4). Tagged adults from Bridge Creek were not used to estimate smolt abundance because their survival may have been different than fish tagged in Nakwasina River, and we have no data to evaluate if the probability of a smolt being tagged was the same for both rearing areas.

Because tagged fish from Bridge Creek were treated as unmarked fish for this estimate, it is necessary that Bridge Creek smolt have the same survival as Nakwasina River smolt for this

estimate to be unbiased. Further, because fish tagged in Bridge Creek spawned in Nakwasina River and none were found spawning in Bridge Creek, Bridge Creek was assumed to be a part of the Nakwasina River rearing area. From the tag recovery data (Table 4), it appears that survival of Bridge Creek smolt was approximately 65% of that for Nakwasina River smolt. However, when smolt survival from Nakwasina River tagging groups is adjusted for relative probability of sampling during the tagging event, it appears the Bridge Creek smolt survival was approximately 76% of that for Nakwasina River smolt.

INSTREAM CODED WIRE TAG RECOVERY AND AGE-SEX COMPOSITION

The fraction of CWT adult coho salmon sampled in Nakwasina River during 2003 was 0.286. Of the 1,074 adult coho salmon examined, 307 had an adipose fin clip. Of these, all but 6 were found to contain a valid coded-wire tag.

The proportion of freshwater age-1. fish was not significantly different (χ^2 = 1.32, P = 0.25) between smolt sampled in 2003 and adults sampled inriver during 2004 (Table 5; Appendix A2). Both groups were predominately (>97%) freshwater age-1. fish. Additionally, no differences were detected in freshwater age by sex (χ^2 = 0.08, P = 0.78).

CONTRIBUTION OF SMOLT TAGGED IN 2003 TO MARINE FISHERIES IN 2004

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2004 was 1,645 (SE = 178, Table 6). Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,425,980, 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 200 fish. Sport-caught Nakwasina coho salmon comprised 12.2% of the harvest in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.37%) than the troll harvest (0.10%). Freshwater harvest of coho salmon in Nakwasina River will not be available until the Division of Sport Fish publishes the results of its annual mail-out angler survey (SWHS).

In 2004, 97 CWTs from Nakwasina River and Bridge Creek were randomly recovered from 307,168 coho salmon sampled in commercial and sport fisheries and nine additional CWTs were recovered incidentally (Appendix A3). Eighty-five coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries. One fish was not used because it did not have quadrant recovery information. Of the 84 random recoveries with quadrant information, all but two were caught in the Northwest Quadrant (Figure 2) of Southeast Alaska between July 1 and September 30, 2004. Nine coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between July 4 and September 26. Three coho salmon bearing CWTs were recovered in the Elfin Cove sport fishery between August 15 and August 30, and one fish was randomly recovered in the commercial seine fishery in the Northwest Quadrant in stat week 31.

Table 5.–Number of age-1. and age-2. Nakwasina River coho salmon smolt and adults, 2000–2004

		Brood year and age class			
		2002	2001	2000	
		1.0	1.1	2.1	Total aged
Females	Sample size		332	4	336
	% age comp		98.8	1.2	
	SE of %		0.6	0.6	
	Average length		640	615	
	SE		2	27	
Males	Sample size	20	488	7	515
	% age comp	3.9	94.8	1.4	
	SE of %	0.9	1.0	0.5	
	Average length	327	626	636	
	SE	5	3	25	
All Fish	Sample size	20	820	11	851
	% age comp	2.4	96.4	1.3	
	SE of %	0.5	0.6	0.4	
	Average length	327	632	629	
	SE	5	2	18	

	Freshwater age[a]			
	1	2	$\chi 2$	P-value
Adults 2004	840	11	1.32	0.25
Smolt 2003	515	11		
Adults 2003	681	13	0.20	0.65
Smolt 2002	210	3		
Adult 2002	663	25	18.53	0.00
Smolt 2001	368	41		
Adult 2001	701	19	0.27	0.60
Smolt 2000	397	13		
2004 Adult Males	488	7	0.08	0.78
2004 Adult Females	332	4		

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

Table 6.–Estimated harvest of adult Nakwasina River coho salmon (tag codes 04-08-17, 04-08-18, and 04-08-19) in sport and commercial fisheries sampled in 2004.

TROLL FISHERY											
Period	Dates	Quadrant	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
3	7/1–8/9	NW	547,304	118,686	1,587	1,560	1,230	1,229	18	296	69
4	8/12–9/30	NE	131,422	27,257	443	436	333	332	2	34	24
4	8/12–9/30	NW	690,256	149,828	2,760	2,710	2,229	2,228	64	1,051	137
Subtotal Troll Fishery			1,368,982	295,771	4,790	4,706	3,792	3,789	84	1,381	156
PURSE SEINE FISHERY											
Week	Dates	Quadrant	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
31	7/25–7/31	NW	3,503	194	9	9	8	8	1	63	63
Subtotal Seine Fishery			3,503	194	9	9	8	8	1	63	63
SPORT FISHERY											
Bi-week	Dates	Area	Estimated harvest	Inspected	a	a'	t	t'	m	r	SE{r}
14	7/4–7/18	SITKA	11,105	2,297	18	18	16	16	1	17	16
15	7/19–8/1	SITKA	8,126	1,465	18	18	15	15	1	19	19
16	8/2–8/15	SITKA	11,438	2,200	33	32	29	29	3	56	32
17	8/16–8/29	SITKA	14,453	3,488	52	51	48	48	2	30	20
19	9/13–9/26	SITKA	381	48	4	4	4	4	1	28	27
16	8/2–8/15	ELFIN COVE	1,210	464	16	16	14	14	1	9	9
18	8/30–9/12	ELFIN COVE	972	385	13	13	12	12	2	18	12
18	8/30–9/12	SITKA	5,810	856	23	23	16	16	1	24	23
Subtotal sport fishery			53,495	11,117	177	175	154	154	12	200	54
Total all fisheries			1,426,980	307,168	4,976	4,890	3,954	3,951	97	1,645	178

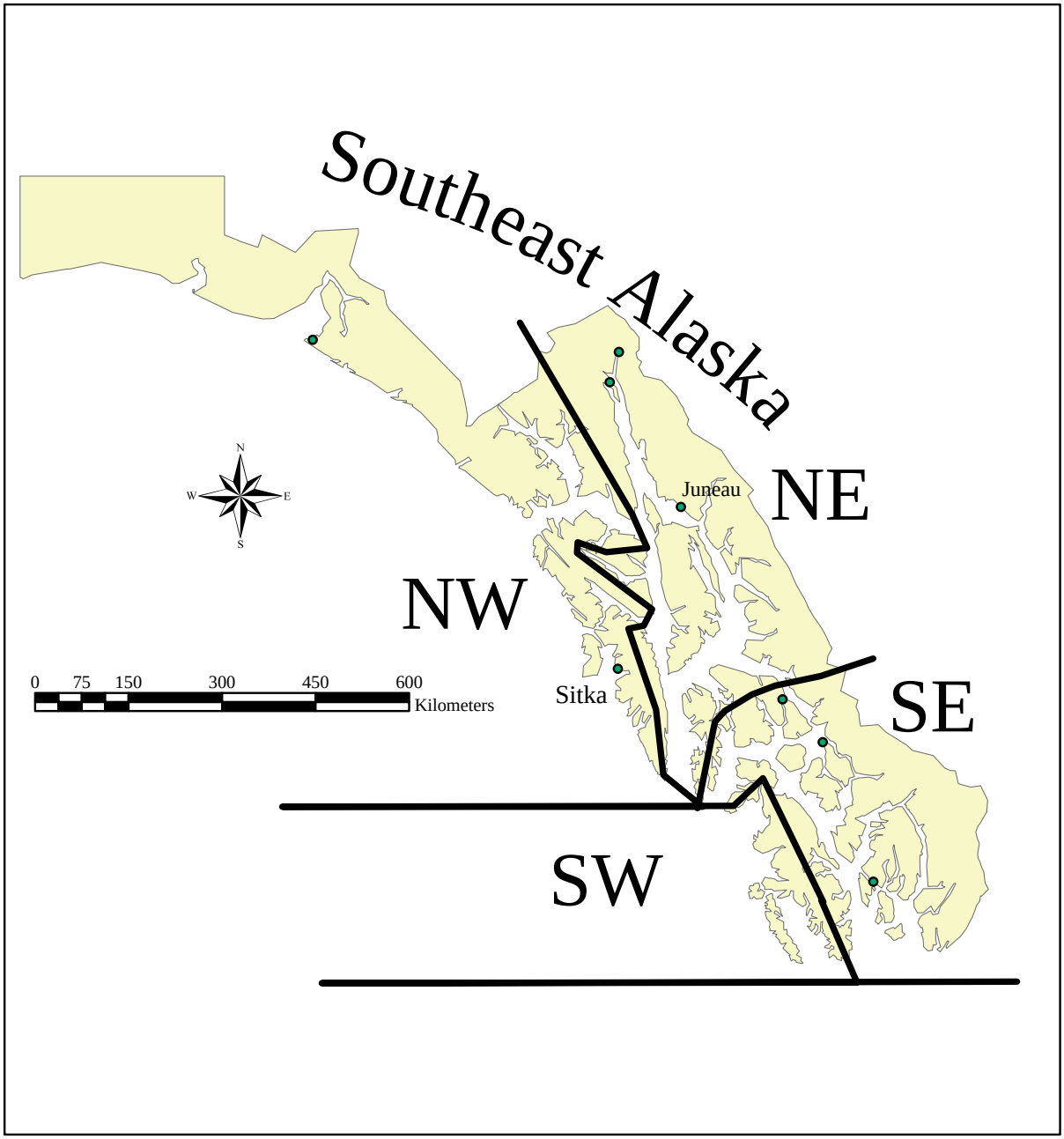

Figure 2.–Map of Southeast Alaska showing the boundaries for CWT quadrants.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 645 mm FL (SE = 5.01).

ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

The estimated spawning escapement of coho salmon in Nakwasina River was 3,867 fish (SE = 937). Coho salmon were marked and recaptured in all 13 weeks of the study. Altogether, 1,074 unique adults were captured and examined, 905 were released, and 156 were recaptured (Table 7; Appendix A4). Only 9 recaptured fish had lost their numbered tag as evidenced by the operculum punches. A total of 325 fish were sacrificed for their CWTs or died on capture. No fish died upon recapture. Most (971) adult coho captured in Nakwasina River in 2004 were captured with either the beach seine or gillnet, while 103 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.

Table 7.–Summarized mark-recapture data for Nakwasina River coho salmon, 2004. Notation follows that in Seber (1982).

Week	Number captured	Number released	Number marked caught in m_i	Losses on capture	Subsequently recaptured
37	3	3			1
38	15	12		3	1
40	33	12		21	4
41	122	85	1	38	27
42	150	115	14	49	31
43	212	181	20	51	45
44	126	111	26	41	11
45	110	85	10	35	24
46	211	202	49	58	8
47	39	40	13	12	3
48	34	38	14	10	1
49	14	17	6	3	
50	5	4	3	4	
Grand total	1,074	905	156	325	156

Instream abundance peaked at 1,929 adults in week 6 and declined to 13 fish in week 13 (Table 8). Period-to-period survival rates varied from 0.023 (constrained) to 1.0 (Table 8). Four estimates of survival and six 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 during period 4 (week 6) of the experiment may have had a different probability of survival and/or subsequent recapture than fish caught prior to period 4 (Table 9, component 1). While the p-values of the test statistics warranted further attention (0.06 for χ^2, 0.08 for Fisher's Exact Test), the test doesn't indicate significant potential for bias in the abundance estimates. In component 2 (Table 9), the χ^2 test statistic for period 5 was significant (p = 0.05), however the sample sizes in the 2x2 contingency table were small, suggesting the χ^2 statistic was biased. However, Fisher's Exact Test yielded a non-significant test result (p = 0.21), and the individual contribution of the period 5 observations was not large enough to influence the overall component 2 test result (p = 0.39). Therefore, the potential for bias from capture or survival heterogeneity was small, and the reported estimate is considered reliable for management purposes.

Twenty percent (20%) of the sample was captured or recovered in section 1, 38% at location 2, 39.4% at location 3, and 2.6% at tidewater (Table 10). In total, 28.6% of the fish inspected for Floy™ tags had either a Floy™ tag or a secondary mark. The probability of capturing a tagged fish was significantly different in section 1 versus section 2 (χ^2 = 4.04, P = 0.045) and section 1 versus section 3 (χ^2 = 19.8, P < 0.0001).

Length distributions of adult coho salmon captured in 2004 in Nakwasina River were not different between gear type used for capture, capture and recapture, or time of capture (Table 11, Figure 3). The average length of female and male coho salmon was 638 mm FL (SE = 1.9) and 626 mm FL (SE = 2.16), respectively. The proportions of males and females captured at locations 1, 2, and 3 were not significantly different (χ^2 = 5.33 P = 0.070, Table 12), but recapture rates were significantly different (χ^2 = 11.27 P < 0.001, Table 12). Based on an escapement estimate of 3,867, a coho salmon marine harvest of 1,645 fish, and smolt abundance of 55,424, the estimated total run in 2004 was 5,512 (SE = 954) and ocean survival was 9.9% (SE = 1.9%). Total exploitation was estimated to be 29.8% (SE = 5.6%).

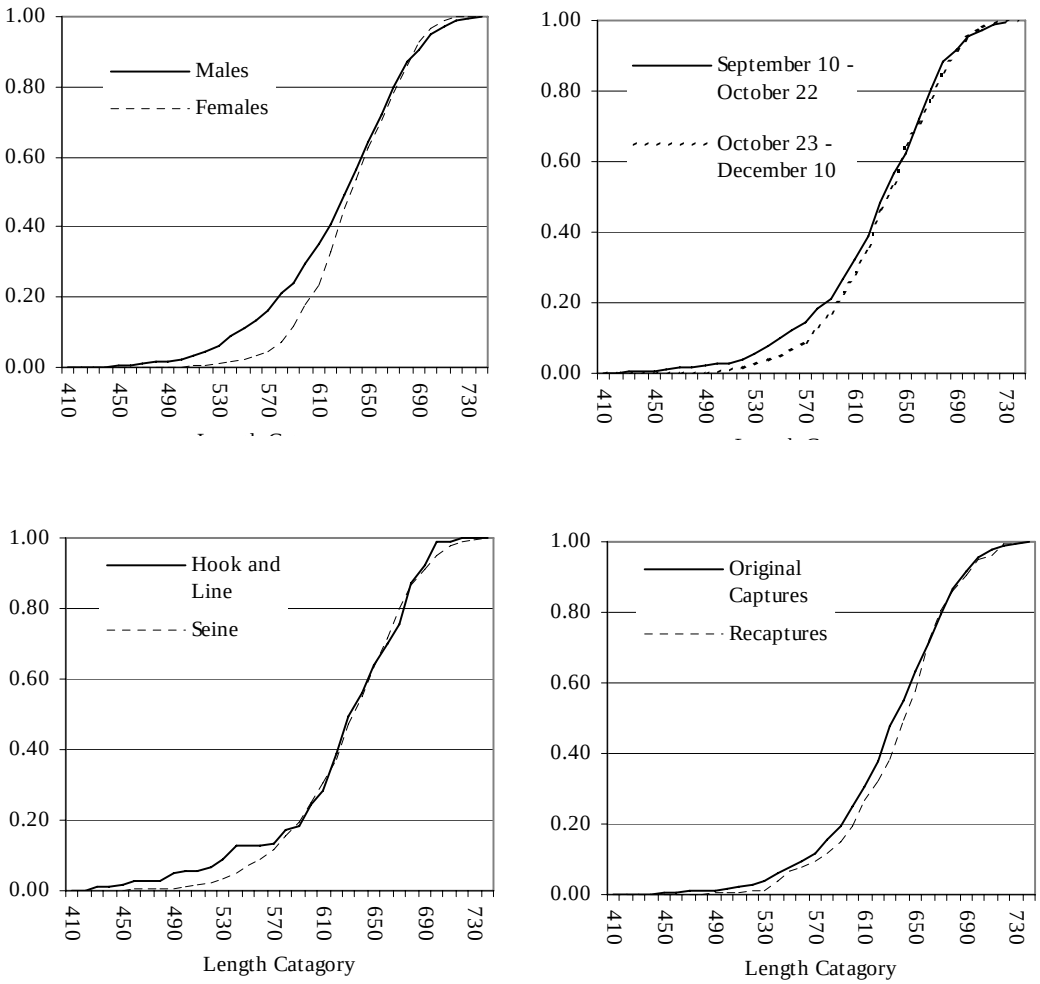

Figure 3.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, time, gear, and capture or recapture, 2004.

Table 8.–Jolly Seber estimates of abundance (N), survival (ϕ), and recruitment (B) of adult coho salmon in Nakwasina River, 2004.

Week(s)	Dates	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$
1-3	9/10–10/2	1,477	335	1.000	0.000	0	0
4	10/3–10/9	1,453	335	0.584	0.122	0	0
5	10/10–10/16	825	246	1.000	0.000	1,152	430
6	10/17–10/23	1,929	413	1.000	0.000	35	511
7	10/24-10/30	1,913	336	0.4179	0.080	714	208
8	10/31-11/6	1,497	234	1.000	0.000	0	0
9	11/7-11/13	1,462	234	0.3553	0.157	0	0
10	11/14-11/20	502	223	0.997	0.786	87	153
11	11/21-11/27	563	421	0.999	0.000	43	205
12	11/28-12/4	595	400	0.023	0.015	0	0
13	12/5-12/11	13	4	0.000	0.000	0	0

VISUAL COUNTS

Visual counts were conducted on Nakwasina River on two occasions in 2004 (Table 13). The peak count (399) occurred November 8 and represented 10.3% of the estimated total escapement.

DISCUSSION

SMOLT ABUNDANCE AND ADULT HARVEST

The smolt-to-adult survival rate of 9.9% in 2004 is low, but comparable to some other systems in the region (Table 14) and similar to the 2000–2004 average of 9.6% (Table 1). Because of the low average smolt-to-adult survival rate in Nakwasina River in 2000–2002 (8.7%), extra care was taken in spring 2003 to insure smolt were given an adequate opportunity to recover and smolt naturally. However, survival remained relatively low in 2003–2004, 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 two 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 smolts marked as in this project and handled competently suffer no detectable mortality from the experience, so we believe 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.

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

Table 9.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group for adult coho salmon in Nakwasina River, 2004. Overall chi-squares are the sum of the individual test statistics.

	Component 1[a]			Component 2[b]		
Period	χ^2 τατσ	df	P-value	χ^2 τατσ	df	P-value
2	0.40	1	0.53	0.00	0	0.00
3	1.30	1	0.25	0.11	1	0.73
4	3.47	1	0.06[c]	1.96	1	0.16
5	0.35	1	0.85	3.95	1	0.05[d]
6	0.61	1	0.43	0.11	1	0.74
7	0.6	1	0.81	0.02	1	0.90
8	0.15	1	0.70	0.14	1	0.71
9	0.16	1	0.69	0.00	0	0.00
10	0.0	0	0.00	0.00	0	0.00
Overall	6.175	8	0.62	6.301	6	0.39

[a] Test for short-term mortality per Robson (1969).
[b] Test for heterogenous survival probabilities per Pollock et al. (1990).
[c] Fisher's Exact Test P-value = 0.08.
[d] Fisher's Exact Test P-value=0.21.

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 (χ^2 = 1.18, P = 0.556; Table 15).

Smolt-to-adult survival rates for smolt tagged in the main stem of Nakwasina River and those tagged in Bridge Creek were not significantly different. However, it appears that survival was lower for smaller smolt (those ≤65 mm) than larger smolt tagged in Nakwasina River. Neither condition S2 nor condition S3 can be satisfied when unequal survival is detected.

To evaluate if condition S1 was satisfied, the assumption that the probability of capture for Nakwasina River smolt was independent of size was tested. The ratio of the catchability coefficients (estimated A) for large to small smolt was estimated using the methods described in Tydingco (2005b). For smolt tagged in 2003, the estimated ratio was 3.368 (SE = 2.021; 95%

Table 10.–Results of $\chi 2$ tests for differences in tagged rate between river sections for adult coho salmon in Nakwasina River, 2004.

Location	Untagged	Tagged	Total	p
Upstream 1	197	49	246	0.199
Middle 2	402	66	468	0.141
Lower 3	443	41	484	0.084
Tide water	32	0	32	
Total	1,074	156	1,230	

CIMCMC: 1.165, 8.835), which provides evidence that smolt from the two size groups had significantly different capture probabilities. It was not possible to compare the probability of tagging Bridge Creek smolt with that of Nakwasina River smolt. Further, there are no expectations that capture probabilities were similar because tagging occurred in geographically separate areas. However, smolt capture occurred throughout the emigration, within most of the available smolt habitat, and was accomplished with minnow traps that captured a wide range of smolt sizes. Smolt tagging occurred just prior to and during the smolt migration. Because approximately equal effort occurred throughout the emigration, later migrating smolt may have had a higher probability of capture. Similarly, recovery effort was expended throughout most of the run of returning adults, but not in exact proportion to fish abundance, and a small number of fish probably returned earlier or later than the tag recovery sampling.

Because none of the conditions S1–S3 were satisfied, the Chapman modification to the Petersen estimator (Seber 1982) could not be used to calculate an unbiased estimate of smolt abundance. It was necessary to employ equations (1-3) to adjust for the differential catchability detected between large and small smolt during tagging. Adjusting for differential catachability will result in an unbiased estimate of abundance subject to the other conditions 1-5 also being satisfied.

The smolt estimate of 55,424 may be biased low, despite the adjustments for differential catchability between large and small smolt tagged in Nakwasina River. Unfortunately, attempts to assess the bias are, at best, speculative because no data are available to measure differences in probability of tagging between the Nakwasina River and Bridge Creek rearing areas. However, if the probabilities of a smolt being tagged were approximately the same for both Nakwasina River and Bridge Creek, then approximately 20–25% of the smolt in the Nakwasina system were in Bridge Creek when tagging was conducted, and the projected true smolt abundance is 1.05 to 1.10 times the estimated value. If Bridge Creek smolt were tagged at a higher rate than Nakwasina River smolt, the potential bias is not so severe. If Bridge Creek smolt were tagged at a lower rate than Nakwasina River smolt, the potential bias is greater than projected.

ADULT ESCAPEMENT IN 2004

There were no indications to suggest problems with the abundance estimate; tag loss was low (<1%), sampling rates were high, assumptions of the JS experiment were met, and the JS model fit the data. Diagnostic testing for handling mortality and/or heterogeneity in probability of capture or survival indicated some potential for these problems, but detailed inspection of these diagnostics led to the conclusion that the potential for bias resulting from these types of problems was very low. Additionally, 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.

A higher rate of recapture was observed for males than females. This may have been due to error in determining the sex of fish early in the run.

Table 11.–Results of Kolmogorov-Smirnov tests for differences between cumulative length frequencies for adult coho salmon in Nakwasina River, 2004.

	Males vs. Females	Sept. 10-Oct. 22 vs. Oct. 23 - Dec 10	Hook and line vs. Seine	Original capture vs. Recapture
Number of lengths compared	643 431	535 539	103 971	1024 156
D_i	0.142	0.055	0.079	0.939
P-value	<0.000	0.386	0.592	0.174

Because the secondary maturation characteristics had not fully developed earlier in the run, it is possible that some fish were misidentified as females. When recaptured, fish previously identified as females may have been identified as males. This would lead to an indication that a higher proportion of males were recaptured. Similar tests from previous years have yielded inconsistent results, with no difference detected between male and female recapture rates in 2000 and 2002, 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 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.

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 is 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 in the experiment during each sampling event. While it is unlikely that equal capture probabilities can be uniformly achieved, field efforts to sample proportional to our perception of fish abundance across the study area are intended to minimize the potential for bias in abundance estimation due to violating this assumption. 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 over-estimates 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

Table 12.–Differences in coho salmon sex composition between capture type, gear, and location in Nakwasina River, 2004.

Capture	Females	Males	% Males	$\chi 2$	p-value
Captured	431	643	59.87%	11.27	0.0008
Recapture	35	103	74.64%		
Gear type					
Hook and line	50	53	51.46%	3.36	0.067
Seine/tangle net	381	590	60.76%		
Location					
1	65	132	67.01%	5.33[a]	0.070
2	159	243	60.45%		
3	189	254	57.34%		
Tide water	18	14	43.75%		

[a] Location 1 vs. 2 vs. 3.

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

Date	Count	Conditions	% of total escapement
10/8/2004	148	Visibility poor, tide high, water normal	3.8%
11/8/2004	399	Visibility poor, tide high, water low	10.3%

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

	Return Year					
Stream	2000	2001	2002	2003	2004	Average
Auke Creek	18.5	28.3	26.8	25	20.7	23.9
Berners River	12.1	11.9	19	19.1	17.7	16.0
Taku River	6.3	8.8	11.1	8.9	8.6	8.7
Ford Arm	12.8	8.2	14.7	17	11.9	12.9
Hugh Smith Lake	6.6	13.5	14.5	13.7	10.4	11.7
Unuk River	3.8	11.4	9.3			8.2
Nakwasina River	6.8	9.5	9.8	11.9	9.9	9.6

bias can result which 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 138 first recaptures of marked fish in 2003, 42% occurred during the sampling event immediately after the tagging event and 68% occurred during either the first or second event immediately after tagging.

Table 15.–Proportion of recovered Nakwasina River adult coho salmon observed with and without adipose fin clips, 2004.

Date	No. clip	Clip observed	Tagged proportion
10-Sep	3		0.00
16-Sep	6		0.00
17-Sep	6	3	0.33
30-Sep	12	6	0.33
1-Oct	7	8	0.53
4-Oct	63	27	0.30
5-Oct	21	11	0.34
11-Oct	7	6	0.46
12-Oct	101	36	0.26
19-Oct	4	3	0.43
20-Oct	83	28	0.25
21-Oct	63	16	0.20
22-Oct	11	4	0.27
27-Oct	34	15	0.31
28-Oct	51	26	0.34
5-Nov	36	16	0.31
6-Nov	40	18	0.31
9-Nov	67	20	0.23
10-Nov	43	19	0.31
11-Nov	43	19	0.31
18-Nov	27	12	0.31
23-Nov	25	9	0.26
29-Nov	12	2	0.14
7-Dec		2	1.00
8-Dec	2	1	0.33
Grand total	767	307	0.286
Sept. 10–Oct. 5	118	55	
Oct.11–Oct. 28.	354	134	
Nov. 5–Dec. 8	295	118	
	χ^2 =	1.18	
	P =	0.556	

In 2004, 32 fish were tagged at tidewater. Of these, 4 were recovered. This recovery rate is similar to sections 2 and 3 (Table 16). These recovery rates indicate that problems associated with tagging mortality near the saltwater/freshwater interface (Vincent-Lang 1993) were not present at detectable levels 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 (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,

Table 16.–Numbers of coho salmon recaptured in Nakwasina River by location of original tagging and location of recapture, 2004.

	Original tag location			
Location of recapture	1 Upstream	2 Middle section	3 Lower section	Tide water
Upstream 1	7	17	23	2
Middle section 2	5	27	34	
Lower section 3	1	16	22	2
Totals	13	60	79	4
Total number of fish tagged	197	402	443	32
Proportion recovered	0.066	0.149	0.178	0.125

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 rate for troll fisheries in the Northwest Quadrant ranged from 9% (District 154) to 21% (District 113). Not all fisheries were sampled, so it is likely that Nakwasina River coho salmon harvest was underestimated in some fisheries.

Table 17.–Numbers of coho salmon harvested and sampled for CWT recovery for districts in which Nakwasina River coho salmon were recovered in 2004.

District	Gear type	Fish harvested	Fish sampled	Proportion sampled
113	Purse	913	98	0.107
109	Troll	113,411	24,050	0.212
113	Troll	752,855	159,569	0.212
114	Troll	181,491	37,106	0.204
116	Troll	93,588	14,581	0.156
154	Troll	48,850	6,008	0.123
183	Troll	6,911	653	0.094
		1,198,019	242,065	0.202

RECOMMENDATIONS

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 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.

ACKNOWLEDGEMENTS

I would like to thank Bob Chadwick, Tom Brookover, and Art Schmidt for assistance in conceptualizing and managing this project, which included helping with site selection and providing advice on run timing and procedural details and logistical support. Dan Reed helped with planning and writing the spring 2003 smolt tagging operational plan and the fall 2004 adult escapement operational plan. Dan Reed also reviewed and provided data analysis and biometric support for this paper. Dave Magnus, Thomas Miller, and Paul Evans assisted with the smolt-tagging portion of this study. Dave Magnus also helped with the mark-recapture portion of this study in 2004. I thank all of the personnel involved with the recovery of CWT coho salmon in 2004. Sarah Larsen and Susan Chartier helped with data entry. Linda Bergdoll-Schmidt provided administrative support and editorial suggestions. I also thank Sue Millard for aging the adult scales.

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APPENDICES

Appendix A1.–Simulated values modeled from observed data used to estimate catchability of coho smolt from the Nakwasina River in 2003.

observed 52 = H_1 ~binomial(H_1'/9925, 9925);

observed 22 = H_2 ~binomial(H_2'/2533, 2533);

observed 24 = H_{BC} ~binomial(H_{BC}'/3304, 3304);

observed 180 = R_1 ~binomial(R_1'/(9925-H_1'), 9925-H_1');

observed 77 = R_2 ~binomial(R_2'/(2533-H_2'), 2533-H_2');

observed 44 = R_{BC} ~binomial(R_{BC}'/(3304-H_{BC}'), 3304-H_{BC}');

T_i' = H_i' + R_i' for i = 1,2, and BC;

observed 6 = R_3 ~binomial(R_3'/307, 307);

observed 333 = 333* $\hat{\phi}_1$ ~binomial($\hat{\phi}_1$ ',333);

observed 77 = 87* $\hat{\phi}_2$ ~binomial($\hat{\phi}_2$ ',87); and

observed 840 = 851* $\hat{p}$ ~binomial($\hat{p}$,851).

At the end of the iterations, the following statistics were calculated:

$$\overline{N}' = \frac{\sum_{b=1}^{100000} \hat{N}'_{(b)}}{100000} \qquad (4a)$$

$$\mathrm{var}(\hat{N}) = \frac{\sum_{b=1}^{100000} (\hat{N}'_{(b)} - \overline{N}')^2}{100000-1} \qquad (4b)$$

Similar formulas were used to calculate $\overline{A}'$ and var($\hat{A}$).

Appendix A2.–Brood year, age classes and lengths of coho salmon by year sampled in the Nakwasina River, 2001–2004.

			Brood year and age class														
Sample year			2002 1.0	2001 1.1	2000 2.1	2001 1.0	2000 2.0	2000 1.1	1999 2.1	2000 1.0	1999 1.1	1998 2.1	1999 1.0	1998 2.0	1998 1.1	1997 2.1	**Total aged**
		Sample size		332	4												336
		% age comp		98.8	1.2												
	Females	SE of %		0.6	0.6												
		Average length		640	615												
		SE		2	27												
		Sample size	20	488	7												515
		% age comp	3.9	94.8	1.4												
2004	Males	SE of %	0.9	1.0	0.5												
		Average length	327	626	636												
		SE	5	3	25												
		Sample size	20	820	11												851
		% age comp	2.4	96.4	1.3												
	All Fish	SE of %	0.5	0.6	0.4												
		Average length	327	632	629												
		SE	5	2	18												
		Sample size						276	6								282
		% age comp						97.9	2.1								
	Females	SE of %						0.9	0.9								
		Average length						635	640								
		SE						2	18								
		Sample size				16	5	405	7								433
		% age comp				3.7	1.2	93.5	1.6								
2003	Males	SE of %				0.9	0.5	1.2	0.6								
		Average length				319	319	614	654								
		SE				8	14	3	13								
		Sample size				16	5	681	13								715
		% age comp				2.2	0.7	95.2	1.8								
	All Fish	SE of %				0.6	0.3	0.8	0.5								
		Average length				319	319	622	648								
		SE				8	14	2	10								

-continued-

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			Brood year and age class														
Sample year			2002 1.0	2001 1.1	2000 2.1	2001 1.0	2000 2.0	2000 1.1	1999 2.1	2000 1.0	1999 1.1	1998 2.1	1999 1.0	1998 2.0	1998 1.1	1997 2.1	Total aged
		Sample size									243	13					256
		% age comp									94.9	5.1					
	Females	SE of %									1.4	1.4					
		Average length									626	647					
		SE									3	11					
		Sample size								2	409	12					423
		% age comp								0.5	96.7	2.8					
2002	Males	SE of %								0.3	0.9	0.8					
		Average length								313	608	641					
		SE								3	3	18					
		Sample size								2	652	25					679
		% age comp								0.3	96.0	3.7					
	All Fish	SE of %								0.2	0.7	0.7					
		Average length								313	615	644					
		SE								3	2	10					
		Sample size													263	5	268
		% age comp													98.1	1.9	
	Females	SE of %													0.8	0.8	
		Average length													630	658	
		SE													2	18	
		Sample size											4	2	433	14	453
		% age comp											0.9	0.4	95.6	3.1	
2001	Males	SE of %											0.4	0.3	1.0	0.8	
		Average length											283	353	621	597	
		SE											6.	28	3	18	
		Sample size											4	2	696	19	721
		% age comp											0.6	0.3	96.5	2.6	
	All Fish	SE of %											0.3	0.2	0.7	0.6	
		Average length											283	353	624	613	
		SE											6	28	2	16	

Appendix A3.–Recoveries of coded wire tags originating from Nakwasina River coho salmon during 2004**.**

Head	Tag Code	Gear Class	Date (CWT)	Stat Week	Quadrant	District	Sub-District	Length	Survey Site	Sample
					Random Recoveries					
260069	40817	TROLL	8/15/2004	34	NW	113	45	511	SITKA	4031147
263472	40817	TROLL	7/4/2004	28	NW	113	31	552	SITKA	4030798
267085	40817	TROLL	9/6/2004	37	NW	114	21	557	PELICAN	4010106
266854	40817	TROLL	9/11/2004	37	NW	113	71	567	PELICAN	4010116
266161	40817	TROLL	7/9/2004	28	NW	113	91	588	PELICAN	4010015
538086	40817	TROLL	7/6/2004	28	NW			590	EXCURSION INLET	4100018
263854	40817	TROLL	7/25/2004	31	NW	113	31	590	SITKA	4031003
265140	40817	TROLL	7/24/2004	30				591	PORT ALEXANDER	4080053
261324	40817	TROLL	9/19/2004	39	NW	113	45	597	SITKA	4031304
261259	40817	TROLL	9/11/2004	37	NW	113	45	601	SITKA	4031277
264274	40817	TROLL	9/8/2004	37	NW	113	11	606	PORT ALEXANDER	4080177
261053	40817	TROLL	8/28/2004	35	NW	113	45	609	SITKA	4031227
266316	40817	TROLL	7/30/2004	31	NW	116	11	612	PELICAN	4010042
266776	40817	TROLL	8/26/2004	35	NW	113	91	613	PELICAN	4019999
260746	40817	TROLL	8/17/2004	34	NW	154		617	SITKA	4031195
260314	40817	TROLL	8/26/2004	35	NW	154		620	SITKA	4031223
267070	40817	TROLL	9/3/2004	36	NW	114	21	620	PELICAN	4010104
262272	40817	PURSE	7/27/2004	31	NW	113		625	SITKA	4031015
263849	40817	TROLL	7/25/2004	31	NW	113	31	625	SITKA	4031003
262840	40817	TROLL	8/8/2004	33	NW	113	41	631	SITKA	4031105
266364	40817	TROLL	8/10/2004	33	NW	116	11	632	PELICAN	4010052
266742	40817	TROLL	8/24/2004	35	NW	113	71	632	PELICAN	4010075
262866	40817	TROLL	8/9/2004	33	NW	113	45	634	SITKA	4031118
261271	40817	TROLL	9/11/2004	37	NW	113	91	637	SITKA	4031278
519390	40817	TROLL	8/19/2004	34	NW	114	21	640	ELFIN COVE	4020163
530928	40817	TROLL	7/18/2004	30	NW	183	10	641	YAKUTAT	4140045
260011	40817	TROLL	8/9/2004	33	NW	113		642	SITKA	4031115
260331	40817	TROLL	8/26/2004	35	NW			645	SITKA	4031226
265458	40817	TROLL	8/25/2004	35	NW	113	11	648	PORT ALEXANDER	4080138
274385	40817	TROLL	8/30/2004	36	NW	154		650	HOONAH	4110316
261301	40817	TROLL	9/18/2004	38	NW	113	81	651	SITKA	4031299
538327	40817	TROLL	8/13/2004	33	NW			654	EXCURSION INLET	4100083
261072	40817	TROLL	8/28/2004	35	NW	113	45	654	SITKA	4031229
261281	40817	TROLL	9/11/2004	37	NW	113	91	655	SITKA	4031278
260111	40817	TROLL	8/14/2004	33	NW	113	31	662	SITKA	4031131
260320	40817	TROLL	8/27/2004	35	NW	154		668	SITKA	4031225
274609	40817	TROLL	9/4/2004	36	NW			670	HOONAH	4110354
261394	40817	TROLL	9/20/2004	39	NW	154		670	SITKA	4031310
274896	40817	TROLL	9/25/2004	39	NW	114		671	HOONAH	4110397
260340	40817	TROLL	8/26/2004	35	NW			672	SITKA	4031226
260525	40817	TROLL	9/2/2004	36	NW	113	45	673	SITKA	4031250
265485	40817	TROLL	8/26/2004	35	NE	109	10	681	PORT ALEXANDER	4080141
262137	40817	TROLL	10/1/2004	40	NW	113	41	714	SITKA	4031325
266864	40817	TROLL	9/13/2004	38	NW	113	91	738	PELICAN	4010118
519432	40817	TROLL	8/31/2004	36	NW			835	ELFIN COVE	4020198
288534	40817	TROLL	7/27/2004	31	NW				JUNEAU	4040504
260589	40817	TROLL	9/20/2004	39	NW	113	45	681	SITKA	4031317
273845	40818	TROLL	8/2/2004	32	NW	116	11	580	HOONAH	4110197
262375	40818	TROLL	8/2/2004	32	NW	113	31	600	SITKA	4031058
262673	40818	TROLL	7/31/2004	31	NW	113	41	622	SITKA	4031038

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Appendix A3.–Page 2 of 3**.**

Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
					Random recoveries					
267097	40818	TROLL	9/7/2004	37	NW			623	PELICAN	4010107
261369	40818	TROLL	9/20/2004	39	NW	113	45	633	SITKA	4031309
266887	40818	TROLL	9/16/2004	38	NW	113	91	643	PELICAN	4010123
266795	40818	TROLL	8/28/2004	35	NW	113	91	646	PELICAN	4010082
261251	40818	TROLL	9/11/2004	37	NW	113	45	659	SITKA	4031276
274611	40818	TROLL	9/4/2004	36	NW			665	HOONAH	4110354
273769	40818	TROLL	7/26/2004	31	NW			675	HOONAH	4110188
263818	40818	TROLL	7/22/2004	30	NW	113	45	682	SITKA	4030980
260106	40818	TROLL	8/14/2004	33	NW	113	41	682	SITKA	4031128
261399	40818	TROLL	9/20/2004	39	NW	154		683	SITKA	4031310
267076	40818	TROLL	9/3/2004	36	NW	114	21	685	PELICAN	4010105
261265	40818	TROLL	9/11/2004	37	NW	113	45	697	SITKA	4031277
260311	40818	TROLL	8/26/2004	35	NW	113	45	704	SITKA	4031222
266891	40818	TROLL	9/16/2004	38	NW	113	91	715	PELICAN	4010123
519404	40818	TROLL	8/25/2004	35	NW	114	21	720	ELFIN COVE	4020176
266879	40818	TROLL	9/15/2004	38	NW	113		725	PELICAN	4010121
260584	40818	TROLL	9/20/2004	39	NW	113	91	740	SITKA	4031315
262869	40819	TROLL	8/9/2004	33	NW	113	45	495	SITKA	4031118
249159	40819	TROLL	7/5/2004	28	NW	113	31	593	SITKA	4030835
262306	40819	TROLL	7/30/2004	31	NW	113	41	602	SITKA	4031030
261016	40819	TROLL	8/25/2004	35	NW	113	45	611	SITKA	4031213
262890	40819	TROLL	8/13/2004	33	NW	113	45	613	SITKA	4031125
261382	40819	TROLL	9/20/2004	39	NW	154		619	SITKA	4031310
260862	40819	TROLL	8/21/2004	34	NW	113	41	631	SITKA	4031200
266865	40819	TROLL	9/13/2004	38	NW	113	91	631	PELICAN	4010118
260357	40819	TROLL	9/1/2004	36	NW	113	45	632	SITKA	4031242
266992	40819	TROLL	9/1/2004	36	NW	116	14	650	PELICAN	4010095
274560	40819	TROLL	9/4/2004	36	NW			650	HOONAH	4110345
260353	40819	TROLL	8/26/2004	35	NW			665	SITKA	4031226
260795	40819	TROLL	8/23/2004	35	NW	113	81	677	SITKA	4031205
262669	40819	TROLL	7/31/2004	31	NW	113	31	683	SITKA	4031037
262676	40819	TROLL	7/31/2004	31	NW	113	41	683	SITKA	4031038
260040	40819	TROLL	8/11/2004	33	NE	109		683	SITKA	4031207
262831	40819	TROLL	8/8/2004	33	NW	113	31	701	SITKA	4031096
261228	40819	TROLL	9/8/2004	37	NW	113	45	710	SITKA	4031268
538231	40819	TROLL	7/19/2004	30	NW			715	EXCURSION INLET	4100039
256884	40817	SPORT	8/27/2004	35	NW	113	45	573	SITKA	4035426
256900	40817	SPORT	9/4/2004	36	NW	113	61	649	SITKA	4035472
288455	40817	SPORT	8/15/2004	34	NW	113	91	650	ELFIN COVE	4025050
256980	40817	SPORT	9/13/2004	38	NW	113	31	658	SITKA	4035486
259648	40817	SPORT	7/21/2004	30	NW	113	45	673	SITKA	4035291
256940	40818	SPORT	8/3/2004	32	NW	113	41	598	SITKA	4035353
288473	40818	SPORT	8/30/2004	36	NW	113	91	690	ELFIN COVE	4025057
259666	40819	SPORT	8/3/2004	32	NW	113	41	560	SITKA	4035342
288477	40819	SPORT	8/30/2004	36	NW	113	91	625	ELFIN COVE	4025057
256859	40819	SPORT	8/13/2004	33	NW	113	41	679	SITKA	4035382
259677	40819	SPORT	8/17/2004	34	NW	113	41	680	SITKA	4035390
256833	40819	SPORT	7/16/2004	29	NW	113	45	682	SITKA	4035263

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Head	Tag code	Gear class	Date (CWT)	Stat week	Quadrant	District	Sub-district	Length	Survey site	Sample
					Select recoveries					
274195	40817	TROLL						655	HOONAH	4110291
901712	40817	TROLL	8/18/2004	34	NW	154			SITKA	4039975
901271	40817	TROLL	9/1/2004	36	NW				SITKA	4039983
901264	40817	TROLL	9/2/2004	36	NW	113	71		SITKA	4039984
901783	40817	TROLL	9/16/2004	38	NW	113	91		SITKA	4039970
901806	40817	TROLL	9/16/2004	38	NW	113	91		SITKA	4039970
288220	40817	SPORT	8/23/2004	35	NW	113	31		SITKA	4035430
900800	40819	TROLL	8/1/2004	32	NW	113			SITKA	4039990
901710	40819	TROLL	8/18/2004	34	NW	154			SITKA	4039975

Appendix A4.–Capture and recovery data from the Nakwasina River coho salmon mark-recapture study, 2004, by area and date.

Week #	Location	Original captures	Recaptures	Total captures	Proportion (Floy) tagged
37	2	2	0	2	0.00
	3	1	0	1	0.00
38	2	6	0	6	0.00
	3	6	0	6	0.00
	Tide water	3	0	3	0.00
40	2	7	0	7	0.00
	3	8	0	8	0.00
	Tide water	18	0	18	0.00
41	2	25	1	26	0.04
	3	97	0	97	0.00
42	1	1	0	1	0.00
	2	80	11	91	0.12
	3	58	3	61	0.05
	Tide water	11	0	11	0.00
43	2	92	8	100	0.08
	3	120	12	132	0.09
44	1	77	14	91	0.15
	2	35	9	44	0.20
	3	14	3	17	0.18
45	2	52	6	58	0.10
	3	58	4	62	0.06
46	1	87	25	112	0.22
	2	62	15	77	0.19
	3	62	9	71	0.13
47	2	26	10	36	0.28
	3	13	3	16	0.19
48	1	30	8	38	0.21
	3	4	6	10	0.60
49	2	13	6	19	0.32
	3	1	0	1	0.00
50	1	2	2	4	0.50
	2	2	0	2	0.00
	3	1	1	2	0.50
Grand total		1,074	156	1,230	0.13

Appendix A5.–Data files used to estimate parameters of the Nakwasina River coho population, 2003 and 2004.

Data file[a]	Description
2004_Adult_CWT_Recoveries.xls	Recovery information from 2004 coded wire tag recoveries in Southeast Alaska.
Nakwasina_River_2004_M-R_and_CWT.xls	Mark, recapture, and coded wire tag recovery information from fish captured in Nakwasina River in 2004.
2004AdultAWL.xls	Age and length information including summary statistics of adult coho captured in Nakwasina River in 2004.
2003_smolt_AWL_data.xls	2003 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 99518-1565.