Regional Operational Plan No. ROP.CF.1J.2023.05

Smolt Abundance and Adult Escapement of Coho Salmon in the Taku River, 2022–2024

by

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March 2023

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	′
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	″
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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Approval

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ABSTRACT

Coho salmon *Oncorhynchus kisutch* smolt abundance and adult escapement will be estimated for the Taku stock of coho salmon originating from the Canadian portion of the Taku River, above the U.S./Canada border. This large glacial river flows into Taku Inlet about 30 km northeast of Juneau, Alaska. Multiple, independent sampling approaches will be used including coded-wire-tagging of smolt, adult harvest sampling, and an inriver adult mark–recapture experiment. A modified Petersen estimator will be used to estimate the smolt emigration during 2022–2024. A mark–recapture experiment will be used to estimate inriver runs of adult coho salmon in 2022–2024. Radio tags will be used to estimate the number of fish tagged during event 1 of the adult mark–recapture experiment that did not pass the U.S./Canada Border. Inriver harvest will be accounted for in determining escapement estimates for coho salmon annually. Scale samples of coho salmon will be used for age analysis to estimate annual age compositions. Coho salmon smolt will be systematically sampled to estimate the mean length for each species.

Keywords: coho salmon, *Oncorhynchus kisutch,* adult production, smolt production, coded wire tag, Petersen estimator, marine survival, exploitation, mark–recapture, radiotelemetry, inriver run, escapement, total run, age composition, Taku River, Southeast Alaska.

PURPOSE

This operational plan details the methods that will be used to estimate the abundance of Taku River coho salmon smolt from 2022–2024 and the marine harvest of these fish from 2023–2025. This operational plan also details the methods that will be used to estimate Taku River adult coho salmon escapement from 2022–2024. Anticipated results from this project will be used to improve management planning and implementation by: (1) Alaska Department of Fish and Game (ADF&G), (2) Fisheries and Oceans Canada (DFO) and (3) Pacific Salmon Commission (PSC). Stock assessment parameters such as harvest, escapement, exploitation rate, and smolt production will be directly estimated through implementation of the smolt tagging and adult escapement projects.

BACKGROUND

The Taku River (Figure 1) produces the largest run of coho salmon *Oncorhynchus kisutch* in Southeast Alaska (SEAK) and north of the Skeena River in British Columbia (McPherson et al. 1998; Yanusz et al. 1999). From 1992–2021, the estimated total run of coho salmon originating from above the U.S./Canada border has averaged 167,000 fish, and the recent 5-year average has been 105,000 fish.

Detailed stock assessment projects designed to directly estimate parameters such as harvest, escapement, exploitation rate, smolt production, survival rates and brood year production have been in place since 1987 for coho salmon. This project is an ongoing cooperative program between ADF&G and DFO in cooperation with the Taku River Tlingit First Nation (TRTFN). Coded wire tags (CWT) were placed in coho salmon smolt captured in the mainstem Taku River beginning in 1991 (Elliott and Bernard 1994). This program was expanded to include Chinook salmon smolt in 1993 (McPherson et al. 2000), and since then both species have been marked with CWTs, annually.

A primary objective of the annual Taku River coho salmon mark–recapture experiment is to estimate spawning escapement above the U.S./Canada border. Unaccounted dropouts (i.e., fish lost to tagging mortality, emigration, or tag loss following initial capture, but prior to crossing the U.S./Canada border) cause mark–recapture abundance estimates to be biased high (Bernard et al. 1999). Radiotagging a subset of spaghetti tagged fish will help to quantify dropout rates and may be applied to reduce bias of abundance estimates.

Figure 1.–The Taku River drainage of northwestern British Columbia and Southeast Alaska.

The Parties (i.e., the U.S. and Canada) concurred on a new Pacific Salmon Treaty (PST) agreement in 2019. Included in that agreement is a specific directive in Annex IV, Chapter 1 of the treaty stating that the Parties affirm their intent to implement abundance-based management regimes for Taku River coho salmon.

OBJECTIVES

1. Estimate the number of coho salmon smolt (≥75 mm fork length (FL)) originating from above the U.S./Canada border leaving the Taku River annually such that the estimate is within 25% of the true value 95% of the time.
2. Estimate the escapement of adult coho salmon (≥350 mm mid eye to tail fork (METF)) above the U.S./Canada border in the Taku River from June to early October annually such that the estimate is within 25% of the true value 95% of the time.
3. Estimate the age composition of adult coho salmon above the U.S./Canada border from June to early October annually such that the proportion estimates are within 5% of the true values 95% of the time.
4. Estimate the age composition of coho salmon smolt (≥75 mm FL) originating from above the U.S./Canada border such that the estimate is within 10% of the true value 95% of the time.
5. Estimate the mean length of coho salmon smolt (≥75 mm FL) originating from above the U.S./Canada border such that the estimate is within 2 mm of the true mean 95% of the time.
6. Estimate the mean weight of coho salmon smolt originating from above the U.S./Canada border such that the estimate is within 0.5 g of the true mean 95% of the time.
7. Estimate the proportion of adult coho salmon (≥ 350 mm METF) tagged with spaghetti tags that did not migrate past the U.S./Canada border in the Taku River annually, such that the estimate is within 5% of the true value 95% of the time.

SECONDARY OBJECTIVES

1. Estimate the marine harvest, marine exploitation, and marine survival of coho salmon originating from above the U.S./Canada border that emigrated as smolt from 2022–2024.
2. Collect genetic tissue from radiotagged adult coho salmon.

Estimation of the above parameters will allow estimates of total adult production, exploitation rates, and survival rates. Annual length and weight data for smolt allow us to examine the optimum smolt production for the system and provide additional information for escapement goal analysis.

METHODS

STUDY DESIGN

Smolt Abundance (Objective 1)

A mark–recapture experiment will be used to estimate the abundance of coho salmon smolt originating from above the U.S./Canada border leaving the Taku River (Figure 1). Smolt will be tagged with CWTs and marked with adipose fin clips as event 1 of a two-event closed population mark–recapture experiment. Returning adult coho salmon will be inspected for a missing adipose fin as part of event 2.

Smolt capture operations to implement the marking event will be based out of an ADF&G camp located just upstream of Canyon Island, as well as the DFO Ericksen Slough camp upstream in Canada (Figure 2). Approximately 150 to 300 minnow traps baited with salmon roe will be fished daily in the mainstem of the lower Taku River near Canyon Island beginning as soon as the river is open to boat and plane traffic, with a tentative startup date of mid-April. Three trap lines will be set between approximately 10 km above and below Smolt Camp. Each trap line will be maintained by 2 personnel and will consist of 50 to 100 traps per trap line. Smolt from all trap lines will be transported back to the ADF&G camp for processing each day. Seine nets will also be used along gravel bars on the Taku River mainstem by 3-person crews to capture coho salmon smolt to supplement minnow trap catches. When smolt outmigration intensifies in early May, seining effort will increase accordingly. All healthy **coho smolt ≥75 mm FL** captured each day will be tranquilized with a buffered tricaine methanesulfonate (MS-222) solution, injected with a CWT, and have their adipose fin excised. Each CWT is formed by cutting a 1.1 mm section of wire from a spool stamped with a numeric code unique to each spool. Two unique codes will be used for coho salmon in different size categories (75–85 mm FL; >85 mm FL), and spools will be changed only after they are completely used.

Adult coho salmon caught at Canyon Island in fish wheels and set gillnets, as well as in inriver assessment and commercial gillnet fisheries, and any headwater sampling will be inspected for missing adipose fins (June to early October). Personnel from the ADF&G, DFO, and TRTFN Fisheries will sample these adults and record the associated data. The marked fraction (fish missing adipose fins) of coho salmon captured in the fish wheels and gillnets will be used to estimate smolt abundance.

Sample Size-Smolt Abundance

Sampling targets for coho salmon smolt are based on historical data. From 2012–2021, coho smolt production from the Taku River averaged 1.5 million smolt and approximately 1.0% or 15,000 of this production was marked and tagged annually (Table 1). Assuming average production and tagging, approximately 6,900 returning adults have to be sampled annually to meet the statistical criteria for objective 1 (Robson and Regier 1964). On average, approximately 1,600 adult coho salmon are inspected annually at Canyon Island and another 11,000 are inspected in the inriver assessment and Canadian commercial fishery (Table 1). It is expected that over 9,000 coho salmon will be inspected annually and statistical criteria will be met.

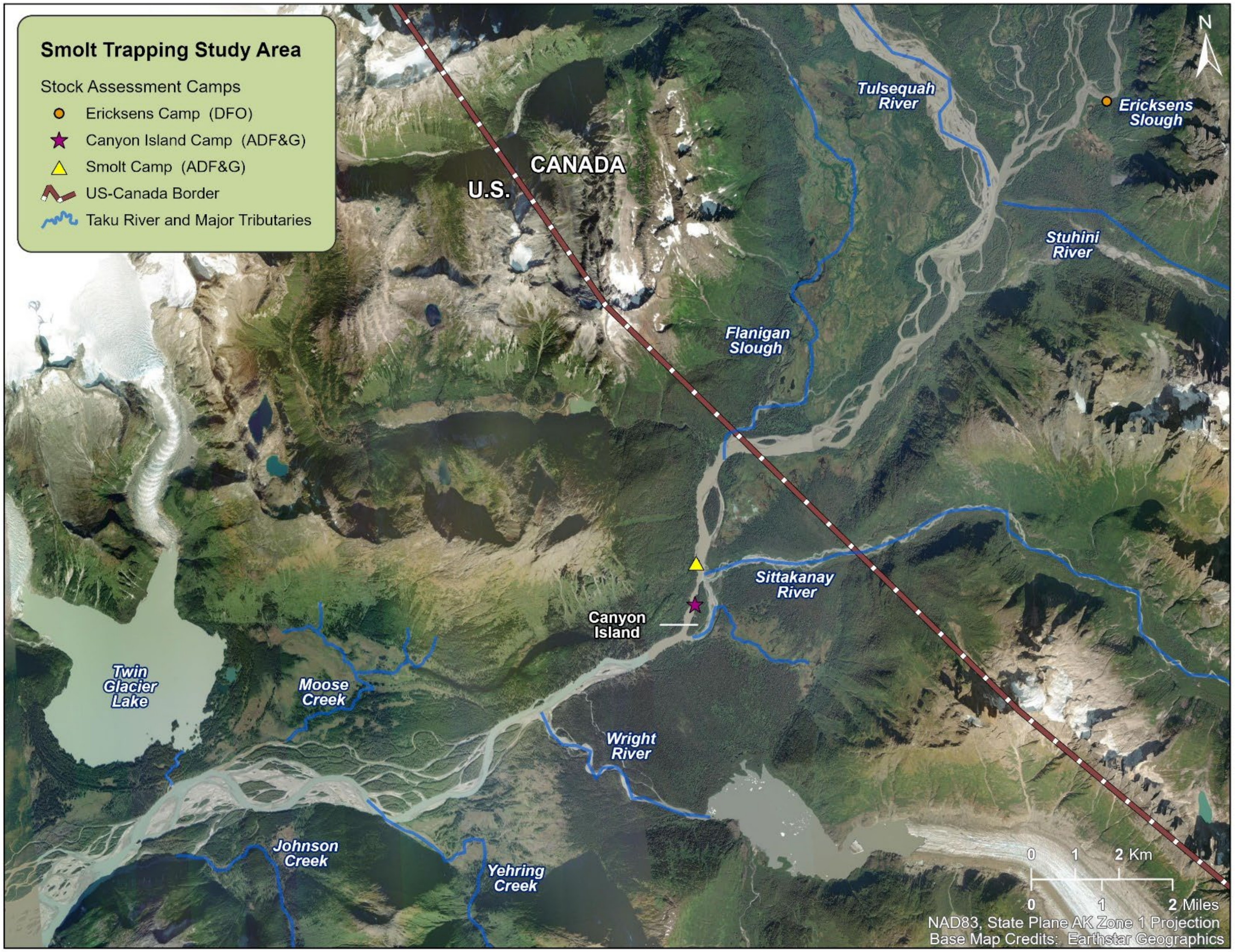

Figure 2.–Location of central portion of study area on Taku River near Canyon Island, Southeast Alaska.

Table 1.–Smolt CWT-tagged, smolt abundance, marine survival, above border run, escapement, Canadian inriver harvest, fish inspected at Canyon Island, and marine harvest rate for Taku River coho salmon.

Year	Smolt CWT-Tagged	Smolt Abundance	Marine Survival	Above Border Run	Escapement	Canadian Inriver Harvest	Inspected at Canyon Island	Marine Harvest Rate
2012	13,596	1,463,444	7.7%	61,797	70,775	14,072	1,130	25%
2013	6,821	1,330,594	10.7%	55,161	68,117	10,375	1,427	45%
2014	4,964	888,565	21.3%	140,739	124,171	16,568	3,646	26%
2015	19,384	700,773	15.1%	70,361	60,178	10,183	1,975	34%
2016	12,026	1,879,204	6.5%	99,224	87,704	11,520	1,288	19%
2017	17,140	2,105,649	5.3%	65,670	57,868	7,802	1,585	41%
2018	11,869	2,482,448	4.1%	60,678	51,173	9,505	1,129	40%
2019	13,651	1,334,798	9.2%	95,011	82,759	12,252	1,782	23%
2020	13,828	1,553,616	4.8%	53,707	52,063	7,036	965	20%
2021	10,937	1,299,077	8.7%	85,800	75,526	10,880	1,465	24%
Average	12,422	1,503,817	9.4%	78,815	73,033	11,019	1,639	30%

Model Assumptions-Smolt Abundance

Two-event closed population mark–recapture experiments are designed so that a Petersen-type estimator may be used to estimate abundance. For the estimates of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures, are:

Assumption I: there is no recruitment to the population between years and removals are random

There should be no recruitment between sampling events. Because almost all surviving smolt return to their natal stream as adults to spawn, there will be no meaningful recruitment added to the population while they are at sea (i.e., low incidence of straying). Incidents of natural mortality or harvest will occur in a random fashion. In other words, marked and unmarked individuals will have the same rates of mortality and the fraction marked should be unchanged.

The population for which abundance is being estimated is smolt produced from stocks that spawn above the U.S./Canada border. Those fish from stocks that spawn downstream of the border should not be subject to capture in this project as either smolt or adults. Approximately 22% of adult coho salmon fitted with radio tags in 1992 near the mouth of the Taku River spawned below Canyon Island (Eiler et al. 1994). Studies on the Taku River in previous years have shown some straying of fingerlings tagged above Canyon Island to tributaries downstream. Also, some adults tagged as smolt leaving tributaries downstream of Canyon Island have been caught in the fishery upstream of Canyon Island. However, it is believed that the observed straying of smolt and adults past Canyon Island will be an insignificant source of potential bias when estimating abundance. Thus, it is assumed that tagged coho salmon smolt represent production from stocks that spawn above the U.S./Canada border.

Assumption II: there is no trap-induced behavior

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. Trap-induced behavior is unlikely because different sampling gears will be used to capture smolt and adults and results from other studies (Elliott and Sterritt 1990; Vincent-Lang

1993) indicate that clipping adipose fins and implanting CWTs does not affect the mortality of tagged salmon smolts.

Assumption III: marked fish will not lose their marks between sampling events and all marks are recognizable

Proper procedures to excise adipose fins will ensure that marks are not lost and that all marked fish are recognizable during event 2 sampling. Adipose fins will not regenerate like other fins if excised properly at the base. Naturally missing adipose fins on wild stocks of coho salmon are very rare (Magnus et al. 2006). All adipose fin clipped fish will be used for estimating smolt abundance regardless of presense of valid CWT wire.

Assumption IV: one of the following three sets of conditions on mortality and sampling will be met

S1) All fish have an equal probability of being captured and marked during event 1; or

S2) Complete mixing of marked and unmarked fish occurs prior to event 2; or

S3) All fish have an equal probability of being captured and inspected for marks during event 2.

Regarding condition S1 for the smolt to adult mark–recapture, minnow traps and beach seines are used to capture smolt. Minnow traps can be size-selective, however about half of the coho salmon sampled are caught in beach seines which are not size-selective. Coho salmon smolt represent at least 2 age groups and cover a range of sizes. In the past there has been size-selective sampling during event 1 for coho salmon emigrating from the Taku River (Appendix A1; Jones et al. 2006), but the use of beach seines should mitigate the effects of size-selectivity.

Regarding condition S2 for the smolt to adult mark–recapture, due to the extended time between the marking and recovery events and behavior of coho salmon between these events, it is believed that complete mixing of marked and unmarked fish occurs prior to the adult recovery events.

Regarding condition S3 for the smolt to adult mark–recapture, adult coho salmon immigrations will be sampled almost continuously with fish wheels and gillnets. These methods promote equal probabilities of capture through migration and, at a minimum, barring environmental events that cause sampling to cease, ensure that no segments of the adult immigrations have zero probability of capture during event 2.

For coho salmon smolt, if the two size categories have unequal marine survival, then it is not likely that condition S3 will be met. Equal survival will be evaluated using a χ^2-test, which will be used to test for independence between the two size categories (secondary objective 2). If no lack of independence between size category is detected, at least condition S2 may be satisfied and Chapman's (1951) modification to the Petersen estimator will be used to estimate abundance after pooling the tag codes. If lack of independence is detected between adult tag recovery rate and tagging group, the equal probability of capture during tagging assumption will need to be evaluated. Details on the approach that will be used if this occurs can be found in Appendix A. The catchability coefficient ($\hat{A}$) for larger to smaller smolt will be estimated, but if the estimate of $\hat{A}$ is not significantly different from 1.0, then Chapman's (1951) formula will be used. Otherwise, a modified estimator will be used to provide an unbiased estimate (see Appendix A).

Spawning Escapement, Age Composition, and Dropout Rate (Objectives 2, 3, 7)

ADF&G, DFO, and TRTRN will cooperatively conduct a mark–recapture experiment to estimate the number of adult coho salmon returning past Canyon Island between mid-June and early

October. Personnel of ADF&G and TRTFN will capture coho salmon in two fish wheels at Canyon Island, where one fish wheel is positioned on each bank of the river. The fish wheels will be operated almost continuously and an aluminum 2-basket design has been implemented to enable fish wheels to turn during periods of low flows, which occur in late fall. See Kelley et al. (1997) and Kelley and Milligan (1997) for project details. If fish wheels are inoperative for more than 2 consecutive days, set gillnets (12 ft x 100 ft, 5 1/8 in mesh) will be used to capture and mark coho salmon at Canyon Island during the hiatus.

Captured fish will be carefully removed from the fish wheel holding boxes or gillnets and placed into a trough filled with fresh river water. All healthy coho salmon ≥350 mm METF caught will be measured, examined to determine sex, inspected for missing adipose fins, and tagged with a length of plastic "spaghetti" tubing imprinted with an individual number sewn through the dorsal musculature just below the posterior portion of the dorsal fin. A portion of captured fish will also be sampled for scales to determine ages. All fish will be released at the site of capture. Past experience (Yanusz et al. 1999) on coho salmon have shown that the loss of spaghetti tags between the marking site at Canyon Island and the recapture area located just upriver above the border is rare, so no secondary mark will be added to tagged fish. Additionally, the loss of the primary spaghetti tag has been viewed as inconsequential as fish are normally recovered within 3 weeks of tagging and tagging scars are still visible and serve as a secondary mark (Yanusz et al. 1999). Recovery of tags from the Canadian commercial fishery is through a recovery and return by fishers (a condition of each fishing license) and past studies have shown that all tags are likely returned (Kelley et al. 1997). DFO personnel annually inspect >40% of the harvest to monitor tag return rate (scars) and rate of detection of adipose fin clipped coho salmon, whose head on submission is also a condition of license. If Canadian commercial fisheries cease to operate prior to the end of the project, a live release assessment fishery will be conducted by DFO and TRTFN to sample adult coho salmon for marks through to the end of the project defined as at least five days beyond end of marking in event one.

A subset of spaghetti-tagged fish will also be tagged with radio transmitters. Each radiotagged fish will receive the ATS™ F1840B radio tag. The tags will be 56-mm long, 17-mm in diameter, 22-g in mass, have a 30-cm external whip antenna, a terminal battery life of 180 d, and operate on several frequencies within the 150.000 to 152.999 MHz range. Two frequencies will have 100 pulse codes resulting in 200 uniquely identifiable radio tags to be deployed each year. Each radio tag will be equipped with a mortality indicator mode that activates when the radio tag is motionless for approximately 24 h.

Radio tags will be gently inserted through the mouth and into the fish's stomach using a 0.7 cm diameter, 30 cm long plastic tube. The esophagus will be visually inspected to ensure that none of the tag body is visible and that the antenna is exiting through the center of the esophagus. Anesthesia will not be used at any time during tagging or marking operations.

The axillary appendage from each radiotagged fish will be collected for genetic stock identification (GSI) and will be stored separately in individual vials in full strength ethanol and paired with the radio tag number.

To determine passage of radiotagged fish across the U.S./Canada border, a stationary telemetry tracking tower will be setup on the border. The remote tracking station will consist of an ATS R4500C integrated receiver and data logger, two directional Yagi antennae (one aimed upstream and one aimed downstream), and a solar panel and battery power system. The setup, operation, and maintenance of the telemetry tower will be in cooperation with Chinook salmon *Oncorhynchus* *tshawytscha* sockeye salmon *Oncorhynchus nerka* radiotelemetry projects being conducted on the Taku River. Details of telemetry tower setup are described in the operational plan titled *Migration, Tagging Response, and Distribution of Chinook Salmon Returning to the Taku River, 2018* (Richards et al. 2018).

Operation of the fish wheels or gillnets will end in early October or when daily catches have dwindled to near zero.

Sample Size-Escapement

Sampling targets for coho salmon escapement are based on historical data (Table 1). The recent 10-year average, 2012–2021, Taku River coho salmon smolt emigration is 1.5 million fish. Multiplying the 10-year average smolt emigration by the recent 10-year average marine survival of 9.4% yields a total run forecast of about 140,000 fish. Multiplying the total run forecast by one minus the recent 10-year average marine exploitation rate of 30%, results in a forecast of 100,000 adult coho salmon to pass Canyon Island. From 2012–2021, approximately 1,600 adult coho salmon were inspected annually at Canyon Island. Recent and past telemetry studies suggest that up to 20% of the fish tagged during event 1 dropout. Using these data and the methods of Robson and Regier (1964), approximately 5,100 adult coho salmon will need to be inspected upriver in the Canadian commercial and any assessment fisheries as part of event 2 in order to meet the statistical criteria for objective 2. From 2012–2021, over 10,000 coho salmon were harvested and sampled annually upriver in the assessment and Canadian commercial fisheries, a sufficient number of fish to meet the statistical criteria for this objective provided that all assumptions hold.

Model Assumptions-Escapement

This two-event closed population mark–recapture experiment is designed so that a Petersen-type estimator may be used to estimate abundance. For the estimate of abundance to be unbiased, certain assumptions must be met (Seber 1982). These assumptions, expressed in the circumstances of this study, along with their respective design considerations and test procedures, are:

Assumption I: the population is closed to recruitment, immigration, and emigration

Given the short distance between Canyon Island tagging site and the inriver fisheries just upstream of the U.S./Canada border, and considering the life history of the species, there should be no recruitment between sampling events. Event 1 tagging efforts (marking) will begin prior to any passage of fish past the tagging sites and will continue through the run until passage has dropped to near zero.

Assumption II: marking and handling will not affect the catchability of coho salmon in event 2

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. Bias in the estimator should be reduced because different sampling gears are used in different sampling events (Seber 1982). However, we will attempt to meet this assumption by minimizing holding and handling time of all captured fish. Any obviously stressed or injured fish will not be tagged. Radiotelemetry studies were conducted on Taku River coho salmon in 1987 (Eiler 1988), 1992 (Eiler et al. 1994), and 2019–2021. Information from radiotagged fish collected in previous studies and from the current study will be used to understand and reduce bias by quantifying the number of fish that are not available to be sampled in event 2, which could be related to handling. In the past, a few fish released at Canyon Island have been caught in marine commercial fisheries. The adjustment for this phenomenon is to censor any marked fish caught in marine fisheries. To that end, the Division of Commercial Fisheries (DCF) and the Division of

Sport Fish (DSF) will sample harvests in the commercial gillnet fishery and the sport fishery near Juneau in District 111 to recover fish marked at Canyon Island. The primary purpose of these independent sampling programs is to recover CWTs. A minimum of 30% of the commercial and sport harvest in the District 111 terminal area will be inspected, consistent with the bilateral agreement by the PSC Transboundary Technical Committee (TTC), a committee established by the PSC to oversee the management of transboundary salmon stocks, and documented in the annual TTC Management Plan (TTC *In press*). While looking for CWTs, any primary or secondary marks from the mark–recapture experiment will be noted. The number of fish recaptured in marine fisheries will be expanded according to the fraction of harvests inspected for marks and the result subtracted from the number marked (see Data Analysis section).

Assumption III: tagged fish will not lose their marks between sampling events and all marks are recognizable and detected

Experience (Yanusz et al. 1999) on coho salmon have shown that the loss of spaghetti tags between the marking site at Canyon Island and the recapture area located just upriver above the U.S./Canada border is rare, so no secondary mark will be added to tagged fish. Additionally, the loss of the primary spaghetti tag has been viewed as inconsequential as fish are normally recovered within 3 weeks of tagging so tagging scars will serve as a secondary mark.

Assumption IV: One of the Following Three Conditions Will Be Met

1. All coho salmon will have the same probability of being caught in event 1, or
2. All coho salmon will have the same probability of being captured in event 2; or,
3. Marked fish will mix completely with unmarked fish between samples.

In this experiment, it is unlikely that marked and unmarked fish will mix completely for fish caught in Canadian fisheries since the tagging and recapture event are so close together spatially. Also, all coho salmon will not have an equal probability of being inspected for marks during event 2 sampling because the commercial fishery is open a variable number of days each week. Fish wheels and set gillnets at Canyon Island will be operated continuously during the migration. This relatively constant sampling effort will tend to equalize the probabilities of capture for all fish passing by Canyon Island regardless of when they pass. Although probability of capture during event 1 may vary from day to day due to short-term changes in environmental conditions, attempting to maintain similar effort over the entire run will be necessary to ensure that all coho salmon have the same probability of being caught during event 1.

Equal probability of capture will be evaluated by time, area, size, and sex. The procedures to analyze sex and length data for statistical bias due to gear selectivity are described in Appendix A2. If different probabilities are indicated, abundance estimates will be stratified.

To further evaluate the three conditions of this assumption, contingency table analyses recommended by Seber (1982) and described in Appendix A3 will be used to detect significant temporal or geographic violations of assumptions of equal probability of capture. Based on previous experience, it is anticipated temporal violations of these assumptions will be detected, and a Petersen-type model would yield a biased estimate. Therefore, abundance will most likely be estimated according to models developed by Darroch (1961) for a two-event mark–recapture experiment on a closed population when temporal or spatial distributions of fish affect their probabilities of capture.

Sample Size-Age Composition

The required sample size to meet the statistical criteria for objective 3 is 480 adults. Sample size calculations are based on the procedures in Thompson (1987), assume a scale regeneration rate of 20%, and assume that the population size is large relative to the sample size. If 2,000 fish are captured at Canyon Island, then every 4th coho salmon caught will need to be sampled for scales in order to collect the required number of samples using a systematic sampling design.

Sample Size-Dropout

Adult coho salmon that were radiotagged in the Taku River using similar methods and tags moved upriver 83% and 98% of the time in 1987 (Eiler 1988) and 1992 (Eiler et al. 1994), respectively. For sample size calculations, we will assume a 17% dropout rate (highest rate from previous studies), that no tag loss or tag failure will occur, and that 2,000 fish will be marked with spaghetti tags. It is believed that tag failure is small. Eiler et al. (2014) deployed nearly 3,000 ATS radio tags in Chinook salmon on the Yukon River and had no known tag failures. All tags will be tested for proper function before deployment. Using the methods in Thompson (2002), the sample size required to estimate the proportion of dropouts within 5% of the true value 95% of the time is 196 fish.

Radio tags will be deployed systematically by tagging one in every ten healthy coho salmon, regardless of capture gear type. If coho salmon run timing is proportional to historical catches at Canyon Island, then the expected number of tags that will be deployed can be found in Table 1. If capture rates are higher or lower than expected, then radio tagging rates will be adjusted accordingly to ensure radio tags are equally applied throughout the run.

Age Composition, Mean Length, and Mean Weight of Smolt (Objectives 4, 5, 6)

A systematic sample of coho salmon smolt captured during the CWT project will be used to estimate age composition, mean length, and mean weight of coho salmon smolt. Scale, length, and weight data will be collected for only coho salmon smolt $\geq$75 mm FL. Smaller fish are more difficult to handle and have a higher probability remaining in the river for subsequent years.

Table 2.–Proposed weekly radiotagging rate of coho salmon on the Taku River.

End of Stat Week	Weekly Expected Catch	Weekly Cumulative Catch	Weekly Radio	Weekly Cumulative Radio
27	5	5	1	1
28	17	22	2	2
29	44	66	4	7
30	67	133	7	13
31	105	238	11	24
32	131	369	13	37
33	149	518	15	52
34	187	704	19	70
35	241	945	24	95
36	239	1,185	24	119
37	264	1,449	26	145
38	270	1,718	27	172
39	227	1,946	23	195
40	55	2,000	5	200

Sample Size-Age Composition, Mean Length, and Mean Weight of Smolt

A sample of 107 smolt is required to meet the objective criteria for estimating age composition, which assumes the worst case scenario that two freshwater ages are equally present as well as assuming that only 90% of the scales are readable (=96/0.9; Thompson 2002). The number of samples required to estimate the mean length of coho salmon smolt to within 2mm of the true value 95% of the time is 129 ($[(1.96)(11.6)/2])^2$, which assumes that the standard deviation of smolt length is the same as the average standard deviation (11.6 mm) since 1999 (Thompson 2002, p. 36). Similarly, the number of samples required to estimate mean weight of coho salmon smolt to within 0.5 g of the true value 95% of the time is 138 ($[(1.96)(3.0)/0.5])^2$, which assumes that the standard deviation of smolt weight is the same as the average standard deviation (3.0 g) seen since 1999. Based on an expected catch of 15,000 smolt, scale, length, and weight data will need to be collected from one in every 109 coho salmon smolt encountered to achieve the objective criteria for each objective. For simplicity, a systematic sample of one in every 100 coho salmon smolt encountered will be used, resulting in an expected sample size of 150 fish.

Marine Harvest (Secondary Objective 1)

Recovery of CWT tagged adults in the various SEAK fisheries will be used to estimate harvest of coho salmon (originating above Canyon Island) in marine fisheries from 2022 to 2025. Marine harvests will be added to inriver harvests from Canada fisheries to estimate total harvest and harvest rates in a calendar year.

DATA COLLECTION

Smolt Tagging

All healthy coho salmon smolt ≥75 mm FL captured near Canyon Island without marks will be tranquilized with a buffered MS-222 solution, tagged with a CWT following procedures described in Koerner (1977), given an adipose fin clip, and then released. Note that all tagged fish will be held overnight to test for post-tagging mortality and a portion will be tested for tag retention. Any smolt captured possessing an adipose fin clip prior to tagging will be tested for the presence or absence of a CWT (i.e., passed through a magnetic tag detector) and recorded as positive or negative before being released.

Codes used will be recorded on the **CODED WIRE VERIFICATION FORM** (Appendix B1) obtained from the CF Mark, Tag, and Age Laboratory (CF Tag Lab); a short section of each spool of coded wire will be taped to the form the first day of tagging with a new tag code. All tag and recapture data will be recorded daily on the form entitled **CWT DAILY TAGGING FORM** (Appendix B2). Environmental conditions will be recorded daily on the form entitled **DAILY ENVIRONMENTAL CONDITIONS FORM** (Appendix B3). A new **CWT DAILY TAGGING FORM** will be filled out for each day of operation (Appendix B2). Daily procedures will be as follows:

1. Record location, date, and species.
2. Record water and air temperature (Min-Max) to nearest 1°C, water depth. Data should be collected at 0800 hours each day.
3. From 0800 to 0830 hours mix the fish in the holding net pens, then net and check 100 fish from each holding pen for tag retention and record this information on the **CWT DAILY TAGGING FORM** (Appendix B2). If tag retention is 98/100 or greater, empty the net pen of all smolt either back to the river or a cooler for transport making sure to count and record all mortalities. Next, transport the smolt to the release site and release all fish. If tag retention is less than 98/100, reprocess the entire batch of smolt in the net pen and retag any that test negative for CWTs. Examine any mortalities for proper tag placement and adjust the head mold if necessary. Check the position of the bevel on the needle and the sharpness of the needle. Reposition, sharpen, or replace the needle if necessary.
4. Check the minnow trap lines and transport all fish to camp for processing. Salmon smolt will be sorted by species and by size for coho salmon (75–85 mm FL; >85 mm FL). Inspect each live fish and count the number possessing adipose fin clips; record the number of fish with adipose fin clips under "Recaptures" on the **CWT DAILY TAGGING FORM** (Appendix B2). Test all recaptures for tag retention. Record results of tag retention on the **CWT DAILY TAGGING FORM** (Appendix B2).
5. For all unmarked fish, apply a CWT and test for a positive reading using a tag detector. If rejected by the detector, retag. Keep an accurate tally of all retags on a hand counter. Write the beginning and ending machine numbers on the form and record retags, mistags, and practice tags. Show your calculations for the number of tags used for each tag code daily.
6. Systematically select every 100^{th} coho salmon from combined catches and measure FL to the nearest whole millimeter, weigh to nearest 0.1 g, collect scales, and record date, length, and weight. Record the total number of coho salmon recaptured.

ADF&G CWT ONLINE RELEASE database maintained by the CF Tag Lab will be filled out after at the end of the tagging season. Information in this database will be used to estimate the number of smolt retaining CWTs. A 5 cm length of coded-wire will be attached to the **CODED WIRE VERIFICATION FORM** to verify the tag codes (Appendix B1). If one roll of coded wire is depleted during a tagging session, a new **CWT DAILY TAGGING FORM** (Appendix B2) will be filled out, and a piece of wire from the new spool will be attached to the **CODED WIRE VERIFICATION FORM** (Appendix B1).

For coho salmon smolt sampled for length, weight, and scales, 12 to 15 scales will be removed from the preferred area (Scarnecchia 1979) on the left side of the fish. Scales from up to four fish will be sandwiched between two 1 in x 3 in microscope slides, and the slides will be taped together with frosted scotch tape. The length of each fish will be written in the corners of the tape portion that correspond to the location of individual fish scales on each slide (Figure 3). Location, species, and date will also be recorded on each slide. Length and weight data for each fish will be recorded on a **SALMON SMOLT LENGTH, WEIGHT, AND SCALE SAMPLES** form (Appendix B4). Additional criteria includes:

1) Do not tape over any scales;
2) Make sure scales are put in the designated area for each fish;
3) Always number each slide at the top;
4) Always record the initials of the sampler under the slide number; and
5) Clean the scales and spread them out so that they are separated and align them as shown in Figure 3.

For sampling adult coho salmon, statistical week, date, water temperature, river level, fish wheel RPM, the hours of fish wheel operation (each fish wheel), and hours of gillnet fishing time will be recorded daily on a **FISHING EFFORT FORM** (Appendix B5). Fish wheel catches will be checked two or more times daily, and the numbers of fish caught and tagged will be recorded on a **FISH WHEEL SAMPLING FORM** (Appendix B6). When the fish wheels are not operational due to environment conditions or maintenance, gillnets will be fished about 6 hours per day and catches will also be recorded on the **FISH WHEEL SAMPLING FORM** (Appendix B6). Dates and tag numbers of adult coho salmon released with spaghetti and radio tags will be relayed daily. During spaghetti tag recovery in Canada, commercial or assessment fishing effort (boats and days open), total catch, fish examined, lengths of fish examined, and individual tag numbers recovered will be relayed weekly by the DFO.

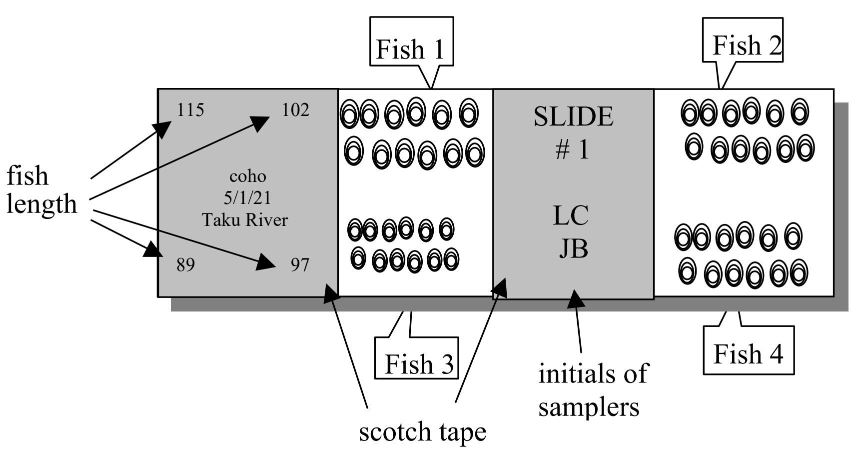

Figure 3.–Preferred microscope slide layout for coho salmon smolt scale samples.

Spawning Escapement and Age, Sex, and Length Composition

Completion of smolt population and harvest estimates requires sampling coho salmon for CWTs in succeeding years. Coho salmon sampling done at Canyon Island using fish wheels and gillnets will have a **HATCHERY RACK AND ESCAPEMENT SURVEY FORM** (Appendix B7) completed for each sample day (fish wheel or gillnet) to document the number of fish examined and the number of fish possessing adipose fin clips. Scale samples will be taken from every fourth coho salmon examined. **Any coho salmon caught at Canyon Island missing an adipose fin will be sacrificed**; a uniquely numbered cinch strap will be attached to each head. Capture site, date, gear, fish sex and length (METF), adipose fin clip quality, sample, and head number (i.e., cinch strap number) will be recorded on the **HATCHERY RACK AND ESCAPEMENT SURVEY FORM** (Appendix B7). Each head and associated data will be shipped to Juneau in specially labeled coolers on the next available flight. The Douglas office will be notified prior to each head shipment, and Douglas staff will transport the heads and associated data forms to the CF Tag Lab.

Every 4th coho salmon caught will be sampled for age. Four scales will be taken from the preferred area (i.e., the left side of the fish; 2 rows up from the lateral line on an imaginary line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Scarnecchia 1979)), and mounted on gum cards for later impression into acetate cards using a scale press. Ages will be determined from patterns of circuli according to protocols in Mosher (1968) and the CF scale-aging group.

A scale sample will also be taken from every adult coho salmon possessing an adipose fin clip, as described above, and cross-referenced to the sample data using the cinch strap number.

Injured, Entangled or Dead Marine Mammals

- Document with photos/video (if possible, remain at least 100 yards from the animal) and record the date, time, and location (latitude/longitude, description of bay, point, island, etc.).
- If possible, record the species of marine mammal, age class, sex (for sea lions), type of gear, a description of the gear (i.e., line, gillnet, etc.) and how the animal is entangled, its relative degree of impairment, and direction of travel.
- As soon as possible, report to **ALASKA MARINE MAMMAL STRANDING NETWORK** (24-hr hotline 877-925-7773; 877-9-AKR-PRD) and include information gathered above. Ideally for dead animals, if communications allow, contact the hotline while near the carcass to determine if additional information/samples can be collected.
- Specifically for an observed live and entangled whale, immediately call the **U.S. COAST GUARD** (VHF Channel 16).

DATA REDUCTION

The field crew leader will record and error-check all data. Data forms will always be kept up to date. Data will be sent to the Douglas office at regular intervals and inspected for accuracy and compliance with sampling procedures. Data will be transferred from field notebooks or forms into Microsoft Excel™[1] spreadsheet files. When input is complete, data lists will be obtained and checked against the original field data.

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

Electronic data files will be used to check tagging totals with field notebooks, to identify lengths less than prescribed guidelines, sampling rates for age and length, and for data on the **CWT DAILY TAGGING** and **HATCHERY RACK AND ESCAPEMENT SURVEY FORMS**. Completed **CODED WIRE VERIFICATION** and **HATCHERY RACK AND ESCAPEMENT SURVEY FORMS** will be sent to the CF Tag Lab in Juneau where all CWT information for ADF&G statewide is compiled and stored. Each year Alaskan CWT data are shared with the Pacific States Marine Fisheries Commission who maintains a permanent and standardized coastwide CWT database.

Adult coho salmon catches, numbers tagged, and those possessing adipose fin clips will be tabulated daily. The number of adult coho salmon, length, and scale samples will be compared to the fish wheel and gillnet catches to determine if sampling protocol was followed. Spaghetti tag numbers and release dates will be compared against recoveries to locate and resolve nonsensical values. Spaghetti tag releases and recoveries will be tabulated by statistical week.

When the reports are completed, electronic copies of the data will be sent to ADF&G DSF Research and Technical Services (RTS) in Anchorage for archiving, along with a data map. Smolt data (date, age, length and weight) will be provided. All other data (CWT tag and release, adult CWT, adult age-sex-length) will be formatted and transferred to ADF&G DCF permanent databases.

DATA ANALYSIS

Smolt Abundance

A two-sample mark–recapture model will be used to estimate the number of smolt emigrating from the Taku River. The appropriate estimator will depend on diagnostic tests, which will be used to evaluate if the necessary assumptions for a closed-population two-event mark–recapture experiment are met. If stratification by size group or time-area is not needed, then abundance will be estimated using a version of the Chapman-modified Petersen formula (Chapman 1951;Seber 1982):

$$\hat{S} = \frac{(M_1 + M_2 + 1)(C + 1)}{(R + 1)} - 1 \tag{1}$$

where M_1 and M_2 are the number of smolt marked by size group (1 = 75–85 mm FL, 2 = >85 mm FL), C is the number of adults inspected for marks, and R is the number of adipose fin clips observed in C. The variance of the smolt estimate will be estimated as:

$$\mathrm{var}(\hat{S}) = \frac{(M_1 + M_2 + 1)(C + 1)(M_1 + M_2 - R)(C - R)}{(R + 1)^2(R + 2)} \tag{2}$$

If the null hypothesis of independence is rejected between adult tag recovery rate and tagging group, and between sampling events and occurrence of freshwater age of fish at smolting from the Taku River (i.e., there is evidence of differential survival among groups and differential tagging rates among groups), a weighted variant of Chapman's modification to the Petersen estimator will be used to estimate abundance and a bootstrap procedure will be used to estimate variance. A description of these equations is provided in Appendix A1.

Mark Fraction, Marine Harvest, Inriver Return, Marine Exploitation, and Marine Survival

Mark Fraction

The fraction of adults marked with adipose fin clips and tagged with CWTs that emigrated in year *j* will be estimated from data collected during event 2 of the smolt abundance mark–recapture experiment. Experience has shown that 100% of smolt tag in year *j* return as adults in year *j+1*, thus the fraction of adults bearing CWTs ($\hat{\theta}_j$) will be estimated as:

$$\hat{\theta}_j = \frac{T_{j+1}\rho_{j+1}}{A_{j+1}} \tag{3}$$

where

A_{j+1} = is the number of adults examined in year *j+1*;

T_{j+1} = is the number of adipose fin clips observed in A_{j+1}; and

ρ_{j+1} = $\frac{t_{j+1}}{t'_{j+1}}$, is the proportion of sacrificed adults from adults in year *j+1* that possess a valid CWT;

t'_{j+1} = is the number of sacrificed adults examined for CWTs from T_{j+1} fish with adipose fin clips; and,

t_{j+1} = is the number of valid CWTs found in t'_{j+1}.

Variance of $\hat{\theta}_j$ will be estimated using parametric bootstrap simulation (e.g. Geiger 1990). The number of adipose clips will be generated as $T^*_{j+1} \sim binomial\left(A_{j+1}, \frac{T_{j+1}}{A_{j+1}}\right)$, and then CWTs will be generated as, $t^*_{j+1} \sim hypergeometric\left(m = \frac{t_{j+1}}{t'_{j+1}T^*_{j+1}}, n = T^*_j - \frac{t_{j+1}}{t'_{j+1}T^*_{j+1}}, k = \frac{t'_{j+1}}{t_{j+1}T^*_{j+1}}\right)$. Notation for hypergeometric parameters follows that of the R language (R Core Team 2021[2]). ρ^*_{j+1} will then be calculated as $\frac{t^*_{j+1}}{\left(T^*_{j+1}t'_{j+1}/t_{j+1}\right)}$, and $\hat{\theta}^*_j$ as:

$$\hat{\theta}^*_j = \frac{T^*_{j+1}\rho^*_{j+1}}{A_{j+1}} \tag{4}$$

Many values of $\hat{\theta}^*_j$ will be simulated and the variance of $\hat{\theta}_j$ and $\hat{\theta}_j^{-1}$ estimated as the sample variance of the simulated values.

Marine Harvest

Marine harvest ($\hat{r}_{k,j}$) of fish that emigrated in year *j* to fishery stratum *k* will be estimated using CWT recovery data (Bernard and Clark 1996):

$$\hat{r}_{k,j} = H_k \left[\frac{m_{k,j}}{\lambda_k n_k}\right] \hat{\theta}_j^{-1} \qquad \lambda_k = \frac{a'_k t'_k}{a_k t_k} \tag{5}$$

where H_k = total harvest in the stratum, n_k = number of fish inspected (the sample) from the fishery stratum, a_k = number of fish in n_k that are missing an adipose fin, a'_k = number of heads from a_k that arrive at the Tag Lab, t_k = number of heads out of a_i with CWTs detected, t'_k = number of CWTs out of t_k that are dissected and decoded, $m_{k,j}$ = number of CWTs from the emigration year of interest *j*, and $\hat{\theta}_j$ = fraction of the cohort tagged with code of interest. H_k is estimated with error in sport fisheries, and $\hat{\theta}_j$ is estimated from sampling returning adults inriver. For these reasons,

[2] R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

unbiased estimates of the variance of $\hat{r}_{kj}$ will be obtained using equations in Table 2 of Bernard and Clark (1996), which show the formulations for large samples. Total marine harvest and its variance will be estimated by summing across fishery strata.

Sport and commercial catch, sample, and CWT recovery data will be summarized using ADF&G preferred expansion definitions. For the traditional troll fisheries, data will be summarized by period and quadrant. For the spring troll fisheries, data will be summarized by period and statistical area. For terminal troll fisheries, data will be summarized by statistical week and statistical area. For the traditional gillnet fisheries, data will be summarized by statistical week and district. For the terminal gillnet fisheries, data will be summarized by statistical week and statistical area. For the common property seine fisheries, data will be summarized by period and seine area. For the terminal seine fisheries, data will be summarized by statistical week and statistical area. More information about preferred expansions definitions for the commercial fisheries can be found in Clark et al. (1985). Data for the sport fishery will come from a variety of sources. Harvest data for the sport fisheries will be from ADF&G Statewide Harvest Survey reports (e.g., Jennings et al. 2015). Sample and CWT recovery data will be obtained from DCF Mark, Tag, and Lab reports. Sport fishery data will be summarized by period and survey site.

Dropouts

Dropouts, defined as the number of marked fish that did not pass the U.S./Canada border, will be estimated using radio tags. It will be assumed that no radio tags fail and that all radio tagged fish are detectable. Previous work has shown that assuming no tag failure is reasonable (Eiler et al. 2014) and a remote tracking station will be placed at the U.S./Canada border to ensure tag detection. The dropout rate, or proportion of tagged fish that did not migrate pass the U.S./Canada border, q, will be estimated as:

$$\hat{q} = \frac{r}{R} \tag{6}$$

where r is the number of radio tagged fish that did not pass the U.S./Canada border and R is the total number of radio tagged fish. The estimated variance of $\hat{q}$ will be calculated as:

$$\operatorname{var}(\hat{q}) = \frac{\hat{q}(1-\hat{q})}{R-1}\left(\frac{n_1 - R}{n_1}\right) \tag{7}$$

where n_1 is the number of coho salmon marked at Canyon Island. Dropouts, d, will then be estimated as:

$$\hat{d} = n_1\hat{q} \tag{8}$$

and the estimated variance of $\hat{d}$ will be calculated as:

$$\operatorname{var}(\hat{d}) = n_1^2 \operatorname{var}(\hat{q}) \tag{9}$$

Spawning Escapement

A two-sample mark–recapture model for a closed population that accounts for dropouts will be used to estimate the number of adult coho salmon passing by Canyon Island (see Appendix A4 for additional details). The appropriate abundance estimator will depend on the results of the tests. If stratification is not needed, we will begin by estimating the inriver run ignoring dropouts ($\widehat{N}$) using Chapman's (1951) version of the Petersen abundance estimator for a closed population (Seber 1982):

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \tag{10}$$

where n_1 = number of marked coho salmon marked at Canyon Island, n_2 = number of coho salmon inspected for marks in the Canadian commercial and assessment fisheries, and m_2 = number of marked coho salmon recaptured in the Canadian commercial and assessment fisheries. The variance of $\hat{N}$ will be computed as:

$$\text{var}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)} \tag{11}$$

Assuming dropouts are germane **only** to marked fish (i.e., dropping out is a result of being marked and/or captured at event 1), then the inriver run prior to dropouts ($\hat{N}_1$) can be estimated as:

$$\hat{N}_1 = (\hat{N} - n_1)\hat{s} + n_1 \tag{12}$$

where $\hat{s}$ is the proportion of tagged fish that pass the U.S./Canada border, which is estimated as $\hat{s} = 1 - \hat{q}$ with $\text{var}(\hat{s}) = \text{var}(\hat{q})$. Variance of $\hat{N}_1$ is calculated as:

$$\text{var}(\hat{N}_1) = \text{var}\left((\hat{N} - n_1)\hat{s} + n_1\right) \tag{13}$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_1) = (\hat{N} - n_1)^2 \text{var}(\hat{s}) + \hat{s}^2 \text{var}(\hat{N}) \tag{14}$$

Similarly, the inriver run after dropouts ($\hat{N}_2$) will be estimated as:

$$\hat{N}_2 = \hat{N}\hat{s} \tag{15}$$

with variance estimated as:

$$\text{var}(\hat{N}_2) = \text{var}(\hat{N}\hat{s}) \tag{16}$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_2) = \hat{N}^2 \text{var}(\hat{s}) + \hat{s}^2 \text{var}(\hat{N}) \tag{17}$$

Equations 12–17 assume dropouts are germane only to the marked population, which may not be a valid assumption in the case that some fish dropout because they spawn below the border. If this is the case, different equations will be used (see Appendix A5).

Above border escapement ($\hat{E}$) will be estimated as the difference between the estimated inriver run of adult coho salmon that passed Canyon Island and inriver harvest above Canyon Island:

$$\hat{E} = \hat{N}_2 - H \tag{18}$$

where H is the inriver harvest of adult coho salmon. Since H is known, the variance of $\hat{E}$ will be computed as:

$$\text{var}(\hat{E}) = \text{var}(\hat{N}_2) \tag{19}$$

Diagnostic tests for equal probability of capture (Appendices A2 and A3) will be performed on the mark–recapture data. If temporal-geographic stratification is not required (Appendix A3), but stratification by size or sex is (Appendix A2), estimates for each stratum will be generated and these estimates will be summed to estimate total abundance and variance.

If geographic or temporal stratification is required (Appendix A3), estimation of abundance will follow procedures described by Darroch (1961) using the computer program SPAS (Arnason et al. 1996). If stratification by size is required, size stratification will be conducted first and methods to correct for geographic or temporal capture heterogeneity will be applied independently to each size stratum. The contingency tables described in Appendix A3 will be further analyzed to identify a) event 1 strata (individual or contiguous groupings of temporal-geographic categories) where probability of recapture during event 2 is homogeneous within strata and different between strata; and b) event 2 strata where marked:unmarked ratios are homogeneous within strata and different between strata. Temporal categories generally will consist of groupings of sample data collected by week. Stratification will also be guided by environmental conditions encountered during data collection (river stage height and rainfall) and by previous experience gained when conducting mark–recapture experiments on this system. If the initial stratification does not result in an admissible maximum-likelihood (ML) estimate of abundance, further stratification may be necessary before an admissible estimate can be calculated. Nonadmissible estimates include failure of convergence of the ML algorithm in SPAS or convergence to estimators with estimated negative capture probabilities or estimated negative abundance within stratum. Goals in this case are always that observations within the pooled stratum should be as homogeneous as possible with respect to capture, migration, and recapture (Arnason et al. 1996). If temporal-geographic stratification is not required but stratification by size or sex is (see Appendix A), estimates for each stratum will be generated and these estimates will be summed to estimate total abundance and variance.

A goodness of fit (GOF) test (provided in SPAS) comparing the observed and predicted statistics will indicate the adequacy of a stratified model. Once a stratification is identified that results in an admissible estimate of abundance, GOF will be evaluated. Further stratification, according to the guidelines described above, may be necessary to produce a model and abundance estimate with a satisfactory GOF. In general, the model selected will be that which provides an admissible estimate of abundance where no stratification guidelines are violated, no significant evidence of lack of fit is detected, and the smallest number of strata parameters are estimated for the model. This model will usually yield the smallest ML estimate of variance for the abundance estimate.

Age Composition

Age composition of smolt (≥75 mm FL) and adult coho salmon (≥350 mm METF) will be estimated by:

$$\hat{p}_j = \frac{n_j}{n} \tag{12}$$

and the associated variance approximated by:

$$\operatorname{var}(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1} \tag{13}$$

where: $\hat{p}_j$ = the proportion in the population in group j;

n_j = the number in the sample of group j; and

n = the sample size.

Systematic sampling will promote sampling proportional to abundance and therefore reduce bias from any inseason changes in age composition.

Mean Length and Weight of Smolt

Standard sample summary statistics will be used to calculate estimates of mean length and weight (Thompson 2002).

SCHEDULES AND DELIVERABLES

OPERATIONS

Field activities for tagging coho salmon smolt near Canyon Island will begin inriver approximately mid-April and extend into early June annually. Adult coho salmon tagging will begin in mid-June and continue into early October annually.

REPORTS

A draft report covering smolt abundance, adult escapement and tagging dropout for 2022–2024, and marine harvest in 2023–2025 will be written by the lead author and distributed to other authors in 2026. The final report will be submitted for final peer review the following spring. This report will be coauthored by the principal investigators from ADF&G, DFO, and the project biometrician. The report will be published in the ADF&G, DCF Fishery Data Series as well as the PSC Technical report series. The final report and all associated data will be provided to ADF&G DSF Research and Technical Services (RTS), Anchorage, and DFO Whitehorse for archiving purposes.

Project results will also be summarized in the TTC annual catch and escapement report.

RESPONSIBILITIES

Jeff Williams, FB II, Project Leader (ADF&G-smolt and adult escapement). Works with Stephen Warta on field operations, data analysis, and report writing. Supervises smolt and adult coho salmon projects; edits, analyzes, and reports data; assists with field work; maintains near-daily email or telephone contact with field camps; arranges logistics with field crew and expeditor. Assures operational plans are followed or modified appropriately with consultation with Peterson. Is coauthor on final report with Randy Peterson and Aaron Foos.

Randy Peterson, BM III (ADF&G-smolt and adult escapement). Provides input to, edits, analyses, and approves sampling design. Coauthors operational plans and provides biometric details, including any changes or statistical techniques needed to provide precise and unbiased estimates for this project. Writes computer code and completes data analysis as necessary. Coauthors final report with Williams and Foos.

Phil Richards, FB III, (ADF&G-smolt and adult escapement). Works with Jeff Williams on planning, budget, sample design, permits, equipment, personnel, and training.

Stephen Warta, FB I. This position serves as crew leader of the smolt camp tagging operations for juvenile Chinook and coho salmon, and collection and recording of all associated biological and catch-effort data with consultation from Williams. This position also serves as the crew leader for the Canyon Island fish wheels and drift gillnet tagging efforts. Ensures that the operational plan is followed to the extent possible and implements inseason changes as authorized. Determines work schedules and assigns tasks to smolt, fish wheel, and drift crew members with Williams. Performs tagging and sampling summaries, and error-checks CWT and adult salmon tagging data daily. Monitors crew performance and corrects or trains the crew as needed. Performs maintenance on all sampling and camp equipment. Ensures pertinent portions of State SOP, such as safety and time reporting, are followed. Maintains near-daily contact with Williams for safety, data, and logistical needs.

Lee Close, FWT III. Will oversee running one of the trap lines and adjusting trap placements accordingly to maximize catches. Will measure Chinook smolt and record lengths and weights in a Rite-in-the-Rain® book. Works closely with crew leader to follow protocol and quality control while maximizing smolt tagging operational efficiency. Will assist in all aspects of field operations, including safe operation of riverboats and all other equipment, tagging, data collection, data recording, and general field camp duties including keeping camp and field equipment neat and orderly. Responsible for fish handling to prevent mortalities or injuries.

John Cooney, FWT II. This position is responsible for assisting in all aspects of smolt field operations, including safe operation of riverboats and all other equipment, tagging, data collection and general field camp duties including keeping camp and field equipment neat and orderly. Will be clipper or tagger in tagging shed as needed.

Gina Iacono, FWT II. This position is responsible for assisting in all aspects of smolt field operations, including safe operation of riverboats and all other equipment, tagging, data collection and general field camp duties including keeping camp and field equipment neat and orderly. Will be clipper or tagger in tagging shed as needed.

Derrick Allen, FWT III. This position is responsible for being second in charge of fish wheel and set gillnet operations for tagging and sampling adult salmon and assists in all aspects of the project. Will be under direct supervision of the Canyon Island crew leader. Will consult with Williams and Warta regarding the efficiency of work and will provide input on changes necessary to improve operations.

Tristin Eidsness, FWT II. This position is responsible for working on the fish wheels and drift gillnetting for tagging and sampling adult salmon and assists in all aspects of the project. Will be under direct supervision of the Canyon Island crew leader. Will consult with Williams and Warta regarding the efficiency of work and will provide input on changes necessary to improve operations. This position will also assist with smolt field operations as needed.

Elijah Bagoyo, FWT II. This position is responsible for working on the fish wheels and drift gillnetting for tagging and sampling adult salmon and assists in all aspects of the project. Will be under direct supervision of the Canyon Island crew leader. Will consult with Williams and Warta regarding the efficiency of work and will provide input on changes necessary to improve operations. This position will also assist with smolt field operations as needed.

Aaron Foos, BI-03, Project Leader (DFO smolt and adult escapement). Coordinates with Jeff Williams on field operations, data collation and analysis, and report writing. Supervises DFO smolt and adult coho salmon projects; edits, analyzes, and reports data; assists with field work; maintains regular contact with DFO field camps; oversees logistics with field crews. Writes smolt and adult coho salmon sampling section of operational plan, assures that it is followed or modified appropriately with consultation with co-authors. Is coauthor on final report with Jeff Williams and Randy Peterson.

Sean Stark, EG-05, Technical Support and coordination (DFO smolt and adult escapement). Coordinates with Aaron Foos all DFO field operations. Support and logistics for all DFO smolt and adult coho salmon projects; coordinates, verifies, enters, and edits data and samples; assists with field work; maintains near-daily contact with DFO field camps; arranges logistics with field crew and expeditor.

Mark Connor, Fisheries Coordinator, TRTFN. Coordinates with Aaron Foos and Jeff Williams on field operations. Supervises TRTFN smolt and adult coho salmon project involvement; assists with field work; enters, edits, and reports data and coordinates samples from TRTFN projects; maintains regular contact with DFO; arranges all TRTFN logistics.

Various DFO and TRTFN Technicians. Implement and conduct all relevant field aspects of coho salmon smolt and adult escapement projects consistent with operational plans and supervisory direction.

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APPENDIX A

On the surface, Petersen's estimator for closed populations seems appropriate for estimating smolt abundance of coho salmon in the context of using CWTs. A sample of smolts is marked and tagged one year, and a sample of adults is inspected for marks in the following year. During the year at sea the population is open to mortality, but because of their life history, the population is closed to recruitment. If all other conditions are met, the mark–recapture experiment should provide an asymptotically accurate estimate of the abundance of smolts.

One condition that is not met for the experiment on the Taku River from 2001–2002 is that each smolt must have an equal probability of being marked or inspected for marks regardless of their size. Smaller smolt were less likely to be captured in 2001 than were larger smolt. Since smaller smolt suffered a higher mortality rate than did larger smolt, smaller smolt also had less of a chance of being recaptured as adults. Ignoring these circumstances produces an estimate of abundance that is biased low.

Under these circumstances, abundance of coho salmon smolt can be estimated accurately using a weighted variant of Chapman's modification of Petersen's closed-population estimator:

$$\hat{N} = \frac{(\hat{A}M_1 + M_2 + 1)(C+1)}{\hat{A}(R_1 + \hat{\pi}R_3) + R_2 + (1-\hat{\pi})R_3 + 1} - 1 \qquad \text{(A1.1)}$$

where M is the number of smolts marked by size group (1 = smaller 75–85 mm FL, 2 = larger >85 mm FL) in 2001, C the number of adults in 2002 inspected for marks, R the subset of C with marks representing a size group of smolts (3 = group unknown), A is the ratio of the catchability coefficients for larger (>85 mm FL) to smaller (≤ 85 mm FL) smolt in 2001, and π is the fraction of adults in 2002 that were smolts 70–85 mm FL in 2001. The estimate A is used to adjust for differences in catchability in 2001 such that A > 1, when larger smolt are more catchable and < 1 when larger smolt are less catchable. Because some recaptured fish are not sacrificed to find tags or some marked adults do not contain tags, π is used to assign recaptured fish of unknown pedigree to the appropriate smolt size group. An estimate of π is:

$$\hat{\pi} = \frac{T_1}{T_1 + T_2} \qquad \text{(A1.2)}$$

where T is the number of all tags representing a smolt size group recovered or recaptured from adult salmon regardless of how or where recovered or recaptured.

Evidence for smolts not having equal probability of being marked or inspected for marks regardless of size can be found in the recovery rates of CWTs. Recovery of tags in 2002 from both smolt groups indicates that smolt in the larger-size group survived about 54% better than did smaller smolt (P<0.0001, $\chi^2 = 20.1$, df = 1):

Smolt size group	***M***	***T***	Recovery rate
Smaller	23,285	163	0.0070215
Larger	27,250	294	0.1078899

Jones et al. (2006, 2012) have shown that coho salmon smolts marked in this project and handled competently suffer no detectable mortality from the experience. Also, there is no reason to believe that capture rates for adults is influenced by the code on a tag imbedded deep within its cartilage. For these reasons, the differences in recovery rates is most likely due to natural differences in survival rates. This difference means that smolts in the smaller-size group were less likely to be inspected for marks as adults than larger smolts.

Further calculations based on estimates of relative age composition of smolts and adults show that catchability of smolt in the larger-size group was about seven and a half times greater than the catchability of smaller smolt in 2001. If $\hat{p}$ is the estimated fraction of all <u>adults</u> that are of age 1-freshwater, if $\hat{\phi}_1$ is the estimated fraction of <u>smolt</u> in the smaller-size group that were age 1-freshwater, and if $\hat{\phi}_2$ is the estimated fraction of <u>smolt</u> in the larger-size group that were age 1-freshwater, an estimate of the ratio of catchability coefficients for larger to smaller smolt is:

$$\hat{A} = \frac{T_2(\hat{\phi}_2 - \hat{p})}{T_1(\hat{p} - \hat{\phi}_1)} \tag{A1.3}$$

(see Appendix Addendum A1.1 for derivation of eq. A1.3). From Appendix Table A1.1, $\hat{\phi}_1$ = 228/242 = 0.9421 and $\hat{\phi}_2$ = 129/284 = 0.4542. Of the 1,112 adults sampled at Canyon Island in 2002, 943 were age 1.1, making $\hat{p}$ = 943/1112 = 0.8480. Given that T_1 = 163 and T_2 = 294 in 2002, $\hat{A}$ = 7.55. Simulations (see below) indicate that this estimated rate is statistically different than 1.

Plugging statistics given above into eq. A1.1 and noting that $\hat{\pi}$ = 163/(163+294) = 0.357, estimated abundance is:

$$2{,}718{,}816 = \frac{([(7.55)(23{,}285 + 27{,}250 + 1][3{,}765 + 1]}{[(7.55(16 + \{0.357\}40) + 26 + \{1 - 0.357\}40) + 1]} - 1$$

Appendix Table A1.1.–Age composition of coho salmon smolt marked with coded wire and sampled for age in the Taku River in 2001.

	Age-1.1	Age-2.1	Total
Small	228	14	242
Large	129	155	284
Total	357	169	526

with $R_1 = 16$, $R_2 = 16$, $R_3 = 40$, and $C = 3{,}765$. The pooled estimate of abundance from the standard modification of Petersen's estimator is 2,292,994, about 16% less.

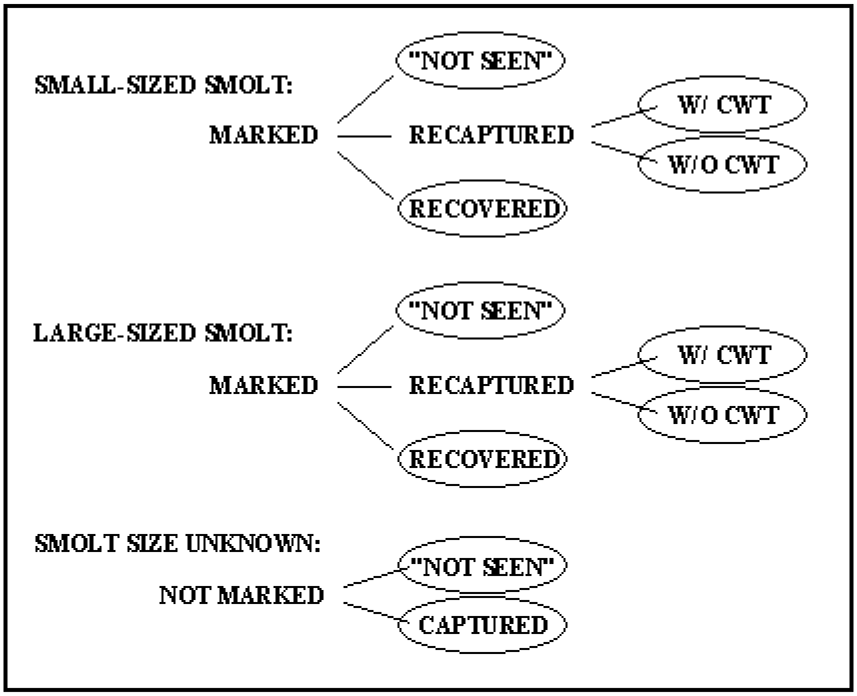
Variance and relative statistical bias in the estimator (eq. A1.1) was estimated with bootstrap procedures described in general by Buckland and Garthwaite (1991). Each bootstrap sample was drawn randomly with replacement from the capture histories of the $\hat{N}$ smolt in the "virtual" population (Appendix Figure A1.1). From the bootstrap sample a new estimate of smolt abundance $\hat{N}'$ was calculated. Then the process was repeated two hundred times to create the frequency distribution $\hat{F}'(\hat{N}')$. At the end of the iterations, the following statistics were calculated:

$$\overline{N}' = \frac{\sum_{b=1}^{200} \hat{N}'_{(b)}}{200} \tag{A1.4a}$$

$$\mathrm{var}(\hat{N}) = \frac{\sum_{b=1}^{200} (\hat{N}'_{(b)} - \overline{N}')^2}{200 - 1} \tag{A1.4b}$$

$$\text{Estimated Relative Bias} = \frac{\overline{N}' - \hat{N}}{\hat{N}}(100) \tag{A1.4c}$$

The 10 capture histories are provided in Appendix Table A1.2. Bootstrap estimates $\hat{\phi}'_1$ were obtained from a binomial distribution with parameters $M'_1/96$ and $\hat{\phi}_1$ (about 1 of every 96 captured smolt were sampled to determine age in 2001); estimates $\hat{\phi}'_2$ were estimated in the same manner. Bootstrap estimates $\hat{p}'$ were obtained from a binomial distribution with parameters 1112 and $\hat{p}$.



Appendix Figure A1.1.–Capture histories (in ovals) concerning smolts in the population emigrating from the Taku River in 2001.

Results of the bootstraps simulations are as follows. The bootstrap estimate $\overline{N}'$ = 2,770,138 indicating an estimate of relative statistical bias in $\hat{N}$ less than 2%. The bootstrap estimate for the standard error of $\hat{N}$ is 364,867 for a CV just over 13.4%. Simulated estimates of $\hat{A}$ had a low of 4.069, a standard error of 2.195, and indicated a relative bias in $\hat{A}$ of just over 29%. The BASIC program SMLTTAKU.BAS was used to conduct the simulations.

Appendix Table A1.2.–Relationships among history variables, capture histories, and model variables in bootstrap simulations.

Program Variable	Capture History	Model Variables	Values
n(1)	Not marked, not seen	$\hat{N} - M_1 - M_2 - C + R_1 + R_2 + R_3$	
n(2)	Marked, not seen - Smaller Smolt	M_1 - T_1	23,250 - 163 = 23,122
n(3)	" " - Larger Smolt	M_2 - T_2	23,285 - 294 = 26,956
n(4)	Marked, recaptured - Smaller Smolt w/ CWT	R_1	16
n(5)	" " - Larger Smolt w/ CWT	R_2	26
n(6)	" " - Smaller Smolt w/o CWT	$\hat{\pi} R_3$	0.357(40) = 14
n(7)	" " - Larger Smolt w/o CWT	$(1-\hat{\pi}) R_3$	(1 - 0.357)40 = 26
n(8)	Marked, recovered - Smaller Smolt	$T_1 - R_1 - \hat{\pi} R_3$	163 - 16 - 14 = 133
n(9)	" " - Larger Smolt	$T_2 - R_2 - (1-\hat{\pi}) R_3$	294 - 26 - 26 = 242
n(10)	Not Marked, captured	C - R_1 - R_2 - R_3	3765 - 16 - 26 - 40 = 3683

Appendix Addendum A1.1–Estimation of the ratio of catchabilities

The fraction p of adults with 1-freshwater age can be expressed as:

$$p = \frac{N_1\phi_1 S_1 + N_2\phi_2 S_2}{N_1 S_1 + N_2 S_2} = \frac{N_1\phi_1 S_1 + N_2\phi_2 B\mathrm{S}_1}{N_1 S_1 + N_2 B S_1} = \frac{N_1\phi_1 + N_2\phi_2 B}{N_1 + N_2 B}$$

where N is smolt number by smolt size group, S their survival rate, ϕ the fraction of the smolt group comprised of smolt age 1-freshwater, and B is the ratio of survival rates S_2/S_1. This relationship simplifies to:

$$\frac{N_1}{N_2} = \frac{B(\phi_2 - p)}{(p - \phi_1)}$$

If α is the capture rate of smolts, then $M_1 = \alpha_1 N_1$ and $M_2 = \alpha_2 N_2$, and:

$$\frac{N_1}{N_2} = \frac{M_1}{M_2}\frac{\alpha_2}{\alpha_1} = \frac{B(\phi_2 - p)}{(p - \phi_1)}$$

If A is the ratio of catchability for the two groups of smolts, then $A = \alpha_2 / \alpha_1$ since fishing effort by definition is equal for both groups. Substitution creates:

$$A = \frac{M_2 B(\phi_2 - p)}{M_1(p - \phi_1)}$$

A naïve estimate of A is therefore:

$$\hat{A} = \frac{M_2 \hat{B}(\hat{\phi}_2 - \hat{p})}{M_1(\hat{p} - \hat{\phi}_1)}$$

Noting that the estimate for the ratio of survival rates is:

$$\hat{B} = \frac{T_2}{M_2}\frac{M_1}{T_1}$$

A simpler estimate for A is:

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

Appendix A2.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during event 1 (M) with that of marked fish recaptured during event 2 (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during event 2 (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:		
Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during event 1 but there is during event 2 sampling.

Case III:		
Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during event 2 but there is during event 1 sampling.

Case IV:		
Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during event 2 which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during event 1 which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from event 2 data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from event 1 data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2} \sum_{i=1}^{j} \left(\hat{N}_i^2 \hat{V}\left[\hat{p}_{ik}\right] + \left(\hat{p}_{ik} - \hat{p}_k\right)^2 \hat{V}\left[\hat{N}_i\right] \right). \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A3.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Tests of consistency for petersen estimator

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time	Area/Time Where Recaptured				Not Recaptured
Where Marked	**1**	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during event 1[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

III.-Test for equal probability of capture during event 2[c]

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}m_2)$				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j \theta_{ij} p_j$ = d, where p_j is the probability of capturing a fish in section j during event 2, and d is a constant.

If dropouts are germane to only the marked population (i.e., only fish captured during event 1 dropout), the population is closed, and the following equations can be used to estimate the inriver abundance at the two time periods.

Let ϕ be the proportion of marked fish, n_1, that did not dropout and were alive at the second time period and N_1 be the initial abundance. Therefore, the abundance of fish at the second sampling event is:

$$N_2 = N_1 - n_1(1-\phi)$$

Since only marked fish dropout, the expected proportion of marked fish at the second sampling event can be expressed as:

$$E\left(\frac{m_2}{n_2}\right) = \frac{n_1\phi}{N_2}$$

By taking the inverse of the above equation and multiplying by n_1, we get:

$$E\left(\frac{n_1 n_2}{m_2}\right) = \frac{N_2}{\phi}$$

Replacing $n_1 n_2/m_2$ with the Chapman estimator, $\widehat{N}$, we can estimate the abundance at the second sampling event as:

$$\widehat{N} = \frac{\widehat{N}_2}{\phi}$$

$$\widehat{N}_2 = \widehat{N}\phi$$

and by substitution, we can estimate the initial abundance as:

$$\widehat{N} = \frac{N_1 - n_1(1-\phi)}{\phi}$$

$$\widehat{N}_1 = \widehat{N}\phi + n_1(1-\phi)$$

$$\widehat{N}_1 = \left(\widehat{N} - n_1\right)\phi + n_1$$

Note ϕ can be estimated by from a subset of the marked population. The proportion of marked fish, n_1, that did not drop out, $\hat{\phi}$, can be estimated as:

$$\hat{\phi} = \frac{R-e}{R}$$

where e is the number of radio tagged fish that dropped out and R is the total number of radio tagged fish. Variance of $\hat{\phi}$ can be estimated as:

$$\mathrm{var}\left(\hat{\phi}\right) = \frac{\hat{\phi}\left(1-\hat{\phi}\right)}{R-1}\left(\frac{n_1 - R}{n_1}\right)$$

Replacing ϕ with $\hat{\phi}$, the initial abundance, $\widehat{N}_1$,can be estimated as:

$$\widehat{N}_1 = \left(\widehat{N} - n_1\right)\hat{\phi} + n_1$$

with estimated variance:

$$\text{var}(\hat{N}_1) = \text{var}\left((\hat{N} - n_1)\hat{\phi} + n_1\right)$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_1) = (\hat{N} - n_1)^2\text{var}(\hat{\phi}) + \hat{\phi}^2\text{var}(\hat{N})$$

Similarly, replacing ϕ with $\hat{\phi}$, the abundance of fish at the second sampling event, $\hat{N}_2$, can be estimated as:

$$\hat{N}_2 = \hat{N}\hat{\phi}$$

with estimated variance:

$$\text{var}(\hat{N}_2) = \text{var}(\hat{N}\hat{\phi})$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_2) = \hat{N}^2\text{var}(\hat{\phi}) + \hat{\phi}^2\text{var}(\hat{N})$$

If dropouts are not germane to only the marked population (i.e., some fish dropout because they spawn below border and some fish dropout because they were marked), then the population is not closed, and the following equations will be used to estimate the inriver abundance at the two time periods and for both the above and below border populations.

Let ϕ be the proportion of marked fish, n_1, that <u>did not</u> dropout and were alive at the second time period and π be the proportion of initial abundance, N_1, that spawned above the border. Therefore, from an initial abundance of N_1 fish, the abundance of fish at the second sampling event is:

$$N_2 = N_1 - N_1(1-\pi) - n_1\pi(1-\phi)$$

$$N_2 = N_1\pi - n_1\pi(1-\phi)$$

$$N_2 = \pi[N_1 - n_1(1-\phi)]$$

Since some of the marked fish dropout and others spawn below the border, the expected proportion of marked fish at the second sampling event can be expressed as:

$$E\left(\frac{m_2}{n_2}\right) = \frac{n_1\pi\phi}{N_2}$$

By taking the inverse of the above equation and multiplying by n_1, we get:

$$E\left(\frac{n_1 n_2}{m_2}\right) = \frac{N_2}{\pi\phi}$$

Replacing $n_1 n_2/m_2$ with the Chapman estimator, $\widehat{N}$, we can estimate the abundance at the second sampling event as:

$$\widehat{N} = \frac{\widehat{N}_2}{\pi\phi}$$

$$\widehat{N}_2 = \widehat{N}\pi\phi$$

and by substitution, we can estimate the initial abundance as:

$$\widehat{N} = \frac{\pi[N_1 - n_1(1-\phi)]}{\pi\phi}$$

$$\widehat{N} = \frac{N_1 - n_1(1-\phi)}{\phi}$$

$$\widehat{N}_1 = \widehat{N}\phi + n_1(1-\phi)$$

$$\widehat{N}_1 = \left(\widehat{N} - n_1\right)\phi + n_1$$

Note $\widehat{N}_1$ as defined above and $\widehat{N}_1$ as previously defined in Data Analysis are not the same and the difference is due to how dropouts are defined and quantified. Dropouts, as defined here, is different than the previous definition in that it is now germane only to fish permanently removed from the study (presumably due to handling and/or tagging mortality). Both ϕ and π can be estimated using data collected from radio tags. The proportion of marked fish, n_1, that <u>did not</u> drop out, $\hat{\phi}$, will be estimated as:

$$\hat{\phi} = \frac{R - e}{R}$$

where e is the number of radio tagged fish that dropped out and R is the total number of radio tagged fish. Variance of $\hat{\phi}$ will be estimated as:

$$\text{var}(\hat{\phi}) = \frac{\hat{\phi}(1 - \hat{\phi})}{R - 1}\left(\frac{n_1 - R}{n_1}\right)$$

The proportion of initial abundance that did not dropout and passes by Canyon Island, $\hat{\pi}$, will be estimated as:

$$\hat{\pi} = \frac{a}{R - e}$$

where a is the number of radio tagged fish passing the U.S./Canada border. Variance of $\hat{\pi}$ will be estimated as:

$$\text{var}(\hat{\pi}) = \frac{\hat{\pi}(1 - \hat{\pi})}{R - e - 1}$$

Replacing ϕ with $\hat{\phi}$ and π with $\hat{\pi}$, the initial abundance, $\hat{N}_1$,will be estimated as:

$$\hat{N}_1 = (\hat{N} - n_1)\hat{\phi} + n_1$$

with estimated variance:

$$\text{var}(\hat{N}_1) = \text{var}\left((\hat{N} - n_1)\hat{\phi} + n_1\right)$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_1) = (\hat{N} - n_1)^2\text{var}(\hat{\phi}) + \hat{\phi}^2\text{var}(\hat{N})$$

So from the estimated initial abundance, $\hat{N}_1$, the number of fish passing the U.S./Canada border, $\hat{N}_{1,above\ border}$, can be estimated as:

$$\hat{N}_{1,above\ border} = \hat{N}_1\hat{\pi}$$

with estimated variance:

$$\text{var}(\hat{N}_{1,above\ border}) = \text{var}(\hat{N}_1\hat{\pi})$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_{1,above\ border}) = \hat{N}_1^{\ 2}\text{var}(\hat{\pi}) + \hat{\pi}^2\text{var}(\hat{N}_1)$$

which, can be simplified to:

$$\text{var}(\hat{N}_{1,above\ border}) = \left[(\hat{N} - n_1)\hat{\phi} + n_1\right]^2\text{var}(\hat{\pi}) + \left[\hat{\pi}(\hat{N} - n_1)\right]^2\text{var}(\hat{\phi}) + (\hat{\phi}\hat{\pi})^2\text{var}(\hat{N})$$

Similarly, the number of fish that did not pass the U.S./Canada border from the initial abundance, $\hat{N}_{1,below\ border}$, can be estimated by replacing $\hat{\pi}$ with $1 - \hat{\pi}$ in the above equations for $\hat{N}_{1,above\ border}$ The abundance of fish at the second sampling event, $\hat{N}_2$, can be estimated as:

$$\hat{N}_2 = \hat{N}\hat{\pi}\hat{\phi}$$

with estimated variance:

$$\text{var}(\hat{N}_2) = \text{var}(\hat{N}\hat{\pi}\hat{\phi})$$

where, by Goodman (1960) for independent variables, is equal to:

$$\text{var}(\hat{N}_2) = (\hat{N}\hat{\phi})^2\text{var}(\hat{\pi}) + (\hat{N}\hat{\pi})^2\text{var}(\hat{\phi}) + (\hat{\phi}\hat{\pi})^2\text{var}(\hat{N})$$

Since the abundance at the second sampling event is defined as the portion of abundance passing by the U.S./Canada border, note:

$$\hat{N}_{2,above\ border} = \hat{N}_2$$

Hence, the number of fish that did not pass the U.S./Canada border at the second sampling event, $\hat{N}_{2,below\ border}$, can be calculated by replacing $\hat{\pi}$ with $1 - \hat{\pi}$.

An average dropout rate can be calculated and used to predict the number of dropouts in years when only the number of fish tagged during event 1 is known, i.e., no radiotelemetry experiment was conducted. The average dropout rate is simply the average observed or estimated annual dropout rate over several years. While computing an average dropout rate is trivial, determining its variance is not. We consider two cases: when dropout rate is known and when dropout rate is estimated.

Dropout rate known

When the number of dropouts is completely enumerated, the average dropout rate is estimated as the expected value of the population of annual dropout rates (ρ_y's):

$$\bar{\rho} = \frac{\sum_{y=1}^{k} \rho_y}{k} \tag{1}$$

where $\rho_y = d_y/M_y$ is the observed dropout rate in year y, d_y is the number of dropouts in year y, and M_y is the number of fish tagged during event 1 in year y, and k is the number of year which data is available to calculate a dropout rate.

The estimated variance for the average dropout rate needs to reflect two sources of uncertainty for any predicted value of ρ, (ρ_{pred}). First is an estimate of the process error (var(ρ), which is the variation across years in the ρ's, reflecting, for example, environmentally-induced effects that influence the number of fish that dropout in a study year), and the second is the sampling variance of $\bar{\rho}$ (var($\bar{\rho}$)), which will decline with additional dropout studies. The variance of ρ_{pred} will be estimated as (Kutner et al. 2005):

$$\mathrm{var}(\rho_{pred}) = \mathrm{var}(\rho) + \mathrm{var}(\bar{\rho}) \tag{2}$$

where

$$\mathrm{var}(\rho) = \frac{\sum_{y=1}^{k} (\rho_y - \bar{\rho})^2}{k-1} \tag{3}$$

and

$$\mathrm{var}(\bar{\rho}) = \frac{\sum_{y=1}^{k} (\rho_y - \bar{\rho})^2}{k(k-1)} \tag{4}$$

such that

$$\mathrm{var}(\rho_{pred}) = \frac{\sum_{y=1}^{k} (\rho_y - \bar{\rho})^2}{k-1} \left(1 + \frac{1}{k}\right) \tag{5}$$

Dropout rate estimated

If in any year the number of dropouts is estimated, then the following equations should be used. When the number of dropouts is estimated, the average dropout rate is estimated as the expected value of the population of annual estimated dropout rates ($\hat{\rho}_y$'s):

$$\bar{\rho} = \frac{\sum_{y=1}^{k} \hat{\rho}_y}{k} \tag{6}$$

where $\hat{\rho}_y = \hat{d}_y / M_y$ is the estimated dropouts rate in year y, $\hat{d}_y$ is the estimated number of dropouts in year y, and the other terms are as described as above. The variance for the estimated dropout rate for prediction will be estimated similar as before (see Eq. 2):

$$\mathrm{var}(\rho_{pred}) = \widehat{\mathrm{var}}(\rho) + \mathrm{var}(\bar{\rho}) \tag{7}$$

The estimate of process error, $\mathrm{var}(\rho)$, should reflect only process error; however, since the ρ_y's are estimated ($\hat{\rho}_y$), these estimates represent process error plus measurement error (e.g. the error due to not having radio tagged all marked fish), which can be expressed as (Mood et al. 1974):

$$\mathrm{var}(\hat{\rho}) = \mathrm{var}[E(\hat{\rho})] + E[\mathrm{var}(\hat{\rho})] \tag{8}$$

Equation 8 can be rearranged to isolate process error, that is:

$$\mathrm{var}[E(\hat{\rho})] = E[\mathrm{var}(\hat{\rho})] - \mathrm{var}(\hat{\rho}) \tag{9}$$

Therefore, an estimate of $\mathrm{var}(\rho)$, ($\widehat{\mathrm{var}}(\rho)$), representing only process error is:

$$\widehat{\mathrm{var}}(\rho) = \mathrm{var}(\hat{\rho}) - \frac{\sum_{y=1}^{k} \mathrm{var}\left(\hat{\rho}_y\right)}{k} \tag{10}$$

where $\mathrm{var}(\hat{\rho}_y)$ is the variance of the estimated dropout rate estimate in year y, which is calculated as:

$$\mathrm{var}(\hat{\rho}_y) = \mathrm{var}(\hat{d}_y)/M_y^2 \tag{11}$$

Both $\mathrm{var}(\hat{\rho})$ and $\mathrm{var}(\bar{\rho})$ are computed similar as before (Eq. 3 and 4), except $\hat{\rho}_y$ is substituted for ρ_y:

$$\mathrm{var}(\hat{\rho}) = \frac{\sum_{y=1}^{k} \left(\hat{\rho}_y - \bar{\rho}\right)^2}{k-1} \tag{12}$$

and

$$\mathrm{var}(\bar{\rho}) = \frac{\sum_{y=1}^{k} \left(\hat{\rho}_y - \bar{\rho}\right)^2}{k(k-1)} \tag{13}$$

such that

$$\mathrm{var}(\rho_{pred}) = \frac{\sum_{y=1}^{k} \left(\hat{\rho}_y - \bar{\rho}\right)^2}{k-1}\left(1 + \frac{1}{k}\right) - \frac{\sum_{y=1}^{k} \mathrm{var}(\hat{\rho}_y)}{k} \tag{14}$$

<u>Bootstrap</u>

For large k (k > 30), equation 14 should provide a reasonable estimate of the prediction variance; however, for small k the estimates may be imprecise and could result in negative estimates. Because k is typically small (k< 10), we will estimate $\mathrm{var}(\rho)$ and $\mathrm{var}(\bar{\rho})$ using parametric bootstrap techniques (Efron and Tibshirani, 1993). The sampling distributions for each $\hat{\rho}_y$ will be simulated using binomial distributions with probability $\hat{\rho}_y$ conditional on the number of radio tags deployed, (r_y), with mean $\frac{d_y}{r_y}$. For each bootstrap iteration, bootstrap dropout rates, $\hat{\rho}_{y(b)}$, will be simulated from a binomial distribution. A value of $\hat{\rho}_{(b)}$ will be randomly chosen from the k values of $\hat{\rho}_{y(b)}$ and a sample of size k will be drawn from the k values of $\hat{\rho}_{y(b)}$ by sampling with replacement. The mean of this sample will be used to calculate $\bar{\rho}_{(b)}$. This procedure is repeated B = 1,000,000 times. We then estimate $\mathrm{var}(\rho)$ as:

$$\mathrm{var}_B(\rho) = \frac{\sum_{b=1}^{B}\left(\hat{\rho}_{(b)} - \overline{\hat{\rho}_{y(b)}}\right)^2}{B-1} \tag{15}$$

where

$$\overline{\hat{\rho}_{y(b)}} = \frac{\sum_{b=1}^{B}\hat{\rho}_{y(b)}}{B} \tag{16}$$

Similarly, we estimate $\mathrm{var}(\bar{\rho})$ as:

$$\mathrm{var}_B(\bar{\rho}) = \frac{\sum_{b=1}^{B}\left(\bar{\rho}_{(b)} - \overline{\bar{\rho}_{(b)}}\right)^2}{B-1} \tag{17}$$

where

$$\overline{\bar{\rho}_{(b)}} = \frac{\sum_{b=1}^{B}\bar{\rho}_{(b)}}{B} \tag{18}$$

The prediction is then estimated using Eq. 7 with the appropriate substitutions.

Estimating dropouts

In years when the number of animals captured during event 1 (M) is known, but the number of dropouts (d) is not, it can be predicted:

$$\hat{d} = \bar{\rho}M \tag{19}$$

and

$$\mathrm{var}\left(\hat{d}\right) = M^2\mathrm{var}\left(\rho_{pred}\right) \tag{20}$$

Similarly, the number of animals captured during event 1 that did not drop out ($\hat{M}$) can be predicted:

$$\hat{M} = (1-\bar{\rho})M \tag{21}$$

and

$$\mathrm{var}\left(\hat{M}\right) = M^2\mathrm{var}\left(\rho_{pred}\right) \tag{22}$$

Estimating abundance

In certain situations, the average dropout rate can be used to directly estimate animal abundance for years where the dropout rate is not known. One common situation where this method would be appropriate is the case that abundance, $\hat{N}$, is estimated using a two-sample mark–recapture model (i.e., either the Chapman or Lincoln-Petersen estimators). The abundance of fish after dropouts, $\hat{N}_2$, can be estimated as:

$$\hat{N}_2 = (1-\bar{\rho})\hat{N} \tag{23}$$

where, by Goodman (1960) for a product of independent variables, the variance is:

$$\mathrm{var}\left(\hat{N}_2\right) = \hat{N}^2\mathrm{var}\left(\rho_{pred}\right) + (1-\bar{\rho})^2\mathrm{var}\left(\hat{N}\right) \tag{24}$$

R Code and examples

Three R code functions - **Dropout**, **DropoutRate**, and **bootDropout** -and an example are included. Note that notation used in the code corresponds to the text of this Appendix.

```
#Dropout: use this function if information about d and M are available
 Dropout <- function(M,d,d_se=NULL) {
  #point estimates
   k=length(d)
   rho=d/M
   rho_est = mean(rho)
  #if d_se is NULL, then the number of dropouts known
   if(is.null(d_se)) {
     estimator = "dropout rate known"
    #process error
     PE = var(rho)
   } else {
     estimator = "dropout rate estimated"
    #process error
     PE = var(rho) - sum(d_se^2/M^2)/k
   }
   #sampling error
    SE = sum((rho-rho_est)^2)/(k*(k-1))
   #prediction error
    rho_var = PE + SE
   #format and return output
    out=list()
    out$rho_est = rho_est
    out$rho_var = rho_var
    out$rho_sd = sqrt(rho_var)
    out$rho_cv = sqrt(rho_var)/rho_est
    out$estimator = estimator
    return(out)
 }

#DropoutRate: use this function if information about rho and M are available
 DropoutRate <- function(M,rho,rho_se=NULL) {
  k=length(rho)
  rho_est = mean(rho)
  #if d_se is NULL, then the number of dropouts is known
   if(is.null(rho_se)) {
     estimator = "dropout rate known"
    #process error
     PE = var(rho)
```

```
  } else {
    estimator = "dropout rate estimated"
   #process error minus measurement error
    PE = var(rho) - sum(rho_se^2)/k
  }
  #sampling error
   SE = sum((rho-rho_est)^2)/(k*(k-1))
  #prediction error
   rho_var = PE + SE
  #format and return output
   out=list()
   out$rho_est = rho_est
   out$rho_var = rho_var
   out$rho_sd = sqrt(rho_var)
   out$rho_cv = sqrt(rho_var)/rho_est
   out$estimator = estimator
   return(out)
 }

#bootDropout: use this function if information about d, r, and M are available
 bootDropout <- function(M,d,r,nreps=9999) {
 k=length(d)
 d_se = M*sqrt(((d/r*(1-d/r))/(r-1))*((M-r)/M))
 PE_boot=rep(NA,nreps)
 SE_boot=rep(NA,nreps)
 for(i in 1:nreps) {
  #at each iteration, a bootstrap value for each pi is drawn from its sampling distribution
   rho_boot = rbinom(length(d), r, d/r)/r #illustrating that the cute trick using rnorm works: y-
rnorm(length(y), y, c(rep(0,length(y)-5),rep(5,5)))
  #randomly choose a value of rho hat from this vector
   rho_bootpred = sample(rho_boot,1)
  #randomly choose k values from this vector, sampling w/replacement
   rho_bootvec = sample(rho_boot, replace=TRUE)
  #compute
   rho_bootmean = mean(rho_bootvec)
  #store
   PE_boot[i] = rho_bootpred
   SE_boot[i] = rho_bootmean
  }
  out=list()
  out$mean = mean(d/r)
  out$bias = out$mean - mean(SE_boot)
  out$var = var(PE_boot) - sum(d_se^2/M^2)/k  + var(SE_boot)
  out$sd  = sqrt(out$var)
```

```
 out$cv  = out$sd/out$mean
 return(out)
}

##########
##########
#EXAMPLES#
##########
##########
#Stikine Chinook
 #1997 & 2005 (Table 6 in FDS 08-33 for dropouts numbers & Table 12 in FDS08-33 for M)
 #2015 & 2016 (from Courtney et al. in prep)
 M = c(359,1022,299,169)
 d = c(31,23,65,31)
 r = c(255,369,299,169)
 #97, 05, 15-16 estimate
  Dropout(M=M, d=d/r*M, d_se=M*sqrt(((d/r*(1-d/r))/(r-1))*((M-r)/M)))
 #97, 05, 15-16 bootstrap estimate
  bootDropout(M=M, d=d, r=r, nreps=9999)
 #97, 05, 15-16 estimate supposing no measurement error
  Dropout(M=M, d=d/r*M)
 #97, 05, 15-16 bootstrap estimate supposing no measurement error
  bootDropout(M=M, d=d/r*M, r=M, nreps=9999)
 #15-16
  Dropout(M=M[3:4], d=d[3:4]/r[3:4]*M[3:4])
```

APPENDIX B

Appendix B1.–Coded wire verification form.

Coded Wire Verification Form

Alaska Department of Fish and Game
Mark, Tag & Age Laboratory
10107 Bentwood Place
Juneau, AK 99811 - 5526
907-465-3483

Page ___________ of ____________

Facility or Project ____

Tag Code	Release Site	Species	# of K Purchased	Wire Samples, one per spool unless sequential wire then one from the beginning and another from the end of tagging.

Appendix B2.–Data form to record daily CWT tagging results.

CWT DAILY TAGGING, ADF&G

Location: Taku River
Species: Coho
Year:

Date: ________________

Tag code: ________________

Machine Serial Number: ________________

a. Number of fish tagged ____

b. Post tagging mortalities ____

c. Total tagged fish released (a-b) ____

Recaptures:

d. Number with CWTs ____

e. Total number of recaptures ____

24 hour tag retention:

f. Number with CWTs ____

g. Total number tested ____

h. Short-term retention % (f/g) ____

i. Adjusted tagged and released (h*c) ____

Cumulative tagged and released: ____

Comments

Appendix B3.–Data form to record daily environmental conditions.

ENVIRONMENTAL CONDITIONS, ADF&G

Location: Taku River
Year:

Date	Air Temp		Water		Precipitation	General Weather Condition
	Min	Max	Temp	Depth		

Appendix B4.–Data form for recording salmon smolt length, weight, and scale samples.

SALMON SMOLT LENGTH, WEIGHT AND SCALE SAMPLES

LOCATION____ YEAR________ PAGE ___ of ___

Samplers____________________________________

Date	Fish #	Slide	Scale #	Length	Wt.	Age	Comments	Date	Fish #	Slide	Scale #	Length	Wt.	Age	Comments
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				
			1								1				
			2								2				
			3								3				
			4								4				

Appendix B5.–Data form for recording Canyon Island adult salmon fishing effort.

Fishing Effort Form				Fish Wheel (FW) Effort				Gillnet Effort
Stat Week	Date	Water Temperature (°C)	River Level (ft)	FW1 Effort (hrs)	FW1 RPM	FW2 Effort (hrs)	FW2 RPM	Hours

Appendix B6.–Data form for recording numbers of fish caught and tagged each day at Canyon Island using fish wheels and gillnets.

Fish Wheel Sampling Form

Chinook						Sockeye				Coho						Pink		Chum		Pink	
Caught		Tagged		Ad Clips		Caught		Tagged		Caught		Tagged		Ad clips		Caught		Caught		Sex Ratios	
Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	Daily	Cum	M	F

Appendix B7.–Hatchery rack and escapement survey form.

Alaska Department of Fish and Game

Coded Wire Tag Sampling Form

Rack Return and Escapement Survey

Southeast Region

Page Info for this Sample Number only! See Instructions → PAGE ____ OF ____ PAGES

SAMPLE NUMBER: 1 _ _ _ _ _ _ _

SOURCE: (circle one) rack return escapement survey hatchery other

SURVEY SITE: ____________________

SAMPLE TYPE: random select

SAMPLER: ____________________

DATE SAMPLED: _ _ - _ _ - 1 _

SAMPLING INFORMATION

This Box to be completed for RANDOM Samples Only

SPECIES (CODE)	TOTAL # FISH CHECKED FOR AD-CLIPS	# AD-CLIPS SEEN	WERE ALL CHECKED?
(410)CHIN			y n
(411)JACK CHINOOK-ONLY			y n
(420)SOCK			y n
(430)COHO			y n
(440)PINK			y n
(450)CHUM			y n
(540)STHD			y n

AREA INFORMATION (DISTRICT - SUBDISTRICT)

101-	106-	111-	116-	157-	191-
102-	107-	112-	150-	181-	192-
103-	108-	113-	152-	182-	OTHER DISTRICTS
104-	109-	114-	154-	183-	______
105-	110-	115-	156-	189-	______

NAME of PLACE SURVEYED: (HATCHERY OR STREAM) ____________________

WATER TYPE: saltwater freshwater

ANADROMOUS STREAM# (FRESHWATER-ONLY) ___-___-___-___-___-___

COMMENTS

HEAD RECOVERY INFORMATION

✓	HEAD NUMBER	SPECIES CODE	LENGTH (mid-eye to fork in mm)	CLIP	SEX

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