Regional Operational Plan No. ROP.CF.1J.2023.01

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

by

Jeffrey T. Williams

Randy L. Peterson

and

Aaron Foos

March 2023

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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by
Jeffrey T. Williams
Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas

Randy L. Peterson
Alaska Department of Fish and Game, Division of Sport Fish, Douglas

and

Aaron Foos
Department of Fisheries and Oceans Canada, Whitehorse

Alaska Department of Fish and Game
Division of Commercial Fisheries
802 3rd St., Douglas, AK 99824-5412
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Jeffrey T. Williams
Alaska Department of Fish and Game, Division of Commercial Fisheries,
802 3rd St., Douglas, AK 99824-5412, USA

Randy L. Peterson
Alaska Department of Fish and Game, Division of Sport Fish,
802 3rd St., Douglas, AK 99824-5412, USA

Aaron Foos
Department of Fisheries and Oceans Canada
419 Range Road, Suite 100, Whitehorse, Yukon, Y1A 3V1, Canada

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Approval

Title	Name	Signature	Date
Project Leader - ADF&G	Jeffrey Williams		4/13/2022
Management Biologist – Commercial Fisheries	Scott Forbes		4/15/2022
Management Biologist – Sport Fish	Daniel Teske		4-1-22
Biometrician	Randy Peterson		4/13/2022
Research Coordinator	Edgar Jones III		4/18/22
Regional Supervisor	Lowell Fair		4/21/22

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ABSTRACT

Chinook salmon *Oncorhynchus tshawytscha* smolt abundance and adult escapement will be estimated for the Taku stock of Chinook salmon originating from the Canadian portions of the Taku River drainage above the U.S./Canada border. This large glacial river flows into Taku Inlet about 30 km northeast of Juneau, Alaska. A modified Petersen estimator will be used to estimate smolt abundance for the 2020–2022 brood years, which are the smolt leaving the system during 2022–2024. Chinook salmon smolt will be captured from April through June, systematically sampled to estimate mean length and weight, and all healthy fish will be implanted with a coded wire tag and marked with an adipose fin clip. Escapement of large (≥660 mm; mid eye to fork of tail) and medium (401–659 mm; mid eye to fork of tail) Taku River adult Chinook salmon in 2022–2024 will be estimated using mark–recapture methodology. Adult Chinook salmon will be captured and marked near Canyon Island in the lower Taku River using fish wheels and drift gillnets from late April through early August. Each healthy fish will be tagged with a uniquely numbered, solid-core spaghetti tag and two secondary marks will be applied. Fish will be sampled for data used in age, sex, and length composition estimates of the spawning escapement.

Keywords: Chinook salmon, *Oncorhynchus tshawytscha*, Southeast Alaska, Taku River, adult production, smolt production, spawning abundance, mark–recapture, escapement, inriver run, fish wheels, set gillnets, drift gillnets, spaghetti tags, secondary marks, coded-wire-tags, radio tags.

PURPOSE

This operational plan details procedures necessary for the estimation of Taku River Chinook salmon smolt abundance, and adult Taku River Chinook salmon harvest for the 2020–2022 brood years using information gathered from coded wire tag (CWT) sampling programs. This plan also details methods that will be used for the estimation of Taku River Chinook salmon escapement in 2022–2024 using information gathered from various adult sampling programs. Improved stock identification is a critical element in the strategy to improve stock assessment and management of Chinook salmon, as outlined in Attachment F to the 1996 U.S. Letter of Agreement (L.O.A), the Pacific Salmon Treaty (PST), and U.S. coastwide Chinook salmon stock assessment standards (USCTC 1997). Stock identification programs provide stock specific harvests, from which total adult production, exploitation rates, harvest distribution and survival parameters are estimated. These data are necessary for implementation and improvement in 1) Alaska Department of Fish and Game (ADF&G) Chinook salmon management, 2) Taku River Chinook salmon terminal run management by the ADF&G and Fisheries and Oceans Canada (DFO) and 3) coastwide Chinook salmon management in the Pacific Salmon Commission (PSC) process. Stock assessment parameters such as harvest, escapement, exploitation rate, smolt abundance, and brood year production will be directly estimated through implementation of the smolt tagging and adult catch and escapement projects.

BACKGROUND

The Taku River (Figure 1) produces the largest run of Chinook salmon *Oncorhynchus tshawytscha* in British Columbia north of the Skeena River, and in Southeast Alaska (Hubartt and Kissner 1987; Pahlke 1997; Pahlke and Bernard 1996; McPherson et al. 1996–1998). The escapement of large Chinook salmon (≥ 660 mm mid eye to fork of tail (METF)) originating from the Taku River has been estimated using mark–recapture methodology in all but 10 years since 1989 (Table 1) when the first mark–recapture study was implemented. No efforts were made in 1991–1994 to conduct a mark–recapture study for Taku River Chinook salmon. Over the past 10 years the escapement consisted of an estimated 2% small, 32% medium and 66% large Chinook salmon, on average.

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

Table 1.—Estimated escapement and standard error (SE) of large (> 660 mm) Chinook salmon originating from the Taku River, 1989–2021. Final estimates of escapement were generated using mark–recapture methodology in years that are bold, and aerial survey expansion methodology in most other years.

Year	Estimated escapement of large Chinook salmon	SE	References
1989	40,329	5,646	Pahlke and Bernard (1996)
1990	52,142	9,326	Pahlke and Bernard (1996)
1991	51,645	21,163	McPherson et al. (2000)
1992	55,889	22,902	McPherson et al. (2000)
1993	66,125	27,097	McPherson et al. (2000)
1994	48,368	19,820	McPherson et al. (2000)
1995	33,805	5,060	McPherson et al. (1996)
1996	79,019	9,048	McPherson et al. (1997)
1997	114,938	17,888	McPherson et al. (1998)
1998	31,039	10,604	McPherson et al. (1999)
1999	16,786	3,171	Jones III et al. (2010)
2000	34,997	5,403	Jones III et al. (2010)
2001	46,544	6,766	Jones III et al. (2010)
2002	55,044	11,087	Jones III et al. (2010)
2003	36,435	6,705	Jones III et al. (2010)
2004	75,032	10,280	Jones III et al. (2010)
2005	38,725	4,908	Jones III et al. (2010)
2006	42,296	5,535	Jones III et al. (2010)
2007	14,854	3,277	Jones III et al. (2010)
2008	26,645	3,010	Jones III et al. (2018)
2009	22,761	2,871	Jones III et al. (2018)
2010	28,769	2,546	Jones III et al. (2018)
2011	19,672	6,734	Jones III et al. (*In prep*)
2012	16,713	5,721	Jones III et al. (*In prep*)
2013	18,002	6,162	Jones III et al. (*In prep*)
2014	23,532	2,217	Williams et al. (*in prep*)
2015	23,567	4,080	Williams et al. (*in prep*)
2016	9,177	1,463	Williams et al. (*in prep*)
2017	8,214	783	Williams et al. (*in prep*)
2018	7,271	779	Williams et al. (*in prep*)
2019	11,558	1,406	Williams et al. (*in prep*)
2020	15,593	3,049	Williams et al. (*in prep*)
2021	11,341	3,882	Williams et al. (*in prep*)

Detailed stock assessment projects designed to directly estimate parameters such as harvest, escapement, exploitation rate, smolt abundance, survival rates, and brood year production have been in place since 1995 for Taku River Chinook salmon. This is a cooperative program between the ADF&G, DFO, and the Taku River Tlingit First Nation (TRTFN). Coded wire tags were placed in Chinook salmon smolt captured in the mainstem Taku River beginning in 1993 (McPherson et al. 2000) and estimates of escapement and age, sex, and length (ASL) composition parameters have been estimated annually since 1995 (McPherson et al. 1996).

In 2009, a Ricker spawner-recruit analysis was performed using the most recent 18 years of brood year production. This investigation suggested the spawning abundance that would produce maximum sustained yield (N_{MSY}) was 25,075 large Chinook salmon with a 90% confidence interval of 18,470–36,530 (McPherson et al. 2010). As a result, a biological escapement goal range of 19,000–36,000 fish with a point goal of 25,500 large spawning Chinook salmon was adopted prior to the 2009 season for management purposes. This goal was formally adopted by ADF&G, the Transboundary Panel (Panel), Transboundary Technical Committee (TTC) and the Chinook Technical Committee (CTC) of the PSC, and the Center for Science Advice - Pacific in 2010.

Management of this Chinook salmon stock is negotiated by the Panel, TTC, and CTC, all being subcommittees of the PSC and each consisting of members from the U.S. and Canada representing cooperating agencies. An international agreement, reached in June of 1999, called for development of an abundance-based management approach for Taku River Chinook salmon by 2005. Through a 2-year negotiation process, the U.S. and Canada came to bilateral agreement at a meeting in Portland, Oregon in February 2005 to implement directed commercial fisheries. Annexes to the PST expired in 2018; thus, Annex provisions were renegotiated and accepted in January 2019 and will be in place until renegotiations in 2028.

Migrating Chinook salmon are captured using fish wheels and a drift gillnet near Canyon Island in the lower Taku River (Figure 2). Healthy fish are marked and released for later recapture in assessment projects. Chinook salmon are recaptured in Canada in inriver assessment fisheries, commercial and/or Aboriginal fisheries, as well as on the spawning grounds. The Canadian commercial fishery consists of both Chinook salmon catches that occur incidentally during the annual sockeye salmon fishery and those that occur during years of directed Chinook salmon fishing.

For abundance-based management, inseason estimates of escapement in 1999–2004, 2007, 2008, and 2014–2016 were generated using a lethal assessment fishery for the recapture event. Inseason estimates for 2005, 2006, 2009 and 2011 were generated using the directed commercial fishery. Inseason estimates in 2010 and 2012 were generated using a combination of lethal assessment and directed commercial fisheries. No inseason estimates were generated in 2013 using a non-lethal assessment fishery because of insufficient recaptures. Due to very weak returns in 2016 and subsequent low preseason forecasts for 2017–2021, no inseason recapture events were conducted.

Postseason estimates of escapement for large Chinook salmon (1989, 1990, 1996, 1997, 1999–2010, 2014–2020) have been generated using mark–recapture methodology. Postseason estimates in 1995, were generated by expanding the estimated medium Chinook salmon escapement estimate to a large escapement based on the ratio of medium to large Chinook salmon observed across all spawning ground samples. This method was used because the numbers of large fish recaptured on the spawning grounds were few (1995: n=8), yielding inadequate sample sizes for mark–recapture estimation. The 1990–1994, 2011–2013, and 2021 estimates of large Chinook salmon were generated by expanding the peak aerial survey counts because insufficient recaptures (e.g., no mark–recapture experiment 1990–1994, 2011: n=9, 2012; n=6, 2013: n=15, 2021: n=10) of large fish were recovered on the spawning grounds.

In general, results from past lethal assessment fisheries have produced coarse, but reliable, run strength estimates by statistical week 21 (approximately mid-May). Per negotiations, the allowable catch is germane to large Chinook salmon and is calculated by subtracting the midpoint of the escapement goal range (27,500 fish), the Base Level Catches (U.S. = 3,500 fish, Canada = 1,500 fish), and harvest in the lethal assessment fishery (1,400 fish) from the preseason forecast. Any remaining fish are considered allowable catch to be allocated between the U.S. and Canada according to a detailed harvest sharing agreement (PSC 2020, p. 29-32, Chapter 1, Paragraph 3(b)(iii). Once available, inseason mark–recapture information generated by this project supersedes the preseason forecast.

Figure 2.–Adult event 1 capture locations on the lower Taku River, Southeast Alaska.

The preseason forecast of the terminal run size of large Chinook salmon is based on a sibling model that predicts age class run size using brood year performance from prior years. In other words, the run of the age-1.2 fish representing brood year *X* is used to estimate the run of age-1.3 fish the following year, also representing brood year *X*. The preseason forecast is used to plan and implement marine and freshwater salmon fisheries prior to having inseason estimates of run strength. The performance of both the preseason forecasts and inseason estimates from 2005 to 2021 are shown in Table 2.

Table 2.–Preseason forecasts, inseason, and final estimates of large Chinook salmon escapement for the Taku River and relative bias (RB) of forecast and inseason estimates compared to final estimate, 2005 to 2021.

Statistical		Final	Preseason forecast		Inseason		
Week	Date	estimate[a]	Point	RB[b]	Estimate	Projection	RB[b]
			YEAR 2005				
21	15 May - 21 May	65,334	99,610	52%	18,565	65,837	1%
22	22 May - 28 May	65,334	99,610	52%	30,175	68,935	6%
23	29 May - 4 June	65,334	99,610	52%	41,313	68,984	6%
24	5 June - 11 June	65,334	99,610	52%	48,414	64,196	2%
25	12 June - 18 June	65,334	99,610	52%	52,463	61,019	7%
			YEAR 2006				
21	21 May - 27 May	61,859	64,150	4%	25,071	67,759	10%
22	28 May - 3 June	61,859	64,150	4%	34,921	68,745	11%
23	4 June - 10 June	61,859	64,150	4%	41,711	69,474	12%
24	11 June - 17 June	61,859	64,150	4%	44,876	54,808	11%
25	18 June - 24 June	61,859	64,150	4%	44,694	55,604	10%
			YEAR 2007				
20	13 May - 19 May	18,650	38,720	108%	5,034	16,404	12%
21	20 May - 26 May	18,650	38,720	108%	7,638	16,428	12%
22	27 May - 2 June	18,650	38,720	108%	10,061	18,889	1%
23	3 June - 9 June	18,650	38,720	108%	12,367	18,400	1%
24	10 June - 16 June	18,650	38,720	108%	15,625	20,108	8%
			YEAR 2008				
20	11 May – 17 May	30,186	30,186	0%	4,047	22,613	25%
21	18 May - 24 May	30,186	30,186	0%	6,827	23,943	21%
22	25 May - 31 May	30,186	30,186	0%	13,255	23,760	21%
23	1 June - 7 June	30,186	30,186	0%	15,445	21,990	27%
24	8 June - 14 June	30,186	30,186	0%	21,467	26,585	12%
			YEAR 2009				
20	10 May – 16 May	35,106	50,164	43%	7,840	43,874	25%
21	17 May - 23 May	35,106	50,164	43%	14,520	47,519	35%
22	24 May - 30 May	35,106	50,164	43%	23,876	50,043	43%
23	31 May - 6 June	35,106	50,164	43%	25,625	39,994	14%
24	7 June - 13 June	35,106	50,164	43%	27,760	37,361	6%
			YEAR 2010				
20	9 May – 15 May	35,784	41,328	15%	18,565	65,837	84%
21	16 May - 22 May	35,784	41,328	15%	30,175	68,935	93%
22	23 May - 29 May	35,784	41,328	15%	41,313	68,984	93%
23	30 May - 5 June	35,784	41,328	15%	48,414	64,196	79%
24	6 June - 12 June	35,784	41,328	15%	52,463	61,019	71%

-continued-

Table 2.–Page 2 of 2.

Statistical		Final	Preseason forecast		Inseason		
week	Date	estimate[a]	Point	RB[b]	Estimate	Projection	RB[b]
			YEAR 2011				
20	8 May – 14 May	31,939	40,986	28%	25,071	67,759	112%
21	15 May - 21 May	31,939	40,986	28%	34,921	68,745	115%
22	22 May - 28 May	31,939	40,986	28%	41,711	69,474	118%
23	29 May - 4 June	31,939	40,986	28%	44,876	54,808	72%
24	5 June - 11 June	31,939	40,986	28%	44,694	55,604	74%
			YEAR 2012				
20	13 May - 19 May	23,908	48,036	101%	4,930	16,316	32%
21	20 May - 26 May	23,908	48,036	101%	5,919	13,273	44%
22	27 May - 2 June	23,908	48,036	101%	6,999	13,090	45%
23	3 June - 9 June	23,908	48,036	101%	8,231	12,655	47%
24	10 June - 16 June	23,908	48,036	101%	9,644	12,513	48%
			YEAR 2013[c]				
–	–	19,388	26,088	35%	–	–	–
			YEAR 2014[c]				
20	11 May - 17 May	27,324	26,781	2%	11,480	34,292	26%
21	18 May - 24 May	27,324	26,781	2%	30,339	25,034	8%
22	25 May - 31 May	27,324	26,781	2%	33,936	31,802	16%
23	1 June - 7 June	27,324	26,781	2%	12,182	19,600	28%
24	8 June - 14 June	27,324	26,781	2%	46,643	66,094	142%
			YEAR 2015[c]				
24	7 June - 13 June	32,058	26,137	18%	15,900	22,712	29%
25	14 June - 20 June	32,058	26,137	18%	24,167	30,420	5%
26	21 June - 27 June	32,058	26,137	18%	23,624	27,053	16%
27	June 28 - July 4	32,058	26,137	18%	25,319	27,550	14%
			YEAR 2016[c]				
23	29 May - 4 June	14,835	29,233	97%	6,933	11,588	22%
24	5 June - 11 June	14,835	29,233	97%	10,037	13,901	6%
25	12 June - 18 June	14,835	29,233	97%	12,040	14,720	1%
26	19 June - 25 June	14,835	29,233	97%	12,495	13,883	6%
27	26 June - 2 July	14,835	29,233	97%	15,528	16,213	9%
			YEAR 2017[c]				
–	–	8,643	13,300	54%	–	–	–
			YEAR 2018[c]				
–	–	7,328	4,700	37%	–	–	–
			YEAR 2019[c]				
–	–	11,797	9,050	23%	–	–	–
			YEAR 2020[c]				
–	–	16,010	12,400	23%	–	–	–
			YEAR 2021[c]				
–	–	11,722	10,300	12%	–	–	–

[a] Final estimates are germane to terminal run size (i.e., escapement plus harvest in the terminal area).

[b] RB is the relative bias and is the absolute difference between the forecast and the final estimate divided by the final estimate.

[c] No inseason estimates were generated in 2013 because of inadequate recaptures in event 2, and no inseason event 2 effort was conducted in 2017-2021 because of low abundance.

Adult marking efforts near Canyon Island using fish wheels and one drift gillnet boat below Canyon Island will serve as event 1 of the mark–recapture studies.

Inseason estimates of abundance will result if the run of large Chinook salmon is adequate to warrant prosecution of inriver fisheries (assessment, Canadian commercial, and Aboriginal) that serve as event 2 of the inseason mark–recapture estimate.

Postseason estimates of abundance will be based off event 2 samples gathered on the spawning grounds. Samples from any inriver fisheries listed above will also be included if marked fractions from the spawning grounds and the inriver fisheries are not significantly different. The spawning ground samples produce the least biased estimates of the marked fraction primarily because a multitude of gear types (rod and reel, carcass weir, live weir, spears, creel surveys, and dip nets) are used and the marked fish are thoroughly mixed temporally with the unmarked population. Sampling on the spawning grounds will take place from late July through mid-September. Ideally, the samples gathered in the lower river will not have significantly different marked fractions than those gathered on the spawning grounds and the samples will be combined as the increased event 2 sample size improves the precision of the final estimate.

PRIMARY OBJECTIVES

1. Estimate the number of Chinook salmon smolt (≥50 mm fork length (FL)) originating from above the U.S./Canada border such that the estimate is within 25% of the true value 95% of the time.
2. Estimate the spawning escapement of large Chinook salmon (≥660 mm METF) in the Taku River originating from above the U.S./Canada border, annually such that the estimate is within 25% of the true value 95% of the time.[1]
3. Estimate the spawning escapement of medium Chinook salmon (401–659 mm METF) in the Taku River originating from above the U.S./Canada border, annually such that the estimate is within 25% of the true value 95% of the time.
4. Estimate the age, sex, and length composition of the spawning escapement of medium and large Chinook salmon in the Taku River originating from above the U.S./Canada border, annually such that the proportion estimates are within 5% of the true proportions 95% of the time.
5. Estimate the mean length of Chinook salmon smolt (≥50 mm FL) originating from above the U.S./Canada border such that the estimated means are within 2 mm of the true mean 95% of the time.
6. Estimate the mean weight of Chinook salmon smolt originating from above the U.S./Canada border to the nearest 0.1g annually such that the estimated means are within 0.5 g of the true mean 95% of the time.
7. Estimate the proportion of large Chinook salmon (≥ 660 mm METF) tagged with spaghetti tags that did not migrate above the U.S./Canada border, such that the estimate is within 5 percentage points of the true value 95% of the time.

[1] This satisfies the PSC requirement of a 15% CV for spawning escapement of large Chinook salmon (≥660mm METF)

Secondary Objectives

1. Estimate the weekly passage of large Chinook salmon migrating above the U.S./Canada border as an aid to inseason management of fisheries in U.S. and Canadian waters using a mark–recapture study if data are available.
2. Estimate the marked fraction, marine harvest, marine exploitation, and marine survival of Chinook salmon originating from above the U.S./Canada border in the Taku River for each brood year via recovery of CWTs.
3. Estimate the spawning escapement of small (≤400 mm METF) Chinook salmon in the Taku River originating from above the U.S./Canada border, annually via a mark–recapture study if data are adequate.

METHODS

Study Design

Smolt Abundance (Objective 1)

All methods described below will be similar for each year of the study (2022–2024).

Separate mark–recapture experiments will be used to estimate the abundance of Chinook salmon smolt emigrating from the Taku River above Canyon Island (Figure 1) and adult Chinook salmon escapement above the U.S./Canada border. Smolt will be captured and tagged with CWTs and marked with adipose fin clips as event 1 of a two-event closed population mark–recapture experiment. To estimate smolt abundance, returning adult Chinook salmon will be inspected for missing adipose fins as event 2 during adult escapement projects described later in this document. Where possible, heads will be recovered for CWT extraction from sampled adults with missing adipose fins.

Smolt capture operations 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 3). Approximately 150 to 300 minnow traps baited with salmon roe will be fished daily in the mainstem of the lower Taku River beginning as soon as the river is open to boat and plane traffic, with a tentative startup date of mid-April each season. Three trap lines will be set between approximately 10 km above and below the 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. Beach seine nets will also be used along gravel bars on the Taku River mainstem by 3-person crews to capture Chinook salmon smolt to supplement minnow trap catches. When smolt outmigration accelerates in early May, seining effort will increase accordingly. All healthy **Chinook salmon smolt ≥50 mm FL** (smaller fish are more difficult to handle and have a higher probability of being fish that will remain in the river for another year) 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 that spool.

Adult Chinook salmon (2022–2024) caught at Canyon Island in fish wheels or drift gillnets, in Canadian inriver assessment and commercial gillnet fisheries, and on the spawning grounds will be inspected for missing adipose fins. 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 Chinook salmon captured in the fish wheels and gillnets will be used to estimate smolt abundance for each brood year. Adults carrying CWTs from smolt marked in one season (one brood year) will return to the Taku River as age-1.1 fish to age-1.5 fish after 1 to 5 years of rearing in the marine environment. Therefore, due to the life history of these fish, sampling over a 5-year period is necessary to obtain data from an entire brood year.

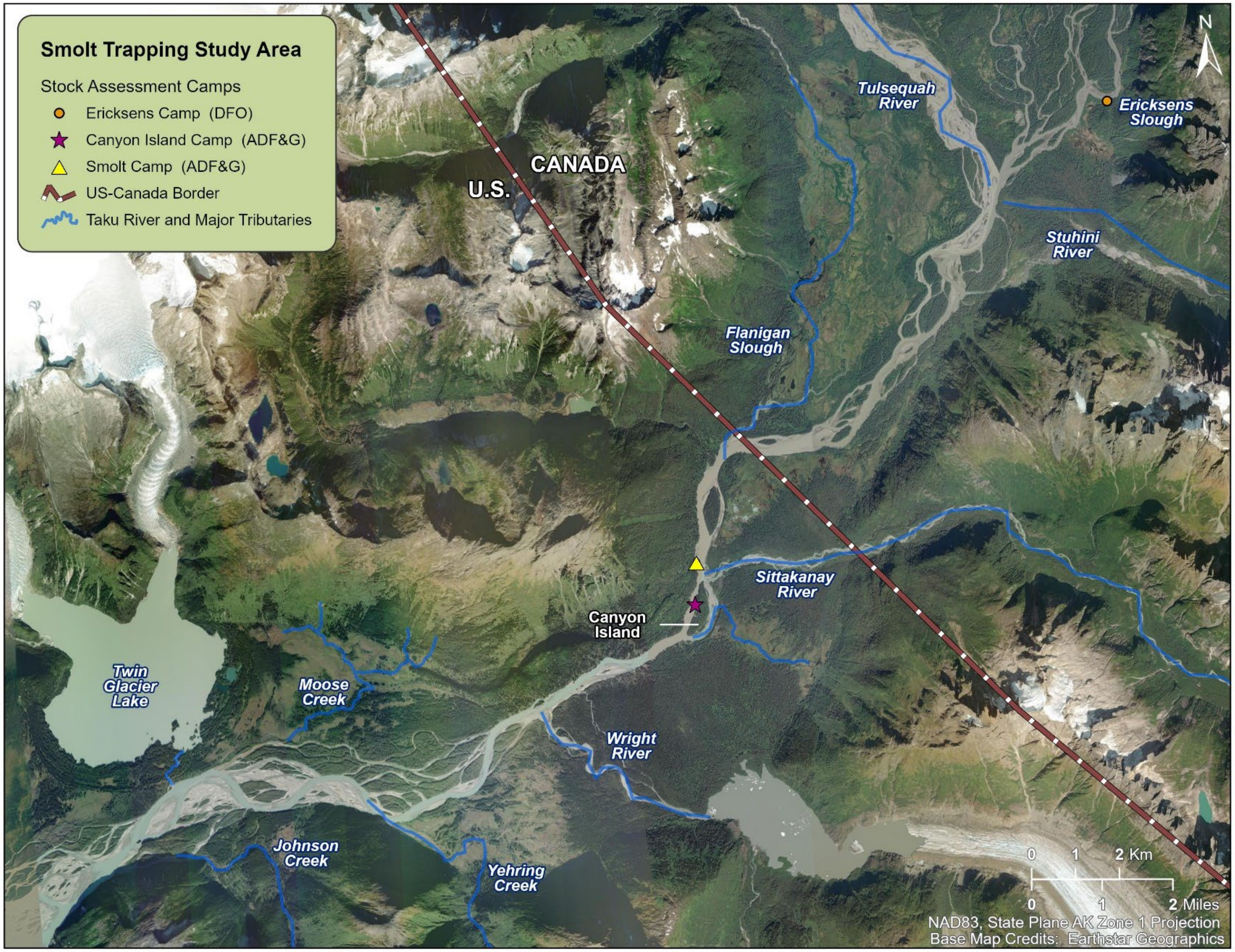

Figure 3.–Location of smolt trapping study area on Taku River, near Canyon Island, Southeast Alaska.

Sample Size-Smolt Abundance

Since 1993, on average about 2 million Chinook salmon smolt left the Taku River each year (Table 3) and marine survival averaged around 2.2%. Assuming similar numbers and survivals, about 44,000 adult Chinook salmon should return off any given brood year. If a total of 25,000 smolt are marked with adipose fin clips during the smolt tagging project (average since 1993), then about 1.3% of the total smolt production (25,000/2,000,000) would be marked, or 550 fish of the expected 44,000 adult Chinook salmon return. To meet the statistical criteria for objective 1, about 5,500 known-age adults will need to be sampled to obtain an expected 68 recaptures for each brood year (Robson and Regier 1964). Returning fish near Canyon Island, in the assessment and Canadian commercial fisheries, and on the spawning ground tributaries to the Taku River (Nahlin, Nakina, Dudidontu Rivers, and Kowatua, Tatsatua, and Tseta Creeks; Figure 1) will be inspected annually over a 5-year duration to collect mark and age data because Chinook salmon mature and return at multiple ages.

Table 3–CWTs released, number of fish inspected for adipose fin clips, smolt abundance estimates and associated coefficient of variation (CV) by brood year for Taku River Chinook salmon.

Brood year	CWTs released	Number inspected for ad clips	Smolt abundance	CV of smolt abundance estimate
1991	10,015	10,267	2,098,862	14%
1992	9,858	3,792	1,968,167	22%
1993	11,121	699	1,112,199	35%
1994	21,588	2,058	1,433,926	18%
1995	37,869	3,279	1,242,135	10%
1996	32,723	5,740	1,917,024	10%
1997	19,531	3,840	1,923,651	16%
1998	17,298	4,486	1,194,260	12%
1999	41,836	7,853	1,738,624	7%
2000	37,776	5,566	1,984,004	10%
2001	27,995	2,494	2,116,807	17%
2002	23,078	2,026	1,559,721	18%
2003	27,335	3,968	1,722,380	12%
2004	36,706	3,769	4,771,709	18%
2005	9,843	4,536	2,030,124	21%
2006	24,022	2,687	3,228,421	22%
2007	16,063	2,428	1,625,666	20%
2008	30,804	2,042	2,330,906	19%
2009	17,698	2,964	1,499,354	17%
2010	18,273	4,168	1,904,823	16%
2011	29,356	3,032	1,413,468	12%
2012	24,146	2,296	1,320,507	15%
2013	22,132	994	1,468,155	25%
2014	32,103	2,687	2,615,016	17%
2015	50,153	2,294	1,798,490	12%

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 to or removal from 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. Negligible numbers of Chinook salmon have been observed spawning in U.S. sections of the Taku River drainage and it is believed that marking near Canyon Island encompasses the vast majority of Chinook salmon production from the Taku River drainage.

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 because of the length of time between sampling events. 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. All tagged smolt will be held to assess overnight mortality.

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 Chinook salmon are very rare (Magnus et al. 2006). All adipose fin clipped fish will be used for estimating smolt abundance regardless of the presence 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 most Chinook salmon sampled are caught in beach seines which are not size-selective. Fish are tagged throughout the emigration.

Regarding condition S2 for the smolt to adult mark–recapture, due to the extended time between the marking and recovery events and behavior of Chinook 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 Chinook 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. Surveys of spawning locations are widespread, however, not all Chinook salmon will have an equal probability of being inspected for marks during event 2 sampling, as not every spawning location will be sampled. Therefore, some stocks will only be sampled by fish wheels and gillnets in the lower river.

For Chinook salmon, condition S1 and condition S2 are generally met.

Spawning Escapement, Age, Sex, and Length Composition, and Dropout Rate (Objective 2, 3, 4, 7, Secondary Objective 1, 3)

Simultaneous mark–recapture experiments will be used to annually estimate the spawning escapements of large and medium Chinook salmon in the Taku River in 2022 to 2024. Immigrating salmon caught using fish wheels and drift gillnets at or near Canyon Island will be tagged and marked as event 1 of the two sampling events. Event 2 will use samples from any inriver fisheries, (assessment, Canadian commercial, and Aboriginal) if abundance warrants their prosecution. These potential fisheries are all located in the lower river above the U.S. Canada border., Additional Event 2 samples will be collected from spawning grounds at Nahlin, Nakina, and Dudidontu Rivers, and Kowatua, Tatsatua, and Tseta Creeks.

Event 1 – Canyon Island Fish Wheels and Drift Gillnet

All event 1 capture locations with reference to Canyon Island and the international boundary are depicted in Figure 2. Personnel from ADF&G and TRTFN will capture Chinook salmon in two fish wheels operated at Canyon Island, one fish wheel on each riverbank. Beginning approximately May 10, or as soon as water levels are high enough to turn the fish wheels, they will operate about 18 continuous hours each day throughout the season. A few Chinook salmon may enter the river prior to project startup but the number is assumed to be negligible.

Generally, on the Taku River, over 95% of the returning Chinook salmon have passed Canyon Island by the first week of July. Fish wheels will be operated throughout the summer and into fall concentrating on capturing sockeye salmon *O. nerka* and coho salmon *O. kisutch*, and Chinook salmon will be sampled whenever captured.

Each fish wheel consists of two aluminum pontoons for floatation, a solid steel axle with connecting struts for up to 4 baskets, two aluminum basket frames covered with seine webbing, and aluminum live boxes. Design of the aluminum basket enables fish wheels to spin over a wide range of water levels or current velocities.

Personnel will also capture Chinook salmon in a drift gillnet project below the U.S.-Canada border near the Wright River confluence with the Taku River. Fishing operations will commence in late April or early May each spring and terminate in late June or early July. One drift gillnet will be used, 36.6 m (approximately120 ft) long and 5.5 m (approximately 18 ft) deep. The drift net mesh will be 18.4 cm, a standard mesh size used for marking Chinook salmon in the nearby Stikine, Unuk, and Chilkat rivers mark–recapture studies. This mesh size tends to catch primarily large and medium Chinook salmon with the occasional small Chinook salmon.

The drift gillnet crew will fish 4 wet hours per day (soak time for each drift will be summed to obtain 4 wet net hours) 7 days per week. Crews will carefully record fishing and processing time. The gillnet will be monitored continuously. When capture of a Chinook salmon is indicated (tug of the net, bobbing cork line), fish will be carefully removed from the net, cutting the net if needed, and placed into a tote partially filled with fresh river water.

Since 1997, the primary mark has been a solid-core spaghetti tag (Johnson et al. 1992), which consists of a 6.4 cm (2 1/2 in) piece of standard tubing shrunk onto 38 cm (15 in) piece of 80 lb monofilament, all laminated with clear plastic tubing. Large and small sized fish will be tagged with blue spaghetti tags while medium sized fish will be tagged with yellow spaghetti tags. Lettering on the tag will read "U.S.-CANADA-PH 907-465-4270 COLLECT" and "SALMON TAG TK?????," where ????? is a unique number between 1,000 to 20,000. These tags will be sewn through the dorsal musculature just posterior to the dorsal fin and the two ends crimped together with an aluminum Jinkai J sleeve.

The 2 secondary marks are as follows:

> Canyon Island (fish wheels) - A double left upper operculum punch (DLUOP) will be given to large and medium sized Chinook salmon, and a clip of the left axillary appendage (LAA) to all fish, located at the base of the left pelvic fin. Small fish will be given a LAA but not operculum punches.
>
> Drift gillnet - A single left upper operculum punch (LUOP), and a clip of the left axillary appendage (LAA), located at the base of the left pelvic fin

These two marks will ensure that marked fish are recognized when encountered during event 2 sampling (i.e., assessment fishery, commercial fishery, Aboriginal fishery, or spawning ground sampling).

A subset of marked large Chinook salmon captured in the drift gillnet will also be tagged with a radio transmitter. Each radiotagged fish will receive the ATS™ F1845B radio tag. The tags will be 52-mm long, 19-mm in diameter, 26-g in mass, have a 30-cm external whip antenna, a terminal battery life of 180 d, and operate on two frequencies within the 150.000 to 152.999 MHz range. Two frequencies will have 100 pulse codes each resulting in 200 uniquely identifiable radio tags. 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 sockeye salmon *O. nerka* and coho salmon *O. kisutch* radio telemetry projects being conducted on the Taku River in 2022-2024. 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)

Event 2 – Inriver Assessment and Canadian Commercial Fishery

The inriver assessment and Canadian commercial fisheries operate primarily within the first 10 km of river above the U.S.-Canada border. Catches in any inriver assessment, Canadian commercial, and Aboriginal fisheries upriver of Canyon Island will be used as inseason event 2 and as part of the postseason event 2. For lethal fisheries, Chinook salmon will be tallied separately by size on fish tickets (sales receipts). DFO personnel will sample any commercial Chinook salmon harvest weekly to collect tags recovered in the fishery, independently estimate marked fractions, inspect for missing adipose fins, and collect age and size data. Any tags recovered downriver of the border may be reported to the ADF&G staff stationed at Canyon Island or to the ADF&G, Division of Commercial Fisheries phone number printed on the tag.

Any inriver assessment fishery catch will have a sampling target of 100% for length, primary tags, secondary marks, missing adipose fins, and age. If inseason abundance estimates warrant a directed Chinook salmon commercial fishery, at least 40% of the harvest will be sampled for length, primary tags, secondary marks, missing adipose fins, and age. Age samples will comprise 5 scales per fish; presence or absence of secondary marks will be noted; length measurements will be cleithral arch to fork (CAF) because the bulk of the harvest from the commercial fishery will be beheaded. When possible, METF and post orbit-to-hypural plate (POH) measurements will also be taken to permit conversion of CAF to METF and POH.

Event 2 – Spawning Grounds Sampling

Sampling will occur at several locations on Taku River spawning grounds as part of event 2 sampling (Figure 1). Sampling will concentrate on post spawn and moribund fish as opposed to carcasses because marks have proven to be more easily recognized on living fish. Chinook salmon sampling in the Nahlin and Dudidontu rivers, and Tseta Creek will be led by ADF&G with participation from DFO and TRTFN; DFO and TRTFN will lead sampling on the Kowatua and Tatsatua Creeks; and TRTFN will operate a carcass weir on the Nakina River. The Nakina River is the larger producer of Chinook salmon in the drainage, and in some years, it can contain over half the total Taku River spawning abundance (Appendix A1). Experience has shown that using a combination of gear types during spawning ground sampling produces the least biased estimates (non-size selective) of abundance, age, sex, and size composition (McPherson et al. 1997). Additional sampling may be conducted depending on, 1) numbers of Chinook salmon marked, 2) number of Chinook salmon seen during helicopter surveys of escapement, and 3) changes in migratory timing from past years. This sampling strategy should cover the most abundant subpopulations within the drainage as well as early, middle, and late run components passing Canyon Island (see Alaska Department of Fisheries 1951 and Pahlke and Bernard 1996; John Eiler, fisheries biologist, Alaska Fisheries Science Center, personal communication).

Like sampling downriver, all Chinook salmon sampled on the spawning grounds will be inspected for marks. Presence or absence of primary and secondary marks will be noted. All fish will be sampled for ASL data and for adipose fin clips to determine the marked rate of CWTs by brood year. All live sampled fish will be marked with a left lower operculum punch (LLOP) and possibly biodegradable orange flagging tape through the dorsal musculature before release to identify them as having been previously sampled. All sampled carcasses will be marked by multiple slashes on the left side of the carcass.

Sample Size-Spawning Escapement

Annual sample size goals in 2022 to 2024 for estimating large Chinook salmon spawning escapement are to mark 600 fish during event 1 (= n_1 200 fish wheels + 400 drift gillnet) and inspect 1,800 fish upriver during event 2 (= n_2 total). Since 2012, large Chinook salmon spawning abundance has averaged 14,500 fish and the number of large fish captured in event 1 has averaged 600 fish. To ensure adequate sample sizes, an average escapement of 14,500 large Chinook will be assumed for calculating sample sizes. Recent telemetry studies suggest that, on average, 20% of the large fish encountered during event 1 dropout. Using these data and the methods of Robson and Regier (1964), approximately 1,800 large Chinook will need to be sampled in event 2 to achieve the statistical criteria.

The sample size goals in 2022 to 2024 for medium Chinook salmon are to mark 300 fish during event 1 (= n_1 Canyon Island + drift gillnet) and inspect 1,600 fish upriver during event 2 (= n_2 total). Escapement of medium Chinook salmon since 2012 have ranged from 3,000 to 16,000 and has averaged 7,300 fish and the number of medium fish captured in event 1 has averaged 300 fish. To ensure adequate sample sizes, an average escapement of 7,300 medium Chinook will be assumed for calculating sample sizes. Radiotelemetry data for medium fish is not available, and so the large fish dropout rate of 20% will be assumed for planning. Using these data and the methods of Robson and Regier (1964), approximately 1,600 medium Chinook will need to be sampled in event 2 to achieve the statistical criteria.

These projections of expected precision for estimates of spawning escapement of both large and medium Chinook salmon assume a simple Petersen-type model will be appropriate for estimating abundance. If fish captured in event 1 dropout, evidenced by recent telemetry studies, then the number of fish marked during in event 1 will be lower than anticipated and the precision criteria not met. We assume a 20% dropout rate for both objectives to mitigate the issue. If some portions of event 2 data must be censored to eliminate potential bias, the precision criteria stated in objectives 2 and 3 may not be met. Also, if the methods of Darroch (1961) must be used to estimate abundance due to temporal and/or geographic capture heterogeneity during both event 1 and event 2 sampling, it is unlikely that the precision criteria will be met.

Model Assumptions-Spawning Escapement

For the estimate of abundance from this mark–recapture experiment 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 include:

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

There should be no significant recruitment between sampling events. Event 1 sampling (marking) will begin prior to any significant passage of fish past the tagging sites and will continue through the run until passage has dropped to near zero. The population of Chinook salmon passing by Canyon Island is closed to significant immigration or emigration because of the fidelity of salmon to their natal stream. Natural mortality may occur if deaths constitute a simple random sample of the marked and unmarked population.

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

There is no explicit test for this assumption because the behavior of unhandled fish cannot be observed. There is some handling-induced behavior that, with no adjustment, may bias estimated abundance. In response to being handled, marked Chinook salmon tend to delay their upriver migration upon release, even temporarily heading downriver into marine waters before resuming their upriver migration (Bernard et al. 1999). In the past, a few fish released at Canyon Island have been caught in late June by the marine commercial sockeye salmon fishery (Pahlke and Bernard 1996; McPherson et al. 1997). Although only a few instances have been documented, this phenomenon may be pronounced with implementation of directed US terminal Chinook salmon fisheries in May and early June. The adjustment for this phenomenon is to censor any marked fish caught in marine fisheries. To that end, the Divisions of Commercial Fisheries and Sport Fish (DCF and DSF) will sample harvest in the commercial gillnet fishery and the sport fishery near Juneau in D111 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 D111 terminal area will be inspected, consistent with the bilateral agreement by the PSC TTC 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).

Radio telemetry studies have been conducted each year on Taku River Chinook salmon since 2015 (Richards et al. 2018). One of the primary objectives of these studies is to quantify the proportion of marked fish that progress upstream and are available to be sampled in event 2. It has been determined through these studies that marked fish sulk downstream of the marking site for varying periods of time and approximately 20% of the marked fish do not progress upriver after handling. In addition, the 2015 and 2016 studies investigated if this sulking behavior was associated with the fishing gear used during event 1. No gear effect was detected. Additional telemetry studies are planned and the results from these and past studies will be used to account for and reduce the bias related to the handling mortality of fish sampled in event 1.

There should be no trap-induced behavior because different sampling gears are used in different sampling events. 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 marked.

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

The use of multiple marks will ensure that all marked fish are recognizable during event 2 sampling. Fish may shed tags during transit but will be identified as marked fish by an operculum punch (DLUOP or LUOP) and a clipped axillary appendage (LAA). Experience has shown a low rate of primary tag loss (spaghetti) and some fading or healing over of the opercular punch can occur. However, there has been no recorded instance on any recoveries of an LAA being unrecognizable as a mark. Marking fish with an operculum punch (LLOP) and biodegradable flagging tape in some cases, and slashing carcasses will prevent double sampling in event 2. There may be some failure to recognize marked fish caught in any Canadian commercial fisheries and the rate of voluntary return of tags may not be 100%, as some fishermen might not recognize secondary marks if the primary mark (tag) is lost as the fish struggles in the net. DFO personnel will inspect a portion of any harvest to determine an error rate for potentially missed marks. Marked fractions from this fishery will be compared with those from spawning grounds and any assessment fishery, as described below, and data from inriver fisheries may be included or censored depending upon test results.

Assumption IV: one of the following three conditions will be met

A1) All Chinook salmon will have the same probability of being caught in event 1;

A2) All Chinook salmon will have the same probability of being captured in event 2; or

A3) 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 event 1 tagging and event 2 recapture are so close in proximity (Condition A3). Also, all Chinook salmon will not have an equal probability of being inspected for marks during event 2 spawning grounds sampling as not every spawning location will be sampled (Condition A2). Under these circumstances it is necessary that event 1 sampling be conducted to ensure that Condition A1 will be satisfied.

Fish wheels and a drift gillnet near Canyon Island will be operated systematically 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 as has been the case in past years (Pahlke and Bernard 1996; McPherson et al. 1996, 1997). Experience has shown that the marked fraction generally does not differ significantly among tributaries under the sampling protocol used at Canyon Island even though populations using those tributaries had different migratory timing. 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 the final spawning destination of different stocks of Chinook salmon within the Taku River system is independent of the probability of capture 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 E1. If different probabilities are indicated, abundance estimates will be stratified by category.

To further evaluate the three conditions of this assumption, contingency table (Chi squared) analyses recommended by Seber (1982) and described in Appendix E2 will be used to detect significant temporal or geographic violations of assumptions of equal probability of capture. Initial tests for violations of equal probability of capture throughout event 1 and event 2 will be based on event 2 data collected on the spawning grounds. After the initial tests are performed, secondary tests will include data from any inriver assessment and commercial fisheries (Appendix E2). If initial and secondary tests indicate no evidence of capture heterogeneity during event 1, all event 2 data will be used to estimate abundance. If initial tests detect no evidence of capture heterogeneity during event 1, but secondary tests detect significant differences in marked to unmarked ratios between the spawning grounds and one or both inriver fisheries, we may conclude sampling bias occurred during any inriver fisheries due to lack of detection of marks in the commercial fishery and/or differential probability of capture between marked and unmarked fish in one or both fisheries. Remedial measures for these sources of bias may include complete censoring of data from a biased source and, where applicable, reducing the effective number of marked fish in the experiment by subtracting marks removed during biased sampling, like what is described for marine sport and commercial fisheries.

Sample Size-Age, Sex, and Length Composition

Based on procedures in Thompson (1987), 509 samples need to be collected in order to meet the statistical criteria for objective 4. Because up to 20% of adult scale samples from Chinook salmon have in the past proven unreadable, 636 (509/0.80) fish will need to be sampled to meet criteria for each age group of fish. These sample sizes will also meet the objective 4 statistical criteria for estimating sex composition, as 384 samples (assuming no data loss) are necessary. These sample sizes will also meet the objective 4 statistical criteria for estimating length composition, as 509 samples are necessary (Thompson 2002). The number of samples collected during the mark–recapture experiment should meet or exceed sample size requirements for estimating age, sex, and length composition. Information on age composition obtained near Canyon Island and on the spawning grounds will be tabulated separately. History has shown that the pooled spawning grounds sample (within medium and large size groups) produces unbiased estimates of age and length composition for the spawning population (McPherson et al. 1997).

Sample Size–Dropout

For sample size calculations, it is assumed 1) there is a 20% dropout rate, 2) no tag loss or tag failure will occur, and 3) 400 fish will be marked with spaghetti tags during event 1 drift gillnet sampling. Large Chinook salmon (≥660 mm METF) radiotagged in the Taku River between 2015 and 2021 using similar methods dropped out of the mark–recapture experiment at a rate of 12% to 23%. It is believed that tag failure is small. Eiler (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. The 2016 to 2021 average number of large Chinook salmon that were spaghetti tagged in the mark–recapture experiment using a drift gillnet was approximately 400. Using these data and the methods in Thompson (2002), the sample size required to estimate the proportion of dropouts within 5 percentage points of the true value 95% of the time is 153. A total of 200 radio tags are planned to be deployed each season, so we expect to meet or exceed the sample size requirement.

Radio tags will be deployed systematically on every other healthy large Chinook salmon captured and marked at the drift gillnet site. If Chinook salmon run timing is proportional to historical catches near Canyon Island, then the expected number of tags that will be deployed can be found in Table 4. If capture rates are higher or lower than anticipated, then the systematic rate of every other salmon radio tagged will be adjusted accordingly to ensure that enough radio tags will be available to apply throughout the run.

Table 4.–Proposed daily radio tagging rate of Chinook salmon on the lower Taku River based on long-term average run timing.

Date	Crew	Radio tags per day	Cumulative
28-Apr	Wright Drift	1	1
29-Apr	Wright Drift	1	2
30-Apr	Wright Drift	1	2
1-May	Wright Drift	1	3
2-May	Wright Drift	1	4
3-May	Wright Drift	1	5
4-May	Wright Drift	1	6
5-May	Wright Drift	2	8
6-May	Wright Drift	2	11
7-May	Wright Drift	2	12
8-May	Wright Drift	2	14
9-May	Wright Drift	2	16
10-May	Wright Drift	2	18
11-May	Wright Drift	2	19
12-May	Wright Drift	2	22
13-May	Wright Drift	4	25
14-May	Wright Drift	2	27
15-May	Wright Drift	3	30
16-May	Wright Drift	3	33
17-May	Wright Drift	4	36
18-May	Wright Drift	4	40
19-May	Wright Drift	4	44
20-May	Wright Drift	5	49
21-May	Wright Drift	5	53
22-May	Wright Drift	3	56
23-May	Wright Drift	4	60
24-May	Wright Drift	4	64
25-May	Wright Drift	4	68
26-May	Wright Drift	4	72
27-May	Wright Drift	5	77
28-May	Wright Drift	4	81
29-May	Wright Drift	6	86
30-May	Wright Drift	4	91
31-May	Wright Drift	4	95

-continued-

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Date	Crew	Radio tags per day	Cumulative
1-Jun	Wright Drift	4	98
2-Jun	Wright Drift	3	101
3-Jun	Wright Drift	3	104
4-Jun	Wright Drift	4	108
5-Jun	Wright Drift	5	113
6-Jun	Wright Drift	4	116
7-Jun	Wright Drift	4	120
8-Jun	Wright Drift	6	126
9-Jun	Wright Drift	5	131
10-Jun	Wright Drift	5	136
11-Jun	Wright Drift	5	141
12-Jun	Wright Drift	5	146
13-Jun	Wright Drift	3	149
14-Jun	Wright Drift	6	155
15-Jun	Wright Drift	4	158
16-Jun	Wright Drift	3	161
17-Jun	Wright Drift	3	164
18-Jun	Wright Drift	4	168
19-Jun	Wright Drift	4	172
20-Jun	Wright Drift	4	175
21-Jun	Wright Drift	3	178
22-Jun	Wright Drift	3	181
23-Jun	Wright Drift	3	184
24-Jun	Wright Drift	3	187
25-Jun	Wright Drift	2	190
26-Jun	Wright Drift	3	192
27-Jun	Wright Drift	2	195
28-Jun	Wright Drift	2	197
29-Jun	Wright Drift	2	199
30-Jun	Wright Drift	2	200

Mean Length and Weight of Smolt (Objective 5, 6)

A systematically drawn sample of 250 Chinook salmon smolt $\geq$50 mm FL will be collected each year of the study.

Sample Size-Mean Length and Weight of Smolt

A sample of 250 will exceed the required sample size of 78 ($[(1.96)(9)/(2)]^2$) needed to meet the statistical criteria in objective 5 (Thompson 2002, p. 36). A sample of 250 will also exceed the required sample size of 246 ($[(1.96)(4)/(.5)]^2$) needed to meet the statistical criteria in objective 6. These calculations assume a standard deviation of 9 mm for length and 4 g for weight, as seen in past studies. Based on an expected catch of 26,000 Chinook salmon smolt, every 104th Chinook salmon smolt should be measured. However, to ensure meeting our sampling target in the event less than 26,000 fish are captured, and for ease of tracking, every 100^{th} Chinook salmon smolt captured will be measured for length and weight.

Mark Fraction, Marine Harvest, Inriver Return, Marine Exploitation, and Marine Survival (Secondary Objective 2)

Application of CWTs allow for the estimation of marine harvest, marine exploitation, and marine survival. Chinook salmon from the Taku River are mostly (i.e., 95% to 100%) age-1.X fish, spending 1 year as fry in fresh water and emigrating as smolt in the following spring (McPherson et al. 2000; Olsen 1992). Thus, tagged smolt from a given sampling year are essentially from the same brood year (e.g., Chinook salmon smolt tagged in 2022 will be from the 2020 brood year). The proportion of tagged smolt returning as adults will be used to estimate the mark fraction. The mark fraction and the number of Taku-origin CWT recoveries in marine fisheries will be used to estimate marine harvest. Marine harvest will be combined with estimates of escapement and inriver return to estimate marine exploitation and marine survival. Total harvest (marine and freshwater) will be estimated by adding marine harvest to inriver harvests.

DATA COLLECTION

Smolt Tagging

All healthy Chinook salmon smolt ≥50 mm FL captured near Canyon Island without marks will be tranquilized with a buffered MS-222 solution, tagged with a CWT (Figure 1) 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.

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 smolt tagging 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. 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 pen, then net and check 100 fish from each holding pen for tag retention and record this information on the **CWT DAILY TAGGING FORM**. 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. 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**. Test all recaptures for tag retention. Record results of tag retention on the **CWT DAILY TAGGING FORM**.
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. Measure and record FL to nearest whole millimeter and weight to nearest 0.1 g for every 100^{th} Chinook salmon smolt captured.

ADF&G CWT ONLINE RELEASE maintained by the CF Tag Lab will be filled out 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. If one roll of coded wire is depleted during a tagging session, a new **CWT DAILY TAGGING FORM** will be filled out, and a piece of wire from the new spool will be attached to the **CODED WIRE VERIFICATION FORM**.

Spawning Escapement and Age, Sex, and Length Composition

Canyon Island Fishwheels

Effort and catch during fish wheel operations will be recorded at Canyon Island on forms used by ADF&G (Appendix C). River height to nearest inch and temperature to nearest 1°C (both collected at about 0900 hrs each day), any shutdown time, and other comments will be recorded on the forms. Water level will be measured at a staff gauge permanently affixed to a rock face adjacent to Canyon Island.

Data collected from each Chinook salmon captured at Canyon Island will be recorded on the **CANYON ISLAND ASL FORM** (Appendix C2) and includes the date and time caught, fish number, sex, length in mm (METF), size class, solid-core spaghetti tag number, secondary marks applied (DLUOP and LAA), and any pertinent comments (state of maturation [bright, dark red, etc.], condition, wounds, previously marked [spaghetti tag number and secondary marks], etc.). The first Chinook salmon captured in the fish wheels and tagged will be given a "5001" for fish number and numbering will continue sequentially throughout the remainder of the season. This means each Chinook salmon caught and tagged will have a unique fish number. Every healthy Chinook salmon of any size will be tagged and marked (DLUOP, LAA) prior to release. Fish number is arbitrarily assigned to keep track of total numbers tagged and released and is not to be confused with the solid-core spaghetti tag number. Large and small sized fish will be tagged with a blue spaghetti tag and medium fish will be tagged with a yellow spaghetti tag. At the fish wheels, the presence or absence of the adipose fin will be determined first, after which the sex will be identified, and a length measurement (METF for all sizes of fish) will be collected for each fish carefully. **Scales will be taken from every fish**; **5** scales will be collected per fish. Scales will be taken from the left side of the fish from the preferred area (2–3 rows up from the lateral line and taken 25 mm (1 in) apart, one from 4–5 rows up 12 mm (1/2 in) from one of the lower three). Scales will be affixed anterior side up on gum cards and labeled completely. Scale samples will remain in camp until mid-July; the total scale sample will then be sent to Juneau in an envelope or box clearly labeled "Attn: Jeff Williams, ADF&G-Commercial Fisheries, 465-8251" and the ADF&G office will be notified accordingly. Electronic age-sex-length forms will be sent in daily via email.

Any fish caught at Canyon Island missing an adipose fin will be sacrificed, sampled for ASL data, and decapitated. Pre-labeled totes and coolers will be provided for this activity. Scales from sacrificed fish will be put on a separate series of gum cards and returned to Jeff Williams at the end of the season. A cinch strap will be affixed to each removed head. The number on the cinch strap along with data on length and sex will be recorded on the **CANYON ISLAND ASL FORM**, or **DRIFT GILLNET ASL FORM** (Appendix C2, C3). A **CODED WIRE TAG SAMPLING FORM** (Appendix C4) will be filled out each day that at least one Chinook salmon is captured regardless of whether any captured fish is missing its adipose fin. All accumulated **CODED WIRE TAG SAMPLING FORMS** and all accumulated heads will be sent to Juneau weekly. Each shipment should be clearly labeled "Attn: Jeff Williams, ADF&G-Commercial Fisheries Fish, 465-8251".

Drift Gillnet

Immigrating Chinook salmon caught in the drift gillnet will be inspected for secondary marks and the presence of an adipose fin. All healthy unmarked fish will be tagged with a uniquely numbered spaghetti tag and given 2 secondary marks, a clip of the left axillary appendage (LAA) and a left upper operculum punch (LUOP). Large and small sized fish will be tagged with a blue spaghetti tags and medium fish will be tagged with a yellow spaghetti tag. A subset of large Chinook will also be fitted with a radio tag and tagged in proportion to the run (Table 4). The first Chinook salmon captured in the drift boat (named "D1") and tagged will be given a "0001" for fish number and numbering will continue sequentially throughout the remainder of the season. This means each Chinook salmon caught and tagged will have a unique fish number. Every healthy Chinook salmon of any size will be tagged and marked (LUOP, LAA) prior to release. These fish will then be included as part of the event 1 release group in the two-event mark–recapture study. Those fish captured already possessing spaghetti tags or secondary marks will have the spaghetti tag number recorded and will be released immediately. Fish captured already possessing only secondary marks and missing the primary tag will be noted as such and retagged with a new spaghetti tag and released immediately. Any fish missing their adipose fin will be sacrificed for coded wire tag sampling purposes.

Canadian Fisheries

If abundance permits, the inriver assessment fishery is will commence a short distance upriver from the U.S.-Canada border in early May, directed Canadian commercial Chinook salmon fisheries may also commence pending abundance., The Canadian commercial sockeye salmon fishery typically begins on the third Sunday in June pending Chinook salmon conservation concerns. If incidental catch of Chinook salmon is permitted to be retained in this fishery, (not permitted 2018–2021) harvested fish will be fully sampled. A small (< 200 fish) intermittent Aboriginal fishery in the same location may also be sampled opportunistically; this fishery has been foregone in recent years for Chinook salmon conservation concerns. All Chinook salmon harvested will be processed according to protocols established by DFO. Each fish will be measured, sexed by inspection of external characteristics (if not beheaded), and the presence or absence of a primary mark, secondary marks, and adipose fin will be noted. Note that it is a requirement of license for adipose clipped fish to be landed head on in Canada. As well, 5 scales will be taken for age determination. Data from any commercial or assessment fishery will be recorded on **COMMERCIAL FISHERY SAMPLE FORM** (Appendix C5). Data from any Aboriginal fisheries will be recorded on the **CANADIAN ABORIGINAL FISHERY SAMPLE FORM** (Appendix C6). Fish sampled with missing adipose fins will be clearly identified, and any heads recovered from these fish will be processed following DFO CWT protocols in Canada. .

Spawning Grounds

All Chinook salmon (regardless of size) encountered on select spawning grounds will be sampled. Sampling will concentrate on moribund fish as opposed to carcasses because marks have proven to be more easily recognized on living fish. Note that the first time a Chinook salmon is examined on the spawning grounds a 6 mm (1/4 in) hole will be punched on the *lower* left operculum (LLOP), and biodegradable flagging tape may be applied through the dorsal musculature. Each fish will be inspected to detect missing adipose fins, the primary mark (individually numbered tag), the three secondary marks, and a mark indicating that the fish had been previously inspected (i.e., LUOP, DLUOP or LLOP). It is crucial that during the spawning grounds sampling we obtain an accurate count of the total number of fish inspected by size and age category, and of those, accurately detect any fish that were marked during event 1 without double sampling.

The following steps will be used for sampling each fish encountered. If a fish has an LLOP mark or slashes, it will be ignored; if a fish does not have an LLOP mark, then observers should look for any of the following marks: 1) LUOP; 2) DLUOP; 3) solid-core spaghetti tag; 4) LAA; or 5) radio tag. The presence of any of these four marks or tags indicates a valid recovery. If a spaghetti tag is present, the number will be recorded; the presence/absence of either secondary mark will also be recorded. After these steps have been completed, the fish should be inspected again for the presence or absence of an adipose fin clip. All fish will be sampled for ASL information and each fish in turn will be given an LLOP, and in addition, slashes if a carcass, before moving on to the next fish. If a fish is missing its adipose fin, it will be sampled for ASL information, decapitated, and the head will be retained and have a numbered cinch strap affixed to it; the cinch strap number will be recorded, the body will be slashed, and the fish will once more be checked for the presence or absence of primary and secondary marks. If questions arise concerning whether an adipose fin is missing, the fish will be treated as if it was adipose fin clipped (missing adipose fin), but a "2" will be recorded in the clip field. If a fish has no marks at all, it will be sampled for ASL information and given a LLOP mark. All data will be recorded on the **SPAWNING GROUNDS SAMPLE FORM** (Appendix C7). Note that it is imperative to look for the presence or absence of the LUOP, DLUOP, or LAA if the spaghetti tag has fallen off.

On the **SPAWNING GROUNDS SAMPLE FORM** (Appendix C7), the date, fish number (1–10), sex, length (METF), and number from a solid-core spaghetti tag number (if present) and the presence or absence of an adipose fin will be recorded for each fish that has not been previously sampled. Note that for length, 200 matched METF and POH lengths will be collected at the Nakina River, elsewhere METF will be the standard length for all fish; each fish should be measured carefully. The book number or gum card number will be recorded in the appropriate column. Most importantly, the presence or absence of the LUOP, DLUOP, and LAA needs to be documented. If confirming the presence or absence of these marks is not possible, record a question mark. If a fish has a scar behind the dorsal fin but no solid-core spaghetti tag, record "scar" in the comments column.

With one exception, all heads with cinch straps will be dissected off-site at either U.S. or Canadian facilities. Heads collected from the Dudidontu and Nahlin Rivers, and Tseta Creek will be sent to

Jeff Williams in Juneau, Alaska. Heads from all other sampling areas will be sent to Aaron Foos in Whitehorse, Yukon. All heads will be sealed in air-tight plastic bags, labelled clearly, and be accompanied with the appropriate forms. The exception occurs at Nakina River, where heads are dissected to a small piece of nose cartilage containing the CWT using a tag reader. This small piece of tissue containing the CWT are sent to Aaron Foos and coded wire tags extracted as per full heads.

Data Processing at Canyon Island

Alaska Department of Fish and Game field staff will relay Canyon Island (fish wheel) and the drift gillnet catch (by size group), effort, tagging, and hydrological data to Jeff Williams ADF&G, Juneau daily. Department of Fisheries and Oceans field staff will relay fishery catch (by size group), effort and tag recovery data to Aaron Foos and Bill Waugh, DFO, Whitehorse. Alaska Department of Fish and Game staff will record and error-check all tagging data from Canyon Island and the drift gillnet tagging site. Data forms will be kept up-to-date at all times and all data will be entered in the field. Data will be sent to ADF&G (Juneau office) at regular intervals and inspected for accuracy and compliance with sampling procedures. Data will be transferred from field books or forms to Excel spreadsheet files in the field using the computer system provided and forwarded to ADF&G Juneau electronically. When input is complete, data lists will be obtained and checked against the original field data.

Staff from DFO will maintain up-to-date forms for inriver fishery data. All data will be entered into Excel™ and error-checked in the field. All biological samples and associated paper data will be sent to Aaron Foos at regular intervals.

On or about the third week in May (approximately statistical week 21), if sufficient inseason mark–recapture data have been acquired, weekly estimates of the inriver run will be generated by ADF&G and DFO. These estimates will then be projected to determine terminal run, and, after consensus by each country (on a weekly basis), recalculation of each country's allowable catch will be made, and managers will be updated accordingly.

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 ANALYSIS

Smolt Abundance

Smolt abundance will be estimated using a two-event mark–recapture model. For each brood year, event 1 will take place during smolt emigration and event 2 will take place over a period of 5 years as these smolt return as adults. Experience has shown that the proportion of adults from a given brood year with adipose fin clips does not change appreciably over return years, and thus recovery data are pooled over the *i* years (5 maximum) in which fish from brood year *j* return. Smolt abundance ($\hat{S}_j$) from brood year *j* will be estimated using a version of the Chapman-modified Petersen formula (Chapman 1951; Seber 1982):

$$\hat{S}_j = \frac{(M_j + 1)(A_{\bullet j} + 1)}{(T_{\bullet j} + 1)} - 1 \tag{1}$$

where

$A_{\bullet j}$ = $\sum_{i=1}^{L} A_{i,j}$, where $A_{i,j}$ is the number of adults examined in year *i* from brood year *j* for missing adipose fins;

L = number of years over which fish from a given brood return (maximum = 5);

$T_{\bullet j}$ = $\sum_{i=1}^{L} T_{i,j}$, where $T_{i,j}$ is the number of adipose fin clips observed in $A_{i,j}$; and

M_j = the number of outmigrating smolt originating from brood year *j* that bore an adipose fin clip.

The variance of the smolt estimate will be estimated as:

$$\text{var}(\hat{S}_j) = \frac{(M_j + 1)(A_{\bullet j} + 1)(M_j - T_{\bullet j})(A_{\bullet j} - T_{\bullet j})}{(T_{\bullet j} + 1)^2 (T_{\bullet j} + 2)} \tag{2}$$

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 will be estimated using data gathered during event 2 of the smolt abundance mark–recapture experiment. Recall that for each brood year, event 2 takes place over a period of 5 years as smolt return as adults. Experience has shown that the estimated fraction of adults from a given brood year with CWTs does not change appreciably over return years, and thus the fraction of adults bearing CWTs ($\hat{\theta}_j$) from brood year *j* will be estimated as:

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

where

$A_{\bullet j}$ = $\sum_{i=1}^{L} A_{i,j}$, where $A_{i,j}$ is the number of adults examined in year *i* from brood year *j* for missing adipose fins;

L = number of years over which fish from a given brood return (maximum = 5);

$T_{\bullet j}$ = $\sum_{i=1}^{L} T_{i,j}$, where $T_{i,j}$ is the number of adipose fin clips observed in $A_{i,j}$; and

$\rho_{\bullet j}$ = $\frac{t_{\bullet j}}{t'_{\bullet j}}$, is the proportion of sacrificed adults from brood year j that possess a valid CWT;

$t'_{\bullet j}$ = $\sum_{i=1}^{L} t'_{i,j}$, where $t'_{i,j}$ is the number of sacrificed adults examined for CWTs from $T_{i,j}$ fish with adipose fin clips; and,

$t_{\bullet j}$ = $\sum_{i=1}^{L} t_{i,j}$, where $t_{i,j}$ is the number of valid CWTs found in $t'_{i,j}$.

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

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

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. Preliminary estimates of $\hat{\theta}_j$ for brood year j will be available after j+3 years (e.g., from age-1.1 returns in 2023 for brood year 2020), but final estimates of $\hat{\theta}_j$ will not be available for j+7 years.

Marine Harvest

Marine harvest ($\hat{r}_{k,j}$) of brood 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 brood year of interest j (i.e. Taku River, brood year 2012), 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, 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.

Inriver Return, Marine Exploitation, and Marine Survival

Inriver return, marine exploitation, and marine survival will be estimated using the methods described in Richards et al. (2008). Inriver return for brood year j will be estimated by adding escapement and inriver harvest data collected in years $j+3, j+4, ..., j+7$ (e.g., escapement and inriver harvest data from 2020 through 2024 will be used to compute the inriver return for brood year 2017). Total return will be estimated by adding inriver return and marine harvest. Marine exploitation is the fraction of the total return harvested in marine fisheries. Marine exploitation will be estimated by dividing the estimate of marine harvest by the estimate of total return. Marine survival is the fraction of smolt that survived and were either harvested by marine fisheries or made it back to the river. Marine survival will be estimated by dividing the estimate of total return by the estimate of smolt abundance.

Dropouts

Dropouts, or the number of marked large fish that did not pass U.S./Canada border, will be estimated for a subset of the marked large fish using radio tags. It is 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 2014), and a remote tracking station will be placed at the U.S./Canada border to ensure tag detection. The proportion of marked fish that did not migrate pass the 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:

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

where n_1 is the number of marked large Chinook salmon moving upriver of 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:

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

Spawning Escapement

A two-event mark–recapture model for a closed population that accounts for dropouts will be used to estimate the number of Chinook salmon passing by Canyon Island each year. The appropriate abundance estimator will depend on the diagnostic tests described below. If stratification is not needed, we begin by estimating the inriver run ignoring dropout ($\widehat{N}$) using Chapman's (1951) version of the Petersen abundance estimator for a closed population (Seber 1982):

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

where n_1 = number of large Chinook salmon marked at Canyon Island , n_2 = number of large Chinook salmon inspected for marks on spawning grounds or caught in the Canadian fisheries (commercial and Aboriginal) or assessment fishery, and m_2 = number of marked large Chinook salmon recaptured on spawning grounds or in the Canadian fisheries (commercial and Aboriginal) or lethal assessment fishery. Note the same estimator will be used to estimate the inriver run of medium Chinook salmon as well and further description of analyses will implicitly represent calculations and tests for both large and medium Chinook salmon. The variance of $\widehat{N}$ will be computed as:

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

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

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

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 $\widehat{N}_1$ is calculated as:

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

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

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

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

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

with variance estimated as:

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

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

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

Spawning escapement ($\hat{E}$) will be estimated as:

$$\hat{E} = \widehat{N}_2 - H \tag{17}$$

where H is the inriver harvest above Canyon Island. Since H is known, the variance of $\hat{E}$ will be computed as:

$$\text{var}(\hat{E}) = \text{var}(\hat{N}_2) \quad (18)$$

Diagnostic tests for equal probability of capture (Appendices D1 and D2) will be performed on the mark–recapture data. If temporal-geographic stratification is not required (Appendix D2), but stratification by size or sex is (Appendix D1), 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 D2), estimation of abundance will follow procedures described by Darroch (1961) using the computer program SPAS (Arnason et al. 1996). The contingency tables described in Appendix D2 will be further analyzed to identify: 1) 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 2) event 2 strata where marked: unmarked ratios are homogeneous within strata and different between strata. It will be necessary to vary from Darroch's suggested model by substituting estimates of (rather than known) numbers of marked fish released in each event 1 strata using methods like those described for equation (7) above. Temporal categories generally will consist of groupings of sample data collected by week and geographic categories of groupings of sample data by location where data were collected. 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 in 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. Non admissible 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).

A goodness of fit (GOF) test (provided in SPAS) that compares 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. If the Darroch (1961) procedure is used to estimate abundance and the number of event 1 and event 2 strata are not equal, the ML estimate of variance provided by the SPAS software will be used. This ML estimate of variance will be biased low because estimated, rather than known, numbers of marked fish will be used in each event 1 strata. If the number of event 1 and event 2 strata are equal for the selected model it may be possible to use bootstrap methodology to estimate variance and confidence intervals, in which case the variability in estimates of event 1 marks can be modeled and the variance estimate will be unbiased.

The estimated escapement is the difference between the estimated passage by Canyon Island and the inriver harvest above Canyon Island (tallies from the lethal assessment, commercial and Aboriginal fisheries in Canada). If the inriver harvest is known without error, the variance for spawning escapement will be the same as the variance estimated for the passage by Canyon Island (equation 9).

Inseason Estimates of Passage

Data from Chinook salmon sampled at Canyon Island, in the drift gillnet effort, in the assessment fishery, and Canadian fisheries (commercial and Aboriginal) will be used to estimate the number of Chinook salmon on a weekly basis passing Canyon Island. Historic run timing information will be used to project the inseason estimates. Diagnostic tests, as described under "Spawning Escapement", for equal probability of capture and model selection will be performed where appropriate and as data becomes available. Inseason estimates of abundance are expected to have more bias than the final estimate because:

a. smaller sample sizes will result in less powerful diagnostic tests, potentially resulting in incorrect model selection;

b. lack of spawning ground samples will preclude evaluation of bias in the assessment and commercial fisheries samples; and

c. the estimate of $\hat{q}$ (see equation 6) may be unavailable or only an approximate due to the time it takes to acquire this estimate.

Abundance will be estimated separately by size category. Additional temporal stratification may be needed if the marked fraction varies significantly over time within a size category. This will require multiple Petersen or Darroch estimators such as those employed to estimate the inriver abundance of coho salmon in the Taku River annually (see Jones et al. 2006 for an example).

Age, Sex, and Length Composition

The fraction of spawning fish ($\hat{p}_{i,j}$) in age (or sex or length) group *j* in stratum *i* (large or medium, or small fish) will be estimated as:

$$\hat{p}_{i,j} = \frac{n_{i,j}}{n_i} \tag{19}$$

where n_i = the number of large (or medium or small) Chinook sampled on the spawning ground, and $n_{i,j}$ = the number from this sample that belong to age (or sex or length) group *j*. The variance for $\hat{p}_{i,j}$ is:

$$\text{var}(\hat{p}_{i,j}) = \frac{\hat{p}_{i,j}(1 - \hat{p}_{i,j})}{n_i - 1} \tag{20}$$

The estimated abundance ($\hat{E}_j$) of group *j* is:

$$\hat{E}_j = \sum_i \hat{p}_{i,j}\hat{E}_i \tag{21}$$

where $\hat{E}_i$ = the estimated abundance in stratum *i* of the mark–recapture experiment. From Goodman (1960), the variance of $\hat{E}_j$ is:

$$\text{var}(\hat{E}_j) = \sum_i \left[\text{var}(\hat{p}_{i,j})\hat{E}_i^2 + \text{var}(\hat{E}_i)\hat{p}_{i,j}^2 - \text{var}(\hat{E}_i)\text{var}(\hat{p}_{i,j})\right] \tag{22}$$

The estimated fraction of the population ($\hat{p}_j$) belonging to group j is:

$$\hat{p}_j = \frac{\hat{E}_j}{\sum_i \hat{E}_i} \tag{23}$$

The variance of the estimated fraction of the population can be approximated with the delta method (see Seber 1982):

$$\operatorname{var}(\hat{p}_j) \approx \hat{E}^{-2} \sum_i \left[\operatorname{var}(\hat{p}_{i,j}) \hat{E}_i^2\right] + \hat{E}^{-2} \sum_i \left[\operatorname{var}(\hat{E}_i)(\hat{p}_{i,j} - \hat{p}_j)^2\right] \tag{24}$$

where $\hat{E} = \sum_i \hat{E}_i$.

Mean Length and Weight of Smolt

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

SCHEDULES AND DELIVERABLES

OPERATIONS

Field activities for tagging Chinook salmon smolt near Canyon Island will begin inriver approximately mid-April and extend into early June. Adult Chinook salmon tagging will begin late April and continue through July, noting that few Chinook salmon are present after early July. Any assessment fishery will begin in early May and end on the third Saturday in June if prosecuted. The Canadian commercial sockeye fishery will commence on the third Sunday of June each season except in years of Chinook salmon conservation when the start is delayed to avoid Chinook salmon. Field activities on the spawning grounds will begin in late July and continue through mid-September (Appendix E1). Aerial surveys will be conducted from late July through early September each season.

REPORTS

A draft report covering adult escapement and tagging dropout for 2022–2024 will be written by the lead author and distributed to other authors in 2026. Smolt abundance and marine harvest for the 2020–2023 brood years will be covered in a separate report in 2030. The final reports will be submitted for final peer review the following year. 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 Fishery Data Series and 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 annual catch and escapement report of the Joint Transboundary Technical Committee, a committee established by the PST to oversee the management of transboundary rivers salmon stocks.

DATA EXCHANGE (ADF&G AND DFO) AND ARCHIVING

1. Canyon Island area ASL-tagging data and inriver fishery effort and catches by size class combined with recoveries will be exchanged daily inseason.

2. Preliminary escapement ASL and mark recovery data will be exchanged by November 1 each year.
3. Aerial survey results will be provided inseason as they become available.
4. Aging results for Taku River Chinook salmon will be exchanged by November 1 each year.
5. Final error-checked ASL data, collated with scale and CWT reading results, will be exchanged by December 1 each year.

Scale cards and original data forms associated with tag application near Canyon Island and from the drift gillnet, and during spawning grounds sampling at the Nahlin and Dudidontu Rivers and at Tseta Creek will be stored in the ADF&G scale archive in the Douglas Regional office in Juneau, Alaska. Scales gathered from the any Canadian fisheries and during escapement sampling on the Nakina River, and Kowatua, and Tatsatua Creeks will be archived at the Pacific Biological Station in Nanaimo, B.C., Original data forms will be stored at the DFO office in Whitehorse, Yukon.

Completed **CODED WIRE TAG SAMPLING FORMs** (Appendix B2) will be submitted to the ADF&G Mark, Tag and Age Laboratory. All U.S. and some Canadian CWT data (sampled fish, decoded tags, location, data type, samplers, etc.) are archived and accessible on a permanent database maintained by ADF&G and are provided annually to the coastwide database at the Pacific States Marine Fisheries Commission. An electronic copy of the ASL, along with the adult mark and recovery data, will be permanently archived in *Oceanak*, an ADF&G database maintained by DCF. Canadian CWT data will be stored in domestic DFO databases and shared internationally through established data sharing and archiving arrangements; but also shared as needed directly with ADF&G.

RESPONSIBILITIES

Jeff Williams, FB II, Project Leader (ADF&G- DCF smolt and adult escapement). Works with Stephen Warta (ADF&G) on field operations, data analysis, and report writing. Supervises smolt and adult Chinook 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. Writes smolt and adult Chinook salmon sampling section of operational plan, assures that it is followed or modified appropriately with consultation with Randy Peterson. Is coauthor on final report with Randy Peterson and Aaron Foos.

Randy Peterson, Biometrician III. 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 programming code, and computes data analysis as necessary, and coauthors final report with Williams and Foos.

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

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. Is responsible for daily operation and cleaning of the Mark IV coded wire tagging machines associated with smolt tag and release operations. 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 drift 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 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 regarding the efficiency of work and will provide input on changes necessary to improve operations.

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 regarding the efficiency of work and will provide input on changes necessary to improve operations.

Paul Warta, 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 regarding the efficiency of work and will provide input on changes necessary to improve operations.

Aaron Foos, BI-03, Project Leader (DFO smolt and adult escapement). Coordinates with Jeff Williams (ADF&G) on field operations, data collation and analysis, and report writing. Supervises DFO smolt and adult Chinook 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 Chinook 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 Chinook 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 (DFO) and Jeff Williams (ADF&G) on field operations. Supervises TRTFN smolt and adult Chinook 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 Chinook salmon smolt and adult escapement projects consistent with operational plans and supervisory direction.

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APPENDIX A: PEAK AERIAL COUNTS OF CHINOOK SALMON IN THE TAKU RIVER

Appendix A1.–Peak aerial counts of Chinook salmon in the Taku River, 1973–2021.

	Peak aerial count						
	Nakina	Nahlin	Kowatua	Tatsatua	Dudidontu	Tseta	5 tributary
Year[a]	River	River	Creek	Creek	River	Creek	total
1973	2,000	300	100	200	200	4	2,800
1974	1,800	900	235	120	24	4	3,079
1975	1,800	274	–	–	15	–	2,089
1976	3,000	725	341	620	40	–	4,726
1977	3,850	650	580	573	18	–	5,671
1978	1,620	624	490	550		21	3,284
1979	2,110	857	430	750	9	–	4,156
1980	4,500	1,531	450	905	158	–	7,544
1981	5,110	2,945	560	839	74	258	9,528
1982	2,533	1,246	289	387	130	228	4,585
1983	968	391	171	236	117	179	1,883
1984	1,887	**951**	279	616	–	**176**	3,733
1985	2,647	2,236	699	848	475	303	6,905
1986	3,868	1,612	548	886	413	193	7,327
1987	2,906	1,122	570	678	287	180	5,563
1988	4,500	1,535	1,010	1,272	243	66	8,560
1989	5,141	1,812	601	1,228	204	494	8,986
1990	7,917	1,658	614	1,068	820	172	12,077
1991	5,610	1,781	570	1,164	804	224	9,929
1992	5,750	1,821	782	1,624	768	313	10,745
1993	6,490	2,128	1,584	1,491	1,020	491	12,713
1994	4,792	2,418	410	1,106	573	614	9,299
1995[b]	3,943	2,069	550	678	731	786	7,971
1996	7,720	5,415	1,620	2,011	1,810	1,201	18,576
1997	6,095	3,655	1,360	1,148	943	648	13,201
1998	2,720	1,294	473	675	807	360	5,969
1999	1,900	532	561	431	527	221	3,951
2000	2,907	728	702	953	482	160	5,772
2001	1,552	935	1,050	1,024	479	202	5,040
2002	4,066	1,099	945	1,145	834	192	8,089
2003	2,126	861	850	1,000	644	436	5,481
2004	4,091	1,787	828	1,396	1,036	906	9,138
2005	1,213	471	833	1,146	318	215	3,981
2006	1,900	955	1,180	908	395	199	5,338
2007[c]	77	277	262	390	4	199	1,010

-continued-

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	Peak aerial count						
Year[a]	Nakina River	Nahlin River	Kowatua Creek	Tatsatua Creek	Dudidontu River	Tseta Creek	5 tributary total
2008	1,437	1,121	690	1,083	480	497	4,811
2009	1,698	1,033	408	633	272	145	4,044
2010	1,730	1,018	716	821	561	128	4,846
2011	1,380	808	377	917	301	128	3,783
2012	1,300	726	402	660	126	–	3,214
2013	1,623	527	708	438	166	–	3,462
2014	1,040	304	384	376	193	–	2,297
2015	1,340	612	622	434	289	–	3,297
2016	800	379	303	92	156	–	1,730
2017	301	134	272	179	37	–	923
2018	765	268	202	121	363	–	1,719
2019	1,070	282	361	330	949	–	2,992
2020	1,249	213	505	390	292	–	2,649
2021	1,034	98	544	358	147	–	2,181
Averages							
1973–1979	2,311	619	363	469	51	10	3,686
1980–1989	3,406	1,538	518	790	233	231	6,461
1990–1999	5,294	2,277	852	1,140	880	503	10,443
2000–2009	2,107	927	775	968	494	315	5,270
2010–2019	1,135	506	435	437	314	128	2,826
All years							
1973–2021	2,814	1,166	605	769	420	310	5,727

[a] Large Chinook salmon spawning abundance was estimated using mark–recapture in bold years. In other years aerial counts were expanded using an expansion factor of 5.2, that represents the average expansion between the mark–recapture estimate of escapement and the total peak aerial count from five tributaries: the Nakina, Nahlin, and Dudidontu Rivers and Tatsamenie Lake in 1989, 1990, 1995–1997 and 2003.

[b] In 1995, due to low tagging and recovery rates in the mark–recapture study, large Chinook salmon spawning abundance was derived by expanding the estimate of medium Chinook salmon by size composition data gathered on the spawning grounds.

[c] Due to poor aerial survey conditions in 2007, obtaining valid counts in most sites was not possible.

APPENDIX B: DATA FORMS

Appendix B 1.–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 B 2.–Data form to record daily CWT tagging results.

CWT DAILY TAGGING, ADF&G Division of Commercial Fisheries

Location: Taku River
Species: Chinook
Year: 2022

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 B 3.–Data form to record daily environmental conditions.

DAILY ENVIRONMENTAL CONDITIONS, ADF&G Division of Commercial Fisheries

Location: Taku River
Year: 2022

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

APPENDIX C: FORMS

Appendix C 1.– Fish wheel effort form.

		FISHING EFFORT							
		New Style				Old Style			
		FW1	FW1	FW2	FW2	FW1	FW1	FW2	FW2
SW	Date	Effort	RPM	Effort	RPM	Effort	RPM	Effort	RPM

Appendix C 2.– Fish wheel age-sex-length (ASL) form, Taku River Chinook salmon.

Taku River Chinook Fish Wheels ASL Form

Date:___________________________ Water Temp: __________ Page #:______of______

Crew:___________________________ Gage Height:__________

Fish #	Gear type	Adipose (P/A)	Sex	Length METF	Scale Card #	Scale #	LAA DLUOP (yes/no)	Spag Tag or Cinch #	Comments

Appendix C 3.– Drift gillnet age-sex-length (ASL) form, Taku River Chinook salmon.

Taku River Drift Gillnet ASL Form

Date: 5/16/2022　　Drift Location: Wright River　　Crew #: Drift 1

Crew: DWD, MPE　　Gillnet Mesh: 7 1/4"　　Page #: 1 of 1

Drift #	Fish #	Drift Time (min)	Adipose (P/A)	Sex	Length METF	Scale Card #	Scale #	LAA DLUOP	Tag/Cinch #	Comments: other species, Chinook caught but not tagged
1	5236	12	P	F	715	D1 - 005	3	Y/Y	16523	
2	5237	12	P	F	825	D1 - 005	4	Y/Y	16524	
	5238		P	M	805	D1 - 005	5	Y/Y	16525	
3		17	P	F	695	D1 - 005	6	N/N		no tag - injured
4	5239	14	A	M	630	D1 - 005	7	N/N	85963	ad clip
5	5240	18	P	M	945	D1 - 005	8	Y/Y	16526	

Appendix C 4.–Coded wire tag sampling form using the Taku River, Canyon Island as an example.

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 1 OF PAGES 1

SAMPLE NUMBER: 1 5 7 8 0 0 2 3

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

SURVEY SITE: Taku River - Canyon Island

SAMPLE TYPE: (random) select

SAMPLER: LaFollette / Dreyer

DATE SAMPLED: 05 - 25 - 15

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	16	1	(y) n
(411)JACK CHINOOK-ONLY	5	0	(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-	111-32	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) Taku River - CYI

WATER TYPE: saltwater (freshwater)

ANADROMOUS STREAM# (FRESHWATER-ONLY) 111-32-10320

COMMENTS

HEAD RECOVERY INFORMATION

✓	HEAD NUMBER	SPECIES CODE	LENGTH (mid-eye to fork in mm)	CLIP	SEX
	172320	410	755	1	F

T:\FORMS\2011VISIO\RACKSE2011.VS D03/07/14 01:30

Appendix C 5.–Commercial fishery sample form.

Taku River Commercial Fishery - CHINOOK 2014

Samplers' Initials: ____________________________ Page ________ of ________ for Week ______

									HEAD ON						
												Operculum Punch			
Sample Date	Catch SW	Catch Day	Scale Book Serial No.	Scale No.	Length (CAF)	AA (P/A/U)	Ad. Fin (P/A/U)	Size (S/M/L)	Length (MEF)	Length (POH)	SEX	SU (P/A/U)	DU (P/A/U)	DL (P/A/U)	CWT Head Label No./ General Comments
				1											
				2											
				3											
				4											
				5											
				6											
				7											
				8											
				9											
				10											
				1											
				2											
				3											
				4											
				5											
				6											
				7											
				8											
				9											
				10											

P = Present A = Absent U = Unknown SU = Single Upper DU = Double Upper DL = Double Lower S = <34cm CAF L = > 57cm CAF

Appendix C 6.–Canadian Aboriginal fishery sample form.

Taku River Food, Social and Ceremonial Fishery - CHINOOK 2015

Samplers' Initials: ______________________ Page ________ of ________ for Week ______

									HEAD ON						
												Operculum Punch			
Sample Date	Catch SW	Catch Day	Scale Book Serial No.	Scale No.	Length (CAF)	AA (P/A/U)	Ad. Fin (P/A/U)	Size (S/M/L)	Length (MEF)	Length (POH)	SEX	SU (P/A/U)	DU (P/A/U)	DL (P/A/U)	CWT Head Label No./ General Comments
				1											
				2											
				3											
				4											
				5											
				6											
				7											
				8											
				9											
				10											
				1											
				2											
				3											
				4											
				5											
				6											
				7											
				8											
				9											
				10											

P = Present A = Absent U = Unknown SU = Single Upper DU = Double Upper DL = Double Lower S = <34cm CAF L = > 57cm CAF

Appendix C 7.–Spawning grounds sample form.

Transboundary Chinook - Escapement Location: Any River Year: 2014 Initials: JD, AB

Date	GEAR	SEX	Left UOPunch Y/N/?	Left AAClip Y/N/?	Adipose Clip Y/N/?	Scale Book Serial No.	Scale Col. No.	Length MEF	Size Class (S, M, L)	Length POH	Condition*		Comments (eg Tag #, Tag Scar, CWT label #, etc)
											pre/mid/post	A/M/C	
1-Aug	-	F	Y*	Y	N	71551	1	-	L	-	post	C	bear kill - tag + length n/a * double
1-Aug	weir	M	N	N	N	71551	2	820	L	715	post	M	
1-Aug	rod	M	Y*	Y	N	71551	3	650	M	550	pre	A	K11092 *single + double lower
1-Aug	spear	F	N	N	Y	71551	4	790	L	695	post	M	092461
							5						
							6						
							7						
							8						
							9						
							10						

* pre-, mid- or post-spawn; A= active, M= moribund; C=carcass

APPENDIX D: SIZE SELECTIVE SAMPLING

Appendix D 1.–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 event 1 and/or event 2 sampling. The event 2 sampling 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 event 1 sampling 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 event 1 and/or event 2 sampling. 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 event 1 or event 2 sampling.

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 event 1 and event 2 sampling.

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 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 event 2 sampling 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 D 2.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

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-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-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-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.

APPENDIX E: SPAWNING GROUND SAMPLING ACTIVITIES

Appendix E 1.–Spawning ground sampling activities by location in the Taku River.

Location	Dates	Lead agency	Methods	Anticipated sample (large Chinook)
Nakina River	July 15–Aug 31	TRTFN	Carcass weir, carcass pitch	500
Tatsatua Creek	Aug 15–Sept 15	DFO	Angling	300
Tatsamenie Lake	Sept 1–Oct 1	DFO	Sockeye weir, carcass pitch	100
Nahlin River	July 25–Aug 7 (3-5 days)	ADF&G	Angling, carcass pitch	250
Upper Dudidontu River	Aug 1–Aug 20 (4–7 days)	ADF&G	Angling, carcass pitch	150
Lower Dudidontu River	Aug 1–Aug 20 (4–7 days)	ADF&G	Angling, carcass pitch	150
Kowatua River	Sept 1–Oct 1	DFO	Angling, carcass pitch	250
Tseta Creek	Aug 1–Aug 20 (3–5 days)	ADF&G	Angling, carcass pitch	200

APPENDIX F: PREDICTING DROPOUTS USING HISTORIC RADIO TELEMETRY DATA

Appendix F 1.–Predicting dropouts using historic radio telemetry data.

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 radio telemetry 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 for prediction purposes is not. There are 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 ($var(\rho)$, 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 for prediction will be estimated as (Kutner et al. 2005):

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

where

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

and

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

such that

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

Dropout rate estimated

If in any year the rate of dropouts is estimated, then the following equations should be used. 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):

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

The estimate of process error, $var(\rho)$, 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):

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

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

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

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

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

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

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

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

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

and

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

such that

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

<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 $var(\rho)$ and $var(\bar{\rho})$ 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 $var(\rho)$ as:

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

where

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

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

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

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

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

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

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

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:

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

R Code and examples

Three R code functions - **Dropout**, **DropoutRate**, and **bootDropout** - and an example are included. Note that the 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])
```