

**Operational Plan: Migration, Tagging Response,  
Distribution, and Inriver Abundance of Taku River  
Sockeye Salmon**

by

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**June 2018**

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**Alaska Department of Fish and Game**

**Divisions of Sport Fish and Commercial Fisheries**



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<b>Weights and measures (metric)</b>		<b>General</b>		<b>Mathematics, statistics</b>	
centimeter	cm	Alaska Administrative Code	AAC	<i>all standard mathematical signs, symbols and abbreviations</i>	
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	$H_A$
gram	g	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	$e$
hectare	ha	at	@	catch per unit effort	CPUE
kilogram	kg	compass directions:		coefficient of variation	CV
kilometer	km	east	E	common test statistics	(F, t, $\chi^2$ , etc.)
liter	L	north	N	confidence interval	CI
meter	m	south	S	correlation coefficient	
milliliter	mL	west	W	(multiple)	R
millimeter	mm	copyright	©	correlation coefficient (simple)	r
		corporate suffixes:		covariance	cov
<b>Weights and measures (English)</b>		Company	Co.	degree (angular)	$^\circ$
cubic feet per second	ft <sup>3</sup> /s	Corporation	Corp.	degrees of freedom	df
foot	ft	Incorporated	Inc.	expected value	$E$
gallon	gal	Limited	Ltd.	greater than	>
inch	in	District of Columbia	D.C.	greater than or equal to	≥
mile	mi	et alii (and others)	et al.	harvest per unit effort	HPUE
nautical mile	nmi	et cetera (and so forth)	etc.	less than	<
ounce	oz	exempli gratia	e.g.	less than or equal to	≤
pound	lb	(for example)		logarithm (natural)	ln
quart	qt	Federal Information Code	FIC	logarithm (base 10)	log
yard	yd	id est (that is)	i.e.	logarithm (specify base)	log <sub>2</sub> , etc.
		latitude or longitude	lat or long	minute (angular)	'
<b>Time and temperature</b>		monetary symbols (U.S.)	\$, ¢	not significant	NS
day	d	months (tables and figures): first three letters	Jan, ..., Dec	null hypothesis	$H_0$
degrees Celsius	°C	registered trademark	®	percent	%
degrees Fahrenheit	°F	trademark	™	probability	P
degrees kelvin	K	United States (adjective)	U.S.	probability of a type I error (rejection of the null hypothesis when true)	$\alpha$
hour	h	United States of America (noun)	USA	probability of a type II error (acceptance of the null hypothesis when false)	$\beta$
minute	min	U.S.C.	United States Code	second (angular)	"
second	s	U.S. state	use two-letter abbreviations (e.g., AK, WA)	standard deviation	SD
<b>Physics and chemistry</b>				standard error	SE
all atomic symbols				variance	
alternating current	AC			population sample	Var
ampere	A			sample	var
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				

***REGIONAL OPERATIONAL PLAN CF.1J.2018.01***

**OPERATIONAL PLAN: MIGRATION, TAGGING RESPONSE,  
DISTRIBUTION, AND INRIVER ABUNDANCE OF TAKU RIVER  
SOCKEYE SALMON**

by

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June 2018

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SIGNATURE/TITLE PAGE

Project Title: Operational Plan: Migration, Tagging Response, Distribution, and Inriver Abundance of Taku River Sockeye Salmon

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## PURPOSE

Inseason estimates of the spawning escapement of Taku River sockeye salmon, *Oncorhynchus nerka*, are needed to fulfill the escapement goal and international harvest sharing requirements for stocks specified by the U.S./Canada Pacific Salmon Treaty. The Taku River mark–recapture project has been conducted annually since 1984 as a joint U.S./Canada program involving the Alaska Department of Fish and Game (ADF&G) and the Department of Fisheries and Oceans Canada (DFO) to provide weekly estimates of the Taku River salmon escapement past Canyon Island, Alaska. The objectives of the studies are to provide inseason estimates of the inriver abundance of sockeye salmon and to document biological characteristics (migratory timing, migratory rates, and age, sex, and size composition) of Taku River sockeye salmon stocks. Spaghetti tagged-to-untagged ratios of salmon harvested in the Canadian inriver gillnet fisheries are used to develop the estimates of the inriver abundance of sockeye salmon.

In addition to the mark–recapture project, ADF&G, in cooperation with DFO and the Taku River Tlingit First Nations (TRTFN), have been allocated funds from the Northern Endowment Fund Committee, administered by the Pacific Salmon Commission, to continue a multi-year sockeye salmon radiotelemetry study on the Taku River that began in 2017. The continuation of the radiotelemetry study will clarify recent insights into key assumptions of annual Taku River sockeye salmon mark–recapture studies that have the potential to influence abundance estimates. Aerial (fixed wing and helicopter), boat, and foot surveys will be used to track radiotagged sockeye salmon to determine spawning locations in the drainage, and to estimate the proportions of mainstem and lake spawners. Our estimate of these proportions will be compared with those obtained during 1984, 1986, and 2017.

## BACKGROUND

The Taku River is a transboundary river (TBR) system originating in the Stikine plateau of northwestern British Columbia and terminating in Taku Inlet in Southeast Alaska (SEAK), about 30 km east of Juneau. The merging of two principal tributaries, the Inklin and Nakina rivers, approximately 50 km upstream from the international border, forms the bulk of the Taku River. The river flows southwest from this point through the U.S./Canada border and Coast Mountain Range, eventually draining into Taku Inlet (U.S. District 111-32) (Figure 1). Approximately 95% of the Taku River watershed lies within Canada and it produces a large run of sockeye salmon, *Oncorhynchus nerka*.

Sockeye salmon returning to the Taku River drainage are harvested in both U.S. and Canadian fisheries. The traditional U.S. commercial drift gillnet fishery in Subdistrict 111-32 primarily targets Taku River sockeye salmon stocks and enhanced chum salmon, *O. keta*, from local Alaska enhancement programs during the spring and summer months; Chinook, *O. tshawytscha*, pink, *O. gorbuscha*, and coho, *O. kisutch*, salmon are also harvested. In some years of high abundance, the U.S. fishery targets Chinook salmon in the spring. During the fall, the U.S. fishery primarily targets wild Taku River and U.S. enhanced coho salmon, and wild Taku chum salmon are caught incidentally. The Canadian inriver fishery is managed to target Chinook salmon in the spring during years of high abundance, sockeye and coho salmon in the summer and fall, while pink salmon, chum salmon, and steelhead, *O. mykiss*, are caught incidentally (TTC 2017).

The Pacific Salmon Commission (PSC) commits Canada and the U.S. to conservation and allocation obligations for salmon originating in the waters of the Canadian portion of the Taku

River. The PSC via the Pacific Salmon Treaty (PST) of 1985, and subsequent revisions, has established conservation (escapement goal of 71,000 to 80,000 sockeye salmon) and harvest sharing (percentage sharing of the allowable catch) obligations for Taku River sockeye salmon. The system-wide interim escapement goal for wild stocks was established by the Transboundary Technical Committee (TTC) of the Pacific Salmon Commission (TTC 2018). The PST mandates cooperative international management of salmon originating in the Canadian waters of the Taku River.

Sockeye salmon abundance in the Taku River has been estimated from U.S./Canada mark-recapture studies conducted annually by the Alaska Department of Fish and Game (ADF&G) and the Department of Fisheries and Oceans, Canada (DFO) since 1984 (Clark et al. 1986; McGregor and Clark 1987, 1988, 1989; McGregor et al. 1991; Kelley et al. 1997, Kelley and Milligan 1997; Andel and Boyce 2014a, 2014b; Boyce and Andel 2014). The primary objective of the mark-recapture project is to estimate inriver abundance above the U.S./Canada border past Canyon Island (Figure 1). Inseason estimates of sockeye salmon abundance are produced on a weekly basis to facilitate abundance-based management as specified by the treaty. In addition to the inseason abundance estimates, managers use catch per unit effort (CPUE) and stock composition data gathered from the U.S. commercial drift gillnet fishery in District 111-32 and Canadian inriver gillnet fisheries to adjust fishing times to comply with treaty obligations.

During the 2017 season, 277 sockeye salmon were captured and radiotagged using three fish wheels in the lower Taku River: two located at Canyon Island and one downriver across from Yehring Creek. Preliminary results from this telemetry study suggested a high level of “dropouts”; fish that were radiotagged at the fishwheels, but for a variety of potential reasons did not migrate upstream past the international border. Similar unaccounted for dropouts (i.e., tag loss due to predation, handling, regurgitation or permanently leaving the Taku River, tag failure prior to upstream migration, unknown fate fish that spawned below the U.S./Canada border, fish caught in the U.S. fishery) of fish spaghetti tagged in mark-recapture studies would cause abundance estimates in the Taku River to be biased high (Bernard et al. 1999). Of the 277 Taku River sockeye salmon that were radiotagged in the 2017 season, 32% did not cross the border (“dropouts”; 90/277). Of the remaining radiotagged fish that crossed the border, 28% were harvested in inriver fisheries (53/187) and 69% (129/187) likely spawned in the Canadian portion of the Taku River. In a 1986 radiotelemetry study of Taku River sockeye salmon, 272 sockeye salmon were tagged with radio transmitters and only 59% (167) were tracked to their final destination (Eiler et al. 1988); the other 41% (the “dropouts”) included fish that disappeared after starting upriver, died after being tagged due to predation or handling, or moved downstream into the marine water.

Dropout rates in radiotagging studies have varied across river systems and species (Eiler et al. 1988; Pahlke and Bernard 1996; Pahlke et al. 1996; Pahlke and Etherton 1999; Richards et al. 2008; Yanusz et al. 2007; Wade et al. 2009; Weller and Evans 2012). A Susitna River sockeye salmon radiotelemetry study experienced a 4.4% dropout rate; of 250 sockeye salmon radiotagged, the fates of only 11 fish were unknown (Yanusz et al. 2007). Of the 2,906 radiotagged sockeye salmon released on the Copper River from 2005–2008, 87 radio tags were never detected after release or last detected downstream of the tagging site, an average dropout rate of 4.1% (Wade et al. 2009). Dropout rates for Chinook salmon in radiotelemetry studies varied from 6% to 20% in the Stikine River (1997, 2005, 2015, 2106), from 11% to 23% in the Taku River (1989, 1990, 2015–2016), and from 12% to 14% in the Unuk River (1994, 2009) due to unknown fates, emigration, mortality prior to spawning, lost transmitters, or regurgitated transmitters (Phil

Richards, Sport Fish Biologist III, ADF&G, Douglas, personal communication; Pahlke et al. 1996; Weller and Evans 2012). It is believed that tag failure is rare. For example, Eiler et al. (2014) deployed nearly 3,000 ATS radio tags in Chinook salmon on the Yukon River and experienced no known tag failures.

The Taku River sockeye salmon population consists of lake (Tatsamenie, King Salmon, Little Trapper, Kuthai) and mainstem (stocks other than the four lake stocks) spawning components. Counting weirs are operated by DFO at Little Trapper and Tatsamenie lakes and by the Taku River Tlingit First Nations (TRTFN) at Kuthai and King Salmon lakes. The counting weirs provide some information on the distribution and abundance of discrete spawning stocks in the watershed. In 1984 and 1986, radiotelemetry was used to locate and characterize the distribution of spawning sockeye salmon in the Taku River (Eiler et al. 1992). Through this work, the mainstem component was shown to contribute approximately 63% to the total inriver run. The mainstem proportion calculated from mark–recapture estimates (79% average from 2013–2017), however, has been much larger than the proportion estimated from the Eiler et al. (1992) radiotelemetry study and from estimates based on stock composition data from both the inriver Canadian fishery (57% average from 2011–2015), and the U.S. District 111 traditional commercial drift gillnet fishery (54% average from 2013–2017) (TTC 2017). The discrepancy between the proportion of mainstem- and lake-spawning components, along with the quarter of a century that has elapsed since the original radiotelemetry work was conducted, highlighted the need to repeat radiotelemetry studies to address potential bias in mark–recapture estimates and to properly define the current spawning distribution of sockeye salmon in the Taku drainage. Improved stock composition data and information concerning the distribution of spawning escapement will also be useful for successful abundance-based management of Taku River sockeye salmon and for evaluation and updating of the escapement goal.



Figure 1.–Taku River drainage in Southeast Alaska and British Columbia identifying key landmarks, including the marking (Canyon Island) and recovery (Canadian fishery) locations of the mark–recapture experiment and radiotelemetry tracking towers.

## OBJECTIVES

### PRIMARY OBJECTIVES

For sockeye salmon ( $\geq 350$  mm measured from mid eye to fork length [MEF]) in the lower Taku River:

#### Mark–recapture project

1. Estimate the abundance of sockeye salmon migrating upstream past the Canadian border on the Taku River with an estimated coefficient of variation no greater than 10% of the estimate.
2. On a weekly basis, estimate inriver abundance with a coefficient of variation no greater than 20% of the estimate.
3. On a weekly basis, estimate the age, length (MEF), and sex composition of adult sockeye salmon ( $\geq 350$  mm MEF) caught in the Canyon Island fish wheels.

4. Estimate the total season age, length, and sex composition of adult sockeye salmon ( $\geq 350$  mm MEF) caught in the Canyon Island fish wheels such that estimates are within 5% of the true proportion 95% of the time.
5. On a weekly basis, forecast total abundance of sockeye salmon passage into the Canadian portion of the Taku River based on tag-recovery data and historical migration-timing data.

### **Radiotelemetry project**

1. Estimate the proportions of Canadian origin sockeye salmon that escape fisheries that return to the two main stock components—lake and mainstem spawners—in the Taku River drainage such that the estimate is within 5% of the true proportion 89% of the time.
2. Identify spawning locations for Canadian origin sockeye salmon that contribute more than 2% of the spawning population, with a probability of at least 99%; if spawners are distributed uniformly among 50 locations, the probability of detecting all 50 locations is at least 76%.
3. Identify the proportion of tagged fish that drop out of the mark–recapture study and determine, to the extent possible, the fate of these fish.

## **SECONDARY OBJECTIVES**

### **Mark–recapture project**

1. Quantitatively describe the migratory timing (mean and variance) of the sockeye, pink, and chum salmon migrations past Canyon Island assuming the fish wheel capture rates are representative of the migrations.
2. Qualitatively describe the migratory timing of the Kuthai, Little Trapper, King Salmon, and Tatsamenie lake sockeye salmon stocks past Canyon Island, assuming the fish wheel capture rates are representative of the migrations.
3. Estimate the sex composition of adult pink salmon caught in the fish wheels.
4. Estimate the age and sex composition of adult chum salmon caught in the fish wheels.

### **Radiotelemetry project**

1. Estimate the migratory timing profiles of sockeye salmon stocks in the Taku River drainage from the point of tagging (Canyon Island fish wheels) to their final spawning destination.

## **METHODS**

The purpose of this study is to provide inseason estimates of inriver abundance and document biological characteristics (migratory timing, migratory rates, and age, sex, and size composition) of Canadian origin Taku River sockeye salmon stocks. A mark–recapture approach will be used to estimate the abundance of sockeye salmon migrating past Canyon Island in 2018. Sockeye salmon at Canyon Island will be caught via fish wheels and spaghetti tagged and marked as the first of two sampling events. The second sampling event will consist of sampling (inspecting) sockeye salmon for marks upriver in the Canadian commercial fishery and test fishery. Ratios of

tagged to untagged fish in these fisheries will be used to develop inseason abundance estimates of sockeye salmon. This study is consistent with those conducted since 1984; however, 2017 radiotelemetry results indicated that one of the key mark–recapture assumptions may be violated (there is no trap induced behavior); there was a high dropout rate in the 2017 season. The cause of the high dropout rate from the 2017 season is unknown. Other studies have documented adverse effects of fish captured and handled in fish wheels with extended holding times (Bromaghin and Underwood 2003; Cleary 2003; Underwood et al. 2004; Bromaghin et al 2007; Liller et al. 2011). Therefore, fish handling at the fish wheels will be modified, in an attempt to reduce stress associated with fish wheel capture and tagging, and an additional telemetry/fish behavior study will also be conducted (Appendix C).

Age, length, and sex data will also be collected from sockeye salmon caught in the Canyon Island fish wheels, and the inriver Canadian commercial fishery. A portion of the fish captured and spaghetti tagged during this study will also be tagged with radio transmitters. Movements of radiotagged fish will be monitored from time of release by a combination of fixed tracking towers located below and above the marking site (Figure 1), and by weekly aerial and boat surveys to track radiotagged fish.

## **CAPTURE AND TAGGING**

### **Mark–Recapture Project**

Sockeye salmon will be captured using two fish wheels in the lower Taku River. Fish wheels will be positioned in the vicinity of Canyon Island on opposite riverbanks, approximately 200 m apart. The Taku River channel at this location is ideal for fish wheel operation since the river is fully channelized through a relatively narrow canyon that has very steep walls. The fish wheels will be secured in position by anchoring to large trees with 0.95 cm steel cable and held out from, and parallel to, the shoreline by log booms. Each fish wheel will consist of two aluminum pontoons in a framework, measuring approximately 12 m in length and 6 m in width and filled with closed cell Styrofoam for flotation, supporting an axle, paddle, and basket assembly; two or three fish-catching baskets are rotated about the axle by the force of the water current against the baskets and/or paddles. As the fish wheel baskets rotate, they ‘scoop-up’ salmon. Angled slides attached to the rib structure of each basket will direct fish to an aluminum liveboxe bolted to the outer sides of the pontoons.

In 2018, the fish wheels will be deployed inriver on approximately June 3<sup>rd</sup>, the beginning of statistical week 23. The fish wheels will then be fished as continuously as possible for approximately 15 hours each day for two shifts (from 04:00 to 11:30 and 16:00 to 23:30), with each shift consisting of a crew of three people. The fish wheels will be shut down between shifts and started again when the next crew’s shift begins (i.e., shut down from 23:30 to 04:00 and from 11:30 to 16:00). Shift hours may be adjusted by the crew inseason to account for slow reductions in day length after late June. To ensure fish holding times are less than one hour, fish wheel catch will be sampled every hour in the morning, afternoon, and evening, and tagging will be conducted from a boat to allow the fish wheels to continue to rotate (Appendices A1 and A2). The crew will remain with the fishwheels during the entire shift to ensure continuous sampling and to ensure holding times do not exceed one hour. The crew members will intermittently switch shifts (from AM to PM or PM to AM) throughout the season to minimize potential differences between crews. Sampling is to be conducted consistently throughout the season (i.e., the crew should not change behavior during peak or low times) and therefore, the crew will release, without tagging, any fish

held for more than one hour. Previous studies have shown increased holding times negatively affect the health of salmon species (Cleary 2003; Bromaghin and Underwood 2003; Bromaghin et al. 2007).

All uninjured sockeye salmon with a length greater than or equal to 350 mm mid eye to fork of tail (MEF) (defined as adults) captured by the fish wheels and having a bin time of less than one hour will be spaghetti tagged as part of the annual mark–recapture project. Sockeye salmon less than 350 mm MEF (defined as jacks) will be enumerated but will not be tagged because fish in this size range are not vulnerable to capture in the upriver Canadian gillnet fishery from which tagged to untagged ratios are used to develop population estimates. Chinook, pink, and chum salmon will not be tagged, and coho salmon operations are described in a separate operational plan (William et al. 2016b).

Sockeye salmon will be tagged with spaghetti tags (Floy Tag and Manufacturing Inc.<sup>1</sup>, Seattle, WA) made of hollow fluorescent orange PVC tubing (approximately 2.0 mm in diameter and 30 cm in length) that are consecutively numbered and labeled with project description information. To apply the spaghetti tags to sockeye salmon, the sampling boat will tie parallel to a fish wheel, and fish will be dipnetted from the fish wheel liveboxes and placed into a tagging trough partially filled with river water located in the middle of the boat. Then, one person will hold the fish in the tagging trough while a second person inserts a 15 cm applicator needle with attached spaghetti tag through the dorsal musculature immediately below the dorsal fin. The ends of the spaghetti tag will be knotted together with a single overhand hitch and cinched tight to the fish's back. The left axillary appendage will be removed from all radiotagged sockeye salmon to acquire a genetic sample for analysis (Rogers Olive et al. *in press*). To reduce tag-induced mortality, fish will be handled carefully, and every effort will be made to limit handling time. Since fishermen remove the tags, a secondary mark (tag hole/scar), created during the tagging process, is used to verify that tagged fish are recognized as such when encountered during the second sampling event (e.g., at Flannigan's Slough, assessment fishery, commercial fishery, or during spawning grounds sampling). Sampling of spawning grounds is only important for run timing information and data collected on the spawning grounds to date has not been used in the mark–recapture project.

Biological sampling will also occur during the application of spaghetti tags. All sockeye salmon captured in fish wheels will be sampled for sex and MEF length. A sub-sample of scales and a sub-sample of paired MEF and cliethral arch to fork of tail (CAF) length measurements will be collected throughout the season (Table 1; Appendix A2). The spaghetti tagging and biological sampling procedures should take from 40 to 60 seconds per fish to complete. The fish will then be immediately released back into the river. Fish with deep wounds, damaged gills, or in a lethargic or otherwise unhealthy condition will be sampled for length, sex, and scales, then released without being tagged.

## **Radiotelemetry Project**

In conjunction with the spaghetti tags, a portion of the fish captured during this study will also be tagged with radio transmitters. Radiotelemetry of salmon is the preferred method to determine the comprehensive spawning distribution of river stocks (Eiler 1995, Koehn 2000, Reine 2005). This project will mimic similar radiotelemetry studies that have been implemented by ADF&G on the Susitna River drainage for sockeye salmon (Yanusz et al. 2007 and 2011) and on the Taku and

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<sup>1</sup> Mention of trade names does not constitute endorsement by ADF&G or DFO.

Stikine rivers for Chinook salmon (Richards et al. 2016a and 2016b). Internal pulse-coded radio tags manufactured by Advanced Telemetry Systems (ATS<sup>TM</sup>) will be placed in sockeye salmon that are handled and marked in conjunction with the spaghetti-tagged sockeye salmon in the mark-recapture project. Radiotagging will be randomized so that fish are radiotagged throughout the shift (i.e., the first fish out of the bin is not always radiotagged but fish are randomly chosen throughout the shift). To randomize the selection of fish, the crew will determine the approach used to systematically radiotag the fish before the shift begins by choosing a number from 1 through 5 (e.g., if 4 is chosen, then every 4<sup>th</sup> fish removed from the fish wheels live boxes will be tagged until the goal for the shift is met). 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 96 d, and operate on several frequencies within the 150.000–152.999 MHz range. Fourteen frequencies will have up to 50 pulse codes, each resulting in a total of 700 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 inserted through the esophagus and into the upper stomach of the fish using a 1.0 cm (outside diameter), 30 cm long plastic tube. The antenna of the radio tag will be threaded through the tube and pinched by hand at the end of the tube, such that the radio transmitter is held tightly against the opposite end of the tube. The plastic tube will be marked with reference points to assist in proper tag insertion depths. Resistance felt during tag insertion will be the most useful indicator, and the esophagus will be visually inspected to ensure none of the radio tag body is visible. The rate of deployment of the radio tags will be determined by total radio tags allotted for 2018 and the historical catch rates of the fish wheels. This plan assumes 475 radio tags will be allocated for 2018 (not including the additional 200 described in Appendix C).

Radio tags will be deployed in proportion to the 2008 to 2017 average weekly catch of sockeye salmon at the two fish wheels located on opposite banks near Canyon Island, combined, in statistical weeks 23 through 39 (Table 1; Appendix A1). Only healthy adult sockeye salmon captured ( $\geq 350$  mm MEF) within each fish wheel, irrespective of sex or size (as long as the fish is  $\geq 350$  mm MEF) will be radiotagged. Radio tags recovered in U.S. and Canadian fisheries may be returned to ADF&G at the Douglas office or to the Canyon Island field camp for a \$5 U.S. cash reward. Recovered radio tags may be redeployed in new fish as necessary.

Movements of radiotagged fish will be monitored from time of release by a combination of fixed tracking towers located below and above the marking site (Figure 1) and through weekly aerial and boat surveys used to track radiotagged fish. Ten tracking towers will be used on the Taku River. One tracking tower will be placed below the marking site and two tracking towers will be placed above the marking site (one between the marking site and the Canadian test/commercial fishery, and one above the main Canadian test/commercial fishery). The distance between the tower at the border and the Tulsequah tower is approximately 9 km. One tracking tower will be placed near the confluence of the Nahlin and Sheslay rivers (start of the Inklin River), and two tracking towers will be placed near the Inklin/Nakina confluence (start of the Taku River mainstem). Radiotelemetry towers will also be placed on the four lake systems with weirs (Tatsamenie, King Salmon, Trapper, Kuthai). The radiotelemetry towers downstream of the tagging site will be used to estimate the emigration rate of radiotagged sockeye salmon from the study area. The upstream radiotelemetry towers will be used to estimate immigration rates into Canada. While aerial surveys will provide in-depth coverage of the majority of radiotagged fish in the drainage, a boat may also be used to obtain more detailed information on behavior and fate of radiotagged fish in the lower river that could not be adequately verified by aerial surveys. These

areas would most likely be Flannigan’s Slough, Tulsequah River, Johnson Creek, Sockeye Creek, Fish Creek, and Twin Lakes. The methodologies and equipment used to track radiotagged sockeye salmon by boat will be the same as via fixed-wing airplane (Yagi or H-style antennae/RC4052 receiver; described below).

Table 1.–The sampling goal for radio tags is 475 and the seasonal goal for biological sampling of scales and paired MEF/CAF lengths of sockeye salmon is 615. Proposed weekly tagging rate of sockeye salmon on the Taku River for radio tags is based on the average fish wheel catches from 2008 to 2017 combined from the two fish wheels.

Statistical Week (SW)	SW Start Date	Expected Proportion of Catch	Cumulative Proportion of Catch	Weekly Tag Deployment	Cumulative Radio Tag Deployment	Weekly Scale/Length Sampling	Cumulative Scale/Length Sampling
23	3-Jun	0.01	0.01	4	4	4	4
24	10-Jun	0.03	0.04	13	17	18	22
25	17-Jun	0.06	0.10	27	44	35	57
26	24-Jun	0.06	0.16	28	72	37	94
27	1-Jul	0.08	0.24	35	107	45	139
28	8-Jul	0.10	0.34	46	153	60	199
29	15-Jul	0.11	0.45	53	206	67	266
30	22-Jul	0.14	0.59	70	276	91	357
31	29-Jul	0.14	0.74	65	341	83	440
32	5-Aug	0.11	0.85	57	398	75	515
33	12-Aug	0.06	0.90	27	425	36	551
34	19-Aug	0.05	0.95	24	449	30	581
35	26-Aug	0.03	0.98	14	463	19	600
36	2-Sep	0.01	0.99	6	469	7	607
37	9-Sep	0.01	1.00	4	473	5	612
38	16-Sep	0.00	1.00	1	474	2	614
39	23-Sep	0.00	1.00	1	475	1	615

## TAG RECOVERY AND TRACKING RADIO TAGS

Tag recovery and secondary mark data will be obtained daily from the Canadian commercial and assessment fisheries. Drift and set gillnets are the principal gear types used in all inriver fisheries. These fisheries occur in Canadian portions of the Taku River within 20 km of the international border. Almost all fish are caught within 5 km of the border. A directed sockeye salmon fishery will take place from 26 June to 18 August, after which time fishing effort will shift to coho salmon. Weekly commercial fishing periods may range from one to seven days. It is anticipated that commercial fishing effort will be low by mid-September, and it will be necessary to conduct an assessment fishery in order to continue to estimate the abundance of coho salmon (William et al. 2016b). A small number of sockeye salmon may still be present at this time.

Commercial license conditions stipulate that both spaghetti and radio tags recovered from harvested sockeye salmon must be submitted to DFO personnel daily. Catch statistics, secondary mark data, and tag information will be collected daily by DFO personnel based at Ericksen Slough and reported to the Whitehorse office via satellite phone, internet phone, and/or email. This information will be forwarded by the Whitehorse office to the ADF&G office in Douglas via email.

Approximately 200 fish per week will be randomly sampled at the Canadian landing stations for matched age (two scales per fish) and CAF lengths (fish are landed headless and gutted rendering MEF lengths and gender unavailable), as well as tagging scars/secondary marks. Spaghetti tags are removed by fishermen prior to landing but spaghetti-tagged fish are identifiable by the presence of entrance and exit holes below the dorsal fin. Inspection of fish for these marks by the DFO crew will help identify if there is loss or non-reporting of spaghetti tags. Weekly sampling effort will be spread out over commercial fishery openings to the extent practical and will be conducted primarily at Cranberry Island, where the majority of landings occur. ADF&G staff will also recover small numbers of spaghetti tags from the U.S. inriver personal use fishery and the District 111 commercial drift gillnet fishery downriver from the fish wheels. As part of other studies, DFO staff will also collect 150 genetic and 192 otolith samples per week. Although the fish are landed headless and gutted and those fish are biologically sampled (age, length, genetics, mark inspection), fishermen save the removed heads in buckets for later otolith extraction. Therefore, it is not possible to match the heads (otolith samples) with the other biological samples. The heads are collected across fishery openings in proportion to the run as much as possible.

Observations and recoveries of spaghetti-tagged fish will also be made at upstream sockeye salmon enumeration weirs at the outlets of Little Trapper, Tatsamenie, Kuthai, and King Salmon lakes. Additional recoveries may also be made during escapement sampling activities directed at Chinook or sockeye salmon at the Nakina, Nahlin, and Tatsatua rivers, and in the mainstem Taku River. Recoveries at the weirs and during escapement sampling activities are only used for migratory timing estimates and to date have not been used in mark-recapture population estimates. Recoveries of radiotagged fish will also be used to identify spawning locations through radiotelemetry fixed towers, fixed-wing aerial surveys, helicopter surveys, and possibly boat surveys if warranted.

### **Fixed Towers**

Remote tracking towers will be placed at six locations to record movements (upstream or downstream passage) of radiotagged fish (Figure 1). The tracking towers will be constructed and operated as described by Eiler (1995), except that they will not have satellite up-link capabilities (also see Richards et al. 2016a). Each remote tracking tower 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 towers will be strategically placed to afford the antennae unobstructed downstream and upstream views. Radiotagged fish within reception range of the tracking towers will be uniquely identified by radio frequency and recorded on the data logger. The detection range of each tracking tower will be verified by placing radio tags in the water column through likely migration routes and observing preliminary data logger results. The tracking towers will record date and time that each radio tag is detected, the antenna that detected the tag (upstream, downstream, or both combined), the signal strength, and the activity pattern (active or inactive) of the radio tag. The tracking towers will be programmed to record data every 60 minutes. The location of each radio tag relative to the tower (upriver or downriver from the site) will be deduced by comparing the upstream and downstream antenna signal strengths. A reference radio tag placed near each tracking tower will verify that the tower components are functioning properly and to identify if/when the tracking tower stops working. Depending on the telemetry tower's location and accessibility, the tower will be checked from weekly to approximately every three weeks and the data will be downloaded from the receivers via a laptop computer and copied onto a separate external hard drive. A logbook will be maintained

at each tower noting date, staff, settings, and battery voltage for each visit. A checklist with radio receiver settings and the download steps will also be stored at each site.

### Aerial Surveys

Ten drainage-wide fixed-wing aerial surveys will be flown to identify spawning locations at two-week intervals starting around 1 July. Surveys will be conducted on the mainstem Taku River and the major spawning tributaries as well as those previously identified by Eiler et al. (1988, 1992). Antennas will be mounted on each side of the aircraft and both antennae will feed into one receiver via a switch box. An ATS™ 4520 receiver with internal GPS receiver will be used during the surveys to record the location of each fish. The date and time of decoding, and the frequency, pulse code, latitude and longitude, signal strength, and activity status of each decoded transmitter will be automatically recorded by the receiver. Spawning locations will be inferred by maximum upstream locations of radio tags and each fish will be then assigned to one of the general spawning locations as described in Table 2.

Table 2.—Known spawning locations of mainstem and lake stock components. Locations in the U.S. and Canada (CND) are labeled accordingly.

Lake	Mainstem
Tatsemenie Lake (CND)	Nahlin River (CND)
Little Trapper Lake (CND)	Nakina River (CND)
Kuthai Lake (CND)	Tulsequah River (CND)
King Salmon Lake (CND)	Hackett River (CND)
	Shustihini Slough (CND)
	Yellow Bluff Slough (CND)
	Sinwa Slough (CND)
	Tuskwa Slough (CND)
	Chunk Mt. Slough (CND)
	Chum Salmon Slough (CND)
	Yonakina Slough (CND)
	Fish Creek (U.S.)
	Stuhini Creek (CND)
	Yehring Creek (U.S)
	Kowatua Creek (CND)
	Tatsatua Creek (CND)
	Takwahoni Slough (CND)
	Honakta Slough (CND)

### FATES

The final “fate” of radiotagged fish will be assigned a two-digit code when radiotelemetry data are processed (Table 3). The left (“ones”) digit will indicate whether or not the tagged fish progressed upstream past the U.S. border. The right (“tenths”) digit will define a further fate for both those that progressed upstream of the border and those that did not.

Table 3.–List of fate codes to be recorded for all radiotagged sockeye salmon on the Taku River, 2018.

Fate Number	Fate Description
0.0	Never located, unknown fate
0.1	Never passed the border, regurgitated tag/died
0.2	Never passed the border, was recovered in a U.S. marine fishery
0.3	Never passed the border, tracked to a tributary below the U.S./Canada border
1.0	Passed the border, unknown fate
1.1	Passed the border, tracked to a probable spawning location
1.2	Passed the border, captured in the Canadian inriver fishery

## SAMPLE SIZE AND PRECISION

### Biological Sampling

The adult sockeye salmon ( $\geq 350$  mm MEF) age composition in the Taku River will be determined from a minimum of 615 scale samples collected from healthy, live fish irrespective of sex or size (as long as the fish is  $\geq 350$  mm MEF) at the two fish wheels. This sample size was selected based on work by Thompson (2002) for calculating a sample size to estimate several proportions simultaneously. A sample size of 510 scale samples is needed to ensure the estimated proportion of each adult age class will be within 5% of the true value 95% of the time. The sampling goal was increased to 615 scale samples to guarantee the sample size target would be achieved, even if 20% of the samples are unreadable.

A daily and weekly scale sampling schedule was developed based on average run timing at the fish wheels during statistical weeks 23 through 39, over the 10-year period 2008–2017 (Table 1; Appendix A2). Depending on whether the run is below or above average, the sampling rate may also be adjusted if it seems too few or too many samples are being collected. These sample sizes will also meet sex composition requirements, as only 385 samples (assuming no data loss) are necessary to achieve the precision criteria for estimating sex composition (Thompson 2002).

Only cliethral arch to fork of tail (CAF) measurements will be available from inriver commercial catch samples, because Canadian fish buyers prefer a headless, gutted product. Paired MEF and CAF measurements will be used to develop linear regressions for converting CAF lengths to MEF lengths. Based on a medium effect size, a significance level of 0.05, and a power of 0.95, a minimum sample of 130 paired MEF and CAF length measurements collected throughout the season will be adequate for a linear regression relationship (Cohen 1988). A medium effect size is defined as one that accounts for about 9% of the Y variance ( $R^2=0.10/(1+0.10)=0.09$ ). Sockeye salmon from different inriver stocks present different morphologies based on dates of adult entry into freshwater, migration distances, spawning dates, and incubation habitats (Blair et al. 1993; Quinn et al. 2001). Due to the size variability across stocks, paired MEF and CAF length measurements will be collected from 615 sockeye salmon throughout the season during fish wheel sampling (Table 1; Appendix A2). The CAF/MEF regression will be updated after the 2018 season.

All chum salmon will be sampled for sex, scales, and MEF lengths. The daily sampling goal for pink salmon is 25 fish; these fish will be sampled for sex and MEF lengths only. All Chinook salmon will be sampled for sex and MEF lengths and examined for missing adipose fins from late April through July. All Chinook salmon  $\geq 660$ mm MEF will be tested with a wand-type metal detector for the presence/absence of a coded wire tag (CWT) and recorded accordingly. All

adipose-clipped fish < 660mm MEF will be sacrificed and the heads will be recovered and sent to the ADF&G Mark, Tag, and Age Laboratory for CWT removal and decoding. Chinook salmon will not be tagged as part of the adult mark–recapture project or sampled for age during the 2018 season. Details on Chinook salmon sampling are presented elsewhere (Williams et al. 2016a; Jeff Williams, Sport Fish Biologist II, ADF&G, Douglas, personal communication; Ed Jones, Fish and Game Coordinator, ADF&G, Juneau, personal communication). All coho salmon will be sampled for sex, scales, MEF lengths, and presence/absence of an adipose fin. A mark–recapture study to estimate the number of adult coho salmon returning past the Canyon Island fish wheels will also be conducted between mid–June through early October as described by Williams et al. (2016b).

## **Radiotelemetry Project**

### *Objective One*

The total of 475 systematically deployed radio tags will provide an estimate of the proportion of mainstem versus lake spawning stocks with an absolute precision within 5% of the true proportion with at least 89% probability and no finite population correction factor. This estimate assumes a 32.5% dropout rate, 18.4% Canadian inriver test and commercial fishery harvest rate (e.g.,  $[475 \cdot 0.675] \cdot [1 - 0.184]$ ; Tables 4 and 5), and a worst-case scenario that the population proportion is equally distributed between the mainstem and lake spawning populations. Therefore, the effective sample size will be 261 radio tags (Thompson 2002). Dropout rates will only include tag loss (due to predation, handling, regurgitation or movement out of the river system into Taku Inlet), tag failure prior to upstream migration, and unknown fate (signal loss).

### *Objective 2*

Objective two is to identify the spawning locations of adult sockeye salmon ( $\geq 350$  mm MEF) through fixed-wing aerial surveys, helicopter surveys, boat surveys, and radiotelemetry towers so that spawning locations representing > 2% of the drainagewide spawning population of sockeye salmon are identified 99% of the time. In the worst-case scenario, spawners are distributed uniformly among approximately 50 locations (100% divided by 2%). The probability of detection of all 50 spawning locations is at least 76%, as follows: with 475 radio tags deployed, a 32.5% dropout rate, and approximately 60 radiotagged fish expected to be caught in inriver fisheries (18.4%), 261 radio tags will be available to identify spawning locations. Using a spatial Poisson process, the expected number of radio tags in locations that have at least 2% of the drainagewide spawning population,  $\lambda$ , is  $261 \cdot 0.02 = 5.22$ , the probability of detecting no radio tags in a location that contains 2% of the drainagewide spawning population is  $\frac{5.22^0}{0!} e^{-5.22} \approx 0.00541$ . The probability of detecting at least one radio tag in a location that contains 2% of the spawning population is  $1 - 0.00541 = 99.46\%$ . The probability of detecting all 50 possible spawning locations is  $(99.46\%)^{50}$  or approximately 76%.

Table 4.–Historical sockeye salmon above border abundance, above border harvests, and escapement for the Taku River, 1984 to 2017.

Year	Expanded Above Border Run Estimate <sup>a</sup>	Canadian harvest (test, commercial, aboriginal)	Canadian harvest (test, commercial, aboriginal) rate	Spawning Escapement	Terminal Run <sup>b</sup>	U.S. Harvest <sup>b</sup>
1984	141,254	27,292	0.193	113,962	198,873	57,619
1985	123,974	14,411	0.116	109,563	198,261	74,287
1986	115,045	14,939	0.130	100,106	175,689	60,644
1987	96,023	13,887	0.145	82,136	150,986	54,963
1988	92,641	12,967	0.140	79,674	118,427	25,785
1989	114,068	18,805	0.165	95,263	177,434	63,366
1990	117,573	21,474	0.183	96,099	226,858	109,285
1991	154,873	25,380	0.164	129,493	260,143	105,271
1992	167,376	29,862	0.178	137,514	288,551	121,176
1993	142,148	33,523	0.236	108,625	284,236	142,089
1994	131,580	29,001	0.220	102,579	229,642	98,063
1995	146,450	32,711	0.223	113,739	238,434	91,984
1996	134,651	42,025	0.312	92,626	322,379	187,727
1997	95,438	24,352	0.255	71,086	174,565	79,127
1998	89,992	19,277	0.214	70,715	139,824	49,832
1999	113,706	21,151	0.186	92,555	176,764	63,058
2000	115,693	28,468	0.246	87,225	246,954	131,262
2001	192,245	48,117	0.250	144,128	396,678	204,433
2002	135,233	31,726	0.235	103,507	251,633	116,400
2003	193,390	33,024	0.171	160,366	330,332	136,942
2004	127,047	20,359	0.160	106,688	204,059	77,012
2005	142,155	22,102	0.155	120,053	188,244	46,089
2006	167,597	21,446	0.128	146,151	233,425	65,828
2007	105,012	17,249	0.164	87,763	170,141	65,129
2008	87,568	19,509	0.223	68,059	163,260	75,692
2009	83,097	11,260	0.136	71,837	119,329	36,232
2010	109,028	20,661	0.190	88,367	155,795	46,767
2011	139,926	24,543	0.175	115,383	211,731	71,805
2012	156,877	30,113	0.192	126,764	207,612	50,736
2013	106,350	25,173	0.237	81,177	206,493	100,144
2014	109,984	17,795	0.162	92,189	143,210	33,226
2015	152,372	19,849	0.130	132,523	194,426	42,054
2016	213,851	37,434	0.175	176,417	288,054	74,203
2017	138,796	30,379	0.219	108,416	213,426	74,630
Average (08-17)	129,785	23,672	0.184	106,113	190,334	60,549
Maximum (08-17)	213,851	37,434	0.237	176,417	288,054	100,144
Minimum (08-17)	83,097	11,260	0.130	68,059	119,329	33,226

<sup>a</sup> The above border run mark-recapture estimate is expanded by an agreed upon factor; estimate/(1-expansion factor) which ranges from 0.001 to 0.128

<sup>b</sup> U.S. harvest and terminal run size are preliminary. U.S. harvest includes D111 gillnet harvest, D111 Amalga seine harvest, and personal use harvest.

Table 5.–Effective sample sizes needed for estimating binomial proportions at a desired precision of  $\pm 0.05$  and a given probability (0.89–0.94) with no finite population correction factor, a 32.5% dropout rate, and an 18.4% harvest rate based on Thompson (2002).

Initial sample size	Sample size after 32.5% dropout rate	Sample size after inriver fishery (18.4% harvest rate)	Probability ( $\alpha$ ) after dropout + inriver fishery
675	456	372	0.94 ( $\alpha=0.06$ )
475	321	261	0.89 ( $\alpha=0.11$ )

# STATISTICAL METHODS

## MARK–RECAPTURE PROJECT

Two-event mark–recapture studies for a closed population (Seber 1982) will be used to estimate the abundance of Taku River sockeye salmon. Adult sockeye salmon will be marked at the fish wheels with a spaghetti tag in the first sampling event (marking) and then sampled on a daily basis from the inriver commercial fishery and anticipated test fishery in the second sampling event (recapture).

The general assumptions that must be met for a mark–recapture estimate to be consistent were provided by Seber (1982:59):

1. all adults have an equal probability of being marked;
2. all adults have an equal probability of being sampled for marks;
3. there is no recruitment or emigration to the population between the fish wheels and the sampling sites upstream (i.e., the population is closed) and the rate of death of tagged and untagged fish is the same;
4. there is no trap induced behavior; and
5. there is no tag loss due to shedding, misidentification, or nonreporting.

An additional assumption based on a stratified estimate is that,

6. all adults released in an initial stratum have the same probability distribution of movement to the final recapture strata.

The first assumption will be true if fishing effort and catchability is constant for all “stocks” (fish that spawn in the same area). Although catchability can vary with changing river conditions, fish will be tagged in proportion to the run (e.g., every healthy fish will be spaghetti tagged and radio tags will be proportioned throughout the run based on historical run timing) and tagged and untagged fish are assumed to mix prior to recapture on the fishing grounds. Recoveries of spaghetti-tagged (marked) fish on the spawning grounds could potentially be used as a secondary test of representative marking during the first event. If non-proportional tagging occurs, the proportions will be stratified by time.

The first five assumptions can be easily generalized to a stratified estimate. The closed population assumption is true for the Taku River sockeye salmon populations; each sampling day is a snapshot of the sockeye salmon population as the fish move past the fish wheels. The population’s location in time functions as if it were a location in space; a salmon population passing the fish wheels in a time stratum could be considered a closed population (Schwarz and Taylor 1998).

Although there should be no trap induced behavior in this study because different sampling gears are used for different sampling events, and capture and handling techniques have been highly refined on the Taku River over the past 22 years of spaghetti tagging (only healthy fish are tagged, and the utmost care is given to each fish; Boyce and Andel 2014), there was a high radio tag dropout rate in the 2017 season. The cause of the high dropout rate from the 2017 season is unknown. Other studies have documented adverse effects of fish captured and handled in fish wheels with extended holding times (Bromaghin and Underwood 2003; Cleary 2003; Underwood et al. 2004; Bromaghin et al. 2007; Liller et al. 2011). Therefore, fish handling at the fish wheels

will be modified for the 2018 season to try to reduce handling stress. The aim of the revised method is for fish holding time to not exceed one hour in the fish wheel live boxes. Also, in 2018, a study will be conducted to compare the dropout rates of radiotagged fish that experienced reduced holding times to radiotagged fish held in live boxes for a longer period of time (i.e., similar to holding times used in the past) (Appendix C).

Although tag loss and non-reporting of tags is assumed to be negligible because of the close proximity of the fishery to the fish wheels (McGregor et al. 1991; Kelley et al. 1997), 200 fish/week will be inspected for secondary/spaghetti-tagging needle marks at the Canadian buying stations. The proportion of secondary marks observed in the commercial and test fisheries samples will then be compared to spaghetti-tag recovery rates to determine if tag shedding or non-reporting has occurred.

Spaghetti-tag release and recovery data will be organized by statistical week for analysis. Statistical weeks begin at 00:01 AM Sunday and end the following Saturday at midnight, with weeks being numbered sequentially beginning with the week encompassing the first Saturday in January. Data will be stratified into size classes after the completion of the mark–recapture project. The Kolmogorov-Smirnov 2-sample test (Conover 1980) will be used to determine if size-selective sampling occurred during the first or second sampling events (Appendix B1). Only CAF measurements are available from inriver commercial catch samples, because Canadian fish buyers prefer a headless, gutted product. Therefore, paired MEF and CAF measurements will be used to develop linear regressions for converting CAF lengths to MEF length for the fishery landings. Chi-square tests will be used to detect sex selectivity during the second sampling event (M versus R; Appendix B1). Chi-square tests cannot be used to detect sex selectivity during the first sampling event (C versus R; Appendix B1), because the sex of headless and gutted fish cannot be identified.

To generate inriver sockeye salmon run estimates on an inseason basis each year, mark–recapture data will be analyzed using the software program Stratified Population Analysis System (SPAS) (Arnason et al. 1996). The program SPAS will be used to evaluate the adequacy of using the Chapman modified pooled-Petersen estimator (PPE) versus the stratified maximum likelihood (ML) Darroch estimator (Darroch 1961; Seber 1982; Appendix B2). One of two conditions must be satisfied for the PPE to be unbiased and the preferred model. The first condition, “complete mixing,” states that recovery probabilities are constant across strata. The second condition, “equal proportions,” states that the expected ratio of marked to unmarked individuals is constant across all recovery strata due to similar migration patterns. Chi-square tests will be used to evaluate these conditions. If either of these conditions are satisfied ( $P > 0.05$ ), based on the output of the chi-square tests, the PPE will be considered the appropriate model and will be used as the abundance estimate (Arnason et al. 1996).

Let  $M$  denote the number of fish marked at the Taku River fish wheels,  $C$  denote the number of fish examined for marks at a different time period (inriver Canadian and test fisheries), and  $R$  denote the number of fish in the second sample that were marked. Then, the estimated abundance ( $\widehat{N}$ ) is calculated as (Seber 1982),

$$\widehat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1, \quad (1)$$

with variance,

$$\text{var}(\widehat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \quad (2)$$

The approximate 95% confidence intervals for  $\hat{N}$  based on a normal distribution is

$$\hat{N} \pm 1.96\sqrt{\text{var}(\hat{N})}, \quad (3)$$

and the coefficient of variation (CV) is

$$\text{CV}(\hat{N}) = \frac{\sqrt{\text{var}(\hat{N})}}{\hat{N}} (100\%). \quad (4)$$

If neither of the conditions of the chi-square tests is met, to reduce bias, the stratified ML Darroch estimator will be used to estimate abundance. Strata that contain zero recoveries or releases will be dropped from the analysis and partial pooling of the recovery and marking strata will be conducted. Partial pooling will be guided by pooling of adjacent strata with similar initial capture or recapture probabilities, pooling of adjacent strata with few initial capture or recapture numbers, minimization of the number of cells with  $\{M_{ij}\} < 5$  (the total number of fish tagged in stratum  $i$  and recovered in recovery stratum  $j$ ) to avoid problems of sampling zeros, goodness of fit (GOF) tests, additional chi-square tests, minimization of the standard error of the abundance estimate, and formulation of admissible ML Darroch estimates of abundance (Arnason et al. 1996; Schwarz and Taylor 1998). If a recovery stratum has few counts it may be an indication that little movement occurred to this stratum; e.g., fish in this stratum died before reaching the inriver fishery (event 2), the recovery effort was small, the stratification interval (time period) was too small, or the catchability of the fish wheels or the fishery changed due to fluctuating riverine conditions. In this case, two or more recovery strata may be temporally pooled. The GOF tests will be used to assess the adequacy of the stratified model for lack of fit. These include nonadmissible estimates of abundance due to failure of the ML algorithm to converge, or convergence to unrealistic estimators such as negative capture probabilities or negative stratum abundances. Other than GOF statistics, there are no formal tests to determine if one should pool or drop strata (Arnason et al. 1996; Schwarz and Taylor 1998).

Inriver sockeye salmon run estimates will be generated inseason on a weekly basis in 2018. After each week of the directed sockeye salmon commercial fishery, data will be analyzed and inriver abundance estimates will be calculated by ADF&G personnel in Douglas and/or by DFO personnel in Whitehorse. Historical migratory timing data will be used each week to project the total inriver run size for the season. Due to the estimated three to four days travel time for fish between the District 111 commercial drift gillnet fishery and Canyon Island (Clark et al. 1986), and since most spaghetti tags applied at the Canyon Island fish wheels are not recovered until the following week in the Canadian fishery, the estimates of inriver abundance will correspond to the movement of Taku River sockeye salmon through District 111 approximately one to two weeks earlier.

## **RADIOTAGGING PROJECT**

Assumptions of the radiotagging study include: 1) sockeye salmon will be radiotagged in proportion to the run, 2) radiotagging will not change the destination (fate) of a fish, and 3) fates of radiotracked fish will be accurately determined.

The first assumption will be true if fishing effort and catchability is constant for all “stocks” (fish spawning in the same area) that enter the river. Sampling effort will be held as consistent as possible during the immigration. If non-proportional tagging occurs, the proportions will be stratified by time and CPUE. If fishing effort in event 1 and/or the Canadian fishery is not consistent across the run, or if run timing is correlated to the final destination of the fish, this will

affect the ratios of radiotagged fish observed in the various spawning areas.

The third assumption will be true if 1) the remote tracking towers and radio tags remain operational throughout the project, 2) remote tracking towers are able to detect all radiotagged fish passing the site, 3) aerial surveys are able to detect all radiotagged fish, and 4) aerial surveys locate radiotagged fish at their final destination. It is likely that radiotelemetry towers and radio tags will remain operational throughout the project and concerted effort will be made to ensure proper installation, testing, and monitoring of all remote tracking towers. Eiler (1995) found tracking success to be >97% for radiotagged Chinook salmon that passed undamaged remote tracking towers on the Taku River, and other Chinook salmon telemetry studies in Southeast Alaska have experienced similar high detection rates (Johnson et al. 1992; Pahlke and Bernard 1996; Pahlke et al. 1996; Pahlke and Etherton 1999; Richards et al. 2008; Weller and Evans 2012). Aerial surveys may not detect the final destination of radiotagged fish if the first survey occurs after fish have reached their final destination and their carcasses have washed downstream, or if the last survey is conducted before radiotagged fish have reached their final destination. We assume that all radiotagged fish that successfully spawn should be at or near their spawning location during at least one of the aerial tracking surveys (Richards et al. 2014).

### **Migratory Timing and Travel Rates**

For the secondary objectives, migratory timing and travel rate statistics will be calculated for individual sockeye salmon stocks (Kuthai, Little Trapper Lake, Tatsamenie, and King Salmon stocks) and pink and chum salmon. These statistics are useful for characterizing the annual timing of fish migrations and for comparing the timing of migrations between years. Although spaghetti tags can provide some migratory timing information, radio tags can provide timing statistics at a finer spatial and temporal resolution. Therefore, migratory timing and travel rates will be calculated separately from both radio and spaghetti-tagged fish.

Migratory timing profiles can be described as time density. Two simple features of the time density are mean date and variance or dispersion of the migration through time. Fish wheel CPUE will be used as an index of the abundance of fish migrating past the Canyon Island fish wheels, and migratory timing statistics will be calculated following the procedures of Mundy (1979, 1982, 1984). Mean date of passage in a migration of  $m$  days will be estimated by,

$$\bar{t} = \sum_{t=1}^m tP_t \quad (5)$$

where:

$\bar{t}$  = the estimated mean day of the migration ( $t=1$  is the first day of the migration and  $m$  is the last day), and

$P_t$  = the proportion of the total cumulative fish wheel CPUE that occurred on day  $t$  (the CPUE on time interval  $t$  divided by the total CPUE).

The calculated mean date is reported as the corresponding calendar date. The variance of the migrations will be estimated by,

$$\hat{S}_t^2 = \sum_{t=1}^m (t - \bar{t})^2 P_t. \quad (6)$$

The timing of individual sockeye salmon stocks past Canyon Island will be derived from recoveries of radiotagged fish on the spawning grounds and will be weighted by fish wheel CPUE to permit the escapement of a particular stock to be apportioned to week of passage past Canyon Island. The proportion of the run occurring each week for each stock is

$$P_{js} = \frac{C_j T_{js}}{T_j - T_{jc} - T_{jd}} / \sum_{j=23}^{39} \frac{C_j T_{js}}{T_j - T_{jc} - T_{jd}}, \quad (7)$$

where:

$j$  = the statistical week of interest,

$C_j$  = the weekly proportion of the total season's fish wheel CPUE,

$T_{js}$  = the number of spawning ground recoveries of stock  $s$  that were radiotagged in statistical week  $j$ ,

$T_j$  = the number of fish radiotagged in the fish wheels in statistical week  $j$ ,

$T_{jc}$  = the number of fish radiotagged at the fish wheels in statistical week  $j$  and caught in the Canadian inriver fishery, and

$T_{jd}$  = the number of fish radiotagged at the fish wheels in statistical week  $j$  but 'dropped-out'.

Migratory timing is likely influenced by many factors including water level and tagging-induced behavior. An assumption implicit in this calculation is that the removal of fish by the Canadian inriver fishery does not alter the migratory timing distribution of individual stocks. This assumption may be violated because the harvest rate of the Canadian fishery on the inriver run varies among fishing periods. "Sulking" behavior, or the tendency for a salmon captured and tagged during upstream migration in a river to pause or move downstream before continuing upstream movement, can result in slower initial migration rates for tagged individuals (Bernard et al. 1999). To account for this, the number of days it takes an individual radiotagged fish to travel from the Canyon Island fish wheels to the first fixed tracking tower (Flannigan) will be used as an adjustment to the migratory timing rates of the spaghetti-tagged fish from the fish wheels to the spawning areas.

### Spawning Distributions

If we assume that the population migrating past each of the two fish wheels was proportionally tagged, the proportion of sockeye salmon destined for probable spawning location  $i$  will be estimated as (Cochran 1977; pg. 52),

$$\hat{p}_i = \frac{r_i}{r}, \quad (8)$$

where:

$r_i$  = number of radiotagged fish out of  $r$  assumed to have spawned in location  $i$ , and

$r$  = number of radiotagged fish released from the marking site that retained upstream migration and were assigned to a probable spawning location.

The variance of  $\hat{p}_i$  will then be estimated by (Cochran 1977; pg. 52),

$$\text{var}(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{r-1}. \quad (9)$$

If the assumption of proportional tagging was not met, the number of fish with radio tags  $r$ , distributed by time stratum  $j$  and spawning location  $i$  will be adjusted to compensate for unequal effort and unequal tagging fractions over time (Ericksen and Chapell 2006),

$$r'_{ij} = \frac{r_{ij}}{\hat{\phi}_j}, \quad (10)$$

where  $\hat{\phi}_j$  = the proportion of sampled fish that were radiotagged, adjusted for unequal fishing wheel effort over time,

$$\hat{\phi}_j = \frac{x_{1j}+x_{2j}}{X_{1j}\frac{H_{1j}}{h_{1j}}+X_{2j}\frac{H_{2j}}{h_{2j}}}, \quad (11)$$

where:

$X$  = number of sockeye salmon caught in fish wheels (fish wheel designation by subscript 1, 2),

$x$  = number of sockeye salmon radiotagged in fish wheels (fish wheel designation by subscript 1, 2),

$H$  = total possible number of hours of fish wheel operation (fishing effort), and

$h$  = actual number of hours of fish wheel operation (fishing effort).

All quantities are specific to time stratum  $j$ . Then, the proportion of fish that spawn in location  $i$  will be estimated as

$$\hat{q}_i = \frac{\sum_j^{\text{weeks}} r'_{ij}}{\sum_i^{\text{fates}} \sum_j^{\text{weeks}} r'_{ij}}, \quad (12)$$

with approximate variance,

$$\text{var}(\hat{q}_i) \cong \frac{\hat{q}_i(1-\hat{q}_i)}{\sum_j^{\text{weeks}} (x_{1j}+x_{2j})-1}. \quad (13)$$

Equation 13 is restricted to those fish that were assigned a spawning fate.

## DATA REDUCTION

The ADF&G tagging crew leader (FB I), Fish & Wildlife Technician III, and Fish & Wildlife Technician II at Canyon Island will record and error check all data from the tagging operation. Errors may consist of incorrect dates, transposed nonsensical lengths (e.g., 360 mm when the fish was actually 630 mm or CAF length > MEF length), and transposed or nonsensical tag numbers. Data forms will be kept up to date at all times. Data will be sent to the ADF&G office in Douglas at regular intervals (preferably the same day but no later than the next morning by 8:20am) and inspected for accuracy and compliance with sampling procedures. Data will be transferred from

field books or forms to Excel spreadsheet files using ONLY state computers. Catch figures and tag release totals will be forwarded daily from Douglas to the DFO office in Whitehorse. The ADF&G project biologist (Andel) will ensure all data sent from camp are collated, entered, and given a final check for errors. Feedback will be given to camp to fix common errors discovered during the season.

The DFO tag recovery team will process data from the Canadian fisheries in a similar manner and send them to Whitehorse. Catch figures, tag recoveries, and secondary mark data will be forwarded daily from Whitehorse to the Douglas office.

The DFO project biologist (Foos) will ensure data from Kuthai, Little Trapper, King Salmon, and Tatsamenie lakes, and the Nakina and Nahlin rivers, are collated and error-checked. Weir escapement data received from DFO should be forwarded to ADF&G office each week inseason.

Scale cards MUST have the names of all personnel at the fish wheels at time of sampling written on each card (this will always be at least three names: the dipper, the tagger, and the data recorder). Scale cards will be checked at camp to ensure that scales are clean and mounted correctly, labeled correctly, and match up with the corresponding Opscan data form. Scales will be remounted when necessary. Scale samples from the Canyon Island fish wheels will be pressed and read in Douglas at the ADF&G Commercial Fisheries scale-aging lab (Iris Frank); likewise, scale samples from the Canadian fisheries and spawning areas will be processed at the DFO Pacific Biological Station (PBS) in Nanaimo, B.C.

## **DATA ARCHIVING**

Copies of the data used to produce the final report will be provided to Research and Technical Services (Division of Sport Fish-Anchorage) for archiving. Tagging site scale cards and acetates will be archived at the ADF&G Douglas scale-aging lab. Recovery site scale cards and acetates will be archived at the Nanaimo PBS lab. ADF&G is also currently in the process of creating a data entry platform to capture current and historical fish wheel project data, which will then be archived in the ADF&G Integrated Fishery Database.

## **SCHEDULES**

### **OPERATIONS**

Field activities for tagging salmon at the Canyon Island fish wheels will begin approximately 3 June and extend to 31 August. Field activities for recovery of tagged sockeye salmon from Canadian fisheries will begin when the commercial fishery starts. Sampling will continue through the coho salmon commercial fishery and conclude with the anticipated coho salmon test fishery. All tracking towers will be installed and functioning prior to any fish being radiotagged and will be checked at, depending on location and accessibility, from once weekly to approximately every three weeks. Data will be downloaded via a laptop computer and will be immediately copied onto a second portable, external hard drive. All telemetry data and genetic samples will be sent weekly to James Andel at the ADF&G office in Douglas.

### **DATA EXCHANGE (ALASKA DEPARTMENT OF FISH AND GAME)**

The Taku Field Data spreadsheet, which contains all data collected from camp, such as fish caught, fish tagged, fish wheel performance, etc., will be sent to the Douglas Office after the last wheel check of the day. If this becomes problematic, data will be sent no later than 8:20 am the following morning.

If internet interruptions occur, internet bandwidth is crimped, or spreadsheet errors occur, data will be typed in the text of an e-mail and reduced to fish caught, effective tags out, and fish wheel sampling time. A single-side band radio will also be re-established at camp for back-up purposes. If neither of the above methods works, a copy of the data file should be taken to the Taku Lodge to be flown to Juneau on the next available flight.

## **DATA EXCHANGE (DEPARTMENT OF FISHERIES AND OCEANS/ ALASKA DEPARTMENT OF FISH AND GAME)**

Canyon Island fish wheel effort, catch, tag, and hydrological data, and Canadian commercial fishery effort, catch and tag data will be exchanged daily inseason.

Detailed, preliminary Canyon Island/Canadian fishery size and tag data, as well as escapement tag data will be exchanged by 1 November 2018.

Final error-checked effort, catch, tag, and size data from Canadian fisheries and escapements will be available by 1 January 2019.

Final error-checked Canyon Island fish wheel effort, catch, tag, size, age and hydrological data will be available by 1 January 2019.

Age results from Canadian fisheries and escapements will be available by 1 January 2019.

## **REPORTING**

A draft report will be written by the lead author (Andel) and provided to the second author (Huebschwerlen) for input by 1 March 2019. Edits will be incorporated by 15 March 2019. The final report will be distributed for publication by 1 April 2019.

## **RESPONSIBILITIES**

### **I. PARTY RESPONSIBILITIES**

#### **U.S.**

ADF&G, Division of Commercial Fisheries will take lead role in project planning, implementation and reporting for the U.S. Will plan project in cooperation with DFO, ADF&G sportfish division, and TRTFN. Will write operational plan with DFO. Will provide up to three seasonal technicians and all required equipment for Canyon Island tagging. Will summarize all tagging data from Canyon Island operations in spreadsheets and provide to DFO. Will cover the logistics associated with U.S. tag recoveries and provide tag rewards to U.S and Canadian fishermen who return radio tags. Will convert all data collected into digital format, and conduct quality-control checks. Will develop/review SPAS estimates for Taku sockeye salmon abundance inseason and post-season. Will assist with escapement sampling of mainstem stocks as required. Will provide all ATS telemetry receivers and about one half of the remote tracking towers and associated hardware. Will purchase all radio tags and necessary hardware. Will install and monitor all remote tracking towers on the lower Taku River. Will conduct radiotracking flights. Will be the primary author on the final radiotelemetry report covering this work. Will co-author the annual mark-recapture report.

#### **Canada**

DFO will take lead role in project planning, implementation and reporting for Canada. Will plan project in cooperation with ADF&G and TRTFN. Will write operational plan with ADF&G. Will

obtain sample/catch statistics, spaghetti and radio tags, and secondary mark data from the Canadian fisheries and contribute to Canyon Island tagging operations with two technicians. Will contract weir enumeration at Little Trapper and Tatsamenie lakes and conduct escapement sampling on the Nahlin and mainstem Taku rivers as required. Will collate data from recovery locations. Will convert all data collected into digital format and conduct quality-control checks. Will provide ADF&G with all data listed above as per schedule outlined in previous section. Will develop/review SPAS estimates for Taku sockeye salmon abundance inseason and post-season. Will provide about one half of the remote tracking towers and associated hardware. Will be primary author on the mark-recapture report and will co-author radiotelemetry report.

TRTFN will participate in project planning with DFO and ADF&G. Will operate enumeration weirs at Kuthai and King Salmon lakes and assist with additional escapement sampling/enumeration as required.

## **II. PERSONNEL RESPONSIBILITIES**

Jim Anandel, ADF&G FB II, Project Leader/Expeditor. In concert with Aaron Foos (DFO), will set up all aspects of project including planning, crew scheduling, budget, sample design, equipment, personnel, and training. Directly supervises Canyon Island operations. Coalesces, edits, analyzes, and reports data; assists with fieldwork when necessary. Provides feedback when required. Develops/reviews SPAS estimates. Incorporates SPAS estimates into the District 111 mixed stock fishery model to estimate wild Taku sockeye salmon harvest/escapement and total allowable catch of Taku sockeye salmon in District 111. Hires ADF&G seasonal technicians and supervises and evaluates entire ADF&G Canyon Island crew.

Aaron Foos/Bonnie Huebschwerlen, DFO. In concert with Jim Anandel, will assist in all aspects of the program, including: tag application, tag recovery, and report preparation and be responsible for scheduling Canadian staff at both the tagging and recovery sites. Will also participate in both the tagging and recovery component of the program, arrange and participate in meetings with Canadian commercial and Aboriginal fishermen, provide recovery data to ADF&G, and, review data, provide input on reports, write sections regarding recovery and serve as co-author.

Cory Whiteley, ADF&G FB I. This position will be responsible for leading all field aspects of the Canyon Island tagging portion of the project under the direction of the Project Leader (Anandel). Ensures the operational plan and other departmental guidelines are followed through the course of this study. Ensures that all crew members are given necessary on-site instruction and training to accomplish all field activities, including fish wheel construction and maintenance, fish handling and tagging, species identification, data collection and recording, conduct in the public's eye, camp organization/cleanliness, and adherence to Departmental policies. Will be responsible for basic equipment maintenance and operation, and submitting data and maintenance schedules accurately and timely to ADF&G office in Douglas. Under guidance of the Project Leader (Anandel) will adjust fieldwork activities and schedules as necessary for full participation in fish wheel checks and data sending routines. With Anandel, will attempt to resolve as many personnel and administrative issues as possible. Will also be responsible for inventories at beginning and end of season. Will also provide Anandel with an end of season purchase list for spring of 2019.

Gordon Krueger, FWT III. This position will be responsible for fish wheel design, construction, set-up, breakdown, and maintenance. This position also assists in all field aspects of the Canyon Island portion of the project under the direction of Whiteley and Anandel. This includes following

operational plan for tagging and safe operations of all field equipment. Will send fish effort and tagging data once per week.

Joshua David Miller, FWT II. This position will be responsible for assisting in all field aspects of the Canyon Island portion of the project under the direction of Whiteley, Krueger, and Anandel. This includes following operational plan for tagging and safe operations of all field equipment. Will assist in fish wheel construction and placement and maintenance of all field equipment and general camp duties as needed.

Ashleigh Stephens, FWT II. This position will be responsible for assisting in all field aspects of the Canyon Island portion of the project under the direction of and Whitely, Krueger, and Anandel. This includes following operational plan for tagging and safe operations of all field equipment. Will assist in fish wheel construction and placement and maintenance of all field equipment and general camp duties as needed.

Olivia Sasser, FWT II. This position will be responsible for assisting in all field aspects of the Canyon Island portion of the project under the direction of and Whitely, Krueger, and Anandel. This includes following operational plan for tagging and safe operations of all field equipment. Will assist in fish wheel construction and placement and maintenance of all field equipment and general camp duties as needed.

Andy Piston, ADF&G FB IV. This position supervises Anandel and oversees all aspects of this project, including review of project goals, budgets, operational plan, and reports.

Richard Brenner, ADF&G Salmon Stock Assessment Biologist. This position is responsible for general oversight of this project. Reviews project planning, operational plans, and technical reports.

Sara E. Miller, ADF&G Biometrician II. Provides input to and approves sampling design. Reviews operational plan and provides biometric details. Writes programming code for statistical analysis. Reviews and conducts analysis in concert with project leaders for the final report.

## **REPORTS**

The mark–recapture and radiotelemetry reports will be co-authored by the principal investigators from DFO and ADF&G. Aaron Foos will serve as lead author for the mark–recapture report for the 2018 field season. It will be published in the Pacific Salmon Commission Technical Report series. It may also be published in departmental report series as a Canadian Manuscript Report of Fisheries and Aquatic Sciences and/or an ADF&G Fishery Data Series report. Jim Anandel will serve as lead author for the radiotelemetry report for the 2018 field season to be published in ADF&G Fishery Data Series. Project results will also be summarized in the annual report of the Pacific Salmon Commission Transboundary Technical Committee.

### **Principal Investigators**

James Anandel, Fishery Biologist, ADF&G

Aaron Foos, Stock Assessment Biologist, DFO

### **Assisting Personnel**

Andrew Piston, Fishery Biologist, ADF&G

Cory Whiteley, Fishery Biologist, ADF&G

Bonnie Huebschwerlen, Fisheries Biologist, DFO

Bill Waugh, Fishery Manager, DFO

Timothy Ackerman, Fishery Technician, ADF&G  
Adam Brennan, Fishery Technician, DFO  
Teresa Bachynski, Fishery Technician, DFO  
Gordon Krueger, Fishery Technician, ADF&G  
Joshua Miller, Fishery Technician, ADF&G  
Mark Connor, Manager, TRTFN  
Brian Mercer, Contract Biologist, DFO  
Chris Kirby, Fisheries Technician, TRTFN  
Tori Knutson, Fishery Technician, DFO  
Danielle Hosick, Fishery Technician, DFO

## REFERENCES CITED

- Andel, J. E., and I. M. Boyce. 2014a. Mark–recapture studies of Taku River adult sockeye salmon stocks in 2011. Pacific Salmon Commission, Technical Report No. 31, Vancouver.
- Andel, J. E., and I. M. Boyce. 2014b. Mark–recapture studies of Taku River adult sockeye salmon stocks in 2010. Pacific Salmon Commission, Technical Report No. 30, Vancouver.
- Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark–recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106.
- Bernard, D. R., J. J. Hasbrouch, and S. J. Fleischman. 1999. Handling-induced delay and downstream movement of adult Chinook salmon in rivers. *Fisheries Research* 44:37–46.
- Blair, G. R., D. E. Rogers, and T. P. Quinn. 1993. Variation in life-history characteristics and morphology of sockeye salmon in the Kvichak River system, Bristol Bay, Alaska. *Transactions of the American Fisheries Society* 122:550–559.
- Boyce, I. M., and J. E. Andel. 2014. Mark–recapture studies of Taku River adult sockeye salmon stocks in 2012 and 2013. Pacific Salmon Commission, Technical Report No. 32, Vancouver.
- Bromaghin, J. F., and T. J. Underwood. 2003. Evidence of residual effects from tagging Yukon River fall chum salmon in 2001. U. S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 67, Anchorage.
- Bromaghin, J. F., T. J. Underwood, and R. F. Hander. 2007. Residual effects from fish wheel capture and handling of Yukon River fall chum salmon. *North American Journal of Fisheries Management* 27: 860–872.
- Champely, S. 2018. pwr: Basic Functions for Power Analysis. R package version 1.2-2. <https://CRAN.R-project.org/package=pwr>.
- Clark, J. E., A. J. McGregor, and F. E. Bergander. 1986. Migratory timing and escapement of Taku River salmon stocks, 1984–1985. *In* ADF&G (Alaska Department of Fish and Game) Section Report in 1985 Salmon Research conducted in Southeast Alaska by the Alaska Department of Fish and Game in conjunction with the National Marine Fisheries Service Auke Bay Laboratory for Joint U.S.-Canada Interception Studies. Division of Commercial Fisheries, Final Report, Contract Report WASC-85-ABC-00142, Juneau.
- Cleary, P. M. 2003. Effects of fish wheels on fall chum salmon (*Oncorhynchus keta*): non-esterified fatty acids and plasma indices of stress. M. S. Thesis. University of Alaska, Fairbanks.
- Cochran, W. G. 1977. *Sampling Techniques*, 3rd edition. John Wiley and Sons, New York.
- Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Lawrence Erlbaum Associates, Hillsdale, NJ.
- Conover, W. J. 1980. *Practical Nonparametric Statistics*, 3rd edition. John Wiley and Sons, New York.
- Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. *Biometrika* 48:241–260.
- Eiler, J. H. 1995. A remote satellite-linked tracking system for studying Pacific salmon with radiotelemetry. *Transactions of the American Fisheries Society* 124:184–193.
- Eiler, J. H., B. D. Nelson, R. F. Bradshaw, J. R. Greiner, and J. M. Lorenz. 1988. Distribution, stock composition, and location and habitat type of spawning areas used by sockeye salmon on the Taku River. NWAFC Processed Rep. 88-24, 43 p. Auke Bay Laboratory, Alaska Fisheries Science Center, Natl. Mar. Fish. Serv., NOAA, 11305, Juneau.
- Eiler, J. H., B. D. Nelson, and R. F. Bradshaw. 1992. Riverine spawning by sockeye salmon in the Taku River, Alaska and British Columbia. *Transactions of the American Fisheries Society* 121:701–708.

## REFERENCES CITED (Continued)

- Eiler, J. G., M. M. Masuda, T. R. Spencer, R. J. Driscoll, and C. B. Schreck. 2014. Distribution, stock composition and timing, and tagging response of wild Chinook salmon returning to a large, free-flowing river basin. *Transactions of the American Fisheries Society* 143:1476–1507.
- Elliott, B. W., and S. J. H. Power. 2016. Production and harvest of Chilkat River Chinook and coho salmon, 2016–2017. Alaska Department of Fish and Game, Regional Operational Plan No SF.1J.2016.16, Anchorage.
- Ericksen, R. P., and R. S. Chapell. 2006. Production and spawning distribution of Chilkat River Chinook salmon in 2005. Alaska Department of Fish and Game, Fishery Data Series No. 06-76, Anchorage.
- Johnson, R. E., R. P. Marshall, S. T. Elliott. 1992. Chilkat River Chinook salmon studies, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92–49, Anchorage.
- Kelley, M. S., and P. A. Milligan. 1997. Adult mark–recapture studies of Taku River adult salmon stocks in 1996. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 1J97-22, Juneau.
- Kelley, M. S., P. A. Milligan, and A. J. McGregor. 1997. Adult mark–recapture studies of Taku River adult salmon stocks in 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 1J97-01, Juneau.
- Koehn, J. D., 2000. Why use radio tags to study freshwater fish? Pages 24–32 [In] D. A. Hancock, D. Smith and J. D. Koehn, editors. Workshop Proceedings, Bendigo, Victoria, September 1999. Australian Society for Fish Biology, Sydney.
- Liller, Z. W., K. L. Schaberg, and J. R. Jasper. 2011. Effects of holding time in a fish wheel live box on upstream migration of Kuskokwim River chum salmon. Alaska Department of Fish and Game, Fishery Data Series No. 11-34, Anchorage.
- McGregor, A. J., and J. E. Clark. 1987. Migratory timing and escapement of Taku River salmon stocks in 1986. Final Report - 1986 Salmon Research Conducted in Southeast Alaska by the Alaska Department of Fish and Game in Conjunction with the National Marine Fisheries Service Auke Bay Laboratory for Joint U.S.-Canada Interception Studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.
- McGregor, A. J., and J. E. Clark. 1988. Migratory timing and escapement of Taku River salmon stocks in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J88-26, Juneau.
- McGregor, A. J., and J. E. Clark. 1989. Migratory timing and escapement of Taku River salmon stocks in 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J89-40, Juneau.
- McGregor, A. J., P. A. Milligan, and J. E. Clark. 1991. Adult mark–recapture studies of Taku River salmon stocks in 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report No. 91-05, Juneau.
- Mundy, P. R. 1979. A quantitative measure of migratory timing illustrated by application to the management of commercial fisheries. PhD. Dissertation, University of Washington, Seattle.
- Mundy, P. R. 1982. Computation of migratory timing statistics for adult Chinook salmon in the Yukon River, Alaska, and their relevance to fisheries management. *North American Journal of Fisheries Management* 2:359–370.
- Mundy, P. R. 1984. Migratory timing of salmon in Alaska with an annotated bibliography on migratory behavior of relevance to fisheries research. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet No. 234, Juneau.
- Pahlke, K. A., and D. R. Bernard. 1996. Abundance of the Chinook salmon escapement in the Taku River, 1989 and 1990. *Alaska Fisheries Research Bulletin* 3:9–20.

## REFERENCES CITED (Continued)

- Pahlke, K. A., and P. Etherton. 1999. Abundance and distribution of the Chinook salmon escapement on the Stikine River, 1997. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 99-6, Anchorage.
- Pahlke, K. A., S. A. McPherson, and R. P. Marshall. 1996. Chinook salmon research on the Unuk River, 1994. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 96-14, Anchorage.
- Quinn, T. P., L. Wetzel, S. Bishop, K. Overberg, and D. E. Rogers. 2001. Influence of breeding habitat on bear predation and age at maturity and sexual dimorphism of sockeye salmon stocks. *Canadian Journal of Zoology* 79:1782-1793.
- R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.
- Reine, K. J., 2005. Tagging and Tracking Technologies for Freshwater and Marine Fishes (No. ERDC/TN-DOER-E18). Engineer Research and Development Center, Vicksburg.
- Richards, P. J., P. Etherton, J. A. Der Hovanisian, K. A. Pahlke, and J. L. Weller. 2008. Abundance and distribution of the Chinook salmon escapement on the Stikine River, 2005 and production and harvest of fish from brood year 1998. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Data Series No. 08-33, Anchorage.
- Richards, P. J., T. Johnson, and S. J. H. Power. 2014. Escapements of Chinook salmon in Southeast Alaska and Transboundary Rivers in 2014. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan No. ROP.SF.1J.2014.11, Anchorage.
- Richards, P., J. Williams, S. J. H. Power, I. Boyce, and B. Waugh. 2016a. Migration, tagging response, and distribution of Chinook salmon returning to the Taku River, 2016. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan No. ROP.SF.1J.2016.04, Anchorage.
- Richards, P., T. Jaecks, S. J. H. Power, and I. Boyce. 2016b. Migration, landslide passage, tagging response, and distribution of Chinook salmon returning to the Stikine River, 2016. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan ROP.SF.1J.2016.05, Anchorage.
- Rogers Olive, S. D., E. K. C. Fox, and S. E. Gilk-Baumer. 2018. Genetic baseline for mixed stock analyses of sockeye salmon harvested in Southeast Alaska for Pacific Salmon Treaty applications, 2018. Alaska Department of Fish and Game, Fishery Manuscript No. 18-XX, Anchorage.
- Schwarz, C. J., and C. G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. *Canadian Journal Fisheries and Aquatic Sciences* 55:281-296.
- Seber, G. A. F. 1982. *The Estimation of Animal Abundance*, 2nd ed. Griffin, London.
- Thompson, S. K. 2002. *Sampling*, 2nd ed. John Wiley and Sons, New York.
- TTC (Transboundary Technical Committee). 2017. Final Estimates of Transboundary River Salmon Production, Harvest and Escapement and a Review of Joint Enhancement Activities in 2015. Pacific Salmon Commission Report TCTR (17)-2, Vancouver.
- TTC (Transboundary Technical Committee). 2018. Salmon management and enhancement plans for the Stikine, Taku and Alsek rivers, 2018. Pacific Salmon Commission Report TCTR (18)-1, Vancouver.
- Underwood, T. J., J. F. Bromaghin, and S. P. Klosiewski. 2004. Evidence of handling mortality of adult chum salmon caused by fish wheel capture in the Yukon River, Alaska. *North American Journal of Fisheries Management* 24:237-243.

## REFERENCES CITED (Continued)

- Wade, G. D., K. M. van den Broek, T. M. Haluska, J. W. Savereide, and J. J. Smith. 2009. Spawning distribution and run timing of Copper River sockeye salmon, 2008 annual report. Prepared by the Native Village of Eyak, Cordova, for the Alaska Sustainable Salmon Fund, Juneau (Project No. 45850).
- Weller, J. L., and D. G. Evans. 2012. Production of Unuk River Chinook salmon through 2009 from the 1992–2006 broods. Alaska Department of Fish and Game, Fishery Data Series No. 12-85, Anchorage.
- Williams, J. T., S. J. H. Power, and E. L. Jones III. 2016a. Estimation of Chinook salmon escapement in the Taku River, 2016–2018. Alaska Department of Fish and Game, Regional Operational Plan No. ROP.SF.IJ.2015.03, Anchorage.
- Williams, J. T., S. J. H. Power, and E. L. Jones III. 2016b. Production and escapement of coho salmon in the Taku River, 2016–2018. Alaska Department of Fish and Game, Division of Sport Fish, Regional Operational Plan No. ROP.SF.IJ.2016.10, Anchorage.
- Yanusz, R., R. Merizon, D. Evans, M. Willette, T. Spencer, and S. Raborn. 2007. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-83, Anchorage.
- Yanusz, R. J., R. A Merizon, T. M. Willette, D. G. Evans, and T. R. Spencer. 2011. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 11-12, Anchorage.
- Zar, J.H. 1999. Biostatistical Analysis (4th Edition). Prentice Hall, Upper Saddle River, New Jersey.



## **APPENDIX A**

Appendix A1.–Daily radiotagging schedule for sockeye salmon at the Taku River fish wheels, 2018. For the regular schedule, the fish wheels will not operate between 23:30 and 04:00 and between 11:30 and 16:00. There will be three crew per shift. The highlighted cells indicate radiotagging for the side project (Appendix C). Shift hours may be adjusted by the crew inseason to account for slow reductions in day length after late June.

Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Tags per shift			Morning shift		Afternoon shift		Tags per shift		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
3-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
4-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
5-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
6-Jun	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	0	0
7-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	1	1
8-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0
9-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1
10-Jun	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	No afternoon shift		0	NA	0
<b>11-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	16:00	23:30	<b>2</b>	<b>0</b>	<b>2</b>
12-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	1	0	1
13-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	1	1
14-Jun	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	1	0	1
15-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	1	1	2
16-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	0	2	2
17-Jun	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:30	0	1	1
<b>18-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>7</b>	<b>1</b>	<b>8</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
19-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	0	1
20-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
21-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
22-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	2	3
23-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
24-Jun	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	No afternoon shift		2	NA	2
<b>25-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>13</b>	<b>1</b>	<b>14</b>
26-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	1	1
27-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
28-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
29-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
30-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
1-Jul	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:00	1	1	2
<b>2-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>12</b>	<b>2</b>	<b>14</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>0</b>	<b>2</b>

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Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Tags per shift			Morning shift		Afternoon shift		Tags per shift		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
3-Jul	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
4-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	2	1	3
5-Jul	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
6-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
7-Jul	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
8-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	No afternoon shift		3	NA	3
<b>9-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>15</b>	<b>1</b>	<b>16</b>
10-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	2	0	2
11-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
12-Jul	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	16:00	23:30	2	3	5
13-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
14-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
15-Jul	3	04:00	11:30	No afternoon shift		3	NA	3	04:00	11:30	16:00	23:30	0	3	3
<b>16-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>20</b>	<b>1</b>	<b>21</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
17-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	1	2
18-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
19-Jul	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	3	2	5
20-Jul	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	16:00	23:30	2	3	5
21-Jul	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	3	3	6
22-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	No afternoon shift		3	NA	3
<b>23-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>24</b>	<b>1</b>	<b>25</b>
24-Jul	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	2	4
25-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
26-Jul	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	16:00	23:30	3	4	7
27-Jul	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	16:00	23:30	4	3	7
28-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
29-Jul	3	04:00	11:30	No afternoon shift		3	NA	3	04:00	11:30	16:00	13:30	1	1	2
<b>30-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>28</b>	<b>1</b>	<b>29</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>2</b>	<b>3</b>
31-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	1	2	3
1-Aug	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	16:00	23:30	3	3	6
2-Aug	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	16:00	23:30	3	3	6

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Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Tags per shift			Morning shift		Afternoon shift		Tags per shift		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
3-Aug	3	04:00	11:30	16:00	23:30	4	3	7	04:00	11:30	16:00	23:30	3	3	6
4-Aug	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
5-Aug	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	No afternoon shift		5	NA	5
<b>6-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>29</b>	<b>1</b>	<b>30</b>
7-Aug	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	3	5
8-Aug	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
9-Aug	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	2	3	5
10-Aug	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
11-Aug	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	2	3
12-Aug	3	04:00	11:30	No afternoon shift		3	NA	3	04:00	11:30	16:00	23:30	2	1	3
<b>13-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>21</b>	<b>1</b>	<b>22</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>0</b>	<b>1</b>
14-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
15-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
16-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
17-Aug	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
18-Aug	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	1	1
19-Aug	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	No afternoon shift		1	NA	1
<b>20-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>11</b>	<b>0</b>	<b>11</b>
21-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	2	3
22-Aug	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
23-Aug	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
24-Aug	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	1	1
25-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
26-Aug	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:30	0	1	1
<b>27-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>9</b>	<b>0</b>	<b>9</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>
28-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
29-Aug	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	1	1
30-Aug	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	1	1
31-Aug	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	1	1	2
1-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	1	1
2-Sep	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	No afternoon shift		1	NA	1

-continued-

Date	Number of Crew	Fishwheel 1							Fishwheel 2								
		Morning shift		Afternoon shift		Tags per shift			Morning shift		Afternoon shift		Tags per shift				
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total		
<b>3-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>5</b>	<b>0</b>	<b>5</b>		
4-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	1	1		
5-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1		
6-Sep	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0		
7-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
8-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
9-Sep	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:30	0	1	1		
<b>10-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>0</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>		
11-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1		
12-Sep	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0		
13-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
14-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
15-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
16-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	No afternoon shift		0	NA	0		
<b>17-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>0</b>	<b>1</b>		
18-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
19-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
20-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
21-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
22-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
23-Sep	3	04:00	11:30	No afternoon shift		0	NA	0	04:00	11:30	16:00	23:30	0	1	1		
<b>24-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>		
25-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
26-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
27-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
28-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
29-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0		
Total						119	119	238							118	119	237
Total with additional project						219	119	338							218	119	337

Appendix A2.–Daily biological sampling schedule (scales and paired MEF/CAF measurements) for sockeye salmon at the Taku River fish wheels, 2018. The fish wheels will not run between 23:30 and 04:00 and between 11:30 and 16:00. There will be three crew per shift.

Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Biological Sampling			Morning shift		Afternoon shift		Biological Sampling		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
3-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
4-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
5-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0
6-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
7-Jun	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	0	0
8-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	1	1
9-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0
10-Jun	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	No afternoon shift		1	NA	1
<b>11-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>1</b>	<b>1</b>	<b>04:00</b>	<b>11:30</b>	16:00	23:30	<b>0</b>	<b>0</b>	<b>0</b>
12-Jun	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	1	1
13-Jun	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	1	0	1
14-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	0	1	1
15-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
16-Jun	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	1	2
17-Jun	3	04:00	11:30	No afternoon shift		2	NA	2	04:00	11:30	16:00	23:30	1	1	2
<b>18-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
19-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	2	3
20-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
21-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
22-Jun	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
23-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
24-Jun	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	No afternoon shift		4	NA	4
<b>25-Jun</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
26-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
27-Jun	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
28-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
29-Jun	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
30-Jun	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	1	3
1-Jul	3	04:00	11:30	No afternoon shift		2	NA	2	04:00	11:30	16:00	23:30	1	2	3
<b>2-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>1</b>	<b>3</b>
3-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3

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Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Biological Sampling			Morning shift		Afternoon shift		Biological Sampling		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
4-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	1	3
5-Jul	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	2	2	4
6-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	1	2	3
7-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	2	2	4
8-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	No afternoon shift		4	NA	4
<b>9-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>1</b>	<b>3</b>
10-Jul	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	2	2	4
11-Jul	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	2	2	4
12-Jul	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	16:00	23:30	3	3	6
13-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	2	3	5
14-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	2	2	4
15-Jul	3	04:00	11:30	No afternoon shift		4	NA	4	04:00	11:30	16:00	23:30	2	2	4
<b>16-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>2</b>	<b>4</b>
17-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	1	2	3
18-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	3	2	5
19-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	2	3	5
20-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	4	3	7
21-Jul	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	3	3	6
22-Jul	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	No afternoon shift		5	NA	5
<b>23-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>3</b>	<b>3</b>	<b>6</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>3</b>	<b>3</b>	<b>6</b>
24-Jul	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
25-Jul	3	04:00	11:30	16:00	23:30	4	4	8	04:00	11:30	16:00	23:30	3	4	7
26-Jul	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	16:00	23:30	4	3	7
27-Jul	3	04:00	11:30	16:00	23:30	4	3	7	04:00	11:30	16:00	23:30	3	4	7
28-Jul	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	16:00	23:30	4	3	7
29-Jul	3	04:00	11:30	No afternoon shift		4	NA	4	04:00	11:30	16:00	23:30	2	2	4
<b>30-Jul</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>3</b>	<b>5</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>3</b>	<b>2</b>	<b>5</b>
31-Jul	3	04:00	11:30	16:00	23:30	2	2	4	04:00	11:30	16:00	23:30	3	2	5
1-Aug	3	04:00	11:30	16:00	23:30	4	4	8	04:00	11:30	16:00	23:30	4	3	7
2-Aug	3	04:00	11:30	16:00	23:30	4	4	8	04:00	11:30	16:00	23:30	4	4	8
3-Aug	3	04:00	11:30	16:00	23:30	4	3	7	04:00	11:30	16:00	23:30	3	4	7

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Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Biological Sampling			Morning shift		Afternoon shift		Biological Sampling		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
4-Aug	3	04:00	11:30	16:00	23:30	2	3	5	04:00	11:30	16:00	23:30	3	3	6
5-Aug	3	04:00	11:30	16:00	23:30	3	4	7	04:00	11:30	No afternoon shift		7	NA	7
<b>6-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>3</b>	<b>2</b>	<b>5</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>3</b>	<b>5</b>
7-Aug	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
8-Aug	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
9-Aug	3	04:00	11:30	16:00	23:30	3	3	6	04:00	11:30	16:00	23:30	3	3	6
10-Aug	3	04:00	11:30	16:00	23:30	3	2	5	04:00	11:30	16:00	23:30	2	2	4
11-Aug	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
12-Aug	3	04:00	11:30	No afternoon shift		3	NA	3	04:00	11:30	16:00	23:30	2	1	3
<b>13-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>2</b>	<b>3</b>
14-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	2	1	3
15-Aug	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
16-Aug	3	04:00	11:30	16:00	23:30	2	1	3	04:00	11:30	16:00	23:30	1	2	3
17-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	2	1	3
18-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	0	1	1
19-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	No afternoon shift		3	NA	3
<b>20-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
21-Aug	3	04:00	11:30	16:00	23:30	1	2	3	04:00	11:30	16:00	23:30	1	1	2
22-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
23-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
24-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
25-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	1	1	2
26-Aug	3	04:00	11:30	No afternoon shift		2	NA	2	04:00	11:30	16:00	23:30	1	1	2
<b>27-Aug</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>1</b>	<b>2</b>
28-Aug	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	1	1	2
29-Aug	3	04:00	11:30	16:00	23:30	1	1	2	04:00	11:30	16:00	23:30	0	1	1
30-Aug	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	1	0	1
31-Aug	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	1	1
1-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1
2-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	No afternoon shift		0	NA	0
<b>3-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>1</b>	<b>1</b>

-continued-

Date	Number of Crew	Fishwheel 1							Fishwheel 2						
		Morning shift		Afternoon shift		Biological Sampling			Morning shift		Afternoon shift		Biological Sampling		
		Start	Stop	Start	Stop	AM	PM	Total	Start	Stop	Start	Stop	AM	PM	Total
4-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	0	0
5-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1
6-Sep	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0
7-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
8-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	1	1
9-Sep	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:30	0	0	0
<b>10-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>1</b>	<b>0</b>	<b>1</b>
11-Sep	3	04:00	11:30	16:00	23:30	1	0	1	04:00	11:30	16:00	23:30	0	0	0
12-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1
13-Sep	3	04:00	11:30	16:00	23:30	0	1	1	04:00	11:30	16:00	23:30	0	0	0
14-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
15-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
16-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	No afternoon shift		1	NA	1
<b>17-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>
18-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
19-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	1	0	1
20-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
21-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
22-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
23-Sep	3	04:00	11:30	No afternoon shift		1	NA	1	04:00	11:30	16:00	23:30	0	0	0
<b>24-Sep</b>	<b>3</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>04:00</b>	<b>11:30</b>	<b>16:00</b>	<b>23:30</b>	<b>0</b>	<b>0</b>	<b>0</b>
25-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
26-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
27-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
28-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
29-Sep	3	04:00	11:30	16:00	23:30	0	0	0	04:00	11:30	16:00	23:30	0	0	0
Total						164	144	308					166	141	307



## **APPENDIX B**

Size- and sex-selective sampling may cause bias in two-event mark–recapture estimates of abundance and size and sex composition. Kolmogorov-Smirnov (KS) two sample tests are used to detect size-selective sampling, and contingency table analyses (chi-square tests of independence) are used to detect evidence of sex-selective sampling.

Results of the KS and chi-square tests will dictate whether the data needs to be stratified to obtain an unbiased estimate of abundance. The nature of the detected selectivity will also determine whether the first, second, or both event samples are used for estimating size and sex compositions.

## DEFINITIONS

- M = Lengths or sex of fish marked in the first event.
- C = Lengths or sex of fish inspected for marks in the second event.
- R = Lengths or sex of fish marked in the first event and recaptured in the second event.

## SIZE-SELECTIVE SAMPLING: KS TESTS

Three KS tests are used to test for size-selective sampling.

- KS Test 1    C vs R    Used to detect size selectivity during the 1<sup>st</sup> sampling event.  
H<sub>0</sub>: Length distributions of populations associated with C and R are equal
- KS Test 2    M vs R    Used to detect size selectivity during the 2<sup>nd</sup> sampling event.  
H<sub>0</sub>: Length distributions of populations associated with M and R are equal
- KS Test 3    M vs C    Used to corroborate the results of the first two tests.  
H<sub>0</sub>: Length distributions of populations associated with M and C are equal

## SEX-SELECTIVE SAMPLING: CHI-SQUARE TESTS

Three contingency table analyses ( $\chi^2$ -tests on 2×2 tables) are used to test for sex-selective sampling.

- $\chi^2$  Test 1    C vs R    Used to detect sex selectivity during the 1<sup>st</sup> sampling event.  
H<sub>0</sub>: Sex is independent of the C - R classification
- $\chi^2$  Test 2    M vs R    Used to detect sex selectivity during the 2<sup>nd</sup> sampling event.  
H<sub>0</sub>: Sex is independent of the M - R classification
- $\chi^2$  Test 3    M vs C    Used to corroborate the results of the first two tests.  
H<sub>0</sub>: Sex is independent of the M - C classification

Table B1 presents possible results of selectivity testing, their interpretation, and prescribed action.

Table B1.–Possible results of selectivity testing, interpretation and action.

Case	KS or $\chi^2$ Test			Interpretation and Action
	M vs. R (2 <sup>nd</sup> event test)	C vs. R (1 <sup>st</sup> event test)	M vs. C (1 <sup>st</sup> vs 2 <sup>nd</sup> event)	
I	Fail to reject $H_0$	Fail to reject $H_0$	Fail to reject $H_0$	<p><b>Interpretation:</b> No selectivity during either sampling event.</p> <p><b>Action:</b>            Abundance: Use a Petersen-type model without stratification.            Composition: Use all data from both sampling events.</p>
II	Reject $H_0$	Fail to reject $H_0$	Reject $H_0$	<p><b>Interpretation:</b> No selectivity during the 1<sup>st</sup> event but there is selectivity during the 2<sup>nd</sup> event.</p> <p><b>Action:</b>            Abundance: Use a Petersen-type model without stratification.            Composition: Use data from the 1<sup>st</sup> sampling event without stratification.            2<sup>nd</sup> event data only used if stratification of the abundance estimate is performed, with weighting according to Equations 1-3 below.</p>
III	Fail to reject $H_0$	Reject $H_0$	Reject $H_0$	<p><b>Interpretation:</b> No selectivity during the 2<sup>nd</sup> event but there is selectivity during the 1<sup>st</sup> event.</p> <p><b>Action:</b>            Abundance: Use a Petersen-type model without stratification.            Composition: Use data from the 2<sup>nd</sup> sampling event without stratification.            1<sup>st</sup> event data may be incorporated into composition estimation only after stratification of the abundance estimate and appropriate weighting according to Equations 1-3 below.</p>
IV	Reject $H_0$	Reject $H_0$	Either result	<p><b>Interpretation:</b> Selectivity during both 1<sup>st</sup> and 2<sup>nd</sup> events.</p> <p><b>Action:</b>            Abundance: Use a stratified Petersen-type model, with estimates calculated separately for each stratum. Sum stratum estimates for overall abundance.            Composition: Combine stratum estimates according to Equations 1–3 below.</p>
V	Fail to reject $H_0$	Fail to reject $H_0$	Reject $H_0$	<p><b>Interpretation:</b> The results of the 3 tests are inconsistent.</p> <p><b>Action:</b> Need to determine which of Cases I-IV best fits the data. Inconsistency can arise from high power of the M vs. C test or low power of the tests involving R. Examine sample sizes (generally M or C from &lt;100 fish and R from &lt;30 are considered small), magnitude of the test statistics (<math>D_{max}</math>), and the <i>P</i>-values of the three tests to determine which of which of Cases I-IV best fits the data.</p>

### Composition estimation for stratified estimates

An estimate of the proportion of the population in the  $k^{th}$  size or sex category for stratified data with  $i$  strata is calculated as follows:

$$\hat{p}_k = \sum_{i=1}^I \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik}, \quad (1)$$

with variance estimated as

$$var[\hat{p}_k] \approx \frac{I}{\hat{N}^2} \sum_{i=1}^I \left( \hat{N}_i^2 var[\hat{p}_{ik}] + (\hat{p}_{ik} - \hat{p}_k)^2 var[\hat{N}_i] \right), \quad (2)$$

and where

$\hat{p}_{ik}$  = estimated proportion of fish belonging to category  $k$  in stratum  $i$ ;

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

$\hat{N}$  = estimated total abundance

Then,  $\sum_{i=1}^I \hat{N}_i$  = the sum of the  $\hat{N}_i$  across strata.

### Tests of Consistency for Petersen Estimator

Three contingency table analyses are used to determine if the Petersen estimate can be used (Seber 1982). If any of the null hypotheses are not rejected, then a Petersen estimator may be used. If all three of the null hypotheses are rejected, a temporally or spatially-stratified estimator (Darroch 1961) should be used to estimate abundance.

Seber (1982) describes 4 conditions that lead to an unbiased Petersen estimate, some of which can be tested directly:

1. Marked fish mix completely with unmarked fish between events.
2. Equal probability of capture in event 1 and equal movement patterns of marked and unmarked fish.
3. Equal probability of capture in event 2
4. The expected number of marked fish in recapture strata is proportional to the number of unmarked fish.

In the following tables, the terminology of Seber (1982) is followed, where  $a$  represents fish marked in the first event,  $n$  fish captured in second event and  $m$  marked fish recaptured;  $m_{.j}$  and  $m_{i.}$  represent summation over the  $i^{th}$  and  $j^{th}$  indices, respectively.

#### I. Mixing Test

Tests the hypothesis (condition 1) that movement probabilities ( $\theta_{ij}$ ), describing the probability that a fish moves from marking stratum  $i$  to recapture stratum  $j$ , are independent of marking stratum:  $H_0: \theta_{ij} = \theta_j$  for all  $i$  and  $j$ .

Area/Time Marking Strata ( $i$ )	Area/Time Recapture Strata ( $j$ )				Not Recaptured $a_i - m_{i.}$
	1	2	...	t	
1	$m_{11}$	$m_{12}$	...	$m_{1t}$	$a_1 - m_{1.}$
2	$m_{21}$	$m_{22}$	...	$m_{2t}$	$a_2 - m_{2.}$
...	...	...	...	...	...
s	$m_{s1}$	$m_{s2}$	...	$m_{st}$	$a_s - m_{s.}$

#### II. Equal Proportions Test<sup>a</sup> (SPAS<sup>b</sup> terminology)

Tests the hypothesis (condition 4) that the marked to unmarked ratio among recapture strata is constant:  $H_0: \sum_i a_i \theta_{ij} / U_j = k$ , where  $k =$  a constant,  $U_j =$  unmarked fish in stratum  $j$  at the time of 2<sup>nd</sup> event sampling, and  $a_i =$  number of marked fish released in stratum  $i$ . Failure to reject  $H_0$  means the Petersen estimator should be used only if the degree of closure among tagging strata is constant, i.e.  $\sum_j \theta_{ij} = \lambda$  (Schwarz and Taylor 1998; p 289). A special case of closure is when all recapture strata are sampled, such as in a fish wheel to fish wheel experiment, where  $\sum_j \theta_{ij} = 1.0$ ; otherwise biological and experimental design information should be used to assess the degree of closure.

	Area/Time Recapture Strata ( $j$ )			
	1	2	...	t
Recaptured ( $m_{.j}$ )	$m_{.1}$	$m_{.2}$	...	$m_{.t}$
Unmarked ( $n_j - m_{.j}$ )	$n_1 - m_{.1}$	$n_2 - m_{.2}$	...	$n_t - m_{.t}$

### III. Complete Mixing Test<sup>a</sup> (SPAS<sup>b</sup> terminology)

Tests the hypothesis that the probability of re-sighting a released animal is independent of its stratum of origin:  $H_0: \sum_j \theta_{ij} p_j = d$ , where  $p_j$  is the probability of capturing a fish in recapture stratum  $j$  during the second event, and  $d$  is a constant.

	Area/Time Marking Strata ( $i$ )			
	1	2	...	s
Recaptured ( $m_i$ )	$m_{1\cdot}$	$m_{2\cdot}$	...	$m_{s\cdot}$
Not Recaptured ( $a_i - m_{i\cdot}$ )	$a_1 - m_{1\cdot}$	$a_2 - m_{2\cdot}$	...	$a_s - m_{s\cdot}$

<sup>a</sup> There is no 1:1 correspondence between Tests II and III and conditions 2–3 above. It is pointed out that equal probability of capture in event 1 will lead to (expected) non-significant Test II results, as will mixing, and that equal probability of capture in event 2 along with equal closure ( $\sum_j \theta_{ij} = \lambda$ ) will also lead to (expected) non-significant Test III results.

<sup>b</sup> Stratified Population Analysis System (SPAS) (Arnason et al. 1996).

## **APPENDIX C**

Appendix C1.–Side project methods. Comparative study on the difference in dropout rates between longer fish holding times (similar to the historical method) and reduced fish holding times (2018 season method).

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### Objective

The current mark–recapture study has been conducted using relatively consistent methods since 1984; however, a high dropout rate of radiotagged fish in 2017 suggests mark–recapture estimates could be biased if spaghetti-tagged fish experience the same dropout rate as radiotagged fish. For this study, dropout rate is defined as the proportion of Taku sockeye salmon radiotagged in the Canyon Island fish wheels that do not cross the U.S./Canada border. Dropout rate can include tag loss (due to predation, handling mortality [trap-induced behavior], regurgitation, or permanently leaving the river system), tag failure prior to upstream migration, and unknown fates such as signal loss. The cause of the high dropout rate in 2017 is unknown. Previous studies have shown that increased holding times negatively impacts the health of salmon (Cleary 2003; Bromaghin and Underwood 2003; Bromaghin et al. 2007). Therefore, fish handling and holding time at the fish wheels will be modified for the 2018 season in an attempt to reduce handling stress. Also, in 2018, a study will be conducted to compare the dropout rates of radiotagged fish that experienced reduced holding time to radiotagged fish held in live boxes for a longer period of time (i.e., similar to holding times used in the past).

### 2018 Season Revised Methods:

For the 2018 season, the fish wheels will be deployed inriver on approximately 3 June (the beginning of statistical week 23). The fish wheels will then be operated as continuously as possible for approximately 15 hours each day for two shifts (04:00 to 11:30 and 16:00 to 23:30), with each shift worked by a crew of three people. Hours may be adjusted by the crew inseason to account for slow reductions in day length after late June. The fish wheels will be shutdown between shifts (from 23:30 to 04:00 and 11:30 to 16:00) and started again when the next crew’s shift begins (at approximately 04:00 and 16:00). The crew will remain with the fishwheels during the entire shift to ensure continued sampling. The aim is for fish holding time to not exceed one hour in the live boxes and for sampling to be consistent throughout the season (i.e., the crew should not change methods during peak or low times). The crew members will intermittently switch shifts (from AM to PM or PM to AM) throughout the season to minimize potential differences between crews. In general, sockeye salmon will be sampled every hour in the morning, afternoon, and evening, except from 11:30 to 16:00 and from 23:30 to 04:00, and tagging will be conducted from a boat pulled alongside the fish wheel (versus the historical method of shutting the fish wheel down during sampling) so the fish wheel will continue to operate and effort will not be affected.

Four hundred and seventy-five radio tags will be deployed throughout the season according to the sampling schedule in Appendix A1. This sampling schedule was developed based on historical fish wheel run timing during statistical weeks 23 to 39 during the 10 years 2008–2017. Radiotagging will be randomized so that fish are radiotagged throughout the shift (i.e., the first fish out of the live boxes will not always be radiotagged). To randomize the selection of fish to be tagged, the crew will begin the shift by choosing a number from 1 through 5. If, for example, the number 4 is chosen, every 4<sup>th</sup> fish removed from the live boxes will be radiotagged until the radiotagging goal for that shift is met. The crew will release, without radiotagging or spaghetti tagging, any fish held for more than one hour.

## 2018 Dropout Rate Comparison Study:

Dropout rates will be compared between the fish radiotagged after only a short holding period (as described above) and 200 additional fish radiotagged after a longer holding period that will mimic the length of time (greater than 1 hour and up to 16.5 hours overnight) fish were historically held in live boxes at the fish wheels. To accomplish this, on the first Sunday of each statistical week, starting Sunday, 10 June, no afternoon sampling will be conducted on one of the two fish wheels. That fish wheel will instead fish continuously from 11:30 on Sunday to 04:00 on Monday, which will allow for a maximum of 16.5 hours of holding time for sockeye salmon caught in that fish wheel. Those fish will then be systematically radiotagged on a schedule based on historic run timing information (Table C1; Appendix A1). To randomize the selection of fish to be radiotagged, the crew will begin the shift by choosing a number from 1 through 5; if, for example, the number 4 is chosen, then every 4th fish removed from the fish wheel live boxes will be tagged until the radiotagging goal for that shift is met. In addition, all of the sockeye salmon captured in this event will be spaghetti tagged to allow comparison of inseason and postseason mark–recapture population estimates generated from spaghetti-tagging data from the two release groups. After all fish are processed, operation of the fish wheels will revert to normal until the following Sunday at 11:30.

### Power Analysis:

Table C1.–The sampling goal for the dropout rate comparison study is 200 radio tags. The proposed weekly tagging rate is based on the average fish wheel catches from 2008 to 2017 from the two fish wheels.

Statistical Week (SW)	SW Start Date	Expected Proportion of Catch	Cumulative Proportion of Catch	Weekly Radio Tag Deployment	Cumulative Radio Tag Deployment
23	3-Jun	0.01	0.01	0	0
24	10-Jun	0.03	0.04	2	2
25	17-Jun	0.06	0.10	7	9
26	24-Jun	0.06	0.16	13	22
27	1-Jul	0.08	0.24	12	34
28	8-Jul	0.10	0.34	15	49
29	15-Jul	0.11	0.45	20	69
30	22-Jul	0.14	0.59	24	93
31	29-Jul	0.14	0.74	28	121
32	5-Aug	0.11	0.85	29	150
33	12-Aug	0.06	0.90	21	171
34	19-Aug	0.05	0.95	11	182
35	26-Aug	0.03	0.98	9	191
36	2-Sep	0.01	0.99	5	196
37	9-Sep	0.01	1.00	2	198
38	16-Sep	0.00	1.00	1	199
39	23-Sep	0.00	1.00	1	200

To determine the power to detect the difference in dropout rate for unequal sample sizes (200, 475),  $n'$  must first be calculated (Cohen 1988),

$$n' = \frac{2n_1n_2}{n_1+n_2} \quad (1)$$

where:

$$n_1 = 200 \text{ and}$$

$$n_2 = 475.$$

Therefore,  $n'=282$ . The power to detect a difference between dropout rates using the historical methods (longer holding times) and the new method that will begin during the 2018 season (<1 hour holding times) is based on a hypothetical effect size index and a desired significance criterion. Based on a non-directional two-tailed hypothesis ( $H_0: P_1 = P_2$ ;  $H_a: P_1 \neq P_2$ ), the difference between arc-transformed  $P_1$  and  $P_2$  was calculated to determine hypothetical effect size indices, i.e.  $|\phi_1 - \phi_2| = h$ . For example, if the dropout rate from <1 hour holding times is 0.20, and the dropout rate from extended holding times is 0.30, then  $h = |\phi_{0.30} - \phi_{0.20}| = |1.159 - 0.927| = 0.23$ . Likewise, to detect a smaller difference in dropout rates, the hypothetical effect size index would be  $h = |\phi_{0.30} - \phi_{0.25}| = |1.159 - 1.047| = 0.11$  (Cohen 1988; Table 6.2.2). The power to detect a difference in dropout rates increases if the hypothesis is formulated as directional ( $H_0: P_1 = P_2$ ;  $H_a: P_1 > P_2$ ); i.e., dropout rate with increased holding times should be greater than dropout rates with decreased holding time. However, if in fact the dropout rates differed in the opposite direction to the prediction, no conclusion could be drawn, even if differences were large. To determine the power values, we used the statistical package ‘pwr’ in Program R (Champely 2018; R Core Team 2018) (Table C2).

Table C2.–Power values based on directional or non-directional hypotheses about dropout rates, hypothetical effect size indices, and desired significance criterion. The sample size is based on equation 1.

Hypothesis	Sample size (n')	Effect Size Index (h)	Significance Criterion ( $\alpha$ )	Power Value
Non-directional	282	0.23	0.05	0.78
Non-directional	282	0.11	0.05	0.26
Non-directional	282	0.23	0.10	0.86
Non-directional	282	0.11	0.10	0.37
Directional	282	0.23	0.05	0.86
Directional	282	0.11	0.05	0.37
Directional	282	0.23	0.10	0.93
Directional	282	0.11	0.10	0.51

### Postseason Statistical Analysis:

To compare the dropout rates from radiotagged fish in 2018 having reduced holding times to those with longer holding times, we will use a chi-square computation modified by applying the correction for continuity (Zar 1999),

$$\chi_c^2 = \frac{n(|f_{11}f_{22} - f_{12}f_{21}| - \frac{n}{2})^2}{R_1 R_2 C_1 C_2}. \quad (2)$$

In equation 2,  $f_{ij}$  denotes the frequency observed in row  $i$  and column  $j$ ,  $R_i$  is the total of the frequencies in row  $i$ ,  $C_j$  is the total for column  $j$ , and  $n$  is the sample size in a  $2 \times 2$  contingency table,

$f_{11}$	$f_{12}$	$R_1$
$f_{21}$	$f_{22}$	$R_2$
$C_1$	$C_2$	$n$