

**Migration, Landslide Passage, Tagging Response, and  
Distribution of Chinook Salmon Returning to the  
Stikine River, 2015**

by

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April 2015

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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 (multiple)	R
milliliter	mL	west	W	correlation coefficient (simple)	r
millimeter	mm	copyright	©	covariance	cov
		corporate suffixes:		degree (angular)	$^\circ$
<b>Weights and measures (English)</b>		Company	Co.	degrees of freedom	df
cubic feet per second	ft <sup>3</sup> /s	Corporation	Corp.	expected value	$E$
foot	ft	Incorporated	Inc.	greater than	>
gallon	gal	Limited	Ltd.	greater than or equal to	≥
inch	in	District of Columbia	D.C.	harvest per unit effort	HPUE
mile	mi	et alii (and others)	et al.	less than	<
nautical mile	nmi	et cetera (and so forth)	etc.	less than or equal to	≤
ounce	oz	exempli gratia (for example)	e.g.	logarithm (natural)	ln
pound	lb	Federal Information Code	FIC	logarithm (base 10)	log
quart	qt	id est (that is)	i.e.	logarithm (specify base)	log <sub>2</sub> , etc.
yard	yd	latitude or longitude	lat or long	minute (angular)	'
		monetary symbols (U.S.)	\$, ¢	not significant	NS
<b>Time and temperature</b>		months (tables and figures): first three letters	Jan,...,Dec	null hypothesis	$H_0$
day	d	registered trademark	®	percent	%
degrees Celsius	°C	trademark	™	probability	P
degrees Fahrenheit	°F	United States (adjective)	U.S.	probability of a type I error (rejection of the null hypothesis when true)	$\alpha$
degrees kelvin	K	United States of America (noun)	USA	probability of a type II error (acceptance of the null hypothesis when false)	$\beta$
hour	h	U.S.C.	United States Code	second (angular)	"
minute	min	U.S. state	use two-letter abbreviations (e.g., AK, WA)	standard deviation	SD
second	s			standard error	SE
<b>Physics and chemistry</b>				variance	
all atomic symbols				population sample	Var
alternating current	AC			sample	var
ampere	A				
calorie	cal				
direct current	DC				
hertz	Hz				
horsepower	hp				
hydrogen ion activity (negative log of)	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

***REGIONAL OPERATIONAL PLAN SF.1J.2015.05***

**MIGRATION, LANDSLIDE PASSAGE, TAGGING RESPONSE, AND  
DISTRIBUTION OF CHINOOK SALMON RETURNING TO THE STIKINE  
RIVER, 2015**

by  
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Alaska Department of Fish and Game  
Division of Sport Fish

April 2015

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**SIGNATURE/TITLE PAGE**

Project Title: Migration, Landslide Passage, Tagging Response, and Distribution of Chinook Salmon Returning to the Stikine River, 2015

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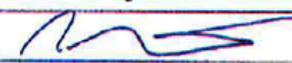
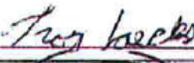
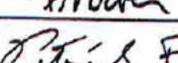
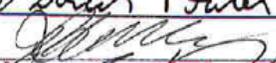
Project Nomenclature: *Pacific Salmon Commission, Restoration and Enhancement Fund-Northern Fund*

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## ABSTRACT

Large Chinook salmon *Oncorhynchus tshawytscha* captured during the annual mark-recapture experiment on the Stikine River will be tagged with radio tags. Remote tracking stations on the lower river will be used to estimate the percent of Chinook salmon that migrate past the U.S./Canada border, the migration rate to the U.S./Canada border and through the Canadian fishery, and tagging response of marked fish. Remote tracking stations located above and below a major landslide on the Tahltan River will be used to determine the number of fish that successfully navigate past the landslide. Aerial surveys will be used to determine spawning distribution.

Key words: mark-recapture, Stikine River, Chinook salmon, telemetry, radio tags, escapement, Tahltan River, landslide, dropout rate, migration rate, Pacific Salmon Treaty, abundance based management.

## PURPOSE

The Alaska Department of Fish and Game (ADF&G), in cooperation from Fisheries and Oceans Canada (FOC) and Tahltan First Nations, has been allocated funds from the Northern Fund Committee of the Pacific Salmon Commission to conduct a Chinook salmon radiotelemetry study on the Stikine River in 2015 and 2016. This radiotelemetry study will help gain insights into key assumptions of the annual Stikine River Chinook salmon mark-recapture experiment that—to an unknown degree—have the potential for biasing abundance estimates. Chinook salmon passage through disrupted habitat as a result of a major landslide on the lower Tahltan River, above which approximately 50% of Stikine River Chinook spawn, will also be monitored. Aerial surveys will be used to identify the spawning distribution extent of Chinook salmon in the drainage while also estimating the proportion returning to the most significant sub-basins to compare with previous radiotelemetry studies conducted on the Stikine River in 1997 and 2005.

## BACKGROUND

Abundance based management of Stikine River Chinook salmon *Oncorhynchus tshawytscha* is mandated by paragraph 2 of the Pacific Salmon Treaty (PST 2008). As part of this requirement, mark-recapture abundance estimates of large Chinook salmon ( $\geq 660$  mm mid eye to fork of tail (MEF)) in the Stikine River have occurred annually since 1996. Objective criteria and methods of the mark-recapture project are described in a separate operational plan entitled *Spawning Escapement of Chinook Salmon in the Stikine River, 2015* (Jaecks et al. *in press*). This mark-recapture program is the foundation for abundance based management of Stikine River Chinook salmon. Any potential violations of the underlying assumptions of the mark-recapture experiment must be quantified to produce accurate inseason and postseason abundance estimates.

The primary objective of the annual Stikine River Chinook salmon mark-recapture experiment is to estimate spawning escapement above the U.S./Canada border. Unaccounted dropouts (i.e., fish lost to tagging mortality, emigration or tag loss following initial capture, but prior to fish crossing the U.S./Canada border) will cause mark-recapture abundance estimates in the Stikine River to be biased high (Bernard et al. 1999). During previous telemetry studies in 1997 and 2005 in the Stikine River, the dropout rate was estimated to be 11% and 6% respectively (Pahlke and Etherton 1999; Richards et al. 2008). During years without radio telemetry, fish marked inriver with spaghetti tags are regularly recaptured downstream of the study site in marine fisheries and in Andrew Creek (Andrew Creek is a small tributary near the mouth of the Stikine River approximately 100 km downstream of Verrett River, the nearest spawning tributary in Canada).

Chinook salmon in Andrew Creek comprise a separate stock and are genetically distinct from Chinook Salmon spawning above the U.S./Canada border). However, these rates are typically

significantly less than what was observed during years with radiotelemetry, therefore likely biasing our estimates high due to unaccounted dropouts (Pahlke and Etherton 1998; Pahlke and Etherton 2000; Pahlke et al. 2000; Der Hovanisian et al. 2001; Der Hovanisian et al. 2003; Der Hovanisian et al. 2004; Der Hovanisian et al. 2005; Der Hovanisian and Etherton 2006; Richards et al. 2012; Jaecks et al. *in prep* a, b, c, d, e, f). Based on CWT recoveries, stray wild and hatchery Chinook salmon are regularly captured in the Stikine River above the U.S./Canada border (Richards et al. 2008; Pahlke et al. 2010; Pahlke 2010). In past years it has been estimated that more than 1,000 Taku River origin Chinook salmon reach the U.S./Canada border in the Stikine River, or approximately 5% of the Stikine inriver run (Peter Etherton, Resource Manager, DFO, Whitehorse, YT, personal communication, November 2014). It is unknown if these fish are temporarily entering the Stikine River and will eventually leave, and thus contribute to fish that emigrate out of this study as *dropouts*, or if they stay in the Stikine River and are therefore correctly accounted for as part of the spawning population. Extensive inriver sampling suggests the number of stray fish entering the Stikine River can be highly variable from year-to-year, therefore potentially causing highly variable dropout rates. This telemetry project will help to quantify dropout rates and the variability surrounding it in two consecutive years. If dropout rates are estimated to be significantly higher than what is estimated during years without radiotelemetry, a correction factor may be applied to help reduce this bias and the resulting effect on abundance estimates.

Migration rates between mark (event 1) and recapture (event 2) sites can influence inseason abundance estimates. Inseason abundance estimates are crucial for abundance based management as mandated by the Pacific Salmon Commission (PSC 2007). Migration rates between the event 1 marking site and the event 2 Canadian fishery average approximately 13 days (SD=8.5); however these rates have ranged from 1 day to >30 days (Pahlke and Etherton 1998; Pahlke and Etherton 1999; Pahlke and Etherton 2000; Pahlke et al. 2000; Der Hovanisian et al. 2001; Der Hovanisian et al. 2003; Der Hovanisian et al. 2004; Der Hovanisian et al. 2005; Der Hovanisian and Etherton 2006; Richards et al. 2008; Richards et al. 2012; Jaecks et al. *in prep* a, b, c, d, e, f). Differences in migration rate by as little as two days can yield changes in inseason abundance projections. Many factors likely influence migration rates including water level, run timing, and tagging-induced behavior, the latter of which often leads to “sulking” behavior and slower initial migration rates (Bernard et al. 1999; Jones and McPherson 2002; Eiler et al. 2014; John Eiler, biologist, National Marine Fisheries Service, Juneau, Alaska, personal communication, February 2015).

Marked Chinook salmon typically delay their upstream migration for approximately 4 days after being released and when they resume upstream migration, they do so at a slower rate than the unmarked population (Bernard et al 1999; Eiler et al. 2014; John Eiler, biologist, National Marine Fisheries Service, Juneau, Alaska, personal communication, February 2015). Therefore, if marked fish transit the event 2 Canadian fishery at a slower rate than unmarked fish due to handling-induced behavior, they will likely be subject to a higher probability of capture in event 2. A higher probability of capture in the Canadian fishery is not known to be a significant issue on the Stikine River, but is a consistent issue on the Taku River. The difference in distance between event 1 and event 2 on the Stikine and Taku rivers, 30 km and 5 km, respectively, is a likely reason for the differences observed in capture probability on the two rivers. Eiler (2014) showed that fish tagged further downstream (i.e., fish that had traveled greater distances after being tagged and released) swam faster and were progressively less variable as they moved upriver. This suggests swimming speed and behavior (collectively, spawning migration) is more abnormal closer to the marking site.

Monitoring radiotagged fish in the lower Stikine River with several remote tracking stations will allow us to assess their migration rates to the U.S./Canada border and through the Canadian fishery. Results will be used to help quantify migration rates and will be applied to future inseason abundance estimates. Results will also be compared to a sister telemetry project conducted on the Taku River in 2015 and 2016.

In spring 2014, a natural landslide occurred on the lower Tahltan River, which with its tributaries accounts for the spawning locations of about 50% of Stikine River Chinook salmon (Pahlke and Etherton, 1999; Richards et al. 2008). The landslide was likely a barrier to most of the Chinook salmon migrating to the Tahltan River in 2014 as an estimated 70% (~8,000-9,000) of the Chinook salmon that entered the Tahltan River failed to navigate the landslide (Peter Etherton, Resource Manager, DFO, Whitehorse, YT, personal communication, November 2014). It appears the landslide was only a barrier to fish passage during the spring freshet, when most of the Chinook salmon migration occurred. After water levels dropped in mid-July, most Chinook and sockeye salmon *Oncorhynchus nerka* successfully passed the landslide (Peter Etherton, Resource Manager, DFO, Whitehorse, YT, personal communication, November 2014). Substantial efforts and funds (approximately \$250,000 CAD) were used to transport fish above the landslide via helicopter, which resulted in 923 large Chinook salmon transported around the slide. To more accurately assess passage rates in 2015, remote tracking stations placed above and below the landslide will assess the degree to which the landslide continues to be a barrier to Chinook salmon in 2015 throughout the entire migration to account for changes due to water levels.

## **OBJECTIVES**

### **PRIMARY OBJECTIVES:**

1. Estimate the percent of large Chinook salmon ( $\geq 660$  mm MEF) tagged during event 1 that migrate past the U.S./Canada border such that the estimate is within 25% of the true value 90% of the time;
2. Estimate the number of large Chinook salmon that successfully pass the landslide on the Tahltan River such that the estimate is within 25% of the true value 90% of the time;
3. Identify the spawning distribution of large Chinook salmon ( $\geq 660$  mm MEF) through aerial tracking (telemetry) surveys so that all spawning areas representing  $> 7\%$  of the spawning population of large Chinook salmon are identified 95% of the time.

### **SECONDARY OBJECTIVES:**

1. Describe tagging response and migration rates of large Chinook salmon tagged during event 1 up to and within the Canadian fishery;
2. Collect paired tissue samples from all radiotagged Chinook salmon for genetic analysis.

## **METHODS**

### **CAPTURE AND TAGGING**

Internal pulse-coded radio tags manufactured by Advanced Telemetry Systems (ATS<sup>TM</sup>) will be placed in large Chinook salmon that are handled and marked in conjunction with the spaghetti-tagged Chinook salmon in the mark-recapture experiment. Objective criteria and detailed methods of the mark-recapture project are described in a separate operational plan entitled *Spawning Escapement of Chinook Salmon in the Stikine River, 2015* (Jaacks et al. *in press*).

Personnel will capture Chinook salmon in drift gillnets near Kakwan Point (Figure 1). Mesh in drift gillnets will be 18.4 cm (stretch), a size that generally catches large Chinook and some jacks (fish <660 mm MEF). Nets will be 36.6 m long and approximately 5.5 m deep. Two skiffs will be used during the drift gillnet tagging operation and a minimum of 2 people will operate each skiff. Two crews will fish, each crew aiming to fish 7 days per week. The time expended fishing during each drift will be tallied and used to complete a minimum of 4 hours of fishing effort per day per crew. Operations will begin in early May and end in mid July. The first Chinook salmon has generally been captured around May 7–9, while the final capture generally occurs around July 8–9.

When capture of a Chinook salmon is indicated (tug of the net, bobbing cork line), fish will be carefully removed from the net, cutting the net if needed, and placed into a neoprene sling in a tote partially filled with recirculating river water. Chinook salmon of any size, captured in good condition will be measured, inspected to determine their sex, sampled to collect scales, and triple-marked (Jaacks et al. *in press*). In addition to the three marks applied in the traditional mark-recapture experiment, large fish will also receive a radio tag. Radio tags will be gently inserted through the mouth and into the fish's stomach using a 0.7 cm diameter, 30 cm long plastic tube (Eiler 1990; Eiler et al. 2014). Anesthesia will not be used at any time during tagging or marking operations. The plastic tube will be marked with reference points in proportion to fish size to assist in proper tag insertion depths. The esophagus will be visually inspected to ensure that none of the tag body is visible and that the antenna is exiting through the center of the esophagus. All large Chinook salmon will receive the ATS<sup>TM</sup> F1845B radio tags which will be 52-mm long, 19-mm in diameter, 26-g in mass, have a 30-cm external whip antenna, a terminal battery life of 180 d, and operate on several frequencies within the 150.000 - 152.999 MHz range. Three frequencies will have 100 pulse codes resulting in 300 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.

The radio tags will be deployed in proportion to historical drift gillnet catches of Chinook salmon in statistical weeks 19 through 28 (Table 1). We will begin the season tagging every healthy large Chinook salmon since the amount of available radio tags is at least equal to the expected number of large Chinook to be captured (Jaacks et al. *in press*). If capture rates are higher than expected, or weekly inseason abundance estimates are larger than the preseason forecast, tagging rates will be reduced accordingly to ensure radio tags are equally applied throughout the run. Radio tags recovered in U.S. and Canadian fisheries will be returned and redeployed in new fish if possible. Approximately 30 radiotagged Chinook salmon are expected to be captured in the Canadian fishery in 2015, of which approximately 15 will be returned in time to redeploy, giving consideration to historic info on run timing and duration.

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

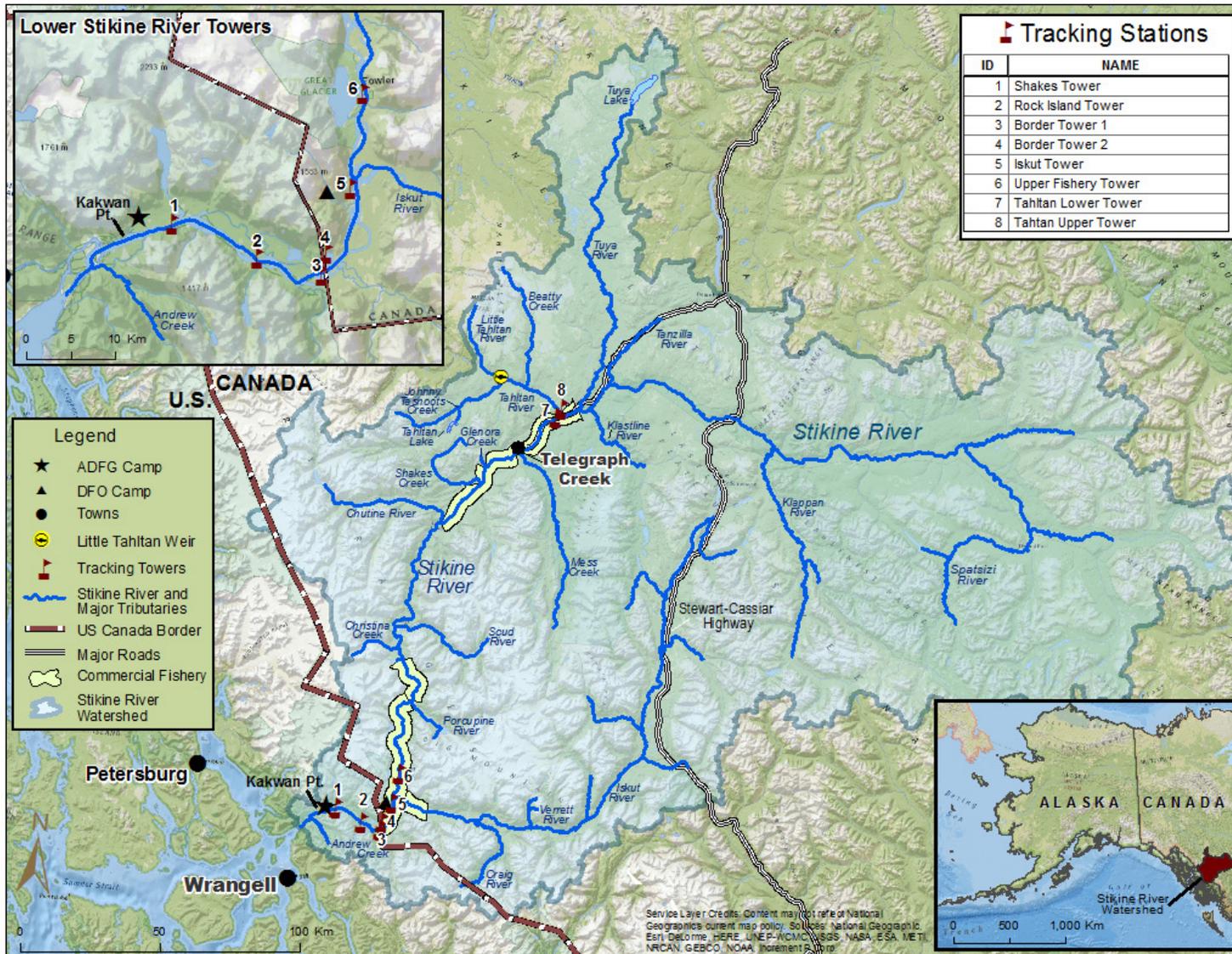


Figure 1.-Stikine River drainage in Southeast Alaska, with locations of the mark-recapture experiment and remote telemetry stations.

Table 1.-Proposed weekly tagging rate of Chinook Salmon on the Stikine River, for radio tags based on the expected run size in 2015.

Statistical Week	Date	Weekly	Cumulative
19	9-May	24	24
20	16-May	28	52
21	23-May	32	84
22	30-May	17	101
23	6-Jun	33	134
24	13-Jun	36	170
25	20-Jun	41	211
26	27-Jun	43	254
27	4-Jul	33	287
28	11-Jul	13	300

## TRACKING AND DATA COLLECTION

Remote tracking stations at eight locations will record movements (upstream or downstream passage) of radiotagged fish (Figure 1). The tracking stations will be constructed and operated as described in Eiler (1995), except that they will not have satellite up-link capabilities. Each remote tracking station will consist of an ATS R4500C integrated receiver and data logger, two directional Yagi antennae (one aimed upstream and one aimed downstream), and a solar panel and battery power system. The stations will be strategically placed to afford the antennae unobstructed downstream and upstream views. Radiotagged fish within reception range of the tracking stations will be uniquely identified and recorded on the data logger. The detection range of each tracking station will be verified by placing radio tags in the water column through likely migration routes and observing preliminary data logger results. The tracking stations 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 stations will be programmed to record this data every 10 minutes. The location of each radio tag relative to the station (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 station will verify that the station components are functioning properly and to identify if/when the tracking station stops working. Each remote telemetry station will be checked at least once weekly and data will be downloaded from the receivers via a laptop computer. All data will be immediately downloaded onto a laptop computer and copied on a separate external hard drive. A logbook will be maintained at each station noting date, staff, settings, and battery voltage for each visit. A checklist with radio receiver settings and the download steps will be at each site.

## FATES

Fate codes are identified in Table 2. The left (“ones”) digit indicates whether the tagged fish progressed upstream, and then passed the US border. The right (“tenths”) digit defines a fate further for both those that progressed upstream of the border and those that did not. For those

that progress upstream the “hundredths” digit would be used to identify whether the fish was located upstream or downstream of the landslide, and the “thousands” digit can be used to further indicate which area of the Stikine the fish were last located in.

Table 2.-List of fates to be recorded for all radiotagged Chinook Salmon on the Stikine River, 2015.

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 fishery
1.31	Passed the border, and tracked upstream of the landslide on the Tahltan River
1.32#	Passed the border and tracked downstream of the landslide on the Tahltan at location #.

## SPAWNING DISTRIBUTION

Attempts will be made to locate each radio transmitter periodically by aerial surveys. Four drainage-wide aerial surveys will be flown to identify spawning distribution at two week intervals starting around July 22. Surveys will be conducted on the mainstem Stikine River and the major spawning tributaries previously identified in Pahlke and Etherton (1999) and Richards et al. (2008). Fish will be tracked with fixed-wing aircraft and helicopters. 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 sites will be inferred by maximum upstream locations of radio tags and each fish assigned to fate 1.1 (probable spawning in a tributary in Canada) will be then assigned to one of 7 spawning areas as described in Pahlke and Etherton (1999) and Richards et al. (2008).

## ASSUMPTIONS

Assumptions of the experiment include: a) fish will be tagged for radiotracking in proportion to the run timing of the run; b) tagging will not change the destination (fate) of a fish; and c) 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) in the immigration. Catchability has historically varied with river conditions. Thus, sampling effort will be remain consistent as possible during the immigration. Successful mark-recapture abundance estimates for Chinook salmon on the Stikine River have occurred for 19 consecutive years. In nearly all years, the results indicate that fish are tagged in proportion to the run or fish mix prior to being recaptured in the Canadian fishery or fish mix prior to reaching the spawning grounds.

Pahlke and Etherton (1999) and Richards et al. (2008) showed that Chinook salmon handling mortality was negligible on the Stikine River. Capture and handling techniques have been highly refined on the Stikine River over the past 19 years, the upmost care is given to each fish, and only healthy fish are tagged (Jaecks et al. *in press*). Eiler (2014) used nearly identical capture and handling techniques to radiotag nearly 3,000 Chinook salmon on the Yukon River and showed similar negligible handling mortality (2-3%) And although short-term behavior was influenced, the long-term behavior and ultimate fate of radiotagged Chinook salmon was not likely influenced.

## **DATA ANALYSIS**

### **PROPORTION OF FISH TAGGED THAT MIGRATE PAST THE U.S./CANADIAN BORDER**

Proportion of tagged fish ( $p_f$ ) that migrate past the U.S./Canadian border will be calculated as:

$$p_f = \frac{m_f}{M} \quad (1)$$

where  $m_f$  is the number of fish in the sample that are detected passing the border divided by the total marked fish  $M$  that were fitted with radio tags. Two remote tracking stations will be placed at the U.S./Canada border to ensure tag detection. Eiler (2014) deployed nearly 3,000 ATS radio tags in Chinook salmon on the Yukon River and had no known tag failures. The amount of error caused by tag failure will therefore be considered negligible and the proportion for this year will be treated as a constant. If conditions are thought to be similar from year to year, an estimate of the variance for years when there is no telemetry project can be calculated using the unbiased estimator presented in Thompson (2002):

$$\widehat{var}(\hat{p}_f) = \frac{\hat{p}_f(1-\hat{p}_f)}{M-1} \quad (2)$$

### **PROPORTION AT OR PASSING A LOCATION**

A location may be defined as the area above the landslide of the Tahltan River or more specifically to an identified spawning area. Either set of locations can be estimated as described below. If non-proportional tagging occurs, the proportions can be stratified by time. However, since the variability will likely increase in this scenario due to decreased sample sizes, making our objectives more difficult if not impossible to attain, we will consider proportional tagging efforts of the utmost importance. Proportional tagging can be evaluated by doing a chi-square test using a contingency table consisting of marked/unmarked categories for rows, and time periods for columns. The analysis described here is for multiple time periods, but if the tagged to untagged numbers at abundance recapture sites are not found to be different by time period via this hypothesis testing, then the following equations can collapse to one time period.

Contingency Table for Test For Proportional Tagging by Time Period

	Time Period Examined			
	1	2	...	t
Marked ( $m_2$ )				
Unmarked ( $n_2-m_2$ )				

The proportion of large Chinook salmon ( $\geq 660$  mm MEF) at a non-overlapping, (mutually independent) location (a) will be estimated for each time period (t) by dividing the number of fish with radio tags found in a particular location by the estimated number of marked fish available. The number of fish available is defined as the estimated number of marked fish that progressed upstream minus those fitted with radio tags that were caught in an inriver fishery.

$$\hat{P}_{a,t} = \frac{r_{a,t}}{m_t - c_t - x_t} \quad (3)$$

$r_{a,t}$  = number of large fish released with radio tags during period t that survived inriver fisheries to spawn in an area a;

$m_t$  = number of large fish released with radio tags during period t;

$c_t$  = number of large fish released with radio tags during period t, but caught in inriver fisheries;

$x_t$  = number of large fish released with radio tags during period t, but subsequently did not progress up stream;

The overall proportion for all time periods combined will be calculated using:

$$\hat{P}_a = \sum_t \hat{w}_t \hat{P}_{a,t} \quad (4)$$

$$\hat{w}_t = \frac{M_t}{\sum_{t=1}^T M_t} \quad (5)$$

Where:

$M_t$  = number of large fish captured near Kakwan Point during period t; and

$\hat{w}_t$  = estimated weight of tags during period t compared to all time periods.

Variances for the  $\hat{P}_a$  will be estimated with parametric bootstrapping (Efron and Tibshirani 1993). Time period statistics will be calculated for fraction of passage by Kakwan Point in period t ( $\theta_t$ ), harvest rate in inriver fisheries for fish fitted with radio tags in period t ( $u_t$ ), the fraction for test subjects fitted with radio tags in period t that will arrive at the location ( $\rho_{a,t}$ ), and the fraction of fish fitted with radio tags in period t that fail ( $\zeta_t$ ):

$$\hat{\theta}_t = \frac{M_t}{M} \quad (6)$$

$$\hat{u}_t = \frac{c_t}{m_t} \quad (7)$$

$$\hat{\rho}_{a,t} = \frac{r_{a,t}}{m_t} \quad (8)$$

$$\hat{\zeta}_t = \frac{x_t}{m_t} \quad (9)$$

A yearly statistic will be calculated for the proportion of fish passing Kakwan point that are caught ( $q$ ):

$$\hat{q} = \frac{M}{\hat{N}} \quad (10)$$

For each iteration of the simulation (denoted by the subscript b), a vector of time period abundance passing by Kakwan Point was generated with the following multinomial distribution:

$$(N_{1(b)}^*, \dots, N_{t(b)}^*, \dots) \sim \text{multinomial}(\hat{N}, \hat{\theta}_1, \dots, \hat{\theta}_t, \dots) \quad (11)$$

In turn, this vector will be translated into numbers of large fish caught ( $M_{t(b)}^*$ ) and the number of test subjects with radio tags released each time period ( $m_{t(b)}^*$ ):

$$M_{t(b)}^* = N_{t(b)}^* \hat{q} \quad (12)$$

$$m_{t(b)}^* = M_{t(b)}^* z_t \quad (13)$$

$$z_t = \frac{m_t}{M_t} \quad (14)$$

Where  $z_t$  is the known proportion of large fish caught that are represented by a tag in time period t. In most cases this should be close to, if not equal to, one. It is not equal to one if at least one fish caught is in such poor condition that it will likely die before continuing to spawning grounds. Chinook salmon exhibiting such conditions will not be tagged.

For each time period (within each iteration), a vector of time period recoveries on the spawning grounds, catches, and failures will be generated with the following multinomial distribution:

$$(r_{1,t(b)}^*, \dots, r_{a,t(b)}^*, \dots, r_{n,t(b)}^*, c_{t(b)}^*, x_{t(b)}^*) \sim \text{multinomial}(cm_{t(b)}^*, \hat{\rho}_{1,t}, \dots, \hat{\rho}_{a,t}, \dots, \hat{\rho}_{n,t}, \hat{u}_t, \hat{\zeta}_t) \quad (15)$$

The resulting vectors will be inserted into equations (3-5) as per obvious substitution to produce a simulated value  $P_{a(b)}^*$  for each iteration. 10,000 iterations will be computed and the variance for  $P_a$  will be estimated by finding the sample variance of the  $P_{a(b)}^*$  simulated values.

## NUMBER OF FISH AT A LOCATION

The number of Chinook salmon  $\geq 660$  mm at a spawning location  $\hat{N}_{LEL}$  will be estimated by multiplying the estimate of abundance of large escaping Chinook salmon  $\hat{N}_{LE}$  (Jaecks et al. *in press*) and the estimate of proportion at a spawning location  $\hat{P}_a$  together:

$$\hat{N}_{LEL} = \hat{N}_{LE} * \hat{P}_a \quad (16)$$

The variance will be estimated using Goodman's equation (1960)

$$var(\hat{N}_{LEL}) = var(\hat{N}_{LE})(\hat{P}_a)^2 + (\hat{N}_{LE})^2 var(\hat{P}_a) - var(\hat{N}_{LE})var(\hat{P}_a) \quad (17)$$

## SCHEDULE AND DELIVERABLES

Field activities for tagging Chinook salmon at Kakwan Point will begin in early May and extend through mid-July. The remote tracking stations will be functioning prior to any fish being tagged in the mark-recapture experiment. Remote tracking stations will be checked at least once weekly and data will be downloaded via a laptop computer. Data will be immediately copied on a second portable, external hard drive. All telemetry data will be sent to Philip Richards and Troy Jaecks weekly. A draft report will be written in Juneau by ADF&G by 30 April, 2017 and distributed for editing and further development to FOC shortly thereafter. Changes to the report will be submitted by FOC to ADF&G by 1 July, 2017 and the final report will be submitted for peer review by 1 September, 2017.

## RESPONSIBILITIES

### I. Agency Responsibilities

- A. ADF&G. Will plan project in cooperation with FOC. Will write operational plan with FOC. Will provide all ATS telemetry receivers and about one half of the remote tracking stations and associated hardware. Will purchase all radio tags and necessary hardware. Will install and monitor all remote tracking stations on the lower Stikine River.
- B. FOC. Will assist in planning of project. Will install and monitor remote tracking stations on the Tahltan River. Will provide about one half of the remote tracking stations and associated hardware.

## **II. U.S. Personnel Responsibilities**

Philip Richards, FBIII, Project Leader. Will oversee and assist with all aspects of the project including planning, budget, sample design, permits, equipment, and supervising field operations. Coalesces, edits, analyzes and reports data; assists with fieldwork.

Troy Jaecks, FBII. In concert with Philip Richards, and Peter Etherton, sets up all aspects of project, including planning, budget, sample design, permits, equipment, personnel, and training. Assists in supervising Kakwan Point operations and assists with supervision of recovery. Coalesces, edits, analyzes, and reports data; assists with fieldwork; arranges logistics with field crew. Takes lead role in analysis and first draft of report.

Ed Jones, Salmon Research Coordinator. This position is responsible for general oversight of this project and the Chinook stock assessment program in the region. Reviews project planning, operational plans and technical reports.

Sarah Power, 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 final report.

Stephen Todd, FBI. This position is responsible for supervising one portion of the field tagging program. Will coordinate schedules with FOC/Tahltan crew and share responsibility for all aspects of field operations, including safe operation of riverboats, and other equipment, tagging, data collection, and general field camp duties. Will assume lead role in equipment and camp maintenance.

Vacant, FTII. Will be responsible for assisting in all aspects of field operations, including safe operation of riverboats, and other equipment, tagging, data collection, and general field camp duties. Will assist in remote tracking station installation and coordinate weekly data downloads.

## **II. Canadian Personnel Responsibilities**

Peter Etherton, Resource Manager. In concert with Troy Jaecks, Philip Richards, and Stephen Todd, assist in all aspects of the program, including: tag application, tag recovery, and report preparation. Will be responsible for scheduling Canadian staff at both the tagging and recovery sites. Will participate in both the tagging and recovery component of the program. Will arrange and participate in meetings with Canadian, commercial, and Aboriginal fishers. Will provide recovery data to ADF&G. Will review data, provide input into report, write sections regarding recovery and serve as co-author.

Kyle Inkster, Tahltan Fisheries Technician. This position is responsible for supervising the other portion of the field tagging program. Will coordinate schedules with the ADF&G crew and share responsibility for all aspects of field operations, including safe operation of riverboats, and other equipment, tagging, data collection, and general field camp duties. Will assist in equipment and camp maintenance.

Kerry Carlick, Tahltan Fisheries Technician. Will be responsible for assisting in all aspects of field operations, including safe operation of riverboats, and other equipment, tagging, data collection, and general field camp duties. Will assist in equipment and camp maintenance. Will work closely with ADF&G crew to fish in the most efficient manner possible.

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