Regional Operational Plan SF.1J.2016.05

Migration, Landslide Passage, Tagging Response, and Distribution of Chinook Salmon Returning to the Stikine River, 2016

by

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May 2016

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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MIGRATION, LANDSLIDE PASSAGE, TAGGING RESPONSE, AND DISTRIBUTION OF CHINOOK SALMON RETURNING TO THE STIKINE RIVER, 2016

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Approval

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Assistant Project Leader	Ian Boyce		April 12, 2016
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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 proportion 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 and aerial surveys will be used to determine the number of fish that successfully navigate past the 2014 landslide. Aerial surveys will be used to determine spawning distribution for significant spawning areas.

Key words: mark-recapture, Stikine River, Chinook salmon, *Oncorhynchus tshawytscha*, 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 have the potential for biasing abundance estimates. In addition, Chinook salmon migration passage will be monitored on the lower Tahltan River, where approximately 50% of Stikine River Chinook salmon spawn above the site of disrupted habitat as a result of a major landslide in 2014. Aerial surveys will be used to estimate the proportion returning to the most significant sub-basins to compare with previous radiotelemetry studies conducted on the Stikine River in 1997 and 2005. If weather conditions and flight time allow, all areas of the drainage will be flown which would allow identification of the spawning distribution extent for Chinook salmon in the drainage.

BACKGROUND

Abundance based management of Stikine River Chinook salmon *Oncorhynchus tshawytscha* is mandated by Chapter 1, paragraph 2 of the Pacific Salmon Treaty (PST 2008). As part of this requirement, mark-recapture abundance estimates of large Chinook salmon (≥ 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, 2016 to 2018* (Jaecks et al. *in prep*). 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). Preliminary results from the 2015 telemetry studies on the Stikine River indicate a dropout rate of 23%. The 23% dropout rate observed on the Stikine

River in 2015 was the highest dropout rate observed for Chinook salmon in Southeast Alaska (Johnson et al 1992; Pahlke and Bernard 1996; Pahlke and Etherton 1999; Pahlke et al 1999; Pahlke and Waugh 2003; Richards et al 2008; Weller and Evans 2012).

Fish marked inriver with spaghetti tags are sometimes recaptured downstream of the study site in marine fisheries. However, these recaptured fish likely only account for a small fraction of the marked fish that dropped out of the system (i.e., dropped out of the mark-recapture experiment), therefore likely biasing our estimates high due to unaccounted dropouts (Figure 1). Dropouts that are not accounted for would bias the abundance estimates high. Radiotagging allows for more accurate estimation for the dropout compared to spaghetti tagging. With radio tagging you should be able to discern up steam movement compared to those that don't, whereas downstream movement of spaghetti tags can only be discerned by the chance interception of spaghetti tagged fish in marine commercial and sport fisheries and in Andrew Creek.

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, 2000; Pahlke et al. 2000; Der Hovanisian et al. 2001, 2003-2005; 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 occasionally captured in the Stikine River above the U.S./Canada border (Richards et al. 2008; Pahlke 2010; Pahlke et al. 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 occurs annually for CWTs and CWT recoveries suggest 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 information, a correction factor may be applied to help reduce this bias and the resulting effect on abundance estimates.

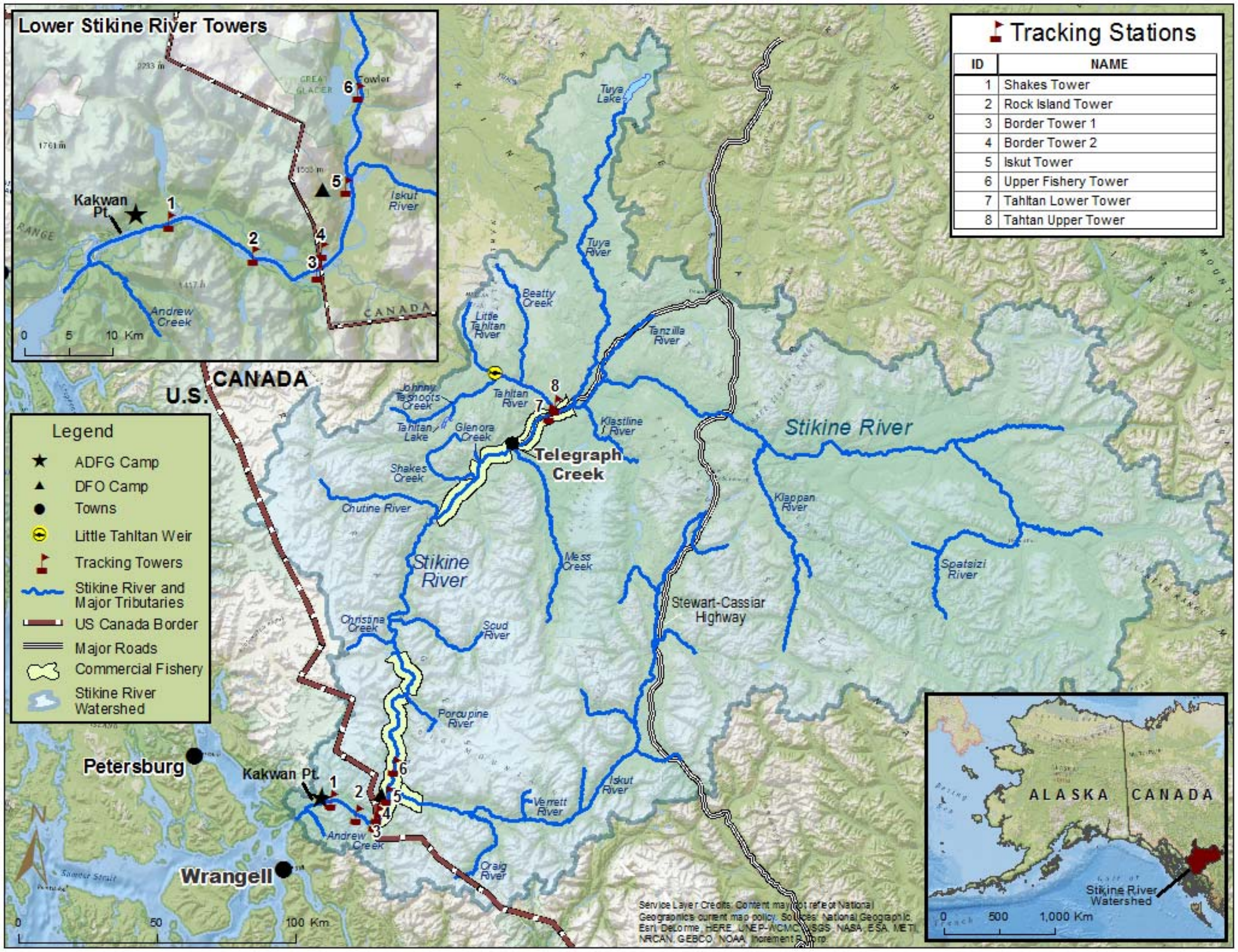

Figure 1.-Stikine River drainage in Southeast Alaska, with locations of the mark-recapture experiment and remote telemetry stations.

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 1998-2000; Pahlke et al. 2000; Der Hovanisian et al. 2001, 2003-2005; 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.

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 area for 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 being transported around the slide. To more accurately assess passage rates in 2016, 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 2016 throughout the entire migration. Although the Tahltan River landslide did not cause any known mortality and preliminary results do not appear to show that the landslide is a substantive barrier to large Chinook salmon in 2015; unusually low water conditions persisted throughout the Chinook salmon migration, likely making water conditions ideal for passage. Therefore we will continue to monitor the landslide in the event that different water conditions result in impedance to salmon passage.

OBJECTIVES

PRIMARY OBJECTIVES:

1. Estimate the proportion of large Chinook salmon (≥ 660 mm MEF) tagged during event 1 that migrate past the U.S./Canada border such that the half-width of the calculated 95% CIs are within 5 percentage points of the point estimate.
2. Estimate the number of large Chinook salmon (≥ 660 mm MEF) that successfully pass the landslide on the Tahltan River such that the half-width of the calculated 95% CIs are ≤ 20 percentage points of the point estimate.

SECONDARY OBJECTIVES:

1. Describe tagging response and migration rates of large Chinook salmon (≥ 660 mm MEF) tagged during event 1 up to and within the Canadian fishery;
2. Collect paired tissue samples from all radiotagged Chinook salmon for genetic analysis.
3. Identify spawning areas of large Chinook salmon (≥ 660 mm MEF) through fixed-wing aerial surveys and radio telemetry so that all spawning areas containing > 2% of the spawning population of large Chinook salmon are identified with a probability at least 99%, and so that if spawners are distributed uniformly among 50 areas, the probability of detecting all 50 areas is at least 22%.

METHODS

CAPTURE AND TAGGING

Internal pulse-coded radio tags manufactured by Advanced Telemetry Systems (ATS™) 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, 2016* (Jaecks et al. *in prep*).

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 (Jaecks et al. *in prep*). 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™ 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 (Jaecks et al. *in prep*). 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 2016, 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.

Table 1.-Proposed weekly tagging rate of Chinook Salmon on the Stikine River, for radio tags based on the expected run size in 2016.

Statistical Week	Date	Weekly	Cumulative
19	8-May	24	24
20	15-May	28	52
21	22-May	32	84
22	29-May	17	101
23	5-Jun	33	134
24	12-Jun	36	170
25	19-Jun	41	211
26	26-Jun	43	254
27	3-Jul	33	287
28	10-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 U.S. 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, 2016

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 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 by Pahlke and Etherton (1999) and Richards et al. (2008). Secondary objective 3 will only be completed if all drainages are flown or all final fates and upstream locations of fish are known. 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 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 remain consistent as possible during the immigration. Successful mark-recapture abundance estimates for Chinook salmon on the Stikine River have occurred for 20 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 20 years, the upmost care is given to each fish, and only healthy fish are tagged (Jaecks et al. *in prep*). Eiler (2014) used nearly identical capture and handling techniques to radio tag 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 (Assumption b) of radiotagged Chinook salmon was not likely influenced.

SAMPLE SIZE AND PRECISION

Primary Objective 1 relates to the dropout rate of tagged individuals. If all spaghetti tagged fish are fitted with a radio tag then this value will be known not estimated. If the number of fish tagged is similar to last year's number of 314, then almost all fish will be tagged (Jaecks et al. *in prep*). In the event that the number of fish tagged is much higher and not all large fish are radiotagged then consider the following.

Last year's preliminary results point toward a 23% drop out rate, the highest rate compared to all previous Chinook salmon radiotelemetry studies in Southeast Alaska. (Johnson et al. 1992;

Pahlke and Bernard 1996; Pahlke et al. 1996; Pahlke and Etherton 1999; Richards et al. 2008; Weller and Evans 2012). For sample size calculations we will use a 25% drop out rate. Tag loss or tag failure prior to upstream migration will be included in the dropout rate since distinguishing between these events is not possible. This may bias estimates, but it is believed that any bias would be small. Eiler (2014) deployed nearly 3,000 ATS radio tags in Chinook salmon on the Yukon River and had no known tag failures. For the sample size determination for the estimates of the proportion of fish that migrate upstream, we assume there is no data loss. Our objectives are written in relation to upstream migration, the converse of the dropout rate. In our worst case scenario this translates to a 75% upstream migration rate after tagging. If the tagging rate is about twice what it was last year then 600 fish would be spaghetti tagged with half of them receiving radio tags. To be within 5 percentage points of the true value 95% of the time, 195 fish are required if using a finite population correction factor (Thompson 2002).

Primary objective 2 is to 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. This estimate relies on two other estimates, the estimated proportion of fish that will pass the landslide and the escapement estimate. Last year's escapement estimate was 21,343 (Jaecks et al. 2015). Preliminary results from 2015 indicate that approximately 32% (59/184) of radiotagged Chinook salmon estimated to have spawned were located above the Tahltan landslide and perhaps all radio tagged Chinook salmon migrating to the Tahltan River passed the landslide. If there are 300 tags applied, with 75% (225) of those progressing up stream, 50 of which are caught in the inriver fisheries, that would give 175 tags (300*.75 - 50) and the variance for the proportion ($\hat{p} = 32\%$), $\widehat{var}(\hat{p})$, would be .0012 (Thompson 2002 pg 40). If conditions were similar to last year, the estimated escapement and its estimated variance will be 21,343 $(\hat{N})$ and 6,003,364 $\widehat{var}(\hat{N})$ respectively. Using Goodman's equation (1961) the estimated variance for number of large Chinook $\widehat{var}(\hat{N}_i)$ that successfully pass the landslide can be calculated.

$$\widehat{var}(\hat{N}_i) = \hat{N}^2\widehat{var}(\hat{p}) + \hat{p}^2\widehat{var}(\hat{N}) - \widehat{var}(\hat{N})\widehat{var}(\hat{p}) \qquad (1)$$

This results in an estimated standard error of approximately 1,083. Then the calculated 95 confidence interval would be within 1.96*1,083 fish, which is about 2,123 fish, or within 10% of the estimated 21,343*32% = 6,830 fish, which is within our precision criteria. Thus radio tagging 300 fish should be sufficient. If stratification by time, area, or other variable is necessary then the estimates will be less precise and objective criteria may not be achieved.

Secondary objective 3 is to identify the spawning areas of large Chinook salmon (≥ 660 mm MEF) through fixed-wing aerial surveys and telemetry so that spawning areas representing > 2% of the spawning population of large Chinook salmon are identified 99% of the time. Additionally if spawners are distributed uniformly among 50 areas (100%/2%), the probability of detection all 50 locations is at least 66%. With 300 tags deployed and 175 available to identify spawning areas, using a spatial Poisson process, the expected number of tags in an area with 2% of the spawning population, λ, is 175*0.02 = 3.5 , the probability of detecting no tags in an area that contains 2% of the spawning population is $\frac{3.5^0}{0!}e^{-3.5} \approx 0.03$. The probability of detecting at least one tag in an area that contains 2% of the spawning population is 1- 0.03 = 97%. The probability of detecting all 50 possible areas is $(97\%)^{50}$ or approximately 22%.

DATA ANALYSIS

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

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

$$p_r = \frac{r}{M} \tag{2}$$

where m_r 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. This equation assumes all marked fish receiving radio tags and tags are detected 100% of the time. 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.

In the event that the number of fish caught for tagging is above the number expected, and radio tags are not applied to every spaghetti tagged fish then the following formulas may be used. We also must consider the possibility of tagging being non-proportional which may require stratification. Appropriate statistical tests will be conducted to determine if stratification is necessary. Such tests include a chi-squared for > 2 strata, such as time, or a t-test for two strata, such as gender. If radio tagging compared to spaghetti tagging is the same proportion for all strata then strata may be combined to form one stratum. The equation for the proportion of radio tagged fish moving upstream, $p_{r,t}$, is as follows:

$$p_{r,t} = \frac{m_{r,t}}{M_{r,t}} \tag{3}$$

Where $m_{r,t}$ is the number of radio tagged fish during strata t detected as progressing up stream of the $M_{r,t}$ radio tagged fish during strata t.

The estimate of the proportion of *spaghetti* tagged fish that pass the border, $\hat{p}_{up}$, will be weighted by the proportion of fish that are spaghetti tagged during strata t in relation to all the fish that are spaghetti tagged during the season, w_t. The weighted proportion is a known quantity with no variance.

$$w_t = \frac{M_t}{\sum_{t=1}^{T} M_t} \tag{4}$$

where M_t is the number of tagged fish, regardless of tag choice that were tagged strata t. The sum of all M_t is equal to the total number of marked fish, *M*, which includes those that were fitted with radio tags as well as those that were not. The estimate for the proportion of tagged fish progressing upstream, $\hat{p}_{up}$, will be:

$$\hat{p}_{up} = \sum_{t=1}^{T} w_t * p_{r,t} \tag{5}$$

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. An estimate of the variance for each location and strata period can be calculated using the unbiased estimator with a finite population correction factor presented in Thompson (2002) multiplied by the square of the weighting factor:

$$\widehat{var}(\hat{p}_t) = w_{l,t}^2 \left(\frac{M_t - M_{r,t}}{M_t}\right) \frac{\hat{p}_{r,t}(1-\hat{p}_{r,t})}{M_{r,t}-1} \quad (6)$$

The variance of the estimated proportion of upstream migration is the sum of the variances for each $\hat{p}_t$.

$$\widehat{var}(\hat{p}_{up}) = \sum \widehat{var}(\hat{p}_t) \quad (7)$$

PROPORTION AT OR PASSING A LOCATION

A location may be defined as the area above a point such as the landslide of the Tahltan River or more specifically to an identified spawning area. Either set of locations can be estimated as described below.

Chi squared tests will be used to determine if geographic or temporal, size or gender stratification is required via procedures outlined in Appendix B of Jaecks et al. 2015. If separate strata are required for abundance estimates those same strata will be used for both abundance and the proportion at or passing a location. The strata, denoted with a ‘t’, may indicate time, or any manner of strata. If strata are not found to be different then the following equations can be simplified to one stratum.

The proportion of large Chinook salmon (≥ 660 mm MEF) at a non-overlapping, mutually independent location (a) will be estimated for each stratum (t) (i.e. time period) 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 in-river fishery.

$$\hat{P}_{a,t} = \frac{r_{a,t}}{m_t - c_t - x_t} \quad (8)$$

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

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

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

x_t =number of large fish released with radio tags during stratum t, but subsequently did not progress up stream. This includes those tagged at Canyon Island as well as those tagged above the US Canadian border.

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

$$\hat{P}_a = \sum_t \hat{w}_t \hat{P}_{a,t} \tag{9}$$

$$\hat{w}_t = \frac{\hat{N}_t}{\sum_{t=1}^{T} \hat{N}_t} \tag{10}$$

Where:

$\hat{N}_t$ = estimated number of large fish to be passing the tagging site during strata t from Jaecks et al. 2015; and

$\hat{w}_t$ = estimated weight of tags during stratum t compared to all strata.

Variances for the $\hat{P}_a$ will be estimated via parametric bootstrapping (Efron and Tibshirani 1993). Statistics for each stratum will be calculated for the proportion of radio tagged fish in stratum t (θ_t), harvest rate in in-river fisheries for fish fitted with radio tags in stratum t (u_t), the proportion for test subjects fitted with radio tags in stratum t that will arrive at the location $(\rho_{a,t})$, and the proportion of fish fitted with radio tags in stratum t that fail(ζ_t):

$$\hat{\theta}_t = \frac{m_t}{\hat{N}_t} \tag{11}$$

$$\hat{u}_t = \frac{c_t}{m_t} \tag{12}$$

$$\hat{\rho}_{a,t} = \frac{r_{a,t}}{m_t} \tag{13}$$

$$\hat{\zeta}_t = \frac{x_t}{m_t} \tag{14}$$

A yearly statistic will be calculated for the proportion of fish that are caught and tagged (q);

$$\hat{q} = \frac{M}{\hat{N}} \tag{15}$$

For each iteration of the simulation (denoted by the subscript b), a vector of strata abundance of tagged fish was generated with the following multinomial distribution:

$$\left(N^*_{1(b)}, \ldots, N^*_{t(b)}, \ldots\right) \sim multinomial\left(\hat{N}, \hat{w}_1, \ldots, \hat{w}_t, \ldots\right) \tag{16}$$

Next, this vector will be translated into numbers of large fish with radio tags released each stratum $\left(m^*_{t(b)}\right)$:

$$m^*_{t(b)} = N^*_{t(b)} \hat{\theta}_t \tag{17}$$

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

$$\left(r^*_{1,t(b)}, \dots, r^*_{a,t(b)}, \dots, r^*_{n,t(b)}, c^*_{t(b)}, x^*_{t(b)}\right) \sim multinomial\left(m^*_{t(b)}, \hat{\rho}_{1,t}, \dots, \hat{\rho}_{a,t}, \dots \hat{\rho}_{n,t}, \hat{u}_t, \hat{\zeta}_t\right) \quad (20)$$

The resulting vectors will be inserted into equations (10-12) as per obvious substitution to produce a simulated value $P^*_{a(b)}$ for each iteration. At least 10,000 iterations will be computed and the variance for P_a will be estimated by the variance produced from the $P^*_{a,t(b)}$ simulated values.

NUMBER OF FISH AT A LOCATION

The number of large Chinook salmon 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. 2015) and the estimate of proportion of large Chinook salmon at a spawning location $\hat{P}_a$ as estimated by this study, together:

$$\hat{N}_{LEL} = \hat{N}_{LE} * \hat{P}_a \quad (21)$$

The variance will be estimated by parametric bootstrapping (Efron and Tibshirani 1993). For each iteration of the simulation (denoted by the subscript b), simulated values of $\hat{N}_{LE(b)}$ from the approximately normal distribution of $\sim N\left(\hat{N}_{LE}, var\left(\hat{N}_{LE}\right)\right)$ (Jaecks et al. 2015) will be multiplied by the simulated values of $P^*_{a(b)}$ as described above to produce an estimate of fish at a location. Similar methods are used in Cleary et al. (2013). A vector of at least 10,000 such estimates will be produced and the variance for $\hat{N}_{LEL}$will be estimated by finding the sample variance of the $\hat{N}_{LEL}$ simulated values.

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.

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.

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.

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

Ian Boyce, Fishery Biologist. 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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