Regional Operational Plan SF.1J.2015.11

Migration, Tagging Response, and Distribution of Chinook Salmon Returning to the Taku River, 2015

by

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June 2015

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

REGIONAL OPERATIONAL PLAN SF.1J.2015.11

MIGRATION, TAGGING RESPONSE, AND DISTRIBUTION OF CHINOOK SALMON RETURNING TO THE TAKU RIVER, 2015

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ABSTRACT

Large Chinook salmon *Oncorhynchus tshawytscha* captured during the annual mark-recapture experiment on the Taku 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 progress upstream, the migration rate to the U.S./Canada border and through the Canadian fishery, and tagging response of marked fish. Aerial surveys will be used to determine spawning distribution and the number of radio tagged fish within the aerial survey index areas.

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

PURPOSE

The Alaska Department of Fish and Game (ADF&G), in cooperation from Fisheries and Oceans Canada (FOC) and Taku River Tlingit First Nations (TRTFN), has been allocated funds from the Northern Fund Committee of the Pacific Salmon Commission to conduct a Chinook salmon radiotelemetry study on the Taku River in 2015 and 2016. This radiotelemetry study will help gain insights into key assumptions of the annual Taku River Chinook salmon mark-recapture experiment that—to an unknown degree—have the potential for biasing abundance estimates. Aerial surveys will be used to determine the spawning distribution extent of Chinook salmon in the drainage, while also estimating the proportion returning to the most significant spawning tributaries to compare with previous radiotelemetry studies conducted on the Taku River in 1989 and 1990. Radio tagged fish will also be tracked during the annual aerial index area surveys to determine the number of radio tagged fish within each aerial index area while the survey is taking place.

BACKGROUND

Abundance based management of Taku 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 (≥ 660 mm mid eye to fork of tail (MEF)) in the Taku River have occurred in 1989 and 1990, and annually since 1995. Objective criteria and methods of the mark-recapture project are described in a separate operational plan entitled *Estimation of Chinook Salmon Escapement in the Taku River, 2015* (Williams et al. 2015). This mark-recapture program is the foundation for abundance based management of Taku 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 Taku 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 crossing the U.S./Canada border) will cause mark-recapture abundance estimates in the Taku River to be biased high (Bernard et al. 1999). During previous radiotelemetry studies in 1989 and 1990 in the Taku River, the dropout rate was estimated to be 11% and 20% respectively, the highest dropout rates observed in Southeast Alaska (Johnson et al. 1992; Pahlke and Bernard 1996; Pahlke et al. 1996; Richards et al. 2008; Pahlke and Etherton 1999; Weller and Evans 2012) and potentially all of Alaska (John Eiler, biologist, National Marine Fisheries Service, Juneau, Alaska, personal communication, February 2015). During years without radio telemetry, fish marked inriver with spaghetti tags are regularly recaptured downstream of the study site in marine fisheries. 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 (McPherson et al. 1996; Pahlke and Bernard 1996; McPherson et al. 1997; McPherson et al. 1998; McPherson et al. 1999; Jones et al. 2010). 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 inriver assessment/commercial fishery (hereafter referred to as the Canadian fishery), a distance of about 5 km, average approximately 12 days; however these rates have ranged from 1 day to >30 days (McPherson et al. 1996; Pahlke and Bernard 1996; McPherson et al. 1997; McPherson et al. 1998; McPherson et al. 1999; Jones et al. 2010). 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 a significant issue on the Taku River, and this has occurred 15 out of the past 16 years (McPherson et al. 1996; Pahlke and Bernard 1996; McPherson et al. 1997; McPherson et al. 1998; McPherson et al. 1999; Jones et al. 2010). Eiler et al. (2014) showed that Chinook salmon tagged further downstream of other Chinook tagged higher up in the in the Yukon River drainage, swam faster and were progressively less variable in their migration rate (km traveled per day) as they moved upriver compared to those that were initially tagged further upstream in the watershed. This suggests swimming speed and behavior (collectively, spawning migration) is more abnormal closer to the marking site.

Monitoring radio tagged fish in the lower Taku 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 Stikine River in 2015 and 2016 (Richards et al. 2015).

Aerial spawning surveys of Taku River Chinook salmon have been standardized since the early 1970s and occur annually in the Nakina, Nahlin, Dudidontu, Kowatua, and Tatsamenie rivers (McPherson et al. 2010; Pahlke, 2010) (Figure 1). In the stock-recruit analysis done by McPherson et al. (2000), peak aerial counts were found to be highly correlated with 5 years of matched mark-recapture studies. At that time, the sum of peak counts was used to develop an expansion factor of 5.2, which would be applied to subsequent peak count sums, to estimate escapements in years without mark-recapture studies. In the succeeding 15 years, the sum of peak counts compared to matched mark-recapture estimates (leading to calculation of an expansion factor)was found to have changed, and has since averaged 7.4 (SD=1.7) (McPherson et al. 2010; Richards et al. *in prep*). An expansion factor of 5.2 or less has not been observed since 1999 (Richards et al. *in prep*). The change in the expansion factor could be due to multiple factors including a change in spawning distribution, changes in environment, factors affecting the efficiency of counting Chinook salmon, and/or biased mark-recapture estimates. In addition to verifying assumptions in the mark-recapture experiment, tracking radio tagged Chinook salmon during the annual aerial spawning surveys will allow us estimate the proportion of tagged fish in each aerial index area over two consecutive years.

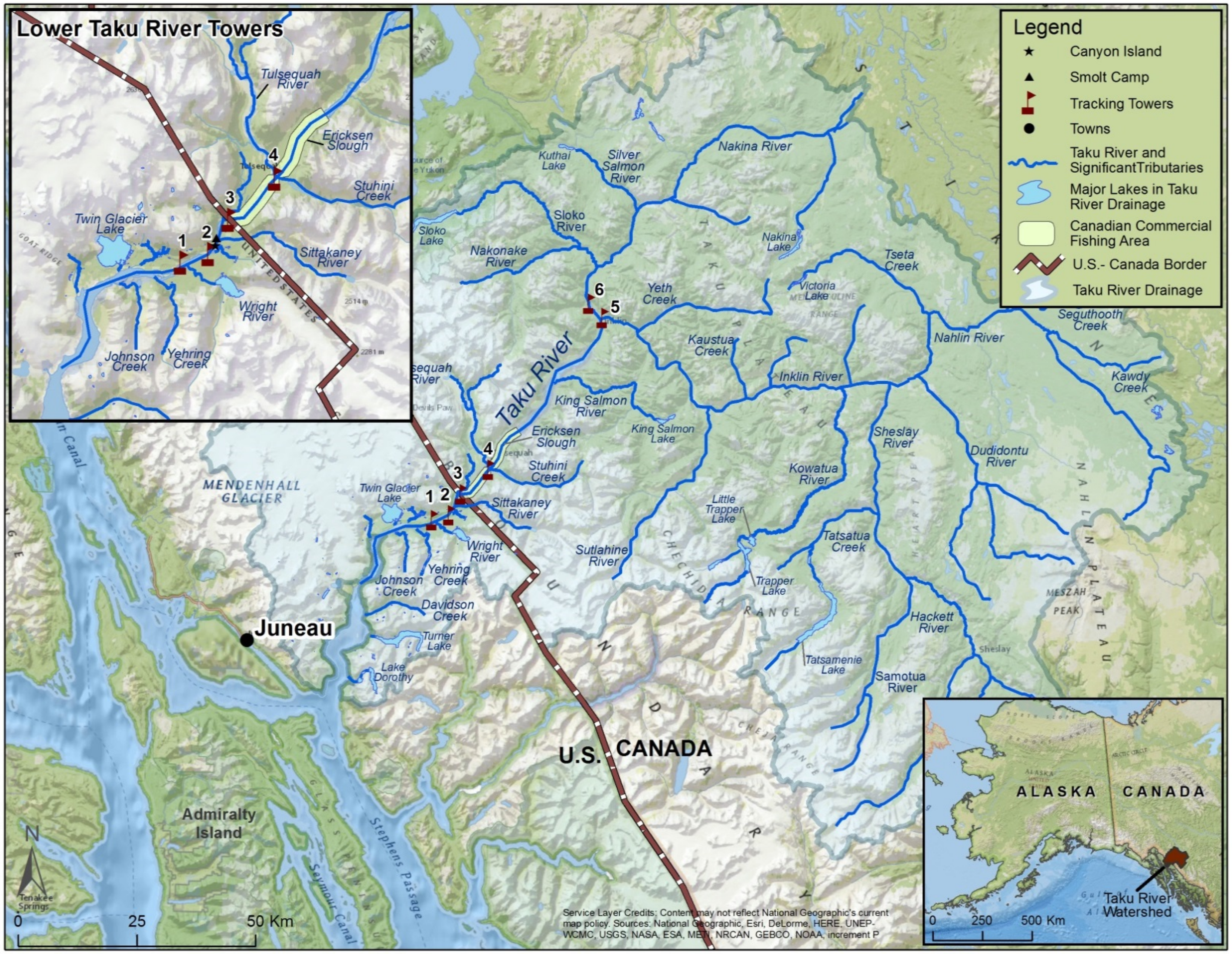

Figure 1.–Taku River drainage in Southeast Alaska, identifying key landmarks, including the locations of the mark-recapture experiment and remote telemetry stations.

OBJECTIVES

PRIMARY OBJECTIVES:

1. Estimate the percent of large Chinook salmon (≥ 660 mm MEF) tagged with spaghetti tags below the border that migrate past the U.S./Canada border, such that the estimate is within 5 percentages points of the true value 95% of the time;
2. Estimate the percent of large Chinook salmon (≥ 660 mm MEF) tagged with spaghetti tags above the U.S./Canada border that progress upstream past the Canadian fishery such that the estimate is within 9 percentages points of the true value 95% of the time;
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 66%.
4. Identify the proportion of large Chinook salmon (≥ 660 mm MEF) within the aerial index area during the traditional index area survey counts and concurrent aerial drainage-wide tracking (telemetry), so that proportion within the index area is within 5 percentage points of the true value 95% of the time.
5. Estimate the number of large Chinook salmon (≥ 660 mm MEF) within the aerial survey index areas on the Taku River such that the estimate is within 35% of the true value 95% of the time.

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 radio tagged Chinook salmon for genetic analysis.

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 *Estimation of Chinook Salmon Escapement in the Taku River, 2015* (Williams et al. 2015).

Chinook salmon will be captured using gillnets and fish wheels near Canyon Island (Figure 1). Personnel from ADF&G will capture Chinook salmon in drift gillnets operated by two teams of two people. The majority of capture will occur below the U.S./Canada border near Canyon Island. When the Canadian fishery is not taking place, one team will go up river to tag fish there (approximately 5 km above Canyon Island), and in so doing act as both an event 1 for newly tagged fish (marking event) and as an event 2 (recapture event, for previously marked fish). Williams et al. (2015) provides a complete description of capture methods to be employed. 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 late April and end in early July. The first Chinook salmon has generally been captured around late April, while the final capture generally occurs around mid-July.

Personnel from ADF&G and TRTFN will capture Chinook salmon in two fish wheels operated at Canyon Island, one on each riverbank. Fish wheels will operate continuously (22–24 hours each day) throughout the season, beginning approximately May 7 or as soon as water levels are high enough to turn the wheels. Each fish wheel consists of aluminum pontoons for floatation, a solid steel axle with connecting struts for up to 4 baskets, two aluminum basket frames covered with seine webbing, and aluminum live boxes. Design of the aluminum basket enables fish wheels to spin over a wide range of water levels or current velocities.

Chinook salmon of any size, captured in good condition will be measured, inspected to determine their sex, sampled to collect scales, and triple-marked as described in Williams et al. (2015). All data will be recorded in forms, also described in Williams et al. (2015). In addition to the three marks applied in the traditional mark-recapture experiment, a proportion of all large fish captured in either gillnet or fish wheels 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.

Every fourth large Chinook salmon captured in the fish wheels and in the drift gillnets will receive the ATS^{TM} 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 and fish wheel catches of Chinook salmon in statistical weeks 18 through 28 (Table 1). We will begin the season tagging every fourth healthy large Chinook salmon, regardless of gear type, since our total expected catch is about 1,200 large fish. If capture rates are higher or lower than expected, 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 radio tagged Chinook salmon are expected to be captured in the Canadian fishery in 2015, of which approximately 20 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 from individual Chinook salmon 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 Taku River, for radio tags based on the expected run size in 2015.

End of Stat Week	Date	Weekly Expected Catch	Weekly Cumulative Catch	Weekly Radio	Weekly Cumulative Radio
18	2-May	71	71	18	18
19	9-May	130	201	33	35
20	16-May	218	419	55	68
21	23-May	199	618	50	122
22	30-May	218	836	55	172
23	6-Jun	141	977	35	227
24	13-Jun	108	1085	27	262
25	20-Jun	57	1143	14	289
26	27-Jun	38	1180	9	303
27	4-Jul	20	1200	5	313
28	11-Jul	5	1205	1	318

SAMPLE SIZE AND PRECISION

Objectives 1 and 2 relate to the dropout rate of tagged individuals. Worse case scenarios estimate up to 20% of tagged fish drop out. (Johnson et al. 1992; Pahlke and Bernard 1996; Pahlke et al. 1996; Richards et al. 2008; Pahlke and Etherton 1999; Weller and Evans 2012). 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 believed that tag failure is small. Eiler (2014) deployed nearly 3,000 ATS radio tags in Chinook salmon on the Yukon River and had no known tag failures. 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 an 80% upstream migration rate after tagging. Tagging will occur in one of two places, below the U.S./Canada border (objective 1) or above the U.S./Canada border (objective 2). For our calculation we assume that 1200 fish will be spaghetti tagged, and 80%, or 960 will be below the U.S./Canada border and 20% or 240 will be above the U.S./Canada border.

Below the U.S./Canada border it is assumed 960 fish will be spaghetti tagged and a quarter or 240 of those will be additionally radio tagged. A sample size of 196 will give us a precision of within 5 percentage points of the true value 95% of the time when using a finite population correction factor. This is within our 240 expected numbers of tags applied.

Above the U.S./Canada border it is assumed 240 fish will be spaghetti tagged and a quarter or 60 of those will be additionally radio tagged. A sample size of 58 will give us a precision of within 9 percentage points of the true value 95% of the time when using a finite population correction factor. This is within our 60 expected numbers of tags applied.

Next consider objective 3 which 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. Also 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 a 20% tag loss/dropout rate, 240 will be 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 240*0.02 = 4.8 , the probability of detecting no tags in an area that contains 2% of the spawning population is $\frac{4.8^0}{0!}e^{-4.8} \approx 0.008$. The probability of detecting at least one tag in an area that contains 2% of the spawning population is 1- 0.008 = 99.2%. The probability of detecting all 50 possible areas is (99.2%)^50 or approximately 66%.

Next consider a subset of spawning areas, the aerial index area (Objective 4). Only certain tributaries of the Taku River run clear enough and have favorable enough conditions that fairly consistent aerial surveys may be conducted. Identifying those fish that spawn inside the aerial index area versus outside the aerial index area is a binomial proportion. The current expansion factors between aerial surveys and mark recapture estimates averages about 7.4 in other words the aerial surveys in aerial index areas count about 13.5% or the drainage wide escapement estimate (McPherson et al. 2010; Richards et al. *in prep*). To be within 5 percentage points 95% of the time, with a 20% data loss rate, and a population of 26,156 the sample size required is 224 fish (Thompson 2002, pg 42).

Now consider the estimated number of fish inside the aerial index areas ($\widehat{N}_i$) (objective 5). To estimate the number of fish inside the aerial index area, take proportion of fish inside the aerial index area and multiply it by the estimated escapement of fish. In order to calculate variance Goodman's equation (1960) is employed using the estimate and estimated variance for both the overall escapement and proportion of fish inside the aerial index areas. For the escapement of fish let us use the preseason forecast of 26,156 (Williams et al. 2015) as an estimate. The estimate of variance for this year's escapement estimate may be calculated in the following manner. Using the preseason forecast of N=26156, $\hat{n}_1$=960 as this years estimated available spaghetti tagging number (1200 with 20% data loss), and $\hat{n}_2$ =4161 from the number of fish inspected for tags last year, we can estimate that $\widehat{m}_2$ using equation 1 below. The estimated number of inspected fish on the second occasion baring spaghetti tag markings would be about 152 fish.

$$\widehat{m}_2 = \frac{(\hat{n}_1+1)(\hat{n}_2+1)}{N+1} - 1 \quad (1)$$

Substitute in the estimated values in for the known values in the variance equation for a modified form of Chapman's version of Petersen's abundance estimator (Seber 1982), below, to calculate the approximate variance expected:

$$\widehat{var}(\widehat{N}) = \frac{(\hat{n}_1+1)(\hat{n}_2+1)(\hat{n}_1-\widehat{m}_2)(\hat{n}_1-\widehat{m}_2)}{(\widehat{m}_2+1)^2(\widehat{m}_2+2)} \quad (2)$$

We get an estimated variance of Chinook abundance of 3,593,927. For the estimated proportion of fish we use the 13.5% of drainage wide fish counted in the aerial surveys. For the estimated variance of that proportion we make use of the fact that we plan on radio tagging 300 fish, 240 of which should be available to calculate the proportion inside the index area and the equation below for the estimated variance for a proportion (Thompson 2002). The estimated variance for then without using a finite population correction factor is approximately 0.000487.

$$\widehat{var}(\hat{p}) = \frac{\hat{p}(\hat{p}-1)}{n} \quad (3)$$

With estimates and estimated variances for both the escapement of fish and the proportion of fish inside the aerial index areas compute an estimated variance for the estimated number of fish inside the aerial index areas using Goodman's equation (1960).

$$\widehat{var}(\widehat{N}_i) = \widehat{N}^2\widehat{var}(\hat{p}) + \hat{p}^2\widehat{var}(\widehat{N}) - \widehat{var}(\widehat{N})\widehat{var}(\hat{p}) \quad (4)$$

This gives an estimated standard error of approximately 630. Then the calculated 95 confidence interval would be within 1.96*630 fish, which is about 1235 fish, or within 35% of the estimated 26,156*13.5% = 3531 fish, which is within our precision criteria. This indicates that our estimate would be within 35% of the true value 95% of the time. 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. In all but the last objective (objective 5) precision criteria are fairly tight, and a useful, but less precise estimates may still be achieved.

TRACKING AND DATA COLLECTION

Remote tracking stations at six locations will record movements (upstream or downstream passage) of radio tagged 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 (also see Richards et al. 2015). 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. Radio tagged 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 programed to record this data every 60 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. Telemetry stations 1-4 (Figure 1) will be checked at least once weekly and data will be downloaded from the receivers via a laptop computer. Telemetry stations 5 and 6 (also Figure 1) will be checked approximately every three weeks. 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 also be stored at each site, such as described in Appendix A.

FATES

Tag and fate codes are identified in Table 2 for those Chinook salmon receiving a radio tag. The hundreds digit will indicate if the fish was captured using gillnet gear (100) or fishwheel gear (200). The tens digit indicates whether the fish was radio tagged above the U.S./Canadian border on the fishing grounds (10) or not (00). For those fish radio tagged below the U.S./Canadian border the ones digit indicates whether that fish passed the U.S./Canada border (0 if not); otherwise the ones digit indicates whether that fish progressed upstream (1). The 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” and/or “thousandths” digit can be used to further indicate which area of the Taku River the fish were last located in. The ten thousandths digit will indicate with a “1” if the fish was captured more than once by gillnet crews that were tagging.

Table 2.–List of tag and fates codes to be recorded for all radio tagged Chinook Salmon on the Taku River, 2015.

Place holder	Digit	Meaning
Hundreds	1	captured using gillnet gear
	2	captured using fish wheel gear
Tens	0	tagged below the U.S. Canada border near Canyon Island
	1	tagged above the U.S. Canada border on Canadian fishing grounds.
Ones	0	(if tagged above the border, but fish did not progress upstream) or (if tagged below the border, fish did not pass the border)
	1	(if tagged above the border, fish progressed up stream), (if tagged below the border, fish progressed passed the border)
Tenths	0	tag never located, unknown fate
	1	regurgitated tag or died near tagging site
	2	recovered in U.S. fishery (marine)
	3	tracked to a tributary below the U.S./Canada border
	4	captured in fishery in Canada
	5	tracked to a probable spawning area above the U.S./Canada border
Hundredths	0	Spawning, but outside of 7 identified spawning areas
	1	spawning area 1
	2	spawning area 2
	#	spawning area # (distinct from spawning areas 1 or 2)
Thousandths	0	outside of aerial survey index areas
	1	aerial survey index area 1
	2	aerial survey index area 2
	#	aerial survey index area # (distinct from aerial survey index areas 1 or 2)
Ten Thousandths	0	never recaptured by tagging crews
	1	captured by tagging crews more than once while tagging

SPAWNING LOCATIONS

Attempts will be made to locate each Chinook salmon fitted with a radio transmitter periodically by aerial surveys. Four drainage-wide fixed-wing aerial surveys will be flown to identify spawning locations at two week intervals starting around July 22. Surveys will be conducted on the mainstem Taku River and the major spawning tributaries previously identified in Pahlke and Bernard (1996). 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 will be then assigned to one of 7 spawning areas as described in Pahlke and Bernard (1996).

Chinook salmon will also be tracked during the traditional helicopter aerial surveys to determine the number of radio tagged fish within each index area during the time of the survey. Seven aerial survey flights are scheduled during the traditional peak spawning period. Richards et al. (*2014*) provide thorough descriptions and methodology related to the annual aerial index surveys for Chinook salmon on select drainages in Southeast Alaska.

ASSUMPTIONS

Assumptions of the experiment include: 1) Chinook salmon will be tagged for radio-tracking in proportion to the run 2) tagging will not change the destination (fate) of a fish; and 3) fates of radio-tracked 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. Sampling effort will be held as consistent as possible during the immigration. Catchability has historically varied with river conditions; however in nearly all years with mark-recapture estimates fish have been tagged in proportion to the run or fish mix prior to being recaptured on the spawning grounds (McPherson et al. 1996; Pahlke and Bernard 1996; McPherson et al. 1997; McPherson et al. 1998; McPherson et al. 1999; Jones et al. 2010). If non-proportional tagging occurs, the proportions will be stratified by time. If fishing effort in event 1 and/or the Canadian fishery is not consistent across the run, and if run timing is correlated to the final destination of the fish, this will affect the ratios of tagged fish seen in the various spawning areas.

The second assumption will be true if tagging does not change the destination of a fish. Although the drift gillnet project is new, capture and handling techniques have been highly refined on the Taku River over the past 22 years; only healthy fish are tagged, and the upmost care is given to each fish (Williams et al. 2015). Eiler et al. (2014) and Richards et al. (2008) used nearly identical capture and handling techniques to radio tag nearly 3,000 and 350 Chinook salmon on the Yukon and Stikine rivers, respectively, and showed negligible handling mortality (2-3%). And although short-term behavior was influenced in the Yukon River, the long-term behavior and ultimate fate of radio tagged Chinook salmon was not likely influenced (Eiler 2014). There are however factors that may influence certain aspects of this study. A higher probability of capturing marked fish occurs nearly every year in the Taku River Canadian fishery when compared to spawning grounds. Tracking the movement of radio tagged fish to and within the Canadian fishery will provide insights to the higher probability of capture. The destination of radio tagged fish will also change if for unknown reasons (i.e., predation, emigration, handling mortality) radio tagged fish are removed at a unequal rate throughout the run. Tracking the movement of radio tagged fish within the Taku River will also provide insights as to how this might affect estimates in inseason abundance.

The third assumption will be true if: 1) the remote tracking stations and radio tags remain operational throughout the project; 2) remote tracking stations are able to detect all fish passing the site; 3) aerial surveys are able to detect all radio tagged fish; and 4) aerial surveys locate fish at their final destination. It is likely that towers and tags will remain operational throughout the project and concerted efforts will be given to installing, testing, and monitoring all remote tracking stations. Eiler (1995) found tracking success to be > 97% for Chinook passing undamaged remote tracking stations on the Taku River and other Chinook salmon telemetry studies in Southeast had similar high detection rates in aerial surveys and at fixed tracking stations (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 fish if the first survey occurs after fish have reached their final destination and their carcasses progressed downstream, or if the last survey is flown before tagged fish have reached their final destination. The use of fixed-winged and helicopter surveys will be employed to attempt to bracket the entire spawning escapement. All fish that were radio tagged and that will successfully spawn should be at or near their spawning location during at least one of the aerial tracking surveys (Richards et al. 2014).

DATA ANALYSIS

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

Proportion of large Chinook (≥ 660 mm MEF) radio tagged fish $p_{r,l,t}$ that migrate upstream will be calculated for two tagging locations, l, and for different strata t. The first location is Canyon Island and fish tagged there must pass the radio towers closest to the U.S./Canadian border to be considered progressing upstream. The second location is above the border in the area where the Canadian fishery is prosecuted and fish must progress past radio towers upstream of the Canadian fishery to be considered progressing upstream. The t strata may be used to distinguish between any number of strata, such as time, size or gender. Appropriate statistical tests will be conducted to determine if stratification is necessary. Such tests include a chi-squared for multiple strata or a t-test for two strata. 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 $p_{r,l,t}$ is as follows:

$$p_{r,l,t} = \frac{m_{r,l,t}}{M_{r,l,t}} \tag{5}$$

Where $m_{r,l,t}$ is the number of radio tagged fish at location l, during strata t detected as progressing up stream of the $M_{r,l,t}$ radio tagged fish at location l 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 at location l during strata t in relation to all the fish that are spaghetti tagged during the season, $w_{l,t}$. The weighted proportion is a known quantity with no variance.

$$w_{l,t} = \frac{M_{l,t}}{\sum_{l=1}^{L}\sum_{t=1}^{T} M_{l,t}} \tag{6}$$

where $M_{l,t}$ is the number of tagged fish, regardless of tag choice that were tagged at location l and strata t. The sum of all $M_{l,t}$ 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:

$$\hat{p}_{up} = \sum_{t=1}^{T} w_{l,t} * p_{r,l,t} \tag{7}$$

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:

$$\widehat{var}(\hat{p}_{l,t}) = w_{l,t}^2 \left(\frac{M_{l,t}-M_{r,l,t}}{M_{l,t}}\right)\frac{\hat{p}_{r,l,t}(1-\hat{p}_{r,l,t})}{M_{r,l,t}-1} \tag{8}$$

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

$$\widehat{var}(\hat{p}_{up}) = \sum \widehat{var}(\hat{p}_{l,t}) \tag{9}$$

PROPORTION AT OR PASSING A LOCATION

A location may be defined as the area above the U.S./Canada border 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 Williams et al. 2015. If separate strata are required for abundance 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.

$$\hat{P}_{a,t} = \frac{r_{a,t}}{m_t - c_t - x_t} \tag{10}$$

$r_{a,t}$ = 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 strata t combined will be calculated using:

$$\hat{P}_a = \sum_t \hat{w}_t \hat{P}_{a,t} \tag{11}$$

$$\hat{w}_t = \frac{\hat{N}_t}{\sum_{t=1}^{T} \hat{N}_t} \tag{12}$$

Where:

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

$\hat{w}_t$ = estimated weight of radio 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):

$$\hat{\theta}_t = \frac{m_t}{\hat{N}_t} \tag{13}$$

$$\hat{u}_t = \frac{c_t}{m_t} \tag{14}$$

$$\hat{\rho}_{a,t} = \frac{r_{a,t}}{m_t} \tag{15}$$

$$\hat{\zeta}_t = \frac{x_t}{m_t} \quad (16)$$

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:

$$\left(N^*_{1(b)}, \ldots, N^*_{t(b)}, \ldots\right) \sim multinomial\left(\hat{N}, \hat{w}_1, \ldots, \hat{w}_t, \ldots\right) \quad (18)$$

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

$$m^*_{t(b)} = N^*_{t(b)}\hat{\theta}_t \quad (19)$$

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

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

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 $\hat{N}_{LE}$ (Williams 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 $\sim N\left(\hat{N}_{LE}, var\left(\hat{N}_{LE}\right)\right)$ (Williams 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 Canyon Island will begin in late April and extend through early 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 and genetic samples will be sent to Philip Richards and Jeff Williams 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 Taku River.

B. FOC. Will assist in planning of project. 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.

Jeff Williams, FBII. In concert with Philip Richards, and Ian Boyce, sets up all aspects of project, including planning, budget, sample design, permits, equipment, personnel, and training. Assists in supervising Canyon Island 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.

Mike LaFollette, FBI. This position is responsible for supervising the Canyon Island portion of the field tagging program. Will coordinate schedules with FOC/TRTFN 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 at Canyon Island.

David Dreyer, F&WT IV. This position is responsible for supervising the drift gillnet portion of the field tagging program. Will coordinate schedules with 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.

Michael Enders, F&WT III. 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 and Bill Waugh, FOC. In concert with Jeff Williams and Philip Richards, 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.

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APPENDIX A

Appendix A.-Description of procedures for downloading radio tracking remote station data on the Taku River.

Procedures for Downloading Radio Tracking Station

ATS 4500 Receivers

1. Check the station for damage.
2. Check that the receiver was configured correctly by the last user:
    a. The receiver is automatically cycling through radio frequencies
    b. The GAIN is turned to “10”
    c. The volume is turned to “0”
3. Turn on Laptop, open ASTWINREC 4500. There is a shortcut labeled “AST Download on the desktop.
4. Connect serial cable to PC/Clone port on the receiver and to the serial port on the laptop
5. On the receiver, press ESC then use the arrow keys to scroll to “PC”. Press ENTER.
6. The receiver should now read, “PC Mode: Active”.
7. In the ATSWinRec window on the laptop, click “Offload Data”. Press “OK”
8. In the notebook in the metal station box, on a new sheet of paper record the:
    a. Date and time
    b. Name of staff completing the download
    c. Number of blocks of data to offload, Click “Offload”
9. After the data has been offloaded, you will be asked if you want to delete targets in the receiver. Click, “NO”. The download can take up to 45 minutes to complete if there are 98,000 blocks of data.
10. Save the data file under: Taku Telemetry\Salmon\Tower Downloads subdirectory. Name the file in “location_date” formate (eg. Border Tower_08012015” for August 1, 2015 at the U.S./Canada tower on the lower Taku River.
11. Exit ATSWinRec after the data file has been saved
12. On the receiver, press ESC to return to the main menu. Press SHIFT then TEST to see the amount of charge in the battery. Record the number of volts in the notebook along with the voltage for the battery and solar panel. On the receiver, press ESC to return to the main menu. Scroll to “STATIONARY” and press ENTER. Scroll to NEW SCAN, press ENTER

-continued-

13. A number of default settings will appear. Click ENTER to agree with all of the default settings except for:
    a. Select “1” for TABLE #
    b. Select “2” for ANTENNA’S
    c. Select “NO” for GOES
    d. Select “YES” for REFERENCE TAG, then enter the reference tag number (eg. 151183)
    e. Select 60 min store rate
14. Make sure the receiver is automatically cycling through all radio frequencies.
15. Disconnect serial cable, keep notebook in enclosure box, secure enclosure box
16. Before closing and locking the box ensure:
    a. The GAIN is turned to “10”, the highest setting
    b. The VOLUME is turned to “0”, the lowest setting

Troubleshooting Downloads

1. After connecting serial cable between receiver and laptop, receiver reads: “PC Mode: No PC”.
    a. On the laptop go to the Microsoft ActiveSync icon in the upper left corner of the screen. Double click.
    b. In FILE, go to Connection Settings. Make sure the first box is **unchecked** (“Allow serial cable or infrared connection to this COM port” should be unchecked).
    c. Once this setting has changed in Microsoft ActiveSync, close ATSWinRec, disconnect serial cable, reopen ATSWinRec, then follow steps 3-4 above.

Backup Data

1. After the download is complete, immediately back up the data on a thumb drive under the same name.

After returning to the cabin, email the latest files to Jeff Williams or Phil Richards