Regional Operational Plan SF.2A.2018.03

Karluk River Steelhead Population Assessment Operational Plan, 2018-2019

by

Tyler B. Polum

and

Adam Reimer

April 2018

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

REGIONAL OPERATIONAL PLAN SF.2A.2018.03

KARLUK RIVER STEELHEAD POPULATION ASSESSMENT OPERATIONAL PLAN, 2018-2019

by
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SIGNATURE/TITLE PAGE

Project Title:	Karluk River Steelhead Population Assessment, 2018-2019
Project leader(s):	Tyler B. Polum, Fishery Biologist III
Division, Region and Area	Sport Fish, Region II, Kodiak Management Area
Project Nomenclature:	
Period Covered	2018-19 (FY18-20)
Field Dates:	1 April, 2018–15 July, 2019
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Approval

Title	Name	Signature	Date
Project leader	Tyler Polum		
Biometrician	Adam Reimer		
Research Coordinator	Tim McKinley		

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ABSTRACT

A mark–recapture experiment will be implemented in 2018 and 2019 in the Karluk River drainage following a similar pilot study completed in 2017 to attempt to estimate the spawning abundance of steelhead in the Karluk River. At least 127 steelhead will be marked prior to spawning during April and May 2018 and 2019 in known overwintering and spawning areas and all emigrating kelts will be recaptured at the Karluk River weir from mid-May through July 15 and examined for tags. This study will update previous population estimates last conducted in 1997.

Key words: steelhead, *Oncorhynchus mykiss*, mark–recapture, abundance, Karluk River, age-sex-length

INTRODUCTION

PURPOSE

This study will estimate spawning abundance of Karluk River steelhead (*Onchorhynchus mykiss*) by means of a mark–recapture experiment. A pilot study conducted in 2017 aimed to replicate the successful mark–recapture study design used in the 1990s (Begich 1999), and this study will be a continuation of the same project for 2018 and 2019. In the 1990s, both kelt (emigrating adult) counts and spawning abundance estimates, when available, were highly variable from year to year (Begich 1999), and therefore a three-year study is preferred over a one-year study so that current estimates can account for some of this variability.

BACKGROUND

The Karluk River (Figure 1), located on the southwest side of Kodiak Island, supports the largest steelhead sport fishery in the Kodiak Management Area (KMA) by both catch as well as popularity for anglers (Table 1). There is a long history of anglers targeting steelhead in the Karluk River drainage but the fishery has recently become more popular with anglers seeking a remote and less crowded steelhead fishing destination. Anglers primarily target steelhead in the Karluk River during the month of October at a location known as “the Portage” (Figure 1).

The Karluk River is approximately 24 miles in length from the outlet of Karluk Lake, through the Karluk Lagoon, to its mouth in the Shelikof Strait (Figure 1). In addition to the steelhead fishery, the Karluk River drainage also supports sport fisheries for sockeye (*O. nerka*) and coho (*O. kisutch*) salmon, and has historically supported a Chinook salmon (*O. tschawytscha*) fishery, although Chinook salmon runs have been severely depressed since 2005. Rainbow trout (the nonanadromous form of steelhead) and Dolly Varden (*Salvelinus malma*) are also caught incidentally to other species. The Karluk River drainage supports large commercial fisheries targeting primarily sockeye and pink salmon (*O. gorbuscha*), but coho and Chinook salmon are also harvested. Subsistence fisheries occur mostly in the Karluk Lagoon and primarily consist of harvests of sockeye and coho salmon; however, harvests do occur in other areas of the Karluk River and other species are harvested in smaller numbers.

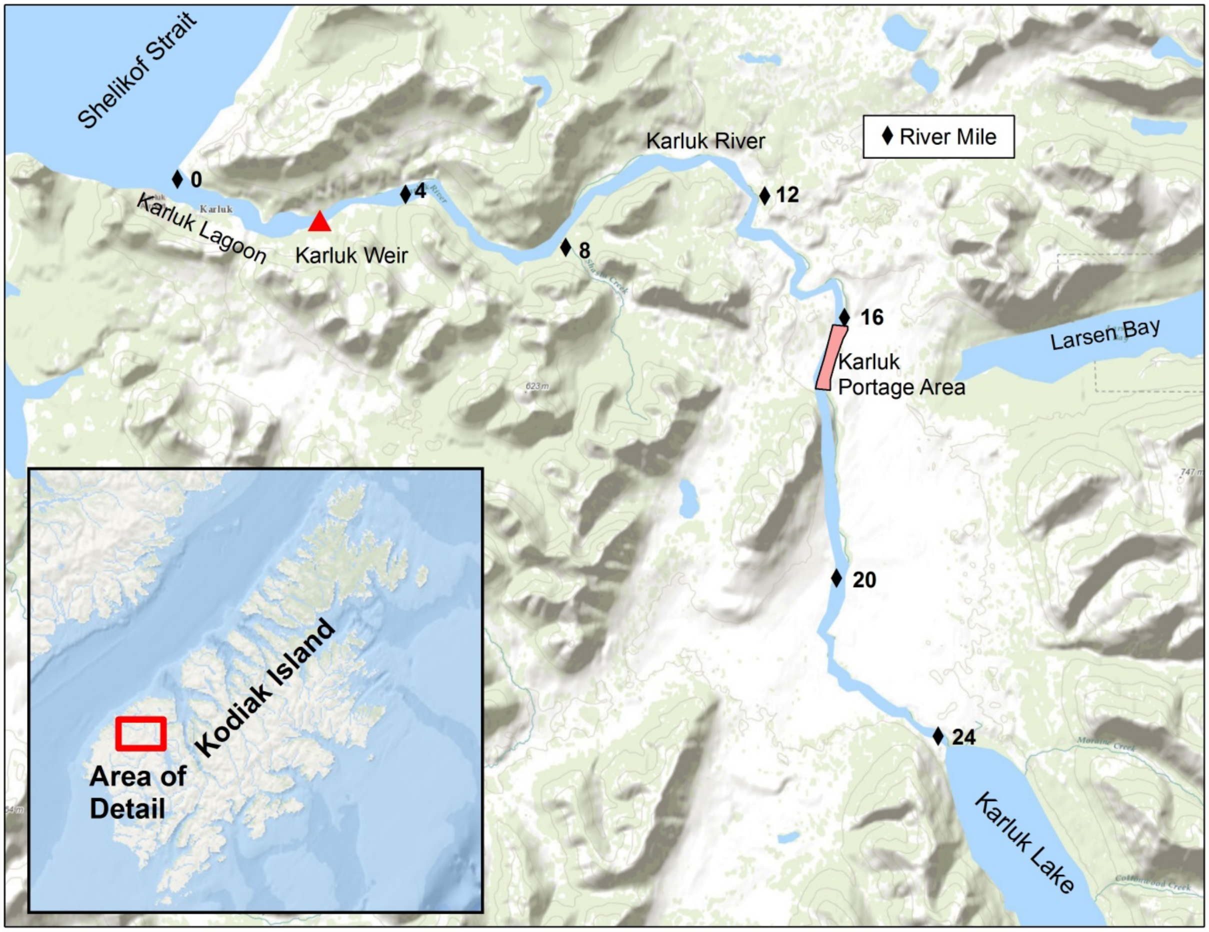

Figure 1.–Map of the Karluk River drainage showing “the Portage,” which is the primary staging area for Karluk River studies, and the locations of river miles (RM) along the Karluk River.

Table 1.–Steelhead catch (harvest plus release) in the Karluk River, 2006–2015.

Year	Guided angler catch	SWHS catch
2007	379	968
2008	348	2,196
2009	751	859
2010	667	216
2011	506	1,556
2012	504	236
2013	250	22
2014	488	108
2015	742	1,005
2016	824	2,724
Average 2007–2016	546	1,171

Source: Freshwater Logbook Database (Alaska Department of Fish and Game, Division of Sport Fish. 2006 to present. Accessed March 16, 2017. [URL not publicly available as some information is confidential. Contact Research and Technical Services for data requests.]); Statewide Harvest Survey (SWHS) estimates from the Alaska Sport Fishing Survey database [Internet]. 1996–present. Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited November 2016). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

Karluk River steelhead return to freshwater in the fall beginning in September and continuing into November, with peak run timing in mid-October. There are no spring-run steelhead in the Karluk River. Overwintering and migration of steelhead in the Karluk River has been documented by Chatto (1987) and indicates that more than 75% of overwintering can occur in river miles (RM) 12–20, surrounding the area known as "the Portage." Other areas of possible overwintering include RM 22–24 near the lake outlet and some areas of the river below RM 12 where spawning also occurs. Spawning primarily occurs in April and May and steelhead migrate to the ocean following spawning. Survival to repeat spawning is generally low, ranging between 24% and 31% (Begich 1999). Several studies concerning the population size and movement of Karluk River steelhead have been conducted (Chatto 1987; Begich 1992-1999). Using a mark–recapture tagging experiment, Begich (1999) estimated population sizes during 1992–1997 that ranged from 4,107 fish to 10,802 fish. Since then, the only indicators of abundance have been weir counts of steelhead that spawned in the river and were migrating to the ocean (kelts). Kelt counts are obtained beginning in late May from a weir operated to enumerate salmon migrating to the freshwater and, as a result, the early portion of the kelt outmigration is not enumerated in some years. In the most recent 5 years (2013–2017), kelt counts at the Karluk River weir have averaged 2,011 and ranged from 1,168 to 4,624 (Table 2). In contrast, kelt counts averaged 4,780 and ranged from 2,749 to 6,928 fish between 1992 and 1997, when spawning abundance was last estimated (ADF&G Division of Commercial Fisheries Westward Region Escapement Database).

Table 2.–Steelhead kelt counts at the Karluk River weir, 2012–2016.

Year	Steelhead kelts
2013	1,605
2014	1,381
2015	1,278
2016	1,168
2017	4,624
Average 2013–2017	2,011

Source: ADF&G Division of Commercial Fisheries Westward Region Escapement Database.

OBJECTIVES

1) Estimate the number of spawning steelhead in the Karluk River during the spring of 2018 and 2019 such that the estimate is within 25% of the actual abundance 95% of the time.
2) Estimate the age, sex, and length composition of the spawning population of steelhead in the Karluk River during the spring of 2018 and 2019 such that the estimates are within 11.5 percentage points of the actual proportions 90% of the time.
3) Count kelts emigrating through the Karluk River weir from approximately 16 May through 15 July, 2018 and 2019.
4) Estimate the age, sex, and length composition of kelts emigrating through the Karluk River weir in each third of the spring of 2018 and 2019 emigrations such that the estimates are within 11.5 percentage points of the actual proportions 90% of the time.

METHODS

STUDY DESIGN

This study will estimate the number of steelhead in the Karluk River spawning population, enumerate the kelt outmigration, and collect biological information. The study design follows similar methods to the 2017 pilot study and Begich (1992-1999).

Steelhead overwinter in the upper Karluk River and concentrate in the Portage area where they can be captured with hook and line and then sampled (Begich 1992; Chatto 1987). After spawning, surviving kelts emigrate through a weir located in the lower river just above Karluk Lagoon (Figure 1). This situation makes it possible to conduct a 2-event, mark–recapture experiment to estimate the abundance of spawning steelhead at the time of tagging. The first event (marking) will primarily occur in RM 12–20 but effort will be directed in areas throughout the drainage where fish are known to congregate prior to and during spawning (based on catch rates and observed fish abundance to determine effort in each location). Fish will be caught with hook and line, tagged, sampled for age, sex, and length, and released. The second event (recapture) will occur at the weir where all emigrating kelts will be examined after the weir is installed. Significant natural mortality is known to occur between spawning and emigration. During the 2017 pilot study, we failed to reach our tagging goal and marked fish also experienced significant handling-induced mortality. Our preliminary abundance estimate (8,803 SE 2,767) assumed that observed tag survival was the product of handling survival and spawning survival and that spawning survival was distributed similarly to estimates from the 1992–1997 studies. This estimate lacked precision and was dependent on survival assumptions that we cannot verify. The 2018 and 2019 studies will assume that mortality occurring between capture and kelt emigration is equal for both tagged and untagged fish. This assumption was considered valid for the 1992–1997 studies and should be achievable during 2018 and 2019 because tagging techniques used in 2017 pilot study will be refined to reduce handing time and handing related stress.

Sampling of the population will occur daily, employing hook and line techniques by 2 crews of at least 3 people that will cover different areas. Based on results of the 2017 study, tagging will occur between mid-April and mid-May as conditions allow and when fish are active and able to be caught by hook and line. During 2017, sampling was planned to occur prior to spawning when fish are overwintering; however, it was found that overwintering steelhead are much more difficult to catch and are very lethargic. Spawning also commences very quickly when water temperatures increase even slightly in the Karluk River, leaving little time to sample fish prior to spawning. For 2018 and 2019, sampling during the marking phase is planned to be done prior to the peak of spawning activity but because spawning commences quickly, it is not reasonable to sample only prespawning fish. Sampling will occur for at least 7 consecutive days or until sampling goals are achieved. During the 2017 season, 2 trips of 3 days were made, which was not enough time for achieving sampling goals. For 2018 and 2019, sampling crews will be deployed until sampling goals are achieved.

Sampling at the weir will occur from approximately mid-May through 15 July. All emigrating kelts will be examined for marks including both tags and fin clips and a fraction of the fish examined will be sampled for age, sex, and length data. In 2017, very few of the recaptured fish were sampled for ASL and efforts to train the weir crew specifically for sampling steelhead will be employed at the beginning of the season to collect all of the data needed on recaptured fish.

Mark–Recapture Assumptions

This experiment is designed to use a Peterson-type abundance estimator. In order for the spawning population estimate produced by this mark–recapture study to be unbiased, certain standard assumptions must be met (Seber 1982). Assumptions of the model are as follows:

1) There is no recruitment, immigration, or emigration from the population over the duration of the experiment.

   This assumption is addressed by the study design and life history of steelhead in the Karluk River drainage: steelhead immigrate into the study area in the fall prior to the marking event, marking occurs prior to emigration, and fish are recaptured during emigration from the study area. We must also assume that spawning mortality is equal among tagged and untagged fish.

2) Marking and handling does not affect the probability of capture.

   There is no explicit test for this assumption and we assume mortality after tagging is attributable to the spawning event rather than the tagging event, though every effort will be made to increase the probability of survival after capture. Holding and handling time will be minimized to reduce stress on tagged fish. Sampling teams will consist of at least 3 people to minimize holding and handling time. Once hooked, fish will be reeled in and captured in a rubber holding net as quickly as possible. One person will hold the fish in the water in the rubber net, one person will tag the fish, and one person will collect age, sex, and length data. This should minimize the time of holding and handling and all steelhead will be released gently from the net quickly after tagging and sampling.

3) No marks are lost between events and all marks are reported at the second event.

   Tagged fish will receive a fin clip in addition to a visual tag to ensure that all tagged individuals are detected at the weir. Weir personnel will individually inspect all emigrating steelhead trout for marks and fin clips at the weir. Extra care will be made to recover all marked fish including those without tags.

4) One of the following 3 conditions is met:
   a) All fish have an equal probability of being marked.
   b) All fish have an equal probability of being captured in the second event.
   c) Marked and unmarked fish mix completely between sampling events.

   Two of these conditions have a reasonable chance of being satisfied with this experimental design. During the marking event, effort will be distributed throughout known overwintering and spawning areas prior to the peak spawning period and all steelhead will have an equal chance of being marked given the relatively concentrated area of overwintering and spawning. In addition, sport fishing gear is not thought to be size selective amongst fish of spawning size. During the recapture event, it is possible that the weir could form a census of emigrating individuals, provided monitoring occurs prior to the start of emigration; however, it is unknown if any steelhead will have emigrated prior to installation of the weir in mid-May. Mixing between events is highly likely given that several weeks elapse between the marking and recapture events and marking occurs prior to spawning and emigration. These conditions will be evaluated by time, sampling area, size, and sex using the procedures described in Appendices A1–A2.

We note that Begich (1992-1999) concluded the mark–recapture assumptions were satisfied between 1992 and 1997 and used a Peterson-type estimator in all years. During the 2017 pilot study, we found evidence that handling mortality must have occurred on both male and female steelhead so marking procedures have been changed to minimize handing and tagging related stress.

DATA COLLECTION AND REDUCTION

Data will be collected for at least 7 days during April and May when the marking event is conducted and from approximately mid-May through 15 July when kelts are enumerated (recapture event) at the weir.

Tagging

Biological data collected during the first event will include measurement from the tip of the snout to the tail fork (FL) to the nearest millimeter, examination for damaged mouth parts that may have resulted from hooking damage, and sex will be recorded. Sex will be determined based on head shape, girth to length ratio, and presence of ovipositor, eggs, or milt. Steelhead will be tagged with an individually numbered Floy T-Bar anchor tag, with contact information for the project leaders included on the tags, and the tag number will be recorded. Tags will be placed on the left side of the fish near the posterior insertion of the dorsal fin. A portion of the right pectoral fin will be clipped on each fish released with a tag.

Scales will be collected for age determination. Steelhead trout scales develop first along the lateral line and spread most rapidly in the middle and posterior part of the body (Paget 1920). Thus, the annulus marking the first year of growth is most likely to be visible on scales from this preferred scale area. Scales from this area also tend to be oval-shaped and symmetrical (Maher and Larkin 1955), and therefore relatively easy to interpret. Four scales will be removed from each fish and mounted on a gum card. Scale impressions will be made into cellulose plastic and read for age determination. Scale analysis will incorporate the methods of Mosher (1969), Jones (*Unpublished*)[1], Wallis (*Unpublished*)[2] and Love (2016).

Biological data will be recorded in a waterproof note book in addition to the date, scale card number, spawning status, and recapture status. All data will be transferred to a sampling form at the end of each day (Appendix B1). All data will be entered into an Excel spreadsheet upon returning to the Kodiak and archived in the Kodiak Division of Sport Fish (SF) data archives.

Weir Sampling

A steelhead trap will be installed in the Karluk River salmon weir to capture emigrating steelhead. SF personnel will assist with installation of this trap and any design modifications. Division of Commercial Fisheries (CF) personnel will examine, sample, and count all emigrating steelhead kelts at the weir. All steelhead kelts will be examined for tags and fin clips, and the tag number and fin clip will be recorded in a waterproof notebook. All tag and finclip information will be recorded daily on the Tag Recovery Form (Appendix B2) and a new form will be started each day. Age, sex, and length information will be collected from a portion of the kelts as

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[1] Jones, D. E. *Unpublished*. Handbook for interpretation of steelhead trout scales in Southeast Alaska. Alaska Department of Fish and Game, Juneau.

[2] Wallis, J. *Unpublished*. Handbook for interpretation of steelhead trout scales from Anchor River. Alaska Department of Fish and Game, Homer.

outlined in the next section and from every marked kelt where the tag is missing or unreadable. These data will be recorded in a waterproof notebook and returned to the SF office in Kodiak with each resupply flight to the weir camp. All data will be entered into an Excel spreadsheet upon returning to Kodiak and archived in the Kodiak SF data archives.

Sample Sizes

All emigrating kelts will be examined for marks after the weir is installed, and therefore all tagged survivors will be recaptured, provided the weir remains in place during the entire emigration. The sample size analysis assumes that the 2013–2017 average of 2,011 kelts will emigrate in 2017. The estimates of annual spawning survival (proportion) during the 1992–1997 study ranged from 0.36 to 0.67 and averaged 0.57 (Begich 1999). In a worst case scenario, where spawning survival is only 0.35 and 10% of kelts migrate downstream before the weir is in place, we would need to tag 150 steelhead during the marking event to expect to meet our objective criteria (within 25% of the actual abundance 95% of the time) using the methods described in Robson and Regier (1964). This sample size should be achievable because both the duration and manpower of the tagging events in 2018 and 2019 will be increased relative to the 2017 pilot study.

To meet the objective criteria for age composition estimates, 138 fish would need to be sampled, assuming a scale regeneration rate of 45%. Because biological data are collected on all tagged steelhead, sufficient samples should be collected in 2017 to estimate both abundance and age composition to satisfy objective criteria.

Age, sex, and length data will be collected from the first 10 of every 40 steelhead that are passed through the weir in 2018 and 2019 and every marked fish where the tag is missing or unreadable. To meet the objective criteria for age composition estimates, 138 fish would need to be sampled from each third of the emigration, assuming a scale regeneration rate of 45%. This sample size will be achieved if the 2018 and 2019 emigrations meet or exceed the 2013–2017 average emigration (2,011 kelts) and 1 out of every 4 emigrating steelhead kelts are sampled. The project leader may increase or decrease the sampling rate inseason if the emigration appears to be considerably larger or smaller, respectively, than the 2013–2017 average.

Tag Recoveries

Tagged steelhead may be harvested by sport, commercial, and subsistence fisheries after the marking event. Tags will include contact information for the project leaders so that tags can be returned and information about harvest location can be collected. Any tags recovered from these fisheries will be recorded on the Tag Recovery Form (Appendix B2).

DATA ANALYSIS

Abundance Estimate

The study design described above is a 2-sample mark–recapture study that has been successfully used before on the Karluk River (Begich 1992-1999). Previous abundance estimates did not require stratification by size, sex, time, or area. If stratification is not required, spawning abundance (N_a) will be estimated by Chapman's version of the Peterson abundance estimator (Seber 1982):

$$\hat{N}_a = \frac{(M+1)(C+1)}{R+1} - 1, \tag{1}$$

where

M = number of fish marked and released in the first event,

R = number of marked fish recaptured in the second event, and

C = number of fish examined for marks in the second event,

and the variance is estimated by

$$\mathrm{Var}\left(\hat{N}_a\right)=\frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \tag{2}$$

Equal probability of capture by size and sex will be evaluated using the procedures described Appendix A1. If capture probability differs by size or sex, the dataset will be stratified into size–sex groups where equal probability of capture is demonstrated within each group and separate abundance estimates will be produced for each size–sex stratum using the procedures described in Appendix A1. Geographic or temporal violations of the probability of capture assumptions will be tested using the procedures described in Appendix A2. Because the marking event will occur in a short period of time (about 7 days), we plan to use area strata[3] for the marking event and temporal strata for the recapture event (each third of the emigration) in the consistency tests described in Appendix A2. If probability of capture differs by time or area, a stratified estimator (Darroch 1961) will be used.

Spawning Survival

The survival of tagged fish to emigration can be calculated by age and sex (S_i) using the weir recapture information. For any class, the survival will be estimated as a binomial proportion (Cochran 1977):

$$\hat{S}_k=\frac{R_k}{M_k}, \tag{3}$$

where

R_k = number of tagged fish at the weir (recaptures) in class k,

M_k = number of fish tagged during spring sampling (marked) in class k.

The variance of survival will be estimated as follows:

$$\mathrm{Var}\left(\hat{S}_k\right)=\frac{\hat{S}_k\left(1-\hat{S}_k\right)}{M_k-1}. \tag{4}$$

Age, Sex, and Length

Mean length-at-age and associated variance will be estimated using normal procedures. The proportion of steelhead in each age, sex, or size class (p_i) will be estimated as a binomial proportion (Cochran 1977):

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[3] Roughly: below Portage, Portage (RM 16–17), and above Portage, although these definitions will be refined and made explicit based on observations the crew makes during the tagging event.

$$\hat{p}_i = \frac{n_i}{n_t}, \tag{5}$$

where

n_i = number of steelhead of age, sex, or size class i, and

n_t = total number of steelhead sampled,

and where the variance is estimated as follows:

$$\text{Var}(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{n_t - 1}. \tag{6}$$

An estimate of abundance by age of the prespawning population will be made as follows:

$$\hat{N}_{ai} = \hat{N}_a \hat{p}_i, \tag{7}$$

and the variance will be estimated by (Goodman 1960)

$$\text{Var}(\hat{N}_{ai}) = \hat{N}_a^2 \text{Var}(\hat{p}_i) + \hat{p}_i^2 \text{Var}(\hat{N}_a) - \text{Var}(\hat{p}_i)\text{Var}(\hat{N}_a). \tag{8}$$

An estimate of abundance by age of the emigrating kelt population will be made with

$$\hat{N}_{wi} = N_w \hat{p}_i, \tag{9}$$

and the variance by

$$\text{Var}(\hat{N}_{wi}) = N_w^2 \text{Var}(\hat{p}_i), \tag{10}$$

where N_w is the count of steelhead kelts.

SCHEDULE AND DELIVERABLES

Results from this project will be summarized in a Fishery Data Series report and submitted as a draft to the Research Supervisor by 1 March 2020. Probable dates for sampling activities are summarized below.

Dates	Activity
1 April–24 April	Field camp prep.
25 April–13 May	Conduct sampling as conditions allow.
16 May–15 July	Tag recovery at the weir; counting and sampling kelts.
November–March, 2018-2019	Data reduction and analysis.
July 2019–March 2020	Write final report covering 2017–2019

RESPONSIBILITIES

Tyler Polum, Fishery Biologist III, Project Leader

Duties: Responsible for the supervision of all aspects of the Karluk River steelhead project, managing the project budget, and writing the final report.

Mark Witteveen, Fishery Biologist II, Project Biologist
Duties: Assist with implementation and coordination of all aspects of field work and sampling. Assist with data entry, reduction, and analysis.

Michelle Stratton, Fisheries Biologist I, Project Biologist
Duties: Assist with implementation and coordination of all aspects of field work and sampling. Assist with data entry, reduction, and analysis.

Katrina Del Carmen, Fish & Wildlife Technician III
Duties: Assist with field camp preparations, sampling in the field, and data entry.

Adam Reimer, Biometrician II
Duties: Assist with project design and data analysis.

Tim McKinley, Fishery Biologist IV
Duties: Final report editing and project support.

BUDGET SUMMARY

FY 18 and 19

Line item	Category	Budget ($K)
100	Personal Services	6.0
200	Travel	1.2
300	Contractual	9.8
400	Commodities	3.0
500	Equipment	0
Total		20.0

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APPENDIX A: MARK–RECAPTURE TESTING PROCEDURES

Appendix A1.–Detection and mitigation of selective sampling during a 2-event mark–recapture experiment.

Size- and sex-selective sampling may cause bias in 2-event mark–recapture estimates of abundance and size and sex composition. Kolmogorov-Smirnov (KS) 2-sample tests are used to detect size-selective sampling and contingency table analyses (chi-square tests of independence) are used to detect evidence of sex-selective sampling.

Results of the KS and chi-square tests (χ^2) will dictate whether the data need to be stratified to obtain an unbiased estimate of abundance. The nature of the detected selectivity will also determine whether the first, second, or both event samples are used for estimating size and sex compositions.

DEFINITIONS

M = Lengths or sex of fish marked in the first event,

C = Lengths or sex of fish inspected for marks in the second event, and

R = Lengths or sex of fish marked in the first event and recaptured in the second event.

SIZE-SELECTIVE SAMPLING: KS TESTS

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

KS Test 1	C vs R	Used to detect size selectivity during the 1st sampling event. H_o: Length distributions of populations associated with C and R are equal.
KS Test 2	M vs R	Used to detect size selectivity during the 2nd sampling event. H_o: Length distributions of populations associated with M and R are equal.
KS Test 3	M vs C	Used to corroborate the results of the first 2 tests. H_o: Length distributions of populations associated with M and C are equal.

SEX-SELECTIVE SAMPLING: CHI-SQUARE TESTS

Three contingency table analyses (χ^2 tests on 2 × 2 tables) are used to test for sex-selective sampling:

χ^2 Test 1	C vs R	Used to detect sex selectivity during the 1st sampling event. H_o: Sex is independent of the C–R classification,
χ^2 Test 2	M vs R	Used to detect sex selectivity during the 2nd sampling event. H_o: Sex is independent of the M–R classification,
χ^2 Test 3	M vs C	Used to corroborate the results of the first 2 tests. H_o: Sex is independent of the M–C classification.

Several actions can be taken depending on the results of selectivity testing (Table A1-1).

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Table A1-1.–Possible results of selectivity testing, interpretation, and action.

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

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COMPOSITION ESTIMATION FOR STRATIFIED ESTIMATES

An estimate of the proportion of the population in the *k*th size or sex category for stratified data with *I* strata is calculated as follows:

$$\hat{p}_k = \sum_{i=1}^{I} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{1}$$

with variance estimated as

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

where

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

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

$\hat{N}$ = estimated total abundance

where

$$\hat{N} = \sum_{i=1}^{I} \hat{N}_i \ . \tag{3}$$

Appendix A2.–Tests of consistency for the Petersen estimator (Seber 1982: p. 438).

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Three contingency table analyses are used to determine if the Petersen estimate can be used (Seber 1982). If any of the null hypotheses are not rejected, then a Petersen estimator may be used. If all 3 of the null hypotheses are rejected, a temporally or spatially-stratified estimator (Darroch 1961) should be used to estimate abundance.

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

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

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

I. Mixing Test

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

Area–Time marking stratum (*i*)	Area–Time recapture stratum (*j*)				Not recaptured
	1	2	…	t	$a_i - m_{i\bullet}$
1	m_{11}	m_{12}	…	m_{1t}	$a_1 - m_{1\bullet}$
2	m_{21}	m_{22}	…	m_{2t}	$a_2 - m_{2\bullet}$
…	…	…	…	…	…
s	m_{s1}	m_{s2}	…	m_{st}	$a_s - m_{s\bullet}$

-continued-

II. Equal Proportions Test[4] (SPAS[5] terminology)

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

	Area–Time recapture stratum (j)			
Status of sampled fish	1	2	…	t
Recaptured ($m_{\cdot j}$)	$m_{\cdot 1}$	$m_{\cdot 2}$	…	$m_{\cdot t}$
Unmarked ($n_j - m_{\cdot j}$)	$n_1 - m_{\cdot 1}$	$n_2 - m_{\cdot 2}$	…	$n_t - m_{\cdot t}$

III. Complete Mixing Test (SPAS terminology)

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

	Area–Time marking stratum (i)			
Status of sampled fish	1	2	…	s
Recaptured (m_i)	$m_{1\cdot}$	$m_{2\cdot}$	…	$m_{s\cdot}$
Not Recaptured (a_i - $m_{i\cdot}$)	$a_1 - m_{1\cdot}$	$a_2 - m_{2\cdot}$	…	$a_s - m_{s\cdot}$

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[4] There is no 1:1 correspondence between Tests II and III and conditions 2–3 above. It is pointed out that equal probability of capture in event 1 will lead to (expected) nonsignificant Test II results, as will mixing, and that equal probability of capture in event 2 along with equal closure ($\Sigma_j \theta_{ij} = \lambda$) will also lead to (expected) nonsignificant Test III results.

[5] Stratified Population Analysis System (Arnason et al. 1996).

APPENDIX B: SAMPLING FORMS

Appendix B1.–Steelhead tagging form.

Sample Date	Tag Number	Recapture (Y/N)	Sex (M/F)	Spawned Out (Y/N)	Snout-Fork Length (mm)	Scales Collected (Y/N)	Fin Clip* (Y/N) - (L/R)	Capture Location	Sampler Initials	Comments

*** Fin Clip - (Y)/(N) = Yes/No ; (R)/(L) = Right/Left**

Appendix B2.–Tag recovery form.

Sample Date	**Tag Number**	**Fin Clip (Y/N)**	**Fin Clip Location**	**Sampler Initials**	**Comments**

*** Fin Clip - (Y)/(N) = Yes/No ; (R)/(L) = Right/Left**