Regional Operational Plan SF.3X-18-XX

Stock Assessment of Sinuk River Arctic Grayling, 2018

by

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and

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May 2018

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



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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 ft3/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 pH

(negative log of)

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)

**Measures (fisheries)**

fork length FL

mideye-to-fork MEF

mideye-to-tail-fork METF

standard length SL

total length TL

**Mathematics, statistics**

*all standard mathematical*

*signs, symbols and*

*abbreviations*

alternate hypothesis HA

base of natural logarithm *e*

catch per unit effort CPUE

coefficient of variation CV

common test statistics (F, t, χ2, 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) log2, etc.

minute (angular) '

not significant NS

null hypothesis HO

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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by

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May 2018

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Signature Page

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# abstract

The Seward Peninsula of western Alaska has many rivers and streams that are easily accessible by road and a majority of these streams support some angling effort for Arctic grayling *Thymallus arcticus*. Numerous studies have been conducted on several important Arctic grayling populations on the Seward Peninsula and that research culminated into a fishery management plan with specific abundance-based management objectives and hypothesis test criteria for evaluation of objectives for each each river, including the Sinuk River. The management objective for the Sinuk River is to maintain an abundance of 1,000 Arctic grayling greater than 15 in TL (350 mm FL) in a 40 km index area. This project will estimate abundance and size composition of the Arctic grayling population present in the Sinuk River in 2018. Based on the results of this assessment, management of the fishery will be reevaluated as prescribed in the Arctic Grayling Management Plan

Key words: Arctic grayling, *Thymallus arcticus,* Sinuk River, Nome, abundance, mark-recapture, length composition.

# Purpose

The Seward Peninsula of western Alaska has many rivers and streams that are easily accessible by way of a road system (approximately 420 km in length), which emanates from Nome (Figure 1). Most streams along this road system support some angling effort for Arctic grayling *Thymallus arcticus* for many of the 9,200 residents of the Nome census area (U.S. Census Bureau 2000), as well as numerous tourists. Since 1989, concerted research has been conducted on several important Arctic grayling populations on the Seward Peninsula (Merritt 1989; DeCicco 1990, 2000, 2002a,) that culminated into a fishery management plan for rivers with Arctic grayling along the Nome Road system and the current regulatory structure (DeCicco 2002b; Scanlon *In prep a*). In this plan, specific abundance-based management objectives with specific hypothesis test criteria for evaluation of these objectives have been established for the Niukluk, Fish, Pilgrim, Nome, Snake, and Sinuk rivers (Figure 1). The research program, as described in the management plan, recommends periodic population assessments for road-accessible streams to ensure that abundances are being maintained at or above prescribed levels.

The management objective for the Sinuk River is to maintain an abundance of 1,000 Arctic grayling greater than 15 in TL (350 mm FL) in a 40 km index area. This size limit is related to the regulation which has a bag limit of 5 only one of which may be ≥350 mm FL. Abundance of Arctic grayling in the Sinuk River was estimated during 1989-1993 and 2013 (DeCicco 1991–1994; Joy 2003). Estimated abundances of Arctic grayling ≥325 mm FL have ranged from 1,114 (SE = 198) in 1991 to 2,675 (SE = 414) in 2003 (Table 2). The abundance of Arctic grayling ≥350 mm FL in 2003 was 2,534 (SE=363). There has been no other assessment of the Arctic grayling population in the Sinuk River since the 2003 estimate.

The Sinuk River has averaged 665 days of sport fishing effort per year over the past 10 years (2006–2015), with catches averaging 367 fish/year and harvests averaging 32 fish/year (Table 1, Scanlon *In prep b*). Much of the sport fishing effort in the Sinuk River is directed at coho salmon and Dolly Varden but it is also remains popular to anglers looking to catch Arctic grayling. In addition, rod and reel became legal subsistence gear in the Nome Subdistrict (which includes all roadside streams in the Nome area) in 2001; therefore, it is likely that there is some harvest that goes unreported by subsistence fishers who do not purchase a sport fishing license. However, Arctic grayling are not regularly targeted by subsistence fishers (who primarily target chum and coho salmon as well as Dolly Varden in freshwater) so therefore the unreported harvest of Arctic grayling in the Sinuk River is likely small.

This project will estimate abundance and size composition of the Arctic grayling population ≥350 mm FL in the Sinuk River for the first time in 15 years. Based on the results of this assessment, management of the fishery will be reevaluated as prescribed in the Nome Roadside Arctic Grayling Management Plan (Scanlon *In prep a*). There are two other length categories of interest. One pertains to when Arctic grayling are reliably recruited to sampling gear (≥ 270 mm FL). The other is for the group of fish ≥ 325 mm FL, which is the size at which abundance had been previously estimated (1989-1992 and 2003), as well as, the size that sport anglers consider Arctic grayling as “large” fish.

****

Figure 1.‑Southern Seward Peninsula with road accessible waters.

Table 1.‑Days fished, catch, and harvest of Arctic grayling in the Sinuk River, 1990–2015.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Year |  | Days Fished |  | Catch |  | Harvest |
| 1990 |  | 343 |  | 232 |  | 0 |
| 1991 |  | 885 |  | 1,291 |  | 129 |
| 1992 |  | 1,504 |  | 300 |  | 0 |
| 1993 |  | 874 |  | 879 |  | 37 |
| 1994 |  | 1,132 |  | 417 |  | 8 |
| 1995 |  | 1,295 |  | 498 |  | 18 |
| 1996 |  | 553 |  | 339 |  | 97 |
| 1997 |  | 443 |  | 1,464 |  | 0 |
| 1998 |  | 123 |  | 25 |  | 8 |
| 1999 |  | 244 |  | 22 |  | 11 |
| 2000 |  | 294 |  | 26 |  | 0 |
| 2001 |  | 490 |  | 218 |  | 43 |
| 2002 |  | 1,324 |  | 432 |  | 103 |
| 2003 |  | 430 |  | 249 |  | 12 |
| 2004 |  | 466 |  | 0 |  | 0 |
| 2005 |  | 549 |  | 171 |  | 16 |
| 2006 |  | 1,234 |  | 1,331 |  | 138 |
| 2007 |  | 933 |  | 902 |  | 77 |
| 2008 |  | 878 |  | 84 |  | 0 |
| 2009 |  | 447 |  | 352 |  | 34 |
| 2010 |  | 616 |  | 348 |  | 68 |
| 2011 |  | 467 |  | 0 |  | 0 |
| 2012 |  | 566 |  | 0 |  | 0 |
| 2013 |  | 464 |  | 107 |  | 0 |
| 2014 |  | 126 |  | 0 |  | 0 |
| 2015 |  | 915 |  | 549 |  | 0 |
|  |  |  |  |  |  |  |
| **Average 06–15** |  | **665** |  | **367** |  | **32** |
| **Average 11–15** |  | **508** |  | **131** |  | **0** |

Table 2.–Estimates of abundance (**)** of Arctic grayling in the 40-km study area of the Sinuk River, 1989–1992 and 2013.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Year |  |  |  |  |  | Size Range mm FL |
| 1989 |  | 1,120 |  | 264 |  | ≥250 |
| 1990 |  | 1,290 |  | 186 |  | ≥325 |
| 1991 |  | 1,114 |  | 198 |  | ≥325 |
| 1992 |  | 1,782 |  | 255 |  | ≥325 |
| 2003 |  | 2,675 |  | 414 |  | ≥325 |

# OBJECTIVES

The project objectives for 2018 are to:

1. estimate the abundance of Arctic grayling ≥ 350 mm in FL in a 40-km index area of the Sinuk River such that the estimate is within 25% of the actual abundance 90% of the time;
2. test the null hypothesis that the abundance of Arctic grayling ≥350 mm FL in a 40-km index section of the Sinuk River is ≥ 1,000, with a 10% chance of Type I error and 15% chance of Type II error if true abundance is 655;
3. estimate the abundance of Arctic grayling ≥ 325 mm in FL in the Sinuk River index area such that the estimate is within 25% of the actual abundance 90% of the time;
4. estimate the abundance of Arctic grayling ≥ 270 mm in FL in the Sinuk River index area such that the estimate is within 25% of the actual abundance 90% of the time; and,
5. estimate the length composition in 25-mm length increments of Arctic grayling ≥ 270 mm FL in the Sinuk River index area such that the estimates are within 10 percentage points of the true value 95% of the time.

The precision criterion for Objective 1 was established as the minimum standard, regardless of population size, and was thought to provide sufficient power for the hypothesis test in Objective 2. The size limit identified in Objective 1, 350 mm FL, is used to determine, by way of Objective 2, whether the management objective has been reached. The management action associated with Objective 2 will be to close the fishery or restrict the fishery to catch and release fishing provided abundance is less than 1,000 Arctic grayling ≥ 350 mm in FL in the Sinuk River index area. The hypothesis test was designed with relatively low probabilities of Type I and II error, with a 10% or less chance of incorrectly recommending a management action if true abundance is at least 1,000 (Type I), and a 15% or less chance of incorrectly failing to recommend a management action if true abundance is 655 or less (Type II). Abundance is also being estimated for two additional length thresholds described in Objectives 3 and 4, and the precision criteria are sufficient for comparison with other Arctic grayling stock assessments. The 325-mm length limit is the length at which the abundance was previously estimated for the Sinuk River, and it is the length at which Arctic grayling are considered large by anglers. The 270-mm length limit is a commonly used stock assessment descriptor and is often the size at which Arctic grayling are reliably recruited to sampling gear. Objective 5 provides an estimate of length compositions of the population in the study area. Because the length at which Arctic grayling recruit to the gear can range between 200 and 270 mm, all fish ≥ 200 mm FL will be tagged in the event abundance for a lower length limit can be estimated.

# Methods

## Study Area

The Sinuk River is 87 km in length and drains a 794-km2 area on the southeast side of the Kigluaik Mountains (Figure 1). The river flows in a southwesterly direction and enters the Bering Sea approximately 40 km northwest of Nome, Alaska. Major tributaries of the Sinuk River include the catchments of Glacial Lake and the Stewart River. The index section of the Sinuk River starts from about 1.7 km downstream from its confluence with Windy Creek and ends at the Nome Teller Highway Bridge (approximately 40 km; Figure 1). This reach of the river is representative of the Arctic grayling stock in the Sinuk River and is the same section of the Sinuk River from which abundance of Arctic grayling was estimated during 1989–1992 and 2003 (Table 1). The study area will be divided into 10 nearly equidistant sections of 4 km in length in order to assess mixing, determine if there is movement between sections between events, and determine if capture probabilities vary by area (e.g. upper river versus lower river). In addition, the sample sections will be the basis of daily sample effort by each crew which will ensure relatively even distribution of fishing effort. Crews will utilize small inflatable rafts to float to each sample section. The starting point will be accessed by helicopter and the take-out will be at the Nome-Teller Highway Bridge.

## Experimental and Sampling Design

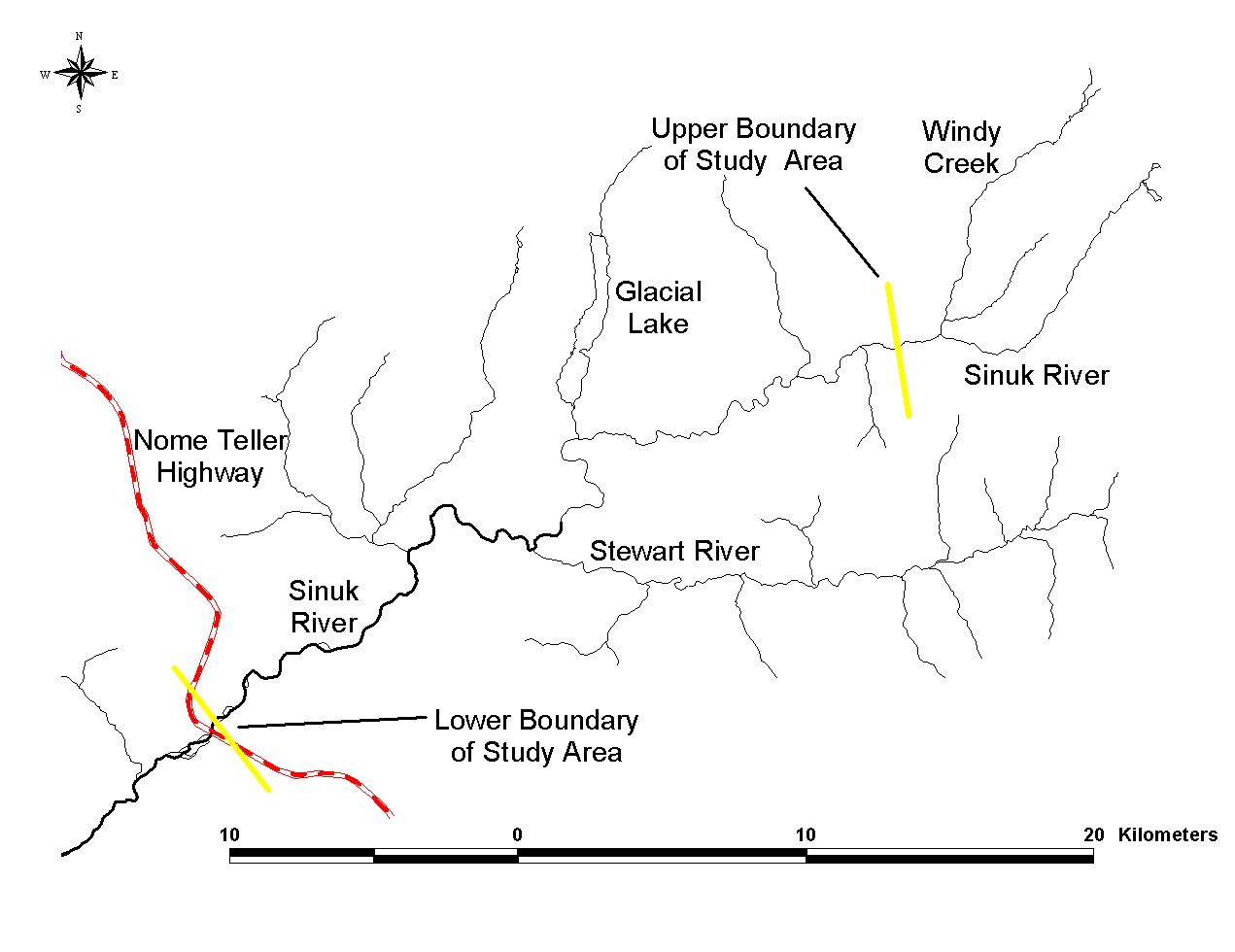
This study is designed to estimate abundances and length compositions of Arctic grayling within the 40-km study area of the Sinuk River (Figure 2) using two-event Petersen mark-recapture techniques for a closed population (Seber 1982) designed to satisfy the following assumptions:

1. the population is closed (Arctic grayling do not enter the population, via growth or immigration, or leave the population, via death or emigration, during the experiment);
2. all Arctic grayling will have a similar probability of capture in the first event or in the second event, or marked and unmarked Arctic grayling will mix completely between events;
3. marking of Arctic grayling will not affect the probability of capture in the second event;
4. marked Arctic grayling will be identifiable during the second event; and,
5. all marked Arctic grayling will be reported when recovered in the second event.

Failure to satisfy these assumptions may result in biased estimates; therefore, the experiment is designed to allow the validity of these assumptions to be ensured or tested. Sufficient data will be collected to perform diagnostic tests to identify heterogeneous capture probabilities (violations of Assumption 2) and prescribed model selection procedures will be followed in the event of such violations. Diagnostic tests are not available to evaluate Assumptions 1, 3, 4 and 5 (although Assumption 1 will be tested to a limited extent). Instead the experiment is designed to ensure that these assumptions will be met thereby avoiding potential biases. The design will ensure that sample sizes will be adequate to meet objective precision criteria and to perform reliable diagnostic tests. For diagnostic tests, the study area will be divided into 10 approximately 4 km sampling sections (Figure 2).

The timing of this study was chosen to coincide with the summer feeding period when Arctic grayling move little (Ridder 1998a, 1999; Ridder and Gryska 2000; Gryska 2001), however; the late August timing of the project may intersect the beginning of migrations to over winter areas. During the last estimate, there was some downstream movement that while significant was deemed to have had small bias relative to the large study area. To counteract the potential of movement impacting the estimate, the schedule will be more compressed, and the project will be completed 4 days sooner. Movement of Arctic grayling during the study will be described by movements of recaptured fish. The sampling schedule will result in an 8-day hiatus for each sampling subsection. This hiatus is important to enhance localized mixing of marked and unmarked fish and to allow marked fish to recover from the effects of handling between events. However, the hiatus is kept relatively short to minimize growth and mortality between events.

The logistics of capturing fish in a river, unlike in a lake, make it difficult to approximate the taking of a simple random sample (i.e., a random sample taken without replacement). In addition, given the territorial behavior of Arctic grayling, complete mixing across the study area during the experiment is highly improbable. The Sinuk River will be sampled systematically by progressively moving downstream while sampling; therefore, the Bailey-modified Petersen estimator (Bailey 1951 and 1952), which is based on the binomial model (sampling with replacement), will be the appropriate abundance estimator. The sampling strategy for this project will be to: 1) sample the entire study area attempting to subject all fish to an equal probability of capture during the first event (i.e., to the extent possible, distribute marks in proportion to abundance throughout the study area); 2) rely on local mixing (i.e., scale of 0.5 km) to produce a uniform marked proportion at that scale and to mitigate potential bias due to pockets of fish isolated from sampling); and, 3) repeat step one for the second event. It is anticipated that the effort made to evenly distribute marks across the study area combined with local mixing will approximate a uniform marked proportion across large (i.e., larger than the scale of mixing) portions of the study area or perhaps across the entire study area. Sampling in any portion of the river during the second event takes place over a short period of time as the crew progresses downriver. Also, Arctic grayling are expected to move only a short distance compared to the distance sampled during a given day. Under these conditions fish recaptured more than once are considered anomalies resulting from releasing fish close to the boundaries between sampling sections. Therefore, fish captured during the second event are given a secondary mark (fin clip) to avoid recounting. If the marked proportion and the second event capture probabilities are not uniform across the entire study area, a completely stratified Bailey-modified Petersen estimator or, if mixing occurs across stratum boundaries, a partially stratified estimator (Darroch 1961) will be used (Data Analysis section).



**Figure 2.–** Upper Sinuk River drainage and study area.

### Evaluation of Assumptions

**Assumption 1:** Assumption 1 will likely not be violated because Arctic grayling typically move little during the summer feeding season (Tack 1973; Ridder 1998b, c; Ridder and Gryska 2000; Gryska 2001). Conducting this experiment during late August, when Arctic grayling are occupying their summer feeding locations will minimize the probability of fish entering or leaving the study area between or during sampling events. However, some small-scale movements (e.g., <1 km) are expected. Movements determined from recaptured fish will be examined for movement away from or towards the study area boundaries to provide evidence of immigration and emigration. This study will be of short duration, and therefore, growth recruitment and mortality will be insignificant.

**Assumption 2:** Marked and unmarked fish are expected to mix on the scale of 0.5 river km, and not throughout the study area. Therefore, Assumption 2 will be met by attempting to subject all fish to the same probability of capture during the first or second event and by relying on mixing at a local scale. While angling, fishing effort will be distributed in proportion to the distribution of Arctic grayling. Based on catch rates and visual observations, effort will be increased in areas where densities appear relatively high (e.g., pools immediately following riffles) and decreased where there appear to be few fish available (e.g., fast, shallow, riffles). If multiple channels are encountered, all navigable channels will be fished. To avoid the possibility of incurring a negative bias resulting from fish that are not subject to capture during the experiment (i.e., during either event) the entire study area (longitudinally) will be sampled (see Sampling Methods). In addition, movement of recaptured fish will be examined at a fine scale (i.e., 200 m) to determine whether mixing was likely sufficient to minimize or eliminate the potential for fish having been isolated from the experiment.

It is also unknown whether fish will have equal probability of capture by length, although results from the previous stock assessment indicated that the length composition of fish ≥ 325 mm FL marked in the first event did not differ significantly from fish examined during the second event or from fish recaptured during the second event (Joy 2006). Hook-and-line gear has been shown to capture representative samples of Arctic grayling for the size range of fish addressed in this experiment (Fish 1996, Joy 2006; Wuttig 2004). However, size selective sampling has also occurred when using these gear types (Ridder et al. 1993; Gryska 2004a). Data sufficient for investigating this potential bias and adjusting for it will be collected and analyzed (Data Analysis section).

**Assumption 3**: The 8-day hiatus between mark and recapture samples of each section should allow marked fish to recover from the effects of handling and marking induced behavioral effects during the first event; therefore, Assumption 3 should be valid. In addition, the use of spin and fly gear will also help mitigate marking induced behavioral effects.

**Assumption 4:** This assumption will be addressed by double-marking each Arctic grayling captured during the first event. Tag loss will be noted when a fish is recovered during the second event with a first-event fin clip but without a FloyTM tag. In addition, tag placement will be standardized, which will enable the fish handler to verify tag loss by locating recent tag wounds.

**Assumption 5:** All fish will be thoroughly examined for tags or recent fin clips. All markings (tag number, tag color, fin clip, and tag wound) for each fish will be recorded.

## Sample Sizes

Joy (2006) recommended using an abundance of 3,000 Arctic grayling ≥325 mm FL to calculate sample size goals. This level of abundance exceeds all previous point estimates of abundance of Arctic grayling ≥ 325 mm FL, as well as those ≥350 mm FL, and it is encapsulated by the 95% CI of the 2003 estimate. If actual abundance is 3,000 fish, then 330 will need to be sampled during each event to meet the criteria specified in Objective 1 (Robson and Regier 1964). Similar sampling requirements can be calculated for Objective 3, but Objective 1 is most meaningful to the management plan and will be the main driver of sample sizes. Nonetheless, field efforts will not be focused on sampling fish in specific size ranges, rather, efforts will be directed at attempting to ensure similar probabilities of capture of all fish during both sampling events.

It has been demonstrated that angling on this and other similar rivers with the effort proposed (Gryska 2001; Joy 2006; Parker 2006) has typically yielded sufficient sample sizes that achieve the established precision criteria. During 2003, 366 and 399 Arctic grayling were sampled during each event, and it is expected that similar if not more samples will be obtained as effort will be doubled (4 people sampling instead of 2). While sample size calculations are presented, the demonstrated performance of the selected sampling methods at the prescribed levels of effort will be the strongest evidence in support of our ability to obtain sample sizes necessary to meet the precision criteria.

Each sampling crew will capture and mark as many Arctic grayling as they can during the time allotted. If actual abundance is less than the number assumed above, the recommended sample sizes may not be achieved. However, it is still expected that an adequate number of fish will be sampled in each event to meet the precision criteria based on experience from similarly designed mark-recapture experiments for Arctic grayling on the Seward Peninsula (DeCicco 1990–2000, 2002a; Gryska 2004b, 2006). In these studies, precision criteria were achieved using similar amounts of fishing effort per river kilometer using hook-and-line gear.

Using methods developed by Thompson (1987) for estimating multinomial proportions, a minimum of 127 fish will be sampled in order to estimate length compositions within the precision criteria. The sample size required for achieving the precision criteria for the abundance estimates are sufficient for meeting those of length composition estimates even if data from only one of the two sampling events can be used in the analysis (Case III or IV; Appendix A1).

## Sampling Methods

Both spin and fly gear will be used and will select for fish ≥ 200 mm FL. Terminal spin gear will consist of rubber-bodied jigs of varied size (1/16–1/4 oz and size 2–6 hooks) and fly gear will consist of an assortment of flies (e.g., Adams fly, Blue Dunn fly, or bead-head nymphs). Both jigs and flies will fish in all waters; however, the ratio of time spent angling a particular reach or hole using flies and jigs will be left to the discretion of the angler as to which appears to be more effective. Always fishing the secondary gear at a minimal level (e.g. 5 casts per hole) will help catch additional fish that would not have selected the primary gear and identify changes in fish preferences for either gear type.

The entire length of each section will be sampled and attempts will be made to subject all Arctic grayling to the same probability of capture during each event by fishing each pool or run with effort in proportion to the distribution of Arctic grayling. Distribution will be assessed based on initial catch rates and by observation of fish if water conditions permit. After sampling, all fish will be released at or near their capture location. In no cases will fish be displaced by more than 100 m from the capture location.

For each event, sampling will be conducted by 2 crews of 2 people each over a 5-day period. The first sampling event will begin on August15 and conclude on August 19. The second sampling event will begin on August 22 and conclude on August 26. Approximately 8 hours per day will be expended by each crew each day while angling a section. Inconsistent amounts of effort (in terms of number of crewmembers and number of days during each event) during a 2001 assessment project of the Snake River was believed to be a contributing factor in observed variability in capture probabilities during an event (Gryska 2004b), therefore in this study, crew size and duration of sampling events will be consistent throughout the experiment. The crew will wade through the sample section while angling and pulling a raft loaded with sampling equipment and camping gear.

During the first event, each captured Arctic grayling ≥ 200 mm FL will be marked with an individually numbered FloyTM FD-94 internal anchor tag placed at the insertion of the dorsal fin so that the tag locks between the posterior interneural rays. A partial upper caudal fin clip will be given to evaluate tag loss. To prevent double sampling of fish during the second event, all captured fish will receive a lower caudal fin clip. The movement of fish during the experiment will be evaluated by recording capture/release locations of all fish as a GPS waypoint (latitude and longitude coordinate in decimal degrees, NAD27 Alaska datum) during each event.

## Data Collection

All data and daily summaries will be recorded in “Rite-in-the-Rain®” notebooks. For each fish, length, capture/release location as a GPS waypoint (decimal degree NAD27 Alaska datum), tag number and color, fin clip, will be recorded in the notebook. All captured Arctic grayling will be measured to the nearest mm FL. If any Arctic grayling die during handling, the otoliths will be collected from the fish for aging and its length measured and recorded.

Each crew will also keep a detailed, daily field journal in a “Rite-in-the-Rain®” notebook. An important goal in recording the information below is to identify conditions that may have a substantial effect on the probability of capture during a sampling event. Information collected should include:

1. gear type that was most effective and at which times it was most effective. For example, a statement such as ‘between 2 and 4 p.m. a hatch of may flies occurred and fly fishing was most effective and used extensively’
2. weather and water conditions (e.g., cloud cover, precipitation, temperature, water level, and clarity);
3. hours worked each day by each crew member;
4. river km and areas sampled each day;
5. way point locations (as decimal degree latitude and longitude coordinates, NAD27 Alaska datum) of release sites, hydrologic features, camps, beginning and ending points of each day;
6. number of fish captured; and,
7. any other relevant details or observations, such as the presence of spawning salmon, logistical information or an itemized listing of first-aid/field/sampling supplies and equipment needs for future field work.

## Data Reduction

Data will be transferred from field notebooks to Microsoft Excel worksheets for analysis. Column headings of the worksheet will include: sample number, date of capture, event, section length, tag number, tag color, release location (longitude and latitude in decimal degree NAD27 Alaska datum), gear type, fin clip, and field comments. In addition, a column will be created to document whether a fish captured during the second event was a recapture. Additional columns may be added for clarity and a glossary of all column headings will be provided in a text box along with a brief project description. Location data (NAD27 Alaska Datum) will be plotted on a map using Arc View GIS software. Final copies of the Excel file will be provided with the completed report when it is submitted for review to be archived in the Sport Fish Division Docushare repository. At that time, a file name and directory will be assigned, which will be included as an appendix in the final report.

## Data Analysis

The data analysis will include testing the validity of the mark-recapture experiment Assumption 2 and, to a limited extent, Assumption 1 (it is assumed based on the experimental design that Assumptions 3, 4, and 5 will not be violated), calculating abundance estimates and correcting for bias if violations of Assumption 2 are identified, and calculating length composition estimates.

### Abundance Estimates (Objectives 1, 4-5)

Relative to Assumption 1, closure will not be tested directly but inferred from examination of the movement of recaptured fish within the study area. The data will be examined for movement away from or towards, either or both boundaries of the study area to provide evidence of immigration and emigration. It is unlikely that migrations will pose a threat to the assumption for several reasons. First, Arctic grayling have been documented to generally be non-migratory during the summer feeding period. Second, previous studies have documented little movement and that the bulk of population exists in this index area (DeCicco 1992, 1993, 1998, 2002a, 2007).

Relative to Assumption 2, differences in capture probability related to fish size, location, and time will be examined. Size-selective sampling will be tested using two Kolmogorov-Smirnov tests (Conover 1980). The tests and possible actions for data analysis are outlined in Appendix A1. If stratification by size is required, capture probability by location will be examined for each stratum, and total abundance and its variance estimate will be calculated by summing strata estimates.

Temporal and spatial violations of Assumption 2 will be tested using consistency tests described by Seber (1982; Appendix A2). If at least 1 of the 3 consistency tests results in a failure-to-reject the null hypothesis, then it will be concluded that at least one of the conditions in Assumption 2 was satisfied. If all 3 of these tests reject the null hypothesis, then depending on the degree of movement, a partially or completely stratified estimator must be used. If there is some movement of marked Arctic grayling between strata but mixing is incomplete, the methods of Darroch (1961) will be used to compute a partially stratified abundance estimate. If no movement of marked Arctic grayling between geographic strata is observed, a completely stratified abundance estimate will be computed using the methods of Bailey (1951, 1952).

To perform the consistency tests, the study area will be divided into 10 geographic strata 4 km in length and capture probabilities will be compared. Sections longer than approximately 2 km are preferred to accommodate localized movements of Arctic grayling (e.g., approximately 1–2 km). Additional stratification schemes may be examined; criteria to be considered when defining these geographic strata include the number of recaptures per stratum, hydrology, and stratum length relative to anticipated movements. When estimating abundance a minimum number of recaptures (approximately 7 fish) will be preferred to permit reliable diagnostic testing and to ensure negligible statistical bias in  (Seber 1982).

Diagnostic tests will be performed separately on fish ≥ 270, ≥ 325, and ≥ 350 mm FL. If no assumptions are violated, the numbers of Arctic grayling ≥ 270, ≥ 325 and ≥ 350 mm FL in the described section of the Sinuk River will be estimated using Bailey's modification of the Petersen estimator (Bailey 1951, 1952). The modified Petersen estimator of Bailey (1951, 1952) and its variance are:

; and, (1)

 (2)

where:

 = the number fish marked during the first sampling event;

 = the number of fish examined during the second sampling event; and,

**=** the number of fish captured during the second sampling event with marks from the first sampling event.

The abundance estimate may be biased low (with the bias undeterminable), regardless of the estimator used, if fish in the population had zero probability of capture during the experiment (i.e., if fish were physically isolated from all fishing effort during both events). Movement of recaptured fish will be examined at a fine scale (e.g., 200 m) to determine whether mixing was sufficient to minimize or eliminate this potential bias. If, for example, >80% of the recaptured fish exhibited no movement, the potential for failing to subject some fish to a non-zero probability of capture during the experiment may be considered significant enough to interpret the estimate as biased low (again with the degree of bias indeterminable). When evaluating the potential for this bias, another consideration includes the likelihood of not fishing areas that hold fish because mixing may be occurring on a scale finer than 200 m.

### Hypothesis Test (Objective 2)

A p-value will be calculated to assess the probability of obtaining the observed abundance estimate assuming the null hypothesis was true. Depending on which estimator is used to estimate abundance (Objective 1), this will be done using Monte Carlo methods, simulating the value of the Bailey estimator assuming a Binomial probability model constructed under the null value. If incomplete mixing precludes use of a Bailey estimator, a p-value will be estimated assuming normality. A p-value < 0.10 will reject the null hypotheses.

### Length Composition (Objective 3)

Kolmogorov-Smirnov tests performed to test for size-selective sampling and test outcomes will be used to determine if stratification by fish size is necessary and if data from the first, second, or both events are to be used. For cases I–III (Appendix A1) stratification is not necessary and length proportions and variances of proportions for Arctic grayling  270 mm FL will be estimated using samples from the event(s):

 (3)

where:

 the proportion of Arctic grayling that are within length category *k*;

*nk* = the number of Arctic grayling sampled that are within length category *k*; and,

*n* = the total number of Arctic grayling sampled.

The unbiased variance of this proportion is estimated as (Cochran 1977):

 (4)

If diagnostic tests indicate case IV, there is size-selectivity during both events and data must be stratified to eliminate variability in capture probabilities within strata for at least one or both sampling events. Formulae to estimate length composition over all strata are presented in Appendix A1. For stratum estimates, the proportion of fish in a length category will be calculated by summing independent stratum abundance estimates for the length category and then dividing by the summed abundances for all categories (i.e., total abundance). First the conditional proportions from the sample are calculated:

 (5)

where:

*ni* = the number sampled from size stratum *i* in the mark-recapture experiment;

*nik*  = the number sampled from size stratum *i* that are in length category *k*; and,

 = the estimated proportion of length category *k* fish in size stratum i.

The variance calculation for  is identical to equation 4 (with appropriate substitutions).

The estimated abundance of fish in length category *k* in the population is then:

 (6)

where:

 = the estimated abundance in size stratum *i*; and,

*s* = the number of size strata.

The variance for in this case will be estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

. (7)

The estimated proportion of the population in length category *k*  is then:

 (8)

where: .

Variance of the estimated proportion can be approximated with the delta method (Seber 1982):

. (9)

Length composition of Arctic grayling will be estimated for 25-mm FL categories for comparison with other Arctic grayling studies.

# SCHEDULES AND DeliverableS

Dates of sampling events in 2016 and other field and office activities are summarized below. All research results will be compiled in a State of Alaska Fisheries Data Series Report.

|  |  |
| --- | --- |
| Date(s) | Activity |
| August 15–19, 2018 | First sampling event on the Sinuk River |
| August 22–26, 2018 | Second sampling event on the Sinuk River |
| September 1–30, 2018 | Data entry |
| October 1–October 31, 2018 | Data analysis, table, and figure preparation |
| November 1–November 30, 2018 | FDS report preparation |
| December 1, 2018 | Draft report due to project biometrician |
| February 28, 2019 | Draft report due to resident species research supervisor |
| April 1, 2019 | Draft report to regional research supervisor |

# RESPONSIBILITIES

List of Personnel and Duties:

Andrew Gryska: Fishery Biologist II; Project Leader

Duties: Overall supervision of the project. Coordinate sampling schedules with project personnel. Analyze data and prepare reports with technical assistance.

Brendan Scanlon: Fishery Biologist III

Duties: Assist in planning of project as needed. Assist in sampling and field collection of data and by providing equipment for field aspects of the project.

Ben Buzzee: Biometrician I

Duties: Prepare statistical design of field investigation for operational plan, assist with capture, sampling, and data collection, and review data analysis and final report.

Dan Reed: Volunteer

Duties: Assist with capture, sampling, and data collection.

James Savereide: FB IV

Duties: Assist with capture, sampling, and data collection.

Tim Viavant: FB IV

Duties: Assist with capture, sampling, and data collection.

Dave Stoller: HB I

Duties: Assist with capture, sampling, and data collection.

Rick Queen: FWT IV

Duties: Assist with capture, sampling, and data collection.

Corey Schwanke: FB II

Duties: Assist with capture, sampling, and data collection.

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**Appendix A**

Appendix A1.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student’s t-test).

**M vs. R C vs. R M vs. C**

*Case I:*

Fail to reject Ho Fail to reject Ho Fail to reject Ho

There is no size/sex selectivity detected during either sampling event.

*Case II:*

Reject Ho Fail to reject Ho Reject Ho

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

*Case III:*

Fail to reject Ho Reject Ho Reject Ho

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

*Case IV:*

Reject Ho Reject Ho Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

*Evaluation Required:*

Fail to reject Ho Fail to reject Ho Reject Ho

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation*. Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the

-continued-

Appendix A1.–Page 2 of 2.

M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

*Case I*. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

*Case II*. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

*Case III*. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

*Case IV*. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (*pk*) is estimated by combining within stratum composition estimates using:

; and, (1)

. (2)

where: *j* = the number of sex/size strata;

 = the estimated proportion of fish that were age or size *k* among fish in stratum *i*;

 = the estimated abundance in stratum *i*; and,

 = sum of the  across strata.

Appendix A2.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

**Tests of consistency for petersen estimator**

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

**I.-Test for complete mixinga**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Section | Section Where Recaptured | | | | Not Recaptured |
|  | Where Marked | **A** | **B** | **…** | **F** | (n1-m2) |
|  | **A** |  |  |  |  |  |
|  | **B** |  |  |  |  |  |
|  | **...** |  |  |  |  |  |
|  | **F** |  |  |  |  |  |

**II.-Test for equal probability of capture during the first eventb**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Section Where Examined | | | |
|  |  | **A** | **B** | **…** | **F** |
|  | Marked (m2) |  |  |  |  |
|  | Unmarked (n2-m2) |  |  |  |  |

**III.-Test for equal probability of capture during the second eventc**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Section Where Marked | | | |
|  |  | **A** | **B** | **…** | **F** |
|  | Recaptured (m2) |  |  |  |  |
|  | Not Recaptured (n1-m2) |  |  |  |  |

a This tests the hypothesis that movement probabilities (θ) from section *i* (*i* = 1, 2, ...s) to section *j* (*j* = 1, 2, ...t) are the same among sections: H0: θ*ij* = θ*j*.

b This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among sections: H0: Σ*ai*θ*ij* = *k*U*j* , where *k* = total marks released/total unmarked in the population, U*j* = total unmarked fish in stratum *j* at the time of sampling, and *ai* = number of marked fish released in stratum *i*.

c This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among sections: H0: Σ*j*θ*ij*p*j* = d, where p*j* is the probability of capturing a fish in section *j* during the second event, and d is a constant.