**Fishery Data Series No. 11-55**

# Stock Assessment of Arctic Grayling in the Chatanika River between Faith and Any Creeks, 2007

**by**

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**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 | $ft^3/s$ |
| 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) |

**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 | $H_A$ |
| base of natural logarithm | $e$ |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, 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 |

# *FISHERY DATA REPORT NO. 11-55*

## STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE CHATANIKA RIVER BETWEEN FAITH AND ANY CREEKS, 2007

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# ABSTRACT

A stock assessment of Arctic grayling Thymallus arcticus ≥270 mm FL was conducted within a 122.6-km study area of the Chatanika River between Faith and Any creeks during 2007 for the purpose of evaluating exploitation rates and proposed regulatory changes. Using a two-event mark-recapture experiment, population abundance and length composition was estimated across varying geographic and length strata. Between Faith and Poker creeks, hook-and-line gear was used to capture fish with the first event occurring July 13–20 and the second July 26–July 31. Between Poker and Any creeks, boat electrofishing was used with the first event occurring July 12–14 and the second July 26–31. Estimated abundance of Arctic grayling ≥270 mm FL for the entire 122.6-km assessment area was 11,934 (SE=1,881) fish. Abundance of Arctic grayling ≥270 mm FL was also estimated for 4 subareas within the overall study area: between Faith and Poker creeks (80.2 km) abundance was 7,797 fish (SE=1,052); between Poker and Any creeks (42.4 km) abundance was 4,155 fish (SE=897); between Sourdough Creek and Perhaps Creek (18.3 km) abundance was 775 fish (SE=152); and between 3.2 km upstream of Elliot Highway Bridge and mouth of Any Creek (29.6 km) abundance was 2,132 fish (SE=526). Based on the most recent five-year average of estimated annual harvests, exploitation was at an acceptable level of approximately 5% for fish ≥270 mm FL and demonstrated that the current regulation of a 5 fish daily bag limit with no length or seasonal restrictions should be sustainable.



Key words: Arctic grayling, *Thymallus arcticus*, stock assessment, abundance, length composition, hook-and-line, mark-recapture, Chatanika River, Alaska.


# INTRODUCTION

The Chatanika River is a clear, rapid-runoff river within the Tanana River drainage and because of its accessibility from Fairbanks it is a popular recreational destination for many, including anglers targeting Arctic grayling *Thymallus arcticus* (Figure 1). Downstream of the Elliot Highway Bridge, fishing effort is largely directed at northern pike *Esox lucius*, Chinook salmon *Oncorhynchus tshawytscha* and Arctic grayling; and upstream of the bridge, where salmon fishing is prohibited and northern pike habitat is very limited, angler effort is almost exclusively directed at Arctic grayling (Appendix A).

Anglers can access the river at the Elliot and Steese highway bridge crossings or at numerous locations (e.g. campgrounds and undeveloped gravel bars) along the Steese Highway where it parallels the river for ~66 river kilometers (rkm). Upstream of the Steese Highway Bridge, the river characterized by a moderate gradient with pool and riffle sequences that can be easily waded. Downstream of the Elliot Bridge, the river is only accessible by riverboat and maintains its pool-riffle character until it approaches Any Creek beyond which point the gravel bars generally disappear and it transitions into an incised channel dominated by mud and sand substrates.

The Arctic grayling fishery in the Chatanika River remains popular and has a long history of studies since the early 1950s, which have ranged from studying the effects of placer mining that has occurred throughout the drainage to assessing populations sizes of Arctic grayling within index areas. A more comprehensive description of the fisheries' history and attendant studies are provided by Brase (2009), Fleming (1998), and Wuttig (2004).

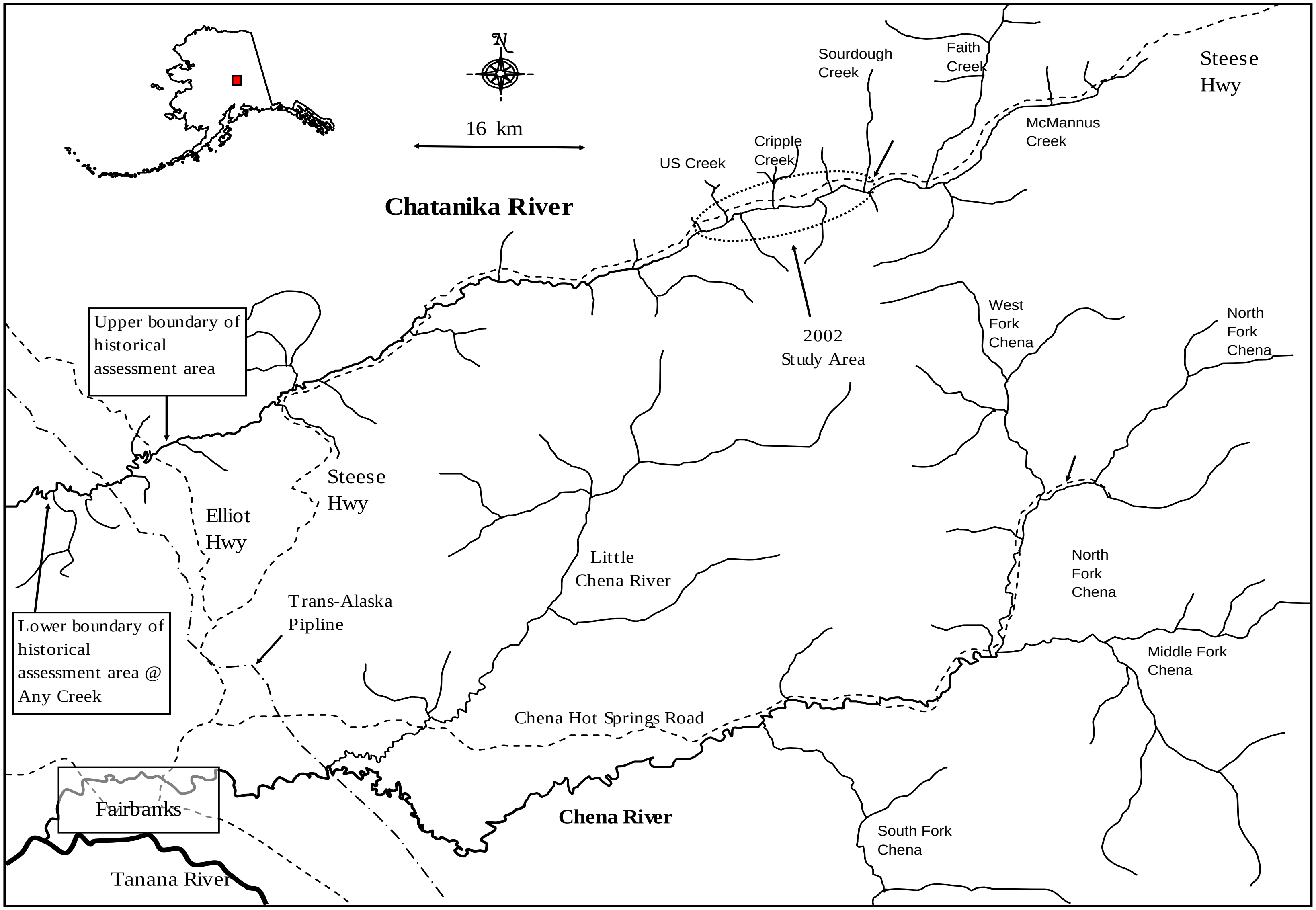


Figure 1.–Chatanika River study area with historical assessment areas demarcated.

As stated within *Policy I* of the *Region III Wild Arctic Grayling Management Plan,* the fishery is managed for long-term sustained yield by employing a conservative harvest regime (Swanton and Wuttig 2004). From 1991 to 2009 the regulations have been:

1. a daily bag and possession limit of five Arctic grayling between June 1 and March 31;
2. any Arctic grayling retained, must be 12 inches total length (270 mm FL) or greater;
3. between April 1 and May 31, catch and release fishing only (i.e., spawning period closure);
4. between April 1 and May 31, only a single-hook, artificial lure may be used upstream of an ADF&G marker (located one mile upstream of the Elliot Highway Bridge); and,
5. only a single-hook may be used downstream of an ADF&G marker (located one mile downstream of the Murphy Dome Road).

In January of 2010, the regulation was changed and the 12-in length limit and the seasonal spawning closure were eliminated based on the preliminary results of the study, which indicated a relatively large population of fish in the Chatanika River.

The Chatanika River fishery has a potential for high exploitation because it is easily accessible by road and allows for a relatively liberal harvest. However, there has never been a single, comprehensive stock assessment of the entire population vulnerable to the fishery. During 1991–1995, exploitation rates were evaluated, in part, by assessing population sizes within a relatively small index area in the Lower Chatanika River that extended from the Elliot Highway Bridge to Any Creek (~29.6 rkm; Figures 1 and 2). The only other stock assessment since then was conducted in 2002, which consisted of estimating abundance of Arctic grayling in an 18-km reach of river in the upper drainage. This study demonstrated that far lower densities of Arctic grayling were present in headwater areas along the Steese Highway compared to downstream of the Elliot Highway Bridge in the early 1990s (Wuttig 2004; Figure 1). For example, the density of fish ≥270 mm FL in the 18-km reach between Sourdough and Perhaps creeks in 2002 was only 13 fish/km, compared to 87 fish/km in 1995 below the Elliot Highway Bridge (Fish 1996, Wuttig 2004). Reasons for the differences are unclear (e.g., related to habitat or fishing pressure), but a need for more comprehensive information on the abundance for the entire length of the fishery was evident because only 45 km of the 122-km long fishery had ever received full stock assessments. Fleming (1998) systematically examined catch rates from Sourdough Creek to the Steese Highway Bridge and found that CPUE tended to increase downriver, but this study was of limited value relative to examining exploitation.

The goal of this study was to provide the area manager with an assessment of the population size for the entire length of the Arctic grayling fishery for the purpose of better evaluating sustainability and potential regulatory proposals in 2010, specifically the elimination of the 12-in length limit and the spawning closure. This study also provided the opportunity to make comparisons with prior stock assessments conducted in 1991–1995 and in 2002.

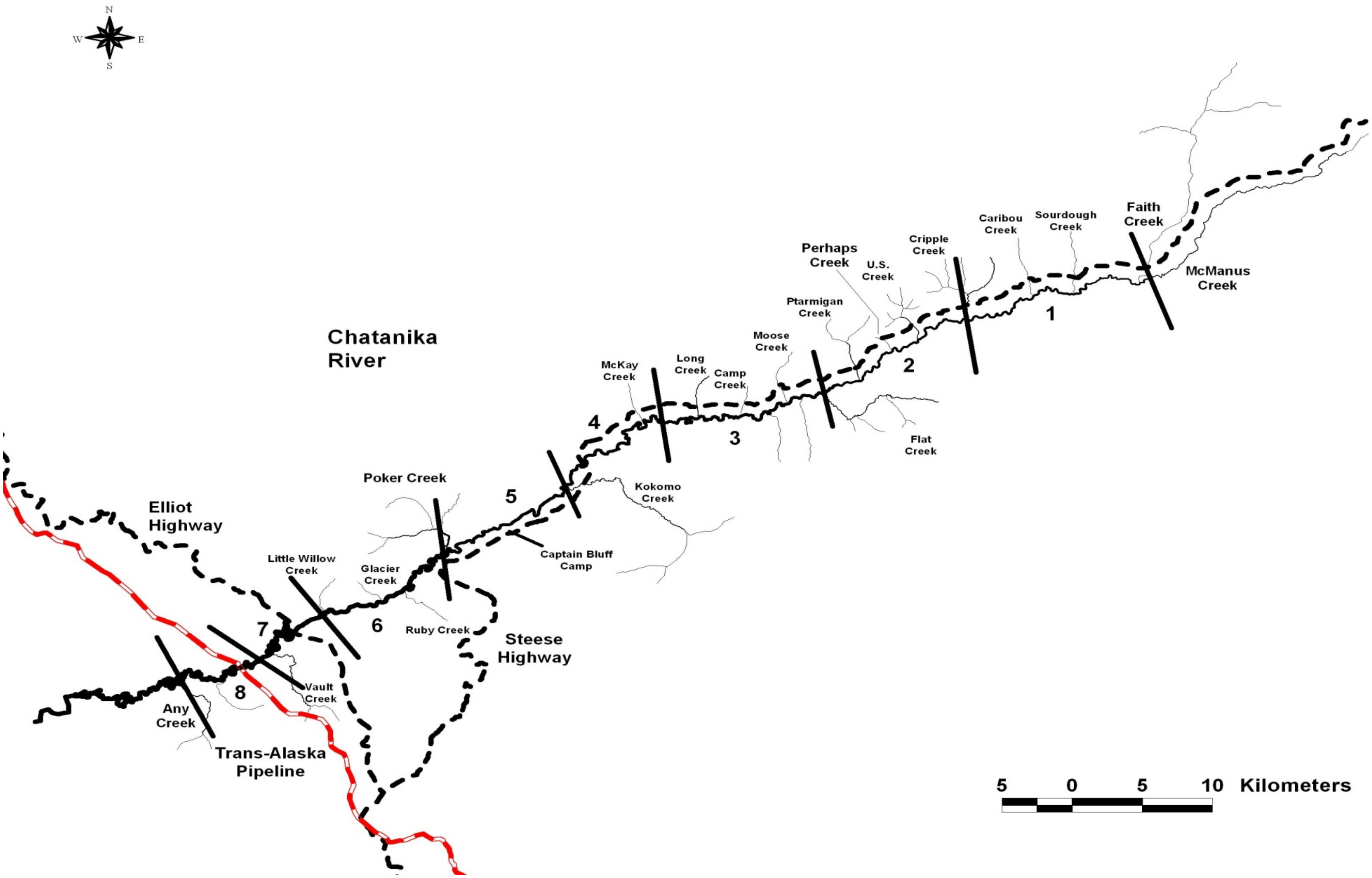


Figure 2.–Chatanika River study area and sampling sections (1–8).

# OBJECTIVES

The research objectives for 2007 were to:

1) estimate the abundance of Arctic grayling ≥270 and ≥330 mm FL during July 2007 in the Chatanika River study area (122.6 km) and within four subareas:
    a) between Faith Creek and Poker Creek (80.2 km);
    b) between Poker Creek and Any Creek (42.4 km);
    c) between Sourdough Creek and Perhaps Creek (18.3 km); and,
    d) between 3.2 km upstream of Elliot Highway Bridge and the mouth of Any Creek (29.6 km);
2) estimate the length composition (in 10-mm intervals) of Arctic grayling during July 2007 in the Chatanika River study area (122.6 km) and within the same four subareas described above.

The desired relative precision for Objective 1 were such that the estimates were within 25% of the actual abundance 95% of the time, and for Objective 2, the length composition estimates by 10-mm length interval were within five percentage points of the true value 95% of the time.

The size limits identified in the objectives, 270 mmFL and 330 mm FL, are commonly used standards in Arctic grayling stock assessments or management objectives within Region III. The 270-mm length limit is typically the smallest size that fish are reliably recruited to boat electrofishing equipment and angling gear during summer stock assessments and corresponds to the 12-inch minimum harvest length for many fisheries. The 330-mm length category corresponds to the length at which Arctic grayling begin to be considered large by anglers and abundance of fish of this size is often used for management objectives or to evaluate the stock quality of Interior Alaska fisheries. Because the length at which Arctic grayling recruit to the gear can range between 150mm and 270 mm, all fish ≥150 mm FL were tagged in the event abundance and length composition at a lower length limit could be estimated.

# METHODS

## STUDY AREA

The study area encompassed a 122.6-km reach of the Chatanika River from the confluence of Faith and McManus creeks to the mouth of Any Creek (Figures 1 and 2) and was almost four times as large as the previous assessment areas (Fish 1996, Wuttig 2004). The study area boundaries contain almost all (i.e., >95%) of the fishing effort directed at Arctic grayling in the Chatanika River (A. Brase, Fairbanks Area Management Biologist, Alaska Department of Fish and Game, Fairbanks, personal communication). Abundance was also estimated for 4 subareas within the overall study area: 1) between a point 3.2 km upstream of the Elliot Highway Bridge and Any Creek (29.6 km); 2) between Sourdough and Perhaps creeks; 3) between Faith and Poker creeks (80.2 km); and, 4) between Poker and Any creeks (42.4 km) n. The first two subareas corresponded to boundaries of previous stock assessments and permitted comparisons of abundance between years. The subarea between Faith and Poker creeks was of value because it is easily accessed from the Steese Highway that parallels its entire length, and because it corresponded to the point where sampling gear types changed from hook-and-line gear to electrofishing.

## EXPERIMENTAL AND SAMPLING DESIGN

This study was designed to estimate abundances and length composition of Arctic grayling within the 122.6-km index area of the Chatanika 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 was closed (Arctic grayling did not enter the population, via growth or immigration, or leave the population, via death or emigration, during the experiment);
2. all Arctic grayling had a similar probability of capture in the first event or in the second event, or marked and unmarked Arctic grayling mixed completely between events;
3. marking of Arctic grayling did not affect the probability of capture in the second event;
4. marked Arctic grayling were identifiable during the second event; and,
5. all marked Arctic grayling were reported when recovered in the second event.

The estimator used was a modification of the general form of the Petersen estimator:

$$\hat{N} = \frac{n_1 n_2}{m_2}, \qquad (1)$$

where:

$n_1$ = the number of Arctic grayling marked and released during the first event;

$n_2$ = the number of Arctic grayling examined for marks during the second event; and,

$m_2$ = the number of marked Arctic grayling recaptured during the second event.

The sampling design and data collected allowed the validity of the five stated assumptions to be ensured or tested. The specific form of the estimator was determined from the experimental design and the results of diagnostic tests performed to evaluate if the assumptions were met (Appendices B1, B2 and B3).

For the entire 122.6-km study area during July 12–August 2, a stratified design was used to estimate the abundance and size composition for two adjacent subareas of river. The upper subarea (80.3 km in length) was divided into 5 sections and was sampled using hook-and-line gear. The lower subarea (42.3 km in length) was divided into 3 sections and was sampled using electrofishing equipment. The two gear types may have different capture efficiencies and this stratification served as a good stratification point for diagnostic testing.

The upper subarea was further divided into 25 subsections (5 per section), which were 3.0–3.3 km in length and were each sampled by a two-person crew in one day using hook-and-line gear. The first event occurred during July 13–20 and the second during July 26–31. Starting at the upper boundary of the study area, three crews systematically angled their assigned subsections while wading downstream, and camping (if needed). Gear was transported in a canoe. The terminal gear consisted of a combination of flies (dry and wet) and rubber-bodied jigs and the frequency for which each gear was used were left to each angler's discretion. To minimize heterogeneity in capture probabilities: 1) the work day was adjusted such that areas of high fish densities were fished for longer periods than low density areas; and, 2) both flies and jigs were used in all subsections, although it was generally left to the anglers discretion as to which lure was most effective at a given moment. All captured Arctic grayling were temporarily held in a five-gallon bucket until data were collected and were generally released at or within 25 m of their capture locations. In no cases were fish displaced by more than 100 m from their capture location.

Similar to the upper stretch, the lower stretch was further divided into subsections or "runs" defined by the distance a drifting electrofishing boat travelled in 20 min (typically 1.5–2.5 km in length depending on water velocities). Starting at Poker Creek, one electrofishing boat (one driver and two dippers) was operated by drifting downstream and alternating fishing along shores thought to contain the better Arctic grayling habitat. The first event was during July 12–14, and the second during July 26–31. After sampling, all captured Arctic grayling were transported approximately 200 m upstream from the lower boundary of a run and released.

For both angling and electrofishing, all subsection boundaries during the first event were marked using surveyor flagging and a GPS to ensure the same subsections were used in the second event. These subsections also provided a means to perform diagnostic testing for mixing at a relatively fine scale. Furthermore, hydrologic features along the river were noted that could be used to further refine potential strata boundaries into more biologically meaningful units.

The timing of sampling and selection of the sampling area helped to ensure that the movement of fish did not violate the assumption of closure. July corresponds to the summer feeding period when movements are localized. For example, during previous experiments in the nearby Chena River, movements were in general <2.5 rkm between sampling events separated by a 1–2 week hiatus for a large majority (i.e., ≥85%) of the population (Clark 1993-1995, Ridder and Fleming 1997; Ridder 1999; Wuttig and Stroka 2007). During these experiments, the observed movement was judged to be inconsequential because the duration of the experiment was short and the scale of movements was very small compared to the large size of the sampling sections. Moreover, the upper and lower boundaries on the Chatanika River were areas of low Arctic grayling densities; therefore, the number of fish immigrating and emigrating across the boundaries, if occurring, was assumed to be insignificant. The short duration of the experiment rendered growth recruitment and mortality insignificant in terms of potential biases that could otherwise affect the estimation of abundance. The hiatus between events promoted localized mixing of marked and unmarked fish, which eliminated pockets of fish that could have been isolated from sampling, and allowed marked fish to recover from the effects of handling between events.

## ELECTROFISHING OPERATION

The electrofishing boat was operated using a three-person crew: two to capture fish with dip nets, and one to pilot the boat and operate the electrofishing gear. The boat was equipped with a pulsed-DC variable-voltage pulsator (Coffelt Model VVP-15) powered by a 3,500-watt single-phase gasoline generator. Anodes consisted of four 15-mm diameter steel cables (1.5-m long) spaced 1 m apart and arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the boat served as the cathode. The electrical output (voltage, amperage, and cycle) was adjusted based on observed response of shocked fish to minimize stress. Initially, settings on the pulsator were set at 50% duty cycle and 30 Hz. Since output amperage will vary at a given voltage due to conductivity, substrate, and water depth, the boat operator attempted to keep amperage constant to minimize injury to fish. Voltage was adjusted (250–300 V) to keep output amperage between 2 and 4 amperes.

## DATA COLLECTION

All fish were measured for length (mm FL), and carefully examined for marks. In the first event, all fish ≥150 mm FL were tagged with an individually numbered Floy™ FD-94 internal anchor tag (brown color, white print, numbered between 1 and 2,000) placed at the insertion of the dorsal fin so that the tag locked between the posterior interneural rays and each fish was given an upper caudal fin clip to identify tag loss. To eliminate duplicate sampling in the second event, all fish received a lower caudal fin clip. All fish in both events were carefully inspected for attendant Floy™ tags and fin clips and had their capture/release locations recorded using a GPS (latitude and longitude coordinates as decimal degrees, NAD27 Alaska datum). Fish captured in the first event that exhibited signs of injury or excessive stress death were not marked and censored from the experiment.

## DATA ANALYSIS

### Abundance Estimate

When capturing fish in a river in a downstream progression (i.e., using electrofishing boats or angling), it is inherently difficult to approximate the taking of a simple random sample (i.e., a random sample without replacement). Therefore, samples from the Chatanika River were taken systematically in the sense of progressively moving downstream and sampling proportionally to the abundance of fish present. Under these circumstances, the Bailey-modified Petersen estimator (Appendix B1; Bailey 1951, 1952) is preferred over the Chapman-modified Petersen estimator (Chapman 1951) for estimating abundance.

Relative to Assumption 1, closure was not tested directly but inferred from examination of the movement of recaptured Arctic grayling within the study area. The data were examined for evidence of movement away from or towards the boundaries of the study area to provide evidence of significant immigration and emigration.

Violations of Assumption 2 relative to size effects were tested using two Kolmogorov-Smirnov (K-S) tests. The tests were performed for various combinations of geographic and length strata. There were four possible outcomes of these two tests relative to evaluating size selective sampling (either one of the two samples, both, or neither of the samples were biased) and two possible actions for abundance estimation (length stratify or not). The tests and possible actions for data analysis are outlined in Appendix B2. If stratification by size was required, capture probability by location were examined for each length stratum.

Tests for consistency of the Petersen estimator (Seber 1982; Appendix B3) were used to determine if stratification by area was required due to spatiotemporal effects and to determine the appropriate abundance estimator: the pooled Bailey-modified Petersen estimator, the completely stratified Bailey-modified Petersen estimator, or a partially stratified estimator (Darroch 1961). Assumption testing was performed at the scale of a subsection (with significance level *alpha* = 0.05). This grouping strategy generally provided a sufficient number of recaptures for diagnostic testing to ensure negligible statistical bias in $\hat{N}$ (Seber 1982) and accommodated localized movements of Arctic grayling.

The abundance estimates for the entire study area was obtained by summing abundance estimates for the two subareas (Faith Creek to Poker Creek and Poker Creek to Any Creek). Similarly, the associated estimates of variance were added to obtain an estimate for the entire study area.

## Length Compositions

Length compositions for the various populations of inference were estimated using the procedures outlined in Appendices B2 and B4 for 10-mm length categories.

# RESULTS

## Movement

In the upper subarea (Faith Creek to Poker Creek), only 18 of 122 fish were not recaptured in the same subsection where marked (Appendix C1), only two of the 18 moved more than one subsection, and the movement was not directional. Therefore, it was inferred that the observed movement (magnitude and direction) relative to the size of the index area did not result in any meaningful bias (i.e., <5%) due to the combined effects of immigration and emigration (i.e., the population was closed).

For the lower subarea (Poker Creek to Any Creek), run boundaries for some subsections between the first and second events did not correspond because some flagging had disappeared during the hiatus, and therefore, did not allow movement at the scale of a run (subsection) to be examined. At the larger scale of a section, no fish movement was observed (Appendix C4 and C5), and this information combined with the lack of movement in the upper subarea provided sufficient evidence that the population was closed.

## Abundance Estimate

For the upper subarea (between Faith and Poker creeks), a total of 2,768 fish ≥150 mm FL were sampled using hook-and-line and included in the analysis, plus the smallest recaptured fish 180 mm FL (Table 1). Based on the diagnostic procedures outlined in Appendix A2, K-S test results indicated that that length stratification was required at 270 and 300 mm FL (Table 2). Results of the consistency tests indicated geographic stratification was not required for all attendant length strata (Table 3) and strata estimates were pooled to estimate abundance (Table 4).

For the lower subarea (between Poker and Any creeks), a total of 786 fish ≥200 mm FL were sampled using electrofishing and included in the analysis (Table 1). The smallest recaptured fish was 207 mm FL (Table 1) and the data set was truncated at 200 mm FL. Based on the diagnostic procedures outlined in Appendix B2, K-S test results indicated that that length stratification was not required (Table 2). Results of the consistency tests indicated geographic stratification was not required for any of the attendant length strata (Table 3) and length strata estimates were pooled when appropriate to estimate abundance (Table 4).

## Length Composition

For the upper subarea (between Faith and Poker creeks), the largest proportions among the 10-mm length categories ranged between 250–319 mm FL (Figure 3 bottom panel, Appendix C6). For the lower subarea (between Poker and Any creeks), the distribution of fish appeared similar to the upper subarea with a slight shift to the right with greater proportions of fish ≥320 mm FL present (Figure 3 bottom panel, Appendix C6).

For the section between Sourdough and Perhaps creeks, the length distribution of all fish sampled using the same gear types (i.e. hook-and-line, jigs and flies) differed between 2002 and 2007. In 2007, the fish distribution was unimodal, and fish ≥340 mm FL were relatively absent (Figure 3 top panel, Appendix C6).

Table 1.–Sampling catch statistics for Arctic grayling within the Chatanika River study area, 2007.

| Subarea (km) | Gear | Strata (mm FL) | $n_1$ | $n_2$ | $m_2$ | $P_{capture}$ 1st event | $P_{capture}$ 2nd event |
|---|---|---|---|---|---|---|---|
| Faith to Poker Cr | H&L | ≥150 | 1,481 | 1,287 | 122 | 0.09 | 0.08 |
| (80.2 km ) | | 150–269 | 706 | 566 | 39 | 0.07 | 0.06 |
| | | ≥200 | 1,385 | 1,203 | 117 | 0.10 | 0.09 |
| | | ≥ 270 | 775 | 721 | 83 | 0.11 | 0.10 |
| | | ≥ 330 | 100 | 91 | 15 | 0.32 | 0.29 |
| Sourdough Cr to | | ≥ 200 | 203 | 225 | 28 | 0.12 | 0.14 |
| Perhaps Cr | | ≥ 270 | 118 | 137 | 20 | 0.17 | 0.15 |
| (18.3 km) | | ≥ 330 | 14 | 25 | 3 | 0.12 | 0.21 |
| Poker to Any Cr | Electro | ≥200 | 392 | 394 | 22 | 0.06 | 0.06 |
| (42.4 km) | | ≥ 270 | 284 | 277 | 18 | 0.06 | 0.06 |
| | | ≥ 330 | 58 | 57 | 3 | 0.05 | 0.05 |
| 3.2 km upstream of Elliot Br to Any Cr (29.6 km ) | | ≥200 | 203 | 225 | 28 | 0.12 | 0.14 |
| | | ≥ 270 | 118 | 137 | 20 | 0.15 | 0.17 |
| | | ≥ 330 | 14 | 25 | 3 | 0.12 | 0.21 |

Table 2.–Results of diagnostic tests used to detect and correct for size-selective sampling for estimating abundance and length composition for Arctic grayling in the Chatanika River study area, 2007.

| **Subarea** | **Strata** | **Comparison** | | **Result** |
|---|---|---|---|---|
| | | **M vs. R** | **C vs. R.** | |
| Faith to Poker Cr | ≥150 | D = 0.24<br>P-value = 0.00<br>Reject $H_0$ | D = 0.21<br>P-value = 0.00<br>Reject $H_0$ | Case IV, stratify @ 270, Weight lengths by estimated stratum abundances |
| | 150–269 | D = 0.15<br>P-value = 0.65<br>Fail to reject $H_0$ | D = 0.10<br>P-value = 0.97<br>Fail to reject $H_0$ | Case I, do not stratify, use lengths from both events for composition analysis |
| | ≥ 270 | D = 0.22<br>P-value = 0.00<br>Reject $H_0$ | D = 0.23<br>P-value = 0.00<br>Reject $H_0$ | Case IV, stratify @ 300, Weight lengths by estimated stratum abundances |
| | 270–300 | D = 0.15<br>P-value = 0.65<br>Fail to reject $H_0$ | D = 0.10<br>P-value = 0.97<br>Fail to reject $H_0$ | Case I, do not stratify, use lengths from both events for composition analysis |
| | ≥300 | D = 0.08<br>P-value = 0.91<br>Fail to reject $H_0$ | D = 0.10<br>P-value = 0.57<br>Fail to reject $H_0$ | Case I, do not stratify, use lengths from both events for composition analysis |
| Poker to Any Cr | ≥200 | D = 0.14<br>P-value = 0.79<br>Fail to reject $H_0$ | D = 0.15<br>P-value = 0.69<br>Fail to reject $H_0$ | Case I, do not stratify, use lengths from both events for composition analysis |
| | ≥270 | D = 0.09<br>P-value = 0.99<br>Fail to reject $H_0$ | D = 0.14<br>P-value = 0.87<br>Fail to reject $H_0$ | Case I, do not stratify, use lengths from both events for composition analysis |

Table 3.–Results of consistency tests for the Petersen estimator for estimating abundance of Arctic grayling in the Chatanika River study area, 2007.

| | | Consistency Test | Consistency Test |
|---|---|---|---|
| | | II | III |
| **Subarea** | **Length (mm FL)** | **Equal probability of Capture, 1st Event** | **Equal probability of Capture, 2nd Event** |
| Faith to Poker Cr | 150–269 | $\chi^2 < 8.05$<br>P-value = 0.09 | $\chi^2 < 14.60$<br>P-value = 0.01 |
| | ≥ 270 | $\chi^2 = 4.97$<br>P-value = 0.29 | $\chi^2 = 15.17$<br>P-value = 0.01 |
| | 270–300 | $\chi^2 = 5.78$<br>P-value = 0.21 | $\chi^2 = 7.32$<br>P-value = 0.12 |
| | ≥300 | $\chi^2 = 4.98$<br>P-value = 0.29 | $\chi^2 = 13.94$<br>P-value = 0.01 |
| Poker to Any Cr | ≥200 | $\chi^2 = 3.71$<br>P-value = 0.16 | $\chi^2 = 3.15$<br>P-value = 0.21 |
| | ≥270 | $\chi^2 = 2.48$<br>P-value = 0.29 | $\chi^2 = 3.46$<br>P-value = 0.18 |
| | ≥330 | $\chi^2 = 2.03$<br>P-value = 0.36 | $\chi^2 = 1.01$<br>P-value = 0.60 |

Table 4.–Estimated abundance of Arctic grayling in the Chatanika River by subarea during 2007.

| Subarea (km) | Gear | Length strata (mm FL) | Abundance | SE | Density (fish/km) |
|---|---|---|---|---|---|
| Faith to Poker Cr ( 80.2 km ) | H&L | ≥150 | 17,805 | 1,838 | 225 |
| | | ≥200 | 15,980 | 1,683 | 200 |
| | | 150–270 | 10,008 | 1,507 | 125 |
| | | 200–270 | 8,183 | 1,344 | 102 |
| | | 270–300 | 5,359 | 1,013 | 67 |
| | | ≥ 270 | 7,779 | 1,052 | 97 |
| | | ≥ 330 | 575 | 127 | 7 |
| Sourdough Cr to | | ≥200 | 1,583 | 270 | 83 |
| Perhaps Cr (18.3 km) | | ≥ 270 | 775 | 152 | 41 |
| | | ≥ 330 | 91 | 37 | 5 |
| Poker to Any Cr (42.4 km) | Electro | ≥200 | 6,732 | 1,334 | 159 |
| | | ≥ 270 | 4,155 | 897 | 98 |
| | | ≥ 330 | 841 | 363 | 20 |
| 3.2 upstream of Elliot Br to Any Cr (29.6 km ) | | ≥200 | 2,938 | 675 | 99 |
| | | ≥ 270 | 2,132 | 526 | 72 |
| | | ≥ 330 | 407 | 172 | 14 |
| Faith to Any Cr (122.6 km) | Both | ≥200 | 21,577 | 1,992 | 176 |
| | | ≥ 270 | 11,934 | 1,881 | 97 |
| | | ≥ 330 | 1,416 | 1,076 | 12 |

# DISCUSSION

The results of this study demonstrated that the harvest levels associated with the most current regulation (i.e., 5 fish daily bag limit with no length or season restriction) will be sustainable. In 2002, very low densities of Arctic grayling ≥270 mm FL were observed in the upper reaches of the Chatanika River (i.e., between Sourdough and Perhaps Creeks, Table 5) and raised questions about the size of the population between the Elliot Bridge and Perhaps Creek because harvests that have averaged approximately 550 fish annually since 2003. In 2007, the population of Arctic grayling ≥270 mm FL (the size range of fish most likely harvested) was estimated at 11,934, which roughly translated to an acceptable 5% annual exploitation rate. Interestingly, the density of Arctic grayling ≥270 mm FL observed in the Chatanika River were comparable to those in the Upper Chena River (Table 5), which has had a catch-and-release regulation in effect since 1991. Lastly, a sizeable population of smaller recruiting fish were (i.e. 200–270 mm FL) present, likely between age 2 and 4, that will easily support future harvests (Table 4).

If future stock assessments are needed for the Chatanika River, it is recommended that the index areas used prior to this study be avoided. Using information from the historical index areas can be difficult to interpret because they may or may not be sensitive to true changes in the population. For example, during a period of relatively stable harvests, the abundance of fish increased markedly for the upper index area (Sourdough to Perhaps creeks) from a disconcerting level of 205 (SE = 36) to a relatively high abundance of 2,132 (SE=526) fish. In addition, length composition also changed from a somewhat bimodal distribution with lengths ranging up to 410 mm FL to a more unimodal distribution and far fewer fish ≥330 mm FL (Figure 3, top panel). The reasons for this change are unclear, but the increase in abundance may simply be related to the population expanding into upstream areas due to improved recruitment. In contrast, the density of Arctic grayling ≥270 mm FL in the lower 29.3-index area during 2007 did not signify an increase in population size because the estimate fell within the observed range since 1991 (Table 5).

The expanded assessment area in 2007 served to remove any ambiguity associated with smaller sized assessment/index areas and also demonstrated that the highest densities of fish resided in the previously unassessed middle portions of the river (i.e., from approximately Flat to Poker Creek) based on daily catch rates and observed capture probabilities. Ideally, future assessments should again use the 2007 "expanded" assessment area for evaluating exploitation. However, in light of likely fiscal constraints, alternative smaller index areas are recommended:

1) Cripple Creek to Poker Creek (hook-and-line sections 2–5), and from 3.2 mi upstream of Elliot Bridge to Any Creek;
2) Flat Creek to Poker Creek (hook-and-line sections 3–5), and 3.2 mi upstream of Elliot Bridge to Any Creek; and,
3) Cripple or Flat Creek to Poker Creek.

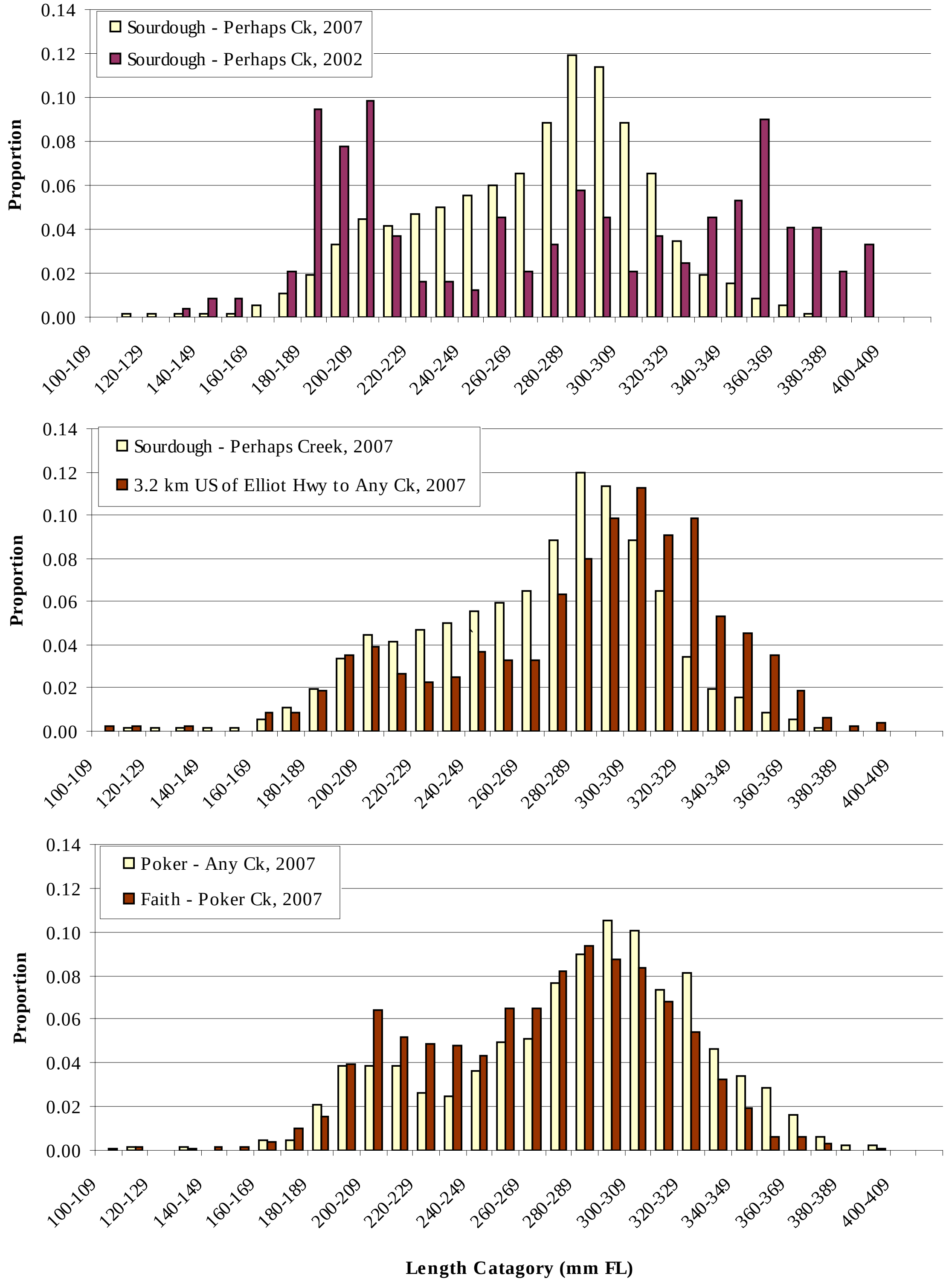


Figure 3.–Length composition of Arctic grayling sampled within defined reaches of the Chatanika River during 2002 and 2007.

Table 5.–Approximate densities of Arctic grayling ≥270 mm FL in assessed areas of the Chatanika and Chena rivers.

| Assessment area | Year | Density | |
|---|---|---|---|
| | | Fish/km | Fish/mi |
| Upper Chatanika River (Faith to Poker creeks; 80.2 km) | 2007 | 97 | 157 |
| Lower Chatanika River[a] | | | |
| (Above Elliot highway Bridge to | 1991 | 50 | 80 |
| to Any Creek; 29.6 km) | 1992 | 43 | 69 |
| | 1993 | 105 | 169 |
| | 1994 | 85 | 137 |
| | 1995 | 87 | 140 |
| | 2007 | 72 | 116 |
| Upper Chatanika River | | | |
| (Sourdough to Perhaps creeks, 18.3 km) | 2002 | 13 | 18 |
| | 2007 | 41 | 66 |
| Upper Chena River[b] | | | |
| (From 1st bridge on | 1991 | 71 | 115 |
| Chena Hot springs Road | 1992 | 57 | 91 |
| to Moose Creek Dike ;~74 km) | 1993 | 86 | 138 |
| | 1994 | 83 | 134 |
| | 1995 | 91 | 146 |
| | 1996 | 140 | 225 |
| | 1997 | 118 | 190 |
| | 1998 | 156 | 251 |
| | 2005 | 73 | 116 |

[a] Density estimates were attained by multiplying abundance estimates presented in a summary table of historic abundance estimates by Fish (1996) by the adjusted proportion of fish ≥ 270 mm FL.

[b] Density estimates from 1991–1995 were attained from a summary table of historical abundance estimates from the Upper Chena River assessment area presented by Ridder (1999) and divided by the length of the study area. Density estimates from 2005 were obtained from Wuttig and Stroka (2007).

Options 1 and 2 would be good indexes because they still account for a large majority of the population, eliminate the need to electrofish the stretch of water between Poker Creek and the Elliot Bridge, and eliminate the uppermost reach(s) where densities are low, especially between Faith and Cripple creeks. An abundance estimate for fish ≥270 mm FL for option 1 was conducted and resulted in 9,370 fish which translates to approximately 80% of the total study area's estimated population found between Faith and Any creeks. Navigation of the river stretch between Poker Creek and the Elliot Bridge with a large electrofishing boat is challenging and even impossible when flows are much below average.

Under option 3, eliminating the historical lower index area (i.e., electrofishing) should be considered because using a single electrofishing boat did not achieve the desired precision criteria and, more importantly, the utility of this index area is questionable. In this lower index area the effects of harvest are more difficult to gauge because fishing occurs only along a very small portion of this index area. Access is fairly limited and effort is concentrated almost exclusively near the Elliot Bridge and the adjacent state campgrounds. If harvests were in fact having a meaningful impact on the population it would be better reflected between Cripple and Poker creeks (~60 km) where there is more preferred habitat and where most of the anglers recreate.

For future stock assessments, a similar study design is recommended for the upper subarea because sampling approximately 2–3 miles per day with hook-and-line using a 2-person crew resulted in good capture probabilities and relatively precise estimates. Electrofishing in the lower river was not as effective as planned. If greater precision is desired for the lower index area, additional electrofishing effort is recommended to increase capture probabilities for at least one event by adding a second boat or completing a two passes with one boat for either the first or second events.

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# APPENDIX A

Appendix A1.–Estimated total sport fishing effort (angler days) for all species of fish, and estimates of sport fishing catch and harvest of Arctic grayling in the lower (downstream of the Elliot Highway Bridge) and upper (Upstream of Elliot Highway Bridge) Chatanika River, 1995–2008.

| | Effort | | | Harvest | | | Catch | | |
|---|---|---|---|---|---|---|---|---|---|
| Year[a] | Lower | Upper | Total | Lower | Upper | Total | Lower | Upper | Total |
| 1995 | 6,988 | 5,709 | 12,697 | 1,145 | 735 | 1,880 | 6,682 | 8,964 | 15,646 |
| 1996 | 4,608 | 3,619 | 8,227 | 255 | 414 | 669 | 6,455 | 7,193 | 13,648 |
| 1997 | 4,290 | 2,612 | 6,902 | 763 | 760 | 1,523 | 11,703 | 12,321 | 24,024 |
| 1998 | 2,140 | 3,433 | 5,573 | 174 | 708 | 882 | 5,578 | 8,014 | 13,592 |
| 1999 | 4,477 | 4,102 | 8,579 | 867 | 573 | 1,440 | 6,010 | 7,751 | 13,761 |
| 2000 | 2,799 | 2,836 | 5,635 | 373 | 400 | 773 | 4,567 | 4,524 | 9,091 |
| 2001 | 1,279 | 1,372 | 2,651 | 174 | 143 | 317 | 826 | 2,176 | 3,002 |
| 2002 | 1,937 | 1,907 | 3,844 | 663 | 694 | 1,167 | 5,248 | 10,065 | 15,313 |
| 2003 | 2,389 | 1,834 | 4,223 | 652 | 303 | 874 | 5,844 | 7,241 | 13,085 |
| 2004 | 2,570 | 2,917 | 5,487 | 272 | 311 | 551 | 2,958 | 5,771 | 8,729 |
| 2005 | 1,894 | 2,711 | 4,605 | 183 | 424 | 474 | 2,932 | 6,394 | 9,326 |
| 2006 | 1,427 | 2,520 | 3,947 | 130 | 514 | 452 | 2,024 | 5,861 | 7,885 |
| 2007 | 2,960 | 2,352 | 5,312 | 230 | 231 | 380 | 3,752 | 6,642 | 10,394 |
| 2008 | 1,592 | 1,966 | 3,558 | 471 | 518 | 892 | 1,986 | 9,243 | 11,229 |

[a] Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006a,b, 2007, 2009a,b, 2010 a,b; Walker et al. 2003.

# APPENDIX B

Appendix B1.–Equations for calculating estimates of abundance and its variance using the Bailey-modified Petersen estimator.

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The Bailey-modified Petersen estimator (Bailey 1951 and 1952) was used because the sampling design called for a systematic downstream progression, fishing each pool and run and attempting to subject all fish to the same probability of capture while sampling with replacement. The Bailey modification to the Petersen estimator may be used even when the assumption of a random sample for the second sample is false when a systematic sample is taken provided:

1) there is uniform mixing of marked and unmarked fish; and,
2) all fish, whether marked or unmarked, have the same probability of capture (Seber 1982).

The abundance of Arctic grayling was estimated as:

$$\hat{N} = \frac{n_1(n_2+1)}{m_2+1}, \qquad (1)$$

where:

$n_1$ = the number of Arctic grayling marked and released alive during the first event;

$n_2$ = the number of Arctic grayling examined for marks during the second event; and,

$m_2$ = the number of Arctic grayling marked in the first event that were recaptured during the second event; and,

The variance was estimated as (Seber 1982):

$$\hat{V}[\hat{N}] = \frac{n_1^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}. \qquad (2)$$

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Appendix B2.–Procedures for detecting and adjusting for size or sex selective sampling during a 2-sample mark-recapture experiment.

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Overview

Size and sex selective sampling may result in the need to stratify by size and/or sex in order to obtain unbiased estimates of abundance and composition. In addition, the nature of the selectivity determines whether the first, second or both event samples are used for estimating composition. The Kolmogorov-Smirnov two sample (K-S) test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events and contingency table analysis (Chi-square test) is generally used to detect significant evidence that sex selective sampling occurred during the first or second sampling events.

K-S tests are used to evaluate the second sampling event 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), using the null test hypothesis ($H_o$) 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. Chi-square tests are used to compare the counts of observed males to females between M&R and C&R according to the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. When the proportions by gender are estimated for a subsample (usually from C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared between samples using a two sample test (e.g. Student *t*-test).

Mark-recapture experiments are designed to obtain sample sizes sufficient to 1) achieve precision objectives for abundance and composition estimates and 2) ensure that the diagnostic tests (i.e., tests for selectivity) have power adequate for identifying selectivity that could result in significantly biased estimates. Despite careful design, experiments may result in inadequate sample sizes leading to unreliable diagnostic test results due to low power. As a result, detection and adjusting for size and sex selectivity involves evaluating the power of the diagnostic tests.

The protocols that follow are used to classify the experiment into one of four cases. For each case the following are specified: 1) whether stratification is necessary, 2) which sample event's data should be used when estimating composition, and 3) the estimators to be used for composition estimates when stratifying. The first protocols assume adequate power. These are followed by supplemental protocols to be used when power is suspect and guidelines for evaluating power.

Protocols given Adequate Power

*Case I:*

| **M vs. R** | **C vs. R** |
|---|---|
| Fail to reject $H_o$ | Fail to reject $H_o$ |

There is no size/sex selectivity detected during either sampling event. 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 but do not include recaptured fish twice.

-continued-

*Case II:*

| **M vs. R** | **C vs. R** |
|---|---|
| Reject $H_o$ | Fail to reject $H_o$ |

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

| **M vs. R** | **C vs. R** |
|---|---|
| Fail to reject $H_o$ | Reject $H_o$ |

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

| **M vs. R** | **C vs. R** |
|---|---|
| Reject $H_o$ | Reject $H_o$ |

There is size/sex selectivity detected during both the first and second sampling events. The ratio of the probability of captures for size of sex categories can either be the same or different between events. 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.

-continued-

Protocols when Power Suspect (re-classifying the experiment)

When sample sizes are small (guidelines provided in next section) power needs to be evaluated when diagnostic tests fail to reject the null hypothesis. If this failure to identify selectivity is due to low power (that is, if selectivity is actually present) data will be pooled when stratifying is necessary for unbiased estimates. For example, if the both the M vs. R and C vs. R tests failed to identify selectivity due to low power, Case I may be selected when Case IV is true. In this scenario, the need to stratify could have been overlooked leading to biased estimates. The following protocols should be followed when sample sizes are small.

*Case I:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Fail to reject Ho | Fail to reject Ho | re-evaluate both tests |
| Power OK/retain test result | Power OK/retain test result | Case I |
| Power suspect/change to Reject Ho | Power OK/retain test result | Case II |
| Power OK/retain test result | Power suspect/change to Reject Ho | Case III |
| Power suspect/change to Reject Ho | Power suspect/change to Reject Ho | Case IV |

*Case II:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Reject Ho | Fail to reject Ho | re-evaluate C vs. R |
| | Power OK/retain test result | Case II |
| | Power suspect/change to Reject Ho | Case IV |

*Case III:*

| **M vs. R** | **C vs. R** | **Implication** |
|---|---|---|
| Fail to reject Ho | Reject Ho | re-evaluate M vs. R |
| Power OK/retain test result | | Case III |
| Power suspect/change to Reject Ho | | Case IV |

-continued-

Guidelines for evaluating power:

The following guidelines to assess power are based upon the experiences of Sport Fish biometricians; they have not been comprehensively evaluated by simulation. Because some "art" in interpretation remains these guidelines are not intended to be used in lieu of discussions with biometricians when possible. When the evaluation does not lead to a clear choice, a stratified estimator should be selected (i.e., the experiment should be classified as Case IV) in order to minimize potential bias.

The reliability of M vs. R and C vs. R tests that fail to reject $H_o$ are called into question when 1) sample sizes M or C are < 100 and the sample size for R is < 30, 2) p-values are not large (~0.20 or less), and the D statistics are large (≥0.2). If sample sizes are small, the p-value is not large, and the D statistic is large then the power of the test is suspect and, when re-classifying the experiment, the test should be considered as having rejected the null hypothesis. If for example, sample sizes are marginal (close to the recommended values), the p-value is large, and the D-statistic is not large then the test result may be considered reliable. It is when results are close to the recommended "cutoffs" that interpretation becomes somewhat more complicated.

Apparent inconsistencies between the combination of the M vs. R and C vs. R test results and the M vs. C test results may also arise from low power. For example, if one of the tests involving R rejects the null hypothesis and the other fails to reject one could infer a difference between M & C; however, the M vs. C test may still fail to reject the null indicating no difference between the M & C. In this case, the apparent inconsistency may be due to low power in the test involving R that failed to reject the null. Finally, an additional Case I scenario is flagged by an apparent inconsistency between test results, this time resulting from power being too high. Under this scenario both the M vs. R and C vs. R tests fail to reject the null hypothesis and their power is thought to be sufficient; however, the M vs. C test rejects $H_o$: no difference between the M & C. The apparent inconsistency may result from the M vs. C test being so powerful as to detect selectivity that would result in insignificant bias when estimating abundance and composition. The reliability of M vs. C tests that reject are called into question when 1) sample sizes M or C are >500, 2) p-values are not extremely small (~0.010-0.049), and the D statistics are small (<0.08). In general all three K-S tests should be performed to permit these evaluations.

Appendix B3.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

The following two assumptions must be fulfilled:

1. catching and handling the fish does not affect the probability of recapture; and,
2. marked fish do not lose their mark.

Of the following assumptions, only one must be fulfilled:

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

**TEST I** [a]

| First Event Sampling Area Released | Second Event | | | | |
|---|---|---|---|---|---|
| | Sampling Area Recaptured | | | | Not Recaptured |
| | **A** | **B** | **…** | **S** | (total) |
| **A** | | | | | |
| **B** | | | | | |
| **…** | | | | | |
| **S** | | | | | |

**TEST II** [b]

| | Second Event: Sampling Area | | | |
|---|---|---|---|---|
| | **A** | **B** | **…** | **S** |
| Recaptured | | | | |
| Not Recaptured | | | | |

**TEST III** [c]

| | Captured During Second Event | | | |
|---|---|---|---|---|
| | **A** | **B** | **…** | **S** |
| Marked | | | | |
| Unmarked | | | | |

[a] This tests the hypothesis that movement probabilities are the same among sections: $H_1$: $\theta_{ij} = \theta_j$. Theta applies to both marked and unmarked fish.

[b] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities between the three river areas: $H_2$: $\Sigma_j \theta_{ij} p_j = d$. Theta applies to both marked and unmarked fish.

[c] This tests the homogeneity on the columns of the 2-by-t contingency table with respect to the probability of movement of marked fish in stratum *i* to the unmarked fraction in *j*: $H_4$: $\Sigma_i a_i \theta_{ij} = kU_j$. Theta only applies to marked fish.

Appendix B4.–Equations for estimating length and age composition and their variances for the population.

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For Case I-IV scenarios (Appendix A2), the proportions of Arctic grayling within each age or length class *k* were estimated:

$$\hat{p}_k = \frac{n_k}{n} \tag{1}$$

where:

$n_k$ = the number of Arctic grayling sampled within age or length class *k* and,

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

When calculating *n* and $n_k$ the diagnostic test results were used to determine the fish were included (Appendix A2). For Case I, used fish from both events.

The variance of each proportion was estimated as (from Cochran 1977):

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}. \tag{2}$$

The abundance of Arctic grayling in each length or age category, *k*, in the population was then estimated:

$$\hat{N}_k = \sum_{k=1}^{s} \hat{p}_k \hat{N}, \tag{3}$$

where:

$\hat{N}$ = the estimated overall abundance (Appendix A1); and,

*s* = the number of age or length classes.

The variance for $\hat{N}_k$ was then estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}[\hat{N}_k] \approx \sum_{k=1}^{s} \left( \hat{V}[\hat{p}_k]\hat{N}^2 + \hat{V}[\hat{N}]\hat{p}_k^2 - \hat{V}[\hat{p}_k]\hat{V}[\hat{N}] \right). \tag{4}$$

For the Case IV scenario (Appendix A2), that requiring stratification by size or sex, the proportions of Arctic grayling within each age or length class *k* were estimated by first calculating:

-continued-

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j} \tag{5}$$

where:

$n_j$ = the number sampled from size stratum *j* in the mark-recapture experiment;

$n_{jk}$ = the number sampled from size stratum *j* that are in length or age category *k*; and,

$\hat{p}_{jk}$ = the estimated proportion of length or age category *k* fish in size stratum *j*.

When calculating $n_j$ and $n_{jk}$ the within stratum diagnostic test results were used to determine which fish were included in the analysis following the rules for *n* and $n_k$ provided above.

The variance calculation for $\hat{p}_{jk}$ is equation 2 substituting $\hat{p}_{jk}$ for $\hat{p}_k$ and $n_j$ for *n*.

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

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk} \hat{N}_j \tag{6}$$

where:

$\hat{N}_j$ = the estimated abundance in size stratum *j*; and,

*s* = the number of size strata.

The variance for $\hat{N}_k$ will be estimated using the formulation for the exact variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s} \left( \hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + \hat{V}\left[\hat{N}_j\right]\hat{p}_{jk}^2 - \hat{V}\left[\hat{p}_{jk}\right]\hat{V}\left[\hat{N}_j\right] \right). \tag{7}$$

-continued-

The estimated proportion of the population in length or age category $k$ $(\hat{p}_k)$ is then:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N} \tag{8}$$

where: $\hat{N} = \sum_{j=1}^{s} \hat{N}_j$ .

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

$$\hat{V}[\hat{p}_k] \approx \sum_{j=1}^{s} \left\{ \left( \frac{\hat{N}_j}{\hat{N}} \right)^2 \hat{V}[\hat{p}_{jk}] \right\} + \frac{\sum_{j=1}^{s} \left\{ \hat{V}[\hat{N}_j] (\hat{p}_{jk} - \hat{p}_k)^2 \right\}}{\hat{N}^2} . \tag{9}$$

# APPENDIX C
# ADDITIONAL TABLES

Appendix C1.–Number of Arctic grayling ≥150 mm FL marked ($n_1$), examined ($n_2$), and recaptured ($m_2$) by subsections (~3.2 km in length) and sections (groupings of five subsections) in the upper subarea (hook and line sampling) of the Chatanika River study area, 2007.

| Subsection where marked | subsection where recaptured | | | | | | | | | | | | | | | | | | | | | | | | | $n_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| 3 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| 4 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 |
| 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 |
| 6 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 62 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 84 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 73 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 29 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 86 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 1 | 0 | 0 | 1 | 102 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 92 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 88 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 63 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 47 |
| $n_2$ | 23 | 43 | 49 | 31 | 46 | 40 | 51 | 38 | 42 | 43 | 61 | 52 | 30 | 55 | 63 | 43 | 44 | 47 | 26 | 62 | 107 | 68 | 119 | 71 | 33 | |

Appendix C2.–Number of Arctic grayling 150–269 mm FL marked ($n_1$), examined ($n_2$), and recaptured ($m_2$) by section in the upper (hook-and-line) subarea of the Chatanika River study area, 2007.

| | | Sub-section(s) where examined | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | $m_2$ | $n_1$ | $(m_2/n_1)$ |
| Sub-section where marked | 1 | 3 | 0 | 0 | 0 | 0 | 3 | 55 | 0.08 |
| | 2 | 0 | 6 | 0 | 0 | 0 | 6 | 132 | 0.06 |
| | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 138 | 0.01 |
| | 4 | 0 | 0 | 0 | 5 | 1 | 6 | 157 | 0.04 |
| | 5 | 0 | 0 | 0 | 2 | 16 | 18 | 224 | 0.09 |
| | $m_2$ | 3 | 6 | 1 | 7 | 17 | | | |
| | $n_2$ | 77 | 86 | 86 | 104 | 213 | | | |
| | $(m_2/n_2)$ | 0.05 | 0.09 | 0.01 | 0.08 | 0.09 | | | |

Appendix C3.–Number of Arctic grayling ≥270 mm FL marked ($n_1$), examined ($n_2$), and recaptured ($m_2$) by section in the upper (hook-and-line) subarea of the Chatanika River study area, 2007.

| | | Sub-section(s) where examined | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | $m_2$ | $n_1$ | $(m_2/n_1)$ |
| Sub-section where marked | 1 | 16 | 0 | 0 | 0 | 0 | 16 | 82 | 0.20 |
| | 2 | 0 | 17 | 0 | 0 | 0 | 17 | 124 | 0.14 |
| | 3 | 0 | 0 | 15 | 0 | 0 | 15 | 223 | 0.07 |
| | 4 | 0 | 1 | 0 | 11 | 0 | 12 | 178 | 0.07 |
| | 5 | 0 | 0 | 0 | 1 | 15 | 16 | 168 | 0.10 |
| | $m_2$ | 16 | 18 | 15 | 12 | 15 | | | |
| | $n_2$ | 115 | 128 | 175 | 118 | 185 | | | |
| | $(m_2/n_2)$ | 0.14 | 0.14 | 0.09 | 0.10 | 0.08 | | | |

Appendix C4.–Number of Arctic grayling ≥200 mm FL marked ($n_1$), examined ($n_2$), and recaptured ($m_2$) by section in the lower (electrofishing) subarea of the Chatanika River study area, 2007**.**

| | | Section(s) where examined | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | $m_2$ | $n_1$ | $(m_2/n_1)$ |
| Section where marked | 1 | **6** | 0 | 0 | 6 | 155 | 0.04 |
| | 2 | 0 | **5** | 0 | 5 | 108 | 0.05 |
| | 3 | 0 | 0 | **11** | 11 | 129 | 0.09 |
| | $m_2$ | 6 | 5 | 11 | | | |
| | $n_2$ | 181 | 81 | 132 | | | |
| | $(m_2/n_2)$ | 0.03 | 0.06 | 0.08 | | | |

Appendix C5.–Number of Arctic grayling ≥270 mm FL marked ($n_1$), examined ($n_2$), and recaptured ($m_2$) by section in the lower (electrofishing) subarea of the Chatanika River study area, 2007**.**

| | | Section(s) where examined | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | $m_2$ | $n_1$ | $(m_2/n_1)$ |
| Section where marked | 1 | 5 | 0 | 0 | 5 | 102 | 0.05 |
| | 2 | 0 | 3 | 0 | 3 | 81 | 0.04 |
| | 3 | 0 | 0 | 10 | 10 | 101 | 0.10 |
| | $m_2$ | 5 | 3 | 10 | 18 | | |
| | $n_2$ | 114 | 57 | 106 | | | |
| | $(m_2/n_2)$ | 0.04 | 0.05 | 0.09 | | | |

Appendix C6.–Estimated length composition of Arctic grayling for defined length (mm FL) and geographic strata in the Chatanika River, 2007.

| Length category | Faith to Poker Ck. | | | | Poker to Any Ck. | | Sourdough to Perhaps Ck. | | 3.2 km upstream of Elliot Hwy to Any Cr. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ≥150 | | ≥200 | | ≥200 | | ≥150 | | ≥200 | |
| | P | SE | P | SE | P | SE | P | SE | P | SE |
| 150–159 | 0.002 | 0.001 | | | | | 0.001 | 0.001 | | |
| 160–169 | 0.005 | 0.002 | | | | | 0.006 | 0.003 | | |
| 170–179 | 0.012 | 0.003 | | | | | 0.011 | 0.004 | | |
| 180–189 | 0.019 | 0.004 | | | | | 0.020 | 0.005 | | |
| 190–199 | 0.049 | 0.009 | | | | | 0.033 | 0.007 | 0.042 | 0.009 |
| 200–209 | 0.079 | 0.013 | 0.082 | 0.013 | 0.042 | 0.007 | 0.045 | 0.008 | 0.029 | 0.008 |
| 210–219 | 0.064 | 0.011 | 0.067 | 0.011 | 0.042 | 0.007 | 0.042 | 0.007 | 0.024 | 0.007 |
| 220–229 | 0.060 | 0.010 | 0.063 | 0.010 | 0.028 | 0.006 | 0.047 | 0.008 | 0.027 | 0.008 |
| 230–239 | 0.059 | 0.010 | 0.062 | 0.010 | 0.027 | 0.006 | 0.050 | 0.008 | 0.040 | 0.009 |
| 240–249 | 0.053 | 0.009 | 0.055 | 0.009 | 0.039 | 0.007 | 0.056 | 0.009 | 0.036 | 0.009 |
| 250–259 | 0.080 | 0.013 | 0.083 | 0.013 | 0.053 | 0.008 | 0.060 | 0.009 | 0.036 | 0.009 |
| 260–269 | 0.080 | 0.013 | 0.083 | 0.013 | 0.055 | 0.008 | 0.066 | 0.009 | 0.069 | 0.012 |
| 270–279 | 0.094 | 0.019 | 0.147 | 0.019 | 0.083 | 0.01 | 0.089 | 0.011 | 0.087 | 0.013 |
| 280–289 | 0.107 | 0.021 | 0.107 | 0.021 | 0.097 | 0.011 | 0.120 | 0.012 | 0.107 | 0.015 |
| 290–299 | 0.100 | 0.020 | 0.100 | 0.020 | 0.113 | 0.011 | 0.114 | 0.012 | 0.122 | 0.015 |
| 300–309 | 0.042 | 0.036 | 0.042 | 0.005 | 0.108 | 0.011 | 0.089 | 0.011 | 0.098 | 0.014 |
| 310–319 | 0.034 | 0.029 | 0.034 | 0.005 | 0.079 | 0.01 | 0.066 | 0.009 | 0.107 | 0.015 |
| 320–329 | 0.027 | 0.023 | 0.027 | 0.004 | 0.088 | 0.01 | 0.035 | 0.007 | 0.058 | 0.011 |

-continued-

Appendix C6.–Page 2 of 2.

| Length category | Faith to Poker Ck. | | | | Poker to Any Ck. | | Sourdough to Perhaps Ck. | | 3.2 km upstream of Elliot Hwy to Any Cr. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ≥150 | | ≥200 | | ≥200 | | ≥150 | | ≥200 | |
| | P | SE | P | SE | P | SE | P | SE | P | SE |
| 330–339 | 0.016 | 0.014 | 0.016 | 0.002 | 0.05 | 0.008 | 0.020 | 0.005 | 0.049 | 0.010 |
| 340–349 | 0.009 | 0.008 | 0.009 | 0.002 | 0.037 | 0.007 | 0.015 | 0.005 | 0.038 | 0.009 |
| 350–359 | 0.003 | 0.003 | 0.003 | 0.001 | 0.031 | 0.006 | 0.008 | 0.003 | 0.020 | 0.007 |
| 360–369 | 0.003 | 0.003 | 0.003 | 0.001 | 0.018 | 0.005 | 0.006 | 0.003 | 0.007 | 0.004 |
| 370–379 | 0.002 | 0.001 | 0.002 | 0.001 | 0.006 | 0.003 | 0.001 | 0.001 | 0.002 | 0.002 |
| 380–389 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.002 | 0.000 | 0.000 | 0.004 | 0.003 |
| 390–399 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| 400–409 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

# APPENDIX D
# DATA FILE LISTING

Appendix D1.–Data files for all Arctic grayling captured in the Chatanika River, 2007.

| File Name |
| --- |
| Chatanika River Data Files for archive - Electrofishing M-R_2007.xls |
| Chatanika River Data Files for archive – Hook and Line M-R_2007.xls |
| Chatanika River Data Files for archive – Length Composition_2007.xls |

*Note*: Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, 1300 College Road, Fairbanks, Alaska 99701-1599.