Fishery Data Series No. 04-22

# Stock Assessment of Arctic Grayling in the Headwaters of the Chatanika and Chena Rivers During 2002

by
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October 2004

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

# Symbols and Abbreviations

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**Weights and measures (metric)**

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

**Weights and measures (English)**

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

**Time and temperature**

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

**Physics and chemistry**

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

**General**

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

**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. 04-22*

# STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE HEADWATERS OF THE CHATANIKA AND CHENA RIVERS DURING 2002

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# ABSTRACT

Two-event mark-recapture experiments were used in 2002 to estimate abundance and length and age composition of Arctic grayling *Thymallus arcticus* for the first time within the headwaters of the Chatanika and Chena rivers. Index sections in each river were selected to be of similar length (approximately 20 km) and discharge to facilitate comparisons, and the assessments were fielded concurrently to help control against seasonal variability. The first event occurred from July 15 to 19 and the second event from July 30 to August 2. The Chatanika River sampling area included the section of river between mile 56 and 66 of the Steese Highway and the Chena River sampling area was located in the North Fork between mile 44 and 52 Chena Hot Springs Road, just upstream from the Middle Fork Chena River. All Arctic grayling were captured with hook-and-line gear. In the Chena River study area, abundance of Arctic grayling ≥ 250 mm FL was estimated at 1,356 (SE = 285). Only 10 of the 327 fish sampled (0.03) were <250 mm FL and only 31 (0.12) were younger than age-5. In the Chatanika River study area, estimated abundance of Arctic grayling ≥ 160 mm FL was 853 (95% CI=414-2,017) and estimated abundance of Arctic grayling ≥ 250 mm FL was 234 (SE=41). Most of the 242 fish sampled 93(0.73) were smaller than 250 mm FL, and 0.39 were younger than age-5. The results demonstrated that there were meaningful differences in the density and length compositions of sub–adult (< 270 mm FL) and adult-sized (≥270 mm FL) grayling in the headwater areas of the Chena and Chatanika rivers, and these differences may be largely explained by the affects of exploitation and habitat quality. The results also demonstrated the density of adult-sized Arctic grayling in portions of the Chatanika headwaters are low (13 fish/km) compared to the Chena River (68 fish/km) and that more comprehensive stock assessment information is needed to adequately evaluate the status of the stock and to formulate a future management plan.

Key words: Arctic grayling, *Thymallus arcticus,* population abundance, age composition, length composition Chena River, Chatanika River, stock density, angling, hook-and-line.

# INTRODUCTION

Each year anglers travel the Steese Highway and the Chena Hot Springs Road to access headwater areas of the Chatanika and Chena rivers to fish for Arctic grayling (Figure 1). The headwater fisheries in these clear, runoff rivers are approximately equi-distant from Fairbanks and offer several road, or near-road access points for anglers. Anglers can access 41 river miles of the Chatanika River at several points between Steese Highway milepost (MP) 31 and 69. In the Chena River drainage, anglers can access approximately 39 river miles of the headwaters between Chena Hot Springs Road MP 27 and 55. These access points, trails (developed and undeveloped), and several developed recreational areas and campgrounds, allow anglers a unique opportunity to fish headwater areas of interior Alaska rivers close to Fairbanks. In these upstream locations, both rivers are small enough to provide fishing while wading or floating. Fishing is directed toward Arctic grayling because salmon fishing is not permitted. In addition to relatively easy access, anglers may be attracted to these areas for the chance to catch large adult Arctic grayling that are commonly observed in headwater areas (Hughes 1999). Although these areas are similar in terms of distance from Fairbanks and provide good access, they differ in estimated levels of angling use (Figure 2) and catches of large Arctic grayling (Figure 3).

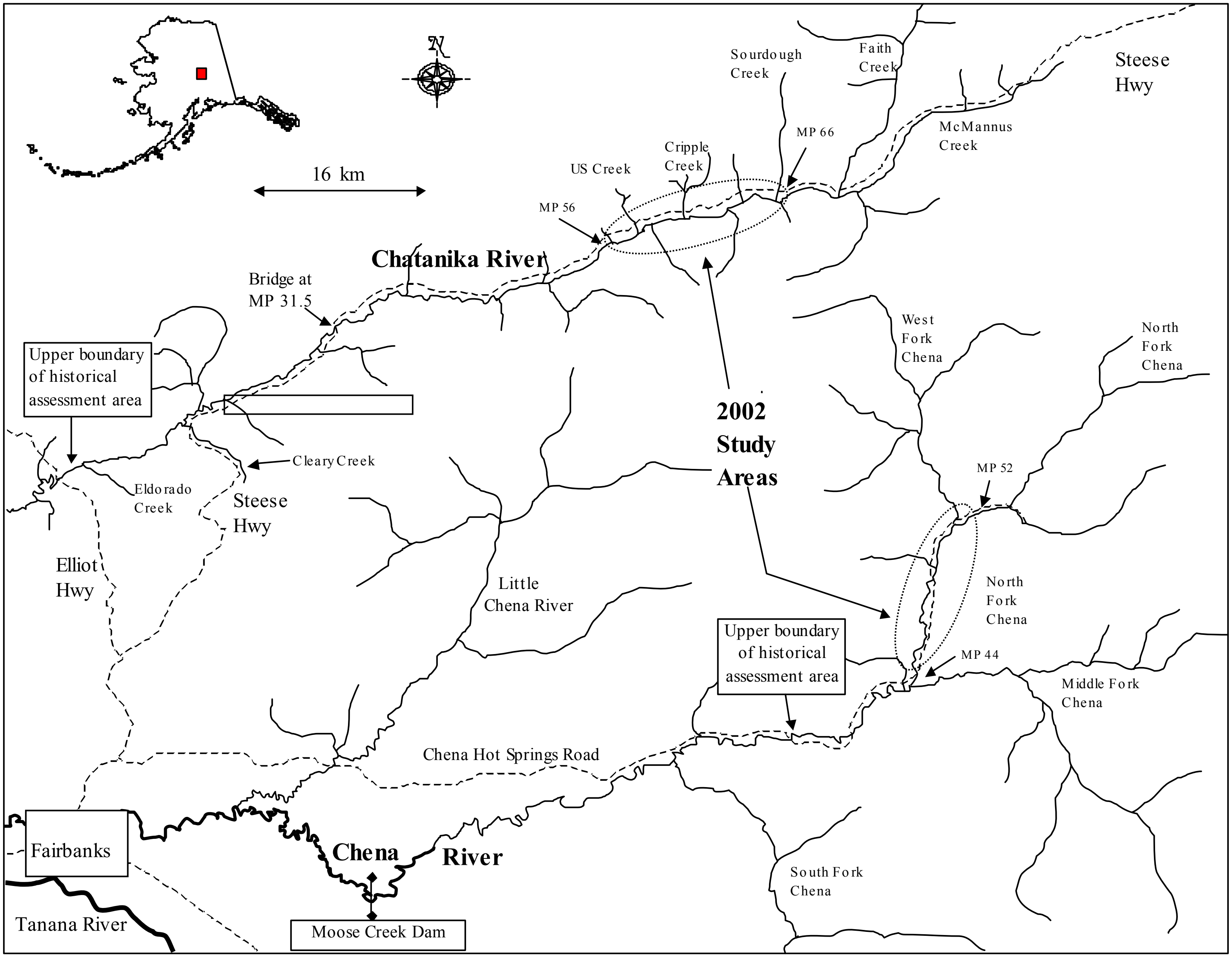



**Figure 1.**–Chena and Chatanika rivers study areas, 2002.

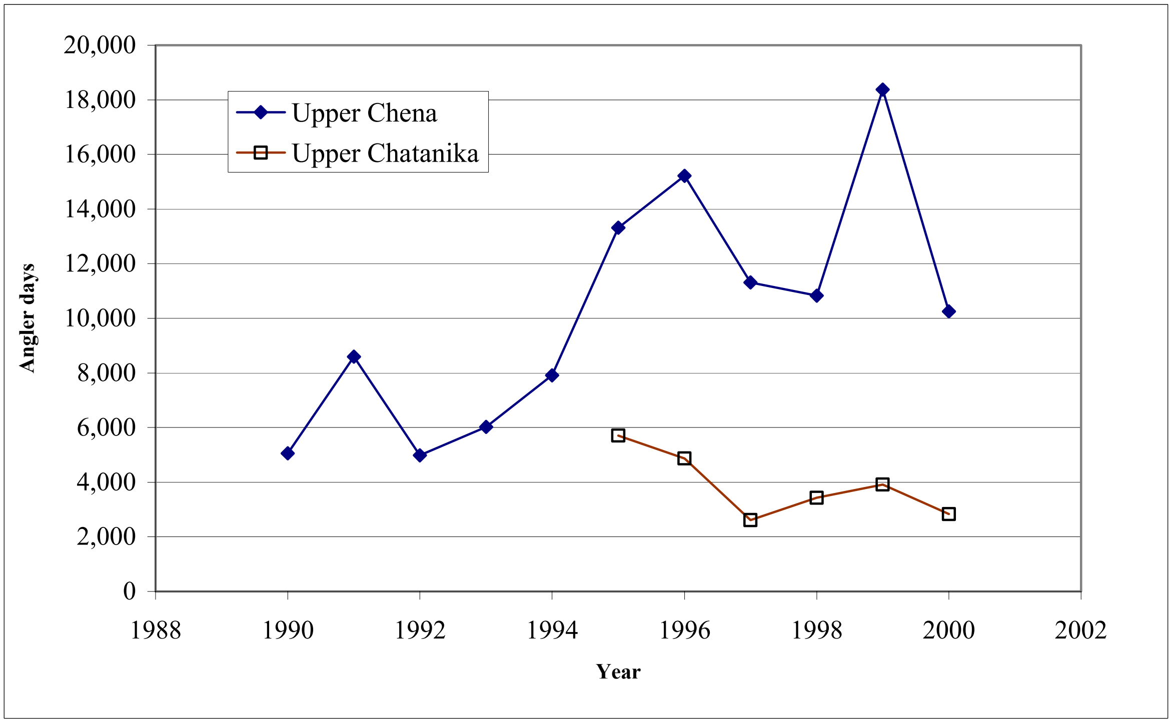



**Figure 2.**–Estimated angler days of fishing effort on the upper Chatanika River (upstream of Elliot Highway Bridge) and the upper Chena River (upstream of Rosehip Campground; Doxey *In prep*).

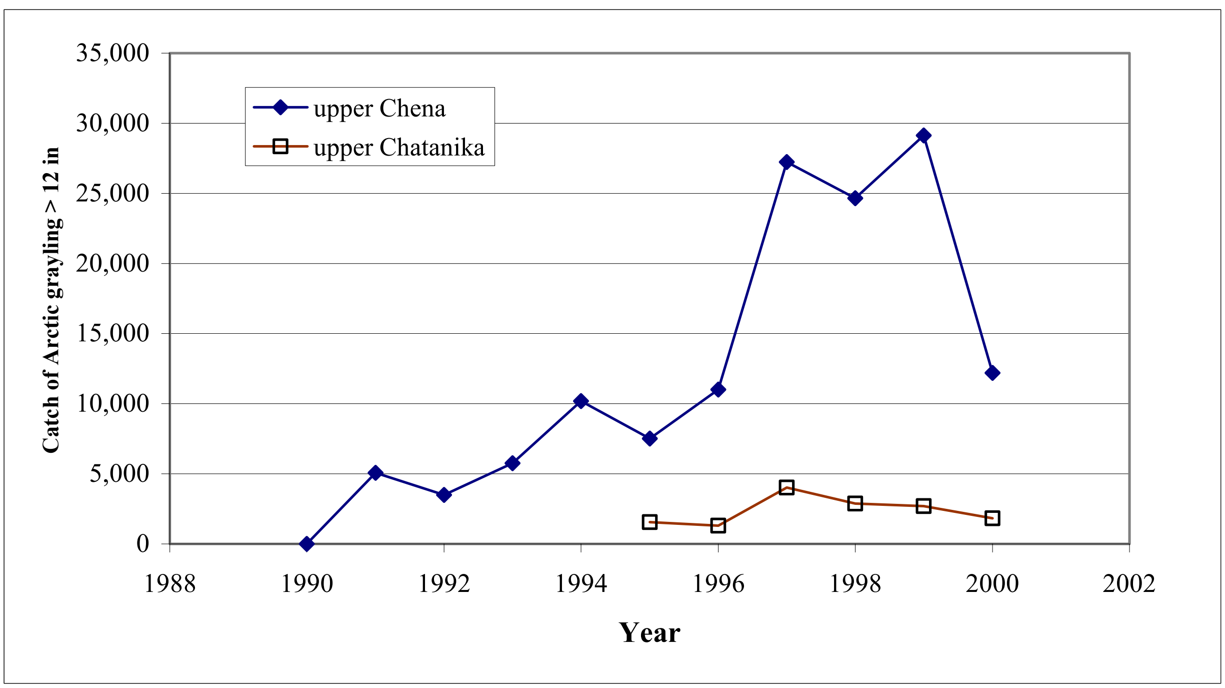



**Figure 3.**–Annual catches of 12-in Arctic grayling on the upper Chatanika River (upstream of Elliot Highway Bridge) and the upper Chena River (upstream of Rosehip Campground; Doxey *In prep*).

The different levels of fishing effort between these two Arctic grayling sport fisheries is likely related to the quality of recreational opportunities and to the grayling population characteristics (e.g., abundance and density). Upstream of MP 27 lies the Chena River Recreational Area where there are: 1) several state maintained campgrounds, recreational cabins, day use areas, and hiking and multiple-use trails; 2) numerous undeveloped road turnouts, trails, and accessible gravel bars for camping on public lands; 3) many private cabins situated along or near the river; and, 4) Chena Hot Springs Resort lies at the end of the road. Moreover, the upper Chena River is a popular destination for day-floaters. Conversely, on the Chatanika River, upstream of the Elliot Highway Bridge, recreational opportunities are fewer with only two developed public camping areas and river access across public lands is restricted to a few undeveloped access roads and trails down to the river. Access to the Chatanika River from the road otherwise requires "bushwhacking" a short distance from the road. Although the Chatanika River is not as developed as the Chena River, the upper Chatanika River is a popular place to fish, float, and camp near Fairbanks. The Alaska Department of Transportation has begun upgrading the Steese Highway to a paved road and it is assumed that this will attract greater numbers of anglers and the resulting harvest potential under current regulations may be excessive.

Harvest of Arctic grayling has always been permitted in the Chatanika River drainage, but in the Chena River drainage angling has been restricted since 1 July 1991 to catch-and-release fishing using only unbaited, single-hook artificial lures. The regulations for Arctic grayling in the Chatanika River since 1992 have been:

1. no harvest of Arctic grayling between April 1 and the first Saturday in June (spawning period);
2. use of only single-hook artificial lures during the spring closure;
3. a 12 inch minimum size limit; and,
4. a daily bag limit of five fish.

Prior to this study, no comprehensive stock-assessment projects in the upper Chatanika River area had been successfully conducted. It has been long suspected that the densities of Arctic grayling in the Upper Chatanika River were low relative to other Interior rivers. In 1974, the average catch rate on the upper Chatanika was 1.02 Arctic grayling per hour (Kramer 1975), and 13 years later it averaged 0.02 per angler hour (Baker 1988). These catch rates are considered low relative to other Interior systems such as neighboring Beaver Creek where CPUE was approximately 10 fish per angler hour during 2002 (Fleming and McSweeny 2001). In response to this most recent information, a stock assessment in the upper Chatanika River was attempted in 1991, but because of low catch rates abundance could not be estimated (Fleming et al. 1992). However, because the length composition in the upper Chatanika River was similar to that in the lower Chatanika River during the 1991 study, stock assessments conducted in the Elliot Highway area (Figure 1) have since been used as an index to monitor populations trends for all exploited areas of the Chatanika River. In 1997, another CPUE study was conducted in response to angling reports of few harvestable fish in the upper 41 mi of the Chatanika River and low catch rates (0.95 fish/hr) were again observed in the upper portions of the study area (Fleming 1998).

Placer gold mining activities that occurred on the Chatanika River prior to 1986 have often been implicated as the cause of low Arctic grayling densities. Some placer mining activities have been shown to have adverse affects on water quality and aquatic invertebrates (Wagener and

LaPerriere 1985) and interfere with Arctic grayling feeding behavior (Scannell 1988). During the 1950s, fishing for Arctic grayling occurred only upstream of Cleary Creek because of turbidity generated from gold placer-mining activity there and downstream (Wojcik 1953). In the upper Chatanika River placer mines have operated periodically since approximately the 1930s in Faith, Smith, Sourdough, No-Name, Flat, and Cleary creeks (Townsend 1987; Wojcik 1953) and the Arctic grayling fishery in the upper Chatanika River was intermittently affected by turbidity from these mines (Wojcik 1953). Placer mining continued in the upper Chatanika River through the early 1980s and recreational use declined following several summers of poor water quality (Townsend 1987). The water quality in the Chatanika River improved in 1986 following the cooperative efforts of the industry and resource agencies (A. Townsend, Habitat Biologist, retired, ADF&G, Fairbanks, personal communication).

The Arctic grayling stock in the Chena River is considered to have fully recovered from heavy exploitation that occurred during the 1980s, and recently anglers have indicated that the Chena River Arctic grayling fishery has been excellent in terms of catch rates and the average length of fish caught (M. Doxey, Sport Fish Biologist, ADF&G, Fairbanks, personal communication). Similar to the Chatanika River, management in the headwaters of the Chena River was based on findings from stock assessments carried out in downstream areas in proxy for the upstream areas (Tack 1973; Holmes 1983, 1985; Holmes et al. 1986; Ridder et al. 1993). Unlike the upper Chatanika River the upper Chena River was relatively unaffected by placer mining activities.

The primary goal of this study was to assess, for the first time, the abundance and composition of the Arctic grayling stocks in the headwater of both the Chatanika and Chena rivers. In addition, the Chena River stock has been relatively unexploited in recent years, and can be viewed as a standard against which to compare information collected from the upper reaches of the Chatanika River, which lies in an adjacent watershed. These assessments were fielded concurrently to help control against seasonal variations in abundance.

# OBJECTIVES

The research objectives for 2002 were to estimate:

1. the abundance of Arctic grayling (≥150 mm FL) in a 10-mile (12 km) section located in the upper Chatanika River, such that this estimate is within 25% of the true abundance 95% of the time;
2. the age composition of the Arctic grayling (≥150 mm FL) in a 10-mile section located in the upper Chatanika River, such that all proportions are within 10 percentage points of the true proportions 95% of the time;
3. the length composition of the Arctic grayling (≥150 mm FL) in a 10-mile section located in the upper Chatanika River, such that all proportions are within 10 percentage points of the true proportions 95% of the time;
4. the abundance of Arctic grayling (≥150 mm FL) in a 10-mile section located in the upper Chena River, such that this estimate is within 25% of the true abundance 95% of the time;
5. the age composition of the Arctic grayling (≥150 mm FL) in a 10-mile section located in the upper Chena River, such that all proportions are within 10 percentage points of the true proportions 95% of the time; and,

6. the length composition of the Arctic grayling (≥150 mm FL) in a 10-mile section located in the upper Chena River, such that all proportions are within 10 percentage points of the true proportions 95% of the time.

# METHODS

Mark-recapture techniques were used to estimate the abundance and length and age composition of Arctic grayling in study areas on the Chena and Chatanika rivers. The study areas were similar in that they were approximately 20 km in length, were road accessible, and their upstream drainage areas were of similar size.

## STUDY SITES

Both the Chatanika and Chena rivers are run-off rivers and have tributaries in the Tanana Uplands that are within 20 mi of each other. The Chatanika River originates at the confluence of Faith, McMannus, and Smith creeks which flow southwest out of the White Mountains. Including McMannus Creek, the Chatanika River flows approximately 167 mi before its confluence with the Tolovana River in Minto Flats. The Chatanika River drainage pattern is generally linear unlike most runoff rivers in the Interior, which tend to be more dendritic (Figure 1). A number of small runoff tributary streams enter the Chatanika River before its confluence with Goldstream and Tatalina creeks in the Minto Flats complex. The Chena River collectively includes headwaters in the North, South, West, and Middle forks, and the mainstem travels more than 100 mi before entering the middle reaches of the Tanana River near Fairbanks. These headwaters originate in the Tanana Uplands and road access is limited to the lower portions of these forks.

The Chatanika River sampling area was 18.3 km in length and was located between the confluence of Sourdough Creek and the mouth of Perhaps Creek, just upstream of a gravel pit at Steese Highway MP 56 (Figure 4). The Chena River sampling area was 20 km in length and was located along the North Fork of the Chena River between confluences of the West Fork and Middle Fork (Figure 5). The size of the sampling sections in each river were considered small enough to allow mark-recapture sampling in both rivers at nearly identical times, and yet were large enough to provide meaningful indices of abundance and density for the upper portion of the drainages (M. Doxey, Sport Fish Biologist, ADF&G, Fairbanks, personal communication).

## SAMPLING DESIGN

Two-event mark-recapture experiments were used to estimate the abundance of Arctic grayling present in the study areas during late July. During the first event, fish were sampled on July 15 - 16 in the Chena River and on July 17 - 18 in the Chatanika River. During second event, sampling occurred during July 30 - 31 on the Chena River and during August 1 - 2 on the Chatanika River. Two three-person crews captured fish while wading using hook-and-line gear during both events. Each crew used a canoe to carry sampling and personal gear, to cross deep channels, and to transit to checkpoints. The choice of terminal gear (nymphs, dry flies, rubber-bodied jigs, or spinners) was left to the angler's discretion as to what was most effective. Within a crew, at least one member typically fished a fly and one fished a jig.

Hook-and-line gear was used on the Chatanika and Chena rivers because their higher gradients and moderately high discharges precluded the use of electrofishing boats and backpack electrofishing gear. In 1991, a four-person crew tried unsuccessfully to use backpack electrofishing gear to capture Arctic grayling in the upper Chatanika River (Fleming et al. 1992).

For each event, the study area on each river was divided into four ~3-mi sections each of which were sampled by one crew in one day (Figures 4 and 5). On the first day, one crew sampled section I while the other crew sampled section III; and, during the second day, sections II and IV were similarly sampled.

In the first event, fish ≥ 150 mm FL were marked with an individually-numbered anchor tag (Floy FD 94) and given a small clip of the upper caudal fin to identify lost tags. In the second event, fish were not tagged but a partial lower caudal fin clip was given to all captures to identify fish sampled multiple times. Sample size objectives for the abundance estimate were established using methods in Robson and Regier (1964) and for compositions using criteria developed by Thompson (1987) for multinomial proportions.

Abundance was estimated using a two-event Petersen mark-recapture experiment (Seber 1982) designed to satisfy the following assumptions:

1. the population was closed (there was no change in the number or composition of Arctic grayling in the population 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 the first and second events;
3. marking of Arctic grayling in the first event did not affect their probability of capture in the second event;
4. marked Arctic grayling were identifiable during the second event; and,
5. all marked Arctic grayling examined in the second-event sample were reported.

The estimator used was a modification of the general form of the Petersen estimator (Seber 1982):

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

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;

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

$\hat{N}$ = estimated abundance of Arctic grayling.

The specific form of the estimator was determined from the experimental design and the results of tests performed to evaluate if the assumptions were met.

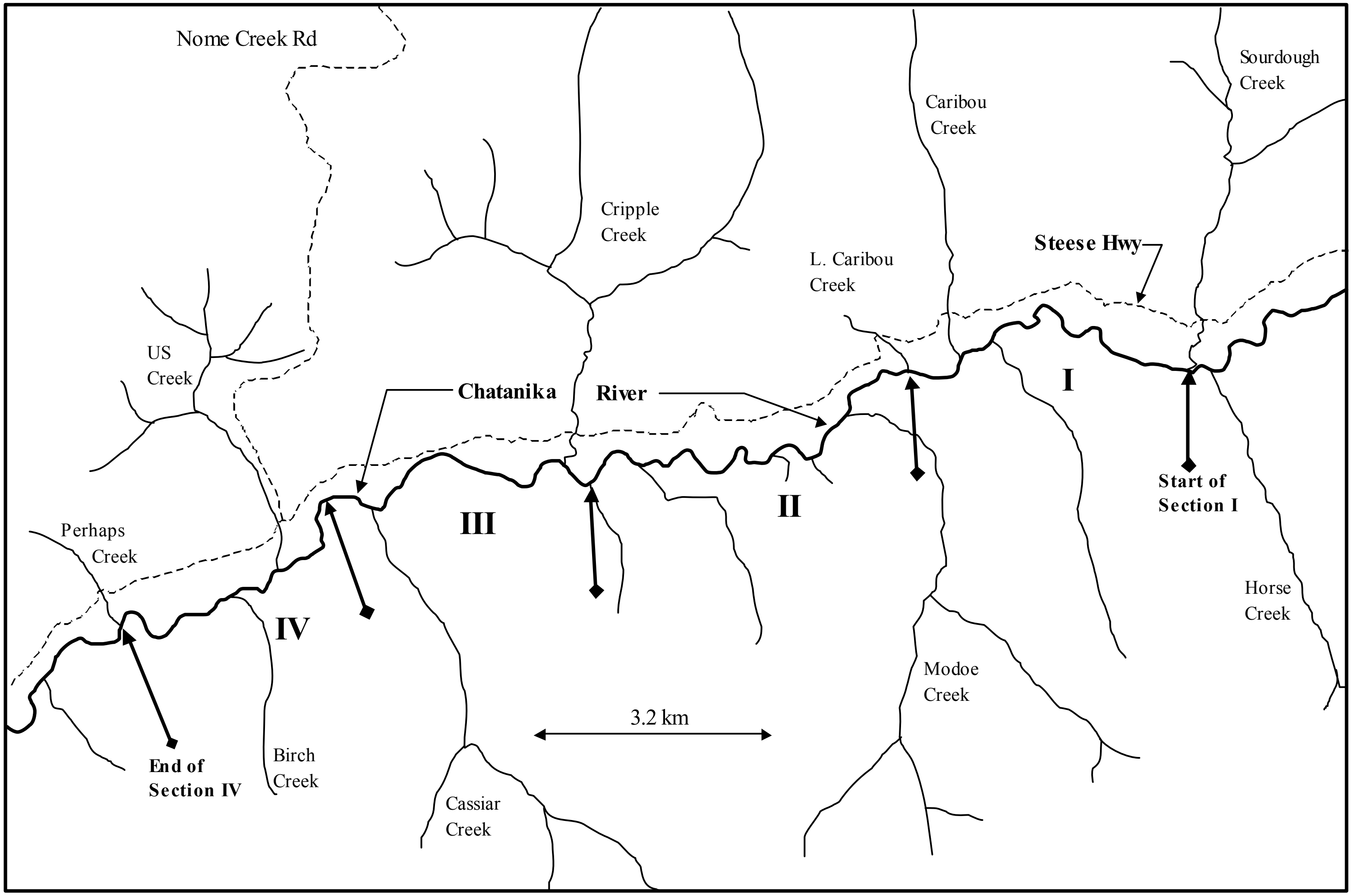



Figure 4.-Chatanika River study area, 2002.

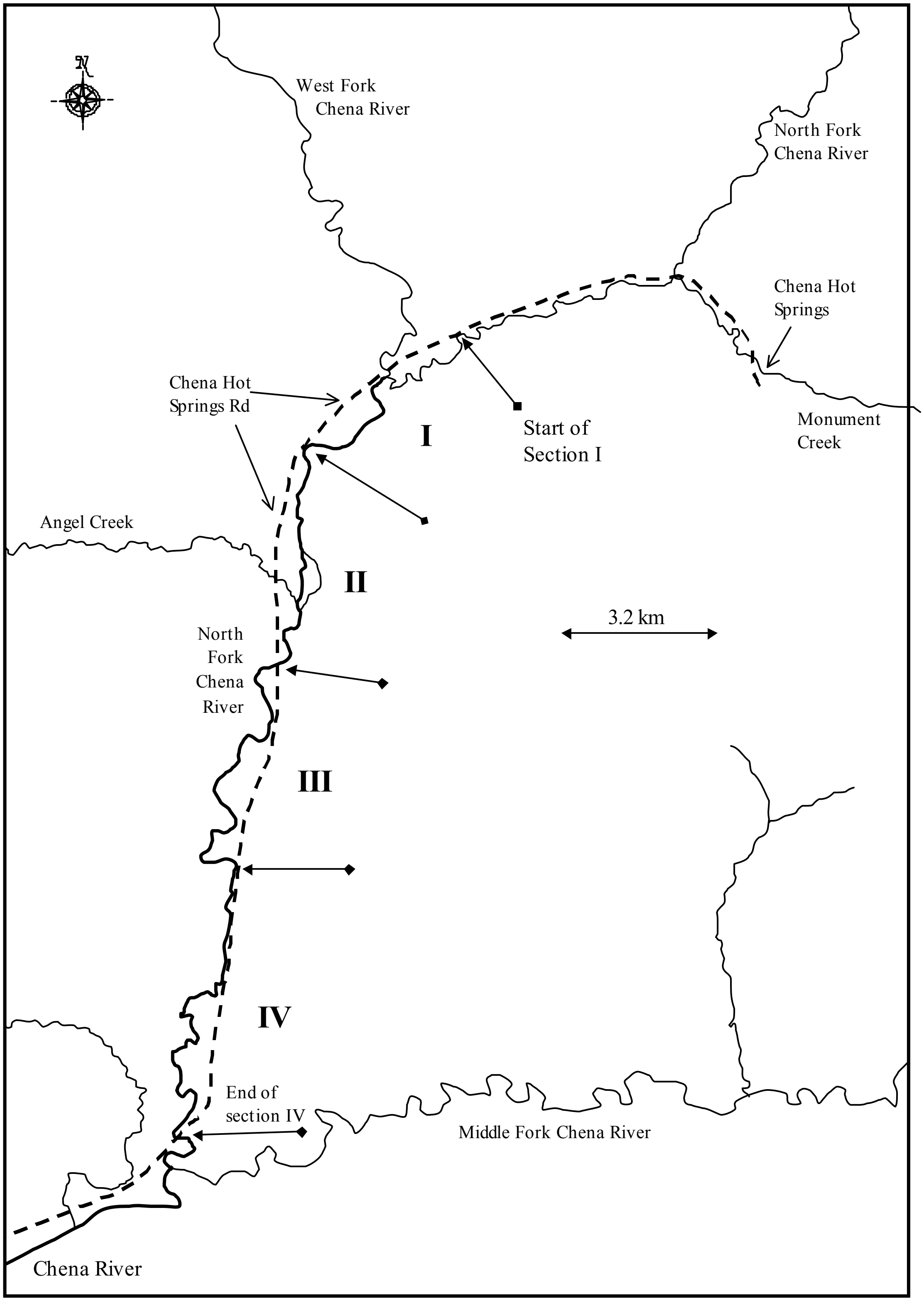



**Figure 5.**-Chena River study area, 2002.

The sampling design allowed the validity of these assumptions to be ensured or tested. To avoid violation of assumption 1, the study was conducted during a period when Arctic grayling were not migrating. During the summer feeding period movement does occur but is generally on a localized scale (e.g., within 1 river km; Tack 1973; Ridder 1998a; Ridder and Gryska 2000). Given that the sampling hiatus was only 12 days, little or no movement out of the study area was expected to have occurred. Location data for recaptured fish were examined for evidence of movement into and out of the study area to evaluate the appropriateness of the assumption. The duration of the study was kept short to render growth recruitment and mortality insignificant.

To help ensure Assumption 2 was met, an attempt was made to subject all fish within each sampling event to the same probability of capture. This was facilitated by creating the four sampling sections for each river. Within each section, sampling intensity was similar and was proportional to Arctic grayling distributions. That is, areas that likely held fish, such as heads of pools, were sampled until fish could not longer be caught in a reasonable duration of time by any of the three crew members (approximately 5 min). Areas that were not likely to hold fish (shallow riffles) were lightly fished as the crew walked downstream to the next pool. If a fish was caught, that particular spot was fished until the crew felt that another fish could not be caught. Geographic landmarks and global positioning system (GPS) waypoints were used to help manage downstream progress within a 3-mile section. This helped to ensure that effort was expended over the entire section. Because Arctic grayling move little during mid-summer, complete mixing of marked and unmarked fish within the study area was not relied on; Rather Arctic grayling were expected to mix on the scale of a river km. To lessen the selectivity of the capture gear toward larger fish, at least one crew member typically fished with a small fly. Violations of Assumption 2 relative to size-selective sampling were tested using two Kolmogorov-Smirnov (K-S) tests. There were three possible outcomes of these two tests; either one, both, or neither of the samples were biased. Tests and adjustments to correct for bias due to size-selective sampling are outlined in Appendix A1. To investigate differences in capture probability by location, tests for consistency of the Petersen estimator (Seber 1982) were performed. The appropriate estimator was selected based on the outcomes of these tests (Appendix A2).

Relative to Assumption 3, a hiatus of 12 days between the first and second events in a given river section was included to allow marked fish time to recover from the effects of being hooked and handled and to resume normal feeding behavior. In addition, continually changing terminal gear served to mitigate potential marking-induced effects in behavior (e.g., gear avoidance).

Relative to Assumptions 4 and 5, Arctic grayling captured during the first event were double marked (internal-anchor tag and finclip) in standardized locations, and all fish caught in the second event were carefully examined to ensure that marked fish recaptured during the second event would be identified and reported as marked.

Length and age composition of the population were estimated using the procedures outlined in Appendix A4.

## DATA COLLECTION

All captured Arctic grayling were processed immediately or soon after capture and released at or very near their capture location. As each fish was caught, crews collected and recorded data for date, location, crew, fork length, scale samples, old fin clips, tag number, tag color, recapture status, and mortality. The Floy™ tags deployed in the Chena River were gray and numbered

2,001-2,056 and 2,201-2,311; and tags used for the Chatanika River were gray and numbered 2,057-2,100, 2,135–2,155, and 2,326-2,366. All data were recorded into field notebooks and transferred into an Excel spreadsheet for data analysis and archival (Appendix C1).

For aging, two scales were removed from all fish caught during both events. Scales were taken from the area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder, Sport Fish Biologist, ADF&G, retired, Delta Junction, personal communication; Brown 1943). In the field, scales were wiped clean of slime and dirt and mounted on gummed cards. Later, triacetate impressions of the gummed cards were made (30 s at 137,895 kPa, at a temperature of 97ºC). Ages were determined by counting annuli from the triacetate impressions magnified to 40X with a microfiche reader. The presence of an annulus was determined as described by Kruse (1959).

# RESULTS

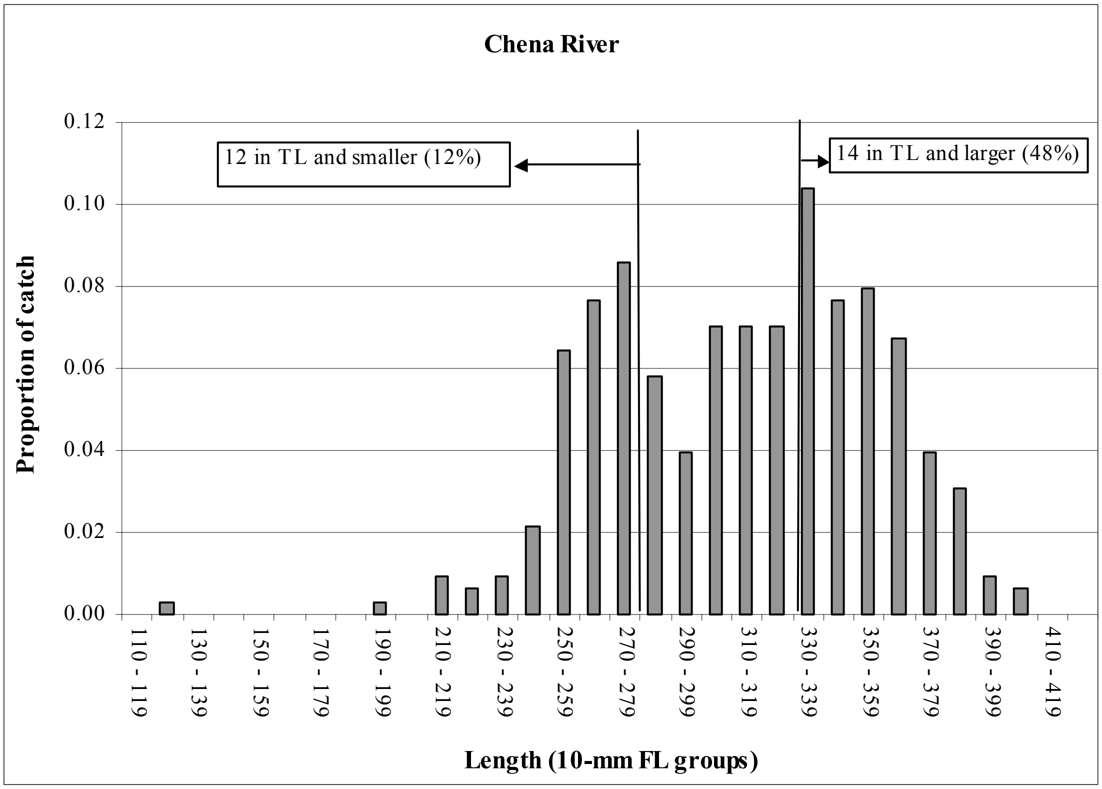
## SUMMARY STATISTICS OF FISH SAMPLED

### Chena River

In the Chena River, a total of 330 unique Arctic grayling were captured, sampled, and released alive during the study (Table 1). The smallest Arctic grayling captured in the first event was 220 mm FL, the smallest in the second event was 135 mm, and the smallest recaptured fish was 263 mm FL. The median length of all fish captured was 327 mm FL and lengths ranged from 135 to 415 mm FL (Figure 6). Scales were collected from 312 Arctic grayling, of which 255 were aged (Appendix C1). Ages ranged from 2 to 9 years.

**Table 1.–**Catches of Arctic grayling in the Chena River and Chatanika River study areas during 2002.

| River | Section | Distance (km) | 1st Event | 2nd Event | Total |
|---|---|---|---|---|---|
| Chena | | | | | |
| | I | 4.6 | 24 | 30 | 54 |
| | II | 4.0 | 39 | 42 | 81 |
| | III | 5.2 | 33 | 47 | 82 |
| | IV | 6.2 | 65 | 48 | 113 |
| | Total | 20.0 | 163 | 167 | 330 |
| Chatanika | | | | | |
| | I | 4.8 | 29 | 34 | 63 |
| | II | 5.2 | 26 | 35 | 61 |
| | III | 4.3 | 18 | 23 | 41 |
| | IV | 4.0 | 25 | 52 | 77 |
| | Total | 18.3 | 98 | 144 | 242 |



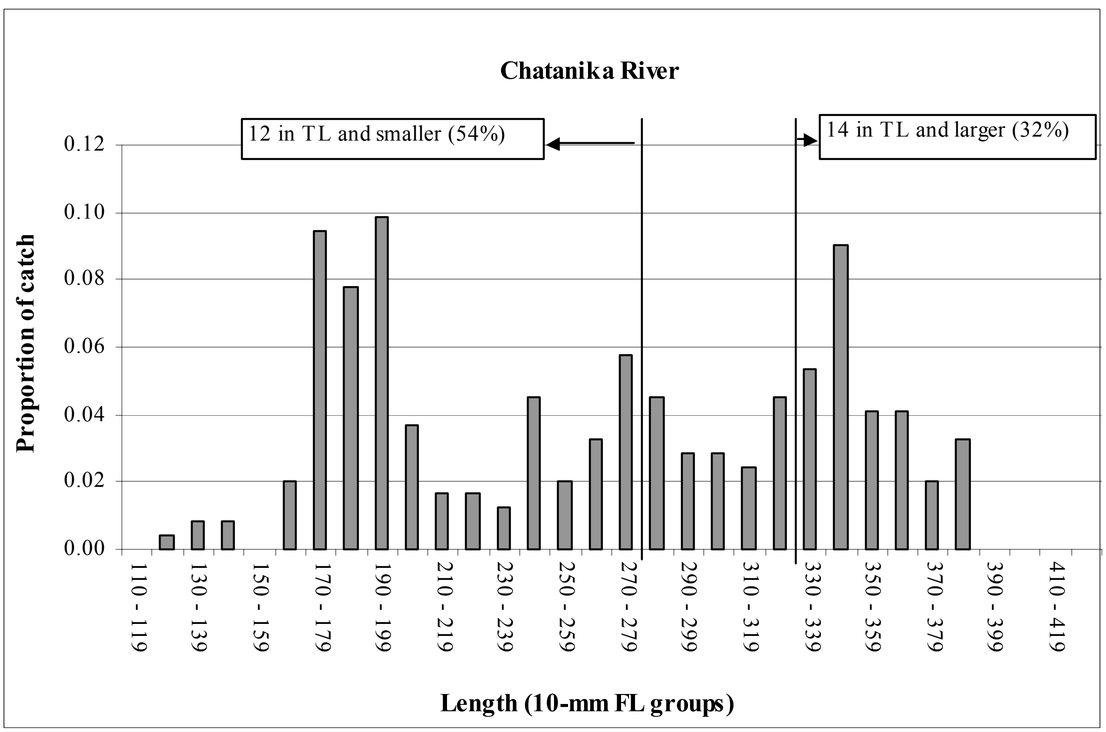




**Figure 6.**–Length distributions of fish sampled from the Chena and Chatanika rivers, 2002.

## Chatanika River

In the Chatanika River, a total of 242 unique Arctic grayling were captured, sampled, and released alive during the study (Table 1). The smallest Arctic grayling captured in the first event was 135 mm FL, the smallest in the second event was 140 mm FL, and the smallest recaptured fish was 180 mm FL. The median length of all fish sampled was 281 mm FL and sizes ranged from 135 to 399 mm FL (Figure 6). Scales were collected from 250 Arctic grayling, of which 191 were aged. Ages ranged from 1 to 10 years (Appendix C2).

### ABUNDANCE ESTIMATE

## Chena River

The abundance of Arctic grayling ≥ 250 mm FL in the Chena River study area was estimated at 1,356 (SE = 285), and density was estimated at 68 (SE = 14) fish ≥ 250 mm FL /km (Table 2).

**Table 2.**–Estimated abundance and density (fish/km) of Arctic grayling in Chena and Chatanika rivers study areas, 2002.

| | Chena River | | Chatanika River | |
|---|---|---|---|---|
| Strata | Abundance (SE) | Density (SE) | Abundance (SE) | Density (SE) |
| ≥ 160 mm FL | N/A | N/A | 853 (305) | 47 (17) |
| ≥ 250 mm FL | 1,356 (285) | 68 (14) | 234 (41) | 13 (3) |
| ≥ 270 mm Fl[a] | 1,129 (236) | 56 (12) | 205 (36) | 11 (2) |
| ≥ 320 mm FL[b] | 450 (90) | 23 (5) | 124 (25) | 7 (2) |

[a] Calculated to compare with other Arctic grayling studies that present an estimate for Arctic grayling ≥270-mm length because it relates to the minimum length at which wild Arctic grayling can be harvested (12 in TL) for most waters within Region III. It also relates to the size at which 50% of a stock of Arctic grayling is presumably mature in within the Tanana River drainage (Clark 1992).

[b] Calculated to compare with other Arctic grayling studies that present an estimate for Arctic grayling ≥320-mm length because it relates to the size above which an Arctic grayling has been informally defined as a large fish by fisheries managers in the Tanana River and Copper River drainages.

The sampling design and results of the testing procedures outlined in Appendices A1 and A2 dictated that: 1) stratification by length was not required; 2) geographic stratification was not required; and, 3) the Bailey-modified Petersen estimator (Bailey 1951 and 1952) be used (Appendix A3). The use of the Bailey-modified Petersen estimator was appropriate because fishing occurred in a systematic, downstream progression while attempting to subject all fish to the same probability of capture.

The estimated abundance of Arctic grayling in the study area was germane to fish ≥ 250 mm FL during mid July. The lower length bound was selected based the length distribution of the recaptured fish and on the interval of interest for the length composition analysis (10-mm). Consideration was also given to the length composition of the sample obtained in each event.

There was little evidence that the assumption of closure was violated. Minimal movement was observed with only three out of 18 (16%) recaptured fish moving out of the section in which they were marked. Movements were not directional and only one of the tags moved more than one section from where it was tagged (Table 3). This suggested that the movement was localized and that the population was closed during the experiment.

**Table 3.**–Test for complete mixing. Number of Arctic grayling ≥ 250 mm FL marked in each section (I - IV) and recaptured or not recaptured during the second event in each section of the Chena River study area, 2002.

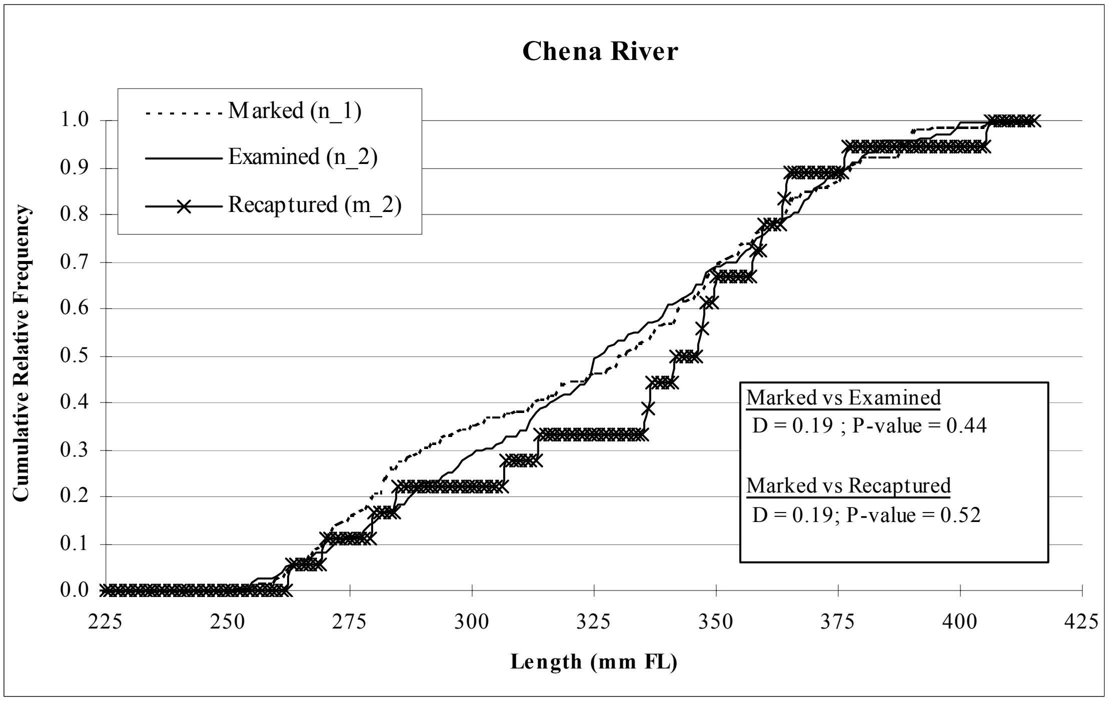
| Section | Section Where Recaptured | | | | Not Recaptured |
|---|---|---|---|---|---|
| Where Marked | I | II | II | IV | ($n_1$-$m_2$) |
| I | 4 | 0 | 0 | 0 | 20 |
| II | 0 | 6 | 0 | 1 | 30 |
| III | 0 | 0 | 1 | 1 | 33 |
| IV | 0 | 1 | 0 | 4 | 59 |

$\chi^2 = 44.51$, df = 12, P-value < 0.01, reject $H_0$

No significant differences were found between empirical cumulative distribution functions (ECDFs) for fish ≥ 250 mm FL when comparing fish marked in the first event and fish recaptured in the second event (D=0.19; P-value=0.52), and comparing fish marked in the first event and all fish examined in the second event (D=0.09; P-value=0.44; Figure 7).

For fish ≥ 250 mm FL, the tests of consistency indicated that mixing of fish between sections was not complete (P-value ≤ 0.01; Table 3). However, the probabilities of being captured by area were not significantly different during the first event (P-value = 0.14; Table 4) and during the second event (P-value = 0.19; Table 5), which satisfied Assumption 2.

Because the size and boundaries of the sampling sections were arbitrary relative to possible geographic variation in capture probabilities, the tests of consistency (Appendix A2) were also performed after grouping sections 1 and 2 into an "upper" section and sections 3 and 4 into a "lower" section. The hypothesis of complete mixing was strongly rejected, second event capture probabilities were significantly different between sections, and first event capture probabilities between pooled sections were marginally not significant (P-value =0.14). An abundance estimate of 1,893 (SE = 558) Arctic grayling was obtained using a stratified estimator (Darroch 1961). This result was not significantly different from the pooled Bailey's estimate and suggested that the marginal P-value was sufficient for meeting the assumptions.



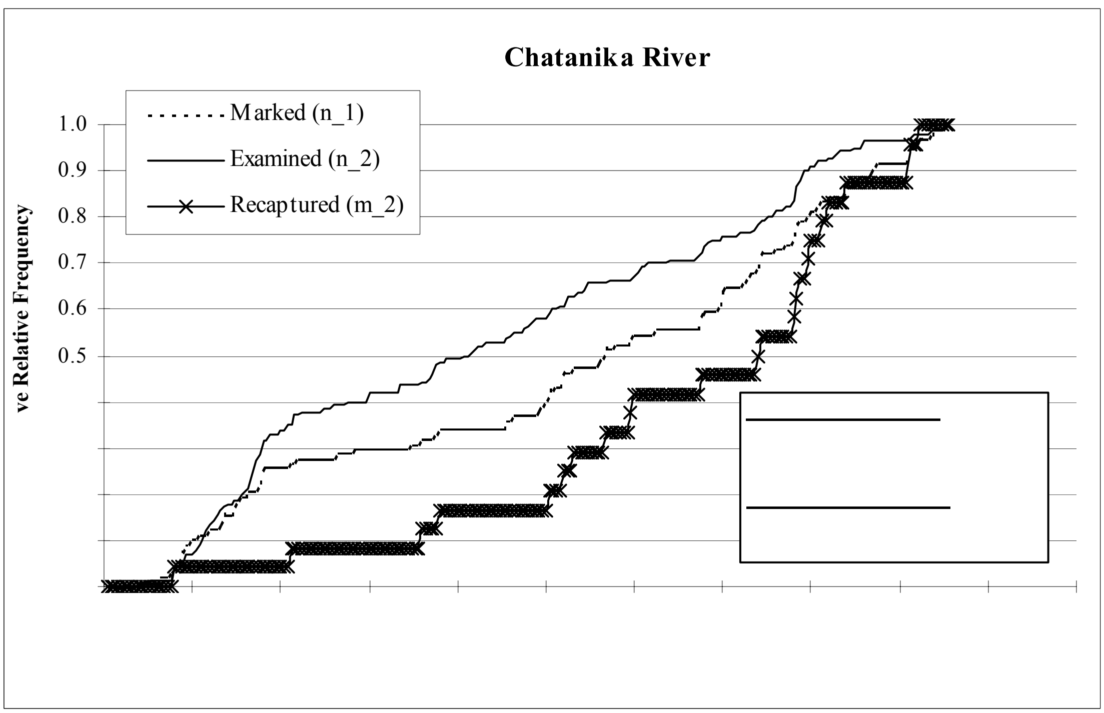




**Figure 7.–**Empirical cumulative distribution functions of Arctic grayling ≥ 250 mm FL sampled from the Chena River and ≥ 160 mm FL sampled from the Chatanika River study areas, 2002.

**Table 4.**-Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 250 mm FL captured during the second event by section (I - IV) in the Chena River, 2002.

| Category | Section Where Examined | | | | All Sections |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Marked ($m_2$) | 4 | 7 | 1 | 6 | 18 |
| Unmarked ($n_2$-$m_2$) | 25 | 34 | 44 | 39 | 142 |
| Examined ($n_2$) | 29 | 41 | 45 | 45 | 160 |
| $P_{capture}$ in 1$^{st}$ event ($m_2/n_2$) | 0.14 | 0.17 | 0.02 | 0.13 | 0.11 |

$\chi^2 = 5.45$, df = 3, P-value = 0.14, fail to reject $H_0$

**Table 5.**–Test for equal probability of capture during the second event. Number of marked Arctic grayling ≥ 250 mm FL that were recaptured or not recaptured during the second event by marking section (I - IV) in the Chena River, 2002.

| Category | Section Where Marked | | | | All Sections |
|---|---|---|---|---|---|
| | I | II | II | IV | |
| Recaptured ($m_2$) | 4 | 7 | 2 | 5 | 18 |
| Not recaptured ($n_1$-$m_2$) | 20 | 30 | 33 | 59 | 142 |
| Marked ($n_1$) | 24 | 37 | 35 | 64 | 160 |
| $P_{capture}$ in 2$^{nd}$ event ($m_2/n_1$) | 0.17 | 0.18 | 0.06 | 0.08 | 0.11 |

$\chi^2 = 4.71$, df = 3, P-value = 0.19, fail to reject $H_0$

## Chatanika River

Estimated abundance of Arctic grayling ≥ 250 mm FL in the Chatanika River study area was 234 (SE = 41), and density was estimated at 13 (SE=3); fish ≥ 250 mm FL/km (Table 2). For Arctic grayling between 160-249 mm FL, estimated abundance was 620 (SE=303), and density was estimated at 34 (SE=17) fish/km. However, due to the limited number of recaptured fish ($m_{2,160\text{-}249}$=2), bootstrap methods of Efron and Tibshirani (1993) and Buckland and Garthwaite (1991) were used to identify possible bias and provide bias corrected confidence intervals using the BCa (bias-corrected and accelerated) method. The bootstrap sampling distribution for $\hat{N}_{160-249}$ was positively skewed, and for the abundance estimate, the preferred, bias-corrected confidence interval (95%) was (220 – 1,820). The bootstrap estimate of bias was 166 fish. The abundance point estimate was not adjusted to account for the bias (i.e., bias-corrected) because the uncertainty associated with the estimated bias was large (Efron and Tibshirani, 1993). Therefore, the Bailey estimate of 620 fish was preferred. The Bailey estimates for the large and small size strata were combined for an estimate of 853 (SE = 305) fish ≥ 160 mm FL corresponding to a density estimate of 47 (SE=17) fish/km. The preferred, bias corrected 95% confidence interval for the overall abundance estimate, calculated using the BCa method, was 414-2,017 and the bootstrap estimate of bias was 182 fish.

Testing procedures dictated: 1) that stratification by length (160-250 and ≥ 250 mm FL) was required; 2) that geographic stratification was not required for either length strata; and, 3) that the Bailey-modified Petersen estimator (Bailey 1951 and 1952) be used for each strata (Appendix A3). The use of the Bailey-modified Petersen estimator was appropriate because fishing occurred in a systematic downstream progression while attempting to subject all fish to the same probability of capture.

The estimated abundance of Arctic grayling in the study area was germane to fish ≥ 160 mm FL during mid July. In selecting this lower length limit, the same criteria used for the Chena River estimate were applied. During the experiment, there was no evidence that the assumption of closure was violated. Only two out of 24 (8%) recaptured fish moved out of the section in which they were marked (Table 6), and only one tagged fish moved more than one section between events.

**Table 6.–**Test for complete mixing. Number of Arctic grayling ≥ 250 mm FL marked in each section (I - IV) and recaptured or not recaptured in each section of the Chatanika River study area, 2002.

| Section | Section Where Recaptured | | | | Not Recaptured |
|---|---|---|---|---|---|
| Where Marked | I | II | II | IV | ($n_1$-$m_2$) |
| I | 6 | 0 | 1 | 0 | 13 |
| II | 0 | 6 | 0 | 0 | 9 |
| III | 0 | 0 | 3 | 0 | 9 |
| IV | 0 | 0 | 0 | 6 | 14 |

$\chi^2$ =58.66, df = 12, p-value < 0.01, reject $H_0$

For fish ≥ 160 mm FL, the K-S test results indicated that stratification by length was not required (Figure 7). The length composition of fish marked in the first event differed from those recaptured during the second event (D = 0.21; P-value < 0.01), but was not significantly different from fish captured in the second event (D = 0.24; P-value = 0.19). However, the insignificant test result for second event capture probabilities by size was likely a result of the small sample size because the D-value was relatively large (0.24). Therefore, differences in capture probabilities between length strata were tested using chi-square testing procedures starting with the strata break point that corresponded to the maximum D-value (250 mm FL). After examining a range of possible break points, 250 mm was selected because it resulted in the largest chi-square statistic, and it happened to facilitate comparisons with the Chena River. At this break point, differences in the probability of capture between fish ≥ 250 mm FL and fish <250 mm FL were significant during the first event (P-value < 0.01) and the second event (P-value <0.01).

For fish ≥ 250 mm FL, no significant differences were found between the ECDFs when comparing fish marked in the first event and fish recaptured in the second event (D=0.13; P-value=0.89), and comparing fish marked in the first event and all fish captured in the second event (D=0.16; P-value=0.23). The tests of consistency indicated that: 1) mixing of fish between sections was not complete (P-value = 0.01; Table 6); 2) the probabilities of being captured in the first event by section but were not significantly different (P-value=0.96; Table 7); and, 3) probabilities of being captured in the second event were not significantly different (P-value=0.98; Table 8).

**Table 7.**–Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling ≥ 250 mm FL captured during the second event by section (I - IV) in the Chatanika River, 2002.

| | Section Where Examined | | | | |
|---|---|---|---|---|---|
| Category | 1 | 2 | 3 | 4 | All Sections |
| Marked ($m_2$) | 7 | 6 | 5 | 6 | 24 |
| Unmarked ($n_2$-$m_2$) | 25 | 29 | 18 | 44 | 116 |
| Examined ($n_2$) | 32 | 35 | 23 | 50 | 140 |
| $P_{capture}$ in 1$^{st}$ event ($m_2/n_2$) | 0.28 | 0.21 | 0.28 | 0.14 | 0.28 |

$\chi^2$ = 0.29, df = 3, p-value = 0.96, fail to reject $H_0$

**Table 8.**–Test for equal probability of capture during the second event. Number of marked Arctic grayling ≥ 250 mm FL that were recaptured or not recaptured during the second event by marking section (I - IV) in the Chatanika River, 2002.

| Category | Section Where Examined | | | | All Sections |
|---|---|---|---|---|---|
| | I | II | II | IV | |
| Recaptured ($m_2$) | 7 | 6 | 3 | 6 | 22 |
| Not recaptured ($n_1$-$m_2$) | 13 | 9 | 9 | 14 | 45 |
| Marked ($n_1$) | 20 | 15 | 12 | 20 | 67 |
| $P_{capture}$ in 2nd event ($m_2/n_1$) | 0.35 | 0.40 | 0.25 | 0.30 | 0.33 |

$\chi^2$ = 0.15, df = 3, p-value = 0.98, fail to reject $H_0$

For fish 160 - 249 mm FL, no significant differences were found between the ECDFs when comparing fish marked in the first event and fish recaptured in the second event (D=0.37; P-value=0.93), and comparing fish marked in the first event and all fish examined for marks in the second event (D=0.17; P-value=0.47). The tests of consistency indicated that: 1) mixing of fish between sections was complete (P-value = 0.57; Table 9); 2) the probabilities of being captured in the first event by section but were not significantly different (P-value=0.29; Table 10); and, 3) probabilities of being captured in the second event were not significantly different (P-value=0.99; Table 11).

**Table 9.**–Test for complete mixing. Number of Arctic grayling 160-249 mm FL marked in each section (I - IV) and recaptured or not recaptured in each section of the Chatanika River study area, 2002. To conduct chi-square tests sections I and II were combined and sections III and IV were combined.

| Section Where Marked | Section Where Recaptured | | | | Not Recaptured ($n_1$-$m_2$) |
|---|---|---|---|---|---|
| | I | II | II | IV | |
| I | 1 | 0 | 0 | 0 | 8 |
| II | 0 | 0 | 1 | 0 | 9 |
| III | 0 | 0 | 0 | 0 | 6 |
| IV | 0 | 0 | 0 | 0 | 5 |

$\chi^2$ =1.11, df = 2, p-value = 0.57, Fail to reject $H_0$

## LENGTH AND AGE COMPOSITION

### Chena River

Of fish ≥ 250 mm FL, the highest proportion (p = 0.11; SE = 0.20) were in the 340-349 mm FL length category, most fish were age-5 (p = 0.26, SE = 0.04) and 0.63 (SE = 0.03) were older than age-5 (Appendix B3). Of the 327 fish sampled for length, 10 (0.03) were less than 250 m FL and 32 of 255 fish aged (0.13) were younger than age-5.

**Table 10.**-Test for equal probability of capture during the first event. Number of marked and unmarked Arctic grayling 160-249 mm FL captured during the second event by section (I - IV) in the Chatanika River, 2002.

| Category | Section Where Marked | | | | All Sections |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Marked ($m_2$) | 1 | 0 | 1 | 0 | 2 |
| Unmarked ($n_2$-$m_2$) | 11 | 14 | 9 | 25 | 59 |
| Examined ($n_2$) | 12 | 14 | 10 | 25 | 61 |
| $P_{capture}$ in 1st event ($m_2/n_2$) | 0.09 | 0.00 | 0.11 | 0.00 | |

$\chi^2$ = 3.71, df = 3, p-value = 0.29, fail to reject $H_0$

**Table 11.**–Test for equal probability of capture during the second event. Number of marked Arctic grayling 160-249 mm FL that were recaptured or not recaptured during the second event by marking section (I - IV) in the Chatanika River, 2002.

| Category | Section Where Examined | | | | All Sections |
|---|---|---|---|---|---|
| | I | II | II | IV | |
| Recaptured ($m_2$) | 1 | 1 | 0 | 0 | 2 |
| Not recaptured ($n_1$-$m_2$) | 8 | 9 | 6 | 5 | 28 |
| Marked ($n_1$) | 9 | 10 | 6 | 5 | 30 |
| $P_{capture}$ in 2nd event ($m_2/n_1$) | 0.11 | 0.10 | 0.00 | 0.00 | 0.67 |

$\chi^2$ = 0.04, df = 3, p-value = 0.99, fail to reject $H_0$

### Chatanika River

Of the estimated population of fish ≥ 160 mm FL, the proportion of fish smaller than 250 mm FL was 0.73 (SE = 0.10). Composition estimates were restricted to fish ≥ 250 mm FL (Appendix C4) because the imprecision for the estimated abundance of Arctic grayling between 160 - 250 mm FL resulted in large uncertainties in composition estimates (i.e., the proportions for length categories ≥ 250 mm FL ranged from 0.02 to 0.04 and their standard errors ranged from 0.09 to 0.13). Of fish ≥ 250 mm FL, most fish were age-5 (P = 0.22, SE = 0.04) and 0.76 (SE = 0.01) were younger than 5 (Appendix B4).

# DISCUSSION

The results of this study demonstrated that there were marked differences in the population characteristics of Arctic grayling between the Chatanika River headwater study area and the historical assessment area downriver, and between the Chatanika River headwater study area and headwater areas in neighboring systems, the Chena River and Beaver Creek. The density of adult-sized Arctic grayling (≥ 270 mm FL) in the Chatanika River headwater study area was five to 15 times lower than what has been observed in historical assessment areas in the Chatanika and Chena rivers (Table 12); approximately five times lower than in the headwaters of the Chena River, and approximately 19 times lower than in a 30-mile study section in the upper reaches of Beaver Creek, which is a similarly sized drainage located approximately 15 miles north of the Chatanika River.

Pronounced differences were also observed in the abundance of small fish (<250 mm FL) between the Chena and Chatanika headwater study areas. The results showed that the abundance of small Arctic grayling in the Chatanika is at least 260 fish (95% confidence) and likely closer to 600 fish. Insufficient numbers of small fish were caught in the Chena River to estimate their abundance. However, because sampling conditions and fishing effort were nearly identical between the two rivers in terms of water and weather conditions, timing, gear, man-hours, and crew, the lack of small fish in the catch (Figure 6) was interpreted as being reflective of a relatively low density. For instance, given a capture probability for small fish similar to that in the Chatanika River (i.e., 4%), the probability of capturing only 10 fish smaller than 250 mm FL in the Chena River during both events is < 1% if the true abundance was ≥ 300 fish and the most likely abundance was between 100 and 125 fish.

Although notable differences existed between the Chena and Chatanika headwater populations, it remains unclear as to the mechanisms that would cause these observed differences. Several related variables exist that could explain the observed differences including: the residual effects from placer mining, Arctic grayling behavior, exploitation from the sport fishery, and differences in habitat.

**Table 12.**–Densities of Arctic grayling ≥270 mm FL in assessed areas of the Chatanika River, Chena River, and Beaver Creek.

| Assessment Area | Year | Density | |
|---|---|---|---|
| | | Fish/km | Fish/mi |
| Lower Chatanika River[a] | | | |
| (Above Elliot highway bridge to | 1991 | 50 | 80 |
| to Any Creek; ~ 30 km) | 1992 | 43 | 69 |
| | 1993 | 105 | 169 |
| | 1994 | 85 | 137 |
| | 1995 | 87 | 140 |
| Chatanika Headwater Area | | | |
| | 2002 | 11 | 18 |
| Upper Chena River | | | |
| (From 1st bridge on | 1991 | 71 | 115 |
| Chena Hot springs Road | 1992 | 57 | 91 |
| to Moose Creek Dike; ~ 80 km) | 1993 | 86 | 138 |
| | 1994 | 83 | 134 |
| | 1995 | 91 | 146 |
| | 1996 | 140 | 225 |
| | 1997 | 118 | 190 |
| | 1998 | 156 | 251 |
| Chena River Headwater Area | 2002 | 56 | 90 |
| Beaver Creek headwater area[c] | | | |
| A 30-mi study section downstream | 2000 | 204 | 328 |
| from confluence of Bear and | | | |
| Champion creeks | | | |

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

[b] Density estimates were attained from a summary table of historical abundance estimates from the upper Chena River assessment area presented by Ridder (1998a) and multiplied by the length of the study.

[c] Fleming and McSweeny (2001).

Historically, placer mining in the Chatanika River undoubtedly affected the Arctic grayling population. The effects of placer mining can be far reaching as it has been shown to suppress primary productivity, decrease invertebrate densities, and ultimately Arctic grayling densities, all largely due to sedimentation and turbidity (VanNiewenhuyse and LaPerriere 1986; Wagener and LaPerriere 1985; Reynolds et al. 1989). However, there may have been sufficient time for the population to recover from any effects from placer mining in the study area because mining has not occurred in the upper reaches for over 15 years, and these headwater areas may not have been as significantly impacted by mining as was the lower river or other nearby rivers that currently support higher densities and larger fish. At some point during a 30-year period between the 1950s and the mid 1980s, the Arctic grayling population recovered downstream of Cleary Creek, where mining at one time generated sufficient turbidity to dislocate Arctic grayling from downriver areas (Wagener and LaPerriere 1985). Also, in their investigations, Wagener and LaPerriere (1985) found that the effects of mining on water quality in Faith Creek were much milder than in other more heavily mined areas such as Birch Creek. However, these studies did not explore all potential negative effects of mining. For example, the degree to which the interdependent process of nutrient cycling ("spiraling") was disturbed, particularly in relation to the hyporheic zone, was not assessed. The exchange of water and nutrients between the hyporheic zone and the surface flows very well could have been negatively impacted by sedimentation from mining. Relative to the Chatanika River, the extent of placer mining on the Chena River was minimal, and was confined to the tributaries of the Middle Fork Chena River and in the Little Chena River.

Marked differences in the riparian habitat and stream characteristics between the two study areas were also observed that could influence overall stream productivity and fish distributions. For instance, the Chena River catchment upstream of the 2002 assessment area differs from that of the Chatanika River in that the Chena River valley is less confined and the channel is more sinuous than the Chatanika River, and the Chena River drainage upstream of the assessment areas is more heavily vegetated with both deciduous and coniferous forests whereas the Chatanika River drains hillsides are more so vegetated with stands of black spruce *Picea glauca* trees. A combination of these factors may result in greater levels of allochthonous inputs and retention of these inputs for the Chena River making it more productive.

The 20-km segment of the Chatanika River selected for study in 2002 may have not have been representative of the upper river because it contained what appeared to be the least amount of preferred Arctic grayling habitat available between the Elliot Highway Bridge and Faith Creek. Compared to the Chena River section, this section of the Chatanika River was less sinuous contained far fewer pools, and pools tended to be shallower. While walking downstream, long reaches (up to ~500 m) were encountered where the channel was uniformly shallow, straight, and largely devoid of lateral or mid-channel scour pools. Downstream from the lower boundary of the Chatanika headwater study area the sinuosity increases markedly as well as the availability of pools and glides.

Fleming (1998) conducted a fishing survey to collect CPUE information in a 72-km stream reach downstream of MP68 near Faith Creek. The 72-km study section was subdivided into ten subsections and similar terminal gear was used as in this study. In subsections downstream of MP55, CPUE estimates were approximately two to four times greater than the two subsections in the 2002 study area. Had a 20–km section of the Chatanika River starting at MP55 been selected, which would still be classified as an upper or headwater area and which is still similar in terms of discharge to the Chena River headwater study area, greater densities of mature-sized Arctic grayling would likely have been encountered. Therefore, a section downstream from the 2002 study area may have been more comparable in terms of fish abundance to the Chena River section.

The greater prevalence of small fish in the Chatanika headwater areas could partially be the result of exploitation on large fish, thus relaxing habitat competition and allowing smaller-sized fish to move in from downstream reaches. Hughes (1994) demonstrated that whole-stream size gradient could be partly explained by larger fish excluding smaller ones from desirable positions in the upper reaches in the stream.

To accurately assess the risk of overexploitation of Arctic grayling in headwater areas, area-specific harvest information is needed. Harvest information for the upper Chatanika River (upstream of the Elliot Highway Bridge) has been available since 1995 and annual harvests have averaged 500 (143 – 760) fish, suggesting exploitation levels are relatively moderate. This study provided evidence that exploitation for some areas of the Chatanika may be low based on the number of fish that were tagged in 1997 and recaptured in this study. As part of the 1997 study, Fleming (1998) tagged 36 Arctic grayling within the study area boundaries and six of these (17%) were caught in 2002. If one were to realistically assume that annual mortality was 20%, and given the capture probabilities observed in this study (30%), one would only expect to recapture 4-5 of these fish assuming 100% fidelity to their summer feeding areas. However, it should be noted that these fish were caught in areas that were not easily accessible from the road and their fates are likely not representative for the remaining population segments in the upper Chatanika River.

In the context of exploitation, comparing the upper Chena and Chatanika rivers can be viewed as a comparison of areas with and without harvest. There is no specific harvest information for the Chena and Chatanika headwater study areas, but the Chena River has been restricted to catch-and-release fishing only since 1991 and it is likely that some moderate level of harvest occurs in the Chatanika River study area. A comparison of length data from Chena River Arctic grayling collected by Grabacki (1981) with data from this study illustrates how angler exploitation can affect the length composition of an Arctic grayling population. One purpose of Grabacki's thesis was to examine the affects of exploitation on Arctic grayling length and age compositions in the upper Chena River by comparing a heavily exploited section (North Fork Chena River) to an unexploited section (Middle Fork Chena River). The North Fork Chena River section extended from the West Fork Chena River to the Middle Fork Chena River, which was almost identical to the section in this study. In his study, Grabacki used hook-and-line sampling and gillnetting to capture Arctic grayling and found no differences in the length composition between the two gear types. The samples collected in 1981 and 2002 are thus comparable in terms of size-selectivity. Since 1981 there has been a dramatic change in the length composition of the catch. In 1981, only 30% of the fish sampled were greater than 270 mm FL and in 2002, 88% were greater (Figure 8). Falling in between these two proportions is the 2002 Chatanika River catch, where 54% was ≥ 270 mm FL. It is likely this lower proportion of small fish in the Chatanika River sample than in the Chena River sample was a result of the relatively moderate exploitation levels that occur in the upper Chatanika River.

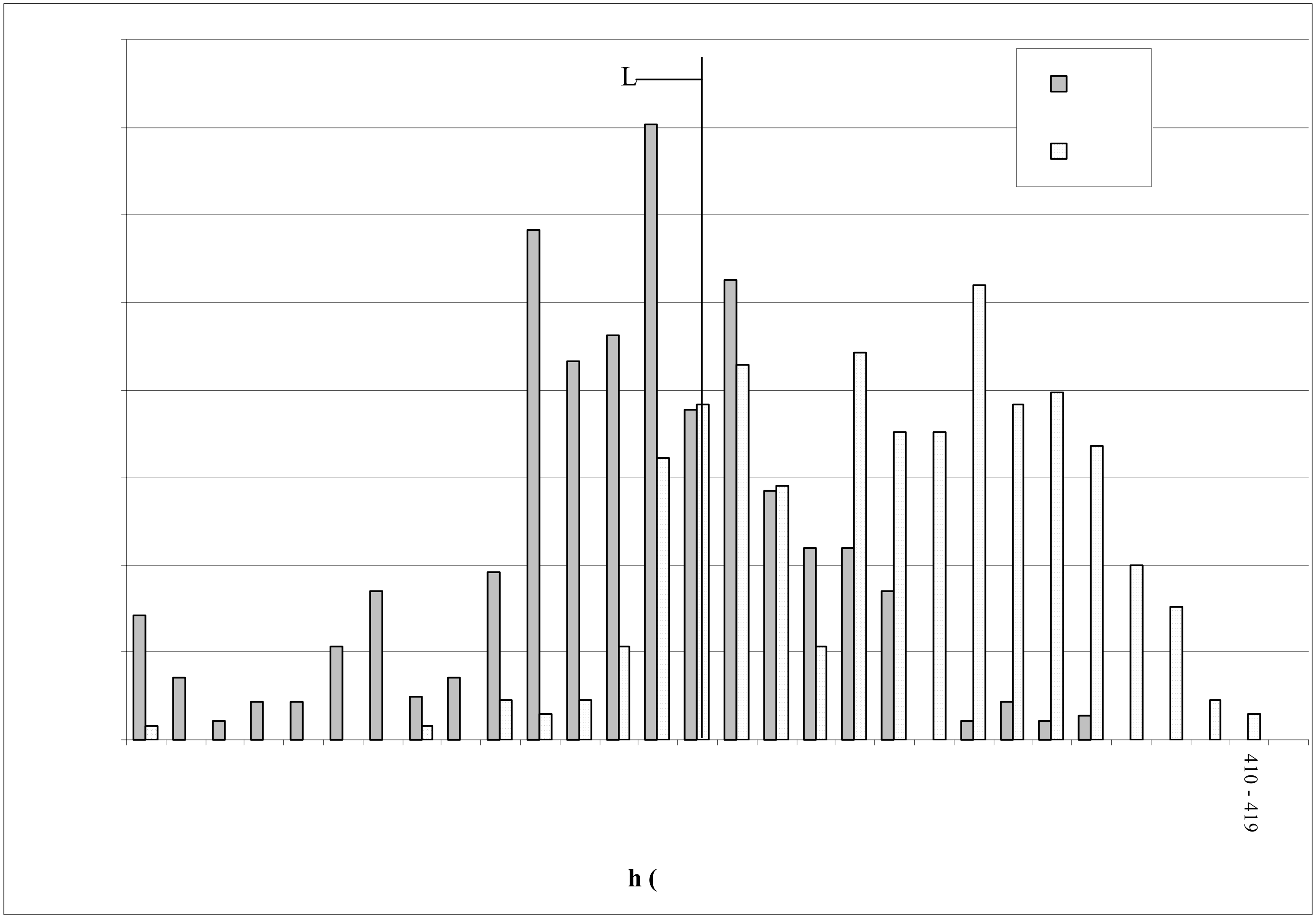



**Figure 8.**–Length distributions of fish sampled from the Chena River study area during 2002 and from the same area by Grabacki (1981). Grabacki's length composition data were not available in a tabular form and were approximated by taking measurements from a histogram presented in the thesis.

In addition to serving as a reference stream for the Chatanika River, the purpose of studying the Chena River population in 2002 was to document the stock characteristics of an Arctic grayling fishery that is considered excellent by the anglers in terms of catch rates and the length composition of the catch (M. Doxey, Sport Fish Biologist, ADF&G, Fairbanks, personal communication). Standards or benchmarks for what characterizes a large fish Arctic grayling fishery have not been clearly defined in any of the current fishery management plans. In the headwaters of the Gulkana River during 2002, the proportion of fish greater than 14 in TL (330 mm FL) was used in hypothesis testing for determining whether or not the catch-and-release regulation implemented had produced the desired effect (more large fish; Gryska *In prep*). The data from this study provided criteria that could be in setting standards for a large-fish fishery: 1) nearly half (48%) of the Arctic grayling caught are ≥ 14 in TL (330 mm FL); 2) at least 10% of Arctic grayling caught are ≥ 16 in TL (370 mm FL); and/or, 3) densities of fish ≥ 12 in TL are greater than 50 fish per mile.

# RECOMMENDATIONS

The results of study demonstrated that there remains an insufficient basis for assessing the stock status and formulating future management plans for the Chatanika headwaters. The abundance of harvestable Arctic grayling in the index area was very low. However, based on CPUE data from Fleming (1998) higher densities of adult-sized Arctic grayling probably exist downstream of the 2002 study areas. It was initially thought that the size of the sampling sections in each river (~11 mi) were considered small enough to allow mark-recapture sampling events in both rivers at nearly identical times and yet are large enough to provide meaningful estimates of abundance and density (M. Doxey, Sport Fish Biologist, ADF&G, Fairbanks, personal communication). However, as demonstrated in this study, a 20-km section of river may not reliably represent the stock status of fish in other parts of the river. Therefore, a stock assessment in the Chatanika River from the Elliot Highway Bridge upstream to the confluence of Faith and McMannus creeks is recommended before the management plan is updated.

If, as predicted, angler effort increases due to upgrades to the Steese Highway, changes in the regulations may be warranted, and without comprehensive stock assessment information there would be a risk of proposing regulatory changes that are inappropriate. Any regulatory change that favors larger fish should be confined to those areas upstream of the Steese Highway Bridge, as there are likely sufficient numbers of harvestable fish in downstream areas. Protecting large fish may help satisfy anglers preferences to have acceptable catch rates of larger-sized fish, such as in the upper Chena River, while maintaining the opportunity to harvest fish in downstream areas. These upstream areas could also then serve as a reserve for recruitment into the lower portions of the Chatanika River.

Finally, in designing future studies it is recommended that the adjustment factor for unreadable scales be increased (e.g., 25%) based on a review of other Arctic grayling studies. In designing this study, the required samples size needed to estimate an age composition within the objective criteria were calculated using the methods developed by (Thompson 1987) and an assumption that 15% of Arctic grayling scales cannot be aged (unreadable). However, 24% of the scales collected from the Chatanika River were unreadable and 18% were unreadable from the Chena River.

# ACKNOWLEDGEMENTS

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# APPENDIX A

## MARK-RECAPTURE MODEL ASSUMPTIONS, TESTS OF ASSUMPTIONS, AND ESTIMATORS

**Appendix A1.-**Methodologies for detecting and alleviating bias due to gear selectivity.

| Case | Result of 1st K-S Test[a] | Result of 2nd K-S Test[b] | Inference | Action |
|---|---|---|---|---|
| I | Fail to Reject $H_o$ | Fail to Reject $H_o$ | There is no size-selectivity during either sampling event. | Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates. |
| II | Fail to Reject $H_o$ | Reject $H_o$ | There is no size-selectivity during the second sampling event, but there is during the first sampling event. | Calculate one unstratified abundance estimate, and ony use lengths and ages from the second sampling event to estimate size and age composition. |
| III | Reject $H_o$ | Fail to Reject $H_o$ | There is size-selectivity during both sampling events. | Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities. |
| IV | Reject $H_o$ | Reject $H_o$ | There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown | Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities |

[a] The first Kolmogorov-Smirnov (K-S) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. $H_o$ for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. $H_o$ for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

**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 mixing[a].**

| Section Where Marked | Section Where Recaptured | | | | Not Recaptured |
|---|---|---|---|---|---|
| | **I** | **II** | **…** | **t** | ($n_1$-$m_2$) |
| **I** | | | | | |
| **II** | | | | | |
| **…** | | | | | |
| **s** | | | | | |

**II. Test for equal probability of capture during the first event[b].**

| | Section Where Examined | | | |
|---|---|---|---|---|
| | **I** | **II** | **…** | **t** |
| Marked ($m_2$) | | | | |
| Unmarked ($n_2$-$m_2$) | | | | |

**III. Test for equal probability of capture during the second event[c].**

| | Section Where Marked | | | |
|---|---|---|---|---|
| | **I** | **II** | **…** | **s** |
| Recaptured ($m_2$) | | | | |
| Not Recaptured ($n_1$-$m_2$) | | | | |

[a] This tests the hypothesis that movement probabilities ($\theta$) from section *i* (*i* = 1, 2, ...s) to section *j* (*j* = 1, 2, ...t) are the same among sections: $H_0$: $\theta_{ij} = \theta_j$.

[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 river sections: $H_0$: $\Sigma_i a_i \theta_{ij} = kU_j$, where $k$ = total marks released/total unmarked in the population, $U_j$ = total unmarked fish in stratum *j* at the time of sampling, and $a_i$ = 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 the river sections: $H_0$: $\Sigma_j \theta_{ij} p_j = d$, where $p_j$ is the probability of capturing a fish in section *j* during the second event, and d is a constant.

**Appendix A3.–**Equations for calculating estimates of abundance and its variance using the Bailey-modified Petersen estimator.

The Bailey-modified Petersen estimator (Bailey 1951 and 1952) is used when the sampling design calls for a systematic manner and 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 estimate is calculated using the equation

$$\hat{N}_1 = \frac{n_1(n_2+1)}{m_2+1}, \qquad \text{(A1)}$$

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;

$m_2$ = the number of Arctic grayling recaptured during the second event; and

$\hat{N}_1$ = estimated abundance of Arctic grayling during the first event.

Variance was estimated as (Seber 1982):

$$\hat{V}[\hat{N}_1] = \frac{n_1^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \qquad \text{(A2)}$$

**Appendix A4.**–Equations for estimating length and age compositions and their variances for the population.

Through inference testing from Appendix A1, case I was found for the Arctic grayling population ≥ 250 mm FL in the Chena. river.

Where case I criteria are satisfied, lengths and ages from both sampling events (pooled) are used for length and age composition estimates. For each study area, the proportions of fish that were in a length or age category (*j*) were estimated as:

$$\hat{p}_j = \frac{n_j}{n} \tag{A3}$$

where:

$n$ = the total number of fish sampled;

$n_j$ = the number of fish sampled from category *j*; and,

$\hat{p}_j$ = the estimated proportion of fish in category *j*.

The variance calculation for $\hat{p}_j$ was

$$\hat{V}\left[\hat{p}_j\right] = \frac{\hat{p}_j\left(1-\hat{p}_j\right)}{n-1} \tag{A4}$$

Where case IV was found through inference testing. When case IV occurs, the second event sample is biased and the status of the first event sample is unknown. Therefore, age and size data from the second event sample were used to estimate compositions. These estimates were adjusted to minimize bias due to size-selectivity. The proportion of fish at age or size was calculated by summing independent abundances for each age or size class and then dividing by the summed abundances for all size strata. First, the conditional proportions from the sample were calculated:

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j}, \tag{A5}$$

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 were age *k*; and,

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

The variance calculation for $\hat{p}_{jk}$ was

$$\hat{V}\left[\hat{p}_{jk}\right] = \frac{\hat{p}_{jk}\left(1-\hat{p}_{jk}\right)}{n_j - 1}. \tag{A6}$$

The estimated abundance of age *k* fish in the population was then:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j, \tag{A7}$$

-continued-

where:

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

*s* = the number of size strata.

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

$$\hat{V}\left[\hat{N}_k\right] \approx \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2 - \hat{V}\left[\hat{p}_{jk}\right]V\left[\hat{N}_j\right]\right). \tag{A8}$$

The estimated proportion of the population that were age *k* $\left(\hat{p}_k\right)$ was then:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N}\,, \tag{A9}$$

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

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

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_{jk}\right]\right\} + \frac{\sum_{j=1}^{s}\left\{V\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2}\,. \tag{A10}$$

Equations 4 through 8 were also used to adjust biased size composition estimates, replacing the number sampled at age *k* that were also in size strata *j* ($n_{jk}$) with the number sampled per 10 mm FL incremental size category *k* that were also in size strata *j*.

# APPENDIX B

## LENGTH AND AGE COMPOSITIONS

**Appendix B1.**–Number and proportion of Arctic grayling by age class and 10 mm FL length categories for Arctic grayling captured from the Chena River, 2002.

| Age | Count | Sample Proportion | Length Category | Count | Sample Proportion |
|---|---|---|---|---|---|
| 2 | 1 | 0.00 | 120 - 129 | 0 | 0.00 |
| 3 | 4 | 0.02 | 130 - 139 | 1 | 0.00 |
| 4 | 27 | 0.11 | 140 - 149 | 0 | 0.00 |
| 5 | 66 | 0.26 | 150 - 159 | 0 | 0.00 |
| 6 | 55 | 0.22 | 160 - 169 | 0 | 0.00 |
| 7 | 60 | 0.24 | 170 - 179 | 0 | 0.00 |
| 8 | 30 | 0.12 | 180 - 189 | 0 | 0.00 |
| 9 | 12 | 0.05 | 190 - 199 | 0 | 0.00 |
| 10 | 0 | 0.00 | 200 - 209 | 1 | 0.00 |
| 11 | 0 | 0.00 | 210 - 219 | 0 | 0.00 |
| 12 | 0 | 0.00 | 220 - 229 | 3 | 0.01 |
| | | | 230 - 239 | 2 | 0.01 |
| **Total** | **255** | | 240 - 249 | 3 | 0.01 |
| | | | 250 - 259 | 7 | 0.02 |
| | | | 260 - 269 | 21 | 0.06 |
| | | | 270 - 279 | 25 | 0.08 |
| | | | 280 - 289 | 28 | 0.09 |
| | | | 290 - 299 | 19 | 0.06 |
| | | | 300 - 309 | 7 | 0.02 |
| | | | 310 - 319 | 29 | 0.09 |
| | | | 320 - 329 | 23 | 0.07 |
| | | | 330 - 339 | 23 | 0.07 |
| | | | 340 - 349 | 34 | 0.10 |
| | | | 350 - 359 | 25 | 0.08 |
| | | | 360 - 369 | 26 | 0.08 |
| | | | 370 - 379 | 22 | 0.07 |
| | | | 380 - 389 | 13 | 0.04 |
| | | | 390 - 399 | 10 | 0.03 |
| | | | 400 - 409 | 3 | 0.01 |
| | | | 410 - 419 | 2 | 0.01 |
| | | | 420 - 429 | 0 | 0.00 |
| | | | **Total** | **327** | |

**Appendix B2.**–Number and proportion of Arctic grayling by age class and 10 mm FL length categories for Arctic grayling captured from the Chatanika River, 2002.

| Age | Count | Sample Proportion | Length Category | Count | Sample Proportion |
|---|---|---|---|---|---|
| 1 | 7 | 0.04 | 120 - 129 | 0 | 0.00 |
| 2 | 35 | 0.18 | 130 - 139 | 1 | 0.00 |
| 3 | 45 | 0.24 | 140 - 149 | 2 | 0.01 |
| 4 | 26 | 0.14 | 150 - 159 | 2 | 0.01 |
| 5 | 26 | 0.14 | 160 - 169 | 0 | 0.00 |
| 6 | 19 | 0.10 | 170 - 179 | 5 | 0.02 |
| 7 | 18 | 0.09 | 180 - 189 | 23 | 0.09 |
| 8 | 14 | 0.07 | 190 - 199 | 19 | 0.08 |
| 9 | 8 | 0.04 | 200 - 209 | 24 | 0.10 |
| 10 | 2 | 0.01 | 210 - 219 | 9 | 0.04 |
| 11 | 0 | - | 220 - 229 | 4 | 0.02 |
| 12 | 0 | - | 230 - 239 | 4 | 0.02 |
| | | | 240 - 249 | 3 | 0.01 |
| **Total** | **200** | | 250 - 259 | 11 | 0.05 |
| | | | 260 - 269 | 5 | 0.02 |
| | | | 270 - 279 | 8 | 0.03 |
| | | | 280 - 289 | 14 | 0.06 |
| | | | 290 - 299 | 11 | 0.05 |
| | | | 300 - 309 | 5 | 0.02 |
| | | | 310 - 319 | 9 | 0.04 |
| | | | 320 - 329 | 6 | 0.02 |
| | | | 330 - 339 | 11 | 0.05 |
| | | | 340 - 349 | 13 | 0.05 |
| | | | 350 - 359 | 22 | 0.09 |
| | | | 360 - 369 | 10 | 0.04 |
| | | | 370 - 379 | 10 | 0.04 |
| | | | 380 - 389 | 5 | 0.02 |
| | | | 390 - 399 | 8 | 0.03 |
| | | | 400 - 409 | 0 | 0.00 |
| | | | 410 - 419 | 0 | 0.00 |
| | | | 420 - 429 | 0 | 0.00 |
| | | | **Total** | **242** | |

**Appendix B3.**–Estimated proportion, by age class and 10-mm length categories, for Arctic grayling ≥ 250 mm FL from the Chena River study area, 2002.

| Age (years) | Count | Proportion | SE | Length (mm FL) | Count | Proportion | SE |
|---|---|---|---|---|---|---|---|
| 2 | 0 | 0.00 | 0.00 | 250 – 259 | 7 | 0.02 | 0.01 |
| 3 | 4 | 0.02 | 0.01 | 260 – 269 | 21 | 0.07 | 0.01 |
| 4 | 27 | 0.11 | 0.02 | 270 – 279 | 25 | 0.08 | 0.02 |
| 5 | 66 | 0.26 | 0.03 | 280 – 289 | 28 | 0.09 | 0.02 |
| 6 | 55 | 0.22 | 0.03 | 290 – 299 | 19 | 0.06 | 0.01 |
| 7 | 60 | 0.24 | 0.03 | 300 – 309 | 7 | 0.02 | 0.01 |
| 8 | 30 | 0.12 | 0.02 | 310 – 319 | 29 | 0.09 | 0.02 |
| 9 | 12 | 0.05 | 0.01 | 320 – 329 | 23 | 0.07 | 0.01 |
| 10 | 0 | 0.00 | 0.00 | 330 – 339 | 23 | 0.07 | 0.01 |
| 11 | 0 | 0.00 | 0.00 | 340 – 349 | 34 | 0.11 | 0.02 |
| 12 | 0 | 0.00 | 0.00 | 350 – 359 | 25 | 0.08 | 0.02 |
| | | | | 360 – 369 | 26 | 0.08 | 0.02 |
| **Total** | **254** | | | 370 – 379 | 22 | 0.07 | 0.01 |
| | | | | 380 – 389 | 13 | 0.04 | 0.01 |
| | | | | 390 – 399 | 10 | 0.03 | 0.01 |
| | | | | 400 – 409 | 3 | 0.01 | 0.01 |
| | | | | 410 – 419 | 2 | 0.01 | 0.00 |
| | | | | 420 – 429 | 0 | 0.00 | 0.00 |
| | | | | **Total** | **317** | | |

**Appendix B4.**–Estimated proportion, by age class and 10-mm length categories, for Arctic grayling ≥ 250 mm FL from the Chatanika River study area, 2002.

| Age (years) | Count | Proportion | SE | Length (mm FL) | Count | Proportion | SE |
|---|---|---|---|---|---|---|---|
| 2 | 0 | 0.00 | 0.00 | 160 – 249 | 93 | 0.73 | 0.10 |
| 3 | 4 | 0.04 | 0.02 | 250 – 259 | 11 | 0.02 | 0.02 |
| 4 | 22 | 0.20 | 0.04 | 260 – 269 | 5 | 0.03 | 0.01 |
| 5 | 24 | 0.22 | 0.04 | 270 – 279 | 8 | 0.05 | 0.02 |
| 6 | 19 | 0.17 | 0.04 | 280 – 289 | 14 | 0.09 | 0.02 |
| 7 | 18 | 0.16 | 0.03 | 290 – 299 | 11 | 0.07 | 0.02 |
| 8 | 14 | 0.13 | 0.03 | 300 – 309 | 5 | 0.03 | 0.01 |
| 9 | 8 | 0.07 | 0.02 | 310 – 319 | 9 | 0.06 | 0.02 |
| 10 | 2 | 0.02 | 0.01 | 320 – 329 | 6 | 0.04 | 0.02 |
| 11 | 0 | 0.00 | 0.00 | 330 – 339 | 11 | 0.07 | 0.02 |
| 12 | 0 | 0.00 | 0.00 | 340 – 349 | 13 | 0.09 | 0.02 |
| | | | | 350 – 359 | 22 | 0.15 | 0.03 |
| **Total** | **111** | | | 360 – 369 | 10 | 0.07 | 0.02 |
| | | | | 370 – 379 | 10 | 0.07 | 0.02 |
| | | | | 380 – 389 | 5 | 0.03 | 0.01 |
| | | | | 390 – 399 | 8 | 0.05 | 0.02 |
| | | | | 400 – 409 | 0 | 0.00 | 0.00 |
| | | | | 410 – 419 | 0 | 0.00 | 0.00 |
| | | | | 420 – 429 | 0 | 0.00 | 0.00 |
| | | | | **Total** | **242** | | |

# APPENDIX C

## DATA FILE LISTING

**Appendix C1.-**Data files[a] for all Arctic grayling sampled in the Chena and Chatanika rivers, 2002.

| Data file | Description |
|---|---|
| Chena data 2002.xls | Sample data from Chena River, 2002. |
| Chatanika data 2002.xls | Sample data from Chatanika River, 2002. |

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.