Fishery Data Series No. 07-18

# Length and Age at Maturity of Arctic Grayling in the Snake River during 2003

by

Alfred L. DeCicco

and

Andrew D. Gryska

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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. 07-18*

# LENGTH AND AGE AT MATURITY OF ARCTIC GRAYLING IN THE SNAKE RIVER DURING 2003

By
Alfred L. DeCicco
and
Andrew D. Gryska
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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*Alfred L. DeCicco,*
*Alaska Department of Fish and Game, Division of Sport Fish,*
*1300 College Road, Fairbanks AK 99701, USA*
*and*
*Andrew D. Gryska,*
*Alaska Department of Fish and Game, Division of Sport Fish*
*1300 College Road, Fairbanks, AK 99701, USA*

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# ABSTRACT

Length and age at maturity were estimated for Arctic grayling *Thymallus arcticus* sampled from the Snake River during late May 2003. These estimates were attained to determine if at least 50% of Arctic grayling ≥ 15-in TL (~350-mm FL) length limit for the Snake River were mature. Hook-and-line gear and beach seines were utilized to capture fish. Most fish (252) were captured by hook-and-line, and 49 fish were captured using a beach seine. Sexual maturity and gender were identified for 231 fish, of which 162 were males and 69 were females. Sex was determined as immature or unknown for 65 fish. The smallest mature fish was 263 mm FL. Probit analysis was used to estimate length at maturity. An estimated 1% of fish were mature at 210 mm FL, 50% were mature at 307 mm FL, and 99% were mature at 404 mm FL. Age at maturity could not be estimated with confidence using probit analysis due to poor model fit. The youngest observed mature fish were age-4, at age-6, 83% were mature, and virtually all (97%) were mature at age-7 and older. The results demonstrated the average length at 99% maturity for Snake River Arctic grayling was about 17.25 in TL. Using probit analysis, about 85% maturity was estimated at 15 in TL. Current regulations limiting the harvest of Arctic grayling to only one fish over 15 in TL per day appear to satisfactorily allow all harvested fish at least a 50% chance of spawning once before being harvested. It is likely that other Arctic grayling stocks on the Seward Peninsula have similar maturity schedules.

Key words: Arctic grayling, *Thymallus arcticus*, maturity, size composition, probit analysis, hook-and-line, Snake River, Alaska.

# INTRODUCTION

The Seward Peninsula of western Alaska has many rivers and streams that are easily accessible by way of an extensive road system (approximately 420 km in length), which emanates from Nome (Figure 1). Most streams along this road system support some angling effort for Arctic grayling, including the Snake River, by many of the 9,200 residents of the Nome census area (U.S. Census Bureau 2001), as well as numerous tourists.

The Snake River is approximately 57 km in length and drains an area south of the Sinuk River between the Nome River to the east and the Cripple River to the west and enters the Bering Sea at Nome (Figure 1) where it serves as the port for Nome. The Snake River is accessible from the Nome-Teller Highway where it crosses the river and from Glacier Creek road, a gravel road that parallels much of the upper river (Figure 2).

Between of its proximity to Nome and good access, the Snake River is a relatively popular location for sport fishing. Estimated annual sport fishing effort on the Snake River has averaged 948 angler days since 1983. The daily bag and possession limit for Arctic grayling on the Snake River has varied over this period. Prior to 1988 the daily limit was 15 fish of which only two could be over 20 inches. From 1988 to 1992 the daily limit was five fish of which only one could be over 15 inches (350 mm TL), and since 1993, the limit has been two fish of which only one may be over 15 inches. Estimated annual harvests of Arctic grayling from the Snake River for these periods have averaged 306 fish (1983-1988), 159 fish (1988-1992) and 98 fish (1993-2004). The Snake River and many other Nome area streams are known for producing large Arctic grayling and the 15-in length restriction was implemented to afford some protection of larger fish that were assumed to be sexually mature. In general, streams with roadside access have more stringent regulations (5 grayling/day and only one may be ≥ 15 in TL) than the background regulations that are applied to the remote streams of the Seward Peninsula (5 grayling/day and no size limit, formerly 10 grayling/day and no size limit prior to 2004).

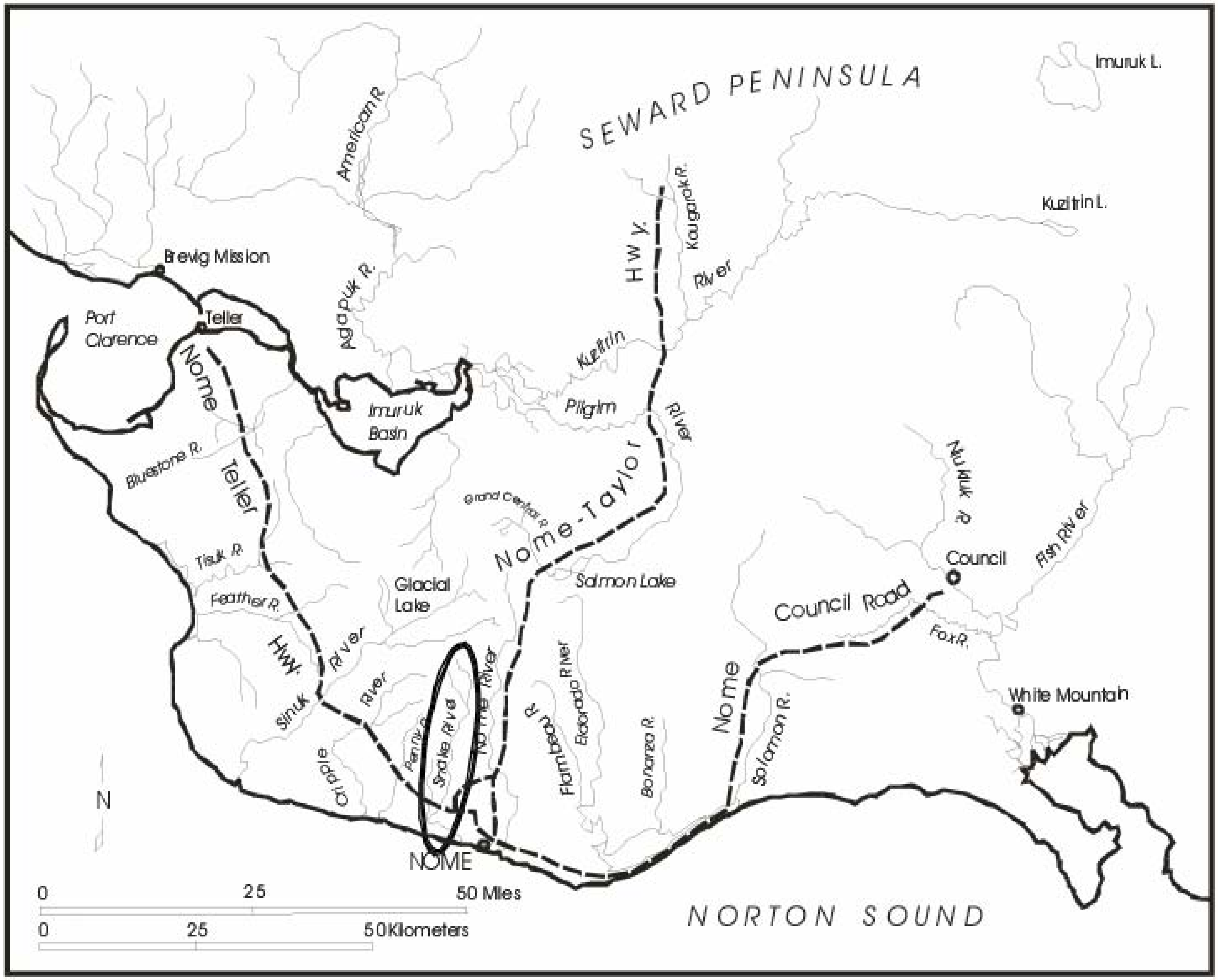


**Figure 1.–**Southern Seward Peninsula showing the location of the Snake River.

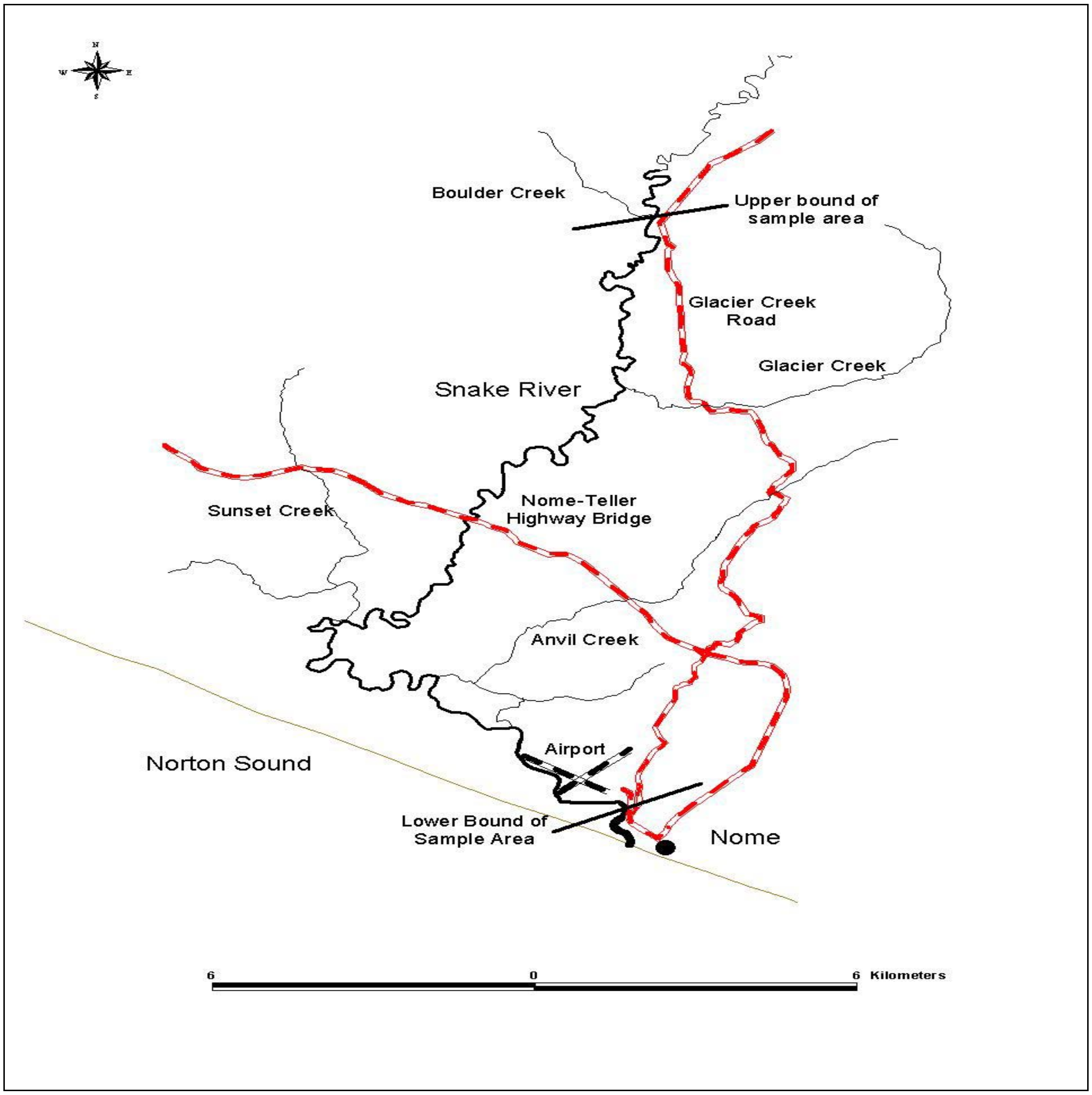


**Figure 2.–**Location of Snake River sampling areas during spring 2003.

It has been reported that the Arctic grayling populations in the Seward Peninsula are small, annual recruitment is low, growth to large size (about 350 mm FL) is fast, and the populations are dominated by large, long-lived, mature fish (Merritt 1989; DeCicco 1990-1992, 2001, 2002a-b). The Seward Peninsula regulations were designed to protect small populations by limiting the overall harvest and to protect the large, mature fish because of their importance in sustaining the population since the rate of recruitment is low. These long-lived fish (up to 30 years) are not quickly replaced due to low and episodic recruitment (i.e., multiple year class failures; DeCicco 2001, 2002a).

The goal of this study was to collect maturity information on Arctic grayling on the Seward Peninsula to: 1) improve our biological knowledge of Arctic grayling populations across Alaska; and, 2) to provide information needed to evaluate regulations. Region-specific data on size and age at maturity is valuable for developing Arctic grayling management strategies. Length at maturity of Arctic grayling varies by water body (Table 1; Clark 1992; Gryska 2003), and even though it has been assumed that the length at maturity of Seward Peninsula Arctic grayling is larger than for the Tanana drainage (i.e., 350 vs. 238-316 mm FL; Clark 1992), this assertion had not been evaluated (DeCicco 2002a) by sampling Arctic grayling on the Seward Peninsula during the spawning period. The Snake River was selected for study because it was an exploited fishery near Nome and it contained a relatively large population of Arctic grayling (Table 2). An exploited stream was preferred because regulations for roadside fisheries are more likely to be modified and a relatively large population was preferred so that an appropriate sample of spawners and non-spawners across a wide range of sizes could be obtained.

**Table 1.–**Estimated length and age at which 50% of a stock of Arctic grayling were mature in several locations within the Tanana River drainage and Jim River**.**

| | Length at 50% maturity | | | Age at 50% maturity | | |
|---|---|---|---|---|---|---|
| | | 95% C.I. | | | 95% C.I. | |
| Location | FL (mm) | Lower | Upper | Age | Lower | Upper |
| Mineral Lake | 238 | - | - | 4 | 3 | 5 |
| Chatanika River | 243 | 240 | 245 | 5 | 5 | 5 |
| Piledriver slough | 244 | 241 | 247 | 4 | 4 | 5 |
| Badger Slough | 270 | 253 | 311 | 5 | 4 | 6 |
| Chena River | 271 | 268 | 278 | 6 | 5 | 6 |
| Fish Creek | 275 | 270 | 280 | - | - | - |
| Goodpaster River | 276 | 273 | 279 | 6 | 6 | 6 |
| Caribou Creek | 279 | - | - | 5 | 5 | 5 |
| Tangle Lake | 289 | 254 | 302 | 5 | 5 | 5 |
| Salcha River | 304 | 294 | 316 | 5 | 5 | 6 |
| Fielding Lake | 316 | 303 | 328 | 6 | 6 | 6 |
| Jim River[b] | 296 | 292 | 299 | 7 | 6.7 | 7.2 |

Source: Tanana River drainage data from Clark (1992).

Source: Jim River data from Gryska (2003).

**Table 2.–**Estimated abundance, SE, 95% C.I., and number of fish/km for Arctic grayling ≥ 250 mm FL in the Snake River between the Nome–Teller Highway Bridge and Boulder Creek (14.7 km) as estimated through mark-recapture experiments (DeCicco 1992-1996; Gryska 2004).

| Year | Period | Abundance | SE | 95 % C.I. | Fish/km |
|---|---|---|---|---|---|
| 1991 | 6/24-6/26 – 7/1-7/3 | 948 | 147 | 660 - 1,236 | 64 |
| 1992[a] | 7/6-7/9 – 8/10-8/13 | 1,702 | 207 | 1,296 - 2,108 | 116 |
| 1993 | 6/30-7/2 – 7/13-7/16 | 1,222 | 107 | 1,012 - 1,432 | 83 |
| 1994 | 6/29-7/1 – 7/6-7/8 | 1,253 | 342 | 583 - 1,923 | 85 |
| 2001 | 8/1-8/4 – 8/6-8/8 | 1,054 | 102 | 854 - 1,254 | 72 |

[a] Indicates a population estimate significantly different than the 2001 estimate at the 95% confidence level.

# OBJECTIVES

The objectives of this project were to:

1. estimate the proportion of Arctic grayling (≥ 230 mm FL) in the Snake River study area that were sexually mature at each given length category (FL mm) such that the estimate of the proportion in a given length category was within 10 percentage points of the actual value 90% of the time; and,
2. estimate the proportion of Arctic grayling (≥ 230 mm FL) in the Snake River study area that were sexually mature at each given age category (ages 3 – 6 and age-7+) such that the estimate of the proportion in a given age category was within 10 percentage points of the actual value 90% of the time.

An additional task was to examine tundra ponds and tributaries in the study area for spawning activity and to sample any fish encountered for maturity.

The objectives were restricted to fish ≥ 230 mm FL because the capture gear cannot effectively capture smaller sized fish.

# METHODS

Arctic grayling from the Snake River were sampled to examine maturity during the brief spawning season. To access the sampling areas, a two-person crew drifted in an inflatable raft from Boulder Creek to a point downstream of the Nome Airport (Figure 2). Two systematic, downstream sampling passes were completed, from May 21 to 27 and May 28 to 30, which were timed to coincide with spawning (Figure 2). Arctic grayling spawn at approximately 4-6°C (Tack 1980; Armstrong 1986; Northcote 1995) and water temperatures were measured every day to ensure sampling occurred near the spawning period.

Boulder Creek was selected as the starting area to determine if the distribution of fish during spring was similar to what has been observed in previous years (1991-1994). It was suspected, as in other Arctic grayling populations, that most of the population would be located in the lower reaches of the river during spawning (Ridder 2000). During the summers of 1992-1994, a pronounced downstream-to-upstream gradient of small to large fish was observed with a marked difference occurring roughly near the Nome-Teller Bridge (DeCicco 1993-1995). For example, among all 3 years combined the average size of an Arctic grayling sampled downstream of the bridge was 300 mm FL (n = 727) and was 358 mm FL (n = 1,566) upstream of the bridge to Boulder Creek.

During the first sampling pass in this study, the clear, transparent water was conducive to visually identifying and targeting both low-density (e.g., one to few fish) and high-density areas (e.g., 10 or more fish) and thereby aiding in the distribution of effort in rough approximation to fish densities. Because only a few Arctic grayling were found upstream from the Nome-Teller Highway and because samples sizes had not been attained, particularly for small fish, a second abbreviated sampling pass was conducted from 1.5 km upstream of the Nome-Teller Highway Bridge to 3.0 km downstream of Sunset Creek. Based on the visual surveys and catches, most of the population (spawning and non-spawning fish) was within this reach.

Arctic grayling were captured using a beach seine (50 x 2 m, 6.5 mm mesh) and hook-and-line gear (fly-fishing and spin fishing), and each gear type was fished wherever it was possible and most effective as determined by the crew (e.g., the beach seine was not used where there were large rocks or a large amount of woody debris).

Captured Arctic grayling were held in a tub filled with clean river water until a few were captured. They were then measured for length, inspected for sex and maturity, fin-clipped to avoid resampling and released. Sex was determined and scales were removed for age determination. Fork length was measured and recorded to the nearest millimeter. Scales were placed in coin envelopes in the field and later cleaned and mounted on gummed cards in the lab. A minimum of two scales was taken approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder *Unpublished*; Brown 1943). The sex of each Arctic grayling was determined by external characteristics or the presence of milt or eggs with slight pressure to the abdomen. Dimorphism manifested itself in some fish by differences in the height of the dorsal fin and in the shape of the pelvic fins. Generally the dorsal fin is taller on males (often extending beyond the adipose fin when laid onto the back) than on females, and males have longer and more pointed pelvic fins (Bishop 1967). In addition, females were differentiated by the presence of a swollen anal vent, abdominal fullness for gravid females, or abdominal flaccidity for spawned-out females (Ridder 1989). Fish for which sex was identified were considered mature. Fish, for which there was some question of sex, were considered immature.

Upon completion of fieldwork, collected Arctic grayling scales were taken to Fairbanks and processed for age determination. Scale impressions were made on 20-mm acetate sheets using a Carver press at 137,895 kPa heated to 97º C for 30 s from scales collected in the field. Ages were determined by counting annuli from the triacetate impressions magnified to 40x with a microfiche reader. Criteria used in determining an annulus were when: 1) complete circuli having cut over incomplete circuli; 2) clear areas or irregularities in circuli were present along the anterior and posterior fields; and, 3) a region of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959).

Proportions of sexually mature fish within length categories were calculated for two length scales. One-inch (25 mm TL) length groups were assessed because the fishery is regulated using English measures (i.e., inches). Ten-mm FL groups were also assessed to correspond to prior research (Clark 1992). The proportion of sexually mature fish within length category, k, and its variance were calculated similarly for each length scale using methods in Cochran (1977):

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

$$\hat{V}\left(\hat{p}_k\right) = \hat{p}_k\left(1 - \hat{p}_k\right) / \left(n_k - 1\right) \tag{2}$$

where: $\hat{p}_k$ = the estimated proportion of Arctic grayling that were sexually mature in the $k^{th}$ length category;

$x_k$ = the number of Arctic grayling in the sample that were in the $k^{th}$ length category and were sexually mature; and,

$n_k$ = the number of Arctic grayling in the sample that were in the $k^{th}$ length category.

Similar calculations were made for estimating the proportion of sexually mature fish within an age category. For each category, k, the sample size needed to fulfill the objective criteria for precision and accuracy (percent maturity estimates within ten percentage points of the true value 90% of the time) was estimated to be 68 Arctic grayling using methods in Cochran (1977). In doing so, the proportion of mature fish was assumed to be 0.5 in order to address the worst-case scenario (i.e., maximum sample size).

Probit analysis was performed to estimate the length and age at 1%, 50%, and 99% maturity. Use of this model to describe maturity distributions is appropriate when the true distribution shows successive increases in the proportion of mature fish, and if these proportions range from 0%-100% for successive age or length categories (type-2 distribution: Trippel and Harvey 1991). This type of distribution has been observed with other Arctic grayling populations (Clark 1992; Gryska 2003). The length or age, number examined, and number mature were treated as the dosage, sample size, and response, respectively in the probit analysis (Finney 1971). The Statistical Analysis System (SAS) PROC PROBIT was used to estimate these corresponding lengths and ages and their 95% confidence limits. The SAS procedure also tested goodness-of-fit to the probit model with a Pearson chi-squared test and likelihood-ratio test.

Total lengths were estimated by dividing fork lengths with a conversion factor of 0.92 (Grabacki 1981).

Electronic data files were archived as described in Appendix A.

# RESULTS

During 2003, 301 Arctic grayling (≥ 225 mm FL) were captured by hook-and-line and with a beach seine. Of the 301 fish, 162 were male, 69 were female, and 70 were of undetermined gender and were judged to be immature. Two hundred nine Arctic grayling were captured during the first pass and 91 were captured during the second pass. The length compositions of these Arctic grayling were shown to be similar between passes using a Kolmogorov-Smirnov test (D-value = 0.124; P-value = 0.18). Also, the proportion of mature arctic grayling was shown to be similar between sampling passes using a chi-square test ($\chi^2$ = 0.56, P-value = 0.46). As a result, the data were pooled for subsequent analyses.

The smallest observed mature male was 263 mm FL and the smallest mature female was 267 mm FL. Nearly all (91%) of all fish between 351 and 373 mm FL (15 to 15.9 in TL) were mature (Tables 3 and 4). One hundred percent maturity was observed between 397 and 420 mm FL (17 – 17.9 in TL). Only three of the 184 Arctic grayling ≥350 mm FL (1.6%) did not have observable sexual characteristics and were classified immature. The Pearson chi-squared test and likelihood-ratio (L.R.) test both indicated that the probit model fit the full dataset (35 categories) well ($\chi^2$ = 17.47, P-value = 0.786; L.R. $\chi^2$ = 19.63, P-value = 0.664). It was estimated that 1% of fish were mature at 201 mm FL (8.9 in TL), 50% were mature at 307 mm FL (13.1 in TL), and 99% were mature at 404 mm FL (17.3 in TL; Table 5). About 85% maturity was estimated at 15 in TL (Appendix B).

**Table 3.–**Estimates of proportion mature by age (year) and fork length (mm) for Arctic grayling collected from the Snake River during spring 2003.

| Age Group | Number Sampled | Number Mature | Proportion Mature | SE (Prop) | Length Group | Number Sampled | Number Mature | Proportion Mature | SE (Prop) |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 0 | 0.00 | 0.000 | 220-229 | 2 | 0 | 0.00 | 0.000 |
| 4 | 20 | 12 | 0.40 | 0.112 | 230-239 | 0 | 0 | 0.00 | 0.000 |
| 5 | 53 | 21 | 0.40 | 0.068 | 240-249 | 1 | 0 | 0.00 | 0.000 |
| 6 | 52 | 43 | 0.83 | 0.053 | 250-259 | 3 | 0 | 0.00 | 0.000 |
| 7+ | 99 | 95 | 0.96 | 0.020 | 260-269 | 10 | 3 | 0.30 | 0.153 |
| | | | | | 270-279 | 13 | 4 | 0.31 | 0.133 |
| | | | | | 280-289 | 10 | 3 | 0.30 | 0.153 |
| | | | | | 290-299 | 18 | 8 | 0.44 | 0.121 |
| | | | | | 300-309 | 16 | 9 | 0.56 | 0.128 |
| | | | | | 310-319 | 14 | 5 | 0.38 | 0.133 |
| | | | | | 320-329 | 13 | 7 | 0.54 | 0.144 |
| | | | | | 330-339 | 10 | 4 | 0.40 | 0.163 |
| | | | | | 340-349 | 7 | 7 | 1.00 | 0.000 |
| | | | | | 350-359 | 9 | 7 | 0.78 | 0.147 |
| | | | | | 360-369 | 7 | 7 | 1.00 | 0.000 |
| | | | | | 370-379 | 21 | 20 | 0.95 | 0.048 |
| | | | | | 380-389 | 15 | 15 | 1.00 | 0.000 |
| | | | | | 390-399 | 26 | 26 | 1.00 | 0.000 |
| | | | | | 400-409 | 20 | 20 | 1.00 | 0.000 |
| | | | | | 410-419 | 17 | 17 | 1.00 | 0.000 |
| | | | | | 420-429 | 13 | 13 | 1.00 | 0.000 |
| | | | | | 430-439 | 20 | 20 | 1.00 | 0.000 |
| | | | | | 440-449 | 18 | 18 | 1.00 | 0.000 |
| | | | | | 450-459 | 6 | 6 | 1.00 | 0.000 |
| | | | | | 460-469 | 8 | 8 | 1.00 | 0.000 |
| | | | | | 470-479 | 1 | 1 | 1.00 | 0.000 |
| | | | | | 480-489 | 3 | 3 | 1.00 | 0.000 |

**Table 4.–**Estimates of maturity in one-inch length categories for Arctic grayling sampled from the Snake River during spring 2003.

| Length Group | | | | | |
|---|---|---|---|---|---|
| Total Length (in) | Fork Length (mm) | Number Sampled | Number Mature | Proportion Mature | SE(Prop) |
| 9 – 9.9 | 210-233 | 2 | 0 | 0.00 | 0.000 |
| 10 – 10.9 | 234-256 | 3 | 0 | 0.00 | 0.000 |
| 11 – 11.9 | 257-279 | 24 | 7 | 0.29 | 0.095 |
| 12 – 12.9 | 280-303 | 34 | 15 | 0.44 | 0.086 |
| 13 – 13.9 | 304-326 | 36 | 16 | 0.44 | 0.084 |
| 14 – 14.9 | 327-350 | 19 | 13 | 0.68 | 0.110 |
| 15 – 15.9 | 351-373 | 22 | 20 | 0.91 | 0.063 |
| 16 – 16.9 | 374-396 | 47 | 46 | 0.98 | 0.021 |
| 17 – 17.9 | 397-420 | 46 | 46 | 1.00 | 0.000 |
| 18 – 18.9 | 421-443 | 39 | 39 | 1.00 | 0.000 |
| 19 – 19.9 | 444-465 | 23 | 23 | 1.00 | 0.000 |
| 20 – 20.9 | 466-488 | 6 | 6 | 1.00 | 0.000 |
| Total | | 301 | 231 | 0.77 | 0.024 |

**Table 5.–**Fork length for 1%, 50%, and 99% sexual maturity from probit analysis.

| Percent Sexually Mature | Length | 95% Limits |
|---|---|---|
| 1 | 201 mm FL | 175 – 231 mm FL |
| 50 | 307 mm FL | 297– 316 mm FL |
| 99 | 404 mm FL | 386 – 432 mm FL |

All fish through age 3 were immature and 60% were immature at age-4 and age-5 (Table 3). At age-6, 83% of fish were mature and virtually all (97%) were mature at age-7 and older. There was a significant lack of fit observed in the probit analysis (Pr $\chi^2$ = 35.50, P-value = <0001; L.R. $\chi^2$ = 13.51, P-value = 0.036), therefore, estimates of maturity by age class were not calculated using this method.

Water temperatures ranged from 1.75°C to 7°C over the course of this study. Temperatures were generally higher in the lower reaches of the drainage at the launch area near the airport. They typically increased throughout the day and cooled during the night. Some days (May 25 and 26) were cool with light snow, and water temperatures never reached 4°C (Table 6).

**Table 6.–**Water temperatures in degrees Celsius within the study area.

| | Boat Launch (airport) | | | Sampling Area (approximate time of day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Morning | Noon | Evening | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 |
| 20-May | | 4.00 | | | | | | | |
| 21-May | | | | | | | | | |
| 22-May | 3.00 | | | 1.75 | 2.25 | 2.50 | 3.75 | 5.25 | 5.50 |
| 23-May | | | | 2.60 | 2.75 | 3.50 | 4.00 | 5.00 | |
| 24-May | 3.50 | | | 2.00 | | | 4.50 | 5.50 | |
| 25-May | 4.75 | | | | 3.00 | | 4.00 | 4.25 | |
| 26-May | | 3.75 | | | | | | 3.25 | |
| 27-May | 3.00 | | 3.25 | | | 3.00 | 3.25 | 3.25 | |
| 28-May | 2.75 | | 6.25 | 2.00 | 3.00 | 4.50 | 5.50 | 6.00 | 6.25 |
| 29-May | 5.00 | | 7.00 | | 3.50 | 4.50 | | 6.50 | 7.00 |
| 30-May | 5.00 | | | | | | | | |

# DISCUSSION

Tack (1980) reported that Arctic grayling spawning commenced when springtime water temperatures reached 3.9$^{o}$C in both bog fed and rapid runoff streams of the Tanana drainage and that spawning activity moved upstream following the 3.9$^{o}$C isotherm. The first spawning activity that we observed was on the afternoon of May 22 as the temperature warmed from about 4$^{o}$C to 5$^{o}$C. Prior to May 22 we were in the upstream part of the sampling area (above the bridge) where water was cooler and few fish were observed, so it is possible that some spawning had occurred in the lower river before we first began sampling there on May 22.

An unbiased estimate of the maturity schedule of a population of fish can only be attained when all sizes and ages of fish are present in the sample (Maki et al. 2001), and when the probabilities of capture of mature and immature fish within a length or age category are equal. In this study, most fish were sampled on or near the spawning grounds during the spawning period because fishing in these areas was most productive, and very few fish were found outside this area. Because of the possibility that mature fish had a greater tendency to be present on spawning grounds than immature fish, the assumption of equal probability of capture of mature and immature fish within a length or age category may have been violated. If so, then the samples will have yielded estimated length- and age-specific proportions of mature fish that were biased high.

Although the magnitude of the bias cannot be quantified, the study was designed to minimize the potential for bias, and there was evidence that mature and immature fish were not segregated during sampling. After the first sampling pass, it was determined that a large majority (e.g., >95%) of the Snake River population was downstream of the Nome-Teller Bridge based on the visual surveys and catches. Among 209 fish captured during the first pass, only 1 fish was caught and 2 fish observed between Boulder Creek and a point approximately 1.5 km upstream of the bridge. This permitted a more focused second sampling pass from 1.5 km upstream of the bridge to Anvil Creek to better distribute effort among spawning and non-spawning areas and to attain sample sizes because catches were low, particularly for smaller-sized fish (e.g., < 300 mm FL). In focusing on a smaller area during the second pass where most of the population was present, it was assumed that the ratio of mature to immature fish in the focused sampling area was representative of the population. During sampling, the crew was cognizant of avoiding disproportionate sampling of spawning areas and the clear water conditions allowed fish in non-spawning areas or refugia (e.g., fish positioned along side brushy cut-banks of a pool, side channel, or sloughs) to be easily identified and targeted. Although notes on habitat type were not taken for all fish sampled, data from a group of fish sampled from a known non-spawning area near the mouth of Sunset Creek demonstrated that there was no evidence of segregation of Arctic grayling by maturity status. For smaller-sized fish $\leq$300 mm FL, nearly half (n = 28) of all sampled (n = 57) were captured from the vicinity of mouth of Sunset Creek, and no significant difference was found between the proportion immature for the “Sunset Creek fish” (22%) versus the proportion mature (38%) for all other fish $\leq$300 mm FL sampled in the Snake River ($\chi^2$=1.83, P-value = 0.18).

The premise of structuring length limits in the sport fishery using a maturity schedule is to ensure there is sufficient egg production to sustain adequate levels of recruitment, which can be episodic in nature, in light of moderate fishing mortality and natural mortality. For Arctic grayling in the Tanana River basin a 12-inch minimum length limit (length at which 50% of Arctic grayling were mature) was instituted at a time when bag limits were more liberal (e.g., 5 to 10 fish per day of any size) to ensure that all harvested fish have had at least a 50% chance of spawning at least once because many of the stocks could be easily overexploited, such as that in the Chena River (Clark 1992). Because of the desire to maintain the size structure of Arctic grayling populations in Seward Peninsula streams where many populations are dominated by large, old fish, management requires a more conservative approach than in other areas of the state. The one fish over 15-in length limit (350 mm FL) was imposed to protect the spawning component of the population, minimize exploitation of large fish, and maintain the natural size composition of the spawning population. The length limit was chosen to be 15-in because growth slows at about this size and it was assumed that reduced growth was a result of fish channeling energy to gamete production. The more conservative regulations are needed for Nome-area, road-side accessible streams because population sizes are relatively small and would be vulnerable to overexploitation if bag limits were liberal, particularly because measurable recruitment on the Seward Peninsula may occur only once every 5 to 10 years (DeCicco 2002b).

The results of this study support retaining the reduced bag limit for fish over 15-in for the Snake River because it conservatively protects egg production and the existing size composition of the population. In this study nearly 100% maturity occurred above 350 mm FL (15 in TL) as only three out of 183 (1.6%) fish sampled were immature and the probit analysis indicated about 85% maturity at 15 in TL. Bias resulting from under sampling immature fish, if present, would not likely affect this choice of length limit because the bias was minimized by design and because estimates of maturity rates in the 80-100 percent range are relatively robust to such bias. As long as effort and harvest remain relatively stable, the existing bag and size limits should ensure that desired population characteristics and annual egg deposition that will allow for recruitment to the population are maintained.

Among Arctic grayling populations for which maturity (i.e., length or age at 50% maturity) has been estimated, the Snake River at 307 mm FL ranked second to Fielding Lake in terms of length (Table 2), however when examined by age, the Snake River stock was similar in terms of age (age-6) to most of the Tanana River populations, including Fielding Lake. This relatively early maturation relative to size is attributed to their rapid early growth. It is likely that these fish experience rapid growth prior to maturity due to the moderating effect of the coastal climate near Nome and the presence of large runs of pink salmon that bring a large quantity of marine nutrients to the freshwater systems (Bilby et al. 1996; Klein et al. 1997; Larkin and Slaney 1997; Michael 1995).

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# APPENDIX A
# DATA SUMMARIES

**Appendix A1.–**Data files for all Arctic grayling captured in the Snake River, 2003.

| Data file | Description |
| --- | --- |
| Snake River Maturity Data.csv | Sample data from 2003. |
| Snake River Maturity Analysis.xls | Sample data from 2003. |

[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.

# APPENDIX B
# RESULTS OF PROBIT ANALYSIS

**Appendix B1–**Results of probit analysis on maturity of Arctic grayling by fork length in the Snake River, 2003.

| | | 95% Fiducial Limits | |
|---|---|---|---|
| Probability | Fork Length | Lower | Upper |
| 0.01 | 209.393 | 175.128 | 231.376 |
| 0.02 | 220.824 | 189.824 | 240.831 |
| 0.03 | 228.077 | 199.129 | 246.850 |
| 0.04 | 233.533 | 206.115 | 251.390 |
| 0.05 | 237.971 | 211.789 | 255.093 |
| 0.06 | 241.748 | 216.611 | 258.252 |
| 0.07 | 245.061 | 220.832 | 261.028 |
| 0.08 | 248.026 | 224.606 | 263.520 |
| 0.09 | 250.723 | 228.032 | 265.791 |
| 0.10 | 253.206 | 231.182 | 267.886 |
| 0.15 | 263.485 | 244.164 | 276.621 |
| 0.20 | 271.654 | 254.394 | 283.650 |
| 0.25 | 278.662 | 263.087 | 289.765 |
| 0.30 | 284.956 | 270.805 | 295.344 |
| 0.35 | 290.788 | 277.861 | 300.610 |
| 0.40 | 296.322 | 284.449 | 305.714 |
| 0.45 | 301.677 | 290.702 | 310.773 |
| 0.50 | 306.946 | 296.717 | 315.981 |
| 0.55 | 312.216 | 302.575 | 321.166 |
| 0.60 | 317.570 | 308.350 | 326.703 |
| 0.65 | 323.104 | 214.125 | 332.621 |
| 0.70 | 328.937 | 320.002 | 339.066 |
| 0.75 | 335.230 | 326.125 | 346.240 |
| 0.80 | 342.239 | 332.715 | 354.457 |
| 0.85 | 350.408 | 340.157 | 364.274 |
| 0.90 | 360.687 | 349.256 | 376.892 |
| 0.91 | 363.170 | 351.419 | 379.973 |
| 0.92 | 365.867 | 353.758 | 383.333 |
| 0.93 | 368.832 | 356.317 | 387.039 |
| 0.94 | 372.144 | 359.160 | 391.194 |
| 0.95 | 375.922 | 362.387 | 395.948 |
| 0.96 | 380.360 | 366.158 | 401.552 |
| 0.97 | 385.816 | 370.771 | 408.467 |
| 0.98 | 393.068 | 376.868 | 417.693 |
| 0.99 | 404.499 | 386.417 | 432.294 |