Fishery Manuscript No. 97-3

# Stock Assessment of Arctic Grayling in the Jim River and Other Streams Adjacent to the Dalton Highway, 1995 – 1997

by

James T. Fish

December 1997

Alaska Department of Fish and Game Division of Sport Fish

## 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 |
| metric ton | mt |
| milliliter | ml |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |
| Spell out acre and ton. | |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| hour (spell out for 24-hour clock) | h |
| minute | min |
| second | s |
| Spell out year, month, and week. | |

**Physics and chemistry**

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

**General**

| | |
|---|---|
| All commonly accepted abbreviations. | e.g., Mr., Mrs., a.m., p.m., etc. |
| All commonly accepted professional titles. | e.g., Dr., Ph.D., R.N., etc. |
| and | & |
| at | @ |
| Compass directions: | |
| east | E |
| north | N |
| south | S |
| west | W |
| Copyright | © |
| Corporate suffixes: | |
| Company | Co. |
| Corporation | Corp. |
| Incorporated | Inc. |
| Limited | Ltd. |
| et alii (and other people) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g., |
| 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 |
| number (before a number) | # (e.g., #10) |
| pounds (after a number) | # (e.g., 10#) |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S. state and District of Columbia abbreviations | use two-letter abbreviations (e.g., AK, DC) |

**Mathematics, statistics, fisheries**

| | |
|---|---|
| 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 | C.I. |
| correlation coefficient | R (multiple) |
| correlation coefficient | r (simple) |
| covariance | cov |
| degree (angular or temperature) | ° |
| degrees of freedom | df |
| divided by | ÷ or / (in equations) |
| equals | = |
| expected value | E |
| fork length | FL |
| 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. |
| mideye-to-fork | MEF |
| minute (angular) | ' |
| multiplied by | x |
| 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 |
| standard length | SL |
| total length | TL |
| variance | Var |

*FISHERY MANUSCRIPT SERIES NO. 97-3*

# STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE JIM RIVER AND OTHER STREAMS ADJACENT TO THE DALTON HIGHWAY, 1995 - 1997

by

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# ABSTRACT

The goal of this study was to collect baseline abundance and composition data for stocks of Arctic grayling *Thymallus arcticus* in rivers and streams crossed by the Dalton Highway. The Jim River supports the largest regional stock, as well as the largest harvest by sport anglers, of Arctic grayling. Estimated abundance during 1995 was 5,105 (SE = 1,103) fish reflecting a density of 240 Arctic grayling per km, while stock composition indicated that age-5 fish were most abundant. Estimated abundance during 1997 was 12,059 (SE = 2,650) fish, reflecting a density of 566 Arctic grayling per km. Stock composition revealed age-3 fish as being the most abundant. During 1996, abundance in Bonanza Creek was estimated to be 1,152 (SE = 445) fish, reflecting a density of 217 Arctic grayling per km, while abundance in Prospect Creek was estimated to be 770 (SE = 231) fish, with a density of 120 Arctic grayling per km. Age-6 were most abundant in Bonanza Creek, while age-2 fish were most abundant in Prospect Creek. Stock composition in Fish Creek indicated the age-4 fish were most numerous. Catch-per-unit-effort studies indicated that catchability of fish in the Jim River is not affected by accessibility from the highway, and that fishing pressure at easily accessible locations along the river is probably not great enough to cause changes in catchability throughout the summer. Modeling of growth data indicated that Arctic grayling sampled in the Jim River during 1995 grow slower than Arctic grayling in the Lower Chena River near Fairbanks.

Key words: Arctic grayling, *Thymallus arcticus,* Jim River, Bonanza Creek, Prospect Creek, Fish Creek, abundance estimate, length composition, age composition, CPUE, growth

# INTRODUCTION

The Dalton Highway, which spans 666 km (414 mi) from just north of Fairbanks to Deadhorse on the North Slope, was opened to the public during the spring of 1995 for recreational and tourist travel. North of the Yukon River lies the Arctic Circle, the Brooks Range Mountains (Continental Divide), and the coastal Arctic plain. Fishery resources north of the Arctic Circle, but south of the Brooks Range, are accessible from the Dalton Highway; yet relatively little life history and population dynamics information exists for these resources. In particular, Arctic grayling *Thymallus arcticus* constitute the largest sport fishery in this region of the State. Many streams and rivers that are crossed by the Dalton Highway are clear, rapid runoff streams which offer spring spawning and/or summer feeding habitat that Arctic grayling utilize (Tack 1980). While angling opportunities in these streams are relatively numerous, angling pressure is assumed to be light to moderate. Additionally, angling success is believed to be strongly influenced by precipitation patterns, where anglers catch fewer fish shortly after periods of heavy rainfall.

Of all the accessible roadside fishing opportunities in this area, the Jim River is thought to be the most productive, as well as most heavily fished, river that supports Arctic grayling. Catches of Arctic grayling are typically greater in the Jim River than in other streams within this area (Hallberg 1975, Netsch 1975, and as cited in the ADF&G 1993 Sport Fishery Management Plan for Arctic grayling in the Yukon drainage). Recent responses to the Statewide Harvest Survey (SWHS) confirm that the largest catch and harvest of Arctic grayling within this region typically come from Koyukuk River drainages, particularly the Jim River. The estimated catch of Arctic grayling in the Jim River during 1990-1996 has averaged 2,122 fish per year, while the estimated harvest has averaged 310 fish per year (Mills 1991-1994, Howe et al. 1995, Howe et al. 1996, Howe et al. *in press*).

The Jim River is approximately 86 km (~53 mi) in length, and originates in the Philip Smith Mountains, east of the Dalton Highway. It flows west to southwest into the South Fork of the Koyukuk River (Figure 1). The lower reaches of the Jim River, and its confluence with the

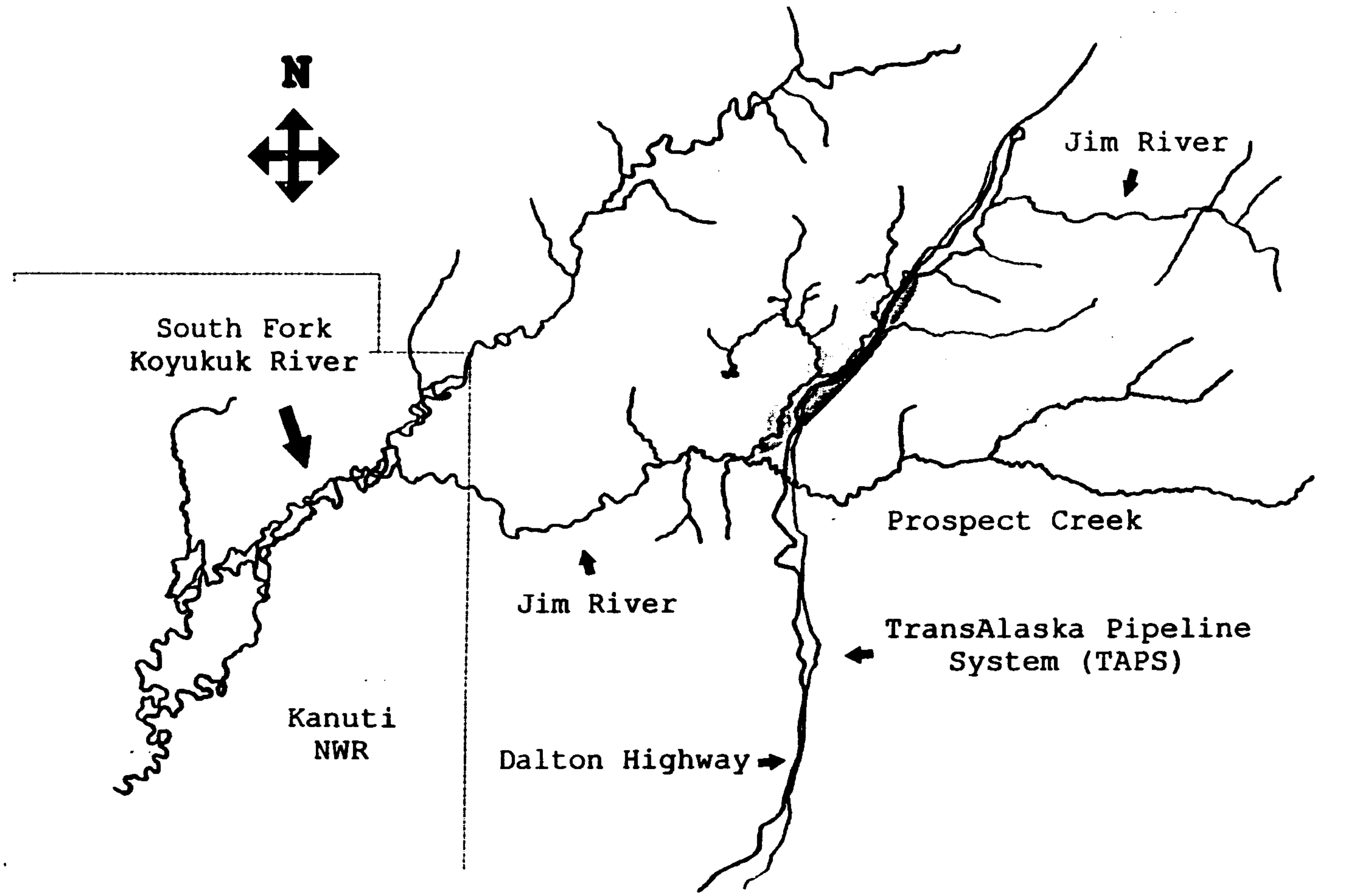



**Figure 1.-Jim River and surrounding area adjacent to the Dalton Highway. The stock assessment study area is denoted by the shaded area.**

Koyukuk River, are within the Kanuti National Refuge (Figure 1). The Dalton Highway crosses the Jim River in three places (Figure 2). Jim River supports the greatest catch of Arctic grayling by anglers fishing along the Dalton Highway, therefore it has been prioritized to collect being the river system along the Dalton Highway where research should be focused to collect baseline stock data and population trend information. A 21.3 km section of the Jim River was chosen for study because it encompasses the summer fishery and is assumed to be representative of Arctic grayling abundance in the Jim River. Convenient access locations along the highway have also facilitated ease of sampling (Figure 2).

Similar to the Jim River, Prospect, Bonanza and Fish creeks are also crossed by the Dalton Highway, and offer recreational Arctic grayling fishing opportunities readily accessible to the angling public (Figure 3). All of these streams originate from runoff. While Bonanza Creek feeds into Fish Creek, Prospect Creek empties into the Jim River (Figure 3). Both the Jim River and Fish Creek terminate at their confluence with the South Fork of the Koyukuk River. Although less heavily fished than the Jim River, these smaller streams support a light catch and harvest of Arctic grayling that is reported in the SWHS. Sections of the streams adjacent to the highway were also chosen for study because little to no data exists concerning characteristics of Arctic grayling stocks within these systems.

The use of fishery resources along the Dalton Highway is expected to increase each year as more people become aware of the uncrowded, road-accessible fishing and camping opportunities available. An increased recreational use of these fisheries may necessitate intensive sport fish management, especially for those areas where fishery resources are within easy walking distance from road crossings. It is suspected that in these areas stocks of Arctic grayling may be prone to "localized" depletions. For example, the conceptual model describing recreational harvest of Arctic grayling in the Jim River (and in other streams adjacent to a road system) assumes angling pressure to be concentrated at specific locations easily accessible to the angling public. It is believed that most anglers traveling the Dalton Highway fish in locations that are within walking distance from the road (~1/8 mi upstream and downstream from footpaths or road crossings or ~ ¼ mi total), where there may be one to four pools of suitable Arctic grayling habitat. Exploitation by recreational angling is targeted at fish inhabiting these locations, and eventually the density of harvestable fish (≥ 12 in) may become lower in these locations by the end of the summer season. Hence, the opportunity for "localized" harvests. If angling pressure is great enough throughout the summer, and if emigration - or small scale movements of Arctic grayling during foraging activities - from adjacent pools is slower than the harvest rate, there is the possibility that localized harvest may lead to seasonal, localized depletions (or depletion harvest). Harvested fish are thought to be replaced the following year by adults that move into the habitat the harvested fish had previously occupied. These "new" adults may have been in the general vicinity the previous year (as Arctic grayling are known to home to summer feeding areas each year; see Ridder 1991 and Tack 1980), and may have been occupying less-preferred habitat during that time. This pattern is supported by evidence from a removal experiment conducted in Twelvemile Creek, in the Yukon River drainage, to examine the distribution of Arctic grayling in a headwater stream (Hughes 1991, Hughes and Reynolds 1994). If depletion harvests occur at each roadside fishing area, angling success later in the season may become restricted. In this scenario, angling opportunity can be viewed as a "first-come-first-serve" phenomenon. From an in-season management perspective, such harvest may have less an impact on the whole stock than more widely distributed effort and harvest, as harvest is eventually limited by seasonal abundance in specific areas. However, if temporary depletions in localized

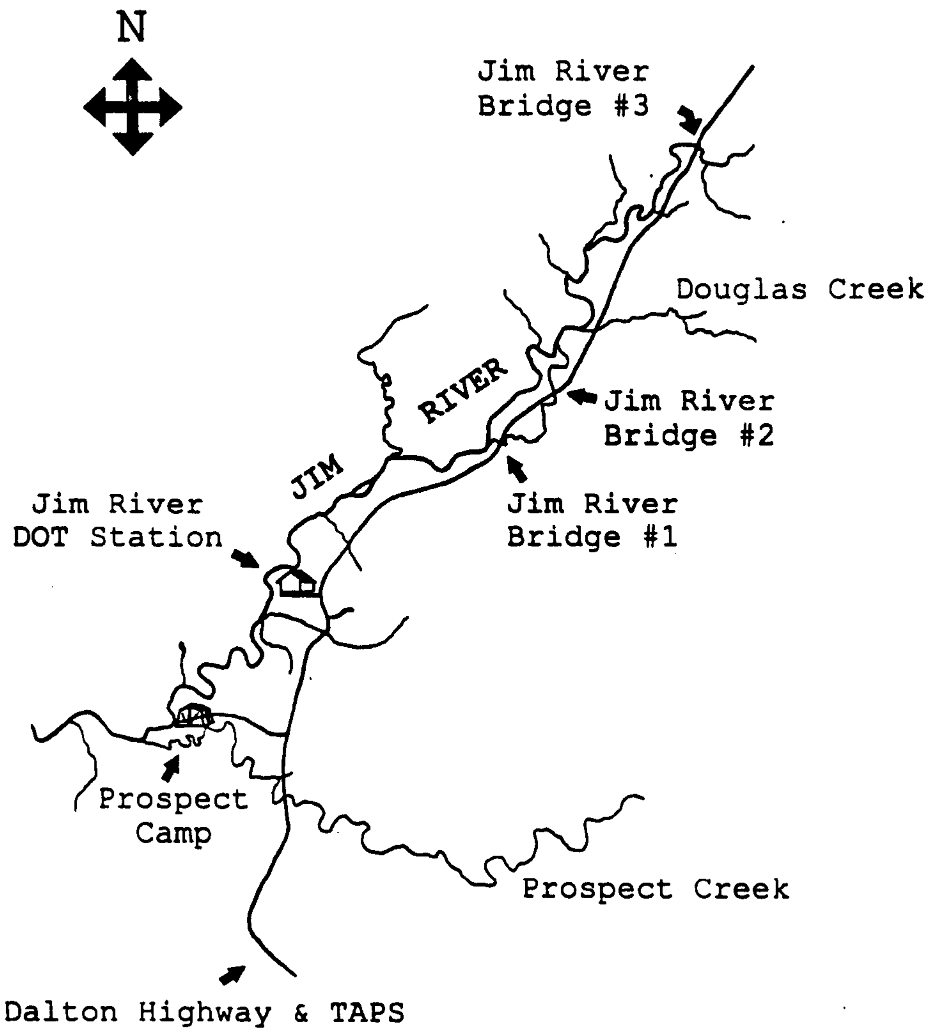



**Figure 2.-Jim River stock assessment study area and river sections. The boundary runs from Jim river Bridge #3 downstream to Prospect Camp.**

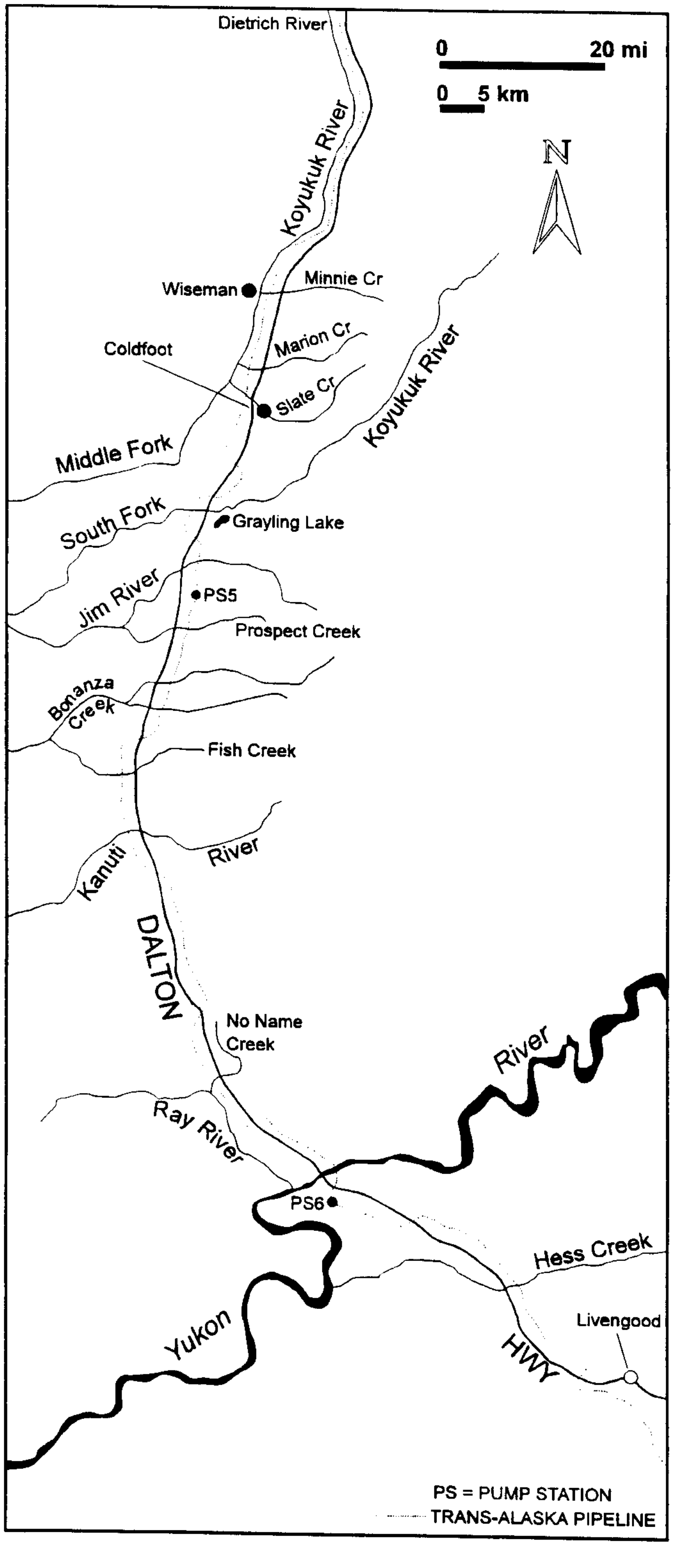



**Figure 3.-Streams adjacent to the Dalton Highway south of Atigun Pass.**

areas occur every year, an eventual change in density of fish (12 in and greater) outside these depleted areas is also thought to occur, as these larger fish colonize those depleted areas the following summer (Bob Clark, Alaska Department of Fish and Game, Anchorage, personal communication). If harvests are great enough to cause temporary, localized depletions, such harvests may eventually cause a stock - or population-wide decline, where aggressive management actions may become necessary.

Depletions of Arctic grayling from localized areas (i.e., ~1/8 mi upstream and downstream from footpaths or road crossings or ~ ¼ mi total) are suspected to occur, during the course of a summer, in river systems adjacent to the Dalton Highway (L. Deegan, Marine Biological Laboratory & Toolik Lake Research Station, personal communication). However, prior to this study no data had been collected to support this suspicion.

## IDENTIFICATION OF BASELINE STUDY NEEDS

With virtually no data for over two decades, there is a need to collect baseline stock information (i.e., abundance and stock composition data) to describe the structure of summer populations of Arctic grayling, in streams crossed by the Dalton Highway, that are exploited by the public. There is also a need to ascertain if potential for localized depletions of Arctic grayling from roadside fishing locations on the Jim River exists, and whether these particular areas may require special management considerations in the future. Additionally, relatively little is known concerning the seasonal distribution and habitat utilization of Arctic grayling within these river systems, and their susceptibility to harvest during various stages of their life history. It is necessary to determine if Arctic grayling in the summer fishery make up a consistent, fishable population. If Arctic grayling in the Jim River constitute a distinct stock, they may be more vulnerable to harvest, than if Arctic grayling are part of a larger Koyukuk River stock, where unharvested sub-populations of Arctic grayling can contribute to, and replenish, the harvest of Jim River fish. If public travel and use of recreational fisheries along the Dalton Highway increase as anticipated, eventually the efficacy of current sport fishing regulations will need to be addressed to provide sustained yield fisheries of Arctic grayling populations in this region of the state.

To address these needs, stock assessment studies, employing mark-recapture techniques, were conducted during the summer of 1995 through 1997. Radio telemetry studies were also initiated during 1997 to examine the migrational timing and habits of Arctic grayling in the Jim River, and to estimate fidelity of fish to the summer fishery. CPUE data were collected during 1997 concurrently with mark-recapture abundance and composition to provide baseline information and possibly some insight to the nature of harvest of Arctic grayling in the Jim River. Data from these studies may eventually aid investigators in understanding whether the effects of harvest are limited locally or distributed on a greater (population) scale. Specific objectives of stock assessment studies are listed below.

## RESEARCH OBJECTIVES FOR STOCK ASSESSMENT

The research objectives during 1995 (F-10-11, Job R-3-2-d) were to estimate:

1. abundance of Arctic grayling (≥150 mm FL) in a 10 km section of the Jim River, such that the estimate is within 25% of the true abundance 95% of the time;
2. abundance of Arctic grayling (≥150 mm FL) in a 6 km section of the Prospect Creek, such that the estimate is within 25% of the true abundance 95% of the time;

3. age composition of Arctic grayling (≥150 mm FL) in the Jim River and Prospect Creek, such that all proportions are within 5 percentage points of the true proportions 95% of the time; and,
4. size composition of Arctic grayling (≥150 mm FL) in the Jim River and Prospect Creek, such that all proportions are within 5 percentage points of the true proportions 95% of the time.

The research objectives during 1996 (F-10-12, Job R-3-2-d) were to estimate:

1. abundance of Arctic grayling (≥150 mm FL) in a 6.4 km section of Prospect Creek, such that the estimate is within 25% of the true abundance 95% of the time;
2. age and length compositions of Arctic grayling (≥150 mm FL) in a 6.4 km section of Prospect Creek, such that all proportions are within 10 percentage points of the true proportions 95% of the time; and,
3. age and length compositions of Arctic grayling (≥150 mm FL) in a 6.4 km section of Bonanza Creek, and an 8 km section of Fish Creek, such that all proportions are within 10 percentage points of the true proportions 95% of the time.

Alternatively, if fewer than 100 fish were caught during the marking event in Prospect Creek, the attempt to estimate abundance of Arctic grayling (in Prospect Creek) was to be determined impractical[1], and the research objectives were to be modified to estimate:

1. abundance of Arctic grayling (≥150 mm FL) in a 6.4 km section of Bonanza Creek, such that the estimate is within 25% of the true abundance 95% of the time;
2. abundance of Arctic grayling (≥150 mm FL) in a 8 km section of Fish Creek, such that the estimate is within 25% of the true abundance 95% of the time; and,
3. age and length compositions of Arctic grayling (≥150 mm FL) in a 6.4 km section of Bonanza Creek, and an 8 km section of Fish Creek, such that all proportions are within 10 percentage points of the true proportions 95% of the time.

The research objectives during 1997 (F-10-13, Job R-3-2d) were to:

1. estimate abundance of Arctic grayling (≥150 mm FL) in a 21.3 km (13.3 mi.) section of the Jim River, such that the estimate is within 25% of the true abundance 95% of the time;
2. estimate age and length composition of Arctic grayling (≥150 mm FL) in a 21.3 km section of the Jim River, such that all proportions are within 5 percentage points of the true proportions 95% of the time;
3. identify at least one overwintering area for Arctic grayling of the Jim River summer fishery, such that there is a 99% chance that at least one tagged fish overwinter in the area;
4. identify at least one spawning site for Arctic grayling of the Jim River summer fishery, such that there is a 99% chance that at least one tagged fish spawns over the site;

---

1 A minimum of 103 fish should have been marked during the marking event to attain an estimate that is within 50% of the true abundance 90% of the time, as determined by calculations of Robson and Regier (1964).

5. estimate fidelity as the proportion of Arctic grayling with functioning radio transmitters that return to the Jim River summer fishery area, such that the estimate is within 50% of the true proportion 95% of the time; and,
6. identify alternative feeding locations to the Jim River of radio-tagged Arctic grayling.

In addition to the above objectives, CPUE data were collected in various locations on the Jim River that represent either remote or accessible locations. Early season, midseason and late season CPUE data were collected as baseline data in order to more clearly define the effects of angling effort depending upon accessibility.

This manuscript summarizes results of population abundance and stock composition studies performed during 1995 through 1997. The results of radio-telemetry investigations will be reported in a separate Fishery Data Series Report, at their conclusion in 1998.

# METHODS

## SAMPLING GEAR AND TECHNIQUES

Many of the rivers and smaller streams that are crossed by the Dalton Highway are clear water systems characterized by shallow riffle areas connected to deeper pools, with streambeds containing sand to boulders (Netsch 1975). Boat travel with outboard engines, as well as the use of boat-mounted electrofishing equipment (typical of Arctic grayling stock assessments undertaken in the Tanana Valley drainages; see Clark and Ridder 1988) is usually impractical. Consequently, appropriate sampling methods included a combination of hook and line, beach seines, and backpack electroshocker. During 1995 and 1997, hook-and-line gear were used to collect fish, while during the 1996 field season, a combination of hook and line, electrofishing, and block net gears were utilized. Sampling with hook and line gear, however, was chosen as the most effective means of collecting fish.

A 21.3 km section of river adjacent to the Dalton Highway, from the Dalton Highway crossing at Jim River Bridge 3, downstream to the confluence of Prospect Creek (Figure 2) defined the Jim River study area. The Bonanza Creek study area included a 5.3 km section of creek, which extended approximately 2.4 km upstream of the highway crossing on the North Fork (at the Trans-Alaska Pipeline System crossing), to downstream 2.9 km, just below the confluence of the North and South forks. The Prospect Creek study area extended from approximately 2.8 km upstream from the Trans-Alaska Pipeline System crossing (TAPS) and continued 3.6 km downstream past the highway crossing, to near the abandoned Prospect Camp (which is now used as an informal campground by the public). The study area in Fish Creek extended downstream from the TAPS access road crossing on the South fork, past the confluence with the mainstem, and downstream to the highway bridge crossing. The area was approximately 1.33 km in length.

Access to sampling locations at Bonanza, Prospect, and Fish creeks was by foot, while access to sampling locations on the Jim River included a combination of wading and canoeing.

Using crews of three or four people, approximately equal length stream sections were sampled from upstream to downstream, and the entire section was sampled as uniformly as possible. Section boundaries corresponded to the distance covered during one day of sampling, and were either marked with flagging or a unique landmark was noted in field notes or on a topographic map. As many Arctic grayling as possible were captured and placed for short periods of time into buckets of water. The fork length of each fish was measured to the nearest 1 mm. All fish greater than 149 mm FL were sampled for age determination (scales), tagged with a Floy FD-68 or Floy FD-94 internal (T-bar) anchor tag, and released bearing an upper caudal partial fin clip. Fish caught during recapture events, however, were released bearing a lower caudal partial fin clip. Three to four scales were taken from each fish sampled for age. All scales came from an area on the fish centered approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin (W. Ridder, Alaska Department of Fish and Game, Delta Junction, unpublished information on refinement of methods described by Brown 1943). Scales were placed on gum cards in the field and retained for future processing and reading. Impressions of the scales were made on triacetate film using a scale press (30 s at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Criteria for determining the presence of an annulus are: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959). Determination of age was performed at least twice for each readable set of scales and all scales were read by one reader. In cases where discrepancies between age determinations occurred, scales were reread twice, ages were confirmed by two additional scale readers, and the most recently determined age was used as the age of the individual fish in question.

All data pertaining to age, length, sampling induced mortality, tag identification numbers and colors, capture location (by stream location), finclips, recapture status, and tag loss were recorded on Alaska Department of Fish and Game Tagging Length Form, Version 1.0, and are electronically stored for analysis and archival.

### ESTIMATION OF ABUNDANCE

The abundance of Arctic grayling (≥150 mm FL) was estimated for a 21.3 km section of the Jim River during 1995; a 5.3 km section of Bonanza Creek during 1996; a 6.4 km section of Prospect Creek during 1996; and a 21.3 km section of the Jim River during 1997 by employing mark-recapture techniques. Generally, the marking event consisted of two to three days for marking and releasing fish, while the recapture event consisted of two to three days for capturing and examining fish for marks. There was a hiatus of two to three days between events. Abundance was estimated with the modified Petersen estimator of Bailey (1951, 1952, as referenced in Seber 1982), using fish tagged during the first two to three days of sampling as marks and fish recaptured and examined for marks as the recaptures and catch, respectively. Alternatively, if emigration and/or immigration were suspected to occur between events, abundance was estimated using the modified Bailey estimator described by Evenson (1988) as the movement estimator.

#### Testing of Assumptions

The assumptions necessary for accurate estimation of absolute abundance in a closed population are as follows (taken from Seber 1982):

1. the population is closed (no change in the number of Arctic grayling in the population during the estimation experiment);

2. all Arctic grayling have the same probability of capture in the marking sample or in the recapture sample, or marked and unmarked Arctic grayling mix completely between marking and recapture events;
3. marking of Arctic grayling does not affect their probability of capture in the recapture sample;
4. Arctic grayling do not lose their mark between the marking and recapture events; and,
5. all marked Arctic grayling are reported when recovered in the recapture sample.

Assumption 1 was assured because of the short hiatus between events. Moreover, a hiatus of one to three days should be sufficiently long to minimize the effect of previous capture on capture probability as related to assumption 2 (see Cross and Stott 1975). Validity of assumptions 2 and 3, relative to sampling induced selectivity of fish, was tested with a series of two-sample Kolmogorov-Smirnov tests generated from the mark-recapture data. The first hypothesis tested was that all marked Arctic grayling have the same probability of capture in the recapture sample. Probability of capture usually differs by the size of Arctic grayling, especially when a size selective gear (electrofishing) is used (see Clark and Ridder 1988). If this test was significant, the recapture sample was biased and the data were partitioned into size classes. Population estimates were generated for each size class and these independent estimates were summed to estimate the entire population. If the test did not detect a significant difference, the data need not be partitioned and a single unstratified population estimate will suffice.

The second hypothesis tested was that Arctic grayling captured during the marking event (first event) have the same length frequency distribution as fish captured during the recapture event (second event). There are four possible outcomes of these two tests; either one or both of the samples are biased or neither are biased. Possible actions for data analysis are outlined in Appendix A1.

Because differences in capture probability of Arctic grayling may reflect geographic differences within a study area, assumption 2 was further validated with a series of chi-squared tests recommended by Seber (1982), as tests of consistency for the Petersen estimator. Contingency tables outlined in Appendix A2 are examined using the chi-square statistic to evaluate the assumptions of accurate absolute abundance estimation listed above. At least one null hypothesis needs to be accepted for the Petersen model to be valid (Chapman 1951 in Seber 1982). If all three test null hypotheses are rejected, and movement was observed, a geographically stratified estimator (Darroch 1961) was used to estimate abundance by river section. Otherwise, if no movement was observed, the geographically stratified estimator of Bailey (1951, 1952, as referenced in Seber, 1982) was used to calculate abundance by river section (see Appendix A3, cases III and IV).

Assumption 4 was assured because all fish are double marked. Assumption 5 was assured because of rigorous examination of all fish for fin clips and tags.

## Calculation of Abundance

The modified Petersen estimator of Bailey (Seber 1982) used to estimate abundance of Arctic grayling in each river section was:

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

where: $\hat{N}$ = the abundance of Arctic grayling in a section (≥150 mm FL); $n_1$ = the number of Arctic grayling marked and released during the first event; $n_2$ = the number of Arctic grayling examined for marks during the second event; and, $m_2$ = the number of Arctic grayling recaptured in the second event.

Variance of this estimator was calculated by (Seber 1982):

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

If significant size biases are detected (either size selectivity or geographic differences in capture probability), separate population estimates were calculated for each resulting stratum. The resulting independent estimates were then summed to produce an estimate of abundance.

If meaningful movement of fish during the mark-recapture experiment was detected, the movement estimator described by Evenson (1988) was utilized to calculate abundance:

$$\hat{N} = \frac{\left[M_1\left(1 - \hat{\ }_d\right) + M_2 + M_3\left(1 - \hat{\ }_u\right)\right]\left[C + 1\right]}{R_{..} + 1} \qquad (3)$$

where: $M_x$ = the number of Arctic grayling marked and released alive during the first sample in section x; downstream section (x = 1), midstream section (x = 2), or upstream section (x =3);

$\hat{\theta}_z$ = the probability that a fish will move out of an area in the *z* direction (upstream or downstream);

C = the number of Arctic grayling examined for marks during the second sample;

$R_{..}$ = the number of fish recaptured during the second event; and,

$\hat{N}$ = the abundance of fish in all sections at the start of the second event.

The probabilities of movements were estimated as:

$$\hat{\theta}_d = \frac{M_2(R_{32} + R_{21})}{R_{2.}(M_3 + M_2)}\text{, and} \qquad (4)$$

$$\hat{\theta}_u = \frac{M_2(R_{12} + R_{23})}{R_{2.}(M_1 + M_2)} \qquad (5)$$

where: $R_{xy}$ = the number of fish that were marked in section *x* during the first event and were recaptured in section *y* during the second event; and,

$R_{2.}$ = the number of fish that were marked in the midstream section during the first event and were recaptured during the second event.

## ESTIMATION OF LENGTH AND AGE COMPOSITION

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in age and length composition samples. Because age and length information are collected during mark-recapture sampling, bias in mark-recapture samples also indicates bias in age and size data that were collected. Age and size composition are used to apportion the population estimate into age classes or length classes or Relative Stock Density (RSD) categories; (Gabelhouse 1984) so that age and length information collected during either the marking sample, the recapture sample, or both samples may be used to calculate age and length composition.

If case I from size selectivity testing occurs (Appendix A1), no adjustments to age and length data are necessary and data from both events may be pooled. If case II occurs, age and length data from the recapture event must be used to estimate compositions. If the population was closed between sampling events the abundance estimate was germane to both sampling events. For these two scenarios the proportion of fish at age was calculated as:

$$\hat{p}_k = \frac{y_k}{n} \qquad (6)$$

where: $\hat{p}_k$ = the proportion of Arctic grayling that are age *k*; $y_k$ = the number of Arctic grayling sampled that are age *k*; and, n = the total number of Arctic grayling sampled.

The unbiased variance of this proportion was estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \qquad (7)$$

Length composition was estimated in a similar manner, replacing age class with 10 mm FL incremental size-classes, or with the RSD categories. The RSD categories are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (greater than 559 mm FL).

If case III or case IV from size selectivity testing occurs, either mark and recapture samples were biased or the recapture sample was unbiased and the status of the mark sample was unknown. If case III occurs, age and length data from both samples can be pooled and adjustments made to these data. If case IV occurs, and the partitioned and unpartitioned abundance estimates are dissimilar, age and length data from the recapture sample must be used to estimate compositions. These data must also be adjusted for bias due to size-selectivity. To adjust age and length data, the proportion of fish at age was calculated by summing independent abundances for each stratum and then dividing by the summed abundances for all age or length classes. First the conditional proportions from the sample are calculated:

$$\hat{p}_{jk} = {}^{n_{jk}}\!/_{n_j} \qquad (8)$$

where: $n_j$ = the number sampled from stratum *j* in the mark-recapture experiment; $n_{jk}$ = the number sampled from stratum *j* that are age *k*; and, $\hat{p}_{jk}$ = the estimated proportion of age *k* fish in stratum *j*. The variance calculation for $\hat{p}_{jk}$ was identical to equation 7 (with appropriate substitutions).

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

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk} \hat{N}_j \qquad (9)$$

where: $N_j$ = the estimated abundance in stratum *j* and s = the number of strata.

The variance for $\hat{N}_k$ in this case was approximated by the delta method (Seber 1982):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s} \left( \hat{V}\left[\hat{p}_{jk}\right] \hat{N}_j^2 + V\left[\hat{N}_j\right] \hat{p}_{jk}^2 \right) \qquad (10)$$

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

$$\hat{p}_k = \hat{N}_k / \hat{N} \qquad (11)$$

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

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

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s} \left\{ \left( \frac{\hat{N}_j}{\hat{N}} \right)^2 \hat{V}\left[\hat{p}_k\right] \right\} + \frac{\sum_{j=1}^{s} \left\{ V\left[\hat{N}_j\right] \left(\hat{p}_{jk} - \hat{p}_k\right)^2 \right\}}{\hat{N}^2} \qquad (12)$$

Equations 5 through 9 are also used to estimate RSD, replacing the number sampled at age *k* that are also in stratum *j*, ($n_{jk}$) with the number sampled in RSD category *k* (*k* = 1, 2, 3, 4, and 5 RSD categories) that are also in stratum *j*. Likewise, the same equations are also used to estimate size composition, replacing the number sampled at age *k* that are also in stratum *j*, ($n_{jk}$) with the number sampled per 10 mm FL incremental size category *k* (*k* = 155,165,175...395) that are also in stratum *j*.

The integrity of composition estimates relies on the same assumptions as for abundance estimates. Unequal movement by length or age, and gear selectivity by length or age, violate these assumptions. Methodology to compensate for bias from violation of these assumptions is outlined in Appendix A1 for the estimate of age and length composition. In addition, there may be bias associated with the estimates of age compositions for three reasons: 1) equal catchability by age was not directly tested (it may not be necessary to test because age and length are correlated); 2) all fish in a sample were not aged (fish that were aged were not randomly selected; scales from larger fish were likely less readable); and, 3) fish < 150 mm FL were not included regardless of age (for example, the estimated proportion of age-2 fish does not include all age-2 fish but only age-2 fish that are ≥ 150 mm FL).

## MEAN LENGTH-AT-AGE

Mean length-at-age was calculated as the arithmetic mean length of all fish assigned to the same age. Variance is reported as the standard deviation of the mean.

## CATCH PER UNIT EFFORT (CPUE)

The catch per unit effort of Arctic grayling from Bonanza, Prospect, and Fish creeks, and the Jim River during June and August of 1995 was calculated from the total fish caught per total hours of fishing effort, and expressed as the average number of fish caught per angler hour of effort.

During 1997, CPUE data were collected from four accessible river areas on the Jim River, as well as from four adjacent areas further away from the road (remote). The accessible areas are known to be popular roadside fishing locations and readily receive angling exploitation, whereas more remote locations are assumed to receive much less angling pressure. Accessible areas were located within ¼ mi of the road, while remote areas were greater than ¼ mi from road crossings (Figure 4). Each location contained one or more pools and were of similar size (approximately 0.125 to 0.25 mi in length). Arctic grayling ≥ 150 mm FL were collected at each location using hook-and-line methods, tagged (with a number sequence unique from tags used during stock assessment activities), and released alive, as described above. Each location was sampled as uniformly as possible, while attempting to catch as many fish as possible. Time spent angling was recorded at each sampling location, and was discriminated from the time spent collecting age and length data from fish. Angling effort ceased when catch rates declined to low levels and time between catches exceeded ~10 min. Tagging data, including GPS readings of fish capture locations, were used to assess fish movement. Sampling occurred during late June, and represented an early season measurement of CPUE. This also provided the opportunity to potentially examine movements of fish between accessible and remote areas during the remainder of the summer. A second sampling event occurred concurrently with stock assessment activities during July. A third sampling event occurred at each location during August, in conjunction with radio telemetry studies. CPUE values were calculated for each location, during each sampling event, as described above.

Differences between the average time elapsed between each landing of a fish, were compared between accessible and remote sites within the same location, during both June and July. Data expressed as the time elapsed between captures were log transformed ln(y+1), and the arithmetic means were calculated. Average elapsed times were examined using a two-sample, one-tail Student's t-test to evaluate for significant differences, using the following formula:

$$t_{obs} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(n_1-1)sd_1^2+(n_2-1)sd_2^2}{n_1+n_2-2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \qquad (13)$$

where $t_{obs}$ = the t statistic

$\overline{X}$ = average time elapsed, or the arithmetic mean of ln(y+1) of time elapsed between landing each fish; and,

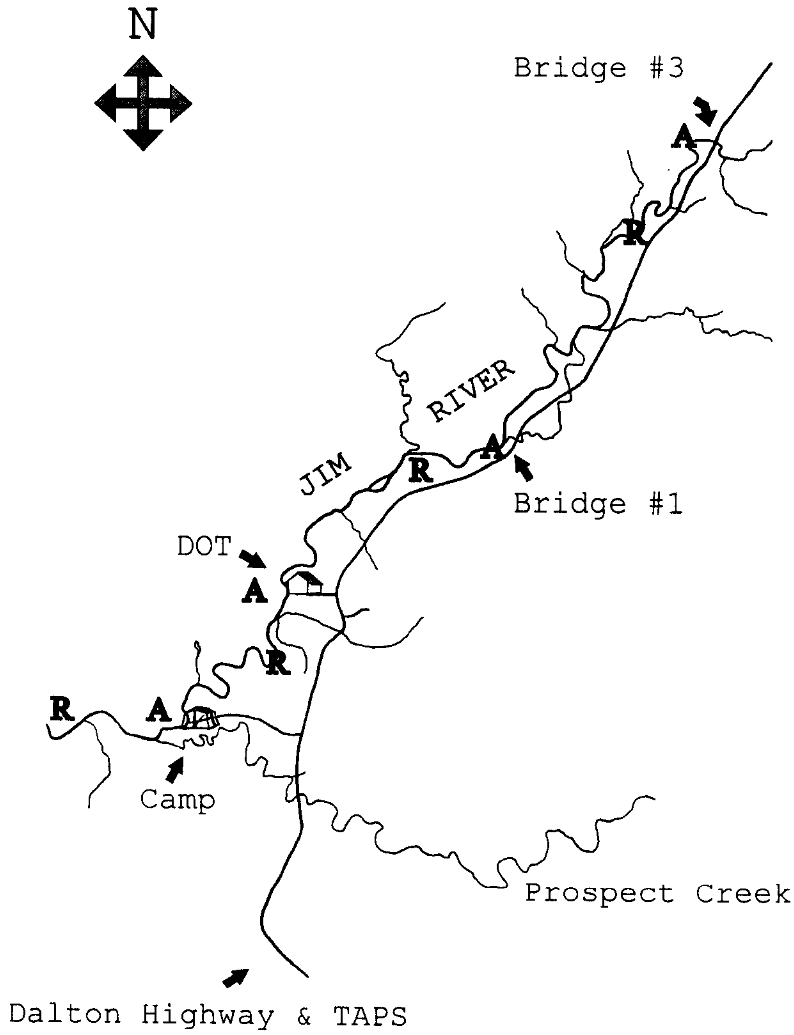



**Figure 4.-Locations of sites were CPUE data were collected within the Jim River stock assessment area, during 1997 (A indicates accessible sites; R indicates remote sites).**

sd = the standard deviation of the mean.

Significance was evaluated at the 0.05 level.

The average time elapsed between captures from the eight sites, during the two months, was also examined as a split-plot ANOVA with repeated measures, with location as a random effect (Milliken and Johnson 1984). The null hypothesis of the access effect was that the average elapsed time at accessible locations was not different from that at remote locations ($H_0$: $\mu_{ACCESSIBLE} - \mu_{REMOTE} = 0$), while the alternative hypothesis was average elapsed time at accessible sites was greater than at remote sites ($H_A$: $\mu_{ACCESSIBLE} - \mu_{REMOTE} > 0$).

## ESTIMATION OF CONTRIBUTION

The proportion of fish marked during the June mark-recapture experiment of 1995 and present in the Jim River study area during August 1995 was estimated as outlined below. Fish were tagged prior to release during both the first and second events of the mark-recapture experiment in June 1995. Fish were sampled during a single sampling event during August 1995. Length and tag data were collected to evaluate stock composition and movement of fish between June and August. Similarly, the proportion of fish marked during both the mark and recapture events during July 1997, and present in the study area during August 1997, was also estimated.

Contribution was estimated in two parts. First the proportion marked and released in the Jim River during June 1995 was estimated from mark-recapture data:

$$\hat{p}_t = \frac{m_t}{\hat{N}} \tag{14}$$

where $\hat{p}_t$ = the estimated proportion released during June 1995 bearing a mark;

$m_t$ = the number marked; and,

$\hat{N}$ = the estimated abundance in the Jim River during June 1995.

Variance of $\hat{p}_t$ was estimated with the delta method (Seber 1982):

$$\hat{V}[\hat{p}_t] \approx \frac{m_t^2 V[\hat{N}]}{\hat{N}^4} \tag{15}$$

where V[N] = estimated variance of the abundance estimate (from equation A3.2).

In the Jim River during August 1995, the proportion of fish originally released during June 1995 that are now in the August 1995 sample was estimated by:

$$\hat{p}_m = \frac{c_m}{n_m} \tag{16}$$

where: $p_m$ = the estimated proportion of fish in the Jim River during August 1995 that were originally marked in the Jim River during June 1995;

$c_m$ = the number examined bearing a mark from the June 1995 mark-recapture experiment; and,

$n_m$ = the number examined in the Jim River during August 1995.

Variance of equation (16) was the variance of a binomial:

$$\hat{V}[\hat{p}_m] = \frac{\hat{p}_m(1-\hat{p}_m)}{n-1}$$

The contribution ($p_c$) was then estimated from the ratio of these two proportions:

$$\hat{p}_c = \frac{\hat{p}_m}{\hat{p}_t} \quad (17)$$

Variance of $p_c$ was then estimated with the delta method:

$$\hat{V}[\hat{p}_c] \approx \left[\frac{\hat{p}_m}{\hat{p}_t}\right]^2 \left[\frac{\hat{V}[\hat{p}_m]}{\hat{p}_m^2} + \frac{\hat{V}[\hat{p}_t]}{\hat{p}_t^2}\right] \quad (18)$$

Contribution of fish marked during the July mark-recapture experiment of 1997 to the population present in the study area during August 1997, was estimated in an identical manner, by making necessary substitutions to equations 14 to 18. Additionally, the contribution of fish tagged during 1995 and recovered during 1997 was estimated in a similar manner, using equations 14 to 18.

## GROWTH

Growth of Arctic grayling tagged during 1995 and recovered during 1997 was examined as the mean increase in fork length for 50 mm size categories. Regression analysis was applied to the increase in fork length at 25 mm FL size category data, as well.

Growth of Arctic grayling in the Jim River during 1995 and 1997 was also modeled using the von Bertalanffy model (LVB). The analysis included length-at-age data collected from fish. Assuming an additive error structure, estimates of $L_\infty$, K, and $t_0$ were obtained from nonlinear least squares procedure, with $L_i$ as the dependent variable and $t_i$ as the independent variable, as outlined by Quinn and Deriso (*in press*) and applied to a MS Excel spreadsheet. The parameters $L_\infty$, K, and $t_0$ were estimated from the LVB equation:

$$L_i = L_\infty(1 - e^{-K(t_i - t_0)}) \quad (19)$$

where: $L_i$ = measured fork length at time $t_i$;

$L_\infty$ = the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975);

K = a constant that determines the rate of increase of growth increments (Ricker 1975); and,

$t_0$ = the hypothetical age at which a fish would have zero length (Ricker 1975).

Data were fit to the model based on an additive error structure, in accordance with the residuals produced by the model. In addition to Arctic grayling from the Jim River, length-at-age data collected from Arctic grayling in the Lower Chena River were also used to model growth, for comparison. Standard errors were calculated using a Hessian matrix algebraic procedure developed for a MS Excel spreadsheet by T. P. Quinn II. The parameter estimates from Jim River, 1995 and Lower Chena River, 1995 data were compared as full and reduced models, as suggested by Quinn and Deriso (*in press*). This F-test procedure compares a full model (different parameter estimates from two data sets) to a reduced model (formed from pooled data sets and a single set of parameter estimates) for equality, using the following formula (from Quinn and Deriso, *in press*):

$$F = \frac{RSS_y - RSS_x}{f_y - f_x} \Big/ \sigma_x^2 \qquad (20)$$

where:

$RSS_y$ = the residual sum of squares of the reduced model, with $f_y = n - p$ degrees of freedom;

$RSS_x$ = the residual sum of squares of the full model, with $f_x = n - p$ degrees of freedom; and,

$\sigma_x^2$ = the residual mean square ($RSS_x/f_x$).

Probability was determined at the 0.05 level.

# RESULTS

## STOCK ASSESSMENT IN BONANZA, PROSPECT, AND FISH CREEKS DURING 1996

Investigators handled 151 individual Arctic grayling ≥ 150 mm FL during the Bonanza Creek mark-recapture experiment, which had a duration of six days from beginning to end, and a hiatus of two days between marking and recapture events. During the marking event (June 6 and 7), 74 fish were captured, but 72 Arctic grayling were tagged and released alive (one fish was killed from hooking injury and excessive bleeding, while one fish was released before being tagged) (capture histories summarized in Table 1). The killed and untagged fish were not included in the marking event. During the recapture event (June 10 and 11), 79 Arctic grayling were captured and examined for marks. Of these 79 fish, 75 were tagged before being released; two were killed from hooking injury, and four were recaptured from the marking event. The killed fish were included in the recapture event. No fish <150 mm FL were caught during either events. Of the four recaptured fish, none lost their tags between marking or recapture. Only one fish was captured using electrofishing and block net gear during the recapture event. All other fish were captured using hook and line gear. Investigators did not identify any Arctic grayling from prior mark-recapture experiments; however, none have ever been performed on this creek. A total of eight fish were caught on the South Fork of Bonanza Creek, but were not included in the mark-recapture experiment, since the South Fork was not sampled during the recapture event.

**Table 1.-Summary of capture histories of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Bonanza Creek, June 1996.**

| | MARK | RECAP | |
|---|---|---|---|
| Area | # marks | # catch | # recaps |
| Upstream | 61 | 37 | 3 |
| Downstream | 11 | 42 | 1 |
| Totals | 72 | 79 | 4 |

Stock assessment studies begun in early June 1996 in Prospect Creek and resulted in only 23 fish being captured during one day of angling, by a crew of four people (only 14 fish were ≥ 150 mm FL). Therefore, abundance was not estimated, and the mark-recapture experiment planned for June was postponed until August, 1996.

A total of 166 Arctic grayling ≥ 150 mm FL were caught and examined for marks during the Prospect Creek mark-recapture experiment of mid-August. During the marking event (August 8 and 9), 80 fish were captured, but 77 Arctic grayling were tagged and released alive (three fish were undersized) (capture histories summarized in Table 2). The undersized fish were not included in the experiment. During the recapture event (August 12 and 13), 93 Arctic grayling were captured and examined for marks. Of these 93 fish, 81 were tagged before being released; four were undersized, and eight were recaptured from the marking event. No fish were killed during the experiment. Of the eight recaptured fish, none lost their tags between marking or recapture. Investigators identified two Arctic grayling tagged during June 1996, and one Arctic grayling tagged during June of 1995.

Investigators handled 51 fish (41 of which were ≥ 150 mm FL) from Fish Creek during 1996. A single sample event was conducted during one day, using hook and line gear only, to collect age and length data. No attempt was made to estimate abundance.

## Estimation of Abundance

Estimated abundance of Arctic grayling within the Bonanza Creek sampling area was germane to fish ≥ 150 mm FL during recapture event. The capture probability and rate of recapture of Arctic grayling during the experiment, within each of two approximately equal-length (~2.6 km) creek sections, were examined with both the ratios of recaptures to captures (R/C) and the ratio of recaptures to marks (R/M). Both R/C and R/M were calculated for each stream section, and then evaluated with chi-squared tests to examine if capture probability differed between each river section, and to examine if marked fish mixed with unmarked fish. The R/C was calculated as the number of fish recaptured divided by the number of fish caught and examined for marks during the recapture event. The R/M was calculated as the number of recaptures divided by the number of fish marked during the marking event. The R/C, from upstream to downstream, for each section within the Bonanza Creek study area was 0.08, and 0.02, respectively. The R/M, from upstream to downstream, in each section within the Bonanza Creek study area was 0.05, and 0.09, respectively (Tables 3 and 4). There were no significant differences between the R/M

**Table 2.-Summary of capture histories of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Prospect Creek, August 1996.**

| | Mark | Recap | |
|---|---|---|---|
| Area | # marks | # catch | # recaps |
| Upstream | 41 | 31 | 6 |
| Downstream | 36 | 58 | 2 |
| Totals | 77 | 89 | 8 |

**Table 3.-Contingency table analysis of recapture rates of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Bonanza Creek, June 1996.**

| | Upstream | Downstream | Total | |
|---|---|---|---|---|
| Recaptured | 3 | 1 | 4 | (R) |
| Not Recaptured | 58 | 10 | 68 | (M-R) |
| Total | 61 | 11 | 72 | (M) |
| Recapture Rate | 0.05 | 0.09 | 0.06 | (R/M) |

$\chi^2 = 0.31$, df = 1, P = 0.58

**Table 4.-Contingency table analysis of capture probabilities of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Bonanza Creek, June 1996.**

| | Upstream | Downstream | Total | |
|---|---|---|---|---|
| Recaptured | 3 | 1 | 4 | (R) |
| Catch-Recaps | 34 | 41 | 75 | (C-R) |
| Total | 37 | 42 | 79 | (C) |
| Capture Probability during 2nd event | 0.08 | 0.02 | 0.05 | (R/C) |

$\chi^2 = 1.34$, df = 1, P = 0.25

values ($\chi^2$= 0.31, 1 df, P = 0.58; Table 3). These results suggest that there was homogeneity in recapture rates between sections. Likewise, there were no significant differences between the R/C values ($\chi^2$= 1.34, 1 df, P = 0.25; Table 4) among the two approximately equal-length creek sections. These results suggest that fish were not differentially captured during the recapture event in either section. Therefore, stratification by area (or day) was not necessary during abundance estimation.

Estimated abundance of Arctic grayling within the Prospect Creek sampling area was germane to fish ≥ 150 mm FL during the recapture event. Capture probability and mixture rate evaluations, obtained from data collected from Prospect Creek, revealed differences in capture probabilities. The R/C, from upstream to downstream, for each section within the Prospect Creek study area was 0.19, and 0.03, respectively. The R/M, from upstream to downstream, in each section within the Prospect Creek study area was 0.15, and 0.06, respectively (Tables 5 and 6) There were no significant differences between the R/M values ($\chi^2$= 1.70, 1 df, P = 0.19; Table 5). There were, however, significant differences between the R/C values ($\chi^2$= 6.25, 1 df, P = 0.01, Table 6) among the two creek sections, suggesting that fish were differentially captured during the recapture event, based on stream section. The results of these tests suggest that stratification was necessary during abundance estimation.

Comparison of areas where Arctic grayling were marked with areas where the fish were recaptured, in both Bonanza and Prospect creeks, indicated that no movement between sections of the study areas occurred. In Bonanza Creek, general locations of where fish were marked and released were recorded on maps. Three of four fish marked and subsequently recaptured were in the same vicinity upon recapture as they were at the time of release during the marking event. No fish moved between the upstream section and the downstream section, between the marking and recapture events. In Prospect Creek, the general locations of release sites were not recorded; however of all fish marked and recaptured, none moved between upstream and downstream study sections, between events. These observations suggest that fish did not move out of the study areas, in neither Bonanza Creek nor Prospect Creek, during the experiments, and that the assumption of closure during the experiments was not violated.

Size selectivity from gear type use during the experiment was examined with Kolmogorov-Smirnov two-sample tests. In Bonanza Creek, there was no significant difference between the length distributions of fish marked during the first event and length distributions of fish recaptured during the second event, within the study area (K/S two-sample test, $D = 0.51$, P = 0.27; Figure 5). Additionally, there was no significant difference between the length distributions of fish marked during the first event and fish caught and examined for marks during the second event (K/S two-sample test, $D$ = 0.20, P = 0.11; Figure 5). These results indicated that there was no difference in capture probability by size (length) during neither the recapture event nor the marking event within Bonanza Creek. Therefore, stratification by size during abundance estimates was not necessary, and lengths and ages obtained from fish caught during both events were used to estimate the length and age compositions of fish within the Bonanza Creek study area (Appendix A1). Similarly, in Prospect Creek, K/S two-sample tests results indicated that there was no difference in capture probability by size (length) during neither the recapture event nor the marking event. There was no significant difference between the length distributions of fish marked during the first event and length distributions of fish recaptured during the second event (K/S two-sample test, $D = 0.43$, P = 0.13; Figure 6), and there was no significant difference between the length distributions of fish marked during the first event and

**Table 5.-Contingency table analysis of recapture rates of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Prospect Creek, August 1996.**

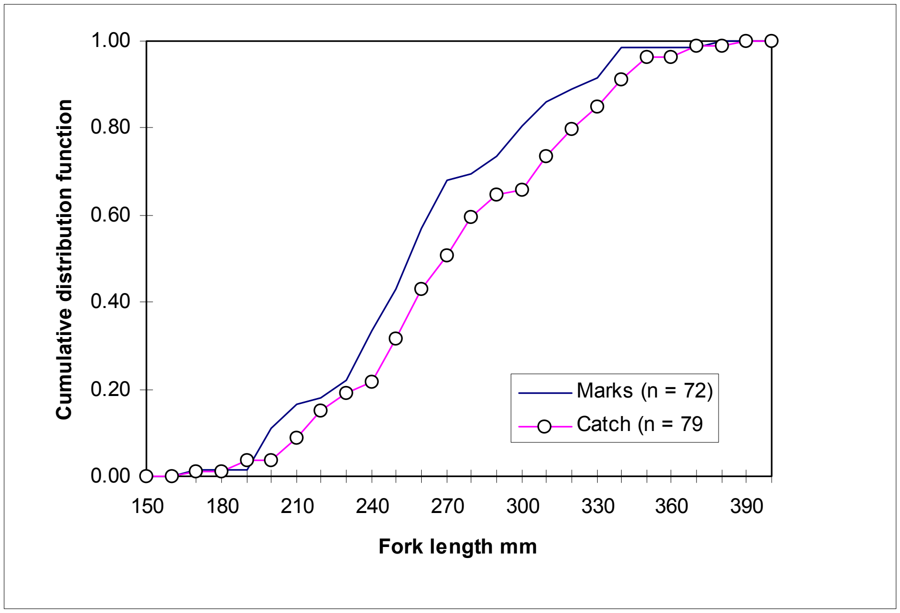
| | Upstream | Downstream | Total | |
|---|---|---|---|---|
| Recaptured | 6 | 2 | 8 | (R) |
| Not Recaptured | 35 | 34 | 69 | (M-R) |
| Total | 41 | 36 | 77 | (M) |
| Recapture Rate | 0.15 | 0.06 | 0.10 | |

$\chi 2 = 1.70$, df = 1, P = 0.19

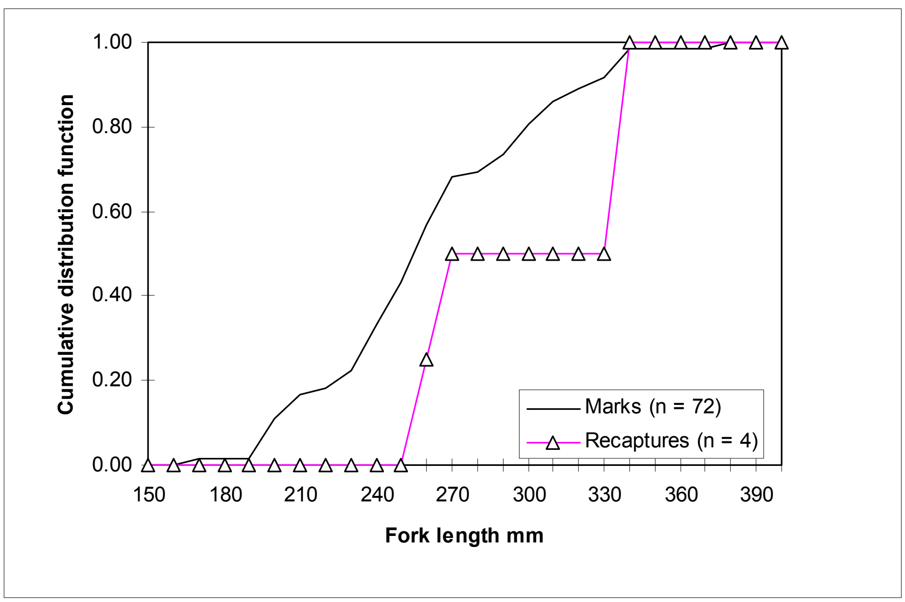
**Table 6.-Contingency table analysis of capture probabilities of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in Prospect Creek, August 1996.**

| | Upstream | Downstream | Total | |
|---|---|---|---|---|
| Recaptured | 6 | 2 | 8 | (R) |
| Catch-Recaps | 25 | 56 | 81 | (C-R) |
| Total | 31 | 58 | 89 | (C) |
| Capture Prob during 2nd event | 0.19 | 0.03 | 0.09 | (R/C) |

$\chi 2 = 6.25$, df = 1, P = 0.01

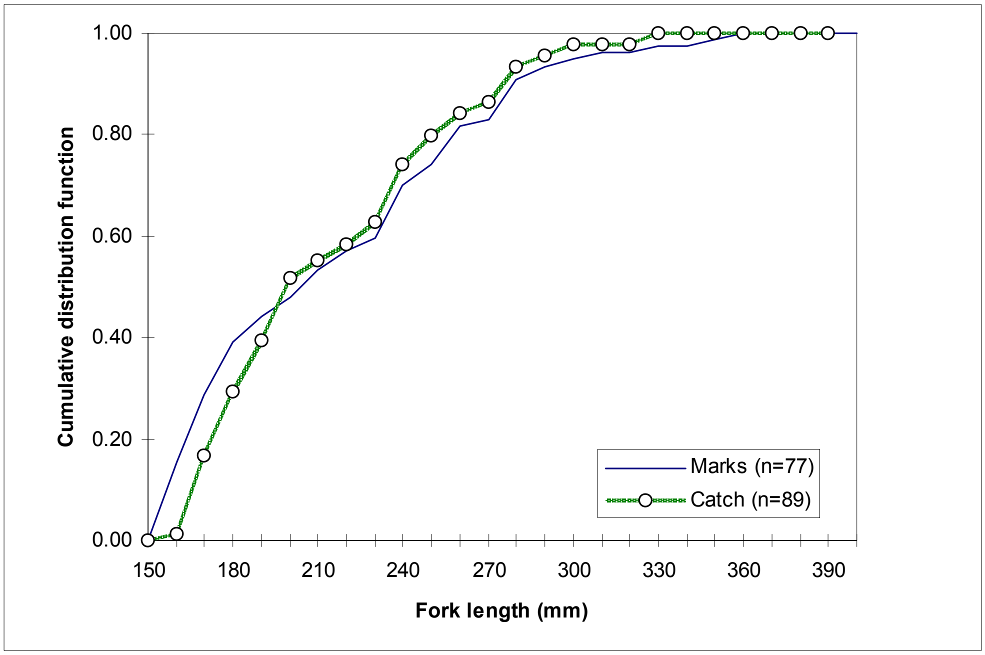



(K/S two-sample test, D = 0.20, P = 0.11)

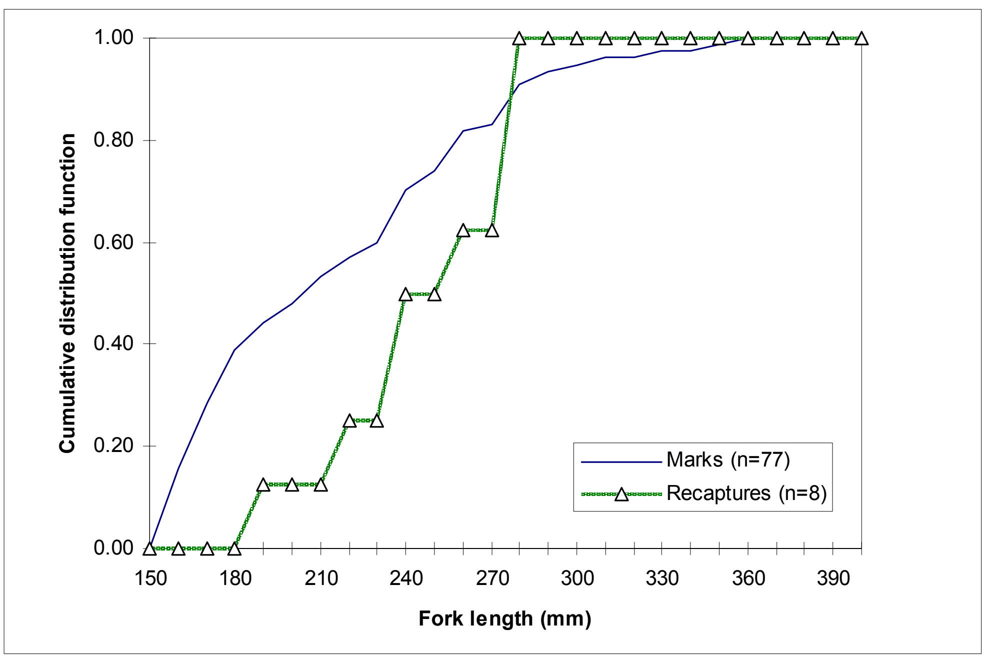



(K/S two-sample test, D = 0.51, P = 0.27)

**Figure 5.-Cumulative distribution functions of fork lengths of Arctic grayling marked, captured, and recaptured within Bonanza Creek, June 6 through 11, 1996.**




(K/S two-sample test, D = 0.17, P = 0.19)




(K/S two-sample test, D = 0.43, P = 0.13)

**Figure 6.-Cumulative distribution functions of fork lengths of Arctic grayling marked, captured, and recaptured within Prospect Creek, August 8 through 13, 1996.**

fish caught and examined for marks during the second event (K/S two-sample test, $D = 0.17$, P = 0.19; Figure 6).

Only one fish was caught using electrofishing gear during the recapture event on Bonanza Creek. Therefore, differences in capture probability or differential size selectivity from varying gear types was not investigated.

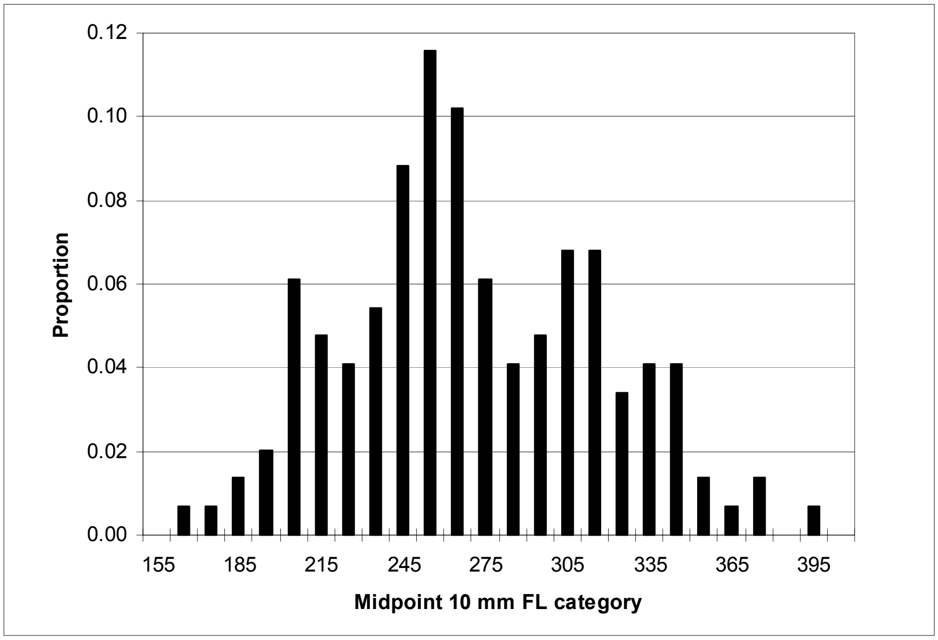
In Bonanza Creek, a lack of significant differences in capture probability between river sections (Table 4) indicated that the mark-recapture experimental assumption of equal capture probability was not violated. Furthermore, a lack of evidence for significant movement of fish into and out of the study area indicated that closure assumptions were not violated. As a result, an unstratified estimate of abundance using the Bailey (1951, 1952) estimator was calculated (see Appendix A2, case I*)*. In Prospect Creek, there was also no evidence for significant movement to or from the study area. However, significant differential capture probabilities detected by Chi-squared tests (Table 6) revealed that assumptions of equal probability of capture were violated, and that the data should be stratified to compensate for such bias. Following the methodology outlined in Appendix A3 (case III), a stratified estimate of abundance using the Bailey (1951, 1952) estimator was calculated, where the estimated abundance of Arctic grayling in the Prospect Creek study area was 895 fish (SE = 350, CV = 39%, 95% CI = (209, 1581)). However, the accuracy of the chi-square test in reflecting true differences between capture probabilities is suspect, when considering the low number of recaptures in the mark-recapture experiment (small sample sizes). For this reason, the data were not stratified to compensate for differences in capture probabilities, and an unstratified estimate of abundance using the Bailey (1951, 1952) estimator was calculated and chosen as a best estimate (see Appendix A3, case I*)*.

Using the Bailey estimate, the unstratified estimated abundance of Arctic grayling within the Bonanza Creek study area was 1,152 fish (SE = 445 fish, CV = 40%, 95% CI = (260, 2045)). Estimated density of Arctic grayling ≥ 150 mm FL was 217 fish per km (SE = 84 fish per km), or 349 fish/mi, within the Bonanza Creek study area. Using the Bailey estimate, the unstratified estimated abundance of Arctic grayling within the Prospect Creek study area was 770 fish (SE = 231 fish, CV = 30%, 95% CI = (317, 1,223)). Estimated density of Arctic grayling ≥ 150 mm FL was 120 fish per km (SE = 36 fish per km), or 193 fish per mi, within the Prospect Creek study area. Netsch (1975) reported an abundance for Arctic grayling ≥ 200 mm FL, in the lower 1 mile of Prospect Creek during August of 1972, of 1,210 fish, based on a Petersen mark-recapture estimate; or 1,191 fish (SE = 147, C.V. = 12.3%, 95% CI = (903, 1478)), based on a Bailey estimate of abundance. This reflects a density of 774 fish per km (SE = 92 fish per km).

## Estimation of Length and Age Compositions

Fork lengths of fish handled during the experiment in Bonanza Creek ranged from 163 mm FL to 386 mm FL (Figure 7). Fork lengths measured from 147 (sum of fish handled during both events minus the number of recaptured fish, one fish killed, and one fish not tagged) Arctic grayling ≥

a)




b)

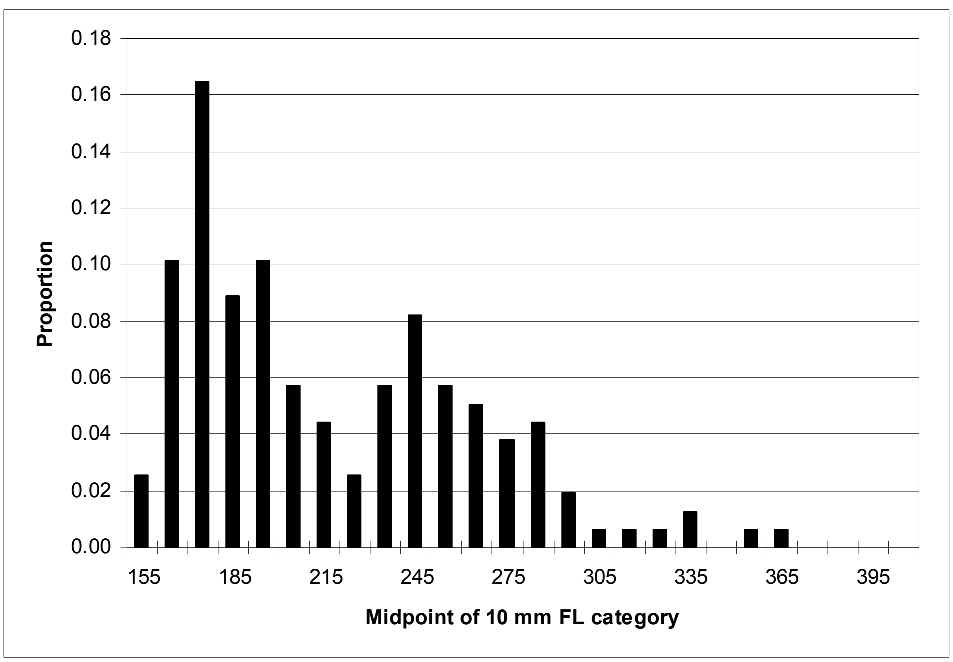



**Figure 7.-Estimated proportions of Arctic grayling ≥ 150 mm FL by 10 mm FL incremental size categories within a) Bonanza Creek study area, June 1996 (n = 147), and b) Prospect Creek study area, August 1996 (n = 158).**

150 mm FL from the Bonanza Creek sampling area during June averaged 266 mm FL. Of these, the proportion of Arctic grayling ≥ 269[2] mm FL within the study area was 0.35 (SE =0.04).

Fork lengths of all fish handled during the experiment in Prospect Creek ranged from 122 mm FL to 359 mm FL. Fork lengths measured from 158 (sum of fish handled during both events minus the number of recaptured fish) Arctic grayling ≥ 150 mm FL from the Prospect Creek sampling area during August averaged 213 mm FL (Figure 7). Of these, the proportion of Arctic grayling ≥ 269 mm FL within the study area was 0.15 (SE =0.03).

Fork lengths of fish caught during June in Prospect Creek were also examined, as were those of fish caught in Fish Creek during August. Within Prospect Creek, 23 Arctic grayling ranged in size from 117 to 370 mm FL. Of 15 Arctic grayling ≥ 150 mm FL, the average length was 245 mm FL (Figure 8). Of these, the proportion of Arctic grayling ≥ 269 mm FL within the study area during June was 0.73 (SE = 0.12). Within Fish Creek during August, 51 Arctic grayling ranged in size from 115 to 343 mm FL. Of 41 Arctic grayling ≥ 150 mm FL, the average length was 211 mm FL (Figure 8). Of these, the proportion of Arctic grayling ≥ 269 mm FL within the study area during August was 0.22 (SE = 0.07). Since stock composition of Arctic grayling in Fish Creek during August was assessed from only one sampling event with a single gear type, no attempt to address size selectivity or capture probability was made. Within Prospect Creek during June, stock composition was assessed from a single sampling event using electrofishing and block net gear, as well as hook and line gear. However, the use electrofishing and block net gear resulted in three fish ≥ 150 mm FL, and seven undersized fish (which weren't included in the estimation of stock composition) being caught. No attempt was made to analyze size selectivity or capture probability differences between gear types with so little data.

Categorization of fork lengths into RSD categories revealed that most fish caught within Bonanza Creek during June were of the stock category, followed by quality and preferred (Table 7). Similarly, within Prospect Creek during August, most fish caught were of the stock category, followed by quality. Few preferred fish were caught during August 1996 (Table 7). Of the fish caught in Prospect Creek during June, most were of the quality category, followed by stock and preferred (Table 8). Within Fish Creek during August, most fish caught were of the stock category, followed by quality and preferred (Table 8). No memorable nor trophy-sized fish were caught in any stream assessed during 1996.

Ages determined from scales of Arctic grayling ≥ 150 mm FL collected during both the marking and recapture events were used to estimate the age composition of Arctic grayling ≥ 150 mm FL within sampling areas. In Bonanza Creek, ages were estimated from 140 of 148 fish ≥ 150 mm FL, and age classes ranged from age-3 to age-9 (Figure 9). Approximately 6% of the scales from fish were regenerated or determined to be unreadable. The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Bonanza Creek study area were age-6 (P = 0.39, SE = 0.04), age-4 (P = 0.19, SE = 0.03), and age-5 (P = 0.14, SE = 0.03), with age-6 representing the most abundant proportion of fish (Figure 9). Ages were estimated from 148 of

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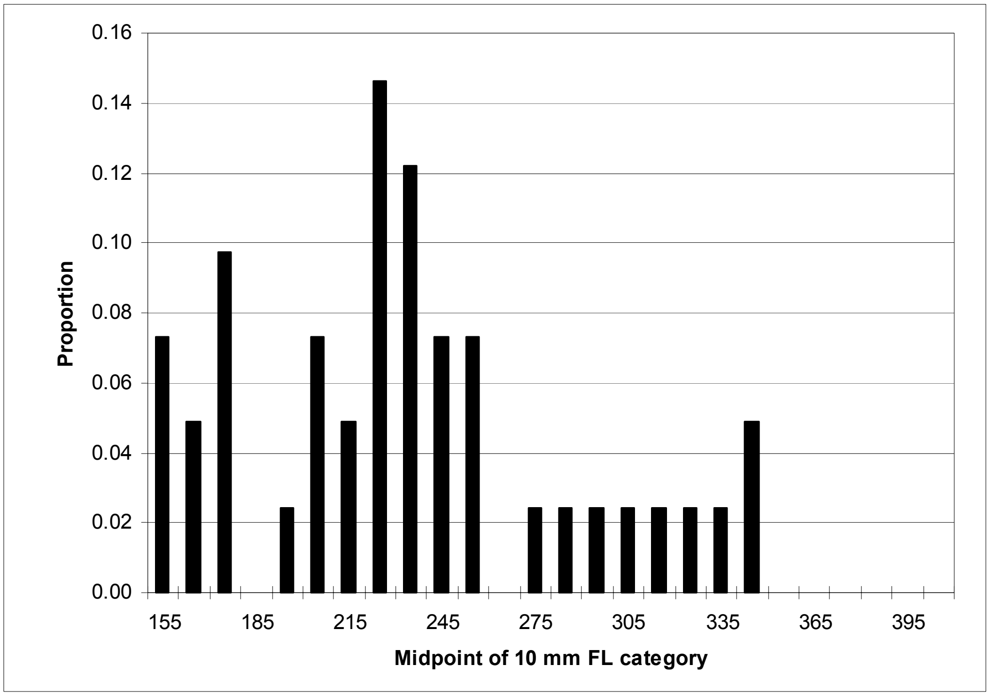
[2] A fork length of ≥ 269 mm approximately corresponds to 12 inches, the minimum legal size limit established for Arctic grayling caught in the Dalton Highway Corridor.

a)

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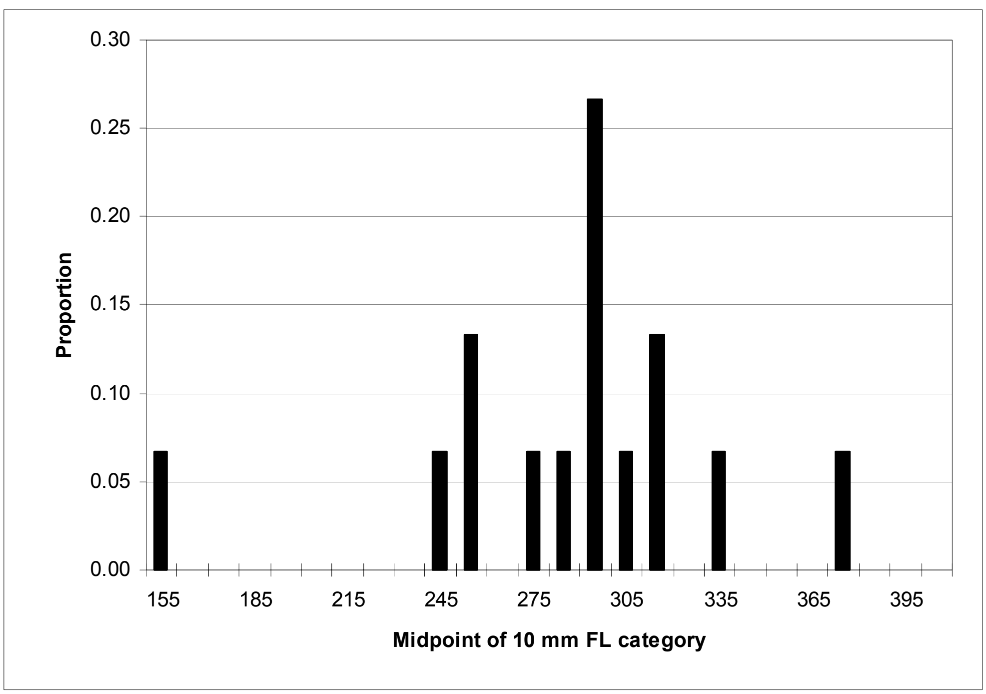



**Figure 8.-Proportions of Arctic grayling ≥ 150 mm FL by 10 mm FL incremental size categories within a) Fish Creek study area, August 1996 (n = 41), and b) Prospect Creek study area, June 1996 (n = 15).**

**Table 7.-Summary of estimated RSD categories for Arctic grayling within Bonanza Creek during June of 1996, and in Prospect Creek during August, 1996[a].**

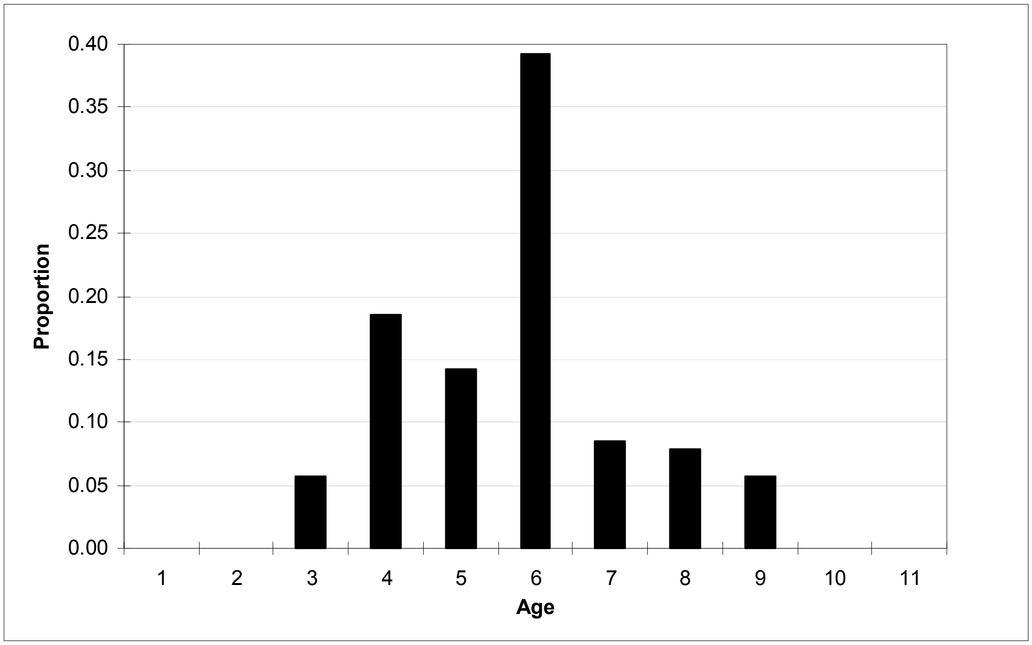
| | | RSD Category | | | | |
|---|---|---|---|---|---|---|
| | | Stock | Quality | Preferred | Memorable | Trophy |
| Bonanza | number | 85 | 51 | 11 | 0 | 0 |
| | RSD | 0.58 | 0.35 | 0.07 | --- | --- |
| | SE | 0.04 | 0.04 | 0.02 | --- | --- |
| Prospect | number | 135 | 21 | 2 | 0 | 0 |
| | RSD | 0.85 | 0.13 | 0.01 | --- | --- |
| | SE | 0.03 | 0.03 | 0.01 | --- | --- |

[a] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150-269 mm FL); quality (270-339 mm FL); preferred (340-449 mm FL); memorable (450-559 mm FL); and trophy (560 mm FL and greater).

**Table 8.-Summary of estimated RSD categories for Arctic grayling within Prospect Creek during June of 1996, and in Fish Creek during August, 1996.**

| | | RSD Category | | | | |
|---|---|---|---|---|---|---|
| | | Stock | Quality | Preferred | Memorable | Trophy |
| Prospect | number | 5 | 9 | 1 | 0 | 0 |
| | RSD | 0.33 | 0.60 | 0.07 | --- | --- |
| | SE | 0.13 | 0.13 | 0.07 | --- | --- |
| Fish | number | 32 | 7 | 2 | 0 | 0 |
| | RSD | 0.78 | 0.17 | 0.05 | --- | --- |
| | SE | 0.07 | 0.06 | 0.03 | --- | --- |

a)

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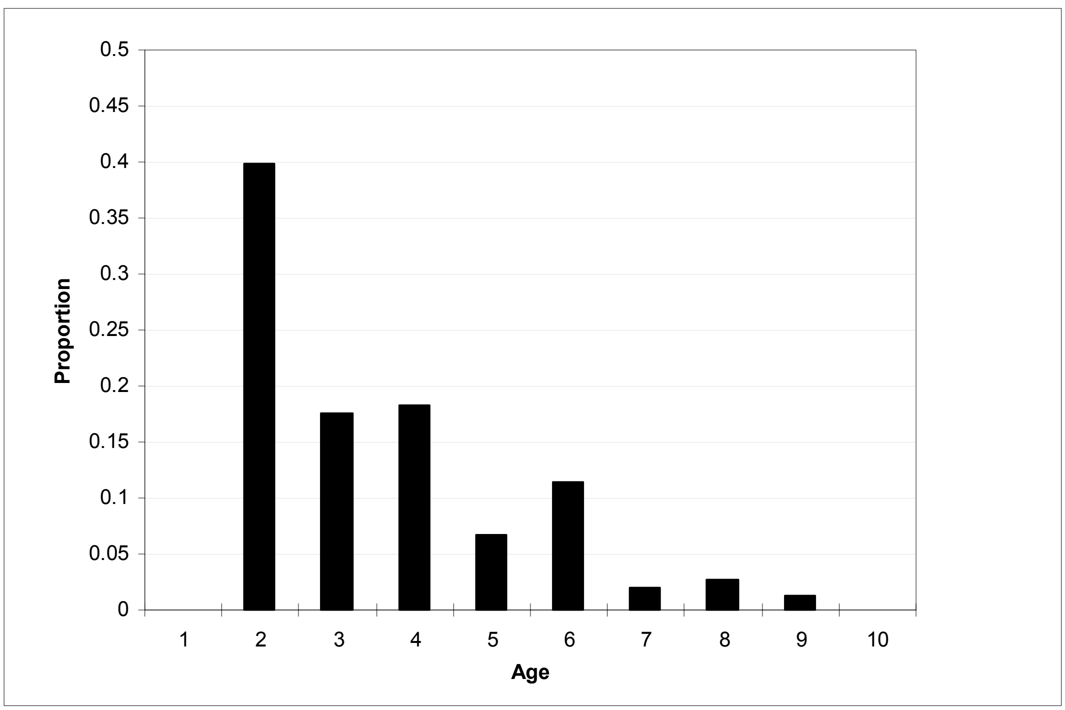



**Figure 9.-Estimated proportions of Arctic grayling ≥ 150 mm FL by age within a) Bonanza Creek study area, June 1996 (n = 140), and b) Prospect Creek study area, August 1996 (n = 148).**

158 Arctic grayling ≥ 150 mm FL captured within Prospect Creek, and age classes ranged from age-2 to age-9 (Figure 9). Approximately 6% of the scales from fish were regenerated or determined to be unreadable. The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Prospect Creek study area were age-2 (P = 0.40, SE = 0.04), age-3 (P = 0.18, SE = 0.03), and age-4 (P = 0.18, SE = 0.03), with age-2 representing the most abundant proportion of fish (Figure 9).

Age composition of Arctic grayling ≥ 150 mm FL was also estimated for study areas within Prospect Creek during June, and Fish Creek during August. In Prospect Creek, only 23 fish were caught during June, 14 of which were ≥ 150 mm FL and aged (Figure 10). Ages of fish in Prospect Creek ranged from age-2 to age-14, with age-6 being the most abundant (P = 0.29, SE = 0.13). However, when considering the age classes of fish of all sizes in Prospect Creek during June, age-2 were most abundant (P = 0.32, SE = 0.10). In Fish Creek, ages of Arctic grayling ≥ 150 mm FL ranged from age-2 to age-8, with age-4 being the most abundant (P = 0.30, SE = 0.07) (Figure 10). However, when considering fish of all sizes, or all fish captured, the number of age-2 fish were nearly equal to the number of age-4 fish.

### Mean Length-at-Age

Mean length-at-age was calculated for Arctic grayling from Bonanza, Prospect and Fish creeks, and is shown in Table 9 and Figure 11, along with mean lengths-at-age for Arctic grayling from the Jim River during 1995, 1997, as well as those reported by Netsch (1975) from the Jim River and Prospect Creek (during 1971-2) combined. Overall, mean length-at-age appears consistent between years, and among the different creeks. Small differences in mean length-at-age are possibly the result of error associated with the age determination process (scale reading).

### Catch Per Unit Effort

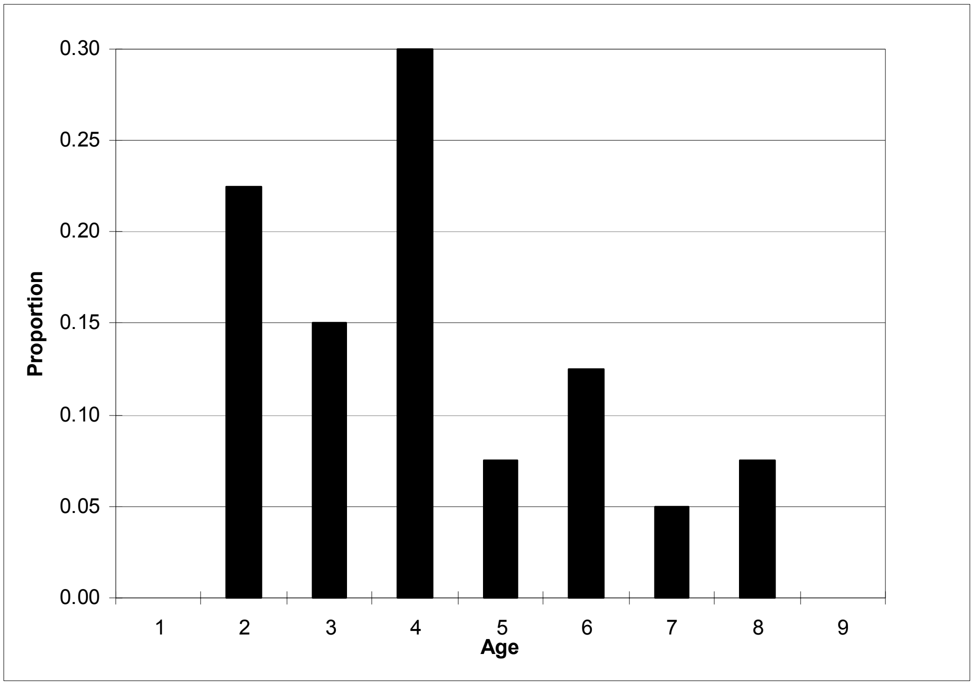
Netsch (1975) reported an average catch of 5.9 Arctic grayling per angler hour, from 533 Arctic grayling per 90.2 hours total angling effort, in three streams combined (Jim River, Prospect Creek, and stream HR2-1405-92), during June, 1972. Netsch also reported that CPUE ranged from 1.5 (during May) to 9.9 (during August) for the three streams combined. During 1996, CPUE from total angling effort in Bonanza Creek during June (ranging from 0.75 to 2.21), and Prospect Creek during August (ranging from 1.48 to 2.33), averaged 1.38 and 1.81 Arctic grayling per angler hour, respectively. The CPUE for all fish caught during the month of June 1996, from all streams combined (including both the North and South forks of Bonanza Creek, and Prospect Creek) averaged 1.18 Arctic grayling per angler hour. The CPUE within Fish Creek during August was 2.67 Arctic grayling per angler hour.

## STOCK ASSESSMENT IN THE JIM RIVER DURING 1995

#### June and August, 1995

During 1995, investigators handled 853 individual Arctic grayling ≥ 150 mm FL during the Jim River stock assessment studies. The mark-recapture experiment had a duration of five days from beginning to end, and a hiatus of two days between marking and recapture events. During the marking event (June 8 and 9), 346 fish were captured, but 339 Arctic grayling were tagged and released alive (four fish were killed from hooking injury and excessive bleeding, and three fish were undersized). The killed and undersized fish were not included in the experiment. During the recapture event (June 11 and 12), 547 Arctic grayling were captured and examined for marks. Of these 547 fish, 502 were tagged before being released, eight were killed from hooking injury, four were undersized, and 33 were recaptured from the marking event (Table 10 for summary of

a)

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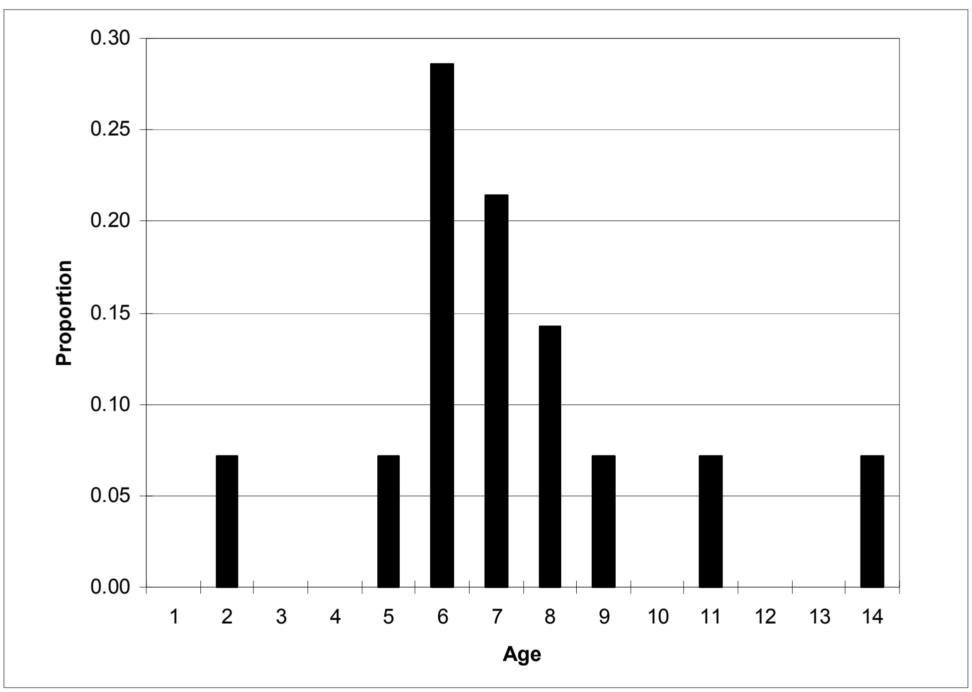



**Figure 10.-Proportions of Arctic grayling ≥ 150 mm FL by age within a) Fish Creek, August 1996 (n = 40), and b) Prospect Creek, June 1996 (n = 14).**

**Table 9.-Mean fork length-at-age of Arctic grayling in Bonanza Creek (1996), Prospect Creek (1996), Fish Creek (1996), and the Jim River (1971-2, 1995, and 1997).**

| | Bonanza Creek, 1996 | | | Prospect Creek, 1996 | | | Fish Creek, 1996 | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | N | $\bar{X}$ [a] FL | SD | n | $\bar{X}$ FL | SD | n | $\bar{X}$ FL | SD |
| 2 | 0 | --- | --- | 59 | 170 | 9.89 | 9 | 162 | 9.11 |
| 3 | 8 | 188 | 14.45 | 26 | 198 | 11.79 | 6 | 212 | 12.14 |
| 4 | 26 | 217 | 18.50 | 27 | 232 | 11.79 | 12 | 225 | 14.73 |
| 5 | 21 | 251 | 19.1 | 10 | 257 | 16.13 | 3 | 269 | 37.58 |
| 6 | 55 | 272 | 25.52 | 17 | 270 | 13.80 | 5 | 266 | 21.14 |
| 7 | 12 | 319 | 26.10 | 3 | 292 | 35.03 | 2 | 311 | 8.49 |
| 8 | 11 | 323 | 16.51 | 4 | 313 | 31.03 | 3 | 340 | 4.62 |
| 9 | 8 | 348 | 22.87 | 2 | 327 | 2.12 | 0 | --- | --- |
| 10 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 11 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 12 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 13 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 14 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 15 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| 16 | 0 | --- | --- | 0 | --- | --- | 0 | --- | --- |
| Total | 141 | --- | --- | 148 | --- | --- | 40 | --- | --- |

-continued-

**Table 9.-Page 2 of 2.**

| | Jim River[b], 1971-2 | | | Jim River, 1995 | | | Jim River, 1997 | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | N | X[c] FL | SD[d] | n | X FL | SD | n | X FL | SD |
| 0 | 6 | 65 | --- | 0 | --- | --- | 0 | --- | --- |
| 1 | 2 | 116 | --- | 0 | --- | --- | 0 | --- | --- |
| 2 | 5 | 123 | --- | 14 | 149 | 11 | 16 | 166 | 12 |
| 3 | 18 | 204 | --- | 34 | 199 | 29 | 190 | 209 | 17 |
| 4 | 24 | 217 | --- | 142 | 227 | 27 | 129 | 243 | 20 |
| 5 | 13 | 255 | --- | 244 | 248 | 20 | 135 | 268 | 20 |
| 6 | 19 | 292 | --- | 112 | 273 | 19 | 99 | 287 | 22 |
| 7 | 15 | 318 | --- | 129 | 293 | 17 | 92 | 306 | 21 |
| 8 | 16 | 348 | --- | 57 | 316 | 20 | 36 | 330 | 19 |
| 9 | 6 | 364 | --- | 22 | 327 | 15 | 21 | 337 | 25 |
| 10 | 3 | 360 | --- | 13 | 341 | 20 | 12 | 344 | 22 |
| 11 | 0 | --- | --- | 6 | 388 | 11 | 14 | 362 | 18 |
| 12 | 0 | --- | --- | 5 | 377 | 15 | 4 | 378 | 24 |
| 13 | 0 | --- | --- | 0 | --- | --- | 3 | 372 | 10 |
| 14 | 0 | --- | --- | 0 | --- | --- | 1 | 375 | --- |
| 15 | 0 | --- | --- | 1 | 410 | --- | 0 | --- | --- |
| 16 | 0 | --- | --- | 0 | --- | --- | 1 | 389 | --- |
| Total | 127 | --- | --- | 777 | --- | --- | 753 | --- | --- |

[a] X = the mean fork length-at-age, calculated as the arithmatic average of fork lengths measured at age.

[b] Data includes fish captured from both Prospect Creek and the Jim River during 1971-2.

[c] X = the mean fork length-at-age, calculated as the arithmatic average of fork lengths measured at age.

[d] Data from Netsch (1975); no standard deviations reported.

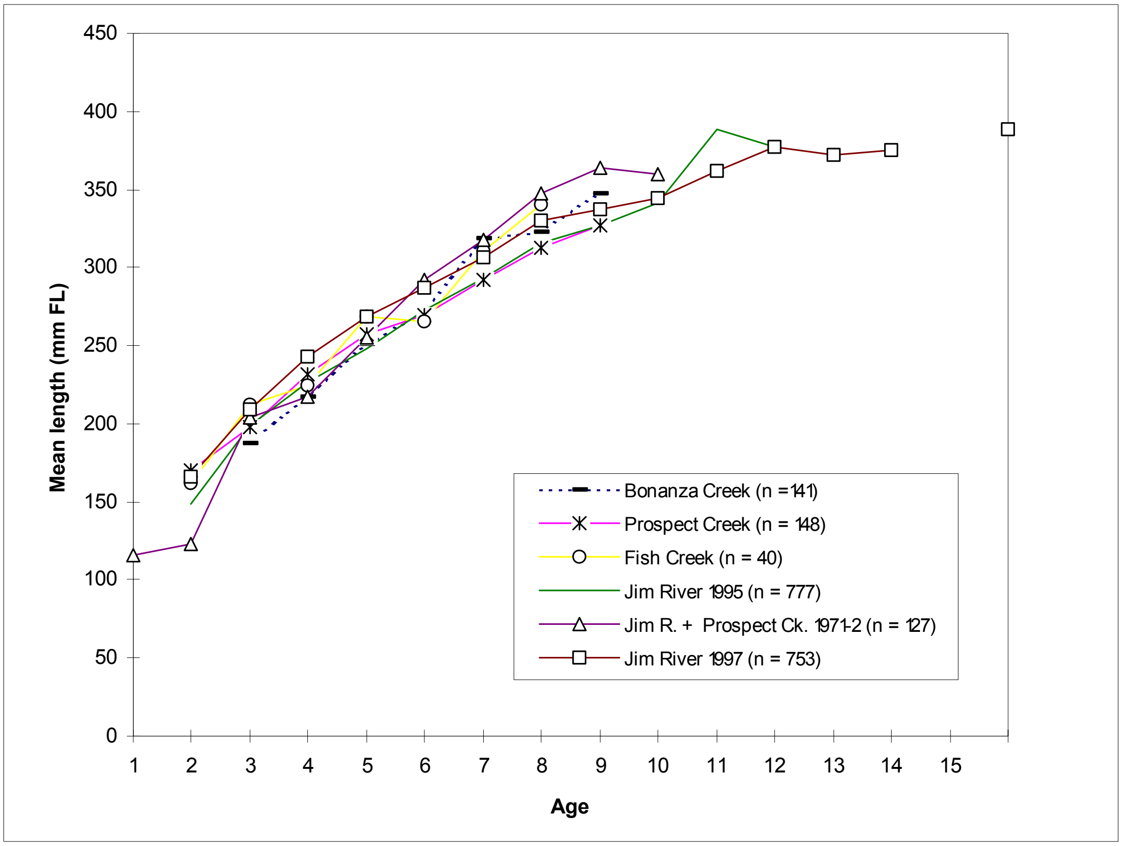



**Figure 11.-Mean fork length-at-age of Arctic grayling in the Jim River (1971-2, 1995, and 1997), Bonanza Creek (1996), Prospect Creek (1996), and Fish Creek (1996).**

**Table 10.-Summary of capture histories of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, June 1995.**

| | MARK | RECAP | |
|---|---|---|---|
| River Section | # marks | # catch | # recaps |
| 1 | 70 | 144 | 10 |
| 2 | 69 | 113 | 7 |
| 3 | 136 | 170 | 8 |
| 4 | 64 | 116 | 8 |
| Totals | 339 | 543 | 33 |

capture histories). The killed fish were included in the experiment. A total of seven fish <150 mm FL were caught during both events (three during the marking event, and four during the recapture event), but were not included in any analyses. Of the 33 recaptured fish, none lost their tags between marking or recapture, however one was killed from hooking injury. Investigators did not identify any Arctic grayling from prior mark-recapture experiments, since the last estimate of abundance was performed in 1972 by Netsch (1975).

A total of 530 Arctic grayling ≥ 150 mm FL were caught and examined for marks during the August sampling event. Of these, 480 fish were unmarked, 50 fish were recovered from the mark-recapture experiment of June (16 from the marking event, and 34 from the recapture event), while four fish were killed from hooking injury. Sampling mortality rate during June was 1.4%, and 0.8% during August, resulting in a total sampling mortality rate of 1.2%.

### Estimation of Abundance

Estimated abundance of Arctic grayling within the Jim River sampling area, during 1995, was germane to fish ≥ 150 mm FL during recapture event. The recapture rate and capture probability of Arctic grayling during the experiment, within each of four approximately equal-length (~5.3 km) river sections, was examined with both the ratios of recaptures to marks (R/M) and the ratio of recaptures to captures (R/C). Both R/M and R/C were calculated (as previously described) for each river section, and then evaluated with chi-squared tests to examine if rates of recovery differed between each river section, and to examine if capture probability differed between each river section. The R/M, from upstream to downstream, in each river section within the study area was 0.14, 0.10, 0.06, and 0.13, respectively (Table 11). There were no significant differences between the R/M values ($\chi^2$= 4.52, 3 df, P = 0.21). These results suggest that recapture rates were similar between river sections. The R/C, from upstream to downstream, for each river section within the study area was 0.07, 0.06, 0.05, and 0.07, respectively (Table 12). Likewise, there were no significant differences between the R/C values ($\chi^2$= 0.89, 3 df, P = 0.83) among the four approximately equal-length river sections. These results suggest that fish were not differentially captured during the recapture event in any given river section. Therefore, stratification by area (river section) was not necessary during abundance estimates.

Comparison of areas where Arctic grayling were marked with areas where the fish were recaptured indicated movement between river sections (Table 13). Of recaptured Arctic grayling, 10 of 33 fish (30%) moved from one section of river to another between marking and recapture events; eight of 33 (24%) moved downstream, while two of 33 (6%) moved upstream. The magnitude of movement suggested that most fish traveled downstream, approximately over 2 km, during the hiatus of the experiment.

A lack of significant differences in capture probability between river sections indicated that the mark-recapture experimental assumptions of equal capture probability and complete mixing were not violated. However, the downstream movement of 24% of the recaptured fish suggests that fish (both marked and unmarked) may have also emigrated from, or immigrated to, the study area, and that the assumption of closure during the experiment may have been violated. As a result, an unstratified estimate of abundance using the Bailey (1951, 1952) estimator, and

**Table 11.-Contingency table analysis of recapture rates of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, June 1995.**

| | Upstream | Mid-Upper | Mid-Lower | Downstream | Total | |
|---|---|---|---|---|---|---|
| Recaptured | 10 | 7 | 8 | 8 | 33 | (R) |
| Not Recaptured | 60 | 62 | 128 | 56 | 306 | (M-R) |
| Total | 70 | 69 | 136 | 64 | 339 | (M) |
| Recapture Rate | 0.14 | 0.10 | 0.06 | 0.13 | 0.10 | (R/M) |

$\chi^2$ = 4.52, df = 3, P = 0.21

**Table 12.-Contingency table analysis of capture probabilities of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, June 1995.**

| | Upstream | Mid-Upper | Mid-Lower | Downstream | Total | |
|---|---|---|---|---|---|---|
| Recaptured | 10 | 7 | 8 | 8 | 33 | (R) |
| Catch-Recaps | 134 | 106 | 162 | 108 | 510 | (C-R) |
| Total | 144 | 113 | 170 | 116 | 543 | (C) |
| Capture Probability during 2nd event | 0.07 | 0.06 | 0.05 | 0.07 | 0.06 | (R/C) |

$\chi^2$ = 0.89, df = 3, P = 0.83

**Table 13.-Number of Arctic grayling recaptured in a river section of the Jim River study area during 1995, summarized according to the section in which the fish was marked.**

*Number Recaptured*

**Recapture Location**

| | ***River Section*** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| **M** | **1** | 9 | 3 | 0 | 0 |
| **A** | **2** | 0 | 3 | 3 | 0 |
| **R** | **3** | 1 | 1 | 5 | 2 |
| **K** | **4** | 0 | 0 | 0 | 6 |

an unstratified estimate of abundance using the Movement estimator (Evenson 1988), were calculated for comparison (see Appendix A3, case II).

Size selectivity from gear type used during the experiment was examined with Kolmogorov-Smirnov two-sample tests. There was no significant difference between the length distributions of fish marked during the first event and length distributions of fish recaptured during the second event, within the study area (K/S two-sample test, $D = 0.16$, $P = 0.43$; Figure 12). Additionally, there was no significant difference between the length distributions of fish marked during the first event and fish caught and examined for marks during the second event (K/S two-sample test, $D = 0.07$, $P = 0.27$; Figure 12). These results indicated that there was no difference in capture probability by size (length) during neither the recapture event nor the marking event. Therefore, stratification by size during abundance estimates was not necessary, and lengths and ages obtained from fish caught during both events were used to estimate the length and age compositions of fish within the Jim River study area (Appendix A1, Case 1).

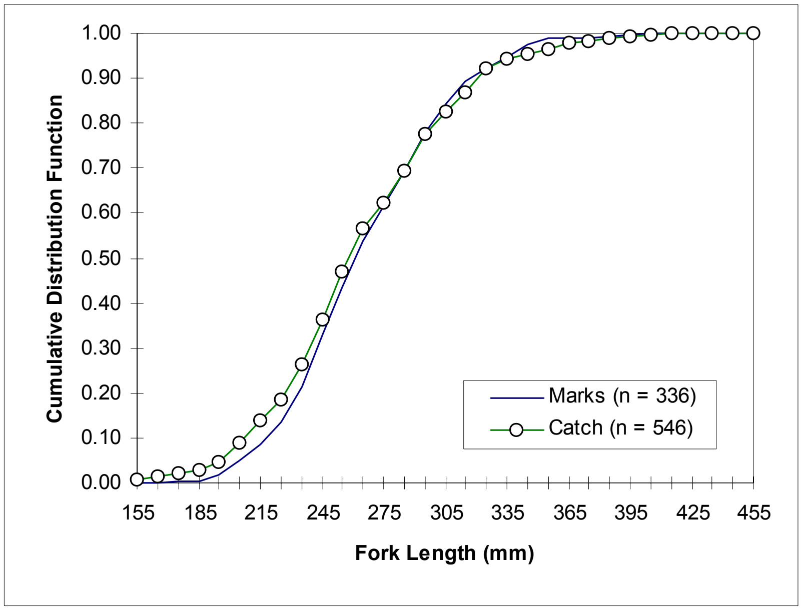
Using the Bailey estimator, the estimated abundance of Arctic grayling in the Jim River study area was 5,428 fish (SE = 887 fish, CV = 16%). The estimate of abundance generated by the Movement estimator was 5,105 fish (SE = 1,103 fish, CV = 22%). (The standard error was generated from an average estimate of 5,284, obtained from 5,000 iterations during bootstrap procedures). Comparison of the Bailey and Movement estimates for similarity revealed that there was a difference of 323 fish, or approximately 6%, between estimates. One could conclude that these estimates were likely similar. Typically, an estimate of abundance having the lower variance is generally chosen as the most appropriate estimate to describe a population (Appendix A3 & A1); in this case variance was lowest with the Bailey estimate. More importantly, however, the observed movement of fish in this experiment provided sufficient evidence to warrant against the use of the Bailey estimator. Therefore, as outlined in the experimental methodology of Appendix A2, the estimate calculated from the unstratified Movement estimator was chosen as the most appropriate estimate of abundance of Arctic grayling in the Jim River study area. Estimated density of Arctic grayling ≥ 150 mm FL was 240 fish per km (SE = 52 fish per km) within the Jim River study area.

## Estimation of Length and Age Compositions

Fork lengths of fish handled during the experiment ranged from 121 to 410 mm FL. Fork lengths measured from 844 (sum of fish handled during both events minus the number of recaptured fish) Arctic grayling ≥ 150 mm FL from the Jim River sampling area during June ranged from 159 to 409 mm FL, and averaged 264 mm FL. The proportion of Arctic grayling ≥ 269 mm FL during June was 0.49 (SE =0.08; Figure 13).

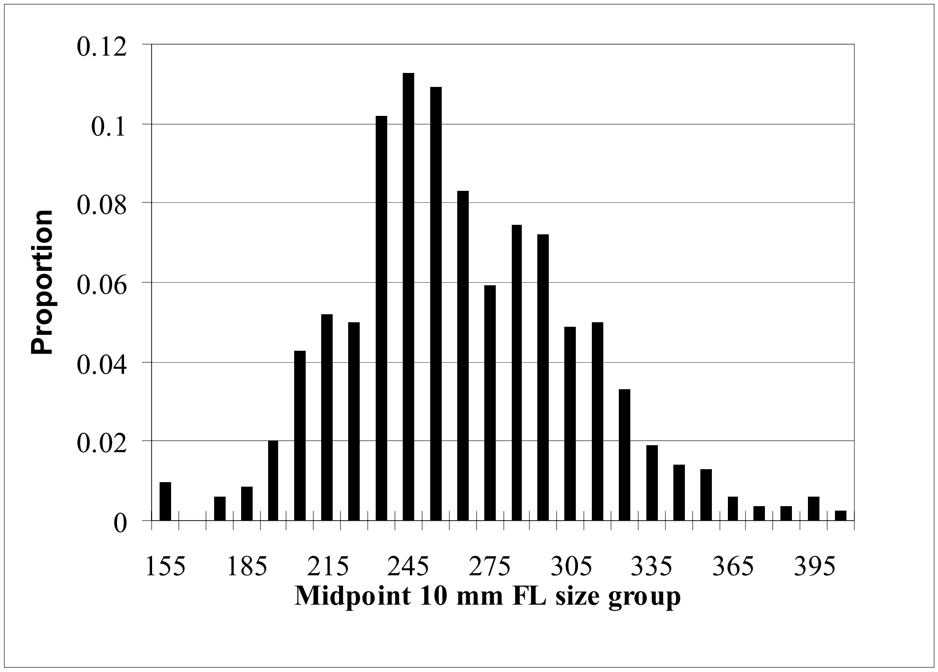
Fork lengths measured from 530 fish ≥ 150 mm FL caught during August ranged from 153 to 400 mm FL, with 267 mm FL being the average length. The proportion of Arctic grayling ≥ 269 mm FL during August was 0.44 (SE = 0.02, Figure 13).

Categorization of fork lengths into RSD categories revealed that most fish caught during both June and August were of the stock category, followed by quality and preferred (Table 14). No memorable- nor trophy-sized fish were caught during 1995.

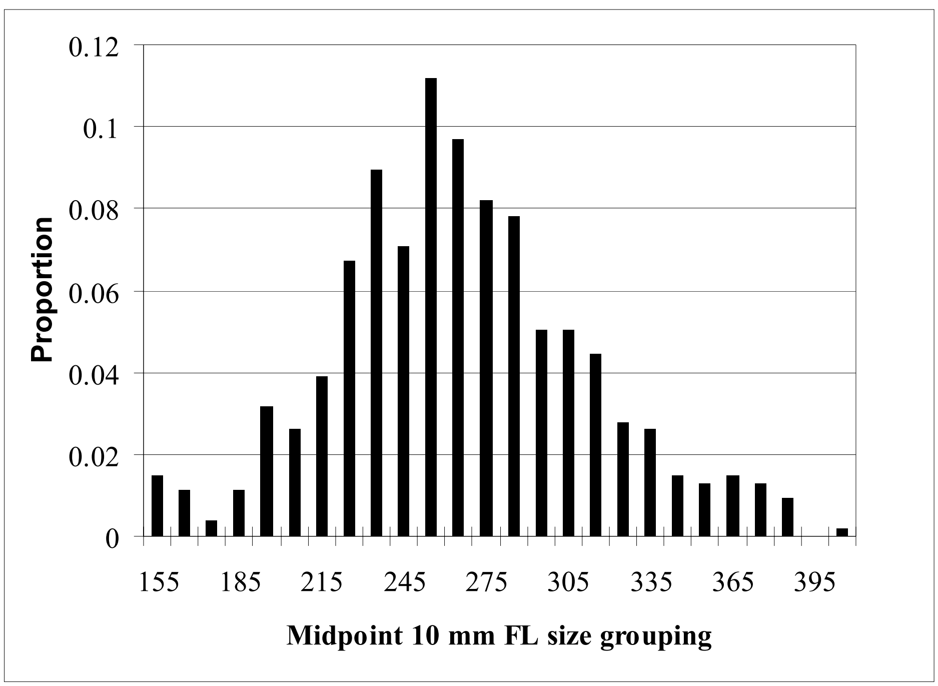



b)

**Figure 12.-Cumulative distribution functions of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured (a), and versus lengths of Arctic grayling examined for marks (b) in the Jim River, June 8 through 12, 1995.**




a)




b)

**Figure 13.-Estimated proportions of Arctic grayling (≥ 150 mm FL) by 10 mm FL incremental size categories in the Jim River during a) June (n = 844) and b) August (n =537), 1995.**

**Table 14.-Summary of estimated RSD categories for Arctic grayling within the Jim River during June and August of 1995.[a]**

| | | RSD Category | | | | |
|---|---|---|---|---|---|---|
| | | Stock | Quality | Preferred | Memorable | Trophy |
| June | number | 308 | 193 | 36 | 0 | 0 |
| | RSD | 0.57 | 0.36 | 0.07 | --- | --- |
| | SE | 0.02 | 0.02 | 0.01 | --- | --- |
| August | number | 502 | 301 | 41 | 0 | 0 |
| | RSD | 0.59 | 0.36 | 0.05 | --- | --- |
| | SE | 0.02 | 0.02 | 0.01 | --- | --- |

[a] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150-269 mm FL); quality (270-339 mm FL); preferred (340-449 mm FL); memorable (450-559 mm FL); and trophy (560 mm FL and greater).

Ages determined from scales of Arctic grayling ≥ 150 mm FL collected during both the marking and recapture events were used to estimate the age composition of Arctic grayling ≥ 150 mm FL within the Jim River sampling area. Ages were estimated from 743 of 833 fish and age classes ranged from age-2 to age-≥ 12 (Figure 14). Approximately 11% of the scales from 833 fish were regenerated or determined unreadable, resulting in 743 fish being used for the age composition analysis. The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Jim River study area were age-4 (P = 0.19, SE = 0.01), age-5 (P = 0.32, SE = 0.02), age-6 (P = 0.14, SE = 0.01), and age-7 (P = 0.16, SE = 0.01), with age-5 representing the most abundant proportion of fish (Figure 14; Table 15).

### Estimation of Contribution

Fish were sampled in August to examine the contribution of fish from the June mark-recapture experiment, or the proportion of fish marked in June occurring in the sample of fish caught in August. Of 530 fish ≥ 150 mm FL caught during August, 50 fish were marked during June experiment (16 from the first event, and 34 from the second event). The contribution of fish marked during the June experiment and caught during August was approximately 61% ($p_c$ = 0.61, SE[$p_c$] = 0.13). Of the 50 fish recovered, 21 fish (42%) moved to different river sections of the study area, from where they were released during June, while 29 fish (58%) remained. Of the fish that moved, four moved upstream, while 17 moved downstream.

### Catch Per Unit Effort

A CPUE of 6.02 Arctic grayling per angler hour was observed during 1995, from 1,420 Arctic grayling caught per 236 hours total angling effort. As mentioned above, Netsch (1975) reported an average catch of 5.9 Arctic grayling per angler hour, from 533 Arctic grayling per 90.2 hours total angling effort in three streams combined (Jim River, Prospect Creek, and stream HR2-1405-92), during June, 1972.

### Mean Length-at-Age

Mean length-at-age (shown in Table 9) was calculated for Arctic grayling the Jim River during 1995, and plotted with mean length-at-age of Arctic grayling from other stock assessment studies (Figure 11). Mean length-at-age of fish collected from the Jim River during 1995 appears consistent with mean length-at-age data from 1971-2 and 1997, as well as with data from creeks sampled during 1996. Error in the age determinations may account for slight differences in mean length, at any given age.

## STOCK ASSESSMENT IN THE JIM RIVER DURING 1997

#### June, July, and August 1997

During 1997, investigators handled 1,165 individual Arctic grayling ≥ 150 mm FL during the Jim River stock assessment and CPUE studies. During CPUE studies conducted in June, 136 fish were marked and released alive. The mark-recapture experiment during July had a duration of seven days from beginning to end, and a hiatus of four days between marking and recapture events. During the marking event (July 17, 18, and 19), 592 fish were captured, but 574 Arctic grayling were tagged and released alive (14 fish were killed from hooking injury and excessive bleeding, and four fish were undersized). One of these 574 fish was not measured for length, but

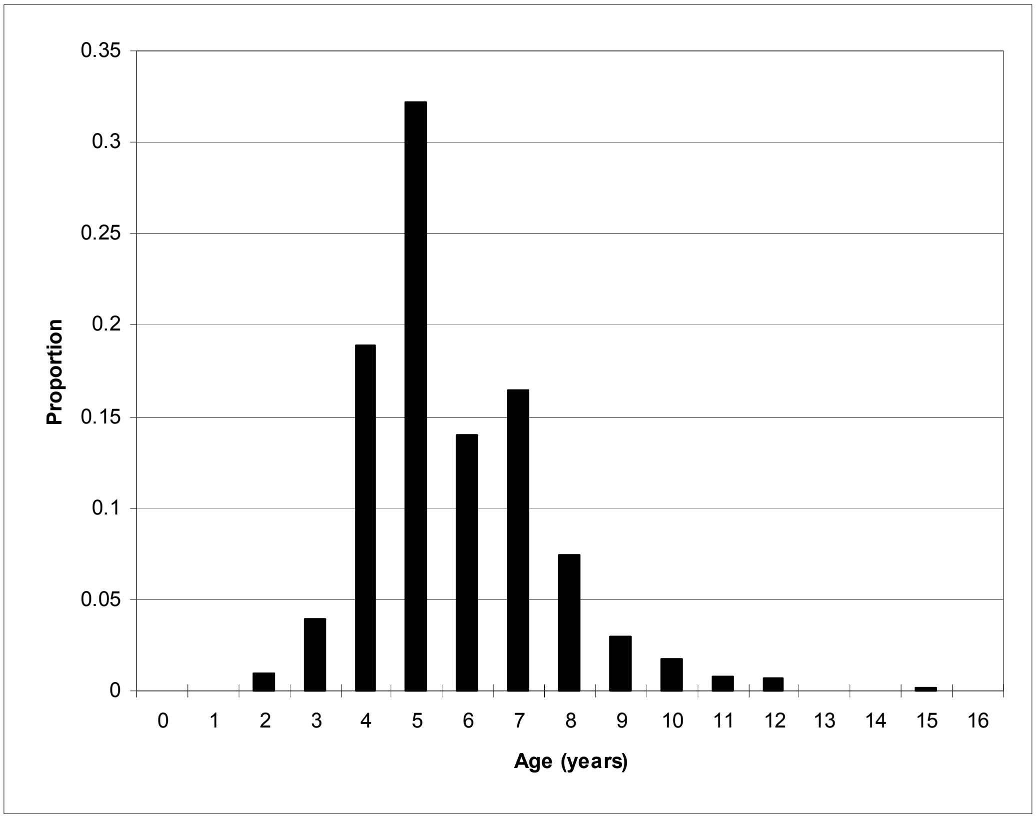



**Figure 14.-Estimated proportion of Arctic grayling (≥ 150 mm FL) by age in the Jim River during June, 1995 (n = 743).**

**Table 15.-Estimates of age composition and abundance by age class with standard errors for Arctic grayling (≥ 150 mm FL) in the Jim River study area, June 8 through 12, 1995.**

| | Age Composition | | | Abundance | | |
|---|---|---|---|---|---|---|
| Age | n | p | SE[p] | Ñ | SE[Ñ] | CV |
| 2 | 7 | 0.009 | 0.004 | 48 | 21 | 42.6 |
| 3 | 29 | 0.039 | 0.007 | 200 | 56 | 28.0 |
| 4 | 140 | 0.189 | 0.014 | 963 | 220 | 22.9 |
| 5 | 239 | 0.322 | 0.017 | 1,644 | 366 | 22.2 |
| 6 | 104 | 0.140 | 0.013 | 716 | 167 | 23.4 |
| 7 | 122 | 0.164 | 0.014 | 839 | 194 | 23.1 |
| 8 | 55 | 0.074 | 0.010 | 378 | 95 | 25.1 |
| 9 | 22 | 0.030 | 0.006 | 151 | 45 | 29.8 |
| 10 | 13 | 0.018 | 0.005 | 89 | 31 | 34.5 |
| 11 | 6 | 0.008 | 0.003 | 41 | 19 | 45.2 |
| 12 | 5 | 0.007 | 0.003 | 34 | 17 | 48.6 |
| 13 | 0 | 0 | --- | 0 | --- | --- |
| 14 | 0 | 0 | --- | 0 | --- | --- |
| 15 | 1 | 0.001 | 0.001 | 7 | 7 | 0.0 |
| 16 | 0 | 0 | --- | 0 | --- | --- |
| Totals | 743 | 1.000 | | 5,105 | --- | |

was included in the mark-recapture experiment. The killed, undersized fish were not included in the experiment. During the recapture event (July 21, 22, & 23), 441 Arctic grayling were captured and examined for marks. These fish were not tagged, but were released bearing a lower caudal partial fin clip. Of these 441 fish, 438 were clipped and released; two were killed from hooking injury, one was undersized, and 22 were recaptured from the marking event. The killed fish were included in the experiment. A total of five fish <150 mm FL were caught during both events (four during the marking event, and one during the recapture event), but were not included in any analyses. Of the 22 recaptured fish, none lost their tags between marking or recapture (see Table 16 for summary of capture histories).

A total of 626 Arctic grayling ≥ 150 mm FL were caught and examined for marks during the August sampling event. Of these, 582 fish were unmarked, 44 fish were recovered from the mark-recapture experiment of July (30 from the marking event, and 14 from the recapture event), while five fish were killed from hooking injury. During CPUE studies conducted in August, 52 fish were captured; seven of which were identified from prior 1997 sampling events. Overall, investigators identified 30 of 841 tagged Arctic grayling from Jim River mark-recapture experiment of 1995. These fish possessed green Floy tags.

During stock assessment studies undertaken in 1997, 55 fish (43 fish collected during the recapture event of the July mark-recapture experiment, and 12 collected during August sampling activities) were also surgically implanted with radio-transmitters to study migrational habits of Jim River Arctic grayling. Investigators hope to identify overwintering and spawning locations, as well as estimate fidelity of Arctic grayling to Jim River summer feeding habitat.

## Estimation of Abundance

During the estimation of abundance, the capture probability and rate of recapture of Arctic Grayling during the experiment, within each of four approximately equal-length (~5.3 km) river sections, was examined with both the ratios of recaptures to captures (R/C) and the ratio of recaptures to marks (R/M). After being calculated, these ratios were evaluated with chi-squared tests to examine if capture probability differed between each river section, and to examine if rates of recovery were similar between river sections. The R/C, from upstream to downstream, for each river section within the study area was 0.11, 0.06, 0.05, and 0.02, respectively (Table 17). The R/M, from upstream to downstream, in each river section within the study area was 0.11, 0.03, 0.04, and 0.02, respectively (Table 18). There were significant differences between the R/M values ($\chi^2$= 12.89, 3 df, P = 0.005). These results suggest that there was heterogeneity in recovery rates between river sections. Likewise, there were also significant differences between the R/C values ($\chi^2$= 8.33, 3 df, P = 0.04) among the four approximately equal-length river sections. These results suggest that fish did not have the same probability of capture, or were differentially captured during the recapture event in any given river section. Therefore, stratification by area (river section) was necessary during abundance estimates, as outlined in Appendices A2 and A3.

Since the R:M and R:C values of some river sections were similar, sections 2, 3, and 4 were combined (see Table 19 for adjusted capture histories). Both R:M and R:C were recalculated for the combined section, differences between Section 1 and the combined sections 2, 3, and 4 were reevaluated with the chi-squared tests described above for differences in capture probability and mixing rates. Results indicated that there were no significant differences between the R/M ratios within the combined section ($\chi^2$= 1.49, 2 df, P = 0.48); nor were there

**Table 16.-Summary of capture histories of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

| | Mark | Recap | |
|---|---|---|---|
| Area | # marks | # catch | # recaps |
| 1 | 72 | 74 | 8 |
| 2 | 124 | 65 | 4 |
| 3 | 193 | 151 | 7 |
| 4 | 184 | 150 | 3 |
| Totals | 753 | 440 | 22 |

**Table 17.-Contingency table analysis of capture probabilities of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

| | Upstream | Mid-Upper | Mid-Lower | Downstream | Total | |
|---|---|---|---|---|---|---|
| Recaptured | 8 | 4 | 7 | 3 | 22 | (R) |
| Catch-Recaps | 66 | 61 | 144 | 147 | 418 | (C-R) |
| Total | 74 | 65 | 151 | 150 | 440 | (C) |
| Capture Prob during 2nd event | 0.108 | 0.062 | 0.046 | 0.02 | 0.05 | (R/C) |

$\chi_2 = 8.3268$, df = 3, P = 0.0397

**Table 18.-Contingency table analysis of recapture rates of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

| | Upstream | Mid-Upper | Mid-Lower | Downstream | Total | |
|---|---|---|---|---|---|---|
| Recaptured | 8 | 4 | 7 | 3 | 22 | (R) |
| Not Recaptured | 64 | 120 | 186 | 181 | 551 | (M-R) |
| Total | 72 | 124 | 193 | 184 | 573 | (M) |
| Recapture Rate | 0.111 | 0.032 | 0.036 | 0.016 | 0.038 | |

$\chi^2 = 12.8938$, df = 3, P = 0.0049

**Table 19.-Adjusted summary of capture histories of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

| | Mark | Recap | |
|---|---|---|---|
| Section | # marks | # catch | # recaps |
| 1 | 72 | 74 | 8 |
| 2[a] | 502 | 366 | 14 |
| Totals | 754 | 440 | 22 |

[a] Section 2 is made up of original sections 2, 3, and 4 together.

any significant differences of R/C ratios within the combined section ($\chi^2$= 2.59, 2 df, P = 0.27). However, there were significant differences between the R/M values when section one was compared to the combined sections 2, 3, and 4 ($\chi^2$= 11.83, 1 df, P = 0.0005; Table 20). Likewise, there were significant differences in R/C values when section one was compared to the combined sections 2, 3, and 4 ($\chi^2$= 6.32, 1 df, P = 0.01; Table 21). These results are consistent with those above, in that differences in capture probability and recapture rates occurred during the mark-recapture experiment, and geographical stratification was necessary during abundance estimates. River section 1 was designated as Stratum 1, while the combined River Sections 2, 3, and 4 were designated as Stratum 2.

Comparison of areas where Arctic grayling were marked with areas where the fish were recaptured indicated that no movement between river sections occurred between marking and recapture events. However, exact locations of capture and release were not recorded with GPS coordinates or river mile location. Investigators noticed that fishing success in specific locations during the recapture event was different from what it was during the mark event. This suggested that movement may have occurred within river sections. Alternatively, fish may have been displaying gear avoidance in some locations and gear happiness in others. However, lack of movement between river sections suggested that emigration and immigration were unlikely between the marking and recapture events, and that a closed population model was appropriate for abundance estimates.

Size selectivity from gear type use during the experiment was examined with Kolmogorov-Smirnov two-sample tests, within each geographic strata. Usually this procedure is performed with unstratified data (Appendix A1). However, because geographical differences in capture probabilities occurred, the K-S tests were performed within each geographic strata. Within Stratum One (which included River Section 1 only; the most upstream portion of the study area), there was no significant difference between the length distributions of fish marked during the first event and length distributions of fish recaptured during the second event, within the study area (K/S two-sample test, D = 0.33, P = 0.40; Figure 15); nor was there a significant difference between the length distributions of fish marked during the first event and fish caught and examined for marks during the second event (K/S two-sample test, D = 0.14, P = 0.54; Figure 15). These results suggest that there was no size selectivity during either event within this stratum. Within Stratum 2 (which included River Sections 2, 3, and 4), there was no significant difference between length distributions of fish marked during the first event and fish recaptured during the second event (K/S two-sample test, D = 0.20, P = 0.64; Figure 16). However, there was a significant difference between the length distributions of fish marked during the first event and fish caught and examined for marks during the second event (K/S two-sample test, D = 0.09, P = 0.05; Figure 16). The median of the lengths of fish marked during the first event was 262 mm FL, while the median of the lengths of fish examined for marks during the second event was 273 mm FL. These results indicated that there was size selectivity during sampling the mark event within Stratum 2, and that it was biologically meaningful (i.e. a median difference between length distributions of 11 mm FL). Therefore, the data were further stratified into small and large size classes, and a stratified abundance estimate was calculated. Stratification of 150 to 285 mm FL for small fish, and ≥ 285 mm FL for large fish were estimated from the largest difference between length distributions in Figure 16. Using the Bailey estimator, abundance estimates from the two size strata (within Stratum 2) were calculated and summed, then added the abundance estimate from Stratum 1, for an overall abundance of 12,059 fish in the Jim River

**Table 20.-Contingency table analysis of adjusted recapture rates of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

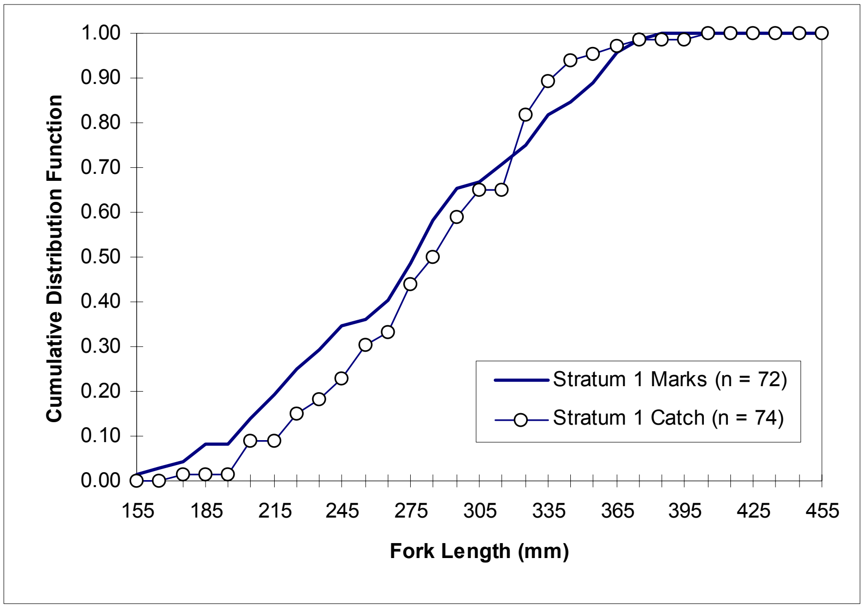
| | Upstream | Mid-Upper | Mid-Lower | Downstream | | |
|---|---|---|---|---|---|---|
| | Section 1 | | Section 2 | | Total | |
| Recaptured | 8 | | 14 | | 22 | (R) |
| Not Recaptured | 64 | | 488 | | 552 | (M-R) |
| Total | 72 | | 502 | | 574 | (M) |
| Recapture Rate | 0.111 | | 0.028 | | 0.038 | |

($\chi 2$ = 11.832, df = 1, P = 0.0006)

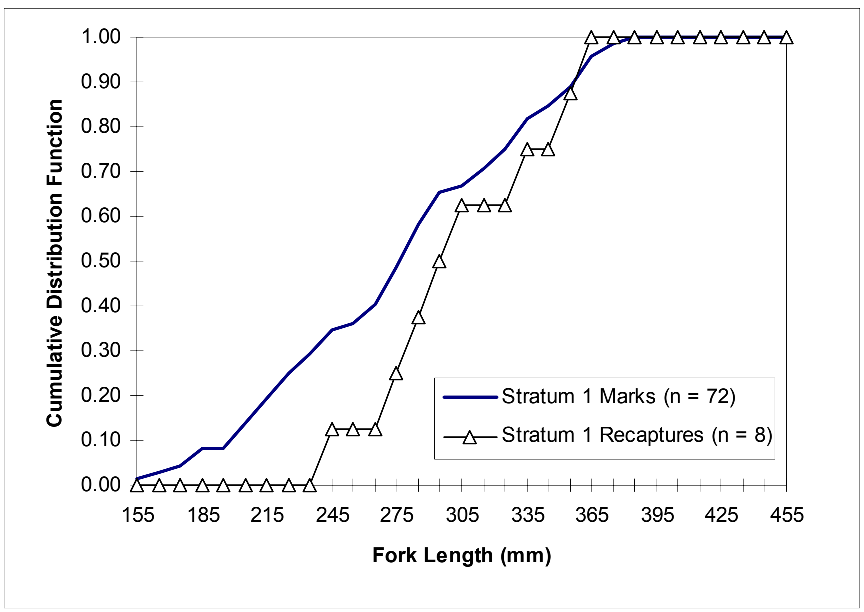
**Table 21.-Contingency table analysis of adjusted capture probabilities of Arctic grayling ≥ 150 mm FL caught during the mark-recapture experiment in the Jim River, July 1997.**

| | Upstream | Mid-Upper | Mid-Lower | Downstream | 1 | |
|---|---|---|---|---|---|---|
| | Section 1 | | Section 2 | | Total | |
| Recaptured | 8 | | 14 | | 22 | (R) |
| Catch-Recaps | 66 | | 352 | | 418 | (C-R) |
| Total | 74 | | 366 | | 440 | (C) |
| Capture Prob during 2nd event | 0.108 | | 0.038 | | 0.05 | (R/C) |

($\chi 2$ = 6.324, df = 1, P = 0.012)

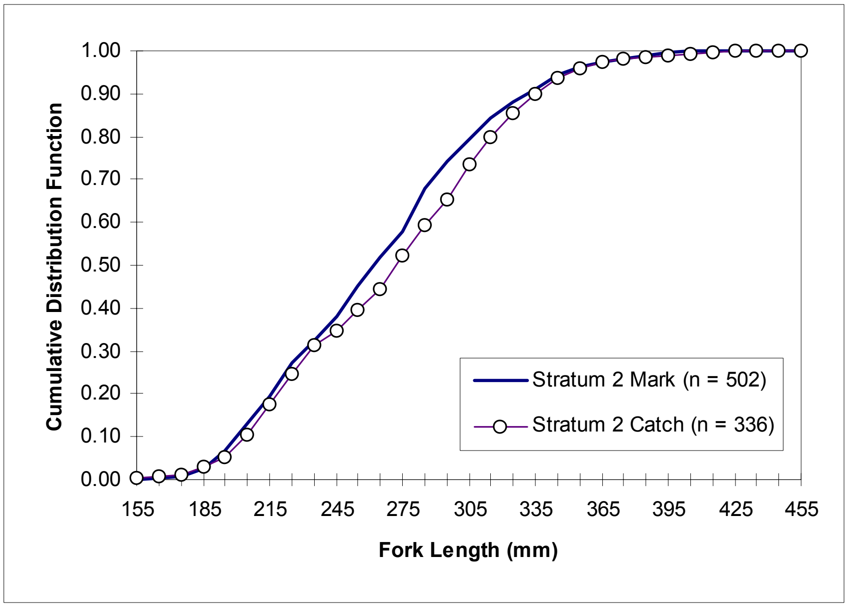



(K/S two-sample test, D = 0.14, P = 0.54)

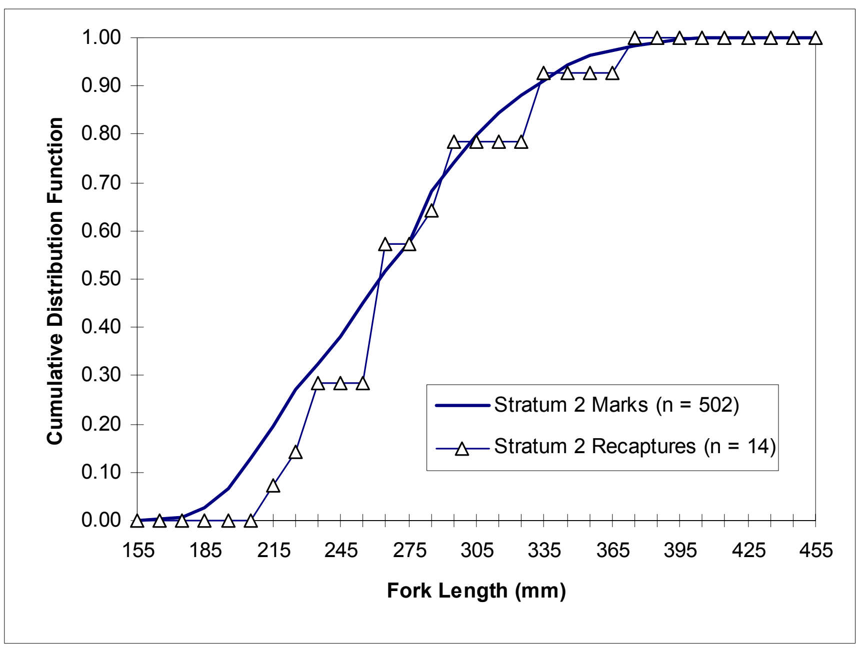



(K/S two-sample tests, D = 0.33, P = 0.40)

**Figure 15.-Cumulative distribution functions of fork lengths of Arctic grayling marked, captured, and recaptured within Stratum 1 of the Jim River study area, July 17 through 23, 1997.**




(K/S two-sample test, D = 0.09, P = 0.05)




(K/S two-sample test, D = 0.20, P = 0.64)

**Figure 16.- Cumulative distribution functions of fork lengths of Arctic grayling marked, captured, and recaptured within Stratum 2 of the Jim River study area, July 17 through 23, 1997.**

study area (SE =2,650, CV = 22%, 95% CI = [6,866; 17,253] ) (Table 22). Adjusted estimates of length and age compositions (described below) were also calculated to estimate the length and age composition of fish in the Jim River (Appendix A1).

Multiple gear types, employed to avoid the bias of selectivity associated with a single gear type, were not utilized during Jim River stock assessments of 1997. This is potentially problematic because fish may display either gear shyness or gear happiness, which would result in differential capture probabilities. In the case of gear shyness, the selectivity of a single gear type would result in an abundance estimate that is biased high. Furthermore, quantification of the bias is not possible without some type comparison of capture probabilities among multiple gear types. Therefore, gear selectivity was examined using data from Arctic grayling assessments conducted on the Seward Peninsula in Northwest Alaska. During 1993, Arctic grayling were captured during a mark-recapture experiment, with a combination of hook-and-line and beach seine gear. A total of 306 fish were marked with beach seine, while a total of 141 fish were marked with hook-and-line gear. The proportions of fish marked, recaptured and not recaptured by either gear type was examined using a chi-squared test, and is shown in Table 23**.** There were no significant differences ($\chi^2$ = 2.24, df = 3. P = 0.5242) the proportions of fish marked, recaptured, and not recaptured by gear type, suggesting that fish did not display gear shyness nor happiness. Although this examination includes fish, circumstances and environmental variables from a different drainage system, as well as a longer hiatus between events, this is evidence to suggest that, given an adequate hiatus (five days) between handling events, Arctic grayling do not display an avoidance to be captured by hook-and-line gear. If this assumption is applied to fish caught during the stock assessment in the Jim River during 1997 (with a hiatus of four days), gear shyness should not have biased abundance estimates high. The observed significant differences in capture probability between river sections are assumed to be caused by something other than gear avoidance, such as changes in personnel between events on a given section of river, changes in streamflow between events, etc. Insofar as significant differences in capture probability between river sections remained, the mark-recapture experimental assumptions of equal capture probability and complete mixing were still violated. As a result, a geographically stratified estimate of abundance, using the Bailey estimator (Bailey 1951, 1952), was calculated. The estimated abundance from the geographic stratification procedure was 12,882 (SE = 3012.43, CV = 23%, 95% CI = [6,978, 18,787]). Since diagnostic tests also indicated size selectivity within a geographical stratum, the data were further stratified, and estimates of abundance for each stratum were summed, as described above.

Typically, an unstratified abundance estimate is compared to a stratified estimate, and the more conservative estimate (usually having a lower variance) is chosen as the best estimate (Appendix A3). Although an unstratified estimate may be more conservative, and have a lower variance, the true value of abundance may not lie in the error coverage of the unstartified estimate. Since the objectives of stock assessment include measurements of variance in addition to point estimates of abundance, the best estimate would be chosen based upon results of diagnostic tests examining the assumptions of accurate abundance estimation. In the case of data from the Jim River during 1997, assumption testing indicated differing capture probabilities and incomplete mixing within the study area. When the geographically stratified abundance estimate is compared to the abundance estimate from both geographic and size stratification, there is a difference of 823 fish (~6%). The estimate of 12,059 fish was chosen as the best estimate of abundance, not because of its lower variance, but because it is a nearly unbiased estimate of abundance, based upon adjustments and corrections made during assumption testing. The

**Table 22.-Summary of marks, catch, recaptures, capture probabilities, and estimated abundance in two geographical strata, and one size strata, used for population estimation of Arctic grayling (≥ 150 mm FL) in the Jim River, 17 July through 23 July, 1997.**

| | Mark (n1) | Catch (n2) | Recap (m2) | m2/n1 (R:M) | m2/n2 (R:C) | Ñ | SE[Ñ] |
|---|---|---|---|---|---|---|---|
| Stratum 1 | 72 | 74 | 8 | 0.111 | 0.108 | 600 | 178 |
| Stratum 2 | | | | | | | |
| 150-285 mm FL | 333 | 217 | 9 | 0.027 | 0.041 | 7259 | 2138 |
| ≥ 285 mm FL | 168 | 149 | 5 | 0.030 | 0.034 | 4200 | 1555 |
| Overall | 573 [a] | 440 | 22 | 0.038 | 0.05 | 12,059 | 2,650 |

[a] A total of 573 fish (instead of 574) were marked in the stratified estimate, since one marked fish was not measured.

**Table 23.-Contingency table analysis of fish marked, recaptured, and not recaptured by gear type during a mark-recapture study conducted in the Snake River (Seward Peninsula), 1993.**

| | Gear Type | Total Marked | Recaptured by Hook and Line | Recaptured by Seine | Not Recaptured |
|---|---|---|---|---|---|
| Marked by | Hook and Line | 141 | 7 | 29 | 105 |
| Marked by | Seine | 306 | 22 | 77 | 207 |

($\chi^2$ = 2.24, df = 3, P = 0.52)

estimate of 12,059 fish (SE =2,650, CV = 22%, 95% CI = [6,866; 17,253] ) reflects a density of 566 fish per km, with the study area.

## Estimation of Length and Age Compositions

Fork lengths of fish handled during the experiment ranged from 121 to 416 mm FL. Fork lengths measured from 991 (sum of fish handled during both events minus the number of recaptured fish) Arctic grayling ≥ 150 mm FL from the Jim River sampling area during July ranged from 154 to 416 mm FL, and averaged 268 mm FL (SD = 50.6 ). Of 991 fish handled, the proportion of Arctic grayling ≥ 269 mm FL within the sample was 0.51 (SE = 0.02). The length composition estimated for the Jim River study area is shown in both Table 24 and Figure 17. These proportions were estimated after corrections were made to data during assumption testing.

Fork lengths measured from 138 fish caught during June ranged from 138 to 379 mm FL, with 253 mm FL being the average length (SD = 46.2). The proportion of Arctic grayling ≥ 269 mm FL within the sample during June was 0.36 (SE = 0.041).

Fork lengths measured from 678 fish caught during August ranged from 155 to 457 mm FL, with 278 mm FL being the average length (SD = 52.27). The proportion of Arctic grayling ≥ 269 mm FL within the sample during August was 0.55 (SE = 0.019).

Categorization of fork lengths into RSD categories revealed that most fish caught during July were of the stock category, followed by quality and preferred (Table 25). No memorable- nor trophy-sized fish were caught during 1997.

Ages determined from scales of Arctic grayling ≥ 150 mm FL collected during the mark-recapture experiment of July, were used to estimate the age composition of Arctic grayling ≥ 150 mm FL within the Jim River sampling area. Ages were estimated from 609 of 843 fish and age classes ranged from age-2 to age 16 (Figure 18). Approximately 10 % of the scales from 843 fish were regenerated or determined unreadable, resulting in 753 aged fish. However, 627 ages were determined from fish collected during the mark-recapture experiment, and were used to estimate age composition (126 ages were collected from fish during June, but were not included in the estimation of age composition). The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Jim River study area were age-3 (P = 0.25, SE = 0.02), age-5 (P = 0.19, SE = 0.02), and age-4 (P = 0.15, SE = 0.02), with age-3 representing the most abundant proportion of fish (Table 26 and Figure 18).

After performing diagnostic procedures to examine for difference in catchability and gear selectivity, attempts were made to correct for bias by stratifying the data based upon geographical differences in capture probability, as well as size selectivity within geographic strata. Results indicated that there was size selectivity during the mark event, but not during the recapture event. As a result ages and lengths from the recapture would normally be used to estimate age and length composition of the population (Appendix A1). However, during stock assessment activities scales were taken mostly during the mark event. Scales were initially taken during the recapture event, until a sample size of 571 was attained. As a result, scales (and lengths) taken during the mark event have bias associated with them because of the occurrence of size selectivity. However, when the abundance estimates are compared (geographically stratified vs. geographically and size stratified), there is a difference of 823 fish (or approximately 6%). This suggests that the bias associated with age and length data taken during

**Table 24.-Estimates of adjusted length composition and abundance by length class with standard errors for Arctic grayling (≥ 150 mm FL) in the Jim River, during July 17 through 23, 1997.**

| Mid-Point Fork Length (mm) | n | adj p | SE[adj p] | CV[adj p] | Ñ | SE[Ñ[ | CV[Ñ] |
|---|---|---|---|---|---|---|---|
| 155 | 1 | 0.0004 | 0.0004 | 106 | 4 | 4.35 | 100 |
| 165 | 3 | 0.003 | 0.002 | 63 | 31 | 19.77 | 64 |
| 175 | 7 | 0.006 | 0.003 | 41 | 75 | 33.43 | 45 |
| 185 | 19 | 0.019 | 0.005 | 24 | 227 | 72.03 | 32 |
| 195 | 29 | 0.032 | 0.006 | 18 | 388 | 113.19 | 29 |
| 205 | 58 | 0.058 | 0.008 | 13 | 695 | 176.13 | 25 |
| 215 | 62 | 0.066 | 0.008 | 13 | 793 | 203.33 | 26 |
| 225 | 71 | 0.073 | 0.009 | 12 | 877 | 218.95 | 25 |
| 235 | 55 | 0.057 | 0.008 | 13 | 691 | 178.86 | 26 |
| 245 | 46 | 0.046 | 0.007 | 15 | 552 | 144.93 | 26 |
| 255 | 60 | 0.062 | 0.008 | 13 | 748 | 191.10 | 26 |
| 265 | 55 | 0.057 | 0.008 | 13 | 691 | 178.86 | 26 |
| 275 | 71 | 0.070 | 0.008 | 12 | 832 | 204.29 | 25 |
| 285 | 87 | 0.088 | 0.009 | 11 | 1,065 | 259.43 | 24 |
| 295 | 64 | 0.064 | 0.008 | 13 | 765 | 190.61 | 25 |
| 305 | 61 | 0.063 | 0.008 | 13 | 757 | 198.87 | 26 |
| 315 | 49 | 0.053 | 0.007 | 14 | 635 | 167.84 | 26 |

**-continued-**

**Table 24.-Page 2 of 2.**

| Mid-Point Fork Length (mm) | n | adj p | SE[adj p] | CV[adj p] | Ñ | SE[Ñ[ | CV[Ñ] |
|---|---|---|---|---|---|---|---|
| 325 | 52 | 0.048 | 0.007 | 15 | 575 | 144.55 | 25 |
| 335 | 40 | 0.037 | 0.006 | 17 | 449 | 118.62 | 27 |
| 345 | 36 | 0.037 | 0.006 | 17 | 441 | 120.97 | 27 |
| 355 | 21 | 0.021 | 0.005 | 23 | 248 | 76.11 | 31 |
| 365 | 17 | 0.015 | 0.004 | 27 | 175 | 56.69 | 32 |
| 375 | 10 | 0.009 | 0.003 | 34 | 108 | 41.82 | 39 |
| 385 | 6 | 0.006 | 0.003 | 42 | 72 | 33.44 | 47 |
| 395 | 5 | 0.006 | 0.003 | 45 | 68 | 33.15 | 49 |
| 405 | 4 | 0.004 | 0.002 | 53 | 44 | 24.77 | 56 |
| 415 | 1 | 0.001 | 0.001 | 99 | 14 | 13.60 | 99 |
| 425 | 1 | 0.001 | 0.001 | 99 | 14 | 13.60 | 99 |
| Total | 991 | 1.000 | | | 12,037 | | |

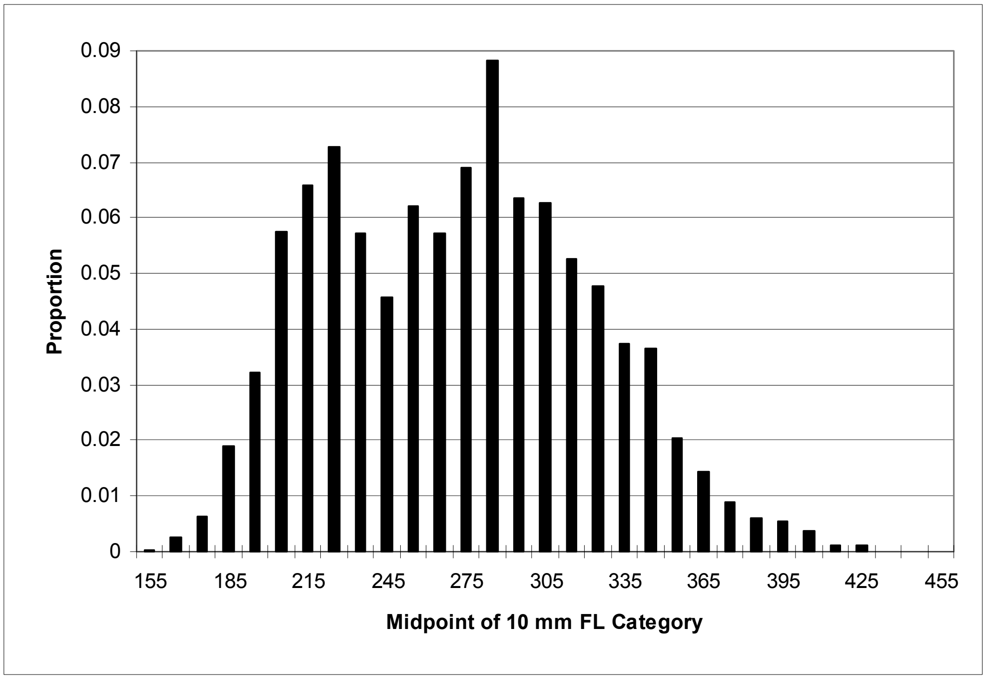



**Figure 17.-Length composition of Arctic grayling (≥ 150 mm FL) in the Jim River study area, July 17 through 23, 1997 (n = 991).**

**Table 25.-Estimated proportion and abundance by RSD category of Arctic grayling (≥ 150 mm FL) in the Jim River during July 17 through 23, 1997.**

| | RSD Category | | | | |
|---|---|---|---|---|---|
| | Stock | Quality | Preferred | Memorable | Trophy |
| n | 494 | 412 | 85 | 0 | 0 |
| adj p | 0.51 | 0.41 | 0.01 | 0 | 0 |
| SE[adj p] | 0.02 | 0.02 | 0.01 | --- | --- |
| Ñ | 6103 | 4972 | 985 | 0 | 0 |
| SE[Ñ] | 1367.37 | 1102.48 | 234.90 | --- | --- |

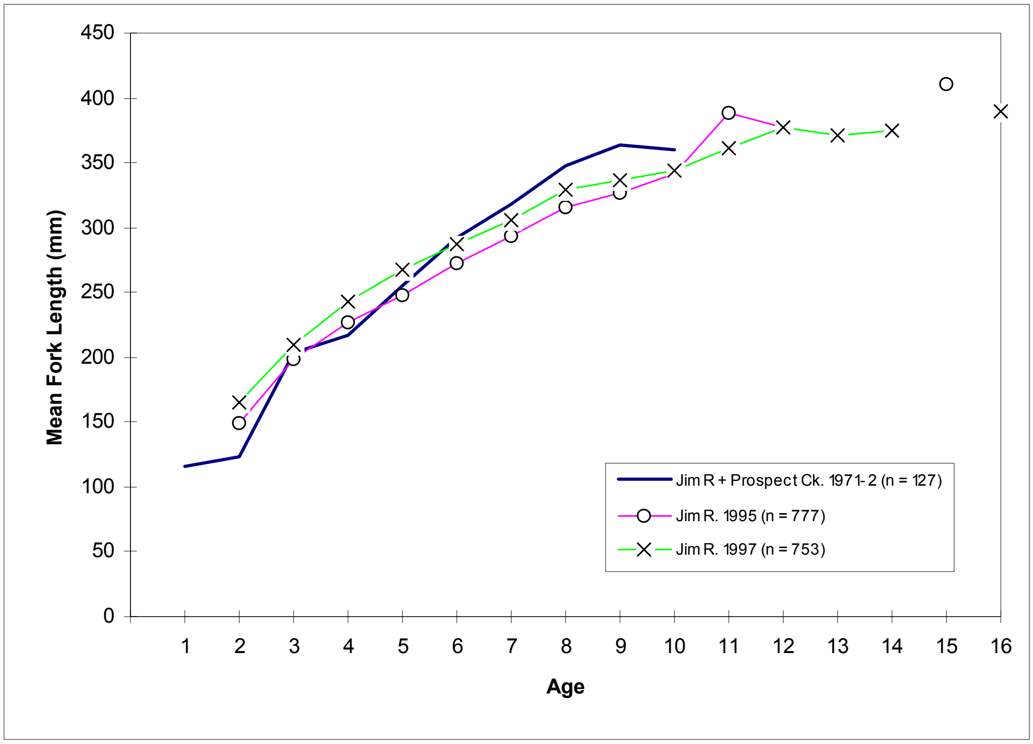



**Figure 18.-Age composition of Arctic grayling (≥ 150 mm FL) in the Jim River study area during July 17 through 23, 1997 (n = 609).**

**Table 26.-Estimates of adjusted age composition and abundance by age class with standard errors for Arctic grayling (≥ 150 mm FL) captured in the Jim River, during the mark-recapture experiment of July 17 through 23, 1997.**

| | Age Composition | | | | Abundance | | |
|---|---|---|---|---|---|---|---|
| Age | n[a] | adj p[b] | SE | CV | Ñ[c] | SE | CV |
| 2 | 10 | 0.014 | 0.005 | 35.6 | 167 | 69 | 41.1 |
| 3 | 157 | 0.250 | 0.019 | 7.5 | 3,010 | 697 | 23.1 |
| 4 | 95 | 0.145 | 0.015 | 10.4 | 1,744 | 422 | 24.2 |
| 5 | 111 | 0.185 | 0.017 | 9.1 | 2,231 | 528 | 23.7 |
| 6 | 75 | 0.127 | 0.014 | 11.2 | 1,532 | 376 | 24.6 |
| 7 | 79 | 0.136 | 0.015 | 10.8 | 1,645 | 401 | 24.4 |
| 8 | 35 | 0.062 | 0.010 | 16.6 | 751 | 205 | 27.3 |
| 9 | 16 | 0.028 | 0.007 | 25.2 | 337 | 111 | 33.0 |
| 10 | 10 | 0.018 | 0.006 | 31.5 | 220 | 83 | 37.8 |
| 11 | 12 | 0.017 | 0.006 | 31.4 | 210 | 79 | 37.7 |
| 12 | 4 | 0.009 | 0.004 | 46.6 | 105 | 53 | 50.5 |
| 13 | 3 | 0.005 | 0.003 | 60.7 | 58 | 37 | 63.1 |
| 14 | 1 | 0.002 | 0.002 | 93.5 | 26 | 25 | 93.9 |
| 15 | 0 | 0 | 0 | --- | 0 | 0 | --- |
| 16 | 1 | 0.002 | 0.002 | 93.5 | 26 | 25 | 93.9 |
| Totals | 609 | 1.0 | --- | --- | 11,952 | 3,111 | 598.13 |

[a] n = number of Arctic grayling sampled at age.

[b] p = estimated adjusted proportion of Arctic grayling at age in the population.

[c] Ñ = estimated population abundance of Arctic grayling at age.

the mark event is likely to be negligible. Whether or not estimations of composition remain biased after corrections were made is unknown, without inferences from simulation studies. In light of the magnitude of bias, however, the estimates of stock composition are probably nearly unbiased, and approximate the composition of the population within the study area.

## Estimation of Contribution

Fish were sampled in August as part of the radio telemetry studies begun during July, and to examine the proportion of fish marked during July occurring in the sample of fish caught in August.

Of 678 fish caught during August, 626 fish were caught during a single sampling event down the entire length of the sampling area. Fifty-two fish were caught during CPUE investigations, and were not included in the calculation of contribution. Of the 626 fish caught during August, 44 fish were marked during July experiment (32 from the first event, and 12 from the second event). The contribution of fish marked during the July experiment and caught during August was approximately 86% ($p_c$ = 0.856, SE[$p_c$] = 0.23). Of the 44 fish recovered, 14 did not have a tag, but rather, had a fin clip. The original release location of these fish could not be determined. Of the 30 fish remaining, six fish (20%) moved to different river sections of the study area, from where they were released during July, while 23 fish (77%) remained in the same river section. Of the fish that moved, three moved upstream, while three moved downstream.

The contribution of fish marked during June and captured during July or August was not calculated because an estimate of abundance is not available for the month of June. However, of 136 fish tagged and released during June, only six were captured again during July, while seven were captured during August. Two of the fish captured during August were also caught during July. None of the fish marked during June and captured during July or August moved to different river locations, between the times of capture.

The contribution of fish marked during 1995 and captured during 1997 was also examined. Of 841 fish marked and released during 1995, 30 were captured during 1997 (Two fish were recorded with erroneous tag numbers, but still had green tags and were included in the analysis). The contribution of tagged fish from 1995 to 1997 was approximately 10% ($p_c$ = 0.10, SE[$p_c$] = 0.03).

## Catch Per Unit Effort

CPUE data were collected at accessible and remote spots during June 25 through 27, July 17 through 19, and August 4, 1997. Catch per unit effort during 1997 ranged from 0.9 fish per angler hour to 14.4 fish per angler hour. Table 27 reports the CPUE calculated for each location during the months of June, July and August. These values of CPUE differ from those collected during 1995 and 1996, in that time spent angling during 1997 was discriminated from time spent collecting age and size data from individual fish. CPUE data collected during August was collected with fewer individuals than during June and July. Furthermore, CPUE data from August were collected after extensive previous sampling efforts, and are suspect to be biased by gear avoidance behavior of fish.

CPUE data were also examined as time elapsed between landing of fish. Figures 19 through 22 are plots of time elapsed between each successive catch and landing of a fish, at each location during June and July. Plotting data in this format allows one to see how catch rates changed during a given amount of effort. Large values of elapsed time indicate when fishing success

**Table 27.-Catch-per-unit-effort (CPUE), expressed as fish per angler hour, at accessible and remote locations on the Jim River, sampled during June, July, and August, 1997.**

| Month | | Location | | | |
|---|---|---|---|---|---|
| | | Bridge 3 | Bridge 1 | DOT | Camp |
| June | Accessible | 2.7 | 9.4 | 4.8 | 2.5 |
| | Remote | 5.8 | 4.3 | 7.8 | 6.7 |
| July | Accessible | 2.7 | 5.6 | 8.8 | 2.2 |
| | Remote | 6.2 | 10.4 | 14.4 | 8.9 |
| August | Accessible | 7.0 | 0.9 | 8.9 | 2.4 |
| | Remote | 6.0 | 3.0 | 10.5 | 10.0 |

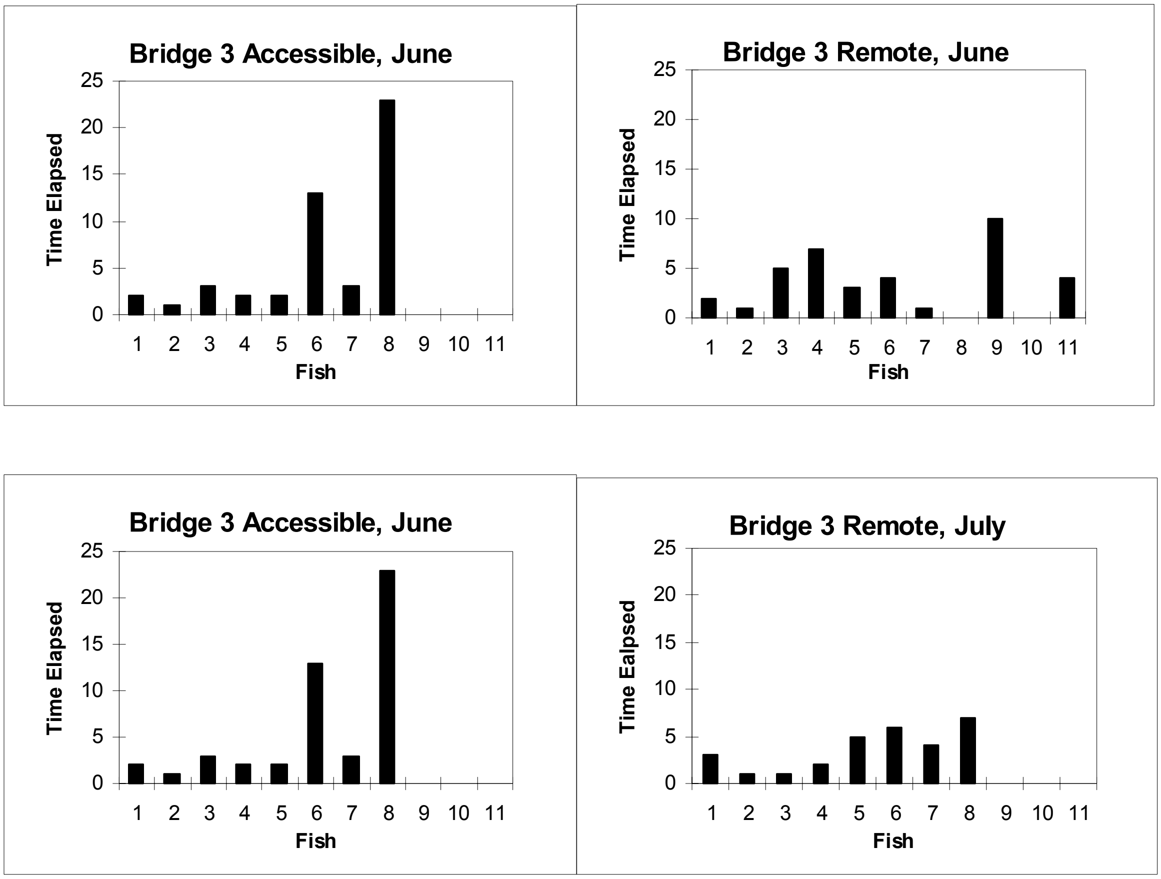



**Figure 19.-Plots of time elapsed (in minutes) between each successive catch and landing of a fish during CPUE studies conducted at accessible and remote sites within the Bridge 3 location on the Jim River, during June and July, 1997.**

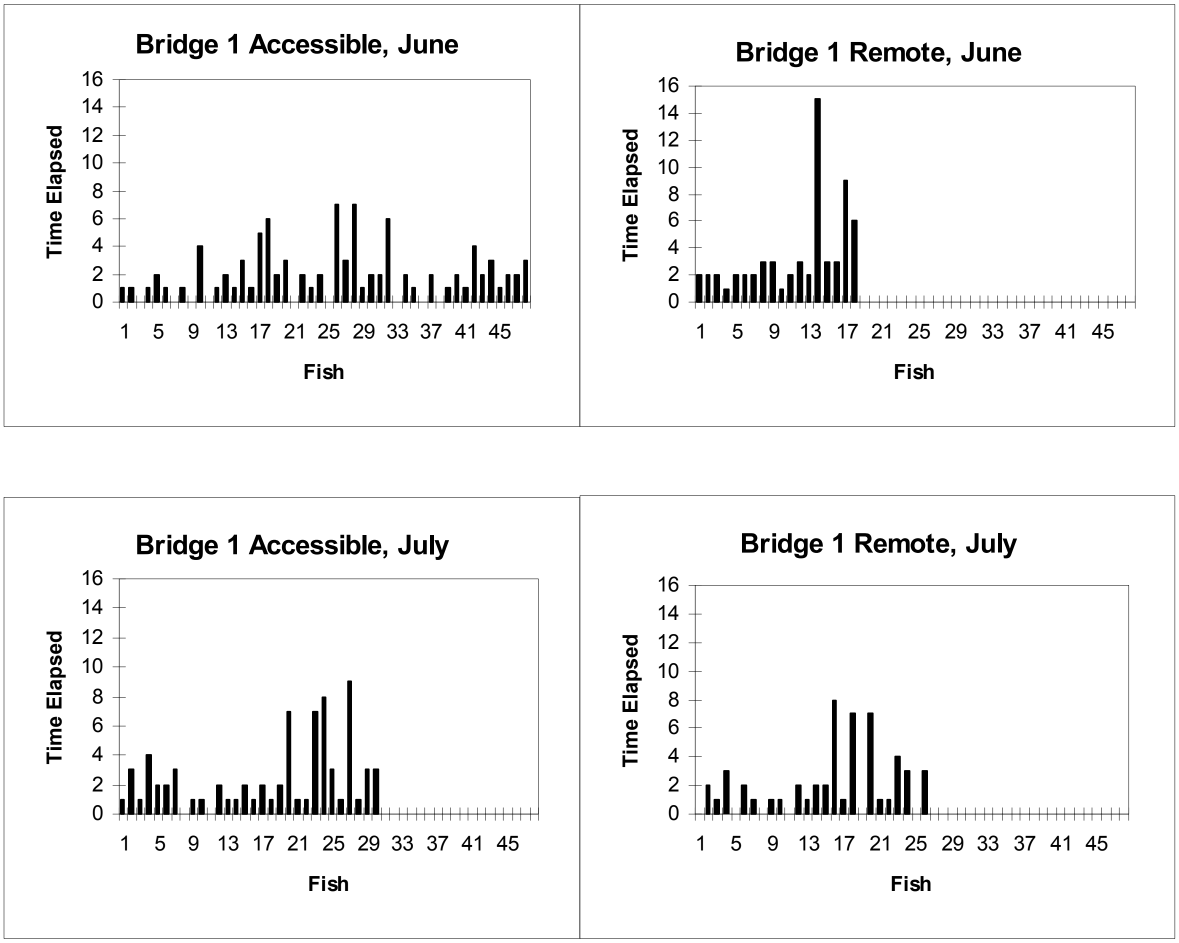



**Figure 20.-Plots of time elapsed (in minutes) between each successive catch and landing of a fish during CPUE studies conducted at accessible and remote sites within the Bridge 1 location on the Jim River, during June and July, 1997.**

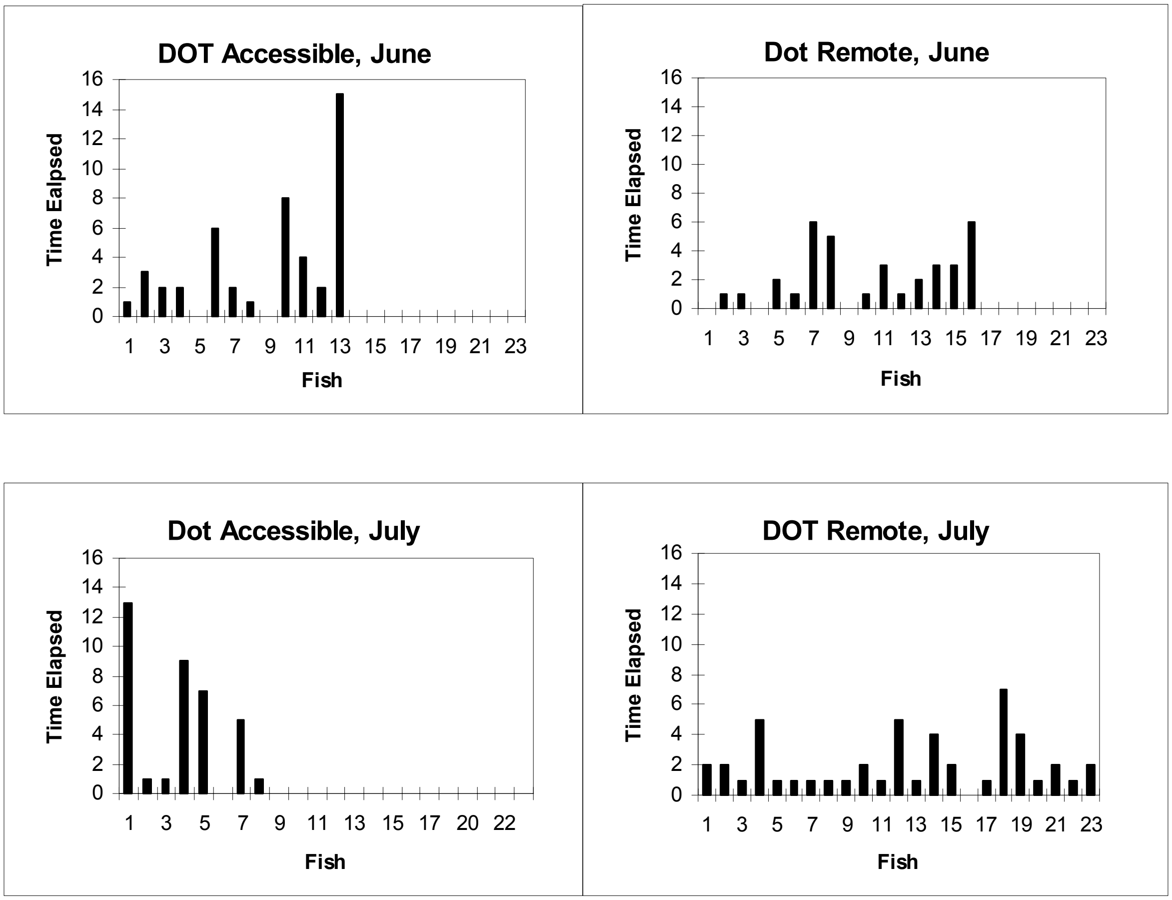



**Figure 21.-Plots of time elapsed (in minutes) between each successive catch and landing of a fish during CPUE studies conducted at accessible and remote sites within the DOT location on the Jim River, during June and July, 1997.**

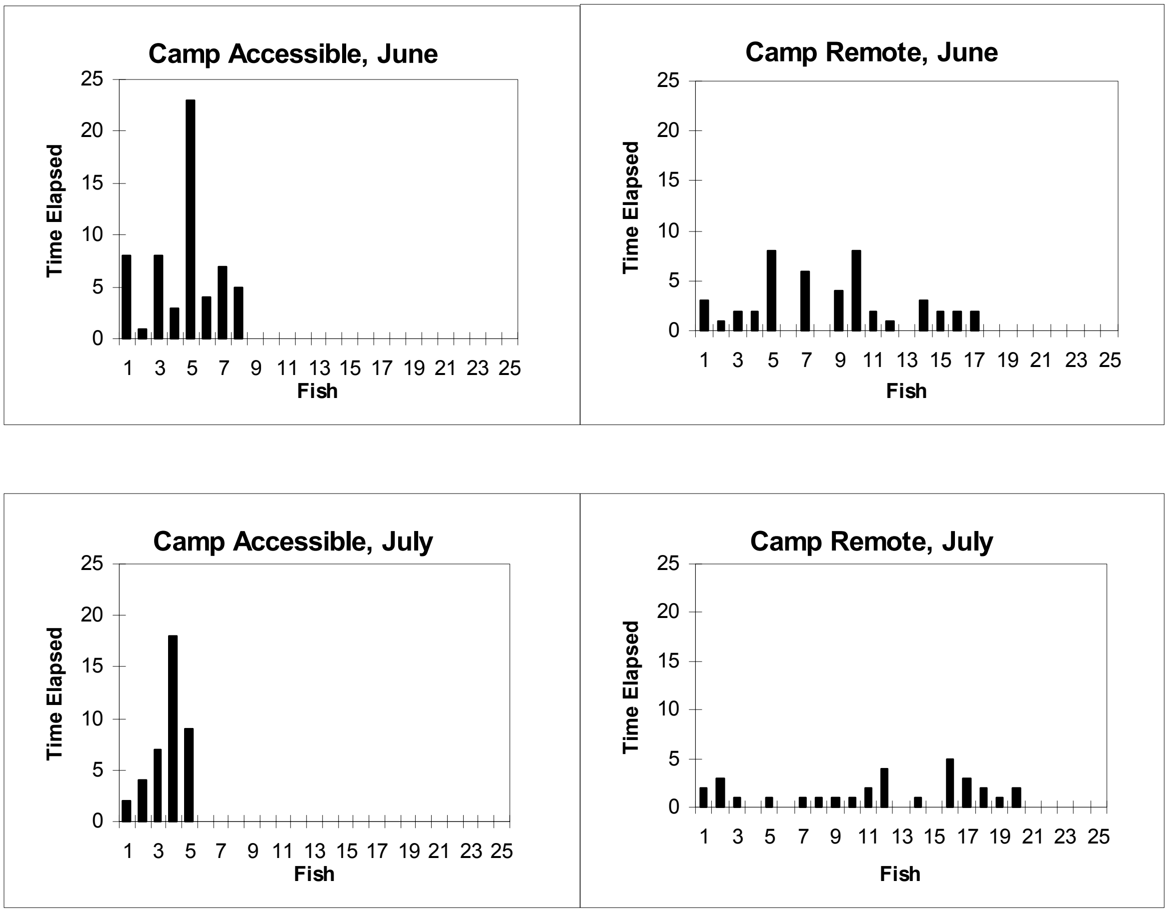



**Figure 22.-Plots of time elapsed (in minutes) between each successive catch and landing of a fish during CPUE studies conducted at accessible and remote sites within the Camp location on the Jim River, during June and July, 1997.**

dropped, and investigators had to spend greater search time to catch a fish. Table 28 reports results from t-test analyses performed with elapsed time data between remote and accessible sites, within locations. There were no significant differences in average elapsed time between catches, between accessible and remote locations, within any of the four locations (Table 28 for *t* statistics and P values). These results suggest that, during either June or July, time between captures of Arctic grayling at accessible locations were not different from time between captures at remote locations. More generally stated, fishing success during either June or July was not affected by accessibility. This analysis was not performed to compare average elapsed time from one particular site between June and July (i.e. time elapsed at Bridge 3 Remote during June vs. time elapsed at Bridge 3 Remote during July), since evidence from tag recoveries suggest different fish may be present during June than during July. If this particular analysis were to be performed, differences in average elapsed time at a site between months, caused by increased angling effort and harvest, would potentially be confounded by the effects of fish movement. August data were also not included in the analyses because it was not collected in a consistent manner with data from June and July.

Results from a split-plot ANOVA with repeated measures (with location as a random effect) indicated that treatments (average elapsed time at remote or accessible) with location by treatment interaction as the error term were not significant ($F = 2.74$, df = 1, $P > 0.20$). In other words, the difference in elapsed time to capture between accessible and remote sites, averaged over June and July, were not significantly different. In addition, treatments (average elapsed time at remote or accessible) with month by treatment interaction were not statistically different ($F= 3.02$, df =1, $P > 0.13$). More generally stated, the difference in average time between captures at remote locations between June and July were not significantly different from those at accessible locations between June and July.

The results of CPUE investigations generally indicate that fishing success in the Jim River during 1997 was not affected by accessibility from the highway crossing.

## Mean Length-at-Age

Mean length-at-age was calculated for Arctic grayling the Jim River during 1997, and is shown in Table 9, and plotted in Figures 11 and 23, with mean length-at-age calculations from other stock assessments. Mean length-at-age appears consistent between years for fish collected from the Jim River. Mean length-at-age of fish from the Jim River is also comparable with that of fish collected in different creeks during 1996. For comparison, age compositions obtained from the Jim River during 1971-2 (Netsch 1975), 1995, and 1997 are shown in Figure 24. Overall, age compositions are similar. Differences between age-3 and age-5 fish during 1995 and 1997 may be explained by both natural variation in yearly stock composition, as well as differences in timing of data collection (i.e. June, 1995 vs. July, 1997).

## Growth

The growth of Jim River Arctic grayling between 1995 and 1997 was examined as mean increase in fork length. Fish were categorized into size classes to show the mean increase in fork length according to size of fish (shown in Table 29). A total of 30 fish were captured during 1997 that had been tagged during 1995, but only 26 had accurate length and tag information. The overall mean increase in fork length was 46.65 mm (SD = 21.99). Linear regression analysis resulted in the regression equation $Y = -0.3401X +143.46$; $R^2 = 0.4672$ (shown in Figure 25).

**Table 28.-Results of one-tailed, two-sample t-tests[a] of average time between landing a fish between accessible and remote sites within a locations on the Jim River, during the months of June and July, 1997.**

| Month | | Location: Bridge 3 | Bridge 1 | DOT | Camp |
|---|---|---|---|---|---|
| June | Accessible vs. Remote | t = 0.93<br>df = 17<br>P = 0.82 | t = -2.68<br>df = 64<br>P = 0.99 | t = 0.89<br>df = 27<br>P = 0.808 | t = 1.82<br>df = 24<br>P = 0.96 |
| July | Accessible vs. Remote | t = 2.37<br>df = 11<br>P = 0.98 | t = 1.08<br>df = 54<br>P = 0.858 | t = 0.33<br>df = 31<br>P = 0.63 | t = 4.27<br>df = 23<br>P = 0.99 |

[a] A one-tailed, two-sample t-test was performed, where the Null Hypothesis is that the average time elapsed between catching and landing a fish is not different between accessible and remote sites , within a particular location ($H_0$ : $\mu_{ACCESSIBLE}$ - $\mu_{REMOTE}$= 0). The alternative hypothesis would be that the average time elapsed between landing a fish is greater at accessible sites than at remote sites within a location ($H_A$ : $\mu_{ACCESIBLE}$ - $\mu_{REMOTE}$ > 0).

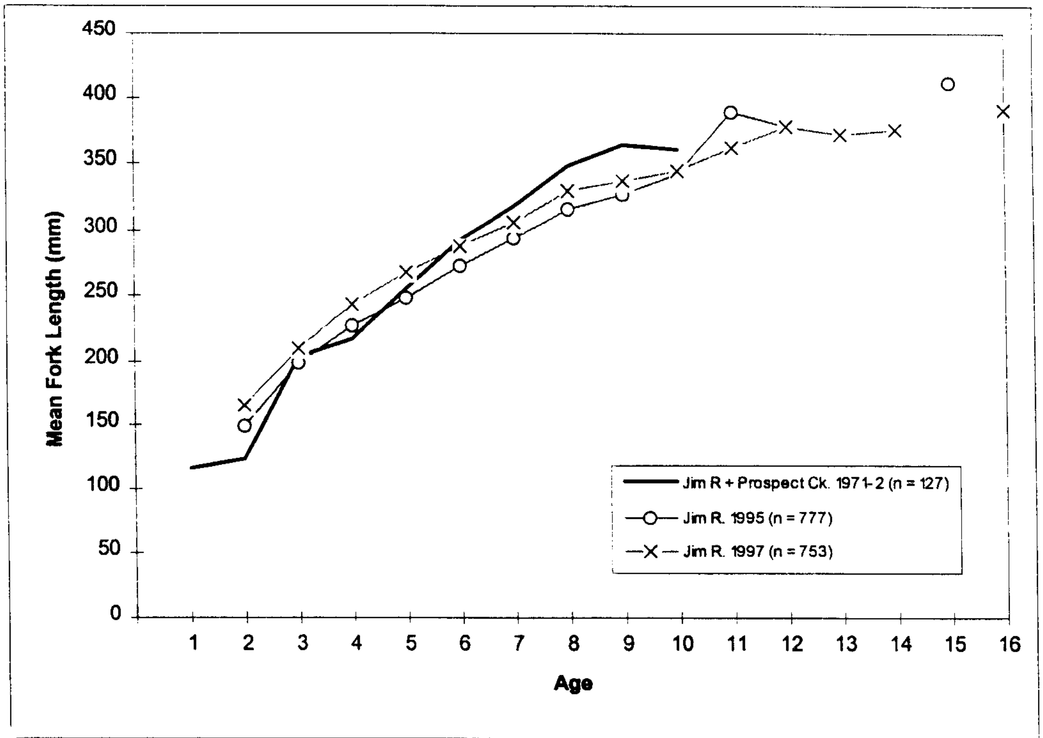



**Figure 23.-Mean fork length-at-age of Arctic grayling captured in the Jim River during the summers of 1971-2, 1995, and 1997.**

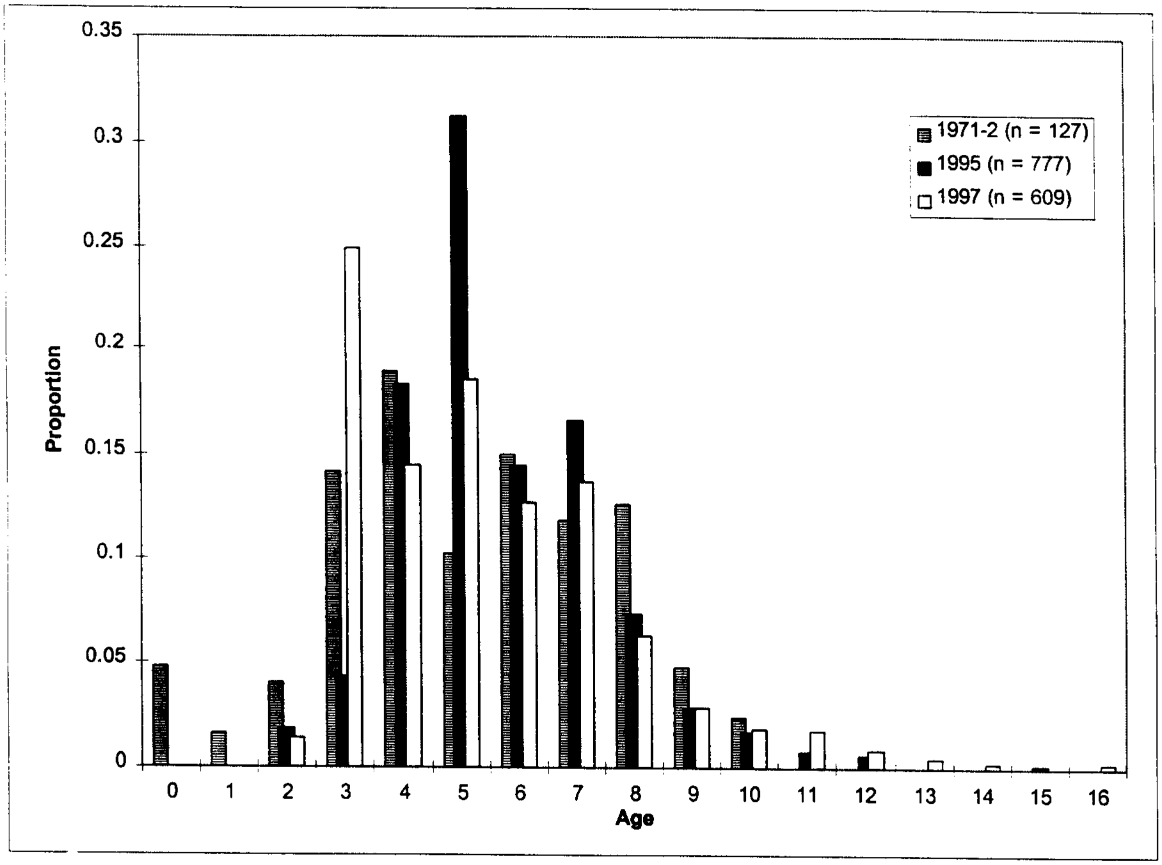



**Figure 24.-Age composition of Arctic grayling (≥ 150 mm FL) in the Jim River study areas during 1971-2, 1995, and 1997.**

**Table 29.-Average increase in fork length of Arctic grayling tagged during 1995 and recovered during 1997 in the Jim River (n = 26). Size classes are partitioned into 50 mm increments.**

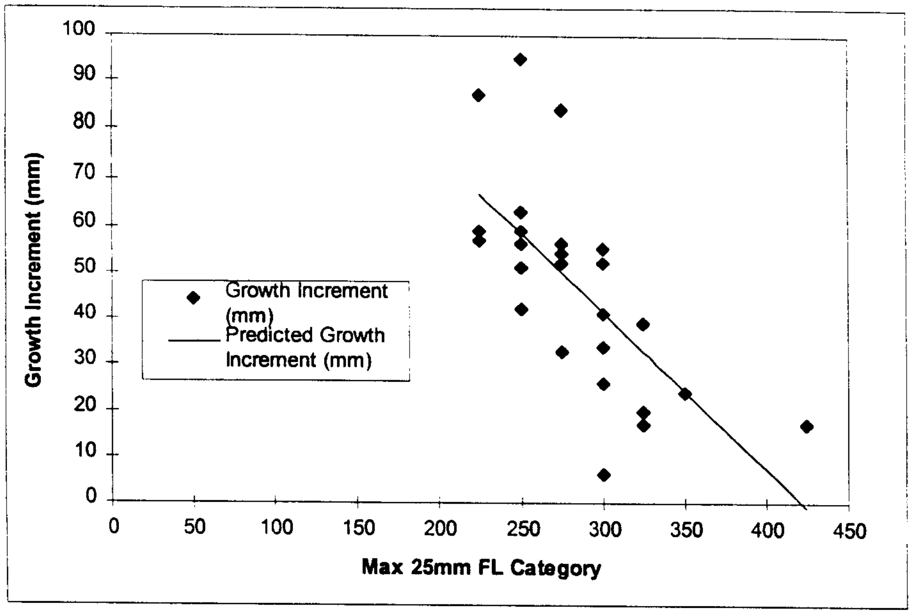
| Size Class (mm FL) | n [a] | Mean Increase [b] | SD | Minimum [c] | Maximum [d] |
|---|---|---|---|---|---|
| 200-249 | 9 | 63.22 | 16.96 | 42 | 95 |
| 250-299 | 12 | 43.92 | 19.52 | 6 | 84 |
| 300-349 | 4 | 25.00 | 9.76 | 17 | 39 |
| 350- | 0 | --- | --- | --- | --- |
| 400-450 | 1 | 17 | --- | 17 | 17 |

[a] n = sample size.

[b] Mean increase = the arithmatic average of increase in fork length from 1995 to 1997.

[c] Minimum = minimum length increase observed.

[d] Maximum = maximum length increase observed.




(Y = -0.3401x + 143.46, $R^2$ = 0.4672)

**Figure 25.-Regression of growth increments by 25 mm FL category of Arctic grayling tagged during 1995 and recovered during 1997 (n = 26).**

Growth was also examined using length-at-age data and modeled using the Von Bertallanfy (LVB) growth model. Parameter estimates for Arctic grayling in the Jim River during 1995 and 1997 are shown in Table 30, as well as those from Arctic grayling in the Lower Chena River during 1995. Plots of observed and predicted length-at-age are shown in Figure 26, and indicate that Arctic grayling from the Jim River are smaller at age than for Arctic grayling from the Lower Chena River, suggesting that Jim River fish grow slower. Results of parameter comparisons (reduced vs. full model) confirm that there is a significant difference between parameter estimates obtained with Jim River, 1995 data and those obtained from Lower Chena River, 1995 data ($F_{obs} = 118.1656$, df = (3, 1932), $P < 0.001$).

# DISCUSSION

The abundance estimates generated for Bonanza Creek during June, 1996, and for Prospect Creek during August, 1996, suggest the number of Arctic grayling in the study areas may range from approximately 250 fish to over 2,000 fish. Obviously, there is a wide range of error associated with the reported estimates; the desired precision and accuracy of the abundance estimates were not achieved as outlined in the objectives. For example, coefficients of variation are 30% in Prospect Creek, and 40% within Bonanza Creek. The small sample sizes, particularly the small number of recaptures, are responsible for such results. Considering the statistical consequences of few recaptures during a mark-recapture experiment, the estimates of abundance in both Bonanza and Prospect creeks should be viewed as lacking precision. They are not meaningless, however, in that they offer a general view of the distribution and density of Arctic grayling within these stream sections, at the particular times the experiments were performed. Ideally, stock assessments of Arctic grayling populations should happen during the summer months (in this case, July) when fish are more stationary, and during the time the summer fisheries occur. When the mark-recapture experiment was conducted within Bonanza Creek, fish may still have been involved in post-spawning migrations. Summer residents of Arctic grayling within the road-accessible reaches of the creek may be composed of a different population structure, with a different abundance, than what was observed during early June. In addition to the timing of assessment, the size of the stream areas that were assessed were relatively small (i.e. approximately 4 mi of study area compared to a 90 mi study area on the Chena River, in the Tanana Valley) and may not reflect the population abundance and structure in the stream as a whole. Considering the timing and magnitude of the assessments, these studies provide a "snapshot" perspective of abundance that serve as meaningful baseline stock information for fishery managers, and offer estimations of relative densities of Arctic grayling in these areas, at these particular times. The SWHS suggests that harvest of Arctic grayling from these near-roadside locations is light, and at present, there is not a management concern for overfishing. Therefore, abundance information with notably large error (e.g. $CV \cong 30\%$) should be adequate for management purposes.

The lack of fish observed during June of 1995 and 1996 in Prospect Creek suggested a conservation concern may have existed in regards to Arctic grayling stocks within this system. It is unclear why so few fish were caught, but investigators suspected that heavy rainfall runoff through mining operations upstream of the study area may have caused significant water quality alterations, resulting in fewer fish. Additionally, the timing of the assessment of Arctic grayling

**Table 30.-Parameter estimates and standard errors of the von Bertalanfry growth model for Arctic grayling from the Jim River, 1995 and 1997, and from the Lower Chena River, 1995.**

| | Parameter | Estimate | Standard Error |
|---|---|---|---|
| Jim River 1995 | $L_\infty$ | 513.93 | 41.86 |
| | *K* | 0.09 | 0.02 |
| | $t_0$ | -2.15 | 0.42 |
| | $Corr(L_\infty,K)$ | -0.99 | --- |
| | $Corr(L_\infty,t_0)$ | -0.93 | --- |
| | $Corr(K,t_0)$ | 0.97 | --- |
| | Sample size | 777 | |
| Jim River 1997 | $L_\infty$ | 408.66 | 10.10 |
| | *K* | 0.17 | 0.01 |
| | $t_0$ | -1.16 | 0.20 |
| | $Corr(L_\infty,K)$ | -.097 | --- |
| | $Corr(L_\infty,t_0)$ | -0.87 | --- |
| | $Corr(K,t_0)$ | 0.96 | --- |
| | Sample size | 753 | |
| Lower Chena River 1995 | $L_\infty$ | 478.61 | 28.03 |
| | *K* | 0.11 | 0.02 |
| | $t_0$ | -2.52 | 0.29 |
| | $Corr(L_\infty,K)$ | -0.99 | --- |
| | $Corr(L_\infty,t_0)$ | -0.91 | --- |
| | $Corr(K,t_0)$ | 0.96 | --- |
| | Sample size | 1,161 | |

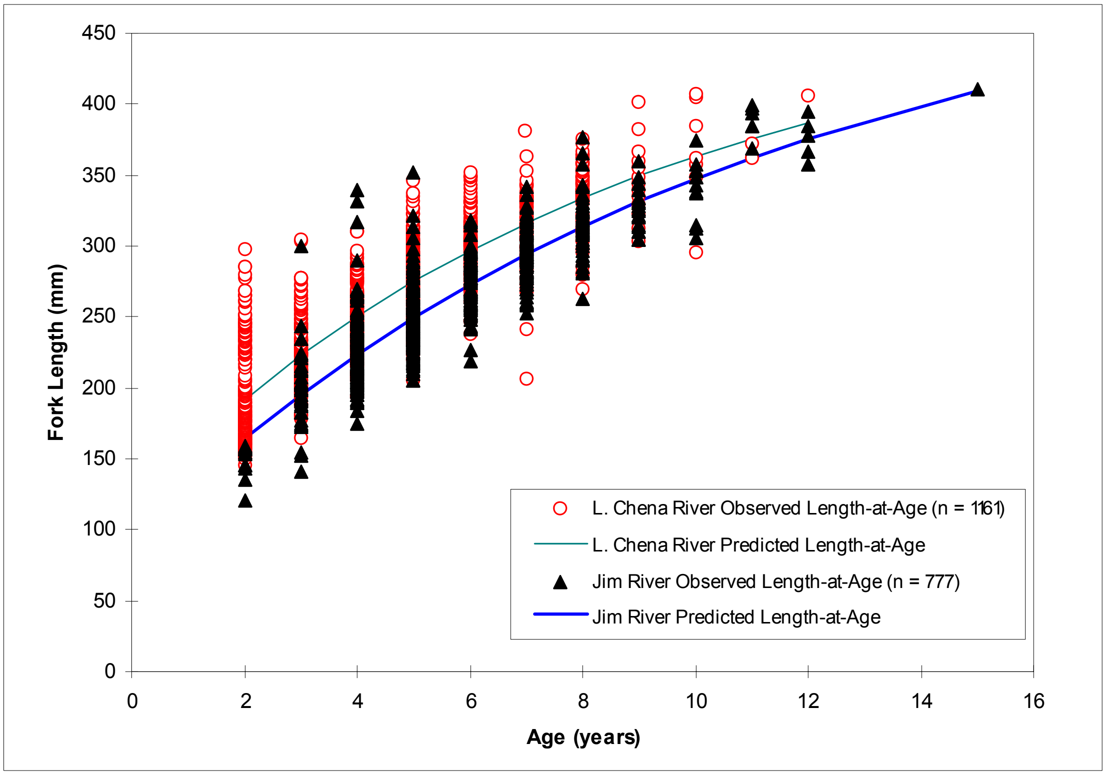



**Figure 26.-Observed and predicted length-at-age of Arctic grayling in the Jim River during 1995, and in the Chena River during 1995.**

in Prospect Creek may have been too early if fish had left Prospect Creek to spawn in other areas more suitable for spawning and/or rearing. The typical size of fish in near-roadside reaches of Prospect Creek appear to be smaller than in the other creeks. There is also evidence to suggest that larger fish reside further upstream. It is possible that the lower reaches of Prospect Creek are more suitable as rearing habitat for smaller fish. Based on the data of Netsch (1975), it is also likely that fish in Prospect Creek are of the same stock that reside in the Jim River. Fish may opportunistically utilize the lower reaches of Prospect Creek as feeding areas during the summer, and move when streamflow changes (such after heavy rainfall) are sufficient to affect foraging opportunities. Alternatively, water quality conditions may not offer ideal habitat for foraging fish. The current level of harvest of Arctic grayling in Prospect Creek does not appear to be high enough to warrant fishery conservation actions.

The abundance estimates of 1995, in particular Prospect Creek (770 Arctic grayling), are difficult to compare with estimates Netsch (1975) reported. An abundance of 1,210 Arctic grayling was reported within the lower 1 mi of Prospect Creek during August, 1972, based on a Petersen mark-recapture estimate. This is equivalent to an estimate of 1,191 Arctic grayling using a Bailey estimator, or a density of approximately 774 fish per kilometer. Compared to a density of 120 fish per kilometer estimated during 1996, it appears estimates are dramatically different between years. However, comparisons between studies is confounded by differences in location, methods, and duration of assessments. For example, the study areas occurred in different locations within the creek (with no overlap). Netsch (1975) also utilized a variety of methods to capture and mark fish, including a fyke weir which was in operation for over 30 days. The abundance estimate of Arctic grayling in Prospect Creek reported by Netsch (1975) was generated from all fish caught during the month of August. The mark-recapture experiment performed in 1996 had a duration of six days. In general, it appears that abundance estimates from 1972 lacked systematic experimental design, but rather were calculated to obtain a general understanding of Arctic grayling densities in various Dalton Highway streams. It is, however, interesting to note that (similar to assessments of 1996) estimates of abundance through mark-recapture experiments conducted during 1972 were only attempted during July and August (and not during other months) because the number of recaptures was too small to obtain reliable abundance estimates.

Similar to abundance information, comparison of age composition data reported by Netsch (1975) and that obtained during 1995-97 is not straightforward. Age data was pooled from Arctic grayling captured from both the Jim River and Prospect Creek, during both 1971 and 1972. Scale samples appear to have been opportunistically collected throughout the summers of 1971-2, and do not represent ages of fish collected during any particular month. The mean length-at-age data reported by Netsch (1975) appears similar, however, to the data investigators collected during Jim River and Prospect Creek stock assessment studies of 1995 through 1997.

Comparisons of CPUE obtained during 1996 and results reported by Netsch (1975) are also somewhat confounded, as Netsch reported a pooled calculation of CPUE, which included catch and effort combined from Prospect Creek, the Jim River, and stream HR2-1405+92 during 1972. The density of Arctic grayling within the Jim River is generally higher than in the smaller creeks, and may account for such differences in CPUE observed in this study and what is reported by Netsch. In addition, since angling was chosen as the most effective means to catch fish during both studies differences in CPUE values may be further confounded by such variables as skill differences between anglers, effectiveness of angling tackle, etc. However, CPUE data are meaningful in that values may reflect a general number of fish that an angler may catch during that time of year, in places were assessments have been performed.

During the Jim River stock assessment of 1995, movement of Arctic grayling into, and out of, the study area was suggested, and the Movement estimator described by Evenson (1988) was chosen to provide the best estimate of abundance. Although its associated variance is larger, the movement estimator provides a better estimate of abundance, than does the Bailey estimator, because the Bailey estimator was thought to possibly overestimate the true abundance of fish within the study area. Movement data suggested that fewer marked fish were available for recapture within the study area during the second event than would have been if no movement occurred. The observed movement of fish, however, may have been both biologically meaningful and sampling-induced. Some fish caught during early June may have been involved in postspawning migrations, where fish move downstream from Spring spawning sites to Summer feeding areas. Since most of the observed movement was downstream, movement may have also been consistent with the use of sequential sampling techniques, where fish are physically displaced by being released downstream from where they are caught. Although fish were not released very far from where they were caught (≤ 100 meters), it is possible that displacement from sampling may have induced fish to move further downstream. Whatever the cause, however, the magnitude of movement was determined to be sufficient to assume that fish were emigrating and/or immigrating to the study area, and warranted the use of the Movement estimator to estimate the abundance of Arctic grayling within the study area.

The observed contribution of fish marked in June, 1995 and caught in August, 1995 was not unexpected considering the length of the hiatus between June and August (~2 months). Although fish probably emigrated and immigrated into the study area, and there was probably recruitment into the population from growth of subsized (≤ 150 mm FL) individual fish, examination of contribution may reveal a general idea of the fidelity of fish within the study area. Over half of the fish caught in June were caught again in August, and of those fish, nearly half either remained in the same general location or moved downstream. Considering that fish may have been moving to summer feeding areas further downstream during early June, and fish may have also been subjected to harvest during the summer months, the proportion of recovered fish (~61%) suggests that fish displayed a relative fidelity to the study area during the hiatus between June and August. This suggests that the population of Arctic grayling within the study area appears to have been relatively stable during the summer months.

An abundance estimate was not performed with the data collected during August since the sampling scheme was not structured for such analyses. There was not sufficient information to resolve between the number of fish dying and the number of fish moving out of the study area during the hiatus between June and August. However, the size composition of Arctic grayling in the Jim River study area caught in June was comparable to that of fish caught in August.

Although the CPUE of Arctic grayling caught in the Jim River study area during June, 1995, was similar to that obtained by Netsch (1975), the density of Arctic grayling during June, 1995 (240 fish ≥ 150 mm FL/km) was much lower than that obtained during June, 1972 by Netsch (1093 fish ≥ 200 mm FL/km). However, Netsch (1975) reported an estimation of abundance of Arctic grayling by using a simplified Petersen estimator, which probably overestimated the true abundance of fish, i.e. the model of the Petersen estimator does not account for emigration of marked fish out of the study area. The hiatus between marking and subsequent recapture was reported as one or more days; therefore, recruitment (through growth of subsized fish or immigration of unmarked fish) was poorly understood and may have also caused an overestimation of abundance.

The abundance estimate of 1997 was more than double what it was in 1995. Many reasons could have accounted for this observed difference in abundance, but most notably is the difference in timing of each mark-recapture experiment. The mark-recapture experiment of 1995 was conducted during early June, when fish were still probably involved in post-spawning migrations. This is supported by the downstream movement of fish during the experiment of 1995, as discussed above. The mark-recapture experiment of 1997 was conducted during mid-July, when fish are assumed to be in a non-migratory stasis. Compared to a contribution rate of ~61% between June and August of 1995, the contribution of ~86% of the fish present in mid-July, 1997 to the composition of fish captured during August, 1997 suggests that fish are more stationary during July. July appears to be the ideal month in which to conduct stock assessment of summer populations of Arctic grayling along the Dalton Highway. Fish may have not only emigrated the study area during June of 1995, but new fish may have also entered the study area during July of 1995. The contribution of ~61% from June to August, 1995 suggested that some form of change in population structure may have occurred between those months during 1995.

The lack of recovery during July and August, 1997 of the 136 fish tagged during the June CPUE investigations suggested that some movement of fish away from these areas may have occurred after they were tagged. When considered with the July abundance, however, the lack of tag recovery from June may have been caused by a "dilution effect," from fish moving into the study area during migrations to summer feeding grounds. The summer of 1997 was also characterized by record-low precipitation levels (e.g. the Chena River in the Tanana Valley experienced the one of lowest recorded summer streamflows). During stock assessment activities on the Jim River, water levels were low enough to prevent navigation on much of the river by canoe. Water temperatures also appeared notably high (e.g. 12 to 15 degrees C.). It is possible that Arctic grayling that normally spend the summer in different locations (such as feeder creeks that empty into the Jim River) moved into the Jim River to seek more preferred and suitable habitat. With little reference data for comparison, it remains unclear if an abundance of 12,059 fish in the study area is typical of mid-summer Arctic grayling abundance in the Jim River.

Comparison of age composition estimates obtained during 1971-2, 1995, and 1997 (Figure 24) suggest that age compositions are similar, even though differences between 1995 and 1997 age-3 and age-5 fish appear large. Natural variation in stock composition from year to year may be large enough to explain such observed differences in age structure. However, such differences may also be explained by the timing of when age data were collected. For example, age data during 1995 were collected during June, whereas age data collected during 1997 were collected during July. Tagging data suggests stock composition may differ between these two months. Therefore, the difference in timing of when age data were collected may also explain observed differences in age structure between years. Comparisons of mean length-at-age (shown in Figures 11 and 23) also suggest that length compositions of Arctic grayling in the Jim River are similar between different years of stock assessments activities.

The observed differences in capture probabilities and unequal mixing of fish during the mark-recapture experiment was also likely affected by changes in streamflow. For example, substantial rainfall occurred, beginning the last day of the marking event, and lasting until the first day of the recapture event. Although tag recoveries during the experiment indicated that fish probably did not emigrate from the study area, fishing success was different at various locations between events. This suggested that fish moved to different locations within the study area, probably in response to increased streamflow. Increased streamflow can bring about changes in water temperature and available forage, which may provide the incentive for fish movement.

Streamflow changes may have also affected results of CPUE investigations For example, if streamflow changes in July changed capture probabilities during the mark-recapture experiment, it is likely that CPUE values at given locations may have also changed accordingly. In fact CPUE values actually increased at some locations, (at both remote or accessible sites). The influence of increased fishing effort throughout the summer (at near-roadside locations on the Jim River) on the distribution and density of fish was probably negligible when compared to the influence of local precipitation and hydrology patterns. It also remains unclear as to whether or not fishing pressure on the Jim River actually increases steadily throughout the summer. Current levels of harvest appear to be sustainable, although information regarding population dynamics for modeling exercises is lacking. If the magnitude of fishing effort were suspected to be great enough to cause temporary depletions in localized areas, the experiment could be repeated and analyzed with creel information to measure the average change in CPUE through time, between locations receiving different levels of angling pressure. During 1997, CPUE data were not collected with harvest information, but were collected as baseline information to better understand if such data is useful in measuring the effects of fishing pressure. Fishing pressure in the Jim River during 1997 did not appear great enough to demonstrate depressed catchability in accordance with accessibility from the highway. It is also doubtful that current levels of harvest of Arctic grayling lead to localized depletions in the Jim River. However, the nature of fishing effort is still poorly understood and potential population responses to increased, localized fishing effort remains unclear.

Differences in average time elapsed at each site between June and July were not compared because evidence from lack of tag recoveries suggests that fish present during June may not be the same fish present during July. The effects of movement of fish would potentially confound the effects of fishing effort and harvest. The CPUE data collected during August was also not included in analyses because it was not collected in a consistent manner with data from June and July. Fewer people fished at each location, and data were collected shortly after previous sampling activities.

The use of electrofishing gear was found to be less effective at catching Arctic grayling than angling gear during stock assessments of 1996, and is consistent with results obtained by Netsch (1975). Much of the habitat within streams that cross the Dalton Highway includes deep pools where the use of electrofishing gear is unsafe, and is inadequate in catching fish. Additionally, stream waters exhibit such low conductivity, or the electrical field is too small, that electrofishing gear is ineffective in stunning fish much of the time. Angling was demonstrated to be the most effective means to catch fish (based on a greater number of fish caught) and appeared to catch all sizes of fish, including those < 150 mm FL. However, the use of angling alone may result in biased estimations of abundance or stock composition, reflected in differential capture probabilities, or size selectivity. For example, fish may exhibit gear-induced behavior (through "gear-happiness" or "gear shyness") where marked fish may not have the same probability of capture during the second event as unmarked fish (Tom Taube, Alaska Department of Fish and Game, Fairbanks, personal communication). However, the use of different gear types to address the incidence gear-induced behavior during the mark-recapture experiments of 1995 through 1997 was not specifically examined. The hiatus between events (two to four days) was assumed to be long enough that fish "recovered" from being caught, and marking fish was assumed not to influence their probability of recapture. Data collected from a stock assessment study conducted in the Snake River (Seward Peninsula) provided evidence that, given a hiatus of five days after being captured hook and line gear, Arctic grayling do not exhibit avoidance of hook and line gear during subsequent sampling activities. Although similar results might not have been obtained, had the same sampling regime been applied to different stocks of Arctic grayling, the data were reported for lack of any known experimental results reported in the scientific literature, in regards to gear avoidance by Arctic grayling. It is recommended that the use of multiple gear types, and their influence on capture probability, be evaluated during future stock assessments when hook and line sampling is utilized.

Growth was modeled with length-at-age data to provide baseline information concerning Arctic grayling population trends in the Jim River. When compared to fish from the Lower Chena River within the same year, there was a significant difference between parameter estimates, suggesting that fish in the Jim River grow slower than fish in the Lower Chena River. Although this is not unexpected, there is little data to demonstrate differences in population dynamics and trends between stocks of Arctic grayling in interior Alaska (Tanana Valley) and those father north (near the Brooks Range). Fish stocks along the Dalton highway likely experience more extreme weather patterns, as well as shorter growing seasons. It is important to realize, however, that growth can vary from year to year, and that parameter estimates can change accordingly (e.g. see parameter estimates from Jim River length-at-age data for 1995 and 1997 in Table 30). The importance of measurement error must also be considered, especially for fish beyond age 6. The likelihood of inaccurately determining the age of a fish from scale impressions increases the older the fish in question is. Such error from mistakenly aged, older fish may change the shape of predicted growth curves considerably. Growth data, however, may provide fishery managers with potentially useful information when considering the applicability of various management strategies.

These stock assessment studies have provided fishery managers with abundance and composition information of Arctic grayling stocks. However, there is still a need for more comprehensive approaches to stock assessments in order to understand how Arctic grayling populations behave, and whether or not "localized depletions" occur in roadside fisheries within the Dalton Highway corridor. From an ecological perspective, the Koyukuk River system may be thought of as a refuge for Arctic grayling. Roadside streams may be opportunistically occupied by a larger population of fish than what the abundance estimates from mark-recapture experiments conducted within these areas may suggest. For example, Arctic grayling within the Jim River and Prospect Creek may be part of a larger Koyukuk River stock. However, the degree to which separate stocks of Arctic grayling are discriminated is largely unknown within this area. There have been few tagging, genetic characterization, or life history studies pursued within this region of the State to define stock discreteness. Data from radio-telemetry studies in progress should provide some insight to the nature of stock structure of Arctic grayling in the Jim River. Telemetry data should also indicate if summer residents of Arctic grayling within the roadside fisheries make up a consistent fishable population.

Considering the sparse stock information that exists for Arctic grayling within the Dalton Highway corridor, the concept of localized depletion may be difficult to define, monitor, and compensate for with management action. The current management plan includes a size-restricted bag limit of five fish per day, within 5 mi of either side of the Highway (Corridor). Size-restriction is borrowed from knowledge of Tanana Valley stocks, and is founded on the assumption that Arctic grayling will have the opportunity to mature, spawn and contribute to the population before being harvested as a 12 inch, or larger, fish. However, the effectiveness of this assumption has not been verified for stocks within Dalton Highway drainages. Modeling length-at-age data obtained from the Jim River during 1995, predicted that age-6 (the age at which Arctic grayling are assumed to be sexually mature) would be 273 mm FL. Observed data however, indicate that few fish above age-6 and less than 269 mm in fork length that may potentially be available to spawn and contribute to the population. Conducting studies to validate the age and size of maturity would provide data to evaluate the rationale behind the 12 inch minimum size restriction of the current regulations

The distribution of Arctic grayling within roadside streams also needs to be considered from an ecological perspective. For example, the age composition of fish within Prospect Creek during August contained few older fish and was dominated by a preponderance of young fish (mostly age-2) within the study area. The study area, although adjacent to the Highway, consists of the lower reaches of the entire Prospect Creek. The theory proposed by Hughes and Reynolds (1994) of size gradient distribution of Arctic grayling within interior Alaskan streams and rivers (where larger fish reside in the upstream reaches during the summer to feed on invertebrate drift, and displace younger, smaller fish to the lower reaches) is consistent with the estimated age and size composition within the Prospect Creek study area. There is also anecdotal evidence to suggest that larger (and older) fish reside upstream in Prospect Creek during the summer months (A. Townsend, Alaska Department of Fish and Game, personal communication). Localized depletions of legal-sized Arctic grayling within roadside fisheries may occur relatively easily if few larger fish reside in these areas during the summer. However, the overall effect on the larger population may be negligible, if most larger fish are upstream during the summer, and away from where most anglers fish. Stock assessment studies may need to include larger stretches of roadside streams, or different forms of assessment, in order to more fully characterize the distribution and abundance of Arctic grayling during the summer fisheries. In addition, future stock assessments may benefit from creel surveys to better characterize the nature of these roadside fisheries. The Statewide Harvest Survey reports catch, effort and harvest information for Arctic grayling within various Dalton Highway streams, but the number of respondents to the survey that fish the waters in this region of the State is usually low, and may not reflect the magnitude and nature of fishing effort. At present, there appears little concern for overharvest in streams crossed by the Dalton highway, but the phenomenon of localized depletions is still poorly understood. Angling effort at various streams may not be high enough to cause such a phenomenon. However, if harvests of Arctic grayling increase as anticipated (from greater public travel and recreation along the Dalton Highway) a better understanding of population dynamics of Dalton Highway Arctic grayling stocks, and how they differ from Tanana Valley stocks, may eventually be necessary to allow for more effective management of this species within this region of the State.

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# APPENDIX A

**Appendix A1.-Methodologies for alleviating bias due to gear selectivity by means of statistical inference.**

| | Result of first K-S test[a] | Result of second K-S test[b] |
|---|---|---|
| Case I[c] | | |
| | Fail to reject $H_o$ | Fail to reject $H_o$ |
| | Inferred cause: There is no size-selectivity during either sampling event. | |
| Case Ii[d] | | |
| | Fail to reject $H_o$ | Reject $H_o$ |
| | Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event. | |
| Case III[e] | | |
| | Reject $H_o$ | Fail to reject $H_o$ |
| | Inferred cause: There is size-selectivity during both sampling events. | |
| Case Iv[f] | | |
| | Reject $H_o$ | Reject $H_o$ |
| | Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown. | |

[a] The first K-S (Kolmogorov-Smirnov) test examines the $H_o$: 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 examines the $H_o$: 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.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: 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.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

## Appendix A2.-Tests for Consistency for the Petersen Estimator[a]

The following two assumptions must be fulfilled:

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

Catching and handling the fish should not affect the probability of recapture because the experiment is designed to mark live fish and later recover carcasses. If the jaw tag is lost, the fin clip given each fish will identify the river section where it was marked.

Of the following assumptions, only one must be fulfilled:

1. Every fish has an equal probability of being marked and released;
2. Every fish has an equal probability of being collected during the survey; or,
3. Marked fish mix completely with unmarked fish between surveys.

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 the Petersen model (Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961 or Bailey, 1952, 1952; depending upon movement) will be used to estimate abundance by river section.

**TEST I**[b]

| First Event River Section Released | Second Event: River Section Recaptured | | | | |
|---|---|---|---|---|---|
| | Upper | Mid-upper | Mid-lower | Lower | Not recaptured |
| Upper | | | | | |
| Mid-upper | | | | | |
| Mid-lower | | | | | |
| Lower | | | | | |

**TEST II**[c]

| | Second Event: River Section | | | |
|---|---|---|---|---|
| | Upper | Mid-upper | Mid-lower | Lower |
| Recaptured | | | | |
| Not recaptured | | | | |

`

**TEST III**[d]

| | Captured During Second Event: River Section | | | |
|---|---|---|---|---|
| | Upper | Mid-upper | Mid-lower | Lower |
| Marked | | | | |
| Unmarked | | | | |

a The tests for consistency were taken from Seber (1982). At least one hypothesis needs to be accepted in order for the Petersen to be valid.

b This tests the hypothesis that movement probabilities are the same among sections:

c This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities between the four river sections:

d This tests the homogeneity on the columns of the 2-by-t contingency table with respect to the probability of movement of marked fish in stratum *i* to the unmarked fraction in *j*:

**Appendix A3.-Methodology to compensate for bias due to unequal catchability by river section.**

| Case | Result of $\chi^2$ Test[a] | Inspection of Fish Movement[b] | Inferred Cause |
|---|---|---|---|
| I[c] | Fail to reject $H_o$ | No movement between sections | There is no differential capture probability by river section or marked fish completely mixed with unmarked fish within each river section |
| II[d] | Fail to reject $H_o$ | Movement between sections | There is no differential capture probability by river section or marked fish completely mixed with unmarked fish across river sections |
| III[e] | Reject $H_o$ | No movement between sections | There is differential capture probability by river section or marked fish did not mix completely with unmarked fish within at least one river section |
| IV[f] | Reject $H_o$ | Movement between sections | Inferred cause: There is differential capture probability by river section or marked fish did not mix completely with unmarked fish across river sections. |

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[a] The chi-squared test compares the frequency of marked fish recaptured during the second event in each river section with the frequency of unmarked fish examined in the second event in each river section. $H_o$ for this test is: capture probability of marked fish in the second event is the same in all river sections.

[b] Inspection of fish movement is a visual comparison of the frequency of marked fish recaptured in the second event that moved from one river section to another with the frequency of unmarked fish examined in the second event in each river section.

[c] Case I: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator.

[d] Case II: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator and calculate one unstratified abundance estimate using the "movement" (Evenson 1988) estimator. If estimates are dissimilar, discard the Bailey estimate and use the movement estimate as the estimate of abundance. If estimates are similar, discard the movement estimate and use the Bailey estimate as the estimate of abundance.

[e] Case III: Completely stratify the experiment by river section, calculate abundance estimates for each using the Bailey (1951, 1952) estimator, and sum abundance estimates.

[f] Case IV: Completely stratify the experiment by river section. Calculate abundance estimates for each using the Bailey (1951, 1952) estimator and sum estimates. If movement out of the sample area is neither probable nor possible, calculate abundance with the partially stratified model of Darroch (1961) and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the Darroch estimate as the estimate of abundance. If estimates are similar, discard the estimate with the largest variance. If movement out of the sample area is probable, calculate abundance with the movement (Evenson 1988) estimator and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the movement estimate as the estimate of abundance (note: this estimate will be biased). If estimates are similar, discard the movement estimate and proceed as if movement were neither probable nor possible.

# APPENDIX B

**Appendix B1.-Data files regarding Arctic grayling stock assessments in the Jim River, Bonanza Creek, Prospect Creek, and Fish Creek archived by the Research and Technical Services of the Alaska Department of Fish and Game-Sport Fish Division.**

| Year | Data File | Contents |
|---|---|---|
| 1995 | Y001ALA5.arc | June Mark, Jim River |
| 1995 | Y001BLA5.arc | June Recapture, Jim River |
| 1995 | Y001CLA5.arc | August, Jim River |
| | | |
| 1996 | Y049ALA6.arc | June, Prospect Creek |
| 1996 | Y063ALA6.arc | June Mark, Bonanza Creek |
| 1996 | Y063BLA6.arc | June Recapture, Bonanza Creek |
| 1996 | Y049ALB6.arc | August Mark, Prospect Creek |
| 1996 | Y049BLA6.arc | August Recapture, Prospect Creek |
| 1996 | Y107ALA6.arc | August, Fish Creek |
| | | |
| 1997 | Y015ALAA.arc | June CPUE, Jim River |
| 1997 | Y015ALBA.arc | July Mark + CPUE, Jim River |
| 1997 | Y015BLAA.arc | July Recapture, Jim River |
| 1997 | Y015BLBA.arc | August, Jim River |
| 1997 | Y015BLCA.arc | August CPUE, Jim River |