Fishery Manuscript Report No. 98-4

# Radio-Telemetry Studies of Arctic Grayling in the Jim River (Dalton Highway) during 1997 - 1998

by
James T. Fish

December 1998

Alaska Department of Fish and Game Division of Sport Fish

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

**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 REPORT NO. 98-4*

# RADIO-TELEMETRY STUDIES OF ARCTIC GRAYLING IN THE JIM RIVER (DALTON HIGHWAY) DURING 1997-1998

by

James T. Fish
*Division of Sport Fish, Fairbanks*

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

December 1998

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-13, Job R-3-2(d).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or a group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

*James T. Fish*
*Alaska Department of Fish and Game, Division of Sport Fish, Region III,*
*1300 College Road, Fairbanks, AK 99701-1599,USA*

*This document should be cited as:*
*Fish, J. T. 1998. Radio-telemetry studies of Arctic grayling in the Jim River (Dalton Highway) during 1997 – 1998. Alaska Department of Fish and Game, Fishery Manuscript Report, No. 98-4, Anchorage.*

The Alaska Department of Fish and Game administers all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood, or disability. For information on alternative formats available for this and other department publications, contact the department ADA Coordinator at (voice) 907-465-4120, or (telecommunication device for the deaf) 1-800-478-3648.

# TABLE OF CONTENTS

**Page**

LIST OF TABLES ..... ii

LIST OF FIGURES ..... ii

LIST OF APPENDICES ..... ii

ABSTRACT ..... 1

INTRODUCTION ..... 1

Study Objectives ..... 1

METHODS ..... 4

Surgical Implantations ..... 4
Transmitters and Tracking ..... 4
Overwintering ..... 6
Spawning ..... 6
Estimation of Fidelity ..... 6

RESULTS ..... 10

Overwintering Locations ..... 11
Spring Spawning Locations ..... 13
Summer Fidelity To Roadside Fishery ..... 17

DISCUSSION ..... 17

ACKNOWLEDGMENTS ..... 20

LITERATURE CITED ..... 20

APPENDIX A ..... 23

APPENDIX B ..... 27

APPENDIX C ..... 31

# LIST OF TABLES

**Table** **Page**

1. Summary of tracking results for radio-tagged Arctic grayling in the Jim River and neighboring drainages during 1997 – 1998 ..... 8
2. Straight line distances (km) between consecutive trackings of 55 radio-tagged Arctic grayling from the Jim River, 1997 – 1998 ..... 10
3. Proportions of Arctic graying a) overwintering and spawning in the Jim River and surrounding drainage during 1998; and b) displaying fidelity to the Jim River fishery during 1998. ..... 14

# LIST OF FIGURES

**Figure** **Page**

1. Jim River and surrounding drainages ..... 2
2. Jim River drainage adjacent to the Dalton Highway ..... 3
3. Overwintering locations of 40 radio-tagged Arctic grayling from the Jim River, considered to be alive during February, 1998 ..... 12
4. Spawning locations of 30 radio-tagged Arctic grayling from the Jim River, considered to be alive during mid-May and early June, 1998 ..... 15
5. Water temperature data collected in the Jim River: A) May 20 through September 28, 1998 at 30 minute intervals beginning May 27; B) May 20 through June 10, 1998 at 30 minute intervals beginning May 27 ..... 16

# LIST OF APPENDICES

**Appendix** **Page**

A1. Length, weight, sex, age and transmitter frequency of Arctic grayling implanted with radio transmitters in the Jim River, July – August, 1997 ..... 24
A2. Length-weight relationships of Arctic grayling from selected waters in the Tanana Valley, Brooks Range, North Slope, Alaska ..... 26
B1. Aerial tracking schedules and search results for radio-tagged Arctic grayling in the Jim River and neighboring drainages, during 1997 and 1998 ..... 28
B2. Data files regarding radio-telemetry studies of Arctic graying in the Jim River during 1997 – 1998, archived by the Research and Technical Services of the Alaska Department of Fish and Game, Sport Fish Division ..... 29
C1. Release locations of 55 radio-tagged Arctic grayling July and August of 1997 ..... 32
C2. Locations of 49 radio-tagged Arctic grayling found in the Jim River and South Fork Koyukuk River during September, 1997 ..... 33
C3. Locations of 48 radio-tagged Arctic grayling found in the Jim River and South Fork Koyukuk River during February, 1998 ..... 34
C4. Locations of 36 radio-tagged Arctic grayling found in the Jim River, South Fork Koyukuk River, and Fish Creek during May, 1998 ..... 35
C5. Locations of 42 radio-tagged Arctic grayling found in the Jim River and the South Fork Koyukuk River during early June, 1998 ..... 36
C6. Locations of 21 radio-tagged Arctic grayling groundtruthed in the Jim River during August, 1998 ..... 37
C7. Locations of 17 radio-tagged Arctic grayling found in the Jim River during October, 1998 ..... 38

# ABSTRACT

This study was initiated to determine overwintering and spawning locations of Arctic grayling *Thymallus arcticus* in the Jim River summer fishery, and to determine the fidelity of Arctic grayling to the fishery area in the Jim River. Arctic grayling were found to overwinter in the portions of the Jim River that included the fishery and the lower river. Fish were also found in portions of the South Fork Koyukuk River and mainstem Koyukuk River, as well as Prospect Creek. The proportion of Arctic grayling that overwintered in the Jim River fishery area was 0.13 (SE = 0.05), while the proportion that overwintered in the lower Jim River was 0.53 (SE = 0.08). The proportion overwintering in the South Fork Koyukuk River, the mainstem Koyukuk River, and Prospect Creek was 0.25 (SE = 0.07), 0.08 (SE = 0.04), and 0.03 (SE = 0.03), respectively. During spring spawning Arctic grayling were located in the lower Jim River and the fishery area. The proportion of Arctic grayling that were considered to have spawned in the lower Jim River was 0.47 (SE = 0.09), while the proportion that spawned in the fishery area was 0.37 (SE = 0.09). Fish were also located in Fish Creek, Prospect Creek, and the South Fork Koyukuk River during spawning, but not in great numbers (p = 0.07, SE = 0.05 in both Fish Creek and the South Fork Koyukuk River, p = 0.03 (SE = 0.03) in Prospect Creek). Arctic grayling tagged in late July 1997 were tracked in the Jim River during mid-June and mid-August 1998 to produce estimates of fidelity of 0.19 and 0.35, respectively. Patterns of habitat use and migration characteristics appear to be similar to those of other stocks of Arctic grayling inhabiting unsilted, rapid runoff rivers in interior Alaska (e.g. within the Tanana Valley). Telemetry data suggest that Arctic grayling in the Jim River are probably a distinct spawning stock of fish that may share overwintering and feeding habitat with other related Koyukuk River stocks.



Key words: Arctic grayling, *Thymallus arcticus*, Jim River, radio-telemetry, overwintering, spawning, summer fidelity, homing, migrations


# INTRODUCTION

Radio telemetry studies were initiated during late July of 1997, as part of research activities to assess Arctic grayling *Thymallus arcticus* in the Jim River. The Jim River, approximately 86 km (~53 mi) in length, flows west to southwest, from the Philip Smith Mountains, into the South Fork of the Koyukuk River (Figure 1). It is an unsilted, rapid runoff stream which offers both spring spawning and summer feeding habitat that Arctic grayling utilize (Tack 1980). The lower reaches of the Jim River, and its confluence with the Koyukuk River, are within the Kanuti National Wildlife Refuge (see Figure 1). The Dalton Highway crosses the Jim River in three places (see Figure 2), and offers easy access to fishery resources for recreational anglers. Responses to the Statewide Harvest Survey (SWHS) confirm that the Jim River supports the greatest catch and harvest of Arctic grayling north of the Yukon but south of the Brooks Range (Mills 1991-1994, Howe et al. 1995-1996). This prompted investigators to focus Arctic grayling research activities on the Jim River. Results of stock assessment activities initiated during 1995 were reported by Fish (1997). This report summarizes radio telemetry studies conducted with Arctic grayling from the Jim River during 1997-1998.

## STUDY OBJECTIVES

Visitor travel along the Dalton Highway is expected to increase in years to come, especially as road improvements are made. Increased travel will likely lead to increased use of fishery resources along the highway corridor. With little baseline information on Arctic grayling stocks available, there was a need to describe life history traits of Arctic grayling inhabiting this particular region of the State. Relatively little is known concerning the seasonal distribution and habitat utilization of Arctic grayling within river systems adjacent to the Dalton Highway, and their susceptibility to harvest during various stages of their life. From a management perspective, it was 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,

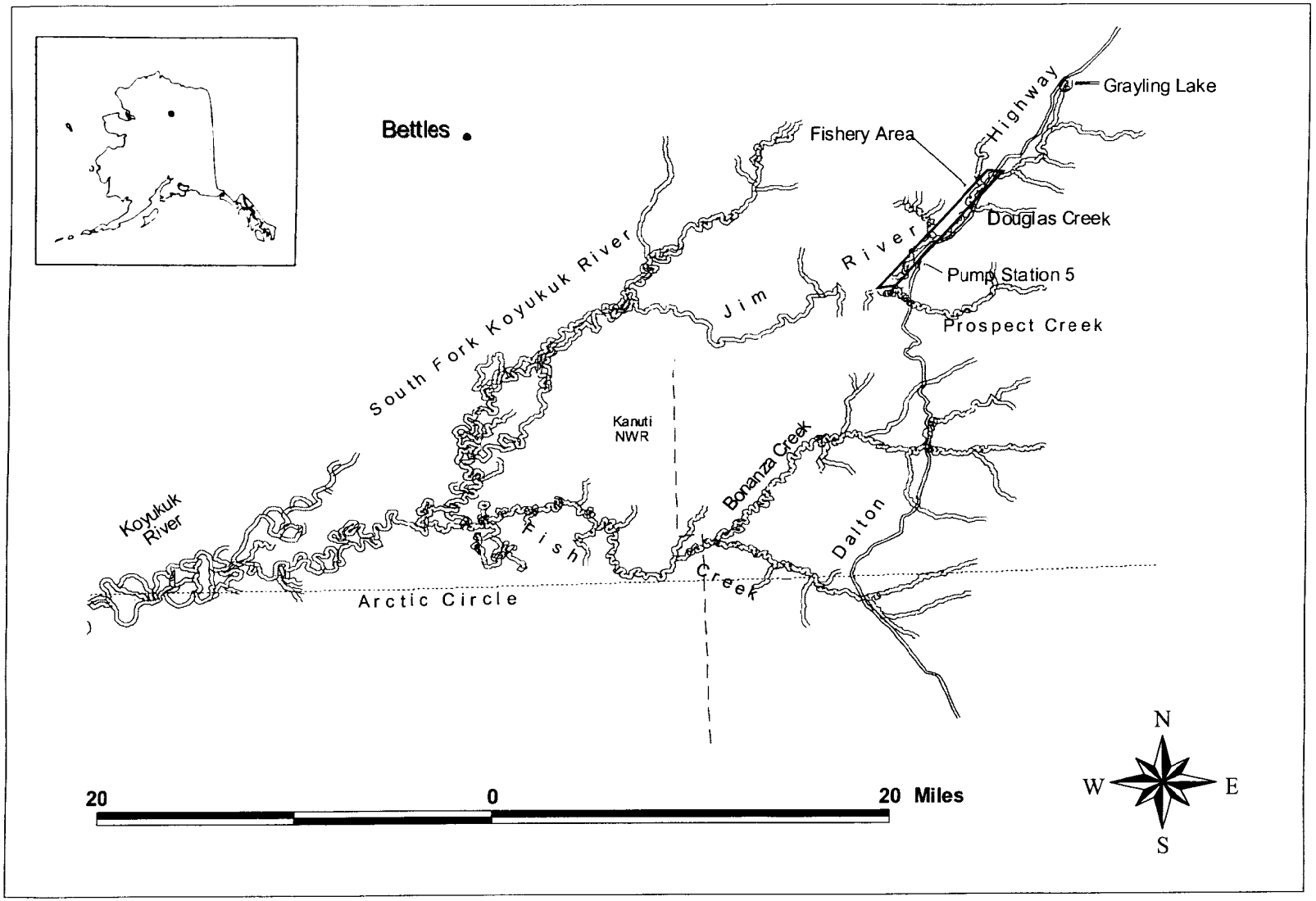



**Figure 1.-Jim River and surrounding drainages.**

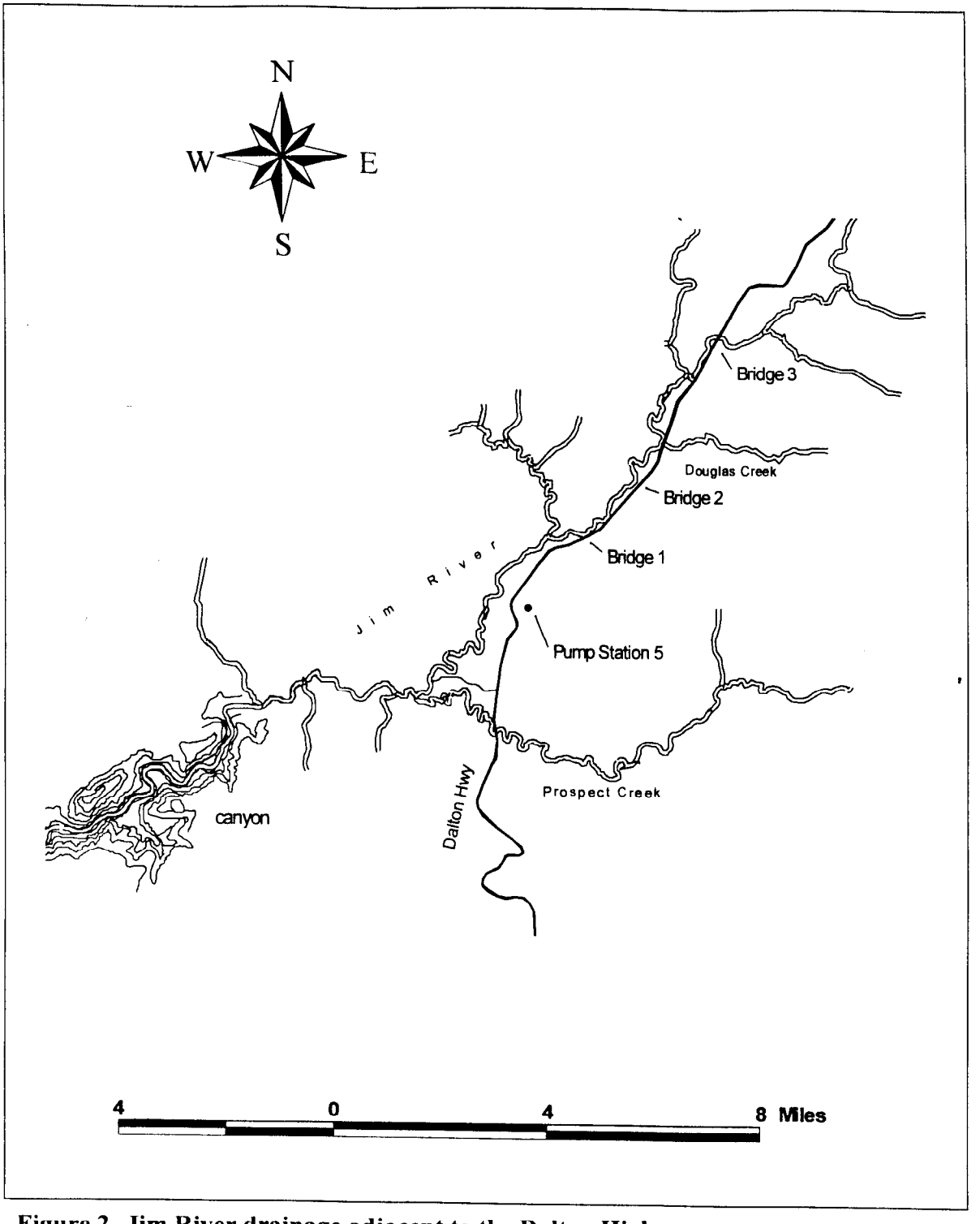



**Figure 2.-Jim River drainage adjacent to the Dalton Highway.**

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. Accordingly, radio telemetry studies were designed to examine the migrational timing and habits of Arctic grayling in the Jim River, and to estimate fidelity of fish to the summer fishery. Specific objectives were to:

1. identify at least one overwintering area for Arctic grayling of the Jim River summer fishery;
2. identify at least one spawning site for Arctic grayling of the Jim River summer fishery;
3. estimate fidelity as the proportion of Arctic grayling with functioning radio transmitters that return to the Jim River summer fishery area; and,
4. identify feeding locations of radio-tagged Arctic grayling alternative to the Jim River.

# METHODS

## SURGICAL IMPLANTATIONS

Arctic grayling, caught by hook-and-line, were implanted with radio transmitters after being captured for stock assessment activities during the summer of 1997. Fish were anesthetized with tricaine methanesulfonate (MS-222) following procedures recommended by Summerfelt and Smith (1990), and surgery proceeded in a manner similar to that described by West et al. (1992). Fish were considered to be in stage three anesthesia when their equilibrium was visibly affected and the fish became docile. Fish were then placed upside down in a padded cradle, and a ~20 mm long incision was made anterior to the pelvic girdle. Gill rakers were basted with the anesthetic, and intermittently rinsed with water during surgery. Transmitters, soaked in cold sterilant, Clinidine®, and rinsed with sterile saline, were implanted in the coelomic cavity, through the incision. The whip antennae of the transmitters was guided to exit the body of the fish through an outlet incision made posterior to the pelvic girdle, by using a curved needle. Incisions were treated with the water-soluble antibiotic powder, Furacin, to minimize infection. Next, incisions were sutured with nonabsorbent, monofilament nylon suture (2-0) with cutting FS needle, using simple-interrupted square knots with a single-instrument tie, as suggested by Summerfelt and Smith (1990), then sealed with VetBond® cyanoacrylate surgical adhesive. Implanted fish were placed in coolers of fresh river water immediately following surgery, and released after turning upright and resuming normal swimming and breathing activities.

Using the "2% Rule," as suggested by Winter (1983), (where the weight of a transmitter should not exceed 2% of the total weight of the fish) Arctic grayling ≥ 320 mm FL were selected for transmitter implantation (this corresponds to an approximate fish weight of 350g , where a 7.0g transmitter is 2% of 350g). The minimum length of 320 mm represents a mean length generated from length-weight relationships reported for Arctic grayling from selected North Slope and Tanana Valley drainages. Length-weight relationships and references are reported in Appendix A2.

## TRANSMITTERS AND TRACKING

A total of 55 fish were captured and implanted with radio transmitters, over the time period of July 21- August 1, 1997. Fish were collected between Jim River Bridge 3 and Prospect Camp during mark-recapture studies, and underwent implantation surgery almost immediately after

being caught. Fifty-five transmitters is the maximum number that two observers can track within one or two flights. A greater number would require the use of digitally-encoded transmitters and unique receiver equipment.

Each transmitter, type 10-28 manufactured by Advanced Telemetry Systems, Inc. (ATS, Isanti, MN, USA), weighed 6.8 g, measured 13 mm x 45 mm, and had a pulse rate of 44 bpm with a pulse width of 18 ms. Transmitter antennas were ~350 mm long, teflon-coated, 7 x 7 "021" wire, and optimized for ¼ wavelength. Each transmitter was programmed to transmit signals 7 h per day. The transmitters were "off" for 14 h per day, thus enabling the internal battery to have a guaranteed life expectancy of one year. All transmitters were hermetically sealed. Transmitter signals operated within the 148-149 MHz range, with individual transmitters separated by 10 KHz (these frequencies did not interfere with studies performed in this area by ADF&G Division of Wildlife Conservation, nor by USFWS). Transmitter failure and immediate mortality of implanted fish was expected to occur, but together, were not expected to exceed 5%.

Transmitter signals were received with either a Lotek SR-2 programmable receiver, or Telonics TR-2 scanning receivers equipped with model TS-1 scanners. H-type antennas were used to track fish from the ground, boat or aircraft. Two antennas were mounted on fixed wing aircraft (either a Piper Super Cub or Cessna 185) and incorporated into an intercom system accommodating two scanning receivers. The aircraft intercom system utilized a switching system that enabled each tracker to selectively isolate transmitter signals from the pilot, as well as from air traffic control signals. This method allowed two observers to more efficiently track fish during any given flight. Transmitter signals were monitored for pulse strength in order to identify the "null point," or a noticeable decline in pulse strength as one passes over the transmitter. Locations of fish implanted with transmitters were recorded by date as GPS coordinates (latitude and longitude) and plotted on USGS topographical maps (1:63,360), with each fish being identified by an individual transmitter frequency. GPS data were entered into a Microsoft Excel spreadsheet. All data were converted to decimal degrees, checked for errors (with field notes) and submitted as a spreadsheet to RTS for archival. All data pertaining to length, sex, tag identification numbers and colors were recorded on Alaska Department of Fish and Game Tagging Length Form, Version 1.0, and were electronically stored for archival. Data files archived are reported in Appendix B2.

The following assumptions, founded on previous radio-telemetry projects conducted in the Tanana Valley, were used to design the study:

1. a tag failure and immediate mortality rate of 5%, and a combined natural and fishing mortality rate of 35%, resulting in a 62% chance of survival of a radio-tagged fish with a functioning transmitter;
2. there are no differences between timing of spawning for male and female fish;
3. time elapsed between flights does not allow for fish to overwinter or spawn without being detected;
4. there are potentially four general areas where Arctic grayling from the Jim River will spawn (Jim River, tributaries of Jim River, South Fork Koyukuk River, tributaries of the South Fork Koyukuk River), and the transition (movement) probability that fish will spawn in one of these areas is 0.25; and,

5. tag detection probability ($p_d$) per flight is 0.68 (based on previous radio tracking experience of ADF&G staff).

## OVERWINTERING

Tracking occurred from both the ground and air during 1997 and 1998. February afforded the greatest daylight for aerial tracking during the winter months. No attempt was made to aerial track during December and January due to the limited daylight. Overwintering locations of fish were defined as positions of fish during the month of February, as suggested by Lubinski (1995).

## SPAWNING

Spawning locations were defined as fish locations during late May, shortly after break-up, as well as fish locations during early June**.** No fish were groundtruthed[1] during spawning activities because of inaccessibility (ice jams in the lower river) and failure to be present on the ground when spawning occurred.

## ESTIMATION OF FIDELITY

Tracking from a boat in the Jim River was conducted during June 11 – 13 (mid-June) and during August 14 – 18, 1998 (mid-August), while fish were tracked from the air during June 3, 5 (early June), and 29 (late June). Fish were not tracked during July 1998. During aerial tracking flights of early June, all 55 radio-tagged fish were searched for. During the tracking flight of June 29, only select radio-tagged fish were located to determine movement patterns. These later fish locations were not used for the determination of summer fidelity. Weather conditions prevented aerial tracking during early August; consequently alternative summer foraging locations of implanted Arctic grayling were not identified. However, 10 radio transmitters were groundtruthed during June and 21 during August to confirm locations of Arctic grayling.

The summer fishery was defined as that portion of the Jim River between Bridge 3, downstream to Prospect Camp (an informal campground and Bettles winter road crossing). This section of river includes all areas adjacent to the Dalton Highway, which are easily accessible to anglers travelling the highway. The number of fish in the summer fishery area during both mid-June and mid-August was used to calculate separate estimates of fidelity of Arctic grayling to the Jim River fishery for each month. The proportion of radio-tagged fish that returned to the Jim River summer fishery during both mid-June and mid-August was determined under the assumption that the number of radio-tagged fish alive during those times was the same as the number alive during early June.

An estimation of fidelity was calculated as the proportion of Arctic grayling with functioning transmitters that returned to the Jim River summer fishery:

$$p = \frac{y}{n} \tag{1}$$

where:

p = the proportion of Arctic grayling alive, with functioning radio transmitters and displaying fidelity,

[1] Groundtruthing is defined in this report as a verification of the position of a radiotransmitter and fish status (live, dead) by visual observation from the ground.

y = the number of Arctic grayling alive, with active radio transmitters in the Jim River summer fishery during mid-June or mid-August, 1998; and,

n = the total number of Arctic grayling alive, with active radio transmitters during mid-June or mid-August, 1998.

Standard error of this proportion was estimated as:

$$SE[p] = \sqrt{\frac{p(1-p)}{n-1}}. \quad (2)$$

Similar calculations were used to determine proportions of overwintering and spawning fish.

Straight-line distances between consecutive locations were used to describe the movement of radio-tagged Arctic grayling. Straight-line distances were calculated as:

$$SLD = \sqrt{((lat_i - lat_{i-1}) * 112km)^2 + ((long_i - long_{i-1}) * 46km)^2} \quad (3)$$

where:

$lat_i$ = the latitude of the $i^{th}$ location in decimal degrees,

$long_i$ = the longitude of the $i^{th}$ location in decimal degrees,

122 km = the distance of 1 degree change in latitude, and

46 km = the distance of 1 degree change in longitude near the $66^{th}$ parallel.

# RESULTS

Fifty-one fish were determined to be male, while one was identified as female and three were of unknown sex. Weights were recorded from 19 fish, and are reported in Appendix A1, with length and age data. Only 19 weights were recorded because the balance failed to operate after being exposed to water. As a result, weight – length relationships were not estimated for Jim River Arctic grayling.

Fish were tracked from the ground approximately one week following surgeries on August 2 – 5, 1997. The first aerial tracking occurred during September. Overall, six aerial tracking flights occurred (Table 1, Appendix B1). All 55 radio transmitter signals were searched for during each month, except during flights on June 29 and October 7. During these flights, only selected transmitter signals were searched for in order to confirm movement, or find missing fish. If a fish was determined to have not moved (particularly upstream) 1.0 km (straight-line distance) after three tracking flights, then that fish was assumed to be dead or to have lost its transmitter. In some cases, fish were assumed to be dead, even if they moved >1 km in straight-line distance, if their movement was consistently downstream after three or more trackings and no subsequent upstream movement was observed. Overall, 20 fish (36%) were assumed to be dead by October. Ten transmitters (18%) were assumed to have failed since their signals were not received for five

**Table 1.-Summary of tracking results for radio-tagged Arctic grayling in the Jim River and neighboring drainages during 1997 – 1998.**

| Aerial Tracking Flight | Searched | Found | Not Found | Determined Alive |
|---|---|---|---|---|
| September 23 & 24, 1997[a] | 55 | 49 | 6 | |
| February 19 & 20, 1998 [b] | 55 | 48 | 7 | 40 |
| May 13, 1998 [c] | 55 | 36 | 19 | 30 |
| June 3 & 5, 1998 [c] | 55 | 42 | 13 | 26 |
| June 29, 1998 [c] | 13 | 11 | 2 | 4 |
| October 7, 1998 [d] | 19 | 17 | 2 | 3 |
| Groundtruthing: | | | | |
| August 2 - 5, 1997 | 55 | 36 | 19 | 35 |
| June 11 – 13, 1998 | 25 | 10 | 15 | 9 |
| August 14 – 18, 1998 | 55 | 21 | 34 | 17 |

[a] Flight with staff from Kanuti National Wildlife Refuge, USFWS.

[b] Flight with Caribou Air.

[c] Flight with ADF&G personnel.

[d] Flight with Arctic National Wildlife Refuge, USFWS.

or more trackings. The amount of mortality observed was not higher than expected, but transmitter failure was. Most mortalities occurred between September and February, or between February and May. Two fish in particular (574 and 582) were alive during spawning, but died afterwards. Table 2 reports straight-line distances moved between trackings, as well as the assumed status of each fish as of October. The locations of each fish determined during each tracking period is shown in Appendices C1 to C7.

Preliminary investigations prior to telemetry studies indicated that individual transmitters had an approximate range of 1 to 1.5 mi, when placed under ~1 ft of ice and aerially-tracked at an altitude of 500 to 1000 ft. Throughout the study, the range of transmitter signals appeared to remain constant. Individual transmitters drifted in frequency, however, from 1 to 6 kilohertz, usually to greater values (e.g. 149.303 drifted to 149.304). During tracking flights, transmitter frequencies were often bracketed between higher and lower frequencies, separated by one or more kilohertz. This allowed investigators to find the best reception frequency, and in some cases demonstrated that some signals could not be heard on alternate frequencies. Overall 53% of the transmitters drifted to different signal frequencies. Transmitters were also programmed to actively transmit signals 7 h per day (1000 to 1700 d.s.t), and remain inactive for 14 h per day. Internal clock mechanisms also drifted in some cases, causing some transmitters to begin transmitting ~1030 and ending at ~1730.

## OVERWINTERING LOCATIONS

The locations of radio-tagged overwintering fish determined during February are shown in Figure 3. Table 2 and Appendices C1 and C2 reveal that all but three fish (or 46 fish) moved between initial tagging and September tracking flights, most of which traveled downstream to the vicinity of the lower Jim River (canyon area) and its confluence with the South Fork Koyukuk River. Straight-line distances of downstream movements ranged from 1 to 60 km, mean = 19, S.D. = 13). Four Arctic grayling moved upstream, one of which moved downstream to the confluence by the February flight (see Table 2). Three fish were determined to have not moved, while six fish were never found. During February, 48 fish were located during tracking flights, 25 of which were in the lower Jim River area (from just upstream of the canyon, downstream to the mouth). Twelve fish were located within the South Fork Koyukuk River, near the mouth the Jim River. Three fish were located in the mainstem Koyukuk River (one fish, #444, was located ~12 mi outside of Allakaket; while two fish, #353 and #744, were located in the Middle Fork ~4 mi upstream its confluence with the South Fork Koyukuk River). One fish (623) was tracked outside of the Jim River, and may have been carried off by a predator, while one fish (723) had also entered Prospect Creek. Three fish (one of which was confirmed dead) were still in the summer fishery area, while three more fish were just downstream of the summer fishery area (see Figure 3). Seven fish were never found during February tracking flights, five of which were also missing during September flights. Sixteen fish were found to have not moved 1

**Table 2.-Straight line distances (km) between consecutive trackings of 55 radio-tagged Arctic grayling from the Jim River, 1997 – 1998[a].**

| Tag | Distance Tagging - Sept | Distance Sept - Feb | Overwinter Location | Distance Feb - May | Distance May & Jun | Spawning Location | Distance E Jun – M Jun | Distance E or M Jun - Late Jun | Distance Jun – Aug | Distance Aug - Oct | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 149.303 | -14.5 | **-0.5** | L Jim | -0.2 | -0.6 | L Jim | | | 0.7 | | Dead since February |
| 149.313 | -27.7 | 1.1 | L Jim | 0.6 | -0.3 | L Jim | | | | | Alive in February |
| 149.324 | 0.6 | -9.3 | Fishery | 1.4 | 0.2 | Fishery | -3.9 | | -0.0 | | Alive in mid-June |
| 149.334 | -6.9 | -18.3 | L Jim | 17.7 | 0.3 | Fishery | 7.3 | | 0.2 | | Alive in mid-June |
| 149.342 | -16.1 | -7.6 | L Jim | **-2.4** | | | | | | | Transmitter Failure & dead |
| 149.353 | -33.5 | -28.9 | MS | | 28.9 | SF | | | | | Alive in early June |
| 149.363 | -17.6 | -0.9 | L Jim | 1.6 | | L Jim | | | | | Alive in May |
| 149.373 | -17.6 | -4.2 | L Jim | 1.7 | **0.7** | L Jim | | 0.3 | -0.3 | -0.8 | Dead since early June |
| 149.384 | -0.7 | -19.4 | L Jim | | 22.7 | Fishery | -4.0 | | -4.7 | | Alive in Aug |
| 149.393 | -37.7 | 0.7 | SF | | **-1.5** | SF | | | | | Dead since early June |
| 149.402 | -13.6 | -4.7 | L Jim | -2.4 | 13.6 | Fishery | 0.3 | | | | Alive in early June |
| 149.414 | -27.0 | **0.8** | L Jim | | -0.9 | L Jim | | 0.3 | | 0.1 | Dead since February |
| 149.423 | -12.4 | -9.4 | L Jim | 1.1 | 0.9 | L Jim | | 9.0 | 11.0 | | Alive in August |
| 149.432 | -17.2 | 1.1 | L Jim | 0.2 | -0.2 | L Jim | | 1.0 | -1.2 | | Alive in August |
| 149.444 | | -77.6 | MS | 50.4 | | Fish Ck | | | | 18.2 | Alive in October |
| 149.453 | -16.7 | -45.5 | SF | **0.3** | -0.8 | SF | | | | -0.6 | Dead since May |
| 149.461 | -20.5 | 2.7 | SF | | 2.8 | L Jim | | 0.4 | | | Alive in early June |
| 149.474 | **-2.9** | 0.3 | Fishery | 0.5 | 0.4 | Fishery | | | 0.1 | | Dead since September |
| 149.483 | -18.0 | **0.7** | L Jim | 0.5 | | L Jim | | 0.6 | | -1.3 | Dead since February |
| 149.492 | -18.5 | -3.2 | L Jim | **-6.9** | 0.6 | L Jim | | | | -0.3 | Dead since May |
| 149.503 | 16.7 | -40.1 | SF | | **-1.0** | SF | | | | | Dead since early June |
| 149.514 | -5.7 | -0.8 | L Jim | 1.3 | 0.7 | L Jim | -1.4 | | 0.2 | | Alive in mid-June |
| 149.522 | -33.7 | -1.1 | SF | **-1.8** | -1.3 | SF | | | | | Dead since May |
| 149.533 | | | | | | | | | | | Transmitter Failure |
| 149.544 | 2.1 | -2.9 | Fishery | 0.8 | 1.4 | Fishery | | | -1.9 | | Alive in August |
| 149.552 | -1.3 | 0.5 | Fishery | 0.6 | 1.0 | Fishery | | | 0.1 | 0.2 | Alive in early June |
| 149.564 | -6.0 | -4.8 | L Jim | 4.3 | 1.5 | L Jim | **-0.7** | 0.3 | -0.1 | 0.1 | Dead since early June |
| 149.574 | 1.8 | -2.6 | Fishery | 1.1 | **0.7** | Fishery | -0.4 | | 0.1 | 0.1 | Dead since early-June |
| 149.582 | -16.4 | 0.7 | L Jim | 1.0 | **0.3** | L Jim | | 0.5 | | -1.0 | Dead since early June |
| 149.593 | -2.9 | 1.9 | Fishery | 3.2 | -1.5 | Fishery | -1.8 | | 0.0 | | Alive in mid-June |
| 149.603 | -2.9 | -2.3 | L Jim | 2.7 | 3.7 | Fishery | | | -6.1 | | Alive in August |
| 149.612 | -7.8 | -3.4 | L Jim | 3.7 | 0.3 | L Jim | | -1.0 | | | Alive in Late June |
| 149.623 | -8.9 | **-3.9** | lake | -3.8 | 2.6 | Lake | | | | | Dead since February |
| 149.633 | -3.7 | **0.6** | L Jim | | 0.1 | L Jim | 0.3 | 0.4 | 0.5 | 0.1 | Dead since February |

-continued-



10

**Table 2.-(Page 2 of 2).**

| Tag | Distance Tagging - Sept | Distance Sept - Feb | Overwinter Location | Distance Feb - May | Distance May & Jun | Spawning Location | Distance E Jun – M Jun | Distance E or M Jun – Late Jun | Distance Jun – Aug | Distance Aug - Oct | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 149.642 | | | | | | | | | | | Transmitter Failure |
| 149.654 | -4.5 | -1.9 | L Jim | -1.2 | 2.9 | Fishery | | | -1.4 | | Alive in August |
| 149.664 | -20.7 | -1.0 | SF | **0.1** | 0.3 | SF | | | | 0.9 | Dead since May |
| 149.672 | -6.0 | 0.3 | L Jim | | | | | | | | Transmitter Failure |
| 149.684 | 0.5 | -17.0 | L Jim | 9.1 | 8.9 | L Jim | | | 0.5 | -0.3 | Alive in early June |
| 149.694 | -21.1 | -1.1 | SF | **0.6** | 0.7 | SF | | | | | Dead since May |
| 149.701 | -7.2 | 0.1 | L Jim | 0.8 | 0.2 | L Jim | | 6.4 | -5.6 | | Alive in August |
| 149.714 | -22.0 | 0.2 | SF | 1.1 | 0.3 | SF/L Jim | | | | -1.0 | Alive in October |
| 149.723 | 1.1 | 1.4 | Prospect | -1.2 | 2.1 | Prospect | | | | | Alive in early June |
| 149.733 | -60.1 | -2.3 | SF | | | | | | | | Transmitter Failure |
| 149.744 | -40.2 | -24.5 | MS | 22.3 | 11.2 | Fish Ck | | | | 14.7 | Alive in October |
| 149.753 | | | | | | | | | | | Transmitter Failure |
| 149.763 | -13.7 | 1.1 | L Jim | -0.5 | 1.3 | L Jim | | | -1.5 | | Alive in August |
| 149.773 | -19.7 | 0.8 | L Jim | | 11.3 | Fishery | | | 8.5 | | Alive in August |
| 149.782 | -18.1 | | | | | | | | | | Transmitter Failure |
| 149.792 | | | | | | | | | | | Transmitter Failure |
| 149.804 | | | | | | | | | | | Transmitter Failure |
| 149.813 | -27.2 | -3.7 | SF | | 1.5 | SF | | | | | Alive in early June |
| 149.822 | -39.7 | **0.8** | SF | | 0.5 | SF | | | | 0.4 | Dead since February |
| 149.833 | -41.4 | **-0.3** | SF | -0.5 | -0.3 | SF | | | | 0.8 | Dead since February |
| 149.843 | -37.9 | | | | | | | | | | Transmitter Failure |

a Positive numbers denote upstream movement, while negative numbers denote downstream movement. Bold numbers indicate when that fish was first determined to be dead.

b L Jim = lower Jim River (just upstream canyon, downstream to the confluence); SF = South Fork Koyukuk River; MS = mainstem Koyukuk River; Fishery = that portion of the Jim River where most fishing pressure is assumed to occur (Bridge 3, downstream to Prospect Camp); Fish Ck = Fish Creek, Prospect = Prospect Creek.



11

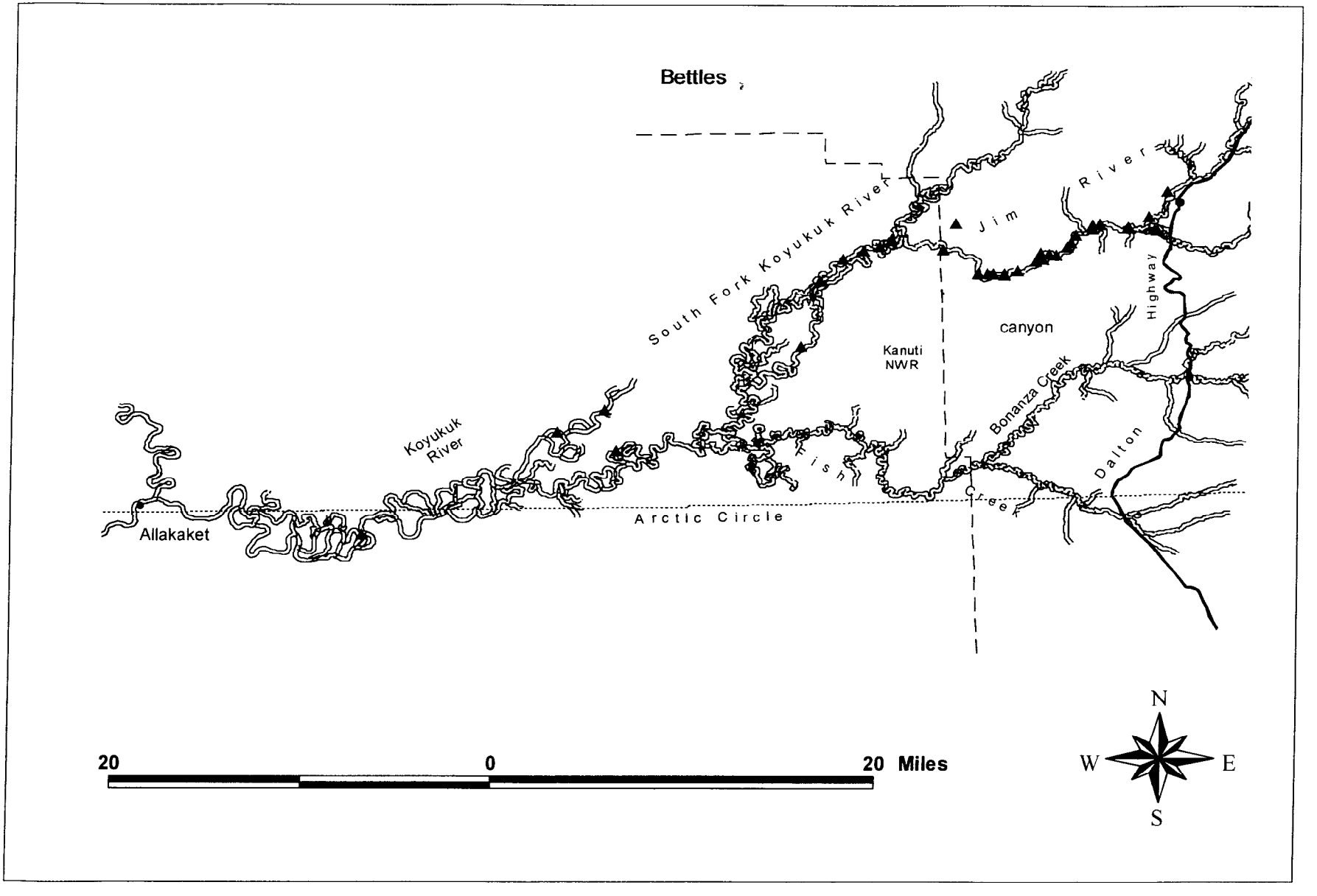



**Figure 3.-Overwintering locations of 40 radio-tagged Arctic grayling from the Jim River, considered to be alive during February, 1998.**

km or more since September, while 32 fish did move. Overall, 40 fish were determined to be alive during February (see Table 2).

Overwintering areas in the lower Jim and Koyukuk rivers were locations where the water was usually deep and covered with substantial ice. Many areas upstream of the canyon in the Jim River remained ice-free, but usually only as short stretches of water. These areas probably remained ice-free by the influx of groundwater. The proportion of Arctic grayling overwintering in the lower Jim River was 0.53 (SE = 0.08; Table 3). The proportion of Arctic grayling overwintering upstream within the fishery area was 0.13 (SE = 0.05). Likewise, the proportion overwintering in the South Fork Koyukuk River was 0.25 (SE = 0.07), while the proportion overwintering in the mainstem Koyukuk River was 0.08 (SE = 0.04). Lastly, the proportion of Arctic grayling overwintering in Prospect Creek was 0.025, (SE = 0.025).

## SPRING SPAWNING LOCATIONS

Locations of spring spawning areas for Arctic grayling are shown in Figure 4, as locations of fish during mid-May and early June. Fish were found in both the fishery and lower portions of the Jim River, the South Fork Koyukuk River, and in portions of Fish Creek (a tributary stream to the South Fork Koyukuk River), as well as in Prospect Creek. Exact locations of spawning activity were not determined since groundtruthing was not accomplished during this time period. However, since all implanted fish located in these areas were mature adults, it is assumed that fish were in these locations to spawn, or were involved in spawning migrations.

Water temperatures were recorded at various times in the Jim River and its tributaries near the highway during early May, and beginning May 27, water temperature was recorded every 30 min with a Hobie Optic Stowaway Temperature Datalogger. Figure 5 shows temperature data recorded in the Jim River approximately 100 yards downstream of Bridge 3, between May 20 and June 10. Arctic grayling are known to spawn when water temperatures are between approximately 4 and 6°C (Armstrong 1986, Tack 1980 and Northcote 1995). Since water temperatures during June 3 through 5 in the Jim River ranged from 4.5 to 8.2°C, fish tracked during early June were assumed to have been at or near spawning grounds. Additionally, Table 2 shows that some fish did not move between February and May trackings, but did move between May and early June trackings, often upstream. This is consistent with Arctic grayling spawning migration behavior observed in other interior Alaskan river systems (Armstrong 1986 and Tack 1980). Additionally, Netsch (1975) examined movements of Arctic grayling in the Jim River during 1972, and determined that spawning occurred during 28 May to June 11. During this time, water temperatures ranged from 2 to 7°C. Therefore, it seems safe to assume that fish locations obtained during both mid-May and early June (Figure 4) represent spawning locations of Jim River Arctic grayling.

The lower reaches of the Jim River (just upstream the canyon, downstream to its confluence with the South Fork Koyukuk), areas within the Jim River fishery, and portions of Fish Creek were determined to be spawning locations of Jim River Arctic grayling. Fish assumed to be spawning were also found in the South Fork Koyukuk River and Prospect Creek. However, most fish in the South Fork Koyukuk River during spawning activity were considered to be dead, since only two fish moved to new locations at later dates.

Overall, 30 fish were also determined to be alive and spawning during late May and early June, most of which moved upstream during this period. This number included two fish (313 and 432) located in the lower Jim River that moved upstream < 1 km during the spawning period, since it

**Table 3.-Proportions of Arctic grayling a) overwintering and spawning in the Jim River and surrounding drainage during 1998; and b) displaying fidelity to the Jim River fishery during 1998.**

**a)**

| | Overwintering | | | Spawning | | |
|---|---|---|---|---|---|---|
| **Location** | **n** | **p** | **SE** | **n** | **p** | **SE** |
| Jim River Summer Fishery | 5 | 0.13 | 0.05 | 11 | 0.37 | 0.09 |
| Lower Jim River | 21 | 0.53 | 0.08 | 14 | 0.47 | 0.09 |
| South Fork Koyukuk River | 10 | 0.25 | 0.07 | 2 | 0.07 | 0.05 |
| Mainstem Koyukuk River | 3 | 0.08 | 0.04 | 0 | ---- | ---- |
| Prospect Creek | 1 | 0.03 | 0.03 | 1 | 0.03 | 0.03 |
| Fish Creek | ---- | ---- | ---- | 2 | 0.07 | 0.05 |
| Totals (Fish Alive) | 40 | 1.0 | ---- | 30 | 1.0 | ---- |

**b)**

| | Summer Fidelity[a] | | |
|---|---|---|---|
| **Month** | **n** | **p** | **SE** |
| June | 5 | 0.19 | 0.08 |
| August | 9 | 0.35 | 0.10 |

[a] Total fish tracked and alive (n = 26)

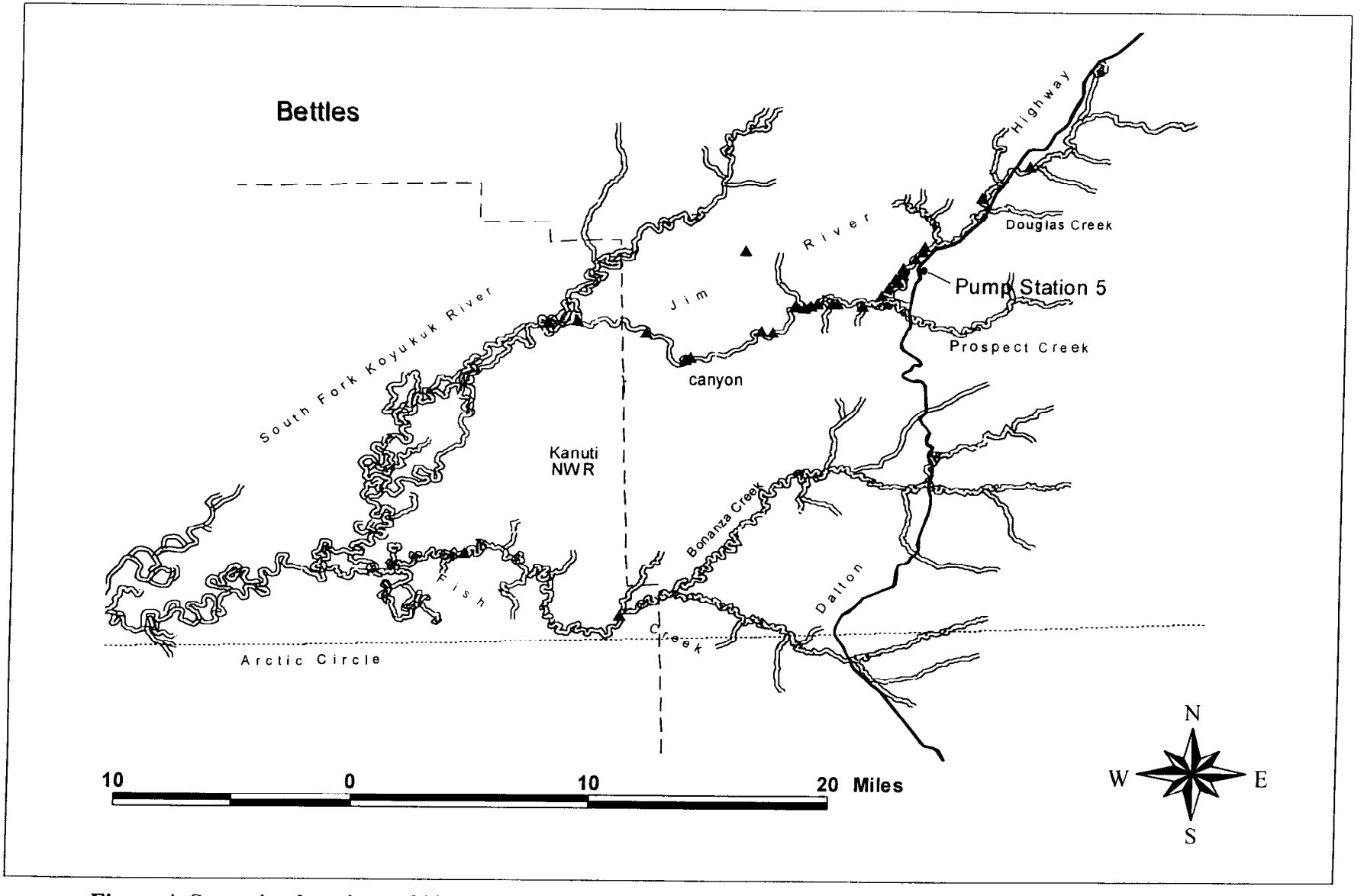
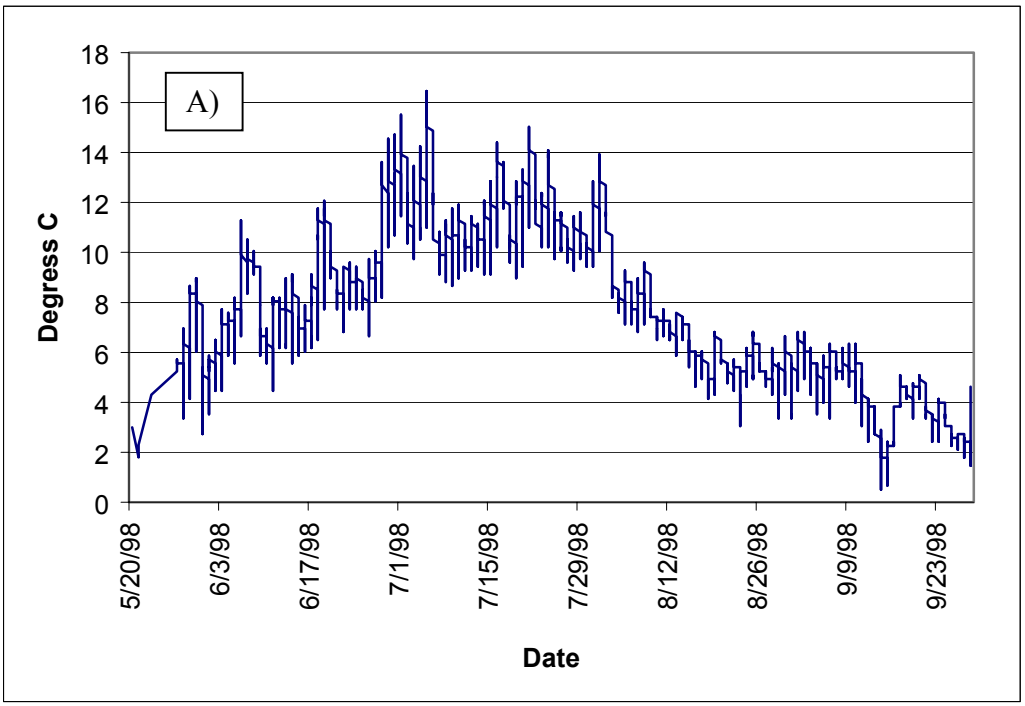



**Figure 4.-Spawning locations of 30 radio-tagged Arctic grayling from the Jim River, considered to be alive during mid-May and early June, 1998.**



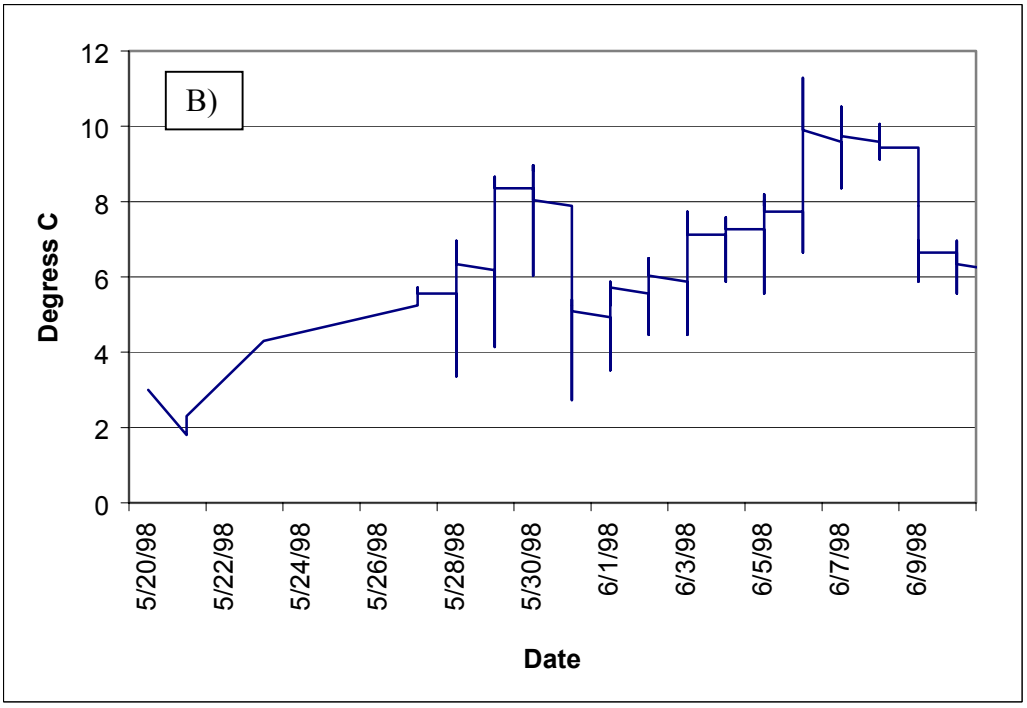




**Figure 5.-Water temperature data collected in the Jim River: A) May 20 through September 28, 1998 at 30 minute intervals beginning May 27; B) May 20 through June 10, 1998 at 30 minute intervals beginning May 27. Vertical bars represent high and low temperatures.**

is likely that they spawned (see Table 2), as well as two fish (354 and 813) located in the South Fork Koyukuk River. Upstream movements of all Arctic grayling in the Jim River considered to have been alive and to have spawned ranged from 0.3 to 23 km (average straight line distance moved = 5.2 km, S.D. = 6.6 km). Arctic grayling in the lower Jim River displayed upstream movements ranging from 0.3 to 18 km (average straight line distance moved = 3.0 km, S.D. = 4.6 km), while those fish in the fishery portion of the Jim River displayed upstream movements ranging from 1.0 to 23 km (average straight line distance moved = 7.6 km, S.D. = 7.6 km). Fish located in Fish Creek displayed movements that ranged from 34 to 50 km, as measured by straight line distances. This represents a distance of at least 60 river km traveled by individual fish.

The proportion of Arctic grayling considered to have spawned in the Jim River within the summer fishery was 0.37 (SE = 0.09), while the proportion of fish considered to have spawned in the lower Jim River was 0.47 (SE = 0.09). The proportion of Arctic grayling that spawned in Fish Creek was 0.07 (SE = 0.05), while the proportion that spawned in South Fork Koyukuk River was 0.07 (SE = 0.05) and the proportion that spawned in Prospect Creek was 0.03, (SE = 0.03; Table 3).

### SUMMER FIDELITY TO ROADSIDE FISHERY

five of 26 fish (p = 0.19, SE = 0.08) assumed to be alive were present in the summer fishery area during June. Nine of 26 fish (p = 0.35, SE = 0.10) were present in the summer fishery area during August (Table 3).

Fish tracked during June 3 – 5 were determined to likely be involved in spawning activities, or post-spawning migrations. Consequently, their locations were not analyzed for summer fidelity to the summer fishery area.

Four of the Arctic grayling groundtruthed within the summer fishery area during June 11 – 13 were also found in the area during August. Seven Arctic grayling returned during 1998 to the general vicinity of where they were tagged during 1997. Straight-line distances for six of those returning fish (during June 11-13) ranged from 0.23 km to 1.8 km from their original tagging location. One Arctic grayling that was located 1.8 km from its tagging site during June was later located 0.95 km from its tagging site during August.

## DISCUSSION

Arctic grayling in the Jim River overwinter in the lower Jim River, the South Fork and mainstem Koyukuk rivers, and Prospect Creek. Fish in the Jim River began to drop downstream during late summer and early autumn. By February, fish moved further downstream, or moved slightly upstream to new locations (at most, 2.74 km). With the onset of break-up and spring, adult fish began spawning migrations. Telemetry data suggest that Arctic grayling, which are summer residents of the Jim River, utilize the lower portions the Jim River, as well as Fish Creek as spawning sites. It is possible that Arctic grayling from the Jim River also utilize Bonanza Creek as a spawning site, since one fish (444) tracked in Fish Creek was located less than 4 km downstream from the confluence of Bonanza and Fish creeks. Whether or not fish use the South Fork Koyukuk River to spawn remains unclear. Two fish (813 and 353), located in the South Fork Koyukuk River during the spawning period of 1998, may have spawned elsewhere since the South Fork Koyukuk River is a muddy, glacial-fed system, and does not typify Arctic grayling spawning habitat. It is likely that fish utilize the South Fork Koyukuk River as a

migration corridor, rather than as spawning location. Most of the fish that were tracked in the Koyukuk River either moved large distances, or had apparently died. Without groundtruthing fish during the spawning period, however, exact locations of spawning grounds remain uncertain.

Telemetry data also indicate that some Arctic grayling return to the Jim River to feed during the summer months. During 1998, seven fish returned to the general vicinity of where they were originally tagged during 1997, while overall 10 returned to the fishery area.

The data from this telemetry study show patterns of adult Arctic grayling habitat utilization and migration characteristics similar to other river systems (Armstrong 1986, Tack 1980, and Northcote 1995). For example, in the Goodpaster River (a rapid runoff tributary to the glacial-fed Tanana River), adult Arctic grayling generally move downstream during early autumn to overwinter. Fish also spawn in the lower portions of the river, near where they overwintered. After spawning, fish migrate back upstream, or to different rivers altogether, to forage in summer feeding locations (Bill Ridder, *In prep*). However, exceptions to this pattern are known to occur. It is possible that fish remained in the lower portions of the Jim River after overwintering and spawning, in order to feed during the summer. Whether or not a greater number of fish moved into the summer fishery area during July, than were observed during mid-June and mid-August, is unknown.

The estimate of fidelity during August (0.35) should be regarded as a minimum since severe weather conditions, increased streamflow, and decreased water temperatures (e.g. 5.1 °C) may have prompted fish to begin downstream movements during mid-August. Arctic grayling may begin downstream movements during late summer or early autumn, their migration presumably being stimulated by decreasing water temperatures (Armstrong 1986 and Tack 1980). The accuracy of the estimate of fidelity may also have suffered due to the lack of tracking during mid-July, and because the determination of whether or not a fish was alive was made from anecdotal information, not from physically handling fish or recovering a transmitter. Rather, fidelity information from mid-June and August demonstrates that at least some Arctic grayling home to the Jim River to feed during the summer. This finding is also supported by the recovery of floy-tagged Arctic grayling in the Jim River. Thirty Arctic grayling originally tagged within the fishery area during 1995 (representing 4% of the fish tagged during 1995), were later recaptured within the fishery area during 1997 (Fish 1997). Telemetry data also suggest that fish use lower portions of the Jim River to feed as well. Most fish that remained in the South Fork Koyukuk River were eventually determined to be dead. Two fish (353 and 813) that were determined to be alive in South Fork Koyukuk River during early June were never located again. Whether or not Arctic grayling seek alternative feeding locations to the Jim River remains unknown.

Although Arctic grayling probably spawn in the lower Jim River (similar to other unsilted, rapid runoff streams), fish may also spawn in the upper reaches of the Jim River, as well as its tributaries. For example, Netsch (1975) reported that of Arctic grayling tagged between 16 May and June 15 at camp, 37 – 42% moved upstream, while 48% moved > 1.6 km from their tagging location. In addition, 15-21% were later recaptured in tributary streams (Stream HR-1405+ 02 and Prospect Creek). While it is possible that these fish were involved in post-spawning migrations to summer feeding areas, the time frame also overlaps with the estimated most intense spawning period (May 28 through June 11) and when both sexes of Arctic grayling were captured ready to spawn. Arctic grayling from the Jim River have also spawned in the outlet of

Grayling Lake and in Grayling Creek, another tributary to the Jim River near the Dalton Highway (G. Pearse, Alaska Department of Fish and Game, Fairbanks, personal communication). However, fish were neither located, nor observed, in the lake outlet or creek during this telemetry project. It was somewhat unexpected to not have found any Arctic grayling spawning in tributary creeks of the upper Jim River (i.e. Douglas Creek or Stream HR-1405+02). Douglas Creek, however, passes through two culverts under the Dalton Highway, both of which had contained ice, and probably prevented fish passage, well into mid-June. Water temperatures in the upstream portions of this creek also remained 2 - 3°C lower during mid-June than those of the Jim River, and still contained areas of aufeis.

It is possible that enough error occurred during tracking procedures (from GPS readings, frequency drift of transmitter signals, human error in determining the strength or location of transmitter signals while radio-tracking, and the speed at which aircraft travel over transmitters) to result in fish locations that indicated movement, when in fact no movement occurred. For example, one fish (474) known to have been dead since September had as much as 0.5 km difference in its subsequent locations. Seasonal migrations of Arctic grayling usually cover large distances (Tack 1980), sometimes in excess of 100 km (West et al. 1992). If an Arctic grayling did not move (≥ 1 km) during three or more trackings (representing a minimum duration of three months), then it is likely that the fish was dead. No fish considered to be dead by this method were observed to move later in the study. Conversely, if a radio-transmitter was expelled from fish, the transmitter could have drifted downstream throughout the duration of the study. Accordingly, telemetry locations that indicated consistent or progressive downstream movement (after three or more consecutive trackings) resulted in determinations of dead fish.

The use of a Super cub to track fish may have resulted in finding more fish during aerial trackings, or in obtaining more accurate locations, than when a Cessna 185 was used. For example, a Cessna 185 could only slow its travel speed to 180 mph before stalling, while a Super cub could slow to 80 mph. This could potentially enable investigators to miss fewer fish during tracking procedures while flying in a Super Cub. While tracking over the lower Jim River in the Cessna 185, signals would often not be heard during the first pass, but would be heard during a second or third pass. Signals bounce off landscape features, and through ice, water and debris also affect how a transmitter signal is received. Telemetry data collected during this study could have been augmented with more data collected by groundtruthing fish locations, and handling fish to determine the extent of mortality. Undoubtedly, some fish may have died simply from surgery to implant radio-transmitters, while others probably died after carrying a transmitter for a few months. A relatively inexpensive alternative to fixed-winged aircraft would be a small helicopter, such as an R-22. This two person aircraft would enable investigators to more accurately determine fish locations, and allow investigators to land on riverbanks to groundtruth fish.

Evidence reported in the literature suggests that Arctic grayling return as adults to their natal locations (or where they emerged) to spawn (Northcote 1995). Therefore, spawning assemblages of Arctic grayling are considered to be somewhat genetically distinct from one another, even within the same drainage. For example, Hop and Gharrett (1989) examined electrophoretic differences between Arctic grayling from tributaries within the same river (i.e. Tanana River), but found only small genetic differences. The authors stated that such small genetic divergence might best be explained by reproductive homing to natal grounds for spawning. When Arctic grayling from three spawning populations were examined (i.e. the Goodpaster, Caribou, &

Volkmar rivers), approximately 97.5% of the Arctic grayling were native to the spawning assemblages, and less than 2.5% of each spawning aggregate was derived from immigrants. From a fishery management perspective, such calculated straying rates may be too small to sustain a (summer) fishery if any contributing (spawning) population is overexploited. If this rationale were applied to the fisheries along the Dalton Highway (e.g. the Jim River), Arctic grayling would be at the greatest risk of exploitation during late May and early June when they are on separate spawning grounds. However, fishing effort along the Dalton Highway appears to be most intense during July and August (summer months), while fishing effort during spring spawning periods is probably very low (personal observation).

Results from this telemetry study, combined with the rationale described above, indicate that Arctic grayling in the Jim River summer fishery probably consist mostly of a distinct stock, while fish from stocks in neighboring streams contribute somewhat to its composition. Arctic grayling from distinct, yet genetically related, spawning populations (i.e. Jim River, Fish Creek, and possibly Bonanza Creek) probably migrate to common feeding grounds within the Jim River. Most fish radio-tagged in the Jim River summer fishery utilized the Jim River as overwintering habitat (53% radio-tagged) and spawning habitat (84% radio-tagged). Significant gene flow probably occurs between assemblages of Arctic grayling in the Koyukuk River tributaries, as suggested for stocks within in the Tanana River drainage (Hop and Gharrett 1989). Whether or not Arctic grayling harvested from the Jim River are replenished by fish from other Koyukuk River tributaries remains unknown. From a management perspective, it cannot be assumed that fish that share common feeding grounds will simply replace those harvested fish from a summer fishery, since unharvested fish may be from different stocks altogether.

## ACKNOWLEDGEMENTS

The author thanks Richard Bettinger, Rhonda Pemberton, John Noll, Steve Stroka, May Lou Thomas, Klaus Wuttig, Monica McGilvary, Mike Wallendorf, Lisa Stuby, and Bill Ridder for their able assistance in the field. Bob Clark, Bill Ridder, Doug Fleming, Fred DeCicco, Matt Evenson, and Don Roach provided useful insights into the biology of Arctic grayling or the execution radio-telemetry projects. Thanks go to Mike Wallendorf for his help in designing this project and his editorial support. Glen Hollit and the Maintenance crew at Jim River DOT Station are thanked for their logistical support and for their insights about the Jim River Arctic grayling fishery. Patsy Martin (of Kanuti NWR), Dennis Miller (of Caribou Air), Gary Pearse (of ADF&G), and Don Carlson (of Arctic NWR) provided safe and reliable piloting skills during radio-tracking flights, that were greatly appreciated by the author. Thanks are also extended to Peggy Merritt for her supervisory and editorial roles. Sara Case is commended for her work in editing and printing this manuscript.

## LITERATURE CITED

Armstrong, R. H. 1982. A review of Arctic grayling studies in Alaska. Alaska Coop. Fish. Res. Unit, Fairbanks, Alaska, Unit Contr. No. 6. 60pp.

Craig, P. C., and V. A. Poulin. 1975. Movements and growth of Arctic grayling (*Thymallus arcticus*) and juvenile Arctic char (*Salvelinus alpinus*) in a small arctic stream, Alaska. Journal of the Fisheries Research Board Canada 32: 689-697.

Fish, J. T. 1997. Stock assessment of Arctic grayling in the Jim River and other streams adjacent to the Dalton Highway, 1995 - 1997. Alaska Department of Fish and Game, Fishery Manuscript Series No. 97-3, Anchorage.

# LITERATURE CITED (Continued)


Hop, H. and A. J. Gharrett. 1989. Genetic relationships of Arctic grayling in the Koyukuk and Tanana rivers, Alaska. . Transactions of the American Fisheries Society 118: 290-295.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Lubinski, B. R. 1995. Winter habitat of Arctic grayling in an interior Alaska stream. M.Sc. Thesis, University of Alaska. 143p.

McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Report to Alyeska Pipeline Service Company, Bellevue, Washington. 170 pp.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Northcote, T. G. 1995. Comparative biology and management of Arctic and European grayling (Salmonidae, *Thymallus*). Reviews in Fish Biology and Fisheries 5: 141-194.

Netsch, N. F. 1975. Fishery resources of waters along the route of the Trans-Alaska pipeline between Yukon River and Atigun Pass in north central Alaska. U.S. Fish and Wildlife Service, Resource Publication 124, Washington.

Summerfelt, R. C., and L. S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-272 *in* C B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Tack, S. L. 1980. Migrations and distribution of Arctic grayling, *Thymallus arcticus* (Pallas), in interior and arctic Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(R-I).

West, R. L., M. W. Smith, W. E. Barber, J. B. Reynolds, and H. Hop. 1992. Autumn migration and overwintering of Arctic grayling in coastal streams of the Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 121: 709-715.

Winter, J. D. 1983. Underwater telemetry. Pages 371-395 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

# APPENDIX A

**Appendix A1.-Length, weight, sex, age and transmitter frequency of Arctic grayling implanted with radio transmitters in the Jim River, July - August, 1997.**

| Date | Location | Frequency | Drift Freq. | Length (mm) | Weight (grams) | Age | Sex |
|---|---|---|---|---|---|---|---|
| 970721 | ds Bridge 3 | 149.303 | 149.304 | 378 | 578 | 10 | M |
| 970721 | ds Bridge 3 | 149.313 | 149.315 | 357 | 521 | 11 | M |
| 970721 | ds Bridge 3 | 149.334 | 149.333 | 322 | 351 | 8 | M |
| 970721 | ds Bridge 3 | 149.324 | 149.330 | 343 | 464 | R | M |
| 970721 | ds Bridge 3 | 149.342 | 149.344 | 323 | 392 | -- | M |
| 970721 | ds Bridge 3 | 149.353 | 149.354 | 371 | 371 | -- | M |
| 970721 | ds Bridge 3 | 149.363 | | 374 | 374 | -- | M |
| 970721 | ds Bridge 3 | 149.373 | | 327 | | 8 | M |
| 970721 | ds Bridge 3 | 149.384 | 149.386 | 397 | | R | M |
| 970721 | ds Bridge 3 | 149.393 | 149.394 | 365 | | 10 | M |
| 970721 | ds Bridge 3 | 149.402 | 149.403 | 321 | | 6 | M |
| 970721 | ds Bridge 3 | 149.414 | 149.417 | 345 | | 10 | M |
| 970721 | ds Bridge 3 | 149.423 | 149.424 | 343 | | 9 | M |
| 970721 | ds Bridge 3 | 149.432 | 149.433 | 325 | | 8 | M |
| 970722 | ds Pump Sta. 5 | 149.444 | | 385 | | -- | ? |
| 970722 | ds Pump Sta. 5 | 149.453 | 149.452 | 340 | | -- | ? |
| 970722 | ds Pump Sta. 5 | 149.461 | 149.462 | 336 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.474 | | 323 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.483 | 149.486 | 337 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.492 | 149.493 | 371 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.503 | | 373 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.514 | | 336 | | -- | F |
| 970722 | ds Pump Sta. 5 | 149.522 | | 365 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.533 | | 327 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.544 | | 328 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.552 | | 330 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.564 | 149.563 | 320 | | -- | M |
| 970722 | ds Pump Sta. 5 | 149.574 | 149.573 | 339 | | -- | M |
| 970722 | us camp | 149.582 | 149.584 | 337 | | -- | M |
| 970722 | us camp | 149.593 | | 346 | | -- | M |
| 970722 | us camp | 149.603 | 149.602 | 322 | | -- | M |
| 970722 | us camp | 149.612 | | 324 | | -- | M |
| 970722 | us camp | 149.623 | | 333 | | -- | M |
| 970722 | us camp | 149.633 | 149.634 | 385 | | -- | M |
| 970723 | us DOT | 149.642 | | 356 | | 5 | M |
| 970723 | us DOT | 149.654 | | 321 | | 10 | M |
| 970723 | us DOT | 149.664 | 149.665 | 344 | | 7 | M |
| 970723 | us DOT | 149.672 | | 374 | | 11 | M |
| 970723 | us DOT | 149.684 | | 328 | | 10 | M |

-continued-

**Appendix A1.-Page 2 of 2.**

| Date | Location | Frequency | Drift Freq. | Length (mm) | Weight (grams) | Age | Sex |
|---|---|---|---|---|---|---|---|
| 970723 | Camp | 149.694 | 149.695 | 348 | | -- | M |
| 970723 | Camp | 149.701 | 149.702 | 349 | | -- | M |
| 970723 | Camp | 149.714 | | 355 | | -- | M |
| 970723 | Camp | 149.723 | 149.724 | 349 | | -- | M |
| 970731 | Douglas Ck | 149.733 | | 408 | 735 | 10 | M |
| 970731 | Douglas Ck | 149.744 | 149.745 | 330 | 336 | 6 | M |
| 970731 | Douglas Ck | 149.753 | | 341 | 394 | 8 | M |
| 970731 | ds Douglas Ck | 149.763 | 149.767 | 341 | 409 | 6 | M |
| 970731 | ds Douglas Ck | 149.773 | 149.776 | 348 | 418 | 6 | M |
| 970731 | ds Douglas Ck | 149.782 | | 329 | 365 | 7 | ? |
| 970801 | ds Bridge 1 | 149.792 | | 371 | 507 | 13 | M |
| 970801 | ds Bridge 1 | 149.804 | | 345 | 438 | 8 | M |
| 970801 | ds Bridge 1 | 149.813 | 149.814 | 337 | 392 | R | M |
| 970801 | ds Bridge 1 | 149.822 | | 340 | 395 | 8 | M |
| 970801 | ds Bridge 1 | 149.833 | | 390 | 665 | 8 | M |
| 970801 | ds Bridge 1 | 149.843 | | 398 | 668 | 13 | M |

**Appendix A2.-Length-weight relationships of Arctic grayling from selected waters in the Tanana Valley, Brooks Range, North Slope, Alaska.**

| Equation | Site | Reference |
|---|---|---|
| logW = -4.997 + 3.035(logL) | Delta Clearwater River<br>July 1976-1983, n = 305 | Ridder, W. P., Alaska Dept. of Fish and Game, Unpublished Data |
| logW = -4.838 + 2.930(logL) | Caribou Creek<br>June 11-20, 1985, n = 337 | Ridder, W. P., Alaska Dept. of Fish and Game, Unpublished Data |
| logW = -5.1047 + 3.0624(logL) | Kaparuk River<br>Summer 1971, n = 88 | McCart, P., et al. 1972. |
| logW = -5.3266 + 3.1324(logL) | Happy Valley Creek<br>June-August, 1971, n = 94 | McCart, P., et al. 1972. |
| logW = -5.346 + 3.151(logL) | Weir Creek & Kavik River<br>Summer 1972-73, n = 110 | Craig, P. C., and V. A. Poulin. 1975. |

# APPENDIX B

**Appendix B1.-Aerial tracking schedules and search results for radio-tagged Arctic grayling in the Jim River and neighboring drainages, during 1997 and 1998.**

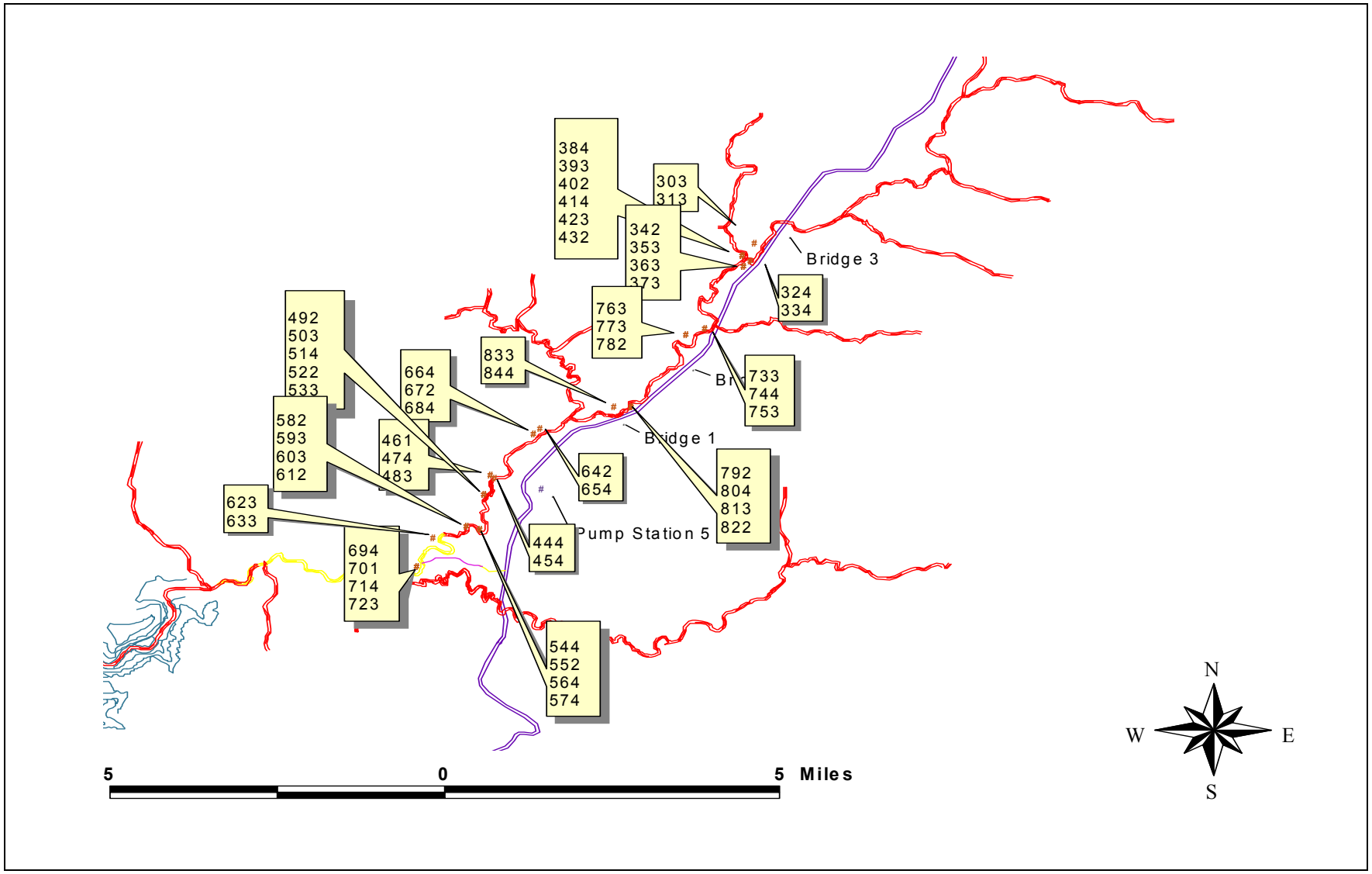
| Date | Aircraft | No. Trackers | Area Searched | Hours Searched | Number of Tags | | |
|---|---|---|---|---|---|---|---|
| | | | | | Searched | Found | Not Found |
| 9/23/97 | Super Cub | 1 | All | 6 | 55 | 46 | 9 |
| 9/24/97 | Super Cub | 1 | All | 2 | 9 | 3 | 6 |
| 2/19/98 | Super Cub | 1 | All | 6 | 55 | 46 | 9 |
| 2/20/98 | Super Cub | 1 | All | 1.5 | 9 | 2 | 7 |
| 5/13/98 | Cessna 185 | 2 | All | 5 | 55 | 36 | 19 |
| 6/3/98 | Cessna 185 | 2 | All | 4.5 | 55 | 24 | 31 |
| 6/5/98 | Cessna 185 | 2 | All | 4 | 31 | 18 | 13 |
| 6/29/98 | Cessna 185 | 1 | Lower Jim R. | 2 | 13 | 11 | 2 |
| 10/7/98 | Super Cub | 1 | All | 4 | 19 | 17 | 2 |

**Appendix B2.-Data files regarding Radio-telemetry studies of Arctic grayling in the Jim River during 1997 – 1998, archived by the Research and Technical Services of the Alaska Department of Fish and Game-Sport Fish Division.**

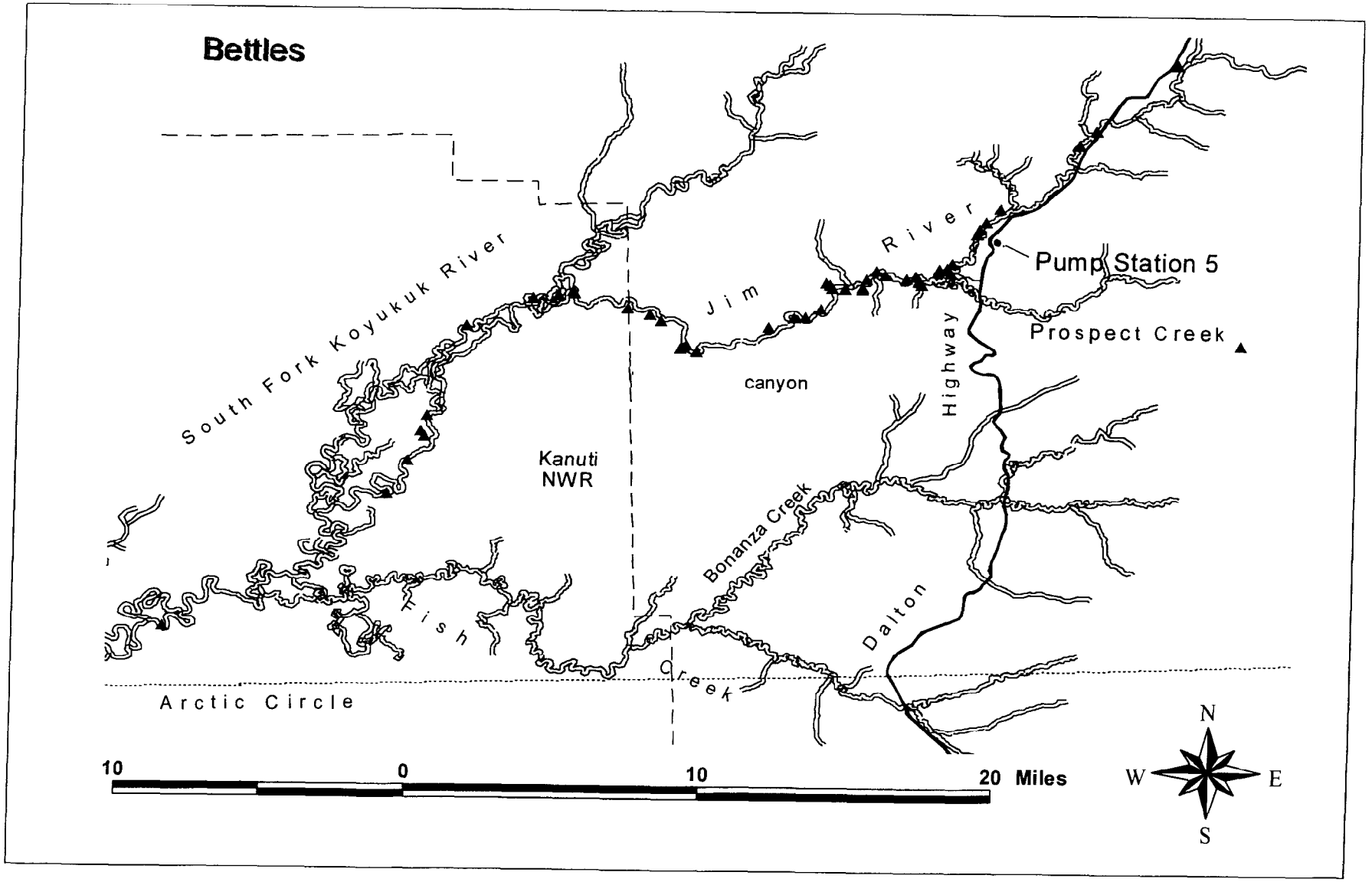
| Year | Data File | Contents |
|---|---|---|
| 1997 | Y015BLDA.arc | AWL data of radio-tagged Arctic grayling from the Jim River |
| 1998 | JimRiver_GPS.xls | GPS data of locations of radio-tagged Arctic grayling from the Jim River, 1997 – 1998 |

# APPENDIX C

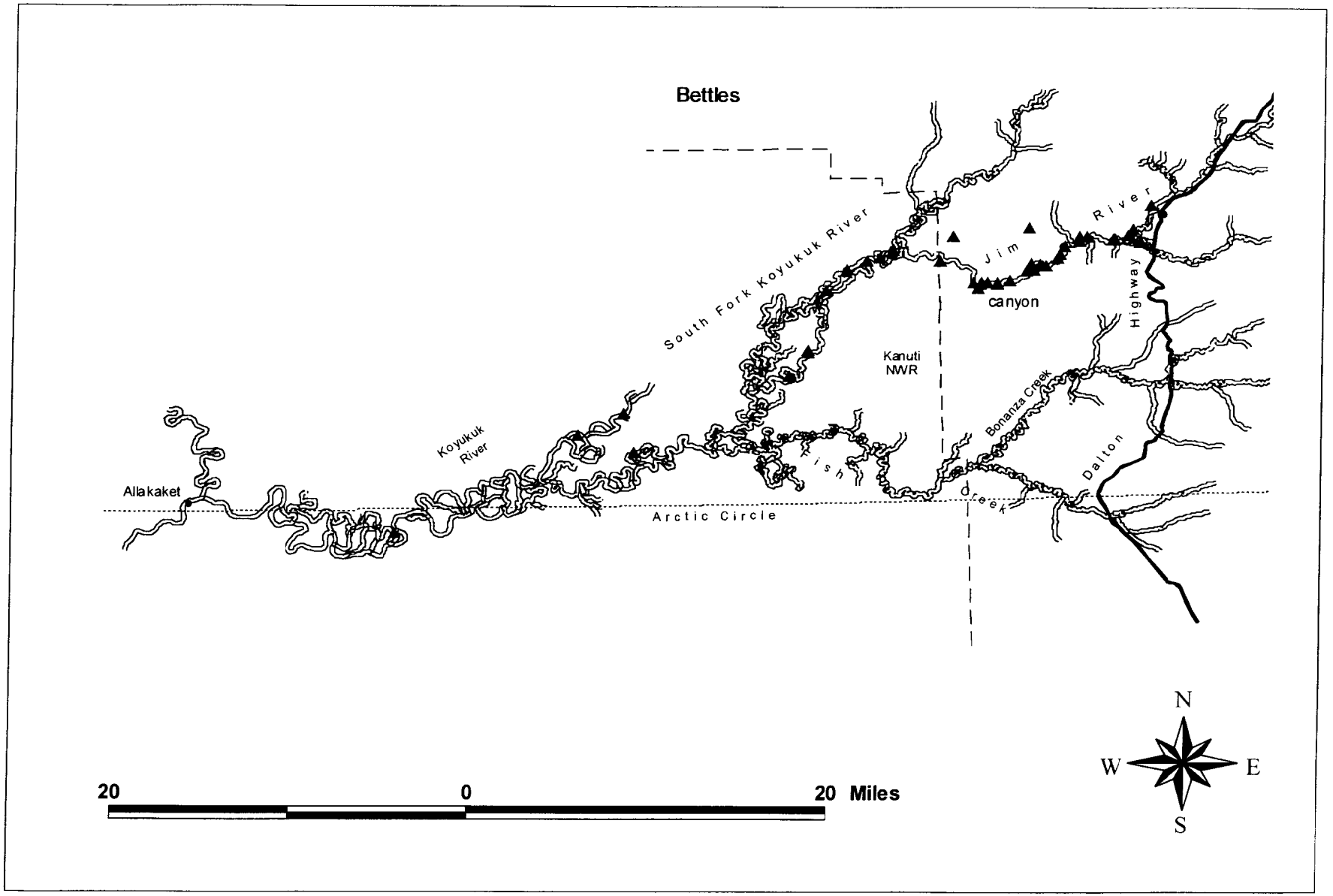
**Appendix C1.-Release locations of 55 radio tagged Arctic grayling July and August of 1997.**



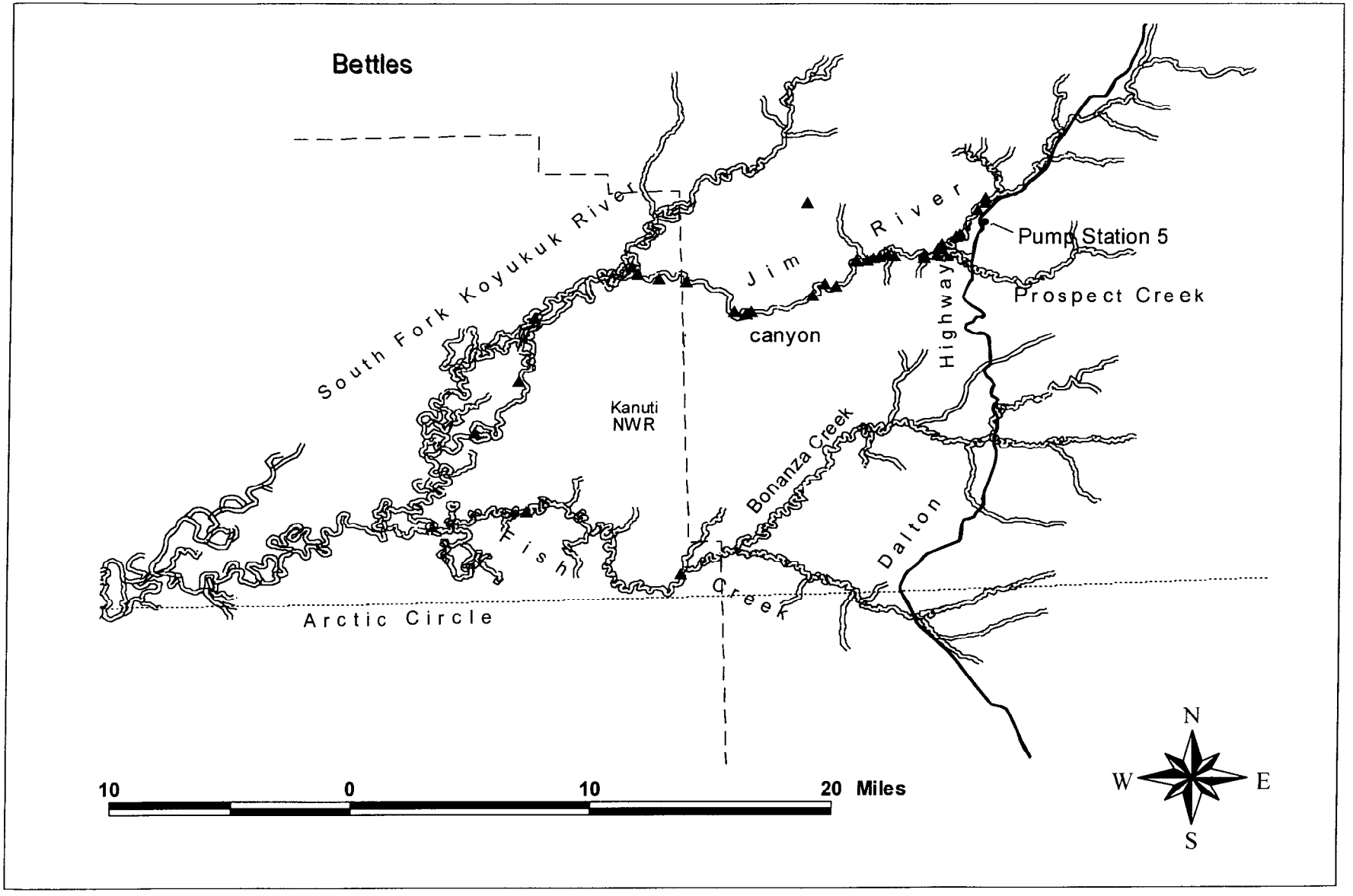
Appendix C2.-Locations of 49 radio-tagged Arctic grayling found in the Jim River and South Fork Koyukuk River during September, 1997.



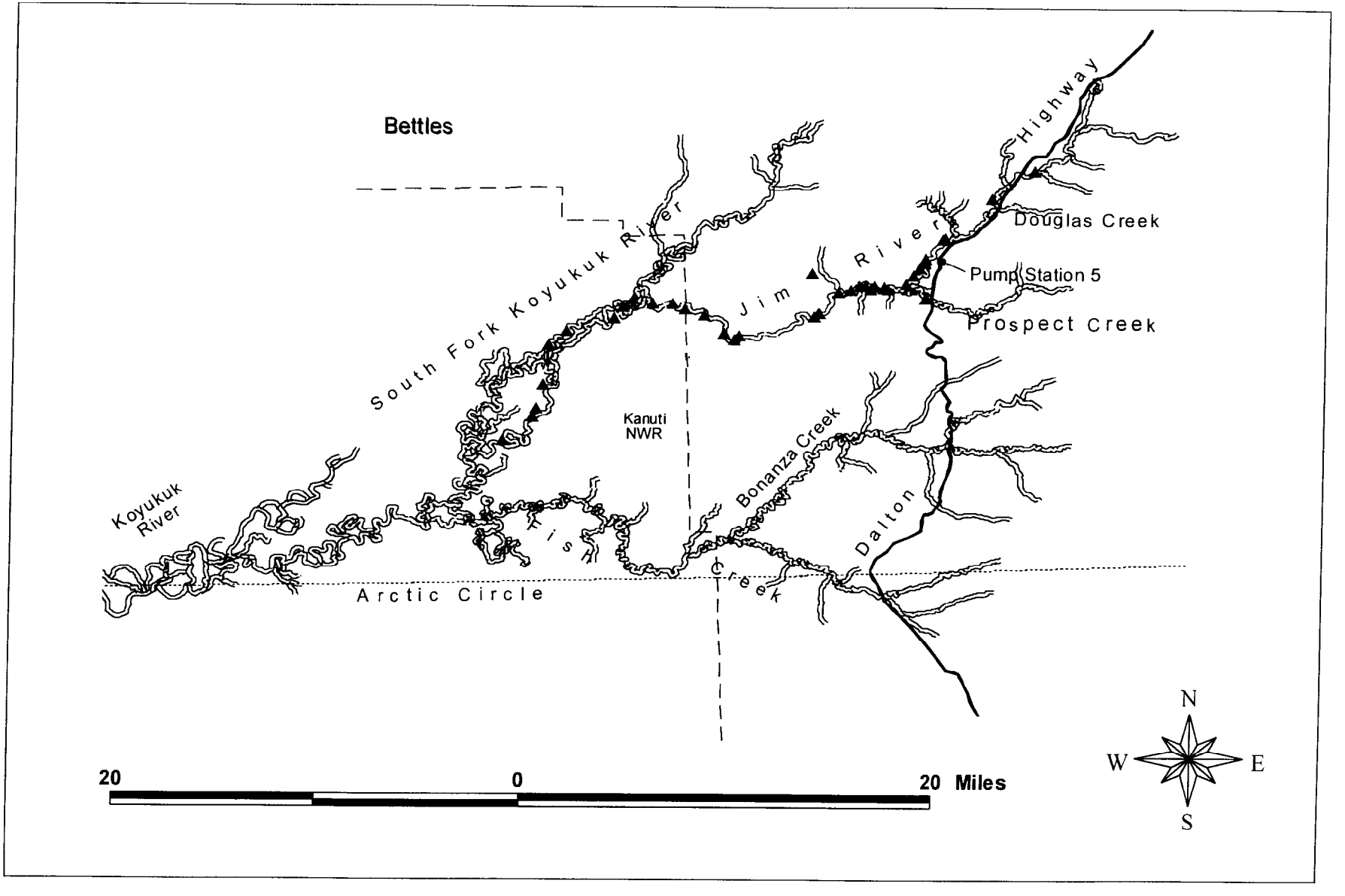
**Appendix C3.-Locations of 48 radio-tagged Arctic grayling found in the Jim River and South Fork Koyukuk River during February, 1998.**



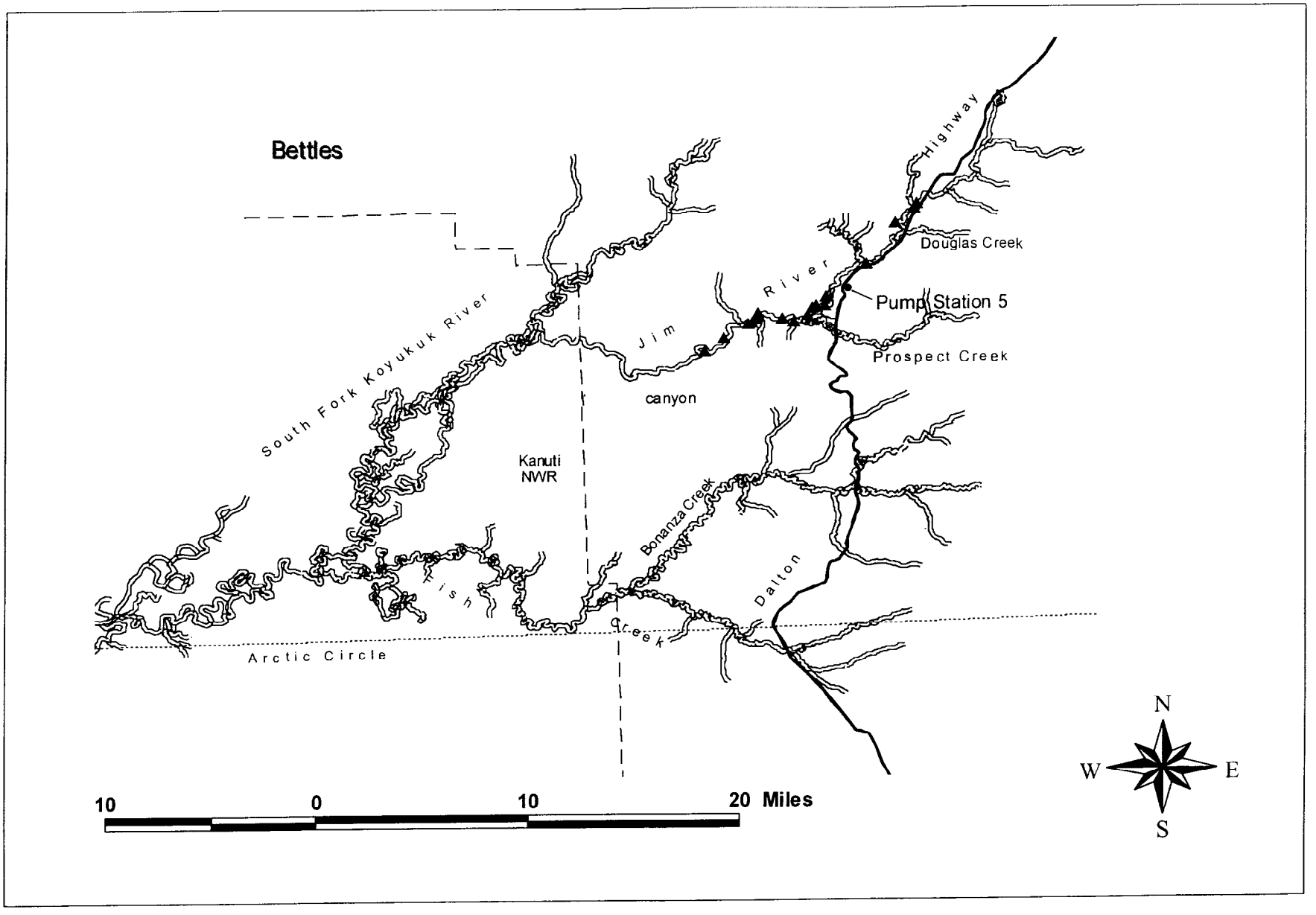
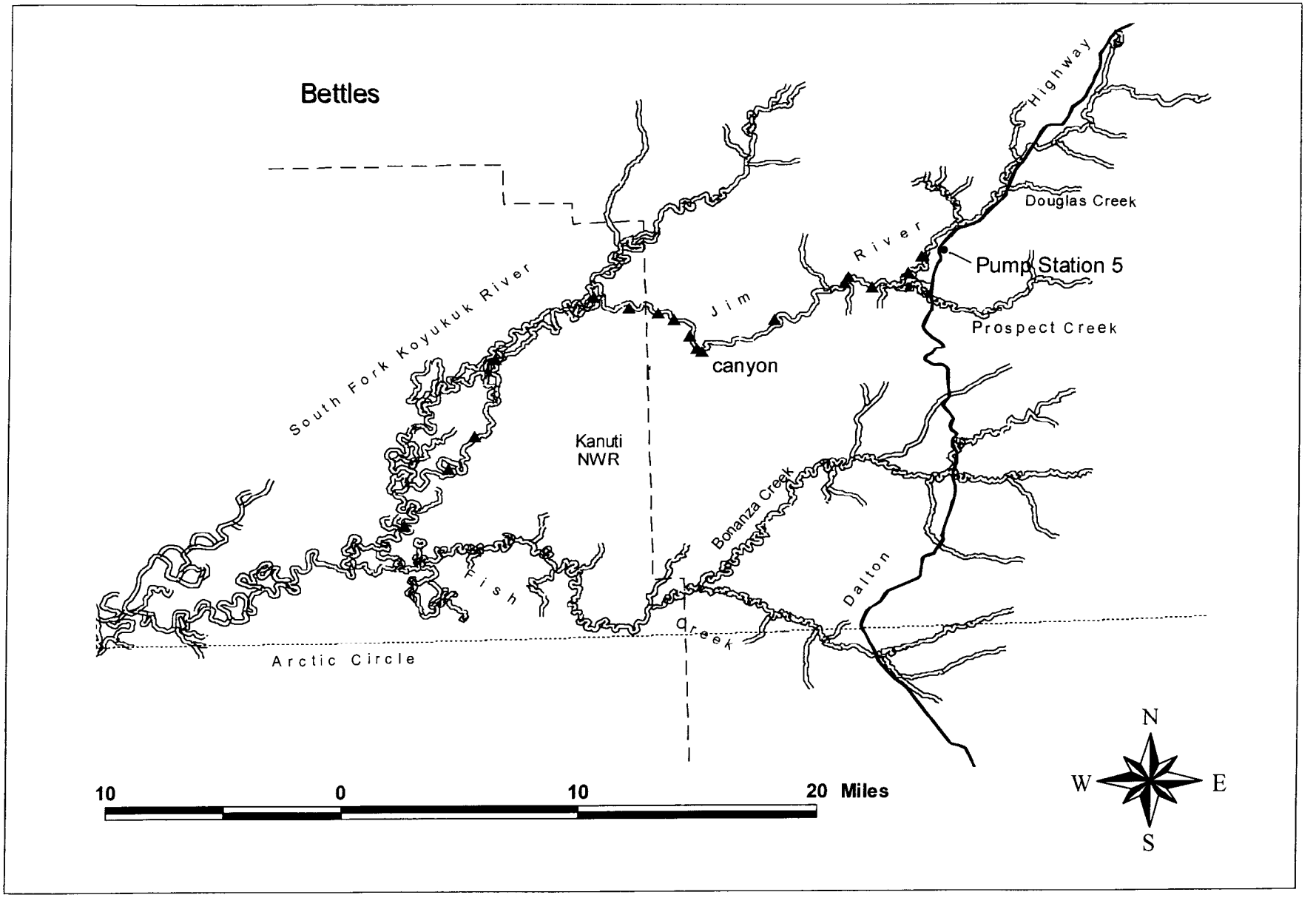
**Appendix C4.-Locations of 36 radio-tagged Arctic grayling found in the Jim River, South Fork Koyukuk River, and Fish Creek during May, 1998.**



**Appendix C5.-Locations of 42 radio-tagged Arctic grayling found in the Jim River and South Fork Koyukuk River during early June, 1998.**



Appendix C6.-Locations of 21 radio-tagged Arctic grayling groundtruthed in the Jim River during August, 1998.



**Appendix C7.-Locations of 17 radio-tagged Arctic grayling found in the Jim River during October, 1998.**