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THE BIOLOGY AND STATUS OF THE ARCTIC GRAYLING IN SUNNYSLOPE CANAL, MONTANA

by

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VITA

Scott Alan Barndt, son of Lee and Marlyce Barndt, was born in Bozeman, Montana, October 7, 1970. He graduated from Laurel Senior High School, Laurel, Montana, in May, 1989. He received a Bachelor of Science degree in Biological Sciences, Fish and Wildlife Management Option, in June, 1994 at Montana State University in Bozeman, Montana. He began graduate studies at Montana State University in June, 1994.

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ABSTRACT

The Arctic grayling (*Thymallus arcticus*) in Sunnyslope Canal were studied to examine factors limiting this population. Population characteristics, fish movements, winter habitat conditions, survival beneath ice cover, spawning, movements and habitat use of age-0 fry, and the presence of other species were examined. Results of this study confirm that Arctic grayling in the upper, 9 km of the Sunnyslope Canal represent a self-sustaining population that reproduces successfully in this unusual habitat, and that survives in remnant pools sustained by water leaking through the gates at Pishkun Reservoir and from springs along the canal during an extended, seven-month period when water does not flow through the canal. Reproduction within the canal was confirmed by a combination of observations: young fry were captured in drift nets 5.8 km downstream from the dam, but not at the outlet at Pishkun Reservoir; age-0 young were both visually observed and captured by seining within the canal; and spawning behavior was seen and developing embryos subsequently collected at a site within the canal. Fish seined in remnant pools, before pools froze over in autumn and then after ice-cover thawed in spring, indicated that overwinter survival was high (at least 75.4% through the winter of 1994-95, 89.5% in 1995-96). Dissolved oxygen concentrations remained high beneath ice cover, from 3.4 to 13.1 mg/l. Locations of recaptured fish and telemetry of radio-tagged fish indicated that they remained in the same pools through the winter. Recaptures of fish marked during the summer flow period and telemetry of radio-tagged fish indicated that fish moved upstream in the canal as water flows were reduced and then stopped at the end of the irrigation season. Concentrations of age-0 young within the upper part of the canal, including within the outlet tunnel beneath the dam, strongly suggested that they also move upstream as flows diminish. Telemetry of larger fish and downstream captures of age-0 and older fish suggested that many fish move down during summer flows and appear to be the source of grayling found in irrigation ditches diverted from the canal and in pools remaining at the lower drop structures after flows cease. During the summer flow period, canal grayling appeared to thrive, with good condition factors and among the fastest growth rates of any population in Montana. Success of grayling in the canal appears related to a combination of their ability to spawn under the flow and substrate conditions present, the ability of age-0 young to maintain position and survive within the upper canal, the tendency of both age-0 and older fish to move upstream as flows are reduced at the end of the irrigation season, their ability to overwinter in a few, remnant pools in the upper canal, the apparent habitat suitability of the canal for grayling during the summer flow period, and the apparent unsuitability of the canal for the principal, non-native potential competitors and predators present-rainbow trout (*Onchorhyncus mykiss*) and northern pike (*Esox lucius*). Numbers of fish (not including early age-0 grayling) remained low throughout the two-year study period, with about 62 to 120 estimated present from spring of 1995 to spring 1996. The loss of thousands of age-0 fish into the reservoir in fall 1994 during repair work at the dam, and continuing, apparently natural, downstream loss of fish have contributed to continuing low numbers, but other factors limiting the population are not known.

INTRODUCTION

Historically, relict populations of Arctic grayling (Thymallus arcticus) (hereafter interchangeably referred to as "Arctic grayling" or "grayling") occurred in two regions within the lower 48 states of North America, within the present states of Michigan and Montana. These populations were geographically isolated as the southernmost populations of Arctic grayling by the Wisconsin glaciation, and both have undergone severe declines within the last century. The Michigan population became extinct by 1936, and the Montana populations have declined until the species persists in its native habitat only in the Big Hole River and Red Rock Lakes (Vincent 1962, Kaya 1992). Both of these populations are reduced from their former numbers. The Big Hole population retains the important distinction of being the only fluvial (entirely riverine) population remaining in the lower 48 states. This is a change from historic grayling distribution in Montana, as fluvial grayling were once widespread and locally common in the upper Missouri River drainage above the Great Falls whereas the Red Rock Lakes (and possibly nearby Elk Lake) contained the only adfluvial (stream spawning, lake dwelling) population in the state. In contrast to fluvial populations, lacustrine populations have become more common by stocking mountain lakes, both in Montana and other states (Kaya 1990).

The decline of the Arctic grayling in its native habitat is attributed to three factors: (1) degradation of habitat, especially by dewatering for irrigation; (2) interactions with non-native salmonids; and (3) overharvest (Vincent 1962, Kaya 1992). Recent studies have focused on determining important factors limiting native fluvial grayling (i.e., Magee and Byorth 1994, Jeanes 1996). Such studies could have important applications to current recovery and reintroduction efforts.

A population of Arctic grayling located in an unusual habitat, the Sun River Slope Canal (Sunnyslope Canal), offered a unique opportunity to study factors which can affect the species. In 1971, Montana Department of Fish, Wildlife and Parks (FWP) biologist Bill Hill determined that Arctic grayling were present in the Sunnyslope Canal. This canal begins at the dam forming Pishkun Reservoir, and these fish occupy a fluvial habitat, at least during the four to five month irrigation season. During this period, the canal carries up to 47.5 cubic meters per second (m^3/s) or about 1680 cubic feet per second (cfs). During the remaining seven months, the canal is completely dewatered, with the exception of intermittent pools extending for about 5.8 km from the dam, and isolated pools at the base of concrete "drop structures" further downstream.

Arctic grayling were stocked in Pishkun Reservoir at least seven times in 1937, 1939, 1942 and 1943 (Everett 1986, Hill 1988, Kaya 1990). Records do not clearly indicate the source of these grayling but they likely originated from Madison River/Ennis Reservoir stocks (Everett 1986, Kaya 1990). Grayling subsequently became established in Sunnyslope Canal apparently from passage through the outlet of fish from these stockings, or their progeny. Some people report the presence of grayling in the canal since the 1940's (L. Vincent, Greenfields Irrigation District (GID), pers. comm.), and they have certainly been present since 1971, when Hill observed their presence. Arctic grayling apparently no longer exist in the reservoir, as the last reported catches of grayling were in 1971 and 1981 (Hill pers. comm.). Grayling in the canal have attracted some angler interest. In the past, anglers reportedly lined up below the reservoir outlet "shoulder-to-shoulder" to catch grayling (T. Tabor pers. comm.) and would "fill buckets" with their catch (L. Vincent pers. comm.).

The Sunnyslope Canal Arctic grayling are genetically distinct from all other Montana grayling populations (Everett 1986, Leary 1990). Despite their likely derivation from Madison River/Ennis Reservoir stock, as well their relatively short existence in the canal, Everett found that the Sunnyslope Canal population shows significant separation from both Red Rock Lake stocks and stocks descendent from the Madison River/Ennis Reservoir population (Everett 1986). Further, Sunnyslope grayling show similar separation from the Big Hole River population (Figure 1).

This present study was initiated in 1994 to determine the conditions under which this population persists within the unusual environment of this seasonally intermittent canal. The purpose of the study was to determine whether there is a self-sustaining population of Arctic grayling in Sunnyslope Canal, adapted to inhabiting the canal and reproducing during summer flow and surviving non-flow conditions, including during winter. This hypothesis was tested by examining:

(1) population abundance, age-size distribution, and individual growth rates;

(2) fish movements, during flow and after;

(3) winter habitat conditions and survival of grayling beneath ice cover;

(4) spawning times, substrates, and locations; and

(5) distribution, movement, and habitat use of age-0 fry and juveniles.

(6) presence of potential competing species.

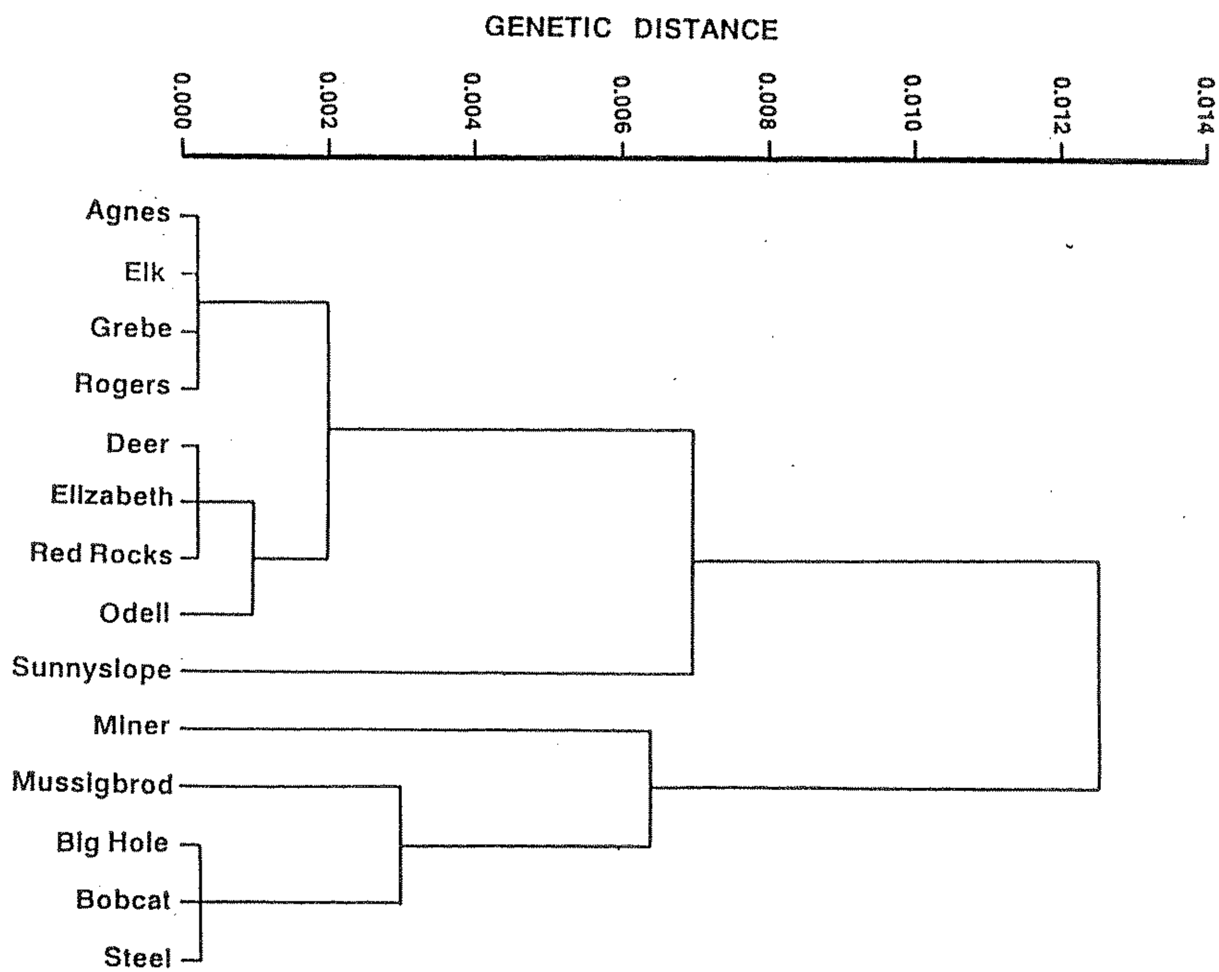

Figure 1. Dendrogram produced by cluster analysis of Nei's genetic distance based on information from 39 protein loci analyzed in Montana and Wyoming Arctic grayling populations (reproduced from Leary 1990).

STUDY SITE DESCRIPTION

Sunnyslope Canal is part of the Sun River Project, constructed by the United States Bureau of Reclamation, and administered by the Greenfields Irrigation District (GID). The canal originates at Pishkun Reservoir (elevation 1341 m) near the Rocky Mountain Front, west of Highway 287 between Choteau and Augusta, Montana (Figure 2). The canal and Pishkun Reservoir are physically separated by a steel, 2.5 cm mesh fish screen located on the reservoir side of the outlet. Pishkun Reservoir is filled by water diverted from the Sun River and transported through Pishkun Supply Canal (Figure 2).

Sunnyslope Canal is the major source of water for the Fairfield bench, irrigating over 32,376 hectares (ha) (about 80,000 acres) of agricultural land. Flow usually begins in early May and continues until early September. At full discharge, the canal carries over 47 m^3/s; upon cessation of flow, nearly the entire canal goes dry except for the upper 5.8 km immediately below the reservoir. In these 5.8 km, a small flow of water (< 0.06 m^3/s) from gate seepage and springs sustains 13 pools which persist until onset of flow the following May and provide overwintering habitat for grayling. Additionally, a series of concrete flumes ('drops') starting about 50 km downstream (Table 1, Figure 3) retain water in the settling pools at their bases; some of these also maintain fish overwinter. These drops are impassable to upstream movement by fish. Excess water not used in irrigation drains into Muddy Creek to the north and east, and into the Sun River to the south (Figure 2). The first potential barrier to upstream movement is a 1.6 km concrete-lined section of canal 9 km below the reservoir.

Table 1. Major physical features on Sunnyslope Canal and their distance downstream from Pishkun Reservoir.

Feature	Distance (km)
Dam	0
Boadle Bridge	5.8
Highway 287	19.0
Upper Turnbull drop	50.0
Lower Turnbull drop	52.8
9-foot drop	54.7
A (Fairfield) drop	60.6

Sunnyslope Canal represents very unnatural habitat. The canal flows through porous glacial till, which results in the rapid dessication of all pools not fed by seepage through the reservoir gates or by springs after discharges end. The channel bottom is kept free of flow impeding, and potential cover forming, objects such as woody debris or large rocks. Vegetation is sparse on the banks of the canal, and consists mostly of a variety of grasses.

During flow conditions, the canal best represents a glide or run habitat type because of its uniform, trapezoidal channel. A small area (<5%) of backwater habitat, as defined by Bisson et al. (1982), is present along canal margins. However, at higher discharges (over 30 m^3/s) backwaters form well beyond the canal margins and may represent 10% of the habitat in the upper 5.8 km. Thalweg water depths during flow conditions range from 1 to 3.5 m depending on discharge and location.

When flow ends, habitat in the upper 5.8 km consists of 1% riffles, 14% pools (lateral scour pools except for a pool in the concrete tunnel

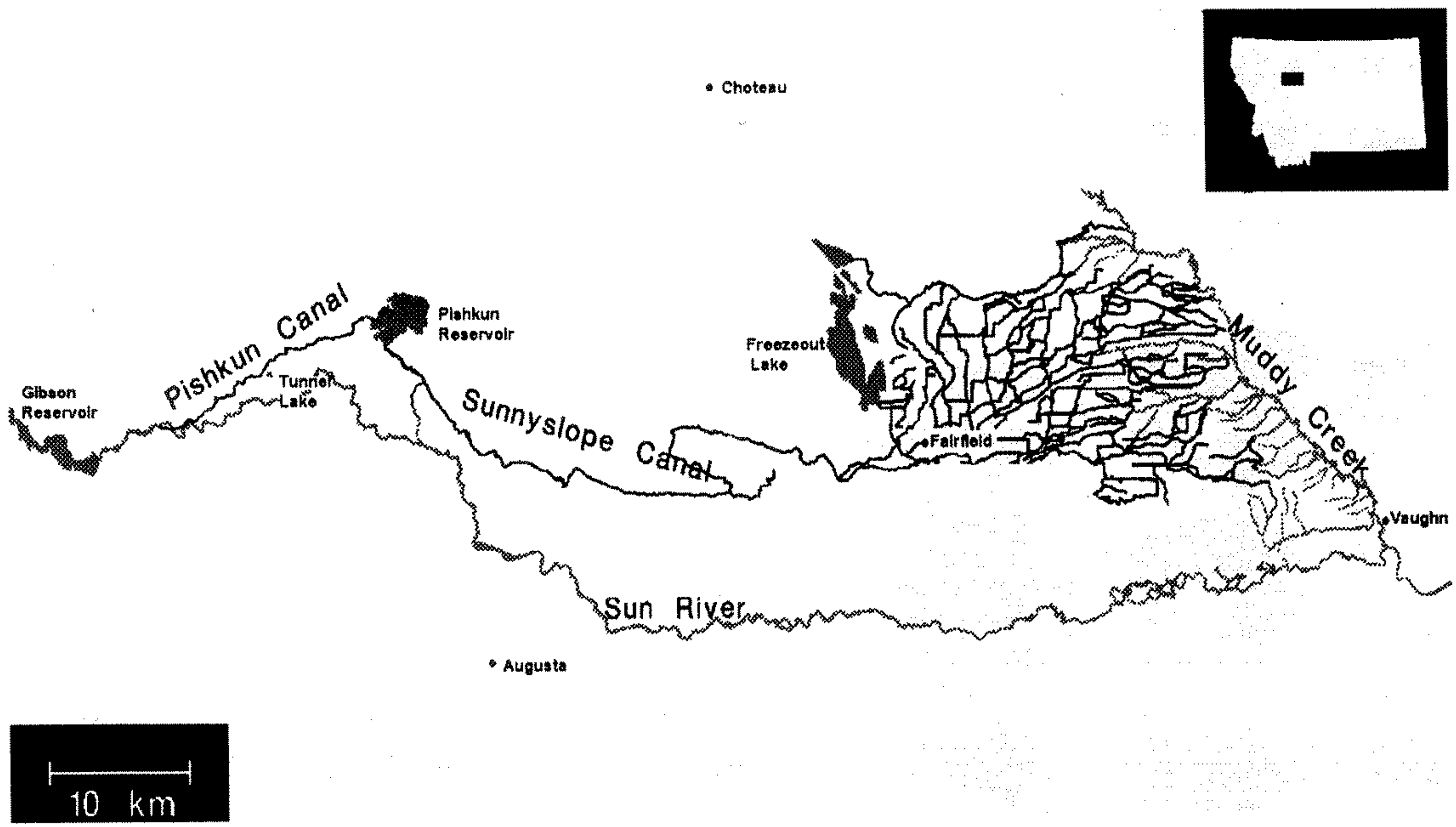

Figure 2. Watershed map of Greenfields Irrigation Project, from the Pishkun Supply Canal to discharge into the Sun River and Muddy Creek.

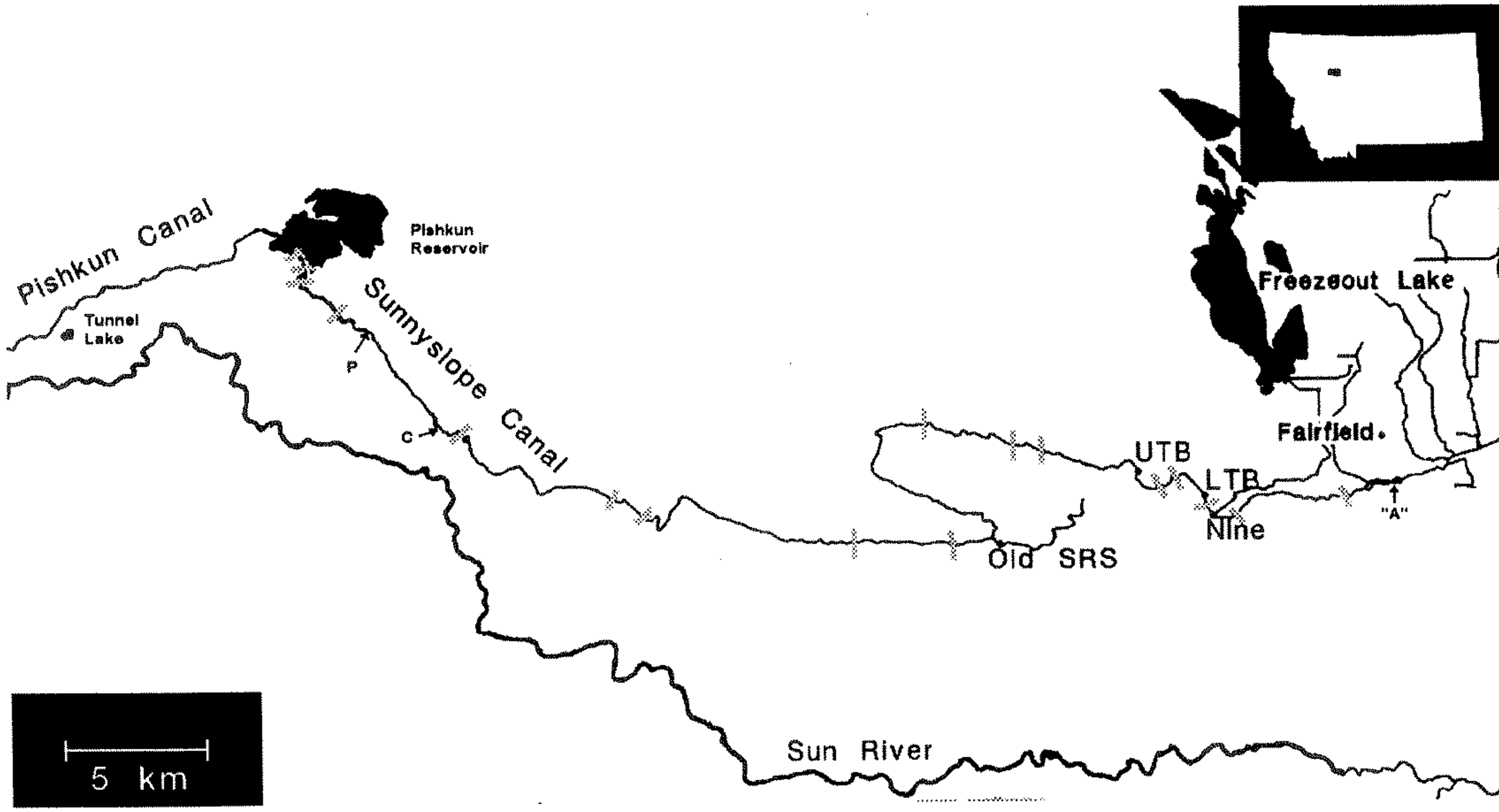

Figure 3. Watershed map of the Sunnyslope Canal study area from Pishkun Reservoir to Fairfield, MT, showing five drop structures (Old SRS, UTB, LTB, Nine, "A") and 17 fry survey transects (short gray stippled lines bissecting canal). The C denotes the beginning of concrete lining which is the first obstacle to upstream movement of grayling. The P shows the downstream extent of post-flow habitat.

beneath the dam closing Pishkun Reservoir), and 85% runs (habitat types from Bisson et al. 1982). During extended freezing conditions, ice formation is complete in riffles and shallower runs.

METHODS

Canal Flow and Water Quality

Physical habitat characteristics were measured during summer flow conditions to evaluate potential limiting factors to grayling during this period. Temperatures were measured on any visit to the canal, using a laboratory-grade mercury thermometer. Temperatures taken in the summer of 1995 were taken in mid-afternoon to evaluate higher daily temperature. Also in summer of 1995, pH, dissolved oxygen, and alkalinity were measured every 2 or 3 weeks with a Hach water quality kit. Conductivity readings were taken with a YSI 3000 TLC conductivity meter concurrent with other water quality measurements. Canal discharges were obtained from GID.

Capture and Analysis Techniques

Abundance, age-size distributions, individual growth rates, and movements were determined from grayling usually captured by seining, although trap nets (1.3 cm mesh), experimental gill nets, backpack electrofishing gear, and angling gear were also used occasionally. Typically, one seine was used as a blocking net, while another was pulled through the selected stretch of canal. Drop structures were seined by encircling the settling pool and hauling the seine to the shallow end of the pool.

Total length (mm) and weight (g) were measured on, and scales collected from, captured grayling for evaluating age-size distributions, condition factors, individual ages, and backcalculating lengths. Scales were taken from below the posterior edge of the dorsal fin (Jearld 1983).

Data were analyzed by micro-computer. Summary statistics and statistical analyses were calculated on the program Quattro Pro 5.0 (Borland 1994).

Age and Growth

Population size structure and age groupings were resolved from length-frequency distributions. Ages of grayling were determined from cellulose acetate scale impressions prepared by Wayne Black of FWP. Impressions were analyzed by microfiche at 48X (Jearld 1983). Lengths were backcalculated using the computer program LGMODEL (Weisberg 1989). Assigned ages were verified by two independent readers, and by recaptures of individually marked fish.

Condition Factors and Sex Ratios

Fulton's condition factor (K) (Anderson and Gutreuter 1983) was computed for all Arctic grayling for comparison with other populations:

$$K = \frac{100000\ W}{L^3}$$

where K= condition factor

W= total weight (g)

L= total length (mm)

The sex of mature fish was determined by examination of the length, shape, and color of the dorsal fin. Male Arctic grayling, especially mature fish, have a long dorsal fin which when depressed reaches nearly to the adipose fin, whereas the depressed dorsal fin of female grayling usually does not approach the adipose fin (Hop 1985).

Population Estimates

Population estimates were generated for the grayling population in the upper 5.8 km, beginning in the spring of 1995, from fish captured by seining during spring and fall sampling periods. All sampling occurred when the gates at Pishkun Reservoir were closed, and all 13 pools in the upper 5.8 km were seined as were five 50 m reaches of run habitat. Different 50-m reaches were seined each sampling period. One marking run was followed by one recapture occasion. These runs were separated by at least four hours for an individual site, and were usually separated by 24 hours. Population estimates were calculated using the program MRPE, which incorporates mark-recapture data to generate the maximum likelihood estimate (MLE) using Bayesian statistical methods (Gazey and Staley 1986, D. L. Gustafson, Montana State University, pers. comm.). Separate estimates were made for mature-sized (age 2 and older) and immature fish (age 0 or age 1).

Movements

Grayling movements were monitored in two ways: (1) by visual observation of recaptured, physically marked fish; and (2) by radio-telemetry. All age-1 and older grayling captured were physically marked with individually numbered visible implant (VI) tags in the adipose tissue behind the left eye, as well as by a fin clip specific to the location of the capture (right pelvic in the 5.8 km below the dam, for example). Grayling observed stranded in ephemeral pools post-flow were captured using seines or a backpack electrofishing unit, checked for marks, marked or remarked, and transported to the nearest wintering area. For example, age-0 grayling stranded in a shallow pool below "A" drop were netted and transferred to that drop. Twelve adult and 183 age-1 grayling captured in the fall of 1994 and spring of 1995 were moved from Ninefoot drop to a pool in the upper canal to supplement grayling remaining in the upper 5.8 km and to monitor their movements to see if they were more likely to move downstream than fish captured post flow in the upper end.

Radio transmitters were surgically implanted into 24 adults using a modified Ross and Kleiner shielded needle technique (J. Garrett, University of Idaho, pers. comm.). Incisions were made just ahead of and above the pelvic girdle. External antenna wires were trailed behind the pelvic girdle. The internal organs were shielded with a groover (trough-shaped metal instrument) while a hypodermic needle was inserted behind the pelvic girdle, moved along the groover, and out the incision. The antenna wire was then threaded through the hypodermic needle which was then withdrawn along with the groover. Incisions were sutured using 2-0 Vicryl material with an FS-1 cutting edge needle. Upon completion of implantation, fish were held in a recovery tank until full activity was regained, and then released. Full activity was considered to be regained when a fish was actively swimming and responding to my presence.

This technique was first practiced on about 18 rainbow trout at a hatchery (large, hatchery grayling were not available). Some of these practice fish were implanted with dummy transmitters. With other fish, the surgical procedure was performed, but transmitters were not left in. These trout were held for two to four weeks after surgery to monitor the effects of the procedure on the fish. Among these fish, all but two survived through the post-operative observation periods, and incision sites appeared to be healing well (one early mortality occurred when a specimen jumped out of the holding tank).

In the spring of 1994 (April 22 and 29), 15 adult fish (seven males and eight females) were implanted with 90-day Custom Telemetry (Watkinsville, GA) radio transmitters, 10 with external antennas and five with internal antennas. Because the maximum tag weight was 5.4 g, each tagged fish was 268 grams or larger so that transmitters were two percent or less of the body weight of a grayling (Winter 1983; J. Garrett, University of Idaho, pers. comm.). Tagged grayling averaged 360.4 mm (range, 317-463 mm) in length and 403.8 g (268-748) in weight. Radio tags were implanted into nine grayling captured within the 5.8 km below the reservoir and six grayling from two different drop structures (Upper and Lower Turnbull).

In 1995, seven male and two female grayling averaging 417.0 mm (375-461) and 623.4 g (509-718) were implanted with 150-d Advanced Telemetry System (ATS; Isanti, Minnesota) transmitters, all in the upper 5.8 km of canal. Six tags were implanted during spring (April 13-14, 20-21) and one on July 26. The two female grayling were implanted with the same type of tags on November 16. The transmitters ranged in weight from 4.2 to 4.8 g, and all fish were larger than 240 g, so that transmitter weights were again less than 2% of fish weights.

Radio-telemetry

Radio-tagged fish were tracked using an ATS receiver and a hand-held, bi-directional, 60 x 61 cm loop antenna. Approximate locations were found by driving along the canal road with the receiver scanning the appropriate frequencies (preprogrammed into the receiver's memory) until a signal was heard. The loop antenna was then manipulated by hand to triangulate the signal, and a visible description of the habitat of the site was recorded, as was the location on the appropriate USGS quadrangle map. In 1995, a truck-mounted whip antenna was used to find the general location of a transmitter, and the loop antenna was then used to localize the signal. In both years, during flow conditions, the entire canal was driven at least weekly from the reservoir to Fairfield. Reaches closer to the reservoir were surveyed three to five times a week during the same period. Most locations were made during daylight hours (0500-2100 h). However, all fish except those in extreme downstream reaches were located at night (2100-0500) at least twice. All telemetry gear was checked for accuracy prior to use by locating transmitters placed in streams at various depths and distances. Due to the small size of the ATS transmitters, fluctuating water temperatures caused frequencies to shift (ATS, pers. comm.), usually downward with a decrease in temperature. For example, transmitter 49.610 (khz) would be found at 49.614 khz at 10 °C while at 1 °C it would signal at 49.608 khz. Once this relationship was determined, an unused transmitter was used to evaluate the proper frequencies to scan each day.

Sexual Maturation and Spawning

Sexual maturity was determined through observations of spawning fish and by internal examination of gonads of radio-tagged fish. Spawning was determined by visual observation of areas in which concentrations of radio-tagged fish gathered, and other areas in which suitable spawning substrate was identified during pre-flow periods. These areas included pool margins and pre-flow riffles, and any areas of the canal sides and bottom which could be reasonably observed during flow conditions. However, because of water depth and turbidity, much of the canal bottom is not visible when water is flowing in the canal. In 1995, measurements of substrate, channel width, depth, and velocity were made at a site where spawning activity was observed and where fertilized eggs were subsequently collected. Substrate was classified using a modified Wentworth classification (Cummins 1962): bedrock (unbroken, solid rock), boulder and cobble (>50 mm), pebble (10-50 mm), gravel (2-15 mm), and fines (<2 mm). The timing and duration of spawning was back-calculated from swimup times and fry sizes by using published hatching times at temperature (Kaya 1990, Northcote 1995).

Distribution, and Habitat of Early, Age-0 Young

Emergence and distribution of grayling fry (fish less than 25.4 mm or 1 inch, in length as defined by Piper et al. 1982) were examined in two ways: (1) by visual observations along the water edge; and (2) by conical drift nets with 1 mm mesh, suspended from the Boadle Bridge about 5.8 km below the reservoir. In 1995, additional nets were set 100 m downstream of Pishkun reservoir, one on each side of the canal. Each net had a 0.9 m diameter opening, was 1.5 m long, and ended with a slotted PVC cup lined with aluminum screen. The cup was held to the net with metal clamps and could be opened by unscrewing the endcap. In 1994, positions of the three nets at the bridge were: (1) at the surface at midstream, (2) in shallow water directly adjacent to the bank, and (3) on the bottom (about 1.5 m deep) two meters from the bank. The nets were held in place by nylon ropes attached to various locations on the bridge. In 1995, nets were again set in positions 2 and 3. The two nets at the reservoir outlet were placed at a depth of 1 m, and about 2 m from the bank. Additionally, in 1995 a drift net with 0.5 mm mesh and attached to a 30 kg weight and towing frame was lowered to the bottom in the thalweg at the bridge prior to fry swimup (the stage when fry first start to swim freely and swim up from the substrate) in an effort to detect bottom-drifting eggs, egg-sac fry, or pre-swimup fry. These nets were set at daybreak and nightfall, beginning the first week of June each year, and were checked at those same times by retrieving each net and emptying the contents of the cup into an 18.5 L bucket for inspection. The nets were set at least three entire days (and nights) of each subsequent week through the end of June, for a total of 12 days each year. A sample of grayling fry were kept for length measurements.

Visual observations for grayling fry were conducted from June 4 to July 28 in 1994. Only the shallow areas along the margins of the canal were able to be surveyed, so the presence of fry grayling using deeper water was unable to be determined. Grayling fry were identified by their distinct silhouettes and vigorous swimming motions, with identifications verified by captured fry. At locations where grayling fry were seen, qualitative notations were made of the microhabitat being used, such as whether the fry was in current, behind some kind of obstruction, in shallow or deep water, and the type of associated substrate. In 1995, the locations where fry were seen in 1994 were again surveyed from June 1 to July 11. In 1995, measurements were taken of habitat occupied by fry, including focal point depth and velocity, distance from cover, distance from the bank, substrate in the 0.25 m^2 under the fish, and total depth at that location. Total lengths were measured on all fry which could be netted. Further, the 60.6 km of canal from Pishkun Reservoir to Fairfield (A drop; Table 1, Figure 3) was divided into five sections: (1) Pishkun Reservoir to Boadle Bridge (5.6 km); (2) Boadle Bridge to Upper Turnbull drop (43.3 km); (3) Upper Turnbull to Lower Turnbull (2.72 km); (4) Lower Turnbull to Ninefoot drop (1.92 km); and (5) Ninefoot drop to A drop (3.7 km). Survey reaches were then chosen from these sections by randomly choosing a pre-determined number of 1 km units, and then marking the 100 m within these units which held the greatest chance of holding young grayling (based on 1994 observations). A total of 17 reaches were surveyed (Figure 3). These reaches were surveyed weekly from June 15, one week after grayling fry were first seen, to June 27, when grayling fry were no longer visible, to evaluate longitudinal distribution of fry. Transects were not surveyed the week of June 8, when a single swimup grayling was first observed near the spawning area, due to the inaccessibility of most transects. Reaches were surveyed along the bank bordered by the road by walking the 100 m section very slowly, stopping every 3-4 steps and examining the immediate area carefully for presence of grayling fry. The reaches were surveyed starting from opposite ends of the canal on alternate weeks, beginning with reservoir to Fairfield the first week. I attempted to capture (dip net) and measure any fry detected, and took habitat measurements in the manner described previously. Habitat measurements were taken whether or not the individual fry was netted. Seines were also used in 1995 and 1996 to sample backwater locations for presence of grayling fry. The features used for identifying different species of fry, from observation and identification keys, are illustrated in Appendix A, Figure 1 (Kaya 1994, unpublished).

Habitat Use by Juveniles and Adults

Habitat use by both adult and juvenile grayling during flow conditions was monitored by the observation of feeding fish. Such habitat was characterized by measuring velocity transects on July 11, 1995 at three locations where grayling were most commonly seen or captured during both summer flows and in winter pools. The first two locations were 50 m apart, 1 km below Pishkun reservoir. The third was 4.5 km downstream from the reservoir. At each site, a 12.7 mm (0.5 inch) diameter nylon rope, graduated every meter, was stretched across the canal perpendicular to the current. A Montedoro-Whitney PVM-2A electronic current meter attached 10 cm above a 1 kg sounding weight was suspended by a cable, graduated at 0.5 m intervals, from a canoe. Velocity measurements were made every 2 m along the transect rope, except for the three closest to each bank, which were measured every meter. At each increment, velocity was noted at the surface, and at 0.5 m intervals until the weight touched bottom, where a final velocity was measured (10 cm above the bottom).

Habitat conditions during winter were characterized through the winters of both 1994-95 and 1995-96. Ice thickness, water depth, and dissolved oxygen concentration (using a YSI Model 54 dissolved oxygen meter) were measured both at pools known to contain grayling and some of the remaining pools in the upper canal for which grayling use was possible but unknown. At these and all other pools in the upper canal, length, width, maximum depth, and water volume were measured on March 8, 1996, to estimate the dimensions of winter habitat available. Relative volume was approximated by multiplying the average maximum depth along the thalweg of a pool by half of the average width and by the total length of the pool. The length of the pool was measured along the thalweg. Widths and depth were measured at 50 m intervals.

Other Species of Fish in the Canal

Sympatric fish species were identified and their relative abundances noted to evaluate potential competitors and predators of Sunnyslope Canal grayling. These species were captured during sampling for grayling.

RESULTS

Canal Flow and Water Quality

Discharge was variable between years, with flows generally peaking at about 45.9 to 47.6 m^3/s during June and early July (Figure 4). In 1994, water was released from Pishkun Reservoir into Sunnyslope Canal from May 6 to September 14. In 1995, discharge began April 22, halted from May 5 to May 20, then restarted until September 22. Initial flows both years exceeded 2.7 m^3/s, and were usually over 6.8 m^3/s (Figure 4). Flows began to decrease in mid-July in both 1994 and 1995. This decrease continued through August in 1994, but in 1995 there was a second peak at 37.5 m^3/s early in the month. When the irrigation season ended, the reservoir gates were shut and then later sealed with sand to reduce leakage to minimal (0.03-0.06 m^3/s) levels.

In 1994, GID conducted maintenance on the gates and tunnel on the reservoir side of the dam after flows ended September 14. Before the gates at the outlet were closed, only a small volume of water was flowing into the canal because the reservoir was drawn down to nearly minimum pool, close to the bottom of the outlet tunnel. During this week, the fish screen in front of the outlet gate at the reservoir was removed for repairs. To isolate the canal from the reservoir and to prevent fish passage, two coffer dams (one on the reservoir side of the fish screen and one below the outlet tunnel) were built. However, these coffer dams failed on September 15 and 20, allowing free passage of both water and fish through the dam.

Mean values of conductivity (285.1 umhos/cm; 222-365), alkalinity (133.1 mg/l $CaCO_3$; 112-146), pH (8.4; 8.0-8.5) and temperatures (4.7 °C to

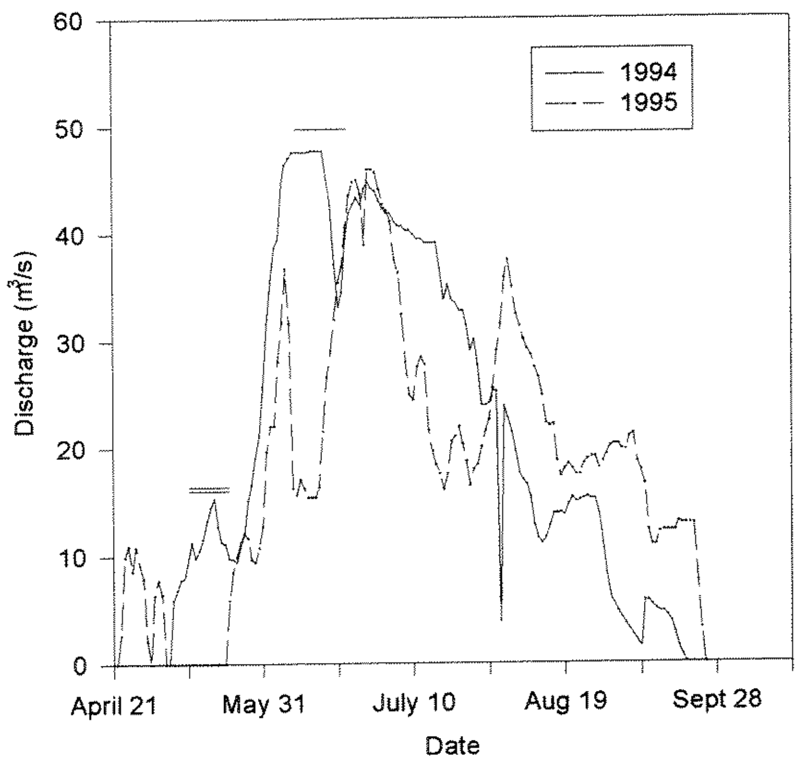

Figure 4. Discharge profiles for Sunnyslope Canal, 1994-95. Double bar indicates approximate spawning times while the single bar denotes fry swimup.

Table 2. Mean, (standard deviation), and range of physical and chemical habitat measurements for upper Sunnyslope Canal during the ice-free period, April 13-November 16, 1995. Conductivity is reported at 25°C.

	Temperature (°C)	Conductivity (umhos/cm)	Alkalinity (mg/l $CaCO_3$)	Dissolved Oxygen (mg/l)	pH
Mean	10.9	285	133	12.2	8.4
sd	(2.9)	(49.7)	(12.4)	(3.4)	(0.2)
Range	4.7-16.0	222-365	112-146	8.6-17.9	8.0-8.5

14.2 °C) for 1995 are presented in Table 2. Dissolved oxygen levels ranged from 8.67 to 17.9 ppm, and reached supersaturation of up to 17.9 ppm in early August. The maximum value (17.9 mg/l) was measured on August 8, 1995 at a water temperature of 13.2 °C. Saturation at this temperature is about 9.6 mg/l, indicating a high level (186%, or 252 mm Hg) of oxygen supersaturation. By August 23, dissolved oxygen dropped to 9.35 mg/l at 16 °C (saturation is 8.5 mg/l). Supersaturation was detected up to 6 km below Pishkun Reservoir.

Age and Growth

The oldest fish captured in Sunnyslope Canal were two age-7 females. Only one male reached age 6 (Table 3). In the first sampling period, spring 1994, 74% of fish captured (32 of 43) were age 3, with total lengths from 341 to 379 mm (Table 3). At the same time, only six grayling (14%) were age 2, ranging from 300 to 322 mm. Male grayling tended to grow faster than females, resulting in longer mean total lengths of males in all age classes through age five, when males were disappearing from the population.

Younger Sunnyslope Canal grayling grew more rapidly than older fish. Both observed lengths-at-annuli and backcalculated lengths (Table 4) show rapid growth in the first two years and a decrease in growth rate during

Table 3. Numbers and mean total lengths (MTL) in millimeters for each age class, by sex and age, of mature Arctic grayling captured in Sunnyslope Canal, spring sampling periods, 1994-96.

Age	Males		Females		Combined	
	Number(%)	MTL (sd)	Number(%)	MTL(sd)	Number(%)	MTL(sd)
			1994			
II	1 (4)	315 (0)	5 (26)	305 (32.0)	6 (14)	307 (29.1)
III	21 (88)	362 (9.0)	11 (58)	358 (13.6)	32 (74)	361 (10.8)
IV	1 (4)	426 (0)	2 (11)	384 (4.9)	3 (7)	397 (24.8)
V	1 (4)	463 (0)	0		1 (2)	463 (0)
VI	0		1 (2)	438 (0)	1 (0)	438 (0)
VII	0		0		0	
Total	24(100)		19(100)		43(100)	
			1995			
II	1 (7)	292 (0)	6 (30)	305 (21.2)	7 (21)	303 (20.0)
III	1 (7)	381 (0)	1 (5)	365 (0)	2 (6)	373 (11.3)
IV	10 (71)	413 (8.7)	8 (40)	401 (16.5)	18 (53)	408 (13.8)
V	2 (14)	449 (17.7)	2 (10)	409 (0.71)	4 (12)	429 (25.3)
VI	0		2 (10)	447 (7.1)	2 (6)	447 (7.1)
VII	0		1 (5)	440 (0)	1 (3)	440 (0)
Total	14(100)		20(100)		34(100)	
			1996			
II	27 (77)	312 (8.3)	64 (77)	300 (12.2)	91 (77)	303 (12.6)
III	3 (9)	372 (15.0)	3 (4)	356 (7.0)	6 (5)	364 (14.0)
IV	0		2 (2)	397 (19.8)	2 (2)	397 (19.8)
V	4 (11)	433 (10.8)	11 (13)	424 (11.8)	15 (13)	427 (11.9)
VI	1 (3)	450 (0)	2 (2)	420 (7.1)	3 (3)	430 (18.0)
VII	0		1 (1)	450 (0)	1 (1)	450 (0)
Total	35(100)		83(100)		118(100)	

year three and especially after year four. Calculated mean growth is 158 mm in the first year, and 144 mm in the second, while observed growth rates were 160 and 141 mm. A negative growth rate is evident in calculated lengths between age 5 and age 6. This reflects the fact that only one male grayling older than age 6 was captured, and male grayling grew faster to age 5 than females (Tables 3, 4).

Table 4. Average calculated lengths at succeeding annuli and annual increments of growth for Arctic grayling captured in Sunnyslope Canal in the springs of 1994-96.

Age	Number(%)	Mean length at Capture (sd)		range	Back-calculated length at each age 1	2	3	4	5	6	7
				1994							
I	13 (28)	172	(7.6)	133-194	168						
II	3 (7)	312	(11.2)	300-322	166	320					
III	27 (57)	363	(11.4)	341-379	158	310	365				
IV	2 (4)	403	(32.5)	380-426	170	315	368	407			
V	1 (2)	463	(0)	---	157	314	359	396	436		
VI	1 (2)	438	(0)	---	171	314	372	401	439	423	
VII	0 (0)										
Total	47 (100)										
Average					162	312	366	403	437	423	
Increment					162	149	54	37	35	-13.9	
				1995							
I	33 (49)	155	(9.8)	136-171	154						
II	9 (13)	303	(17.6)	280-335	153	302					
III	1 (1)	365	(0)	---	154	302	367				
IV	17 (25)	404	(13.1)	348-432	148	297	361	407			
V	5 (8)	429	(21.9)	408-461	151	295	360	404	432		
VI	2 (3)	447	(7.1)	440-452	144	290	350	395	422	431	
VII	1 (1)	440	(0)	---	154	293	356	395	424	431	428
Total	68 (100)										
Average					152	298	360	405	429	431	428
Increment					152	172	37	45	24	2	-2.4
				1996							
I	7 (9)	163	(10.3)	154-185	162						
II	50 (65)	300	(13.0)	250-320	162	300					
III	4 (5)	358	(7.4)	349-365	162	300	356				
IV	2 (3)	403	(27.6)	383-422	162	300	357	403			
V	12 (16)	432	(10.7)	415-450	161	299	355	402	433		
VI	1 (1)	415	(0)	---	162	298	355	401	433	413	
VII	1 (1)	450	(0)	---	159	297	352	398	430	410	444
Total	77 (100)										
Average					162	300	356	401	433	411	444
Increment					162	138	56	46	32	-22	33
Grand average					158	302	361	404	432	429	439
Increment					158	144	59	42	28	-2.5	9.7
Number					192	139	77	45	24	6	2
Observed average					160	301	362	403	433	437	445
Increment					160	141	61	41	30	4	8

Both calculated and observed growth rates show that Sunnyslope grayling grow little after age 5. Two recaptured female grayling illustrate the slow growth of older fish as they grew little between their sixth and seventh years, averaging 4 mm (2-6 mm) (Appendix A, Table 1). Correspondingly, little change was seen in scale annulus formation, with one of these fish laying down only one observable circulus over this time and the other female showing a few tightly packed circuli. These scales, as well as those from other fish, showed evidence of reabsorption, which makes it difficult to accurately age older fish. Without scales from previous years, the ages of these fish would have been underestimated by at least one year. During this study, the ages of all fish over age 5 were verified by scale samples from previous years.

Table 5. Comparison of summer and winter growth (mm) for 11 recaptured, VI-tagged Sunnyslope Canal Arctic grayling, 1994-96. W94= winter of 1994-95; S95= summer of 1995; W95= winter of 1995-96.

Sex	Age at First Capture	Length Fall 1994	Spring 1995	Fall 1995	Spring 1996	Growth Increments W94	S95	W95	Mean Increment W94	S95	W95
F	1	315	335	384	390	20	49	6	20	49	6
F	2	356	365	409	411	9	44	2			
F	2	---	280	349	349	--	69	0	9	57	1
F	3	406	405	436	442	-1	31	6			
F	3	392	384	420	425	-8	36	5	-4.5	33.5	5.5
M	4	---	417	429	430	--	12	1			
F	4	---	408	422	424	--	14	2			
M	4	---	402	429	420	--	27	-9			
M	4	---	409	428	425	--	19	-3	---	18	-2.3
F	5	---	408	418	415	--	10	-3	---	10	-3.0
F	6	---	442	446	450	--	4	4	---	4	4

Most growth occurs in the months between spawning in June and the following season of ice formation in November (Table 5). Older fish (age-3 and older) show practically no growth during the winter months. Negative values indicated for some older fish probably reflect measurement error.

Length-Frequency Distributions

Length-frequency distributions illustrate that grayling recruitment fluctuated widely before and during this study. Very few fish shorter than 330 mm were captured in 1994 (Figure 5) indicating weak year classes for 1993 and 1992. This relative scarcity in spring 1994 of smaller, age-1 and age-2 fish was alleviated with the appearance of age-0 young produced during 1994 and present as yearlings in spring 1995 (Figure 6). This 1994 year class was conspicuous in the spring of 1996 as age-2 fish ranging from about 280-320 mm (Figure 7). The 1994 year class of grayling was clearly stronger than either the 1993 or 1995 year classes, and the 1995 year class appeared to be somewhat larger than the 1993 year class.

The range of lengths in each year's length-frequency distributions were similar as total lengths ranged from 160 to 463 mm, 132 to 461 mm, and 154 to 450 mm total length in the spring sampling periods of 1994, 1995, and 1996 (Figures 5, 6, 7). The length-frequency distributions of males peaked at longer lengths than for females, suggesting that the males grew faster than females. The relationship was less pronounced in 1996 as fewer older males remained in the population.

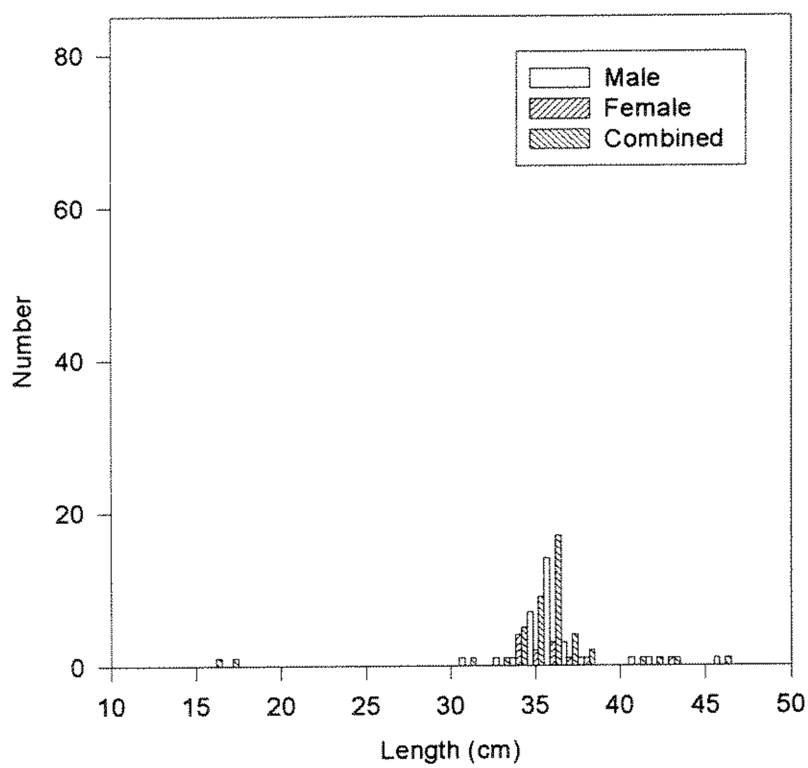

Figure 5. Length-frequency distribution of Arctic grayling in upper Sunnyslope Canal, in spring 1994.

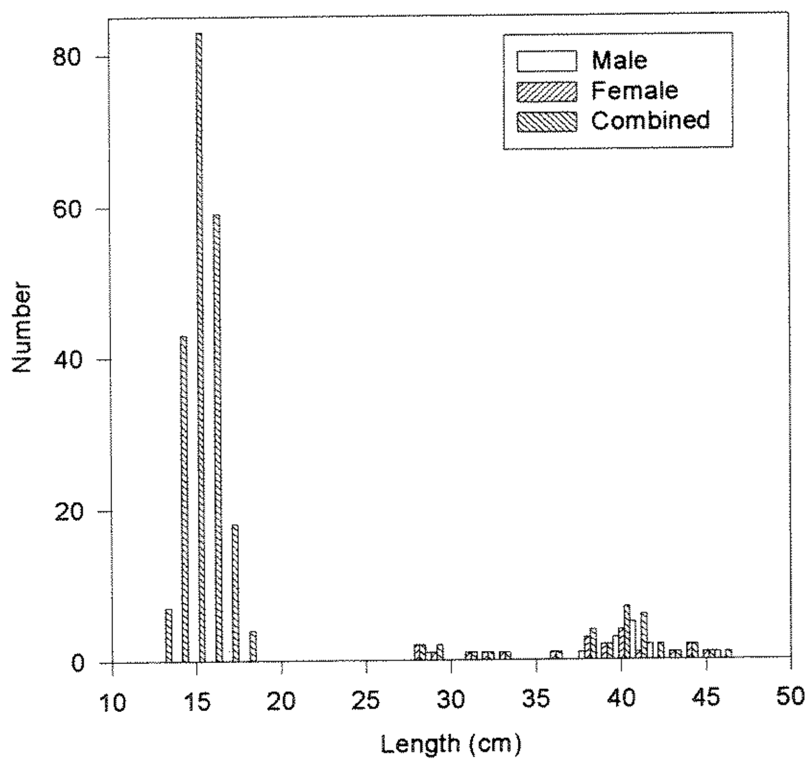

Figure 6. Length-frequency distribution of Arctic grayling in upper Sunnyslope Canal, in spring 1995.

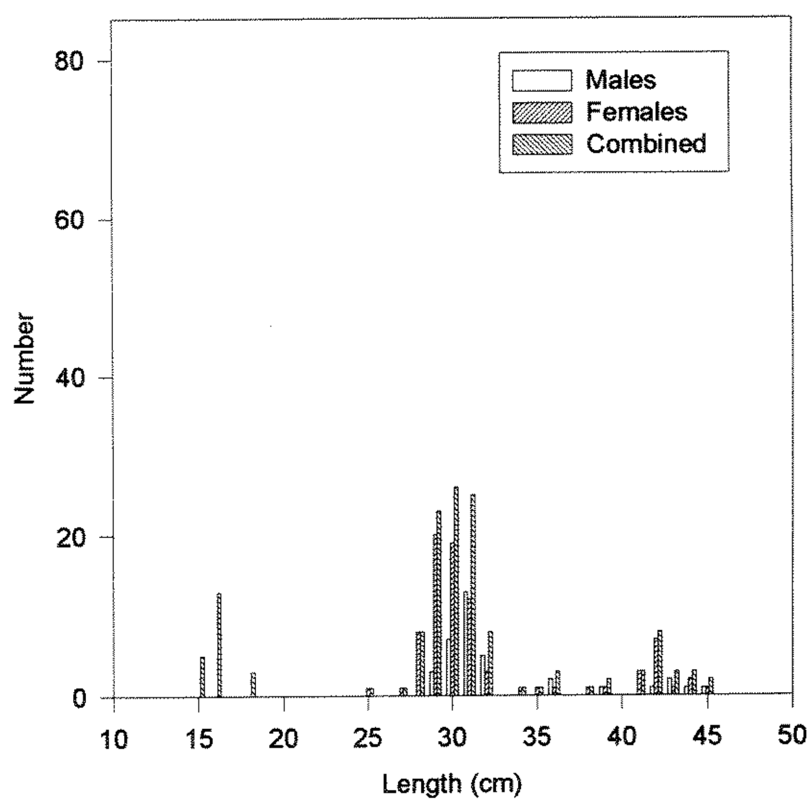

Figure 7. Length-frequency distribution of Arctic grayling in upper Sunnyslope Canal, in spring 1996.

Condition Factors and Sex Ratios

The adult-sized grayling (age 2 and older) captured in the canal generally increased in mean lengths and weights from the spring of 1994 until fall of 1995. However, in the spring of 1996, both mean lengths and weights of the adults decreased as the 1994 year class reached their second year (Table 6) and comprised the largest segment of this subpopulation. Males exceeded females in mean total lengths, and in three of the four sampling periods during which weights were measured, also had higher mean weights. The largest grayling, both in length (470 mm) and weight (1255 g) were males.

Condition factors for Sunnyslope Canal grayling were very similar across the sampling periods, with mean condition factors of females greater than that of males (Table 6). In the spring of 1996, mean condition factor of males was higher than at previous sampling times, and was very close to that of females (0.93 for males, 0.94 for females). Overall, condition factors were highest in spring 1996, even though the preceding winter habitat conditions seemed to have been more severe in 1995-96 than the winter of 1994-95. Age-0 (young of the year) grayling had lower condition factors during the springs of 1995 and 1996 than in the spring of 1994, whereas values for length and weight were higher in 1994 and 1996 than 1995. However, far fewer age-0 grayling were present in 1994 and 1996 than in 1995.

Sex ratios shifted from 1.7 : 1 (M : F) in the spring of 1994 to 1 : 1.1 by the following fall, and remained in favor of females through spring of 1996 (Table 6). The final sex ratio was the most heavily weighted towards females (1 : 3.3).

Table 6. Numbers, sex ratios, and means and ranges of total length (mm), weight (g), and condition factor (K) for male and female adult (age 2 or older) and for juvenile (age 0 and age 1) Arctic grayling captured in Sunnyslope Canal, 1994-96.

	Spring			Fall		
	Males	Females	Age 1	Males	Females	Age 1
			1994			
Total Number	34	20	22	14	15	102
Sex Ratio(M:F)	1.7	1		1	1.1	
Length (mm)	365.0	351.1	166.7	389.6	339.3	125.8
(s.d.)	(26.5)	(37.1)	(13.6)	(60.8)	(60.6)	(8.8)
range	315-463	248-438	133-194	288-470	237-406	109-146
Weight (g)	388.7	390.3	39.6	509.9	366.3	---
(s.d.)	(83.4)	(99.2)	(9.5)	(189.5)	(163.7)	---
range	284-748	268-664	24-62	195-824	152-604	---
Mean K	0.80	0.86	0.86	0.82	0.87	---
(s.d.)	(0.08)	(0.06)	(0.28)	(0.10)	(0.06)	---
range	0.71-1.2	0.79-0.99	0.6-2.0	0.72-1.1	0.75-0.97	---
			1995			
Total Number	14	21	234	23	51	37
Sex Ratio (M:F)	1	2		1	2.2	
Length (mm)	407.1	371.3	155.2	322.2	329.5	156.5
(s.d.)	(37.9)	(54.9)	(10.1)	(46.5)	(57.3)	(5.4)
range	292-461	280-452	132-183	275-429	244-446	143-169
Weight (g)	556.9	519.3	30.8	---	---	---
(s.d.)	(127.6)	(191.7)	(6.6)	---	---	---
range	178-718	217-795	20-48	---	---	---
Mean K	0.81	0.92	0.77	---	---	---
(s.d.)	(0.07)	(0.07)	(0.09)	---	---	---
range	0.7-0.95	0.81-1.1	0.61-1.0	---	---	---
			1996			
Total Number	34	83	25	---	---	---
Sex ratio (M:F)	1	3.3		---	---	---
Length (mm)	334.8	324.6	168.4	---	---	---
(s.d.)	(46.4)	(50.6)	(13.2)	---	---	---
range	294-450	250-450	154-200	---	---	---
Weight (g)	372.6	353.6	39.8	---	---	---
(s.d.)	(217.9)	(227.0)	(17.2)	---	---	---
range	206-1255	147-1108	26-80	---	---	---
Mean K	0.93	0.94	0.79	---	---	---
(s.d.)	(0.19)	(0.14)	(0.14)	---	---	---
range	0.77-1.7	0.73-1.6	0.64-1.2	---	---	---

Population Estimates

Grayling abundance remained at low levels throughout the study. Population size was first estimated in the spring of 1995 at 62 age-2 and older fish (95% confidence interval, 37-230) (Table 7). In fall 1995, the estimated number of age-1 and older grayling was 69 (95% C.I., 62-85), which did not include 20 age-1 grayling moved to the upper canal from a desiccating pool 10.7 km below the reservoir. In the following spring, 1996, the estimated number of fish age 2 and older was 120 (95% C.I., 116-129). This increase partially reflected the addition of the 20 age-1 (age-2 in spring 1996) grayling moved upstream in the fall of 1995, but likely was also influenced by increased capture efficiency since more grayling were captured. During spring, seining is more efficient in the canal as water levels in the remnant pools are lower than in fall. This final population estimate was the highest for adult grayling throughout the

Table 7. Population estimates for Sunnyslope Canal, 1995-1996.

Year	Age	n_1	n_2	m	Nmle	STD	N_o	Nlow	Nhi
S95	1	69	78	20	269	52.95	127	204	390
S95	2+	8	31	4	62	85.73	35	37	230
F95	0	24	16	13	29	3.76	27	27	38
F95	1+	37	47	25	69	6.52	59	62	85
S96	1	19	15	11	25	4.18	23	23	36
S96	2+	77	105	67	120	3.54	115	116	129

n_1= number marked on first capture occasion
n_2= number caught on second capture occasion
m= number of marked fish caught on second capture occasion
Nmle= maximum likelihood estimator
STD= standard deviation
N_o= minimum population number
Nlow= lower confidence limit
Nhi= upper confidence limit

course of the study. The estimated numbers of juvenile, age-1 grayling were highest in spring, 1995, reflecting the strength of the 1994 year-class. Conversely, the 1995 year-class of young grayling was relatively small, as indicated by low estimated numbers of age-0 fish in fall 1995, and of age-1 fish in spring 1996.

Movements

Mortality and Transmitter Performance of Radio-tagged Grayling

Overall, 16 (67%) of the 24 radio-tagged grayling were successfully tracked until transmitter expiration. Six of the 24 implanted fish either were found dead or appeared to have dropped their transmitters based on the presence of the radio signal in locations which did not appear to be suitable habitat (areas with extreme velocity or where the transmitter remained in a completely dessicated location after the irrigation season). Two additional transmitters were not relocated after the second week following tagging in 1994, one because of strong local signal interference and the other apparently because of illegal angling. Some of the other transmitters were repeatedly located in the same locations, with no apparent movements from those places, perhaps indicating that either the radio-tags were dropped or that the fish had died. However, a male grayling (VI tag CA3) which was tracked for two years (1995 and 1996) did not make any noticeable movements from his summer feeding location for up to five weeks in the summer of 1995, and certain fish were recaptured by angling at the same locations (within 50 m) within a three-week period in the summer of 1995, indicating that these grayling move very little under summer conditions. Therefore, I am unable to confirm the status of the tagged fish which remained stationary in 1994, since none of them were recovered, and their transmitters expired well before flows ceased in the canal. Only two of the 24 radio-tagged fish were recaptured during sampling periods later than a week after initial tagging.

The maximum transmitter duration the first study season (1994-95) was 84 days. Minimum duration could not be determined. The maximum duration the second study season (1995-96) was 14 months, and the minimum known duration was 122 days.

Radio Telemetry, 1994

In 1994, grayling radio-tagged in the upper canal were most likely to move downstream out of the upper 9 km of canal. I was able to track five fish (of nine originally radio-tagged), for more than two weeks (Figure 8; Appendix B, Figures 1-4). All five grayling made initial downstream movements from their overwintering locations when flows began on May 6, and four of the five fish (CJ6, CB6, CB2, and CJ9) moved downstream between 40 and 60 km within 3 weeks of the beginning of water discharge from Pishkun Reservoir (Appendix B, Figures 1-4). The remaining fish (CD6) remained within 1.5 km of the reservoir (Figure 8). During this period, radio-tagged fish did not form long-lasting aggregations suggestive of large groups of spawning fish, although two males (CJ6 and CB6) were located together once at a site with substrate which appeared to be suitable for spawning (Appendix B, Figures 1, 2).

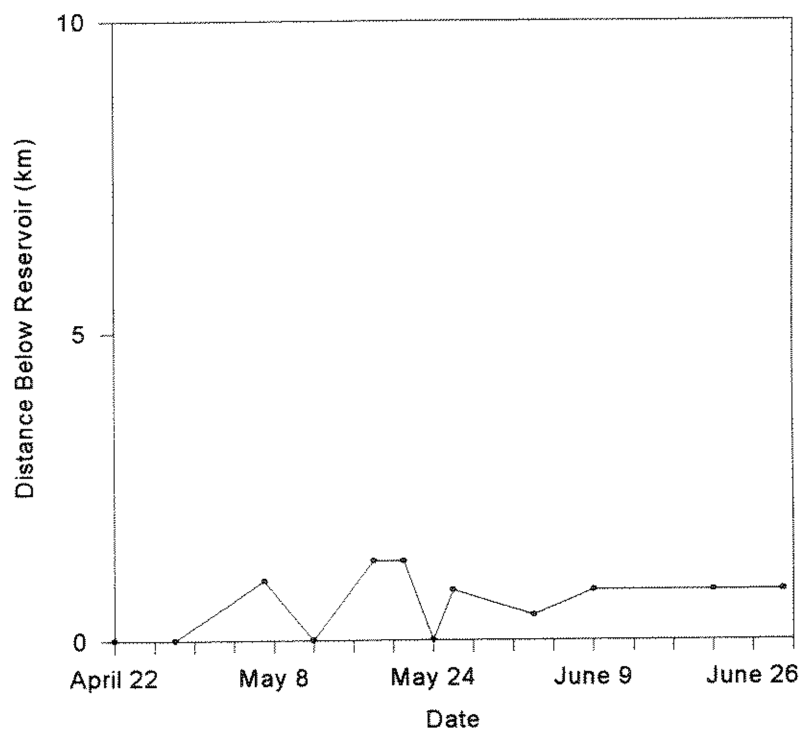

Figure 8. Movements of radio-tagged grayling CD6 (radio-frequency 49.054 mhz) during the spring and summer of 1994, from tagging until transmitter expiration.

Grayling overwintering in drop structures did not remain close to these structures after canal discharge began. All six grayling radio-tagged in the drop structures in 1994 (F12, F08, CJ0, CJ1, CH5, and CH6; Appendix B, Figures 6-11) moved downstream between 1.6 and 3.2 km and over at least one drop structure within three weeks of the beginning of canal discharge.

Within a month of the beginning of discharge, most of the grayling still being tracked (6 of 8) began holding at discrete locations where they were repeatedly located until their transmitters failed. For example, the fish remaining in the upper canal (CD6) was repeatedly located 0.8 km below Pishkun Reservoir at a location where fish clearly identifiable as grayling were often seen rising to feed on surface insects (Figure 8). None of these radio-tagged grayling used available backwater locations. Additional observations of individual grayling are presented in Appendix B.

Radio Telemetry, 1995-1996

In 1995 and 1996, radio-tagged grayling in the upper canal showed a three- or four-stage pattern of movements. I was able to track three fish (of six originally radio-tagged) for more than five weeks (Figure 9). Two of these three grayling (F42, F57, and CA3) made initial downstream movements of between 4.3 and 5.6 km after canal discharge began on April 22, 1995 (Figure 9). Both fish moved upstream in response to decreasing flows at the beginning of the 2 week temporary shutdown. All three fish then moved upstream between 1.2 and 3.7 km in mid-May, apparently for spawning. As will be described later, these fish apparently participated

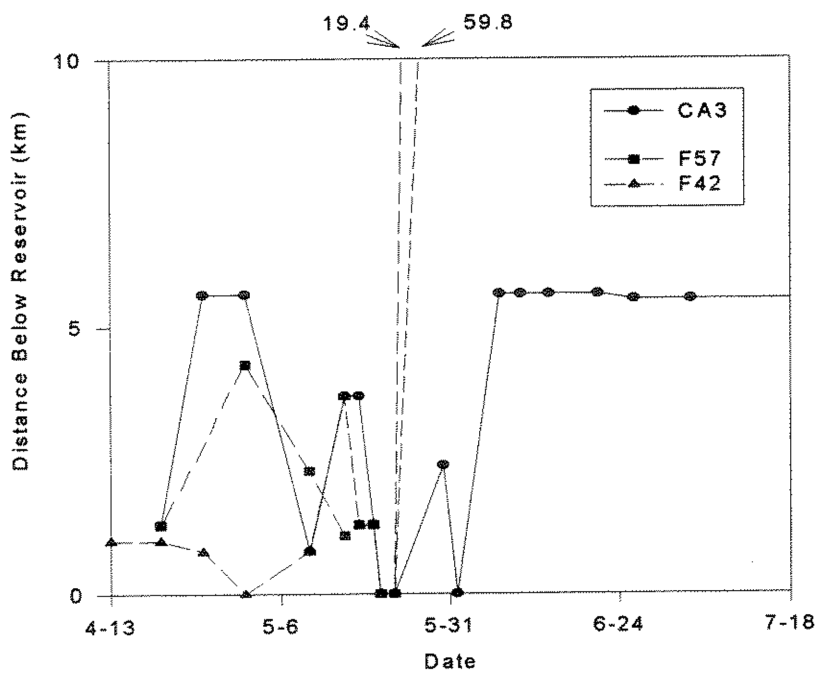

Figure 9. Movements of three radio-tagged male Arctic grayling during spring and summer, 1995, in Sunnyslope Canal.

in spawning activities I observed in the upper canal. After spawning, two fish made downstream movements of between 19.4 and 59.8 km out of the upper canal. One fish (F57) was later found dead and another (F43) dropped its tag or died. The remaining fish (CA3) moved downstream 5.6 km below the reservoir where it remained throughout the summer, moved upstream 4.1 km to overwinter at the same location where he had been tagged, and then repeated the same pattern of movements in 1996 from beginning of discharge through spawning (Figure 10). Also in 1996, another grayling (F30) moved downstream 2.6 km from its wintering pool to a point 6.3 km below Pishkun Reservoir. It remained there through spawning, then moved downstream 1.5 km to a location 7.3 km below Pishkun Reservoir where it had been captured by angling the previous summer.

Radio-tagged grayling did not move between overwintering pools during the non-flow period during the autumn and winter of 1995 and 1996. Both CA3 and F30 remained in separate pools from the time discharges ended in 1995 and began in 1996.

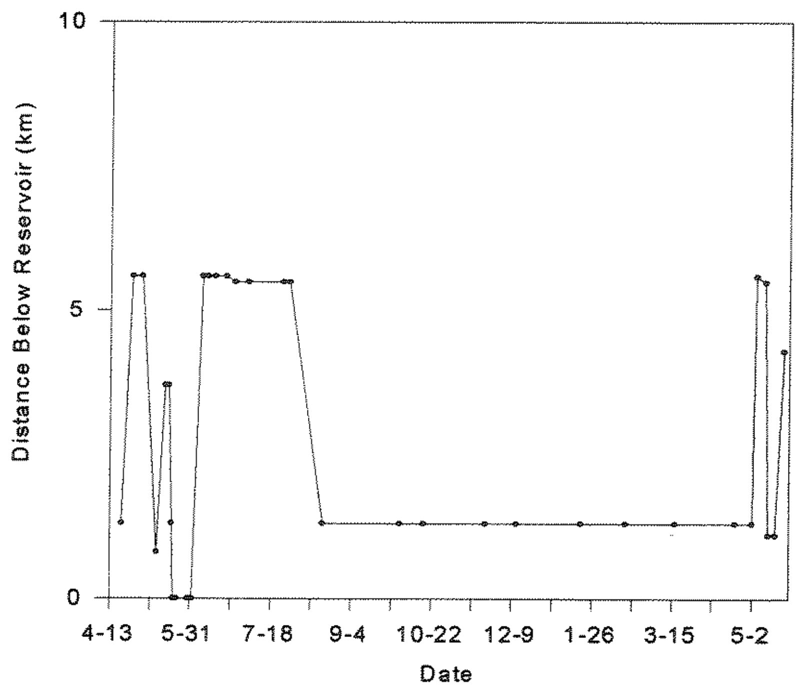

Figure 10. Movements of male Arctic grayling CA3 (49.613 mhz) during 1995 and 1996, in Sunnyslope Canal.

were observed jumping against the fish screen in apparent attempts to continue moving upstream. From recaptures of these fish, it was estimated that over 3000 were present in the area. However, far fewer age-0 grayling were captured throughout the upper 5.8 km of canal after the two occasions when the coffer dams failed, indicating that these fish likely had moved into the reservoir. In 1995, with fewer age-0 fish present in the upper canal, only 23 juveniles were captured in the tunnel under the dam after flows ceased, while one was captured in the rest of the remnant pools of the upper canal.

Sunnyslope Canal grayling showed some level of fidelity to overwintering pools. Among 21 grayling marked in post-flow pools in autumn 1994 and recaptured the following autumn (1995), 13 (61.9%) were recaptured in the same pools as in 1994. Among the remaining 1994-marked grayling recaptured in fall 1995 which were not captured in the same pools as in 1994, six had been captured in 1994 in a pool which froze to the bottom in 1995.

VI-tagged fish did not appear to move from overwintering pools before the release of water from Pishkun Reservoir. In the springs of 1995 and 1996, all grayling were recaptured in the same pools where they had been captured the previous autumn.

Whereas grayling in the upper canal showed evidence of returning to the same post-flow pools, fish at the downstream drop structures did not. One age-1 fish, marked at Upper Turnbull in spring 1994, was recaptured three drops (10.6 km-"A" drop) downstream the following spring. This fish was one of seven age-1 and two older grayling marked with VI tags in Upper Turnbull in the spring of 1994. Eighteen age-1 juveniles marked in Lower Turnbull drop were not captured again either in Lower Turnbull or anywhere else. This suggests that they disappeared farther downstream. None of the grayling marked in the upper canal, including fish moved to the upper canal from downstream drop pools, were subsequently recaptured at any of the downstream drop pools. However, grayling appeared more abundant at downstream locations when they were relatively abundant in the upper canal. For example, in the fall of 1994 prior to the probable loss of fish into the reservoir during construction at the dam, 782 age-0 fish were captured in the upper canal while 204 were captured in the lower canal. However, in the spring of 1996 only 21 young grayling representing the 1995 year-class were captured in the upper canal, and only four were captured in the lower canal.

Sexual Maturation and Spawning

At least some Sunnyslope Canal grayling appear to mature at age 2. Three age-2, 317 mm female grayling which were tagged in the spring of 1994 with internal transmitters contained maturing ova, and female fish in the age-2 size class were seen spawning in 1995. Sexual dimorphism of the dorsal fin was apparent in most age-2 fish.

Initiation of flows may have provided the stimulus for final ripening of gametes and spawning behavior, as spawning began between 1 and 2 weeks after water was released from Pishkun Reservoir in 1994, 1995, and 1996. Adult grayling examined immediately prior to initiation of flows (May 8, 1994; April 20, 1995; May 7, 1996) were not ripe (lacked manually expressible ova or milt). Initial flows in 1994 were over 5.8 m^3/s, increased to a maximum of about 25.6 m^3/s for the month of May, and reached to 47.5 m^3/s by June 11 (Figure 4). Whereas no spawning was visually observed in 1994 because of relatively high canal flows and turbidity, free-swimming fry were seen on June 8. Because canal temperature remained at 10 °C from beginning of flow May 8 until June 6, backcalculated times to hatching and swimup at this temperature (reviewed by Kaya 1990) place spawning three weeks prior to June 6 (about May 14), which would have been less than a week after flow began. In 1995, when flows began on April 22, a mostly-spent female grayling was caught by angling 0.6 km below the reservoir on May 11 after the canal flow had been temporarily shut down May 5. While no grayling spawning activity was apparent at that time, the spawned-out condition of the fish indicated that ripening had occurred and spawning had begun. Five days later, while the canal was still shut down, spawning grayling (including a radio-tagged male, F57; Appendix B, Figure 15) were observed 1.1 km below the reservoir. In 1996, when free-swimming fry were observed on June 14, spawning was backcalculated to the second and third weeks of May at temperatures between 9 and 10 °C.

Even though relatively high discharges prevented visual observation of spawning in 1994 and 1996, the combination of the locations of newly swimming fry and of radio-tagged grayling during back-calculated spawning times indicated possible spawning locations. Substrate which appears suitable for spawning (gravel) is present in numerous locations along the sides and bottom of the canal, and, in 1994, radio-tagged fish did not remain in any particular locations during spawning times to suggest concentrations of spawning fish. However, post swim-up fry were observed as close as 200 m to the outlet from the dam despite powerful flows, suggesting that at least some spawning occurred near the outlet. In 1996, a radio-tagged male grayling (CA3) moved upstream eight days after canal flows began to the same location (1.1 km) where spawning had been visually confirmed in 1995. This fish remained at this location for about 9 days

(May 14-23). Newly swimming grayling fry were very common immediately below this location on June 14 but were not found upstream of it. Another radio-tagged fish (F30) did not move upstream like the other radio-tagged grayling. This female remained about 6.2 km below the dam in an area which appears to contain suitable spawning substrate. Grayling fry were also very common below this location in 1996.

Because of the temporary cessation of flows between May 5 and May 20, one spawning location was confirmed in 1995. This was a short riffle (18 m, see Table 9) 1.1 km below Pishkun reservoir where spawning was seen on May 17 and 18. Mean depth of the riffle was 24.1 cm, mean velocity was 0.30 m/s, and substrate was primarily cobble (greater than 50 mm), with gravel (between 10 and 50 mm) the second most common substrate size (Table 10). Although grayling remained in the area of the riffle, no spawning activity was seen on May 19 or before 3:00 p.m. on May 20, when the canal flow resumed. However, numerous grayling were seen in the pool below the riffle, and two more radio-tagged male grayling (F42 and CA3) moved into the area just prior to resumption of canal flows. One male (F42) moved 2 km upstream to the pool below the spawning area the afternoon of May 19, and the other (CA3) was in a group of at least five adult grayling that moved into the pool the morning of May 20.

After canal flows resumed, an aggregation of radio-tagged fish suggested a concentration of spawning grayling just below Pishkun Reservoir. On May 21, 1995, the morning after the canal flow resumed, all three of the radio-tagged males were 200 m below the reservoir (Figure 8), another location with suitable-appearing spawning substrate, and which appeared to have been used by at least some fish the previous year. One

Table 9. Physical parameters of the spawning riffle used by Arctic grayling in Sunnyslope Canal in spring 1995. Measurements were taken at two meter increments along the total length of riffle used (18 m).

	Width (cm)	Depth (m)	Velocity(m/s)
Mean:	71.0	24.1	0.30
STD:	7.1	10.5	0.10
Range:	(61-81)	(15-45.2)	(0.17-0.43)

Table 10. Percentages of substrate sizes (mm) estimated in 0.5 m^2 plots taken every two meters in an Arctic grayling spawning riffle in Sunnyslope Canal, 1995.

	<2	2-10	10-50	>50
Mean:	6.1	13.9	27.2	56.0
STD:	6.5	13.2	12.8	27.6
Range:	(0-20)	(0-40)	(15-50)	(0-80)

day later, on May 22, all three radio-tagged males were still in the area and a male was seen pursuing a female at this location, suggesting that spawning may have been occurring. All three of the radio-tagged males were in this area until May 23, and one (CA3) remained in the area until at least May 25 (Figure 8).

All observed spawning occurred in the afternoon and evening. On May 18, spawning was first seen at dusk, and continued for some time after dark. Spawning resumed the following day at 12:00 p.m., with the grayling (including F57) moving upstream out of the large pool (maximum depth 1.5 m) 100 m below the riffle. Water temperature had risen from 9.8 °C earlier that morning to 10.5 °C. By 12:15 p.m., five large males established territories within the riffle. These territories were roughly equal, about 4 m long, with the width depending on the width of the riffle at that location (mean width, 71 cm; Table 9). The dominant male was the uppermost in the riffle. The lowermost male appeared to be a radio-tagged male (F57), based on its radio signal. Territorial, courtship, and spawning behavior conformed closely to descriptions from other populations of Arctic grayling (e.g., Brown 1938, Tyron 1947), and a brief description is presented in Appendix D.

Spawning success was confirmed in 1995 by the presence of fertilized eggs in the riffle prior to resumption of canal flow. Eggs were sampled on May 20, and some were already in the eyed stage, indicating that spawning probably had been occurring for at least a week or more. Mean water-hardened egg size (n=9) was 3.6 (3.4-3.7) mm. Some of the adhesive nature of these eggs is apparently retained when water hardening occurs, as some of the eyed eggs were observed still attached to cobble and pebble sized (>50 mm, 10-50 mm respectively) substrate.

Distribution and Habitat Use of Early, Age-0 Grayling Fry

Newly swimming grayling fry in 1994, 1995, and 1996 appeared in early June and remained in shallow areas for four to six weeks, when they disappeared from view and apparently moved to deeper water. Fry were found from June 8 to July 14, 1994, as canal flows declined from 46.7 m^3/s to 28.3 m^3/s (Figure 4) and temperatures increased from 9.8 to 12.5 °C. Newly swimming grayling fry were first observed in 1995 on June 8 and were visible until July 6. Discharges within this period ranged from 15.6 to 36.7 m^3/s, while temperatures increased from 8.9 to 11 °C. Grayling fry were first seen along canal margins on June 14, 1996, when canal flows reached 47.5 m^3/s and water temperature was 10 °C.

Fry were always found along the periphery of the canal where current was slowed by some type of obstruction. On two occasions on June 8, 1994, fry were seined from small backwater areas with a slight current; however, these locations were immediately adjacent to the main channel. Large, pond-like backwater areas exist on the upper stretches of the canal adjacent to locations where fry were observed, but no fry were seen or captured by seining in such backwaters at any distance from areas with current. Backwaters were seined when fry disappeared from the canal margins, but none were observed or captured.

Fry appeared to be much more common in 1994 and 1996 than in 1995. Sixty-two fry were observed on June 14, 1996 which was over three times as many fry as were seen on any one day in the same areas in 1995. These fry were found singly or in groups of up to five and were holding in the slow velocity areas along the canal margins.

Captures of very young, age-0 fry in drift nets indicate very different origins for grayling and northern pike fry in the canal. In both years, all grayling fry taken by drift nets were netted at Boadle Bridge, 5.8 km downstream from the dam, and none were netted at the dam (Table 11). In contrast, 86.2% (50 of 58) northern pike fry from both years were netted at the dam. Grayling fry were collected in the two drift nets closest to the bank for the two weeks following swimup in 1994, but only one was captured in the shallow midstream net during the same period. A single, 10 mm sac-fry grayling was captured by the net anchored on the bottom of the thalweg on May 31, 1995. More grayling were caught in night sets (57%)

Table 11. Age-0 grayling and northern pike captured by drift nets at the reservoir outlet and at Boadle Bridge (5.8 km downstream) in Sunnyslope Canal, 1994 and 1995. Sampling began when swimup grayling fry appeared on June 8 both years, and continued until of fry disappeared from canal margins. Two nets were set at each location each year.

	Location		
	Boadle Bridge		Dam
Year	1994	1995	1995
Days	12	12	12
Total Grayling	23	2	0
Mean Length (mm) (Range)	14.2 (14-15)	15 (None)	0 (NA)
% Night	57	100	0
% First 2 Weeks	100	100	0
Total Northern Pike	1	7	50
Mean Length (mm) (Range)	20 (NA)	37.3 (23-50)	33.1 (21-66)
% Night	100	86	66
% First 2 Weeks	100	57	69

than day sets (Table 11).

Fry densities in 1995 were highest below reaches that were near the known or suspected spawning areas (Table 12), and fry became less common and more scattered in downstream survey reaches. No grayling fry were observed in survey reaches after June 22, when mean fry length was 19.5 mm. However, one 27 mm juvenile was captured outside of the survey reaches on July 6, indicating that some fry were using shallower areas of the canal for a month after fry were first visible. After the irrigation season in 1994, 82 juvenile grayling were captured in dessicating pools in the small lateral canals which branch off of Sunnyslope Canal. These fish captured in laterals as far as 50 km below Pishkun Reservoir.

Table 12. Grayling fry observed in seventeen 100 m transects from Pishkun Reservoir to Fairfield, on June 15 and June 22, 1995. Observations were made June 27 and July 5 but no fry were seen.

Reach #	Distance Downstream (km)	Date	
		June 15	June 22
*1	0.1	0	1
*2	1.3	11	1
3	2.3	1	0
4	3.7	1	0
5	10.8	1	0
6	18.8	0	0
7	19.8	0	0
8	29.4	0	0
9	33.4	1	0
10-17	43.4-60.6	0	0

* Transects in the nearest reaches below known or suspected spawning areas; see Figure 12.

In 1995, young grayling fry averaging 17.6 mm (16-20) were found in the upper third of the water column where focal point water velocity averaged 0.04 m/s (Table 13). One week later, fry were larger (mean length 19.5 mm) and used faster water (mean velocity, 0.06 m/s) and deeper water, although they were still fairly high in the water column (mean focal point depth of 30 mm). A single 27 mm grayling observed on July 5 was holding at a focal point velocity of 0.1 m/s. This same fish demonstrated, by its response to my presence, that it was clearly able to move rapidly upstream through water of this velocity. Sunnyslope Canal grayling fry were sometimes seen holding close to cover, but often when these fry were disturbed they would move away from the cover rather than exploiting it.

Table 13. Habitat use parameters of Sunnyslope Canal grayling fry in summer 1995 where TD is total depth (cm), FD in focal depth (cm), FV is focal velocity (m/s), and DC is distance from cover (cm).

Date	Length (mm)	TD	FD	FV	DC
June 15	17.6	30.4	21.7	0.04	7.5
(s.d.)	(1.73)	(6.97)	(6.67)	(0.012)	(9.39)
range	14-20	19-46	11-34	0.01-0.06	0-27
n	12	19	19	19	19
June 21	19.5	49.5	30.0	0.06	10.0
(s.d.)	(4.95)	(14.3)	(11.6)	(0.014)	(12.3)
range	16-23	28-59	19-40	0.04-0.07	0-25
n	2	4	4	4	4
July 5	27.0	53.0	51.0	0.10	16.0

At swimup, Sunnyslope Canal grayling averaged 14.2 mm in 1994, whereas a single, newly swimming fry sampled in 1995 was 15 mm (Table 14). By a month later in both years, fry had approximately doubled in length. In 1996, four swim-up fry averaged 14.1 mm in total length (range, 14-14.5 mm).

Table 14. Mean lengths (mm) of age-0 grayling in Sunnyslope Canal during the summers of 1994 and 1995.

1994	Number	Length (range)	1995	Number	Length (range)
June 8	5	14.2 (18-20)	June 8	1	15.0 (NA)
June 23	11	19.3 (14-15)	June 15	2	17.5 (14-20)
June 29	2	20.0 (18-27)	June 21	11	19.5 (16-23)
July 6	1	37.0 (NA)	July 5	1	27.0 (NA)

Habitat Use by Juveniles and Adults

Spring and Summer Flow Period

Velocity profiles show the uniform nature of Sunnyslope Canal at three locations (Figure 11) where grayling were repeatedly seen surface feeding. Water velocities were similar at each location (Figure 12), with values near zero close to the bank, and maximum velocities 0.6 m/s in the upper thalweg. In the first transect, the zero values near the north bank (right in the diagram) reflect a large, slow eddy.

Grayling were commonly seen surface feeding at these locations, usually within 5 m of the south bank (left in the velocity profile diagrams). Velocities within this portion of the profiles range from 0 to 0.45 m/s. In a location downstream of these transects, one large adult grayling was observed surface feeding for over two hours in the center of the thalweg. With the overall uniform nature of the canal channel, it is likely that the water velocity at this location would be very similar to the mid-channel velocities at the transect sites, which show velocities over 0.5 m/s. The flow conditions at these sites may not be the principal reason for the presence of grayling, because they were also often present at these locations, in remnant pools, during non-flow periods. Grayling were never seen using backwater areas for feeding or other purposes at any time, even though large, pond-like backwaters are available. However, grayling were seen holding near the bottom of the canal within 5 m of the bank.

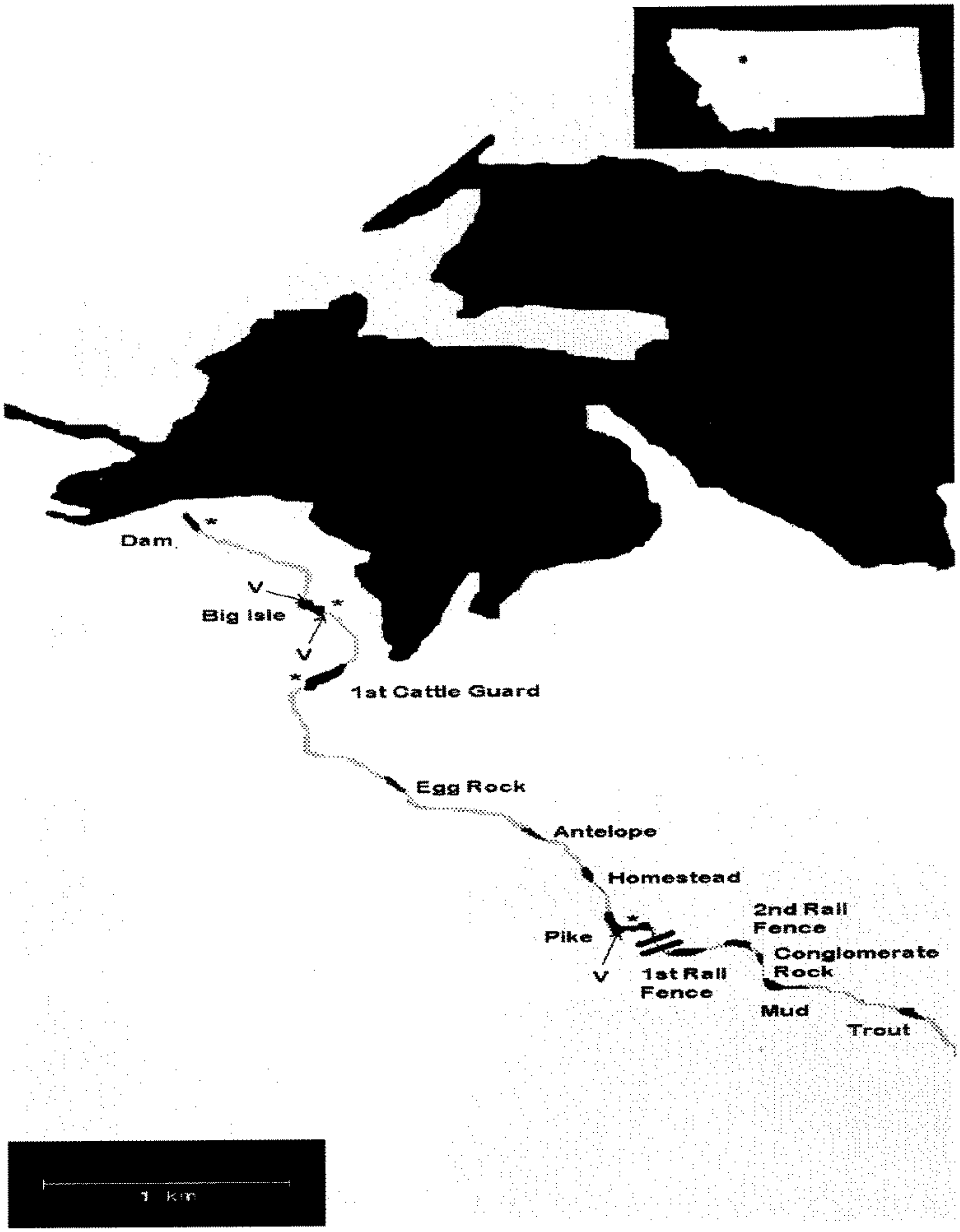

Figure 11. Overwintering areas (in black, and named) in upper Sunnyslope Canal, and locations of three velocity transects (V) during summer flow. Major overwintering locations are denoted with an * , and double lines indicate the downstream extent of winter habitat in 1995-96.

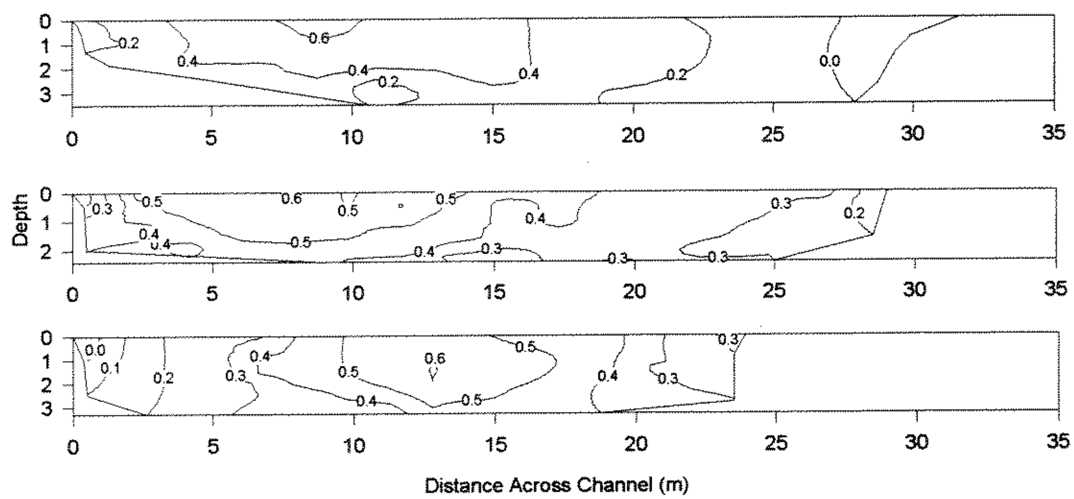

Figure 12. Velocity profiles (m/s) of three areas used by Sunnyslope Canal Arctic grayling during flow conditions.

Non-Flow Period, Including Winter

During the extended, seven-month period when water does not flow through the canal, up to thirteen pools remain in the upper reaches closest to the reservoir (Table 15, Figure 11). Of these, four appear to hold the majority of overwintering fish, as indicated by both fall and spring seining and telemetry data. Both seining and radio-telemetry indicate that grayling remain in the same pools from late fall to spring, and the majority of grayling were captured in the same four pools in both years. In fall 1995 and spring 1996, all mature grayling were captured in these pools. Under winter conditions, these four pools, with a combined length of 342 m, comprise 64% of winter habitat by volume (1487 m^3) (Table 15).

Over-winter survival appeared to be very high in overwintering pools. Over 71% of age-2 and older grayling captured in the fall of 1994 were recaptured in the spring of 1995. Similarly, high percentages of grayling captured in the four major overwintering areas in the fall of 1995 were recaptured in the same pools the following spring of 1996: 76% (19 of 25) at the dam, 88.9% (8 of 9) at Big Island, 90.9% (30 of 33) at 1st Cattle Guard, and 100% (7 of 7) at Pike Pool. Additionally, all 22 age-1 grayling moved from desiccating pools downstream to Pike Pool in the fall of 1995 were recaptured in spring, 1996 at this same location.

In winter 1995-96, the five downstream pools (Table 15; Figure 11) winterkilled. This occurred because these pools either froze to the bottom, or, because of their downstream location, large volumes of water flowed over the ice during a warming trend and the weight of this water appeared to push the ice to the bottoms of these pools. In either case, by February, 1996, all of these pools had over a meter of water over the ice, which was resting on or very near the bottom. Winter-kill was confirmed in spring, 1996, when many dead sculpins and snails were found at these locations.

Table 15. Characteristics of the 13 pools in upper Sunnyslope Canal under ice cover, March 4, 1996. Major overwintering pools are denoted with an *. The final five pools winter-killed in 1996.

Pool	Water Depth Beneath Ice Cover (m)	Volume (m^3)
Dam*	0.43	160
Coon	0.29	50
Big Isle*	0.93	244
1st Cattle Guard*	0.53	263
Egg Rock	0.44	198
Antelope	0.35	113
Homestead	0.60	167
Pike*	0.66	980
1st Rail Fence	0.47	160
2nd Rail Fence	0.50	175
Conglomerate Rock	0.30	42
Mud	0.40	172
Trout	0.75	184

Ice thickness was greater in 1995 than in 1994, and no open water periods were observed in 1995 from November 16 until early April (Table 16). In 1994, some pools were open in early March.

Dissolved oxygen levels remained fairly high in most pools in both years (Table 16). The lowest reading was 3.4 mg/l at one site in 1995, and levels generally remained much greater than this. Levels in the upper and lower water column were similar, although some pools did show signs of stratification beneath the ice.

Table 16. Mean and (range) of physical and chemical habitat measurements during ice-cover in the winters of 1994-95 (1994) and 1995-96 (1995) in Sunnyslope Canal: Temperature (°C), specific conductance (umhos at 25 °C), dissolved oxygen (mg/l), and ice and water depth beneath ice (cm).

Location	Year	Temperature Top	Temperature Bottom	Conductivity Top	Conductivity Bottom	Dissolved Oxygen Top	Dissolved Oxygen Bottom	Ice Depth	Water Depth
Dam	1994	1.8 (NA)	---	---	---	13.1 (NA)	---	3.3 (0-10)	20.3 (11-25)
	1995	2.5 (1.1-3.3)	---	372 (366-380)	---	9.2 (8.2-11.0)	---	8.3 (0-15)	26.3 (11-40)
Big Isle	1994	0.8 (NA)	3.0 (NA)	---	---	12.6 (NA)	7.1 (NA)	12.7 (0-38)	64.0 (NA)
	1995	1.0 (0.5-1.6)	3.2 (1.9-4.5)	371 (275-425)	462 (461-463)	7.9 (6.6-9.2)	7.4 (6.5-8.2)	44.3 (30-58)	76.7 (70-90)
1st C.G.	1995	1.0 (0.4-1.9)	3.6 (3.0-4.1)	458 (447-470)	599 (NA)	7.7 (6.0-9.6)	7.4 (6.5-8.2)	27.3 (20-35)	58.7 (50-63)
Egg Rock	1994	2.4 (1.9-2.9)	1.7 (1.4-2.0)	---	---	8.8 (7.1-10.4)	8.5 (6.7-10.2)	17.7 (0-29)	70.5 (66-75)
	1995	0.5 (NA)	7.8 (NA)	542 (NA)	1467 (NA)	9.6 (NA)	3.4 (NA)	35.0 (NA)	25.0 (NA)
Pike	1994	1.4 (NA)	3.1 (NA)	---	---	9.6 (9.4-9.8)	10.3 (9.0-11.5)	17.0 (0-28)	66.5 (66-67)
	1995	0.9 (0.4-2.0)	2.6 (0.7-4.1)	548 (420-848)	591 (450-786)	8.9 (6.6-11.2)	7.8 (4.7-9.1)	32.0 (32-38)	82.5 (80-90)
R. Fence	1994	2.6 (2.0-3.1)	4.4 (3.5-5.3)	---	---	9.2 (7.9-10.5)	8.7 (7.9-9.5)	16.3 (0-29)	51.0 (32-70)
	1995	2.5 (NA)	3.5 (NA)	1462 (NA)	1462 (NA)	4.4 (NA)	4.6 (NA)	32.0 (20-38)	30.5 (26-36)
Nine	1994	1.2 (1.0-1.3)	1.4 (1.0-1.8)	---	---	8.1 (7.8-8.3)	6.6 (4.9-8.2)	8.3 (0-15)	122.5 (120-125)
	1995	2.9 (1.7-3.7)	3.4 (2.6-3.9)	435 (355-547)	552 (463-641)	14.5 (11.4-19.4)	14.8 (11.4-19.4)	40.3 (35-48)	112.3 (105-119)
"A"	1994	1.0 (0.5-2.0)	---	---	---	14.7 (8.2-19.0)	---	24.0 (15-32)	8.7 (6-10)
	1995	1.5 (1.0-2.0)	---	423 (295-551)	---	17.8 (15.5-20.0)	---	42.5 (40-45)	6.8 (0-12)

Other Species of Fish in the Canal

Whereas grayling were the most common species collected in Sunnyslope Canal, eight other species of fish were collected while sampling for grayling. These species were: mottled sculpin (*Cottus bairdi*), northern pike, rainbow trout (*Oncorhynchus mykiss*), spottail shiner (*Notropis hudsonius*), white sucker (*Catostomus commersoni*), longnose dace (*Rhinichthyes cataractae*), lake chub (*Couesius plumbeus*) and yellow perch (*Perca flavescens*). The most common of these in the upper canal were white suckers, mottled sculpin, yellow perch, and northern pike, in approximately that order. Lake chub and longnose dace were never captured in upper Sunnyslope Canal, but were very common at some downstream drop structures. Lake chubs were also captured in Pishkun Supply Canal above Pishkun Reservoir. Brook trout (*Salvelinus fontinalus)* have also been reported in the canal as recently as 1993 (Hill pers. comm.). Beside grayling, white suckers were the only other species observed spawning in Sunnyslope Canal (see Appendix E).

Of these species, yellow perch and rainbow trout are considered potential competitors with Arctic grayling (Kaya 1993), and northern pike are a potentially important predator. Fry of yellow perch and northern pike were the most common species collected in drift nets at the reservoir outlet, indicating large numbers of these species moving out of Pishkun Reservoir. Fry of rainbow trout were never captured in drift net samples. All perch fry and some northern pike fry captured in drift nets were dead. This may be because fry of pike and perch were coming out of the reservoir and were being killed by the violent passage through the outlet. However, since adults and juveniles of these species are found in the canal, spawning in the canal is possible.

Most northern pike captured by seining were age 0. In all seining attempts, only six large northern pike, with total lengths ranging from 600-710 mm, were captured. A subsample (n=11) of 136 smaller northern pike in the spring of 1995 had a mean total length of 290 mm (range, 216-343). The vast majority of pike (164; 89%) were captured in the upper canal after the two events in fall 1994 which allowed free movement from the reservoir into the canal and prior to flows the following spring (1995). Stomach contents were examined on all northern pike (185) captured by seining in the upper canal. No grayling were found in any of these stomachs, although sculpins and white suckers were very common.

Many northern pike appeared to move downstream from the upper canal during the flow season. Numerous northern pike were seen, seined, or found dead in desiccating pools and drop structures after flows ceased.

Like northern pike, most rainbow trout captured in Sunnyslope Canal were age 0. Some of these trout appeared to be wild fish from the Sun River, while others were marked DeSmet strain hatchery fish stocked into Pishkun Reservoir (Hill, pers. comm.). Only eight larger rainbow trout were captured in the upper canal, ranging from 271 to 426 mm.

Additional information on other species including the first record of a species of fish leech in Montana, are reported in Appendix E.

DISCUSSION

Physical and Chemical Habitat

Vincent (1962) identified grayling habitat as water with velocities between 0.31 and 0.61 m/s, gradient between 0.09% and 0.28%, depth between 31 and 91 cm, and spawning substrates consisting primarily of gravel and coarse sand with beds of aquatic vegetation. Measurements at transects during summer flow in the Sunnyslope Canal show a range of velocities closely meeting these criteria (Figure 12). Canal depths of about 3 m in the main channel exceeded his cited depths (Figure 12). However, grayling were historically present in the main stem of the Missouri River (Vincent 1962, Kaya 1992), and probably inhabited deeper waters similar to depths present in the canal. The gradient of the canal is far less than that given by Vincent, at 0.002%, gravel and coarse sand substrates appear common, and some vegetation is present in the remnant pools.

Sunnyslope Canal undergoes severe dewatering on an annual basis. Canal discharges during flows usually are between 5.6 and 47.6 m^3/s but decrease dramatically after the gates close at Pishkun Reservoir to less than 0.06 m^3/s (L. Vincent pers. comm.). While dewatering, especially due to irrigation, has been considered an important factor contributing to grayling declines, the dewatering of the canal differs from dewatering of natural systems in important ways. Unlike natural rivers, Sunnyslope Canal becomes dewatered in September or later each year, after the potential for elevated water temperatures has passed and when flows in natural rivers are also likely to be low. Therefore, while the truncation of habitat from dewatering likely limits the Sunnyslope Canal population by reducing the amount of usable habitat available (especially overwintering pools), the timing of flow reduction does not disrupt spawning, fry rearing, or suitability of summer feeding habitat.

Values of pH, conductivity, alkalinity, and dissolved oxygen were higher during flow conditions in Sunnyslope Canal (Table 2) than in the Big Hole River (Liknes 1981), which contains the only remnant, fluvial population of Arctic grayling in Montana. Dissolved oxygen levels in Sunnyslope Canal ranged from 8.67 to 17.9 mg/l (Table 2), higher than the 6.5-11.6 mg/l reported by Liknes (1981) for the Big Hole River. Supersaturated dissolved oxygen levels in the canal were likely the result of the turbulent inflow of water into Pishkun Reservoir (Christian Fritzen, Biology Department, Montana State University, Bozeman, pers. comm.). Although N_2 was not measured, the excess O_2 was likely also accompanied by nitrogen supersaturation.

I saw a rainbow trout captured by an angler in Pishkun Reservoir, near the outlet to the canal, which had visible bubbles within its fins, skin, and eyes. This suggests that gases were supersaturated in the water before it left the reservoir. The increase in oxygen concentrations in the canal coincided with dropping reservoir levels and increased inflows through Pishkun Supply Canal. The inlet to Pishkun Reservoir is only about 500 m from the outlet, and this, combined with the shape of the reservoir (Figure 3), would likely result in direct water flow through the reservoir and the conservation of gas supersaturation from the inlet to the outlet of Sunnyslope Canal.

Such oxygen supersaturation may stress grayling in the canal. The majority of grayling which were captured by angling in the summer of 1995 were caught during July and August, when oxygen supersaturation was highest, but no signs of superficial embolisms were detected on the fish.

However, some age-1 grayling caught close to the outlet showed reddening of the fins, opercle, and lateral line, which may be a manifestation of the effects of gas supersaturation on the circulatory system (Beth MacConnell, U.S. Fish and Wildlife Service, Fish Technology Center, Bozeman, Montana, pers. comm.).

Dissolved oxygen levels remained above values thought to limit Arctic grayling (Kaya 1990, Northcote 1995) in the wintering pools known to contain grayling through both winter periods, never dropping below 6 mg/l in most of the locations (Table 16). Very high survival rates through winter confirmed that conditions in wintering pools were not limiting during the course of this study. Even though conditions within pools may not be limiting, the amount of pool habitat may be. Conditions in the winter of 1995-96 effectively truncated winter habitat in the upper canal from 13 pools to eight. Few grayling seemed to winter in those five pools which became eliminated as habitat during the second year of my study, as only two grayling were captured in any of these pools the previous autumn. However, at times when grayling are more abundant in the canal, more fish may use these lower pools and may be lost during winter.

Very high dissolved oxygen levels (up to 20 mg/l) were seen at two of the drop structures. This is most likely the result of exosolution of oxygen and other gasses from the freezing water (Dr. John Priscu, Dept. of Biology, Montana State University, Bozeman, Montana, pers. comm.). Twenty-three grayling survived the winter of 1994-95 in "A" drop, enduring both high dissolved oxygen levels of 9.5-19.0 mg/l and very shallow water depths of 6-10 cm (Table 16). Several rainbow trout carcasses at this site indicated that they did not survive the winter at this location.

large numbers of age-0 (probably near 3000) and possibly older grayling, had not been lost into the Pishkun Reservoir during fall, 1994. Almost certainly, the majority of the 1994 year-class of age-0 grayling was lost into the reservoir. Further, since adult fish may have also been lost into the reservoir during fall, 1994, such loss may have contributed to lower numbers of spawning fish and the weak year-class of age-0 fish in 1995.

Estimated grayling densities have been reported to range from 20 adult to 1480 "catchable" grayling per km in Alaska and Canada (Northcote 1995). Densities of age-1 and older grayling in Montana's Big Hole River have ranged from 14 to 69 per km in recent years (Kaya 1992). The final estimate of 120 age-2 and older grayling in Sunnyslope Canal puts densities of these fish at only slightly over 13 per km within their major area of concentration within the upper 9 km of canal downstream from the reservoir.

In 1994, the majority of Sunnyslope Canal grayling were age-3 fish from the 1991 year-class (Table 3, Figure 5). Both older and younger fish were uncommon. Despite the apparent loss of much of the 1994 year-class, this group of fish formed the largest segment of the population by the spring of 1996 (Table 3; Figure 7). Part of this is due to artificial maintenance of the population by our moving 183 age-0 fish from downstream locations in fall 1994, but in large part, it reflects the strength of this year-class.

Growth Rates and Condition Factors

Conditions in Sunnyslope Canal did not appear to limit grayling growth. Among populations in Montana, only Red Rock Lake grayling grew faster than Sunnyslope fish, but only for the first two years of life. By their fourth year, Sunnyslope Canal fish appeared to be the fastest growing grayling population of any studied in Montana (Table 17; Figure 13) as well as Alaska and Canada (Craig and Poulin 1975, Armstrong 1986, Northcote 1995). Sunnyslope Canal grayling grew far faster than Big Hole River grayling, the only completely fluvial population of the species in Montana. Calculated lengths of canal grayling were longer at age 2 than of Big Hole River fish at age 3. The majority of growth in Sunnyslope grayling

Table 17. Calculated total lengths (mm) at succeeding annuli of six Montana Arctic grayling studies from Montana. Studies are arranged in descending order based on length at age-V.

Population	Length at Age							Reference
	I	II	III	IV	V	VI	VII	
Sunnyslope C.	158	302	361	404	432	429	439	this study
Hyalite Res.	86	246	350	395	418			Wells 1976
Red Rock L.	190	319	364	384	404	418	422	Mogen 1996
Red Rock L.	151	282	343	373	396	406		Nelson 1954
Big Hole R.	118	222	275	309	379			Liknes 1981
Big Hole R.	145	249	297	322	340			Shepard & Oswald 1989

occurred in the first two years of life, which is also true for other populations (Table 17) with the exception of Hyalite Reservoir fish, which grew most rapidly in their second and third years (Wells 1976). By mid-September, 1994, age-0 Sunnyslope Canal grayling averaged about 126 mm in total length, while age-0 fish in the Big Hole River measured 104-108 mm (Skaar 1989, McMichael 1990).

Male Sunnyslope Canal grayling grew faster than females, but females appeared to live longer. This sexual differential is responsible for the negative growth rate indicated for the estimated mean total lengths between

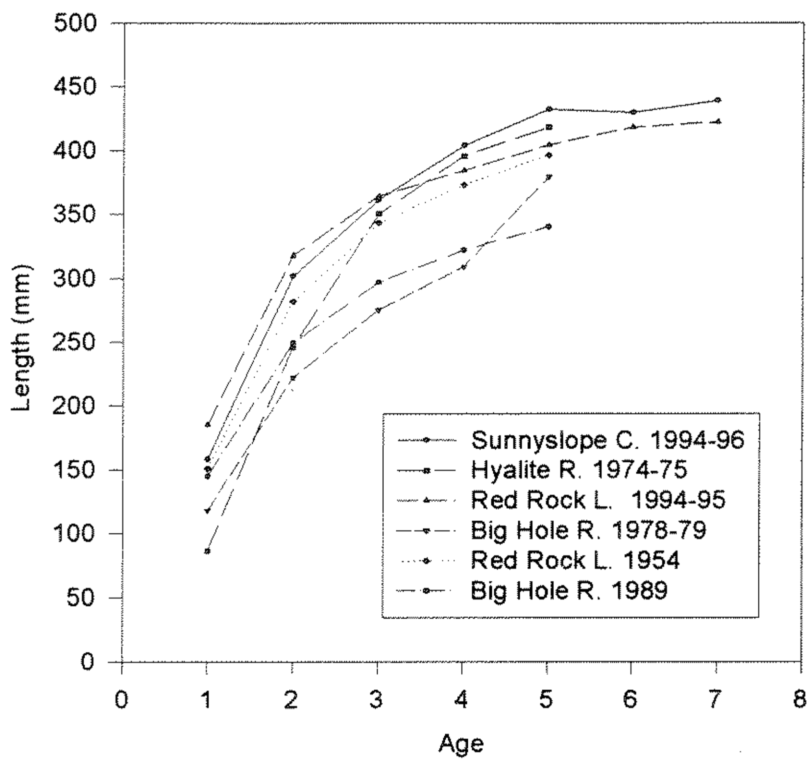

Figure 13. Growth curves of six Arctic grayling populations in Montana.

years five and six (Figure 13). Males have also been reported to grow faster in other populations in Montana (e.g., Peterman 1972, Lund 1974, Mogen 1996).

The two longest grayling captured in Sunnyslope Canal were a 470 mm male of unknown age and an age-5, 463 mm male (Table 3). The largest female was 450 mm and age 7 (Table 3). The longest Big Hole River grayling reported by Liknes (1981) was 381 mm at age-5. The longest fish reported from adfluvial populations in Montana were an age-7, 436 mm female from Upper Red Rock Lake (Mogen 1996), an age-5, 444 mm female from Hyalite Reservoir (Wells 1976) and age-7 males measuring 457 and 470 mm from Elk Lake (Lund 1974).

Sunnyslope Canal grayling were relatively long-lived, especially when compared to Big Hole River fish. The oldest recorded Big Hole fish have been age 5 (Liknes 1981, Shepard and Oswald 1989), while the oldest Sunnyslope Canal grayling were age-7 females (Table 3). Among lacustrine populations in Montana, age-7 grayling have been caught in Red Rock Lakes and Elk Lake (Lund 1974, Mogen 1996), and an age-10 fish was captured in Lower Twin Lake (Nelson 1954).

The use of scale annuli for aging has been shown to underestimate the ages of older grayling, especially of those older than age 7 (Craig and Poulan 1975, Sikstrom 1983). The exact ages of both age-7 fish in this study would likely have been underestimated by a year if their ages had not been determined in previous years. These results show the usefulness of unique tagging of individual fish as a validation technique (Wydoski and Emery 1983).

Mean condition factors of age-2 and older (248 to 463 mm; 0.80 to 0.94), and juvenile, age-0 and age-1 (133 to 200 mm; 0.77 to 0.86) canal grayling were lower than for fish in the Big Hole River. In two Big Hole River studies, grayling had mean condition factors over 0.90 for fish 175 to 315 mm (Liknes 1981) and over 1.0 for age-1 and older fish (152 to 305 mm) (Skaar 1989).

Mortality of Radio-tagged Grayling

The mortalities of radio-tagged grayling in this study may be the result of these fish having radio-tags implanted very close to spawning times. At least two grayling in 1994 and three in 1995 died or dropped their transmitters prior to spawning. Two male grayling died or lost their transmitters after spawning in 1995. Surgical procedures are not recommended within one month before or after spawning (Winter 1983, Garrett pers. comm.). However, due to the short period between ice-out and the initiation of flows in the canal, such time periods were not feasible in this study.

Transmitters may also be lost from fish which do not die. Chisholm and Hubert (1985) found that rainbow trout encapsulated and passed dummy transmitters through the intestines and out of the anus with out any ill effects. Since none of the grayling which lost their transmitters were recaptured, I do not know if any of the transmitters were lost in this fashion.

Movements

Sunnyslope Canal grayling appeared to undergo annual movement patterns similar to those of fluvial Arctic grayling in the Big Hole River (Shepard and Oswald 1989) and in Alaska (Tack 1980), although on a much smaller scale (Figures 8, 9). Fluvial Arctic grayling have been shown to use different parts of a stream for spawning, summer feeding, and wintering habitats, sometimes moving over 100 km between each of these three areas (Tack 1980, Northcote 1995).

All telemetered fish in Sunnyslope Canal moved downstream from wintering locations when flows began (Figures 8-10; Appendix B, Figures 1-16). In all three years, at least one telemetered fish moved downstream after initiation of flows to areas where they remained for up to a week, and then moved upstream to known or suspected spawning areas (Figures 8-10). Other fish remained in downstream areas or moved even further downstream (Appendix B, Figures 1-12,16). All of the fish which displayed upstream movement, presumably for spawning, later moved downstream for distances ranging from 1 km to about 60 km.

At least among those radio-tagged fish which remained in the upper 9 km of canal, these downstream movements appeared to be to summer feeding stations. Grayling were commonly seen surface-feeding in locations different from spawning sites throughout June, July, and August of both 1994 and 1995. These locations ranged from 0.5 km below the outlet at Pishkun Reservoir to 9 km below the outlet, which is just above the concrete-lined section of canal. In the summer of 1995, only one mature grayling was captured above 1.3 km, and the majority of mature fish were captured below 6.2 km. Conversely, most immature fish were captured above 4 km (Table 8). Subadult and adult grayling also used habitat differently in Alaska (Armstrong 1986), but subadult fish used downstream locations of rivers, and adult fish used upstream areas.

As flows subsided after the irrigation season, both telemetered fish and fish marked after being captured by angling in summer feeding areas moved upstream to wintering pools, some from areas as far downstream as 6.6 km (Figure 10; Table 8). This upstream movement seemed to be in response to decreasing flows, as grayling made such movements whenever the dam's outlet was shut down. This included the spring of 1995, when the outlet was temporarily closed in May (Figure 9). Similarly, in irrigation canals off the Gallatin River, trout and other fish moved upstream either to the river itself, or to an area with cover and water depth in the canal, when water levels were lowered gradually (Clothier 1953b, 1954).

In the Sunnyslope Canal, it is likely that once a grayling moves over 9 km below the reservoir, it is lost to the population. This is because of the long (over 1 km), concrete-lined section of canal followed by a large lake-like pool which retains water depths over 1 m for well over a month post-flow. This pool appeared to concentrate fish which had moved below the lined canal section, as 47 age-1 and older grayling were found stranded in this location in the fall of 1995. This pool desiccates fully by early winter, killing any resident fish. During flow conditions the concrete-lined section may be difficult to ascend, as there are no places for fish moving upstream to rest in this section of canal. Water levels drop very quickly in this lined section when flows cease, allowing little time for fish passage upstream. None of the radio-tagged fish which moved below the lined section moved back upstream past it.

Fish which move upstream become concentrated within wintering habitat of less than 1 km of pools, and the combined total length of the four known overwintering pools is 0.34 km (Table 15). In Alaska, fluvial grayling concentrated in overwintering areas, although densities were not known (Craig and Poulin 1975, West et al. 1992).

There appeared to be no relationship between the distance downstream of summering vs. wintering locations. For example, fish captured by angling in the summer of 1995 at 7.4 km wintered far upstream at 0.8 km, while other fish captured at 2.6 km moved only a short distance and wintered at 1.3 km. Radio-tagged grayling did not move from these wintering areas during winter conditions (Figure 10; Appendix B, Figure 16).

Prior to freezing over of the pools and also after thawing, some movement may occur between pools. One grayling captured at 2.2 km in the fall of 1995 was recaptured at 3.7 km a week later, where it wintered. Another fish, a radio-tagged male, was located at 3.2 km a day after being tagged at 2.2 km on April 22, 1996. In all three years, all other fish captured in the remnant pools were recaptured in the same pools in subsequent seining efforts before flows began.

Both radio-telemetry and recapture data indicate that some portion of the population is lost downstream each year. As noted previously, at least in adult fish, some of this downstream movement occurs after the spawning period. Both telemetered fish which made major (over 9 km) downstream movements in 1995 did so after the apparent spawning period (Appendix B, Figures 14, 15). In 1994, three out of four radio-tagged grayling moved downstream after the approximate spawning period (Appendix B, Figures 1-3). Recaptures of fish captured by angling indicate that younger grayling (age 1 and 2) were more likely to move downstream than older fish.

Grayling in the pools at the downstream drop structures appeared to be fish moving from the upper canal. This premise is supported by the observation that when grayling numbers (especially age-0 young) were higher in the upper canal, numbers of grayling in the drop structures were also relatively higher after flow ceased, indicating their continued movement downstream. Although no fish marked in the upper canal were recaptured at any of the downstream drop pools, grayling marked in these pools before flows began did not return to the drops. In 1983, Bill Hill marked 290 age-1 grayling at "A" drop in the spring before canal flow started. Fall sampling at this site revealed only three of these fish in this drop.

Downstream movement of canal grayling may account for reports of grayling in the Sun River as recently as the 1970's (Peterson 1981), and in Muddy Creek (Leathe 1993). The canal drains into both of these systems (Figure 2), and grayling could easily move down into these streams. Downstream movement and loss from the population of large numbers of age-0 grayling were also observed in the outlet stream of Deer Lake in Montana (Deleray and Kaya 1992). This loss occurred from the Deer Lake population even though this population has been subjected to the severe selection pressure of a waterfall within 200 m of the principal spawning areas, and has probably existed for at least as long as grayling in Sunnyslope Canal. As suggested by Lentsch (1985), who similarly observed losses of rainbow trout fry from a population above a waterfall, such downstream movements and losses may indicate that the populations are not completely adapted to their presence above one-way barriers.

Sexual Maturation and Spawning

The age of sexual maturity appears to be related to growth rate (Kaya 1990, Armstrong 1986). At least some Sunnyslope Canal grayling mature at age 2, when they range from 250 to 335 mm (mean length, 303), and when most show signs of maturity through the development of sexually dimorphic characters (dorsal fin size, principally). Crowded environments and higher latitudes favor slow growth and later maturity (Hubert et al.

1985). The Sunnyslope Canal fits neither of these categories. Alaskan Arctic grayling mature when they reach 300 mm in length, independent of age, and sometimes by 270 mm (Armstrong 1986). Craig and Poulin (1975) used 300 mm as a criterion separating mature and immature grayling, based on internal examination of gonads. In the Big Hole River population, Liknes (1981) reported that some fish mature at age 3, at about 275 mm, and Shepard and Oswald (1989) reported that 66% of age-2 grayling were sexually mature, at a mean total length of about 248 mm. Among adfluvial populations in Montana, only 4% of spawning grayling from Upper Red Rock Lake were age 2 (Nelson 1954). This was similar to reports from other populations (Brown 1938, Peterman 1972). However, Mogen (1996) found that 31% of the spawning fish in Upper Red Rock Lake were age-2 fish. Since male Sunnyslope Canal grayling grow faster than females, males may mature earlier than females. Among age-2 grayling in the spawning run from Upper Red Rock Lake, males were represented more heavily than females (Mogen 1996). This difference was attributed to earlier maturity of the male grayling.

The sex ratios of adult-sized fish changed from 1.7 M: 1 F in the spring of 1994, to an inverse ratio by a year later (Table 6). The majority of fish in the population in the spring of 1994 were age 3. The shift in sex ratio by the spring of 1995 could have been produced by differential mortality, or by fish moving downstream out of the population. Telemetry data shows that two males and two females moved downstream out of the population, providing no evidence of a greater propensity for downstream emigration of male grayling. However, the sample size of telemetered fish is very small and may not represent the entire population. During spring 1996, there were over three females for each male (Table 6).

This ratio may under-represent male grayling in the age-2 grouping, as Hop (1985) found that sexing grayling by external characteristics underestimated numbers of male grayling by 4%. Lund (1974) and Peterman (1972) both also found sex ratios of over 2 females for each male, while Wells (1976), Shepard and Oswald (1989), and Beauchamp (1990) reported ratios in favor of male grayling.

Arctic grayling populations in Montana spawn in the spring (April through July), and initiation of spawning is thought to be related to water temperature (Kaya 1990). Spawning in Alaskan streams may be initiated by 4 °C water temperatures associated with high flow periods (reviewed by Armstrong 1986). Shepard and Oswald (1989) reported that Big Hole River grayling spawned when mean daily water temperatures were 8.3 °C, between high flow events. Sunnyslope Canal grayling appear to use the increase in flows as a stimulus for final maturation and spawning. In 1994, 1995, and 1996, temperatures in pools and the riffle habitats between them were well within the ranges of known spawning temperatures, ranging up to 10 °C before the beginning of canal flows. However, in all three years, there was no evidence of ripe fish before canal flow was initiated.

In 1995 and 1996, radio-tagged fish began to make upstream movements in Sunnyslope Canal about a week after initiation of flows. In 1994 and 1996, high canal flows precluded visual observation of actual spawning. However, radio-tagged fish were determined to be holding position in water at least 1 m deep, in areas in which suitable spawning substrates had been seen prior to initiation of flows. Spawning at depths of over 1 m would be within the range reported for grayling, ranging from 1.5 m (Kruse 1959) to 8 cm (Kaya 1990).

Not all radio-tagged grayling made upstream movements to possible spawning areas. This is especially true for 1994, when only one male grayling made a short (slightly over 1 km) upstream movement (Figure 8). Three other grayling this same year were observed holding position in other locations which held suitable substrates for spawning (Appendix B, Figures 1-3). In 1996, a female grayling made short upstream movements in an area which also contained suitable spawning substrates, but far downstream of areas where grayling were concentrated in 1995.

My observations do not permit conclusions on whether Sunnyslope Canal grayling use distinct portions of the canal for spawning, as suggested by the 1995 visual observations, or if localized groups of grayling make use of suitable substrate at several or many locations. However, the movement in 1996 of the male grayling CA3 upstream to the same area 1.1 km below the reservoir where spawning was observed in 1995, and his remaining there for over a week, provide evidence that some grayling may return to discrete spawning locations. Two sites which appear to be important spawning locations, based on radio-telemetry and visual observations, are (1) a 0.2 km stretch beginning about 200 m below the outlet at the reservoir, and (2) an 18-m length beginning 1.1 km below the outlet. In 1995, the opportunity to visually confirm spawning was possible because of a ten day period of interrupted flow in May (Figure 4). The very small flows of about 0.18 m^3/s were much less than the typical minimum flow of about 5.1 m^3/s early in the irrigation season (L. Vincent pers. comm.).

A wide range of substrates are used by Arctic grayling for spawning, ranging from fine silt to large rubble and even vegetation (Scott and Crossman 1973). The most commonly used substrates are those with particle diameters between 0.5 and 3.8 cm (Hubert et al. 1985). Sunnyslope Canal grayling were observed spawning in a riffle containing predominately (56%) >50 cm substrate. However, substrate between 10 and 50 cm comprised 27% of the substrate in the spawning riffle. It was this type of substrate from which eggs were taken. This may have resulted from grayling actually "preferring" this type of substrate, or from water hardened eggs being displaced onto the smaller substrates.

The mean water-hardened egg diameter for Sunnyslope Canal grayling measured 3.57 mm (n=9 eggs). This is slightly larger than Big Hole River egg diameters (3.4 mm), is near the lower end of egg diameters of other Montana grayling (3.4-4.2 mm) (Kaya 1990), and is in the middle of the range of values of egg diameters for North American populations (2.7-4.3 mm)(Scott and Crossman 1973).

Distribution and Habitat of Early, Age-0 Young

The smallest newly swimming grayling fry in Sunnyslope Canal measured 14 mm total length (Table 14). This is larger than the length of Big Hole River fry, which are about 10 mm at swimup (Kaya 1991). After 20 days, Big Hole River fry reach a length of 18 mm (Kaya 1991), while Sunnyslope Canal fry are larger than 20 mm (Table 14).

Newly swimming Sunnyslope Canal grayling fry used water velocities within the ranges listed for other populations. In the Chena River, Alaska, grayling fry between 15 and 34 mm used mean water velocities of 0.04 m/s in water about 40 cm deep (Lee 1985). Deleray (1990) observed that fry less than three weeks post-swimup used velocities less than 0.05 m/s in Deer Creek. Sunnyslope Canal fry between 14 and 23 mm in total length used water velocities less than 0.07 m/s in water less than 50 cm deep (Table 13). These grayling fry were holding positions in the upper half of the water column, while Deer Creek fry held close to the bottom (Deleray 1991). All of these grayling fry were observed and captured while holding positions in areas along the margins of the canal where some current was evident, and not in adjacent areas with nearly stationary water. Fluvial grayling fry (less than 51 mm) require habitat containing mean column velocities less than 0.15 m/s (Hubert et al. 1985, Reynolds 1989). Such areas are common along the margins of Sunnyslope Canal at any discharge volume, especially at maximum flows, and were the areas where grayling fry were observed.

Fluvial Arctic grayling fry show an ontogenetic shift in both the water velocities and depths they use (Vascotto 1970 cited in Northcote 1995, Kratt 1977, Lee 1985). Chena River grayling fry and juveniles between 35 and 54 mm used water with a mean velocity of 0.25 m/s and a depth of 49 cm (Lee 1985). Juvenile Big Hole River grayling (>51 mm total length) use mean column velocities of about 0.06 to 0.26 m/s and depths between 0.15 and 0.40 m (Skaar 1989, McMichael 1990). These measurements indicated that juvenile grayling in the Big Hole River chose faster and deeper water at higher frequencies than available. Similarly, young grayling in Sunnyslope Canal appeared to leave slower velocity areas by their third or fourth week of life. Young grayling became uncommon in slow velocity areas along the canal margins as they reached about 25 mm in total length. A single 27 mm grayling captured on July 5, 1995, was holding at a focal point velocity of 0.10 m/s (Table 13). When disturbed, this fish was able to swim rapidly upstream through water of this velocity. Another young grayling, with an estimated length of over 35 mm, was observed holding in over 1 m of water, about 1.5 m from the bank. Backwater and slower velocity areas along canal margins were seined within six weeks of swimup of grayling fry in both 1994 and 1995, but no young grayling were captured. Thus, the age-0 fish did not move to slower water as they grew larger, but apparently moved into deeper, faster water.

During their first several weeks after becoming free swimming, Sunnyslope Canal grayling fry did not position themselves within cover and when disturbed, would often actually move away from cover. Such non-usage of cover has been observed for grayling fry in the Chena River, Alaska (Lee 1985), and in the outlet from Deer Lake, Montana (Deleray 1991). These observations appear to contradict the report by McClure and Gould (1991), that grayling in an artificial stream preferred cover, and reports by Hubert et al. (1985), Skaar (1989), and McMichael (1990), who observed juvenile grayling using cover. However, the grayling in these studies were juvenile grayling >51 mm while those observed in Sunnyslope Canal were fry 14 to 27 mm in length (Table 14).

Age-0 Sunnyslope Canal grayling appeared to exhibit a tendency to move upstream as flows are reduced. In both 1994 and 1995, after cessation of flows, the majority of age-0 grayling were captured in the tunnel underneath the dam at Pishkun Reservoir.

Recruitment seems to be negatively correlated with stream flow in the first weeks of grayling life (Shepard and Oswald 1989, Clark 1992b). However, the weaker year class of grayling in 1995 cannot be attributed to this phenomenon, as flows at swimup were higher in 1994 than 1995 (Figure 4). Discharge data show that the flows in 1994 peaked in June and were higher at potential swimup times than in any year among the last 11 (GID 1996). Over those 11 years, flows were consistently highest in June of each year. However, maximum flows in the canal do not produce the turbulent, chaotic conditions often associated with seasonally peak flows in a natural river, and in the canal the same types of fry holding habitat are available along the margins at any flow level. Lower numbers of swimup fry along canal margins in 1995 than in 1994 may have resulted from lower numbers of spawning grayling in 1995, or from the unusual flow conditions which resulted in the grayling spawning in minimal flows while canal flow was temporarily interrupted. This latter condition might have caused grayling to use spawning sites not ordinarily used, or caused eggs and egg-sac fry to be washed downstream or be damaged when flows increased from 0.18 m^3/s back to 5.1 m^3/s (Figure 4).

Other Species of Fish in the Canal

Whereas grayling were the most common species in Sunnyslope Canal, white sucker were the next most numerous, both as young and adults, and were the species for which spawning was also confirmed. Adult rainbow trout, northern pike, and yellow perch were present but uncommon in the upper canal, although age-0 young of pike and perch entered the canal in large numbers from the reservoir based on drift net samples. In the case of northern pike, such downstream movement into the canal likely has been occurring since the early 1950s (Hill pers. comm.). This suggests that the canal does not provide suitable habitat for these species. Conditions in the canal do not appear to meet critical components described in habitat suitability indices for these species (Inskip 1982, Krieger et al. 1982, Raleigh et al. 1984).

Reasons for the failure of rainbow trout to become established in the canal are not apparent. The survival of age-0 grayling suggests that young rainbow trout may also be able to survive in the canal. Young wild trout, apparently from the Sun River, and hatchery trout stocked into

Pishkun Reservoir are found in the canal. However, it may be that the majority of these fish are too large to pass through the outlet screen at the dam by the time they enter, or are planted, into the reservoir. Thus, perhaps too few rainbow trout enter the canal to provide a spawning population. Or, the canal may not provide a suitable combination of substrate and water depth for redd construction by rainbow trout.

Yellow perch require cover in slow water habitats. Krieger et al. (1983) report optimal yellow perch habitat as 30-80% pools and backwater areas containing 25-50% cover. During flow conditions, especially as canal levels drop, these types of habitats are increasingly scarce. Those backwater habitats which do occur generally lack any type of cover at all.

Northern pike also prefer backwater and slow pool habitat in lotic systems, with habitat becoming increasingly more suitable as the area of these types of habitat increases (Inskip 1982). At discharges less than 20 m^3/s, these types of habitats are uncommon in the canal.

Kaya (1992, 1993) speculated that the persistence of the grayling in the upper Big Hole River might be related to conditions which are less suitable for competing fish, especially non-native salmonids. Findings in this study support that speculation.

SUMMARY

1. Sunnyslope Canal grayling appear to persist and complete their life cycle within about 9 km of canal during the irrigation season. These grayling appear to use different areas of this 9 km for spawning and summer feeding areas.

2. During spring and summer flows, the canal appears to provide suitable habitat for grayling. Large flow volumes of about 5.6 to 47.6 m^3/s, water temperature averaging 10.9 °C, low gradient of 0.002%, and water velocities of about 0.2 to 0.6 m/s are predominant during this period.

3. Telemetry of larger fish and downstream captures of age-0 and older fish also indicate that many fish move downstream during summer flows and appear to be the source of grayling present in irrigation ditches diverted from the canal, and in pools remaining at lower drop structures and within the lower parts of the canal, when flows cease. Such fish are lost to the population, and those in temporary, downstream pools die when these pools dry out.

4. Upon cessation of flows, grayling move to wintering pools, which experience minimal flows (less than 0.06 m^3/s) provided by leakage from the outlet gate at the dam and spring seepages throughout the late fall and winter months. These pools provide wintering habitats similar to those reportedly used by fluvial grayling populations in Arctic rivers. At least in some winters, the canal grayling may be confined to four pools, with a combined length of less than 350 m. At the rates of leakage from the dam and spring seepage present during the two winters of this study, dissolved

oxygen levels remained relatively high in these pools beneath winter ice cover (3.4 mg/l or higher) and overwinter survival of grayling was high.

5. While dewatering, especially due to irrigation practices, is considered to be one of the major factors affecting grayling decline in Montana, grayling in Sunnyslope Canal persist despite the drastic dewatering of the canal from each fall through the following spring. However, unlike natural rivers, Sunnyslope Canal becomes dewatered in September or later each year, after the potential for elevated water temperatures has passed and when flows in natural rivers are also likely to be low. Therefore, while the truncation of habitat may indeed limit the Sunnyslope Canal population by reducing the amount of usable habitat available, it does not disrupt spawning, fry rearing, or suitability of summer feeding habitat.

6. These grayling are able to spawn under varying flows in the canal. Appearance of fry indicated that spawning occurred during relatively high flows (9.6 to 15.3 m^3/s) in 1994 and 1996, and spawning was visually confirmed during very low, interrupted flows (less than 0.2 m^3/s) in 1995. Spawning during high flows appears to represent the normal situation for this population, and fry appeared much more numerous in 1994 and 1996 when flows were higher than in 1995.

7. Grayling in the canal appeared to reach sexual maturity at age 2, when they reached mean total lengths of 303 to 307 mm.

8. Grayling fry hold positions in slower velocity areas along the canal margins for about a month after swimup, but are always found in areas with some current even though backwater areas with nearly no velocity exist. This suggests that canal grayling fry are adapted to maintaining position in current. Further, juveniles exhibit a tendency to move upstream as flows subside following cessation of flows.

9. Growth rates of both juvenile and adult-sized fish are among the fastest recorded for Arctic grayling across its range, both in North America and Asia, especially compared to fluvial populations. During this study, Sunnyslope Canal grayling reached mean total lengths over 300 mm by their second annulus. Male fish grew faster than females and the oldest fish aged in this study were age-7 females.

10. Conditions in the canal appear to minimize competition with a non-native salmonid (rainbow trout), as well as northern pike and yellow perch. Despite the continuous passage of age-0 young of these species each year from Pishkun Reservoir, only six adult northern pike and no adult yellow perch were captured in the canal. There was no evidence of reproduction by either species in the canal. Although both rainbow trout and northern pike have been in Pishkun Reservoir, and thus have entered Sunnyslope Canal, for at least as long as grayling, neither species was common in the canal.

11. The size of the population in the canal was small during this study, with estimates ranging between 62 and 120 mature-sized grayling in 1995 and 1996. The final estimate of 120 grayling indicates a density of 13 fish per km in the upper 9 km of canal. These small population numbers are at

least partially the result of thousands of age-0 grayling, and probably some older fish, apparently lost into Pishkun Reservoir in September, 1994 during repair work on the dam. Continuing, apparently natural, downstream loss of fish is also contributing to these low numbers. Neither the reasons for the scarcity of fish from the 1992 and 1993 year-classes, nor other factors which may be limiting this population, are evident from this study.

12. The selection processes operative in Sunnyslope Canal have produced a unique and distinctive population of Arctic grayling. They represent the only non-native population of grayling in Montana which is at least partially fluvial, despite repeated attempts to start or restart grayling populations in river systems.

MANAGEMENT IMPLICATIONS

The Sunnyslope Canal grayling population represents a unique part of Montana's grayling populations. It is the only known instance of grayling becoming newly established in a fluvial environment (Kaya 1992), and the unique genetic signature of this population may result from that. University of Montana geneticist Fred Allendorf, in a letter to FWP in 1985, stated that he felt that the distinctness of this population might be its success in non-lake, or lotic, environments and felt its preservation was important. He also stated:

> "...any plans to preserve the existing genetic variation in Montana Arctic grayling should put high priority on the protection of the Sunnyslope Canal population."

The fluvial nature of these grayling may represent a remnant of the formerly fluvial Madison River/Ennis Reservoir grayling from which they originated. The original stockings of fish in Pishkun Reservoir were made within about 35 years of the closure of the dam at Ennis Reservoir (Kaya 1992). While these fish would probably have been at least eight generations removed from fluvial progenitors, it is unknown how behavioral characteristics would have been modified due to the lacustrine conditions. Whatever the origin of the fluvial nature and behavior of these grayling, preservation of this population is important both as a unique portion of the genetic variation within Montana grayling and as a possible source of gametes for reintroduction efforts. Given the vulnerability of the population to perturbations because of its constriction to a small section of canal, preserving wintering habitat and starting a brood stock in a lake are ways of guarding against the loss of this population. Priority should be given to maintaining the population within the canal itself, so that it retains its unique adaptations.

Arctic grayling are considered to be susceptible to angling but angling pressure in the upper canal during the course of this study was very light. Angling could potentially devastate this population, especially when members are concentrated in the residual pools, so catch-and-release regulations put in place in 1993 should at least be maintained. Closing the upper canal to all fishing might strengthen the opportunity to preserve the population when it is reduced to small numbers, by reducing mortalities from incidental catches. Grayling were easily captured by angling for the purposes of this study.

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APPENDICES

APPENDIX A

TABLE AND FIGURE RELATING TO RESULTS

Table 1. Lengths at annulus (in mm) for 30 recaptured Sunnyslope Canal Arctic grayling, from spring 1994 to spring 1996.

Sex	Age Each Capture	Spring 1994	Spring 1995	Spring 1996	Growth Between Captures
M	3 4	---	355	388	33
M	3 4 5	367	417	430	50 13
M	3 4 5	369	414	442	45 28
M	3 4 5	367	402	425	35 23
M	3 4 5	369	405	427	36 22
M	3 4	371	411	---	40
M	3 4	378	421	---	43
M	3 4	374	414	---	40
M	3 4	360	410	---	50
M	3 4	365	403	---	38
M	3 4	362	403	---	41
M	4 5	---	417	438	21
M	5 6	---	425	450	25
F	2 3	---	335	390	55
F	2 3	---	280	349	69
F	3 4	---	365	411	46
F	3 4 5	352	384	423	32 39
F	3 4 5	362	402	423	40 21
F	3 4 5	344	382	405	38 23
F	3 4 5	344	377	398	33 21
F	3 4	360	395	---	35
F	4 5	---	405	439	34
F	4 5	---	394	424	30
F	4 5	---	408	423	15
F	4 5	---	409	427	18
F	4 5	---	419	440	21
F	4 5	---	410	422	12
F	4 5 6	387	408	417	21 9
F	6 7	438	440	---	2
F	6 7	---	442	448	6

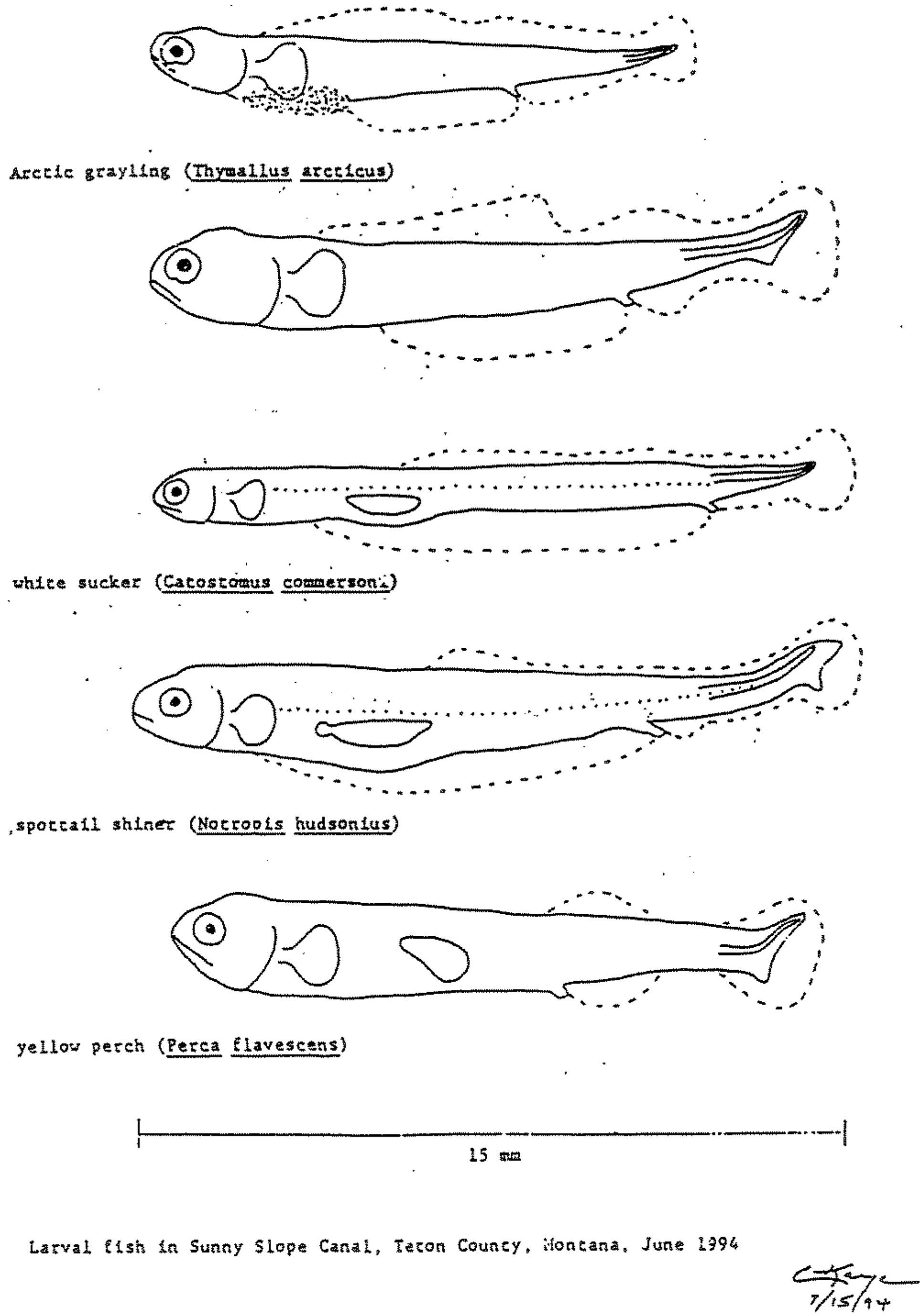

Figure 1. Larval fish captured in Sunnyslope Canal in 1994 and 1995 (Kaya 1994, unpublished).

Characteristics of Fry in Sunnyslope Canal
(Kaya 1994, unpublished)

at 10-13 mm length:

grayling

gas bladder not readily visible through body walls

elongate, wide, dorsal fin

origin far anterior, over pectoral fins

fin width similar to that of elongate mid-ventral fin

shallow indentation in dorsal fin, shortly anterior to anus, marking start of separation of adipose fin

urostyle straight or slightly curved dorsally

may have residual yolk sac when swimming initiated

yellow perch

oval-shaped gas bladder clearly visible, fills posterior end of abdominal cavity

dorsal fin posterior, over anal fin, the fin origin far back of gas bladder

urostyle straight or slightly curved dorsally

At 14-16 mm total length:

grayling

gas bladder not readily visible through body wall

blunt head from lateral and dorsal views, with large eye

long, wide, dorsal fin with indentation for adipose fin

origin of dorsal fin far anterior, over pectoral fins

indentation behind dorsal fin, shortly anterior to anus, clearly separates adipose fin

dorsal fin width similar to that of mid-ventral fin

urostyle bent dorsally at about 45° angle white sucker

narrow head and body

mouth slightly subterminal (hard to see)

eccentric spindle-shaped gas bladder clearly visible at dorsal part of abdominal cavity.

urostyle straight or with slight dorsal bend

narrow dorsal fin starts over gas bladder

width is less than 1/2 that of mid-ventral fin

dorsal edge of fin lacks indentation (no adipose fin)

single row of small melanophores along lateral line, from operculum though caudal peduncle

short, single row of small melanophores from isthmus to front of mid-ventral fin

yellow perch

gas bladder easily visible, filling back end of abdominal cavity, bladder oval in smaller specimens, and eccentric tear-drop shape in larger, with point anterior

dorsal fin far posterior, over anal fin

urostyle curves upward and then turns horizontally, forming shallow S-shape

spottail shiner

double bladder - anterior round, posterior spindle-shaped - in dorsal part of abdominal cavity

single row of small melanophores along lateral line, similar to that of sucker fry

irregular row of melanophores from isthmus to anal fin, in places may be more than 1 cell wide (unlike sucker fry)

dorsal fin projects upward from narrow elongate dorsal fin-fold, origin over back margin of gas bladder

APPENDIX B

TELEMETRY OF INDIVIDUAL GRAYLING IN SUNNYSLOPE CANAL

Individual Grayling, 1994

Of the nine adults radio-tagged in 1994 near the reservoir, four were lost, died, or lost their transmitters within two weeks. A large age-5 male, (CE2), was captured and tagged about 1.6 km below the reservoir and he was relocated a week later about 1 km downstream. Two weeks after tagging (April 29) and prior to beginning of flow, neither the fish nor the transmitter could be located. It appeared to have been removed from the canal, possibly by illegal fishing; a pair of anglers were seen fishing in the canal in the location where this fish was located prior to its disappearance. An age-3 female (CB0) tagged at the dam could not be relocated because the frequency of her transmitter coincided with that of strong local interference. A large, age-4 male either died or dropped its transmitter immediately below the dam, as the transmitter remained at the same location from commencement of flow until the expiration of the transmitter. A radio-tagged age-3 female (CC4) was seen in poor condition in the shallow water next to the bank 0.8 km below the outlet a week after the initiation of flows. The transmitter was no longer in the fish. The transmitter signal was detected from the location where it was dropped (2 km below the reservoir) until its battery failed about 90 days after implantation.

Four of the remaining five fish implanted with transmitters close to the dam moved downstream shortly after flow commenced, two weeks after implantation. Two age-3 males, CJ6 and CB6, were both found about 6.4 km downstream the morning after flows began (Figures 1, 2); a week later they were located together 9.6 km below the reservoir. On May 18, over two weeks after beginning of canal flow, CJ6 was located 11.2 km below the

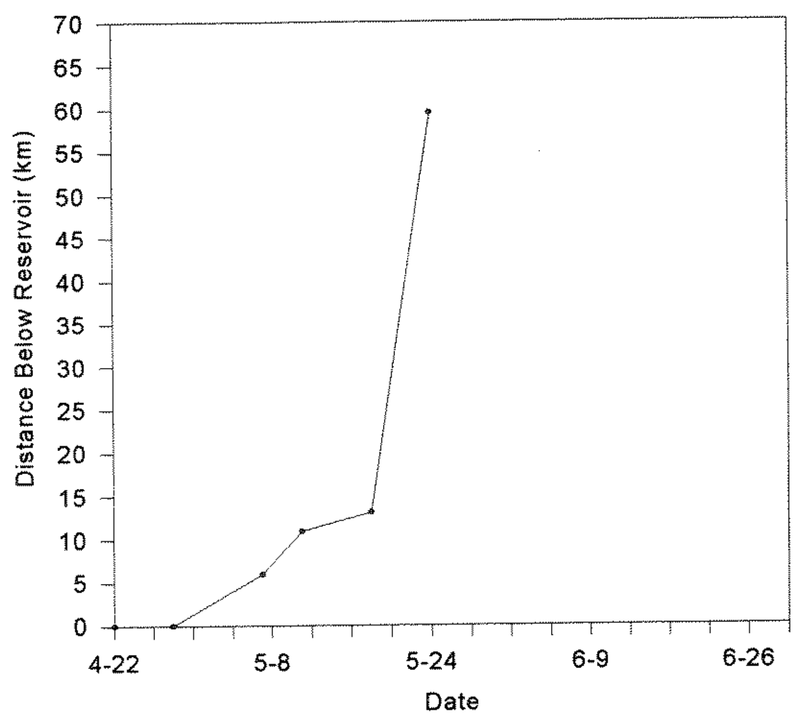

Figure 1. Movements of grayling CJ6 (49.302) during spring 1994 in Sunnyslope Canal from tagging until tag expiration.

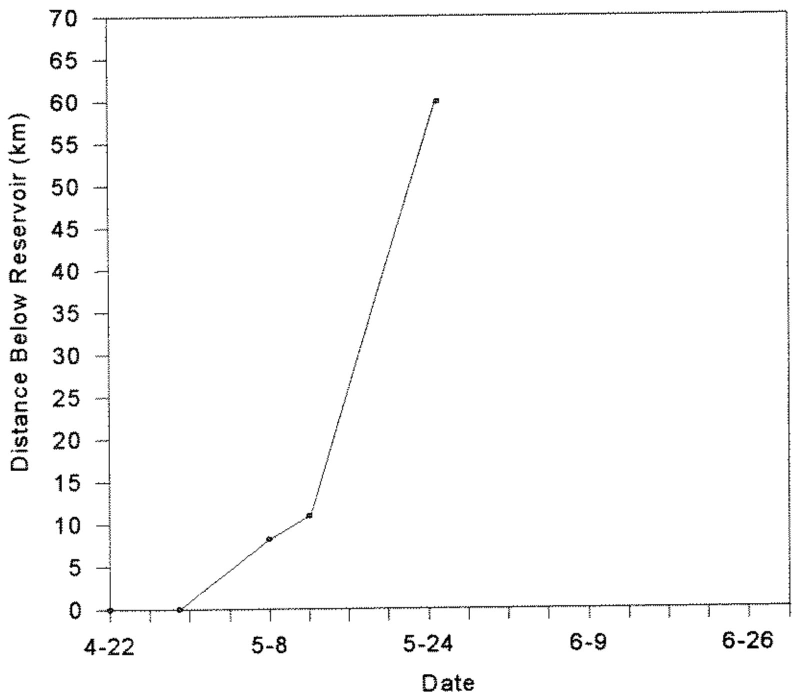

Figure 2. Movements of grayling CB6 (49.352) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

reservoir. On May 24, both fish were located 0.3 km apart some 56 km below the reservoir, and below the first three drop structures. Thereafter, I could not relocate either of these fish in surveys of the canal downstream about 65 km to the location where the canal divided into north and south portions. A three-year-old female, CJ9, also moved downstream quickly (Figure 3). Within a week of flow initiation, she moved over 16 km downstream, and a month later she reached a location about 6.4 km above the first drop. No movement was noted from this time until expiration of the radio tag about 2 weeks later. Finally, another three-year-old female, CB2, moved 8 km downstream during the first week. Three weeks later she was located further downstream, 4 km above the last drop structure ("A" drop) (Figure 4). The fish remained in the same vicinity, making only localized movements, until her tag expired.

Only one fish (CD6) tagged in the upper canal remained there until its transmitter ceased operating (Main Body of Thesis, Figure 8). This fish, an age-3 male, was relocated 24 times from initiation of canal flows until the beginning of July when all of the transmitters expired. During this 10-week period, it remained within the upper 1.6 km of the canal immediately below the dam, and was most often in the main channel adjacent to a large backwater area about 0.8 km below the outlet. At this location, fish that could clearly be identified as grayling were seen rising to feed on surface insects on numerous occasions, with several individuals rising at any one time. During the initial period after flow commenced, CD6 moved frequently, usually upstream to about 100 meters below the dam where it would hold for one or two hours, and then back downstream. Its movements became reduced and more localized from the beginning of June.

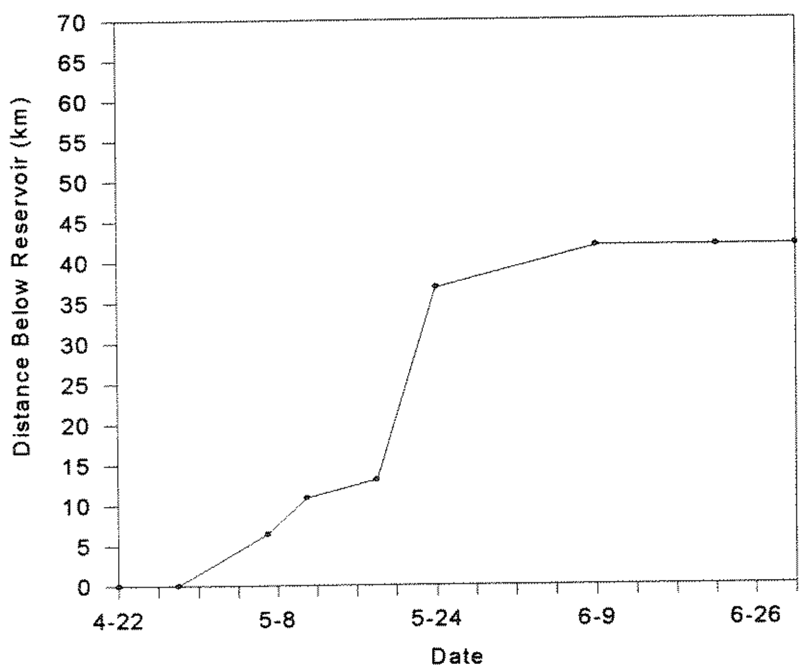

Figure 3. Movements of grayling CJ9 (49.228) during spring and summer of 1994 in Sunnyslope Canal from tagging until tag expiration.

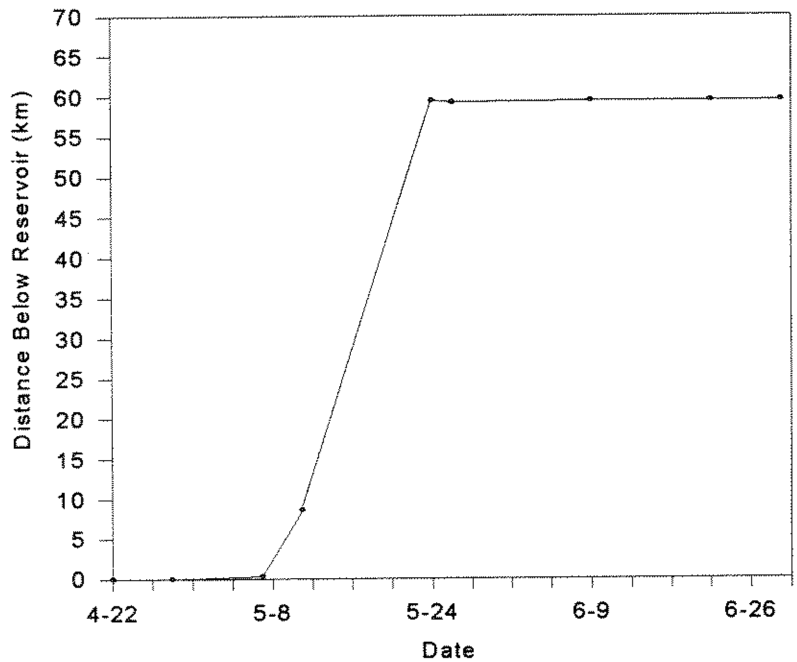

Figure 4. Movements of grayling CB2 (49.128) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

Neither grayling (F08, an age-2 female and F12, an age-4 female) tagged at Upper Turnbull (UTB) drop structure, 50 km below the reservoir (Main Body of Thesis, Figure 3), remained in the section of canal between UTB and Lower Turnbull (LTB). A week after flows began (14 days after implantation of the transmitters), both fish were 0.8 km below the drop (Figures 5,6). F12 was never relocated. Three weeks later, F08 was 3.2 km below the drop and 0.3 km above LTB. A month after flow commencement, the same fish was located in the settling pool of LTB. One week later, its location shifted to 100 m downstream, where it remained until transmitter failure. All four fish tagged at the second drop (Lower Turnbull) (Main Body of Thesis, Figure 3) moved downstream over the third drop structure (the Nine-foot drop) shortly after flows began. Within one week, one fish, CJ0 (an age-2 female) had passed over the Nine-foot drop (Figure 7). The other three fish (CH5 and CH6, both age-3 males, and CJ1, an age-2 female) passed over this drop within two weeks (Figures 8, 9, 10). From May 18 until its radiotag expired, CJ0 was located beneath a bridge one mile below Nine-foot drop. CJ1 moved within two weeks of the beginning of flows to a location 0.5 km above the fourth drop ("A" drop). This fish was located in the same locale on an irregular basis on subsequent dates, and the signal was very weak. Both males continued moving downstream. CH6 was relocated in the north fork of the canal just beyond the headworks where the canal divides into north and south forks (about 65 km below the reservoir), and CH5 was located in the stretch between the "A" drop and the split in the canal (Figures 9, 10).

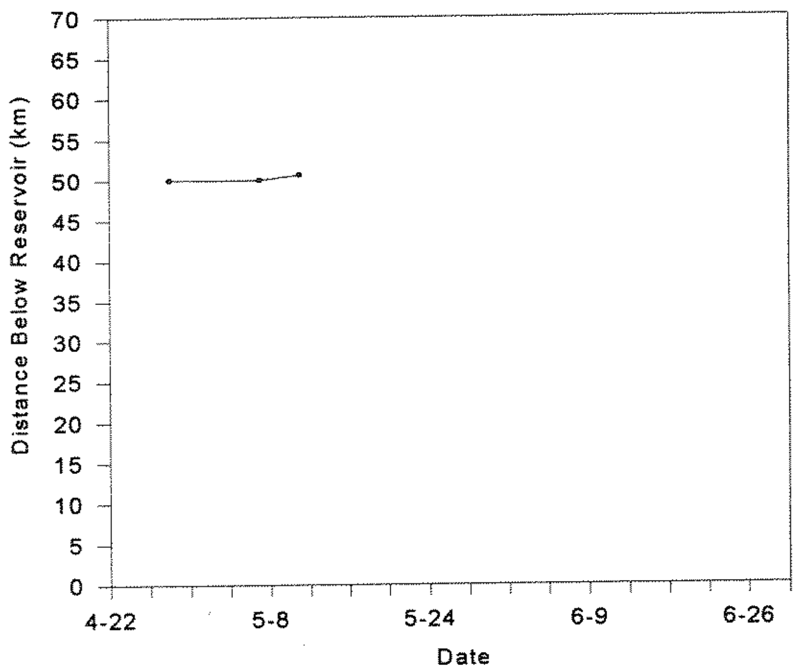

Figure 5. Movements of grayling F12 (49.203) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

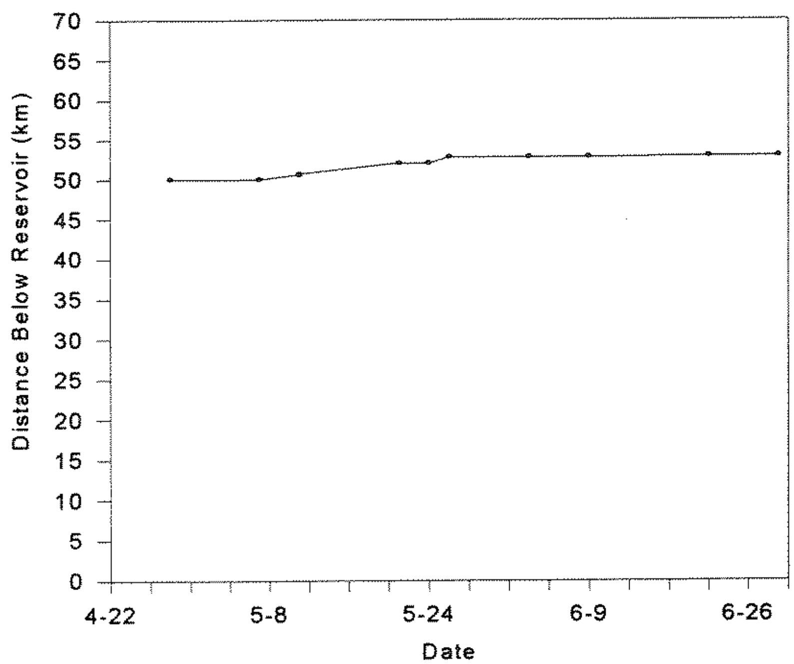

Figure 6. Movements of grayling F08 (49.177) during spring of 1994 in Sunnyslope Canal from tagging until loss of contact.

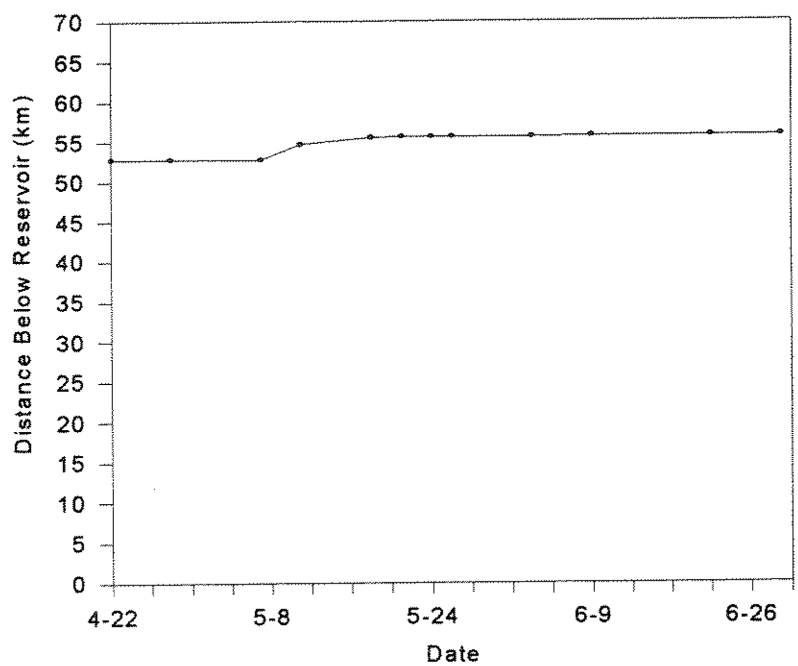

Figure 7. Movements of grayling CJ0 (49.277) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

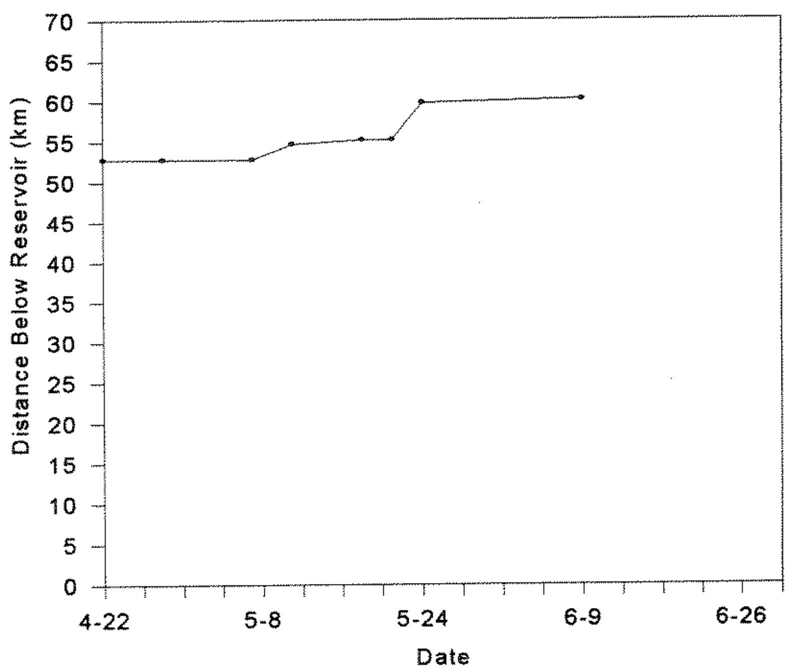

Figure 8. Movements of grayling CJ1 (49.327) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

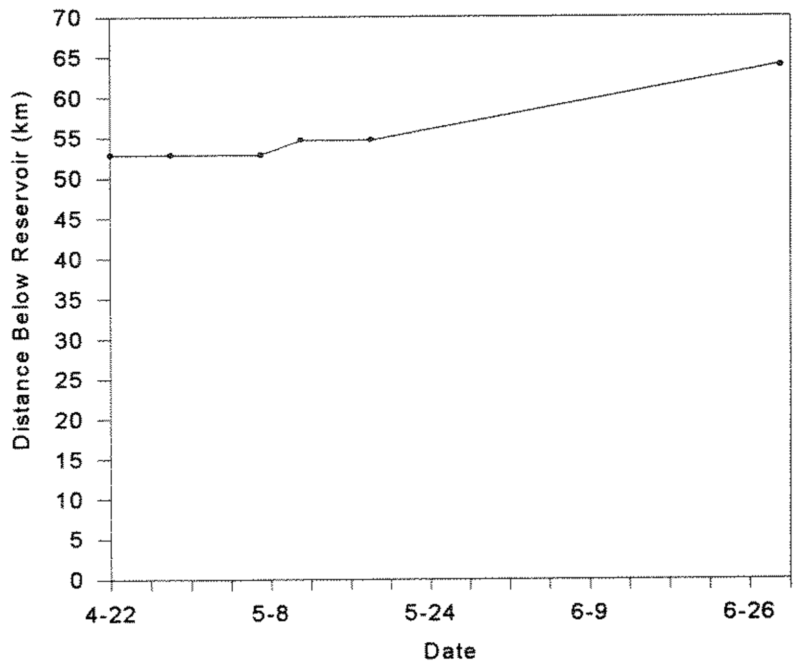

Figure 9. Movements of grayling CH5 (49.003) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

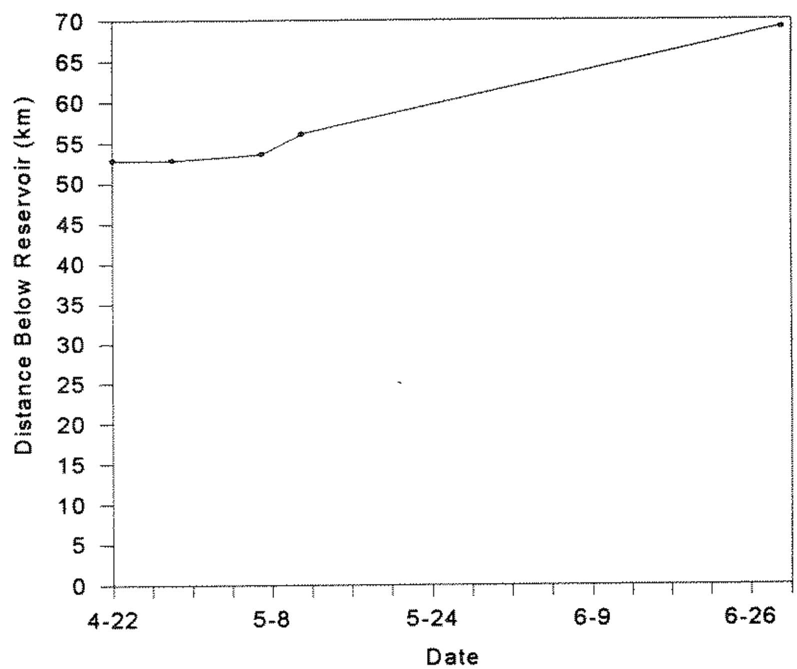

Figure 10. Movements of grayling CH6 (49.103) during spring and summer 1994 in Sunnyslope Canal from tagging until tag expiration.

Individual Grayling, 1995-96

Of the six male grayling tagged in spring 1995, three were found dead or had dropped their tags within five weeks. An age-4 fish (CJ4) tagged on April 13 moved downstream 9.4 km in the first four days after flows began on April 23, and was at this location after the canal was temporarily shut off on May 5 (Figure 11). The decomposing carcass of the fish was located on May 19, with its transmitter still inside. Its incision was completely healed and the sutures were intact, and the cause of death was not evident.

An age-4 grayling (F58) tagged on April 20 moved downstream 7.4 km within ten days of beginning of canal flows (Figure 12). After canal shutdown two days later on May 5, the fish moved upstream to a location 5.6 km below the reservoir. On May 7, it was 1 km further upstream and by May 16, was 3.7 km below the reservoir. The following morning, May 17, the fish was seen 0.2 km farther upstream, in poor condition near the surface. The fish had a mottled appearance and reacted slowly to any nearby disturbances. On May 18, the signal remained at the same location, but the fish could not be seen. The area was seined, but the fish was not recovered and no carcass was found. The canal flow was restarted on May 20, and the transmitter remained in this location until it expired about August 20.

An age-4 grayling (F43) tagged on April 14 moved 9.4 km downstream the first four days after flows began (Figure 13), 11 days after being tagged. On May 2, the fish was 8.6 km below the reservoir. After the canal was shut down on May 5, the fish moved upstream, and was 4.6 km below the reservoir by May 11. The tag remained in this location until its failure 122 days after tagging. No carcass was found at this location, and

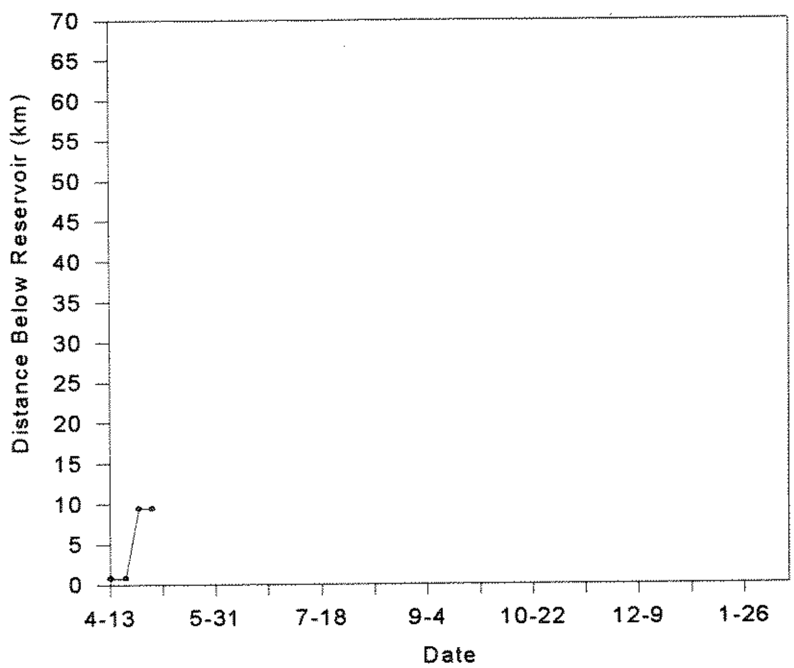

Figure 11. Movements of grayling CJ4 (49.494) in Sunnyslope Canal during spring 1995 from tagging until death.

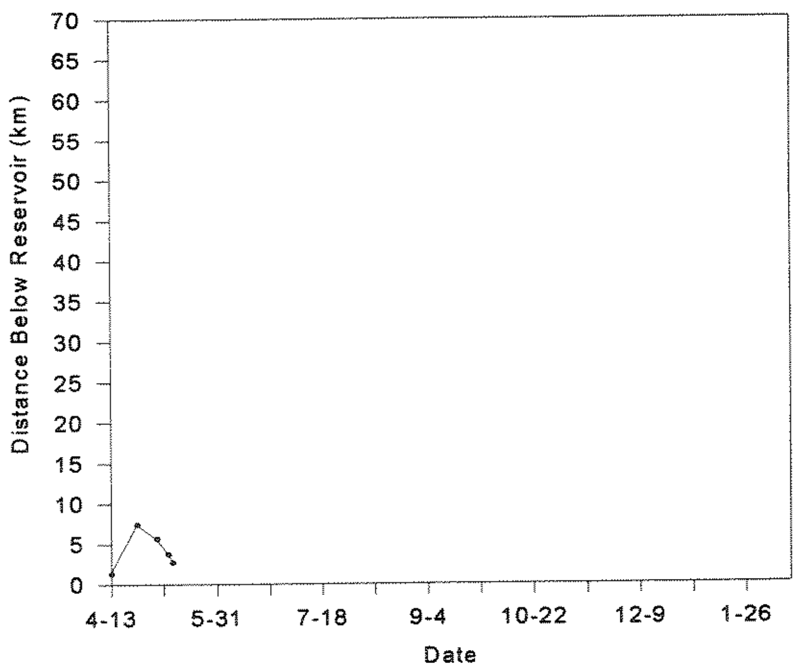

Figure 12. Movements of grayling F58 (49.553) in Sunnyslope Canal in spring 1995 from tagging until assumed death.

seining at the site before canal flow resumed (May 18) captured no grayling, indicating that the tag was dropped before that time.

Two grayling (F42 and F57) exhibited movements within 9 km of the reservoir for four to five weeks after flows began and may have participated in spawning. An age-4 male (F42) was tagged at April 13, 1.3 km below the reservoir (Figure 14). The fish remained in this location until canal flows began on April 23, at which time it moved upstream 0.5 km (to 0.8 km below reservoir). On May 2, the fish was farther upstream, 0.2 km below the reservoir. A week after the temporary shut-down began on May 11, it moved back downstream to 0.6 km below the reservoir. On May 16, this fish was located at 3.7 km. At both of these last two locations, F42 was in the proximity of another radio-tagged male, CA3 (Main Body of Thesis, Figure 9). On May 18, F42 moved upstream to 1.3 km below the reservoir to the pool 0.25 km below the location where grayling were seen spawning on May 17 and 18. The fish remained at this location until the canal flow was restarted on again May 20. F42 moved upstream to 0.2 km below the reservoir that same day, and was found there with two other telemetered males through May 23. On May 30, this fish was located 19.4 km below the reservoir. No distinct movements were noted from this location at any time from May 30 until the canal was turned off; the transmitter remained at this location after the canal dried up, indicating that this fish had died sometime around May 30.

Another age-4 male (F57) was found 1.3 km below the reservoir on April 20. On May 2, shortly after canal flow started, this fish was located 4.3 km below the reservoir (Figure 15). On May 11, one week after the canal flow was shut down, F57 moved upstream to 2.3 km. On May 16, this fish was at 1.1 km, and was observed holding a territory and engaging

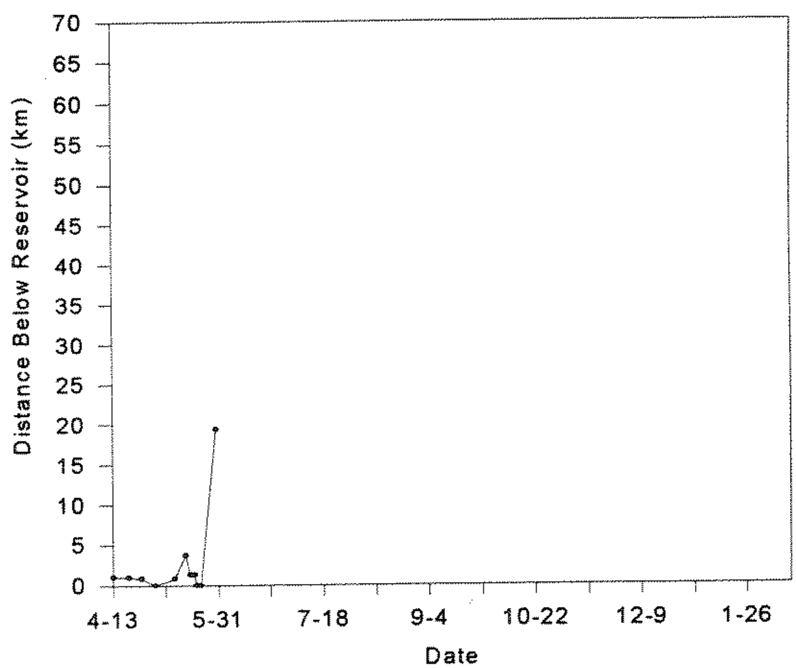

Figure 14. Movements of grayling F42 (49.494) in Sunnyslope Canal during spring 1995 from tagging until assumed death.

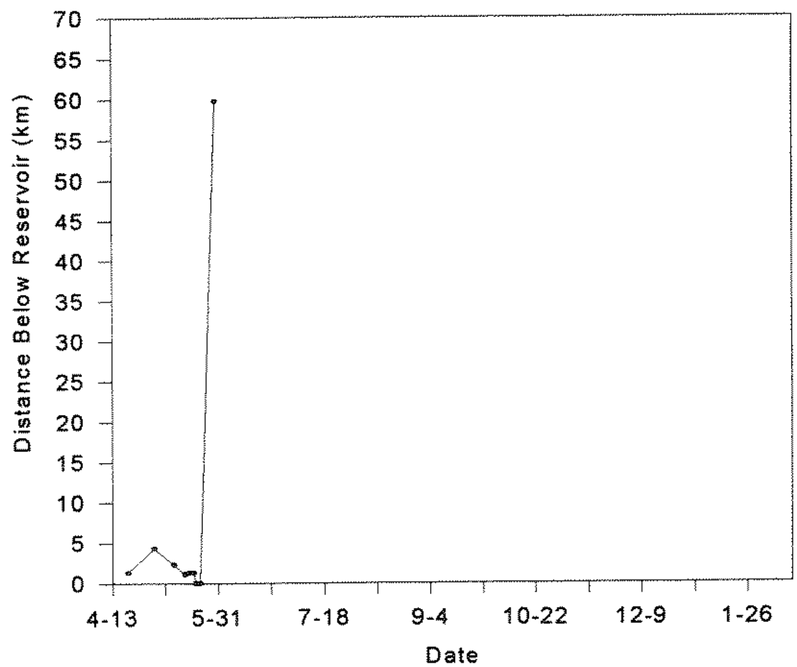

Figure 15. Movements of grayling F57 (49.594) in Sunnyslope Canal during spring 1995 from tagging until death.

in agonistic displays with other males at the base of a riffle where spawning was occurring. On May 18, this fish was in the first major pool downstream of the spawning riffle (about 250 m) with another male, F42. The fish remained in this location on May 20, and was joined by the other telemetered males, F42 and CA3 (Main Body of Thesis, Figure 9). After the canal was restarted this same day, F57 was located with these same males within 200 m of the reservoir outlet until May 23. F57 was located, dead, 59.8 km below the reservoir on May 30.

Another age-4 male grayling (CA3), tagged on April 20, 1995 at 1.3 km, was tracked for over a year, throughout two spawning periods and the interim summer and winter. After canal flow began in 1995, it was located at 5.6 km until May 3 in an area which is dry before flow begins (Main Body of Thesis, Figure 10). On May 11, after the canal was shut down, CA3 moved upstream to 0.8 km. By May 16, the fish was 3.7 km below the reservoir and remained there through May 18. On May 16, CA3 was in the company of another radio-tagged male, F42. CA3 moved to 1.3 km on May 20, and was in the company of males F42 and F57 (Main Body of Thesis, Figure 10). After canal flow restarted on May 20, this fish joined the other two males just below the reservoir outlet, where they remained through May 23. On May 30, CA3 was at 2.4 km, but moved back upstream to the reservoir outlet by June 1. On June 7, this fish was at 5.6 km, and remained here until June 27, when he moved slightly upstream to 5.5 km. CA3 remained here until the canal was shut down on September 22, and by September 26 it had moved up to 1.3 km. This fish remained at this location through the winter. After flows began on May 8, 1996, CA3 moved downstream to the same position it had occupied the previous summer (5.6 km). In the afternoon of May 14, he moved upstream to the location where grayling were witnessed spawning the previous spring (at 1.1 km). This fish remained at this location through May 18, when he moved to 5 km where he remained through June 10.

An final age-4 male (CC9) was tagged on July 5 at 2.6 km. On July 26, this fish was at 3.7 km, and by July 30 was located at 10.7 km where it remained after canal shutdown. This location is a large lake-like pool during flow conditions, and retains water for quite some time after cessation of flow. However, due to the porous substrate at this location, seepage empties this pool by late autumn or early winter. On October 10, the pool was about 200 m^2. At this time, 20 age-1 grayling were captured by seining but CC9 was not. Ice cover formed over this pool about October 12, and by November 16 this pool was reduced to about 20 m^2 and all remaining fish were dead, apparently from anoxia. Twenty-seven dead grayling were recovered by dip-netting carcasses from the pool. CC9 was not among them. The transmitter signal came from the pool at that time, but was located 200 m southeast on December 5. Therefore, it is not known whether this fish was killed as a result of anoxia, or had died earlier.

Two female grayling were tagged November 16, 1995 to monitor movements throughout the winter and subsequent spring. One age-4 female (F30) was tagged at 3.7 km and remained at this location throughout the winter (Figure 16). The other (HB1), an age-3 fish, was tagged at 0.8 km and was subsequently relocated there twice. However, the transmitter was not detected after December 5. Ice formation over the pool made it very unlikely that the fish would have moved out of the pool, and transmitter failure may have occurred.

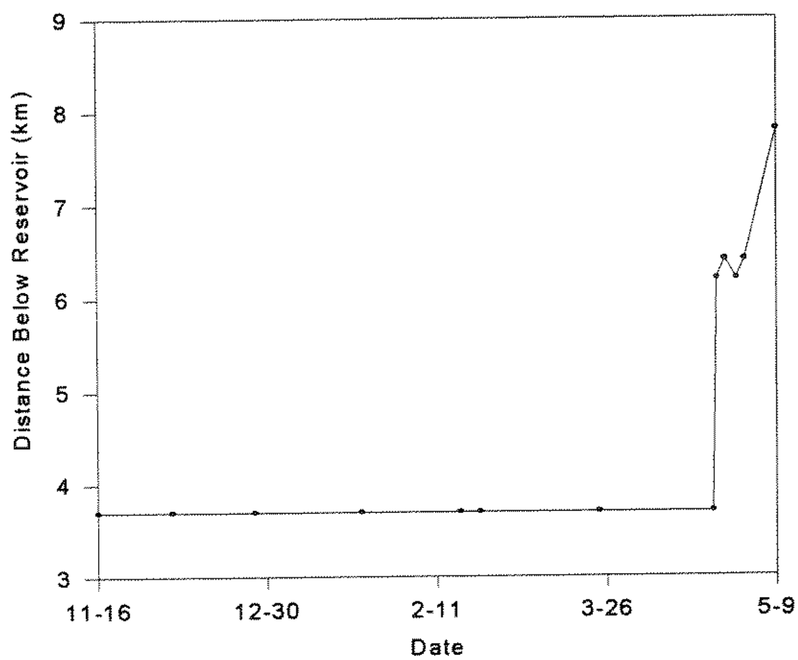

Figure 16. Movements of grayling F30 (49.628) in Sunnyslope Canal during winter 1995-96 and spring 1996 from tagging until loss of contact.

After flows began on May 8, 1996, F30 moved downstream to 6.3 km, where it remained with localized movements until it moved downstream to 7.8 km on May 21. This was the same location where it had been captured by angling the previous summer (on August 9).

APPENDIX C

INCIDENTAL OBSERVATIONS OF GRAYLING AT TUNNEL LAKE

Incidental Observations of Grayling at Tunnel Lake

Tunnel Lake (elevation 1368 m), a small lake located about 6.4 km southwest of Pishkun Reservoir (Figure 2 in Study Site Description for the canal), contains a population of grayling which originated from Sunnyslope Canal. This lake has no outlet, but has a short (180 m), intermittent inlet stream. This inlet begins flowing, apparently through seepage when the Pishkun Supply Canal is filled in the spring, and continues for some time after this canal is shut off.

Tunnel Lake has been repeatedly, but sporadically, stocked with grayling taken from the canal drop structures near Fairfield. These stockings began in May, 1985 and continued until April, 1993, with a total of 1395 grayling being moved (Table 1; Hill pers. comm.). Most of these grayling were age 1, with a few age-2 and older fish also being stocked. Although Tunnel Lake has not been monitored, reports by anglers suggest grayling are very commonly caught by angling. Spawning by these fish has not been previously observed, and reproduction was assumed to be limited by

Table 1. Grayling transferred to Tunnel Lake from Sunnyslope Canal, 1985 to 1993.

Date	Number
May 2, 1985	184
Sept 24, 1986	725
April 30, 1987	100
May 6, 1991	365
April 23, 1993	16

the short inlet stream, which contains little gravel/cobble size substrate. For this reason, FWP stocked grayling from Somers Fish Hatchery into the lake in the summers of 1993 and 1994 to sustain the recreational fishing which had developed.

Observations at Tunnel Lake were made for two reasons:

(1) to provide insight on spawning and fry behavior of canal grayling, because many of these grayling originated from the Sunnyslope Canal and;

(2) to evaluate whether canal grayling could be captured in breeding condition from Tunnel Lake, if the lake were to be used to maintain a brood stock in the future.

Methods

The inlet stream was visually searched for the presence of spawning fish. Measurements made of observed spawning sites including water depth, velocity, and substrate. Eggs were collected from spawning sites by kick sampling with a dip net to confirm spawning success.

The inlet stream was also visually searched for the presence of post-swimup fry. Measurement of habitats occupied by Tunnel Lake grayling fry were taken in the same manner as described in the methods section for the canal.

Results

Spawning of grayling in Tunnel Lake was confirmed by observation of fish in the spawning stream, and by collection of fertilized eggs from the stream. Grayling were observed spawning in the inlet to Tunnel Lake on May 23, 1995, when the water temperature was 12.2 °C. At this time, two males and six females were seen in the stream. Eggs collected in the stream were still in early stages of development, indicating that they had been recently spawned. Grayling were observed in the stream until May 27;

however, some spawning may have occurred after that date as newly spawned fertilized eggs were found in the stream on May 31, when the water temperature was 19 °C. Only low numbers of spawning grayling were ever seen in the inlet, with the most being the original number of eight.

Grayling were also observed spawning in the Tunnel Lake inlet on the evening of May 20, 1996, when three males and four females were in the stream (temperature, 6.7 °C). Spawning was confirmed when I searched for young over three weeks later, on June 13, and found swimming fry.

The inlet stream is about 180 m long, but the section of stream extending from 74 to 144 m from the lake was the only portion where spawning was observed or where eggs were collected. Below 74 m the stream bottom is predominated by fine substrate (<2 mm); above 114 m the stream becomes very shallow (<5 cm deep).

Table 2. Physical characteristics of six observed Arctic grayling spawning locations in the inlet of Tunnel Lake.

	Width (cm)	Depth (cm)	Velocity (m/s)
Mean:	9.85	39	0.28
(SD):	(5.72)	(6.7)	(0.06)
(Range):	(0.85-16.8)	(30-47)	(0.18-0.33)

Spawning sites were predominately gravel (33%) although pebble and cobble substrates were important (20 and 24% respectively (Table 3). Further, the sites were very variable in composition. One site was predominately (50%) bedrock; viable eggs were found in the substrate around the bedrock, and downstream from, but not on, it.

Table 3. Percentage of substrate sizes (mm) at six observed spawning sites in the inlet to Tunnel Lake.

	<2	2-10	10-50	>50	Bedrock
Mean:	16.7	20	33	24	8
(SD):	(29)	(15.8)	(20.1)	(22.2)	(20.4)
Range:	(0-75)	(5-50)	(5-65)	(0-60)	(0-50)

Swimming grayling fry were observed in the inlet to Tunnel Lake on June 14, 1995. With one exception, all newly-swimming fry grayling in Tunnel Lake were within 50 m of the lake. The stream at this location contained areas with slow velocity, unlike the majority of the stream above. The average focal point velocity of the newly swimming grayling fry was 0.07 m/s (Table 4). The first week, Tunnel Lake grayling fry were in the upper third of the water column. A week later, the mean focal point velocity decreased, but the range of values was about the same as the first week. While focal depths decreased the second week, grayling again were in the upper third of the water column.

All fry observed in 1996 were in the shallow, sandy depositional area where the stream enters the lake. The presence of fry at only this location likely resulted from the stream no longer containing areas of slow current before its confluence with the lake.

Table 4. Habitat use parameters of grayling fry in Tunnel Lake, Montana, in summer, 1995.

Date	Length (mm)	Total Depth (cm)	Focal Depth (cm)	Focal Velocity (m/s)	Distance to Cover (cm)
6-14	15	30	10.4	0.07	2.9
(s.d.)	(1)	(10.5)	(3.5)	(0.009)	(7.7)
range	14-16	29-31	9-19	0.04-0.08	0-22
n	3	15	15	15	15
6-21	16.2	33.7	19	0.05	18.6
(s.d.)	(4.1)	(15.7)	(11.2)	(0.009)	(9.8)
range	13-23	24-59	13-40	0.04-0.07	0-25
n	5	10	10	10	10
7-6	32	44	13.2	0.08	88
(s.d.)	NA	(1.7)	(2.3)	(0.02)	(21.5)
range	NA	(43-47)	(7-14)	(0.07-0.13)	(34-99)
n	1	9	9	9	9

Discussion

Like Sunnyslope Canal fish, Tunnel Lake grayling seem to wait for suitable flows in the inlet stream before beginning spawning movements. This likely occurs because flows before mid-May are insufficient for grayling to even enter the stream.

Observations at Tunnel Lake offer further evidence supporting the wide range of substrates used by grayling for spawning. While the predominate substrate (33%) at spawning locations was between 10 and 50 cm, substrates 2-10 cm (20%) and >50 cm (24%) were also represented. Further, one site was mostly bedrock (80%).

Tunnel Lake grayling fry also used water velocities similar to those described for other populations (Kratt 1977, Lee 1985, Deleray 1991). These fry measured 13-14 mm at swimup, and fish between 13-23 mm had focal point velocities between 0.04 and 0.08 m/s (Table 4). Fry were found in the Tunnel Lake inlet for about a month after swimup, although after the third week these grayling were observed moving between the lake and stream freely and most of the fry were at the confluence of the lake and stream.

Conclusions

The ability of the grayling in Tunnel Lake to use the short inlet stream for reproduction probably makes the present population in the lake unsuitable as a brood stock of Sunnyslope Canal grayling for at least two reasons. First, any grayling currently present that have originated from spawnings in the lake inlet may have been exposed to selection pressures for lacustrine, rather than fluvial, adaptations. Second, grayling with canal ancestory may have interbred with the fish from hatchery stockings. However, if grayling were to disappear from the lake, it would be a good location for a canal brood stock since it is close to the canal and gametes could be collected from the grayling in or near the inlet stream.

It was impossible to conclude from the behavior of the fry whether they retained any of the fluvial adaptations of Sunnyslope Canal ancestory. Since the inlet stream to the lake is so short, and lacks low velocity areas for fry to hold, they appear to be swept down to the lake at or even before swim-up.

APPENDIX D

OBSERVATIONS OF SUNNYSLOPE CANAL SPAWNING BEHAVIOR

Observations of Sunnyslope Canal Grayling Spawning Behavior

The spawning behavior of Sunnyslope Canal grayling is consistent with descriptions in reviews by Armstrong (1986), Kaya (1990), and Northcote (1995) for populations in Alaska, Montana, and Canada. As with studies reported in Northcote's review (1995), Sunnyslope Canal grayling spawned in the afternoon and evening, and continued after dark. Grayling were absent from spawning areas in the morning hours.

Male grayling in the spawning riffle established and maintained their territories through agonistic behaviour, raising and displaying their dorsal fins to each other. Often this behaviour would be followed by the dominant fish chasing and nipping at the subordinate male.

The spawning act closely resembled descriptions for Montana Arctic grayling provided by Brown (1938) and Tryon (1947). In the shallow water of the riffle, the male's dorsal fin would cause a distinctive "ripping" sound as it broke the water during vigorous vibrations accompanying the release of gametes. The vibration would continue for 10-15 seconds, and usually a plume of disturbed sediment and milt would be visible moving downstream of the fish. The substrate at these locations was visibly brighter after a spawning event, because of the cleaner undersurfaces of overturned substrate particles. Larger female fish passed by the subordinate males at the base of the riffle, moving up to the uppermost males. A particular female would often spawn with at least two different males, usually at separate times; however, subordinate males would sometimes rush in as a spawning event began, approaching the opposite side from the other male, and participate in the act. After a spawning event, the male and female would drift apart and rest for a time. Some females moved to the head of the riffle after spawning, apparently to rest.

APPENDIX E

OBSERVATIONS OF OTHER SPECIES IN SUNNYSLOPE CANAL

Observations of Other Species in Sunnyslope Canal

Fry collected in drift nets were first caught in 1994 in the following chronological sequence: grayling (June 8), perch and pike (June 15), spottail shiner and sculpin (June 22), and white sucker (June 29). The same pattern of temporal progression occurred in 1995, although specific dates differed slightly. Further, unlike in 1994, northern pike were present in drift nets throughout the 1995 sampling period. The chronological progression of their appearance aided in identification of fry.

White suckers were observed spawning in the canal May 17-20, 1995, and eggs which appeared viable were collected from one spawning location. These eggs averaged 2.76 (2.7-2.9) mm in diameter. Suckers spawned in aggregations which included one female and one to several males. Spawning was observed in pools and at the tail of one riffle. This riffle is the same one used by spawning grayling during the same period, although both species were not present in this area concurrently. Both white sucker and grayling eggs were obtained from the same location in the same sample. Both perch and sucker fry were observed in the reservoir near the outlet both years, and spottail shiner fry were also captured in the reservoir in 1995.

Grayling and other species of fish were found to be hosts of the fish leech *Cystobranchus verrilli* Meyer (identified by D. Gustafson, Montana State University). This is the first formal record of this organism in Montana. These leeches were very common on fish, especially white suckers captured during non-flow periods. In contrast, these leeches were not seen on grayling captured by angling in the summer of 1995, during canal flow.