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Reproduction, Growth, and Winter Habitat of Arctic Grayling in an Intermittent Canal

Abstract

Life history and winter habitat characteristics were determined for a population of Arctic grayling (*Thymallus arcticus*) in an irrigation canal with seasonally intermittent flow: (1) approximate locations and times of spawning; (2) growth rates; (3) numbers present in the residual pools and their survival through winter; and (4) depths and dissolved oxygen (DO) beneath ice cover of inhabited pools. Water flowed for five months from late April-early May to late September, peaking at 46-48 m^3/s and averaging 11.4°C (range 4.7-16.0). Reproduction within the upper canal was confirmed by sightings of spawning fish and observations and collections of developing embryos and newly swimming young. Spawning occurred in May, within one or two weeks after flow started. During the seven months without flow, 8 to 13 residual pools within the uppermost 6 km provided potential fish habitat. Four pools with combined length of 342 m and volume of 1487 m^3 provided the major wintering habitat during winter 1995-1996, and 76-100% of fish survived until spring in these pools. Under ice cover, mean DO ranged from 7.4 to 9.2 mg/l and mean depths from 0.26 to 0.82 m. These Arctic grayling had growth rates among the highest known among populations in Montana, but numbers of age-I and older fish in the upper canal were estimated at less than 350 in spring 1995 and 1996. The persistence of this population, unlike their disappearance from all but one stream known to have been inhabited by the species in Montana, may be related to the failure of non-native fishes to become established in the canal, together with summer water volume and temperature and availability of wintering pools.

Introduction

Reports that a population of Arctic grayling was established in an intermittently-flowing irrigation canal were in sharp contrast to the disappearance of nearly all fluvial populations in Montana. Arctic grayling were historically widely distributed in the upper Missouri River and its tributaries above the Great Falls in Montana (Vincent 1962), but have disappeared from about 95% of that historic range (Kaya 1992). The only remaining fluvial population in Montana is confined to the upper Big Hole River. Although reasons for the decline of fluvial populations are not well understood, habitat alterations—especially construction of dams and dewatering of streams through diversions—and establishment of non-native salmonids appear to have been major contributing factors (Vincent 1962; Kaya 1992).

Arctic grayling have been present in Sunnyslope Canal since at least 1971, when fish were observed by Bill Hill (Montana Department of Fish, Wildlife and Parks, pers. comm.). The population apparently originated from repeated stockings of age-0 Arctic grayling into the canal's water source, Pishkun Reservoir, from 1937 to 1943 (Kaya 1990). These fish came from a state hatchery in Anaconda, and originated as gametes collected from an introduced population in Georgetown Lake. The species has not been caught in Pishkun Reservoir since 1981 (Bill Hill, pers. comm.), and is not established upstream in the Sun River drainage. Rainbow trout (*Oncorhynchus mykiss*), white sucker (*Catostomus commersoni*), and northern pike (*Esox lucius*) were also known to be present in the canal, possibly as fish being discharged out of the reservoir. Investigations into the life history and habitat characteristics of this population of Arctic grayling were conducted to determine conditions under which these fish have been able to persist in the canal.

Study Site

Sunnyslope Canal (Figure 1), constructed and managed to provide water for irrigation, is located in Teton County in west central Montana. Its source, Pishkun Reservoir, is at an elevation of 1341 m and receives water diverted from the Sun River.

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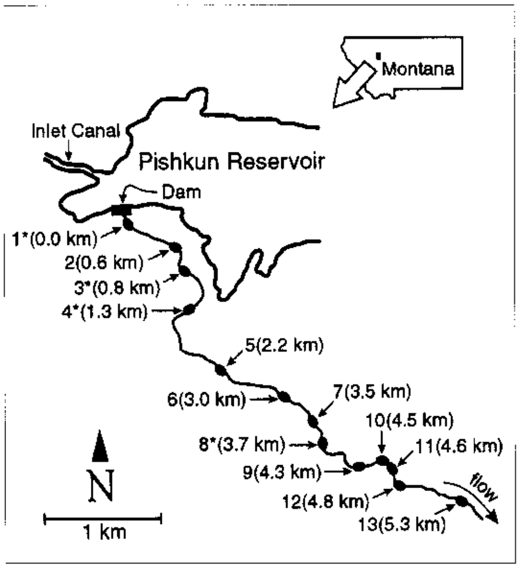

Figure 1. Locations of residual pools in upper Sunnyslope Canal when water is not flowing, numbered in downstream sequence. Distance from the canal's origin at Pishkun Reservoir is indicated by (km). Major wintering pools are identified by *. Lengths of pools are not to scale, and widths of pools are exaggerated to identify their locations. Actual pool widths are narrower than the canal.

The Sun River is a tributary of the upper Missouri River and originates in east slopes of the Rocky Mountains. Canal flow is controlled by the local Greenfield Irrigation District (GID), and is stopped for about seven months of the year. A steel screen at the dam (2.5 cm mesh) prevents larger fish from being discharged from the reservoir into the canal. The canal is from 24 to 32 m wide and from 2 to 3.5 m deep during peak flows. The canal has a sinuosity (canal length/straight-line-distance) of 1.2 and a gradient of 0.002% between the reservoir and the first drop structure 50 km downstream. The drop structures are concrete flumes angling steeply into plunge pools and are impassable barriers to upstream movements by fish. The canal is formed from rocks and soil of the regional glacial till, except for a 1.6 km concrete-lined section 9 km below the reservoir. The canal bed has a relatively smooth bottom and steeply sloping sides typical of an artificial ditch and lacks the habitat diversity of a natural stream. This study focused on the upper 6 km of the canal, where irregularities on the canal bottom retained residual pools of water after flow was terminated in the fall. The remainder of the canal goes dry before resumption of flows the following spring, except at the plunge pools below the drop structures.

Methods

Water Flow and Quality

Physical and chemical data were obtained during the periods of canal flow and from residual pools during non-flow periods, from April 1994 to April 1996. Data on daily discharge volumes were obtained from the irrigation district, which monitors a flow gauge near the dam. Surface temperatures were measured with a mercury thermometer. At two to three week intervals during the period of canal flow in 1995, dissolved oxygen (DO), pH, and alkalinity were measured with a field kit (Hach Chemical Company), and specific conductance with a YSI (Yellow Springs Instruments) Model 3000 conductivity meter. During fall 1995 residual pools were seined to determine which contained Arctic grayling (methods to be described). At least once monthly during winter 1995-1996, holes were drilled through ice cover over pools known to be inhabited by Arctic grayling, and specific conductance, DO (with a YSI Model 54 meter), ice thickness, and water depth beneath the ice were measured. Ice and water depths were measured with a weighted, calibrated line. On 8 March 1996 residual pool lengths, widths and depths were measured at 50 m intervals to estimate water volumes. The volume of each pool was estimated as [(length) x (maximum depth along the thalweg) x (0.5 average width)].

On 11 July 1995, water depths and velocities were measured at three locations known to be occupied by Arctic grayling, where numerous individuals could be seen feeding at the surface on drifting insects. Two locations were at km 0.8, about 50 m apart, and the third was at km 3.7 (Figure 1). At each site a calibrated line was secured across the canal and measurements were taken across the transect from a canoe, at 1 m intervals within 3 m of either bank and at 2 m intervals at other points across the transect. Velocities were measured with an electronic current meter (Montedoro-Whitney Company) with its sensor attached to a weighted, graduated cable. Measurements were taken at depths of 0.5 m intervals from the surface to the bottom.

Arctic Grayling Age, Size Distribution, Growth and Abundance

Fish were sampled primarily by seining, during March and April before canal flows began and again in September and October after canal flows ended. Fish were seined using a barricade net and a seine, each 30.5 m in length and with 6.3 mm mesh. A few Arctic grayling were also sampled by angling during canal flows. Total length of captured fish was measured to the nearest mm, and weight to the nearest gram. For length-frequency distributions, seined fish were separated into categories to the nearest cm. Age-1 and older fish were marked individually with a coded alphanumeric visible implant (VI) tag inserted into the clear tissue behind the eye (Haw et al. 1990). In 1994-95, VI-tagged individuals were also marked with fin clips so that fish could be identified as recaptures if VI-tags were not retained. Of 73 grayling recaptured from this group, 72 (99%) retained their VI-tags. Scale samples were taken from for age determinations from the area between the posterior edge of the dorsal fin and the lateral line (Jearld 1983). Ages were determined by analyzing impressions of scales on cellulose acetate slides, with the aid of a microfiche reader at 48X magnification (Jearld 1983). Lengths were back calculated using the Weisberg method (Weisberg and Frie 1987, Weisberg 1993a, 1993b). Assigned ages were verified by comparisons of independent readings by both authors, and also by recaptures of individually marked fish. Ages assigned by annuli and estimated lengths at annuli were verified by comparisons of changes in scale morphology vs. changes in body lengths indicated by length-frequency distributions and changes measured in 30 age-3 to age-7, individually marked, VI-tagged fish recaptured a year apart during spring samplings of 1994-1996.

Numbers of Arctic grayling present within the upper 6 km of canal that retained residual water were estimated during spring of 1995 and 1996. All 13 pools present were seined as were five deeper reaches between some of the pools. Other reaches between pools were very shallow, from a few cm to less than 0.5 m. Population abundance was estimated from mark and recapture data using Bayesian statistical procedures (Gazey and Staley 1986) incorporated into a computer program written by D. L. Gustafson (Montana State University, Environmental Statistics Group). Separate estimates were made for age 1 and for age 2 or older fish.

Winter Survival

Minimum survival through the winter in residual pools was estimated as the difference between numbers of fish marked in a pool prior to ice cover and number of marked fish recaptured during spring after ice cover melted but prior to canal flows. To provide an estimate of recapture efficiency and winter survival, 22 age-0 fish were moved from a drying pool below the study reach in fall 1995, VI-tagged, and added to the fish present in pool 8.

Spawning

Occurrence and time of spawning by Arctic grayling in the canal were investigated three ways: examining larger (300 mm or more) specimens captured during spring prior to water flow, sampling for age-0 young with drift nets, and visually surveying for the appearance of age-0 young along the canal margins. The gender of larger Arctic grayling was determined by the appearance and size of the dorsal fin, which is longer, higher, and more colorful on males than females. We subjectively evaluated whether females captured during spring prior to canal flow appeared to be carrying maturing eggs (abdomen distended) or were spent (abdomen soft and not distended).

Age-0 Arctic grayling were sampled with drift nets from early June to the end of the month. Nets were set at least three days per week, remained set for 24 hours each day and were examined at daybreak and nightfall. In 1994 three drift nets were placed at a bridge 5.8 km from the dam, and in 1995 two nets were placed at the bridge and two nets 100 m below the dam's outlet, on each side of the canal. At both dam and bridge, nets were suspended in the current at depths of about 1.0-1.5 m, within 1-2 m of the bank. The third net at the bridge in 1995 was suspended at midstream near the surface. Each net was 0.9 m in diameter, 1.5 m in length, had mesh size of 1 mm, and had a removable screened collection cup.

Visual searches for Arctic grayling fry were conducted from 4 June to 28 July 1994 and 1 June to 11 July 1995. Searches were focused on shallow, slower-moving water close to shore where newly swimming Arctic grayling in streams are typically present (Nelson 1954; Northcote 1995). Searches were concentrated within the uppermost

6 km of canal in both years, but also extended to 60 km in 1995. In 1995 the upper 60 km of canal was divided into five sections, 1 km subsections were randomly selected within each section, and three or four 100 m segments within each subsection were searched. Arctic grayling fry were identified by their size, shape, and swimming movements; their identities were confirmed by capturing samples with a dip net.

Other Species

Observations on other species were incidental and limited to specimens captured or seen during sampling for Arctic grayling. Specimens were identifiable as age-0 young from their initial appearances during canal flow and as they increased in size through summer and fall. Whether fish older than age-0 were adult in size was based on average growth rates and ages at maturation for the species in Montana (Brown 1971). The stomach contents of all captured northern pike larger than fry were examined to evaluate northern pike predation on Arctic grayling.

Results

Water Flow and Quality

Water was released from the reservoir into the canal from 6 May to 14 September in 1994 and from 22 April to 22 September in 1995. Flows peaked in both years at 46 to 48 m^3/s during June and early July (Figure 2). Flows were interrupted for 15 days in 1995, when discharge began on 22 April, stopped on 5 May when irrigation needs were suspended after heavy rainfalls, then started again on 20 May. During summer flows, Arctic grayling that subsequently overwintered in residual pools were captured by angling up to 9 km below the reservoir. Measurements on 11 July 1995 across three transects, at sites where numerous, larger Arctic grayling (numbers and sizes not determined) were observed feeding on surface insects, provide examples of depth and velocity profiles in the canal during summer flows (Figure 3). With canal flow of 28.5 m^3 the maximum

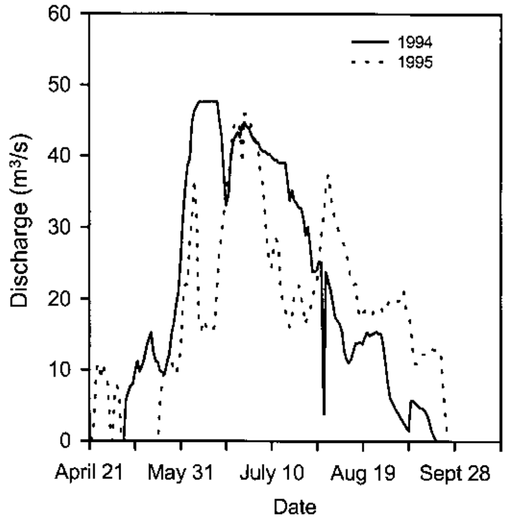

Figure 2. Discharge profiles for Sunnyslope Canal, 1994-95.

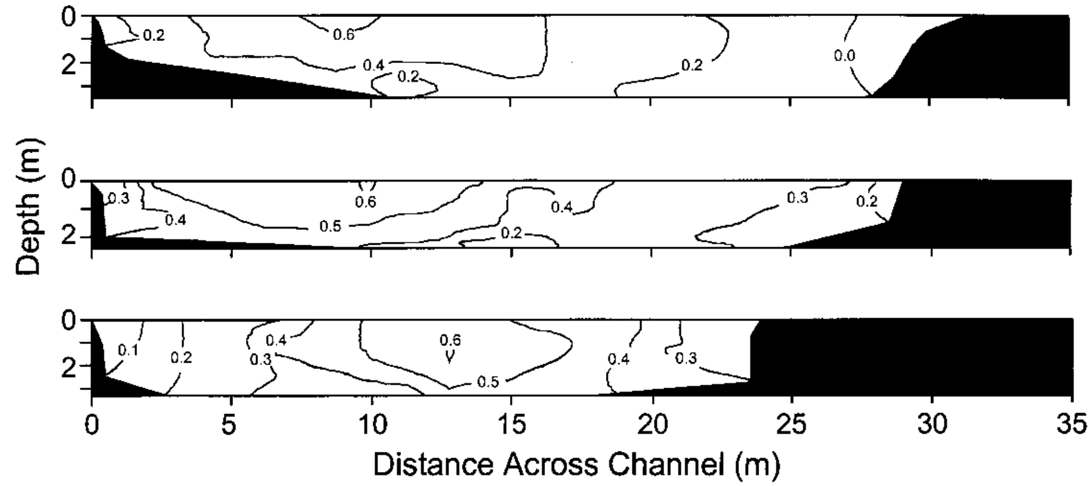

Figure 3. Velocity profiles (m/s) in the Sunnyslope Canal on 11 July 1995 across three transects through areas occupied by Arctic grayling. Canal flow on this date was 28.5 m^3/s. The upper two sites were about 50 m apart at km 0.8, and the lowest site was at km 3.7.

TABLE 1. Lengths and estimated volumes on 4 March 1996 of the 8 pools in upper Sunnyslope Canal which did not freeze to the bottom during the winter of 1995-1996, and numbers of Arctic grayling marked during fall 1995 and recaptured during spring 1996 in the pools.

Pool No.	Length (m)	Volume (m^3)	Number of Fish: Marked in Fall	Number of Fish: Recaptured in Spring	% Recaptured
1	217	160	25	19	(76.0)
2	93	50	0	0	(0.0)
3	146	244	9	8	(88.9)
4	250	263	33	30	(90.9)
5	213	198	0	0	(0.0)
6	64	113	0	0	(0.0)
7	88	167	0	0	(0.0)
8	700	980	7	7	(100.0)

TABLE 2. Mean and (range) of physical and chemical parameters during ice cover, of the four pools in Sunny Slope Canal known to be inhabited by Arctic grayling through the winter of 1995-1996: temperature (C), specific conductance (µmhos/cm), dissolved oxygen (DO, mg/l), ice thickness (cm), and water depth beneath ice cover (cm). Except for Pool 1, which had mean depth <0.5 m, chemical measurements presented were taken near the pool bottoms. Measurements taken at the tops of pools 3-8 near the ice surface generally had lower temperatures, higher DO, and lower specific conductance than near the bottom. Locations of pools are indicated on Figure 1.

Pool	Temp. C	Specific Conduct.	DO mg/l	Ice cm	Water cm
1	2.5 (1.1-3.3)	372 (366-380)	9.2 (8.2-11.0)	8.3 (0-15)	26.3 (11-40)
3	3.2 (1.9-4.5)	462 (275-425)	7.9 (6.5-8.2)	44.3 (30-58)	76.7 (70-90)
4	3.6 (3.0-4.1)	458 (447-470)	7.4 (6.5-8.2)	27.3 (20-35)	58.7 (50-63)
8	2.6 (0.7-4.1)	591 (450-786)	7.8 (4.7-9.1)	32.0 (32-38)	82.5 (80-90)

velocities were 0.5-0.6 m/s, and maximum depths 3.5 m. During the flow period of 1995, mean values for water quality measurements were: temperature 11.4°C (4.7-16.0), specific conductance 285 µmhos/cm (222-365), alkalinity 133 mg/l $CaCO_3$ (112-146), DO 12.2 mg/l (8.6-17.9), and pH 8.4 (8.0-8.5).

During the seven months (September to April) when water did not flow through the canal, up to 13 pools persisted within the uppermost 6 km closest to the dam (Figure 1). These residual pools received water leaking from the outlet gate at the dam, estimated by the irrigation district at less than 0.06 m^3/s, and probably from an unknown volume of discharge by springs within the canal bed. Pools were connected by narrow, shallow reaches of water from a few cm to about 0.5 m in depth, much of which froze to the bottom during winter. The pools had ice cover from November until early March in 1995 and early April in 1996. During the winter of 1995-1996, the five pools farthest downstream, pools 9 to 13, either froze to the bottom or became so shallow that surface ice contacted the bottom and then became overlain by water from snowmelt and rain.

Seining during fall 1995, prior to formation of ice cover, indicated Arctic grayling were present in four of the remaining eight pools—pools 1, 3, 4, and 8 (Table 1). During March 1996, toward the latter part of the annual period of ice cover, these four pools had a combined length of 342 m and volume of 1487 m^3 (Table 1). Characteristics of these four pools are summarized in Table 2 for winter 1995-1996. Dissolved oxygen remained high in the pools, with averages ranging from 7.4 to 9.2 mg/l, and the lowest measured value of 4.7 mg/l. Mean ice thickness ranged from 8.3 to 44.3 cm, with the greatest measurement of 58 cm. Mean water depths beneath ice cover ranged from 26.3 to 82.5 cm, with greatest measurement of 90 cm.

Arctic Grayling Age, Size Distribution, Growth and Abundance

Arctic grayling attained a mean length of 158 mm at the first annulus and 302 at the second (Table 3). Growth rates estimated from annuli corresponded closely with sizes at ages indicated by length-frequency distributions (Figure 4). Males grew faster than females; by the fourth annulus males were significantly longer than females (t-test, $p = 0.03$), averaging 410 mm ($n = 11$, $SD = 13$), whereas females averaged 396 mm ($n = 10$, $SD = 15$). Comparison of body lengths of 11 VI-tagged Arctic grayling that were repeatedly captured during fall and spring 1994, 1995, and 1996 indicate that most growth occurred during the spring and summer period of canal flows (Table 4).

Estimated population sizes during spring 1995 and 1996 suggest that less than 350 Arctic grayling one year or older were present in the canal during the springs of 1995 and 1996 (Table 5).

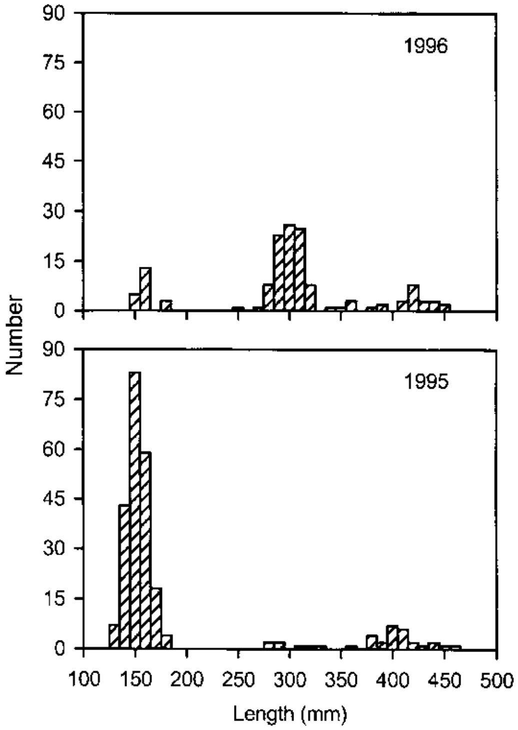

Figure 4. Length-frequency distributions of Arctic grayling in upper Sunnyslope Canal, in spring 1995 and 1996.

TABLE 3. Mean total length (standard deviation in parenthesis) and weight at time of capture and calculated mean total length at each annulus for Arctic grayling age 1 and older captured in Sunnyslope Canal in 1994, 1995, and 1996. N_W is the number of known-age fish weighed and N_L is the number of known-age fish measured.

					Calculated length (mm) at age						
Age Group	N_W	Mean total weight (g)	N_L	Mean total length (mm)	1	2	3	4	5	6	7
1	52	33 (9)	52	160 (12)	159						
2	59	252 (47)	62	301 (14)	161	301					
3	32	401 (61)	32	362 (11)	158	309	364				
4	18	564 (62)	21	403 (15)	151	299	361	407			
5	17	750 (127)	18	433	158 (16)	297	357	402	433		
6	3	758 (69)	4	437	155 (16)	298	357	398	429	425	
7	2	885 (261)	2	445	157 (7)	295	354	397	427	421	436
Mean back-calculated length (mm)					158	302	361	404	432	423	436
Mean increment of back-calculated length (mm)					158	144	59	43	28	-9	13

TABLE 4. 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 (mm) 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

TABLE 5. Population estimates for Sunnyslope Canal, spring 1995 and 1996, where n_1= number marked on first capture occasion; n_2= total number caught on first recapture occasion; m= number of marked fish caught on first recapture occasion; Nmle= population estimate; N_0= minimum population number; Nhi= upper confidence limit; Nlow= lower confidence limit; and STD= standard deviation.

Year	Age	n_1	n_2	m	Nmle	STD	N_0	Nlow	Nhi
S95	1	69	78	20	269	52.95	127	205	390
S95	2+	8	31	4	62	85.73	35	37	230
S96	1	19	15	11	25	4.18	23	23	36
S96	2+	77	105	67	120	3.54	115	116	129

Estimates are presented separately for age-1 fish and those two years or older (2+). Male:female ratios for fish age-2 or older were 1:2 in 1995 (n = 35) and 1:3.3 in 1996 (n = 107). Age-1 fish were much less common in 1996 than in 1995, suggesting poor spawning success during 1995 or low survival of the young.

Winter Survival

Results from seining the residual pools before and after the period of ice cover indicated high survival of Arctic grayling through winter, ranging from 76.0 to 100% (Table 1). Additionally, all 22 age-0 fish moved to pool 8 during fall 1995 were recaptured there as age-1 fish the following spring 1996. Fish remained in the same pools through winter; all Arctic grayling recaptured during spring 1996 were present in the same pool in which they had been captured during the preceding fall 1995. Also, fish tended to return to the same residual pools in fall of 1995 that they had occupied in 1994. Among 21 Arctic grayling that had been marked during the fall 1994 and recaptured during fall 1995, 13 (61.9%) were recaptured in the same pools as in 1994. Although most Arctic grayling were captured in residual pools, 40 age-1 and 3 age-2 or older fish were captured in reaches between pools in spring 1995. However, all of these reaches were immediately adjacent to a residual pool, and none were captured in other reaches.

Spawning

Both sexes of Arctic grayling became sexually mature at age 2. Sexual dimorphism of the dorsal fin was evident in fish ≥ 300 mm in length, and three age-2 females dissected in May 1994 contained maturing ova.

Arctic grayling spawned in the canal from early to mid-May, about one or two weeks after canal flows began. During the springs of 1994, 1995, and 1996, a total of 88 Arctic grayling (≥300 mm total length) were examined within two days before canal flow began. None had freely expressible ova or milt, but all females had abdominal distention suggesting maturing ova. In 1994 and 1996, age-0 Arctic grayling were first seen between 8-14 June. Water temperature in the canal was 9-10°C since initiation of flows on May 6, and time to hatching and first swimming at this temperature would be about three weeks (Kaya 1990; Northcote 1995). Spawning was thus estimated to have begun about the second and third weeks in May, one to two weeks after seasonal canal flow started. Turbidity and high, turbulent flows through the canal prevented visual observations of spawning sites or activity in 1994 and 1996.

The temporary interruption of canal flow during spring of 1995, described earlier, provided an opportunity to visually confirm occurrence, location and time of spawning in the canal. Small flow volume from leakage at the dam produced riffles between some of the pools, and spawning was observed in one riffle at km 1.1 on 17 and 18 May, at water temperature of 9.8-10.5°C. Five large males established territories within the 18-m long riffle and were seen spawning with at least 5 females. White suckers were also observed spawning, at the downstream end of the riffle. Measurements taken at 2 m increments along the length of the riffle indicated a mean depth of 24.1 cm (range 15-45), mean width of 71 cm (range 61-81), and mean velocity of 0.30 m/s (range 0.17-0.43). Substrate consisted predominantly of cobble (diameters 10-50 mm) and gravel (2-10 mm). The riffle was sampled on 20 May by dislodging substrate upstream from a dip net, and embryos of both Arctic grayling and white suckers, distinguishable by differing egg diameters, were collected. Arctic grayling embryos were in varying stages of development; the most advanced had pigmented eyes, which would occur in about 7 to 10 days at water temperature of about 10°C (Henshall 1907). Spawning was not seen in other riffles through the 6 km study reach during the 15 days of interrupted flow.

Visual surveys and drift netting also indicated that newly swimming Arctic grayling originated from spawnings in the upper reaches of the canal. During summer flows of all three years, Arctic grayling fry were most commonly seen in the upper reaches of the study section. On 15 and 22 June 1995, 14 of the 17 fry found were in 4 canal segments from 1.3-3.7 km below the reservoir. Also seen along the canal margins, collected, and identified were many fry of white sucker, and a few fry of yellow perch (*Perca flavescens*) and spottail shiner (*Notropis hudsonius*).

Drift nets had limited effectiveness in capturing fish fry in the canal; however, results were consistent with observations on spawning and on visual locations of young. During June 1994 and 1995, a total of 25 Arctic grayling fry were captured in drift nets at the 5.8 km bridge, but none were captured in drift nets set at the dam outlet in June 1995 (nets were not set at the outlet in 1994). Drift nets indicated a reservoir origin for northern pike and yellow perch fry, with 50 northern pike fry captured at the dam outlet in 1995 but only 1 at the bridge in 1994 and 7 in 1995. Large, uncounted numbers of yellow perch fry were also captured in drift nets at the dam outlet and the bridge.

Other Species

Other species collected by seining in the upper canal were northern pike, rainbow trout, white sucker, spottail shiner, yellow perch, and mottled sculpin (*Cottus bairdi*). White sucker and mottled sculpin were common at sizes ranging from age-0 to adults. Northern pike and yellow perch were present mostly as age-0 fish, with only 14 northern pike and 1 yellow perch older than age-0 fish collected through the two years of sampling. No Arctic grayling were found among the stomach contents of the 185 northern pike whose stomachs were examined. Forty-two rainbow trout were collected in the canal, mostly older than age-0. Spottail shiners were collected in the canal only near the dam.

Discussion

Our results confirm that there is a small, self-sustaining population of Arctic grayling which grow rapidly in upper Sunnyslope Canal, despite extreme changes in habitat volume and characteristics. Estimated numbers of age-1 and older fish, averaging 238 during spring 1995 and 1996, represent densities of 26/km and 9/hectare in the upper 9 km of the canal during the summer flow period. These densities are lower than the 35/km and 28/hectare of age-1 and older fish estimated for the upper Big Hole River (Liknes and Gould 1987), which supports the only riverine population of Arctic grayling in Montana, and much lower than densities of about 400 to 500/km reported for certain Alaskan streams (Oswood et al. 1992). During the five months of spring and summer flows, the canal appears to provide favorable conditions for growth of Arctic grayling. Growth rates of Arctic grayling in the canal are similar to those of adfluvial populations in Montana with rapid growths, Upper Red Rock Lake and Hyalite Reservoir, and exceed that of the fluvial population in the Big Hole River of Montana (Figure 5).

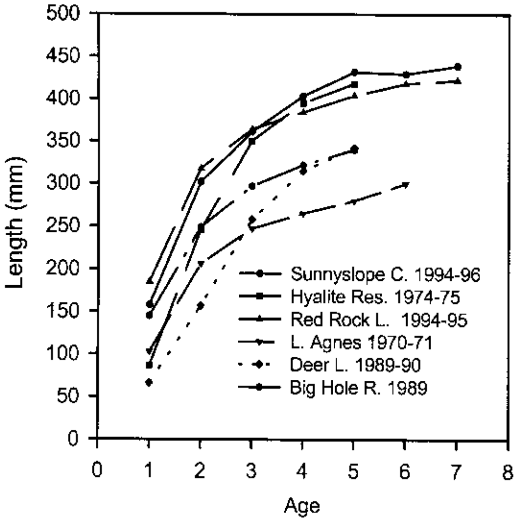

Figure 5. Growth curves of Arctic grayling in Sunnyslope Canal and examples of other populations in Montana: Upper Red Rock Lake (Mogen 1996), Hyalite Reservoir (Wells 1976), Lake Agnes (Peterman 1972), Deer Lake (Deleray 1991) and the Big Hole River (Shepard and Oswald 1989). Growth rates of Arctic grayling in Upper Red Rock Lake and Hyalite Reservoir are among the fastest known among populations in Montana (Kaya 1990, Mogen 1996).

Characteristics of the canal during both flow and non-flow periods may contribute to the ability of this population to persist there despite the disappearance of the species from most of the streams historically occupied in Montana. Peak flows greater than 45 m^3/s are similar to late summer flows of rivers in Montana which once supported Arctic grayling populations, including the Madison and Beaverhead rivers (U. S. Geological Survey 1983), and exceed summer flows of the Big Hole River. During midsummer flows, with a gradient of 0.002%, maximum thalweg velocities of about 0.6 m/s, and depth of about 3 m, the canal would resemble deeper reaches of a river with similar volume in a low gradient area. Historical accounts of Arctic grayling in the upper Missouri River basin (Evermann 1893; Vincent 1962) indicate that low-gradient reaches of the Missouri River and larger tributaries like the Madison River were important habitat for the species. During canal flow, temperatures remained cool and averaged 11.4°C, within the optimum range described by Hubert et al. (1985) for the species. Mean alkalinity (133 mg/l), pH (8.4) and specific conductance (285 µmhos) during summer flow in the canal were similar to values during summer for the upper Madison River in Yellowstone National Park (Zeikus and Brock 1972), and the upper Missouri River below its origin at its Three Forks (U.S. Geological Survey 1983), which were among the most important habitats for native fluvial populations of Arctic grayling in the upper Missouri River drainage (Vincent 1962).

Although availability of habitat was drastically reduced during seven months when water did not flow through the canal, conditions within the small volume of residual water did allow high survival of Arctic grayling. Dewatering of streams by human diversions commonly occurs during summer, when diminished flows not only reduce habitat space but also contribute to elevated temperatures that can reach lethal levels for Arctic grayling (Lohr et al. 1996). However, dewatering of the Sunnyslope Canal occurs from early autumn through mid-spring, when cooler temperatures prevail. By late winter in March 1996, the pools that provided the major winter habitat for the Arctic grayling were reduced to 1487 m^3 beneath ice cover. This would be the approximate equivalent of water volume present within only 16.5 m of canal length (with depth of about 3 m and width of 30 m) during peak summer flows, a volume reduction of over 99% from peak summer flows. The larger pools retained high concentrations of dissolved oxygen despite the shallow water that persisted beneath ice cover during the winter of 1995-1996. Estimated survival of Arctic grayling through winter ranged from 76 to 100%, at densities of about 0.2/m^3 (1023/ha), in the four known wintering pools during 1995-1996. Although survival rates and fish densities are not reported, a critical role of wintering pools in frozen rivers has also been reported for Arctic grayling in Alaska (Reynolds 1989, West et al. 1992), and in the Big Hole River of Montana (Pat Byorth, Montana Department of Fish, Wildlife and Parks, pers. comm.). The drying out of most of the canal and use of residual pools for winter habitat could be considered analogous to the situation described for certain Alaska streams, in which stream reaches completely freeze and Arctic grayling occupy spring-fed pools during winter (Armstrong 1986).

Reviews of Arctic grayling reproduction in Alaska, Montana, and Canada (Armstrong 1986; Kaya 1990; Northcote 1995) indicate that different populations spawn at depths ranging from a few cm to more than 1 m, and over substrates ranging from silt to cobbles and boulders (unlike many other salmonids, Arctic grayling do not bury their eggs in excavated redds). The bed of Sunnyslope Canal is composed of varied substrates from fine sediments to cobbles, and water depth ranges from less than 1 m to more than 3 m as flow volumes change during the irrigation period. The spawning acts observed in 1995 occurred at shallow depths averaging only 24 cm and over coarse substrate, as has been described for some other populations (Kaya 1990; Northcote 1995). However, this activity occurred during an unusual set of circumstances when canal flow was temporarily stopped, except for leakage from the dam; a review of flow records indicated that this type of flow stoppage had not occurred during the previous 10 flow years (GID, unpublished data). Spawning also occurred during normal canal flows of 1994 and 1996, and the resident Arctic grayling thus appear able to spawn under widely varying flows and depths.

The inability of non-native species to become established in the canal may also be important to the persistence of Arctic grayling. Competition from or predation by non-native species may have been an important contributor to the decline of fluvial Arctic grayling in Montana; one or more species of non-native rainbow trout, brown trout (*Salmo trutta*) or brook trout (*Salvelinus fontinalis*) are established in all streams known to have been formerly inhabited by Arctic grayling (Vincent 1962; Kaya 1992). Although we did not observe northern pike predation of Arctic grayling, predation may still be important, especially in years when large numbers of northern pike are produced in the Pishkun Reservoir. Only white sucker and mottled sculpin appear to be maintaining populations in the canal, and among fishes present in the canal only these two species are native and sympatric with Arctic grayling in the upper Missouri River basin in Montana.

The other species in the canal appear to originate as small fish passing through the 2.5 cm outlet screen at the dam. Northern pike and yellow perch are known to spawn in the reservoir and small age-0 young were collected in drift nets below the dam. However, such age-0 young appeared to drift downstream with canal flow or followed receding water downstream when flows ceased, as few or none were present in residual pools during fall. Rainbow trout are established in the section of the Sun River from which water is diverted into the reservoir and are occasionally planted directly in the reservoir. Adult spottail shiners were visible in the reservoir at the dam and are small enough to pass through the outlet screen.

Although the population persists in the upper canal, many Arctic grayling, especially age-0 young, are lost downstream annually. After flows cease in September, hundreds of age-0 fish are present in temporary, drying pools farther downstream in the canal, in plunge pools at the bases of drop structures 50 or more km downstream, and in temporary pools in irrigation ditches which receive water from the canal (S. Barndt, unpublished data). We do not know whether these downstream losses occurred through summer or when water drained from the canal after outlet gates were closed at the dam. It is likely that such downstream losses have occurred throughout the existence of this population, and Arctic grayling ranging from age-0 to larger fish have been seen during fall at these downstream pools since at least 1971 (Bill Hill, pers. comm.). As has been proposed for other populations, such downstream losses may represent a continuing selective pressure toward the adaptation of a population to existence in upper reaches of a stream (Deleray and Kaya 1992).

Survival and reproduction of fish in the canal could be influenced by many factors. Physical factors could include effects of winter duration and severity on pool volume and water quality. Biological factors may include fish density per winter pool, and predation on age-0 grayling by other species transient in the canal, especially age-0 northern pike. Human activity also contributed directly to loss of Arctic grayling from the canal during this study. The irrigation district removed and cleaned the screen surrounding the outlet at the dam in September 1994. For this operation the reservoir level was drawn down to about 0.5 m above the floor of the outlet tunnel and the outlet gate remained open. Age-0 Arctic grayling were visible in the shallow water of the outlet tunnel and its discharge area at the head of the canal, with many concentrated at and swimming against the outlet screen. We sampled and marked 782 age-0 fish in the tunnel and discharge area before the screen was removed but many more were present. To prevent loss of these grayling from the canal into the reservoir, the irrigation district constructed a low earthen barrier in the reservoir around the tunnel entrance. However, the barrier was breached by waves after the screen was removed and the age-0 fish disappeared, apparently lost into the reservoir. Thus, this population, confined seasonally to a few residual pools within only about 6 km of canal, may be very susceptible to influence from both natural factors and stochastic events related to canal operations.

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