



Movement and utilization of fluvial habitat by age-0 Arctic grayling, and characteristics of spawning adults, in the outlet of Deer Lake, Gallatin County, Montana  
by Mark Arthur Deleray

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management  
Montana State University  
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**Abstract:**

The Arctic grayling (*Thymallus arcticus*) population of Deer Lake (Gallatin County) differs from most Montana lacustrine populations in being outlet spawners and in having an extended period of stream residence of young fish. Estimated numbers of spawning adults were  $803 \pm 104$  in 1989 and  $1109 \pm 124$  in 1990, with a male:female ratio of about 1.0:1.0 in both years. After swimming up from the gravels, age-0 young remained in the stream for at least their first 2 to 3 months and some young for over a year. Age-0 grayling used slow water velocities, silt and sand substrate, and shallow depths while in the stream. The mean water column velocity (0.6 depth) and total depth at preferred fry locations increased with fry growth. These observations suggest habitat characteristics that may be important to young grayling in a fluvial environment. The extended stream residence of the young also suggests that Deer Lake grayling may be able to permanently inhabit streams.

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## APPROVAL

of a thesis submitted by

Mark Arthur Deleray

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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## ABSTRACT

The Arctic grayling (Thymallus arcticus) population of Deer Lake (Gallatin County) differs from most Montana lacustrine populations in being outlet spawners and in having an extended period of stream residence of young fish. Estimated numbers of spawning adults were  $803 \pm 104$  in 1989 and  $1109 \pm 124$  in 1990, with a male:female ratio of about 1.0:1.0 in both years. After swimming up from the gravels, age-0 young remained in the stream for at least their first 2 to 3 months and some young for over a year. Age-0 grayling used slow water velocities, silt and sand substrate, and shallow depths while in the stream. The mean water column velocity (0.6 depth) and total depth at preferred fry locations increased with fry growth. These observations suggest habitat characteristics that may be important to young grayling in a fluvial environment. The extended stream residence of the young also suggests that Deer Lake grayling may be able to permanently inhabit streams.

## INTRODUCTION

Within this century both Montana and Michigan have had indigenous stocks of Arctic grayling (Thymallus arcticus). The Michigan grayling is extinct due to a combination of factors including overfishing, grazing and logging practices, and introductions of non-native fishes (Vincent 1962). The original range of the Montana grayling was the upper Missouri River drainage above the Great Falls. Montana still has populations of the native grayling. However, only one fluvial population remains (Big Hole River) and it too appears to be declining in numbers (Kaya 1990). The fluvial populations of Montana grayling have diminished, possibly due to the effects of introduced exotic salmonids (Salmo trutta, Salvelinus fontinalis, Oncorhynchus mykiss), poor land use practices, overfishing, and dewatering of streams. All other populations are lacustrine and introduced, except those of Red Rock and Elk lakes, which are indigenous (Vincent 1962).

There is interest in recovering the Big Hole River grayling population and in reintroducing grayling into other Montana streams. Grayling used in restoration efforts must be capable of living in a fluvial system. It has been shown that young Montana grayling from different

stocks behave differently in running water (Kaya 1989, 1991). The Big Hole River stock is the most obvious choice for restoration of fluvial populations. However, because of their low numbers, it is difficult to capture ripe Big Hole grayling for spawning purposes. Also, it is questionable whether all grayling used in restoration efforts should originate from a single source. A single origin, from a population reduced to low densities, may limit the genetic diversity of reestablished fluvial populations.

Unlike most grayling populations in Montana, the Deer Lake (Gallatin County) grayling are outlet spawners (allacustrine), rather than inlet spawners. Previous observations suggested that young of the Deer Lake population may remain in the outlet stream for at least several months before moving up into the lake (C. M. Kaya, Montana State University, pers. comm. 1989). In contrast, young of inlet-spawning populations typically move downstream into a lake soon after swimming up from the gravels.

The objectives of this study were to determine: (1) if young Deer Lake grayling have an extended period of residence in the outlet stream; and, if so, (2) the habitat selected by young grayling during stream residence. The results of this study will help determine the likelihood for successful transplants of Deer Lake grayling into a

stream or into a lake with only an outlet stream. Results will also be valuable because of the scarcity of information on habitat use and selection by very young grayling in fluvial habitats. In conjunction with primary objectives, I also determined characteristics of the spawning population entering the Deer Lake outlet stream.

## STUDY SITE

Deer Lake is located in the Madison Range of southwestern Montana, within the Gallatin National Forest and the Lee Metcalf Wilderness Area. The Deer Lake trailhead starts on Highway 191, 76 km north of West Yellowstone and 61 km south of Bozeman, Montana (Figure 1). The lake is in a large cirque at 2780 m above sea level (USGS 1950), and 10 km from the trailhead. At this elevation, whitebark pine (Pinus ablicaulis), limber pine (P. flexilis), and subalpine fir (Abies lasiocarpa) dominate and grouse whortleberry (Vaccinium scoparium) is the most prevalent shrub. Deer Lake is oval shaped, roughly 400 m long and 160 m wide, and covered by ice 6 to 7 months of the year. The southern end of the lake is relatively shallow, while the northern end is quite deep. No depth measurements have been taken.

Deer Creek originates at the southeast end of Deer Lake and flows southeast to the Gallatin River. After flowing roughly 300 m from the lake, Deer Creek plunges over a waterfall. This waterfall acts as a barrier blocking any upstream fish movement (Figure 1). The 300 m stream section from the lake outlet to the waterfall formed the study site, and is hereafter referred to as the outlet

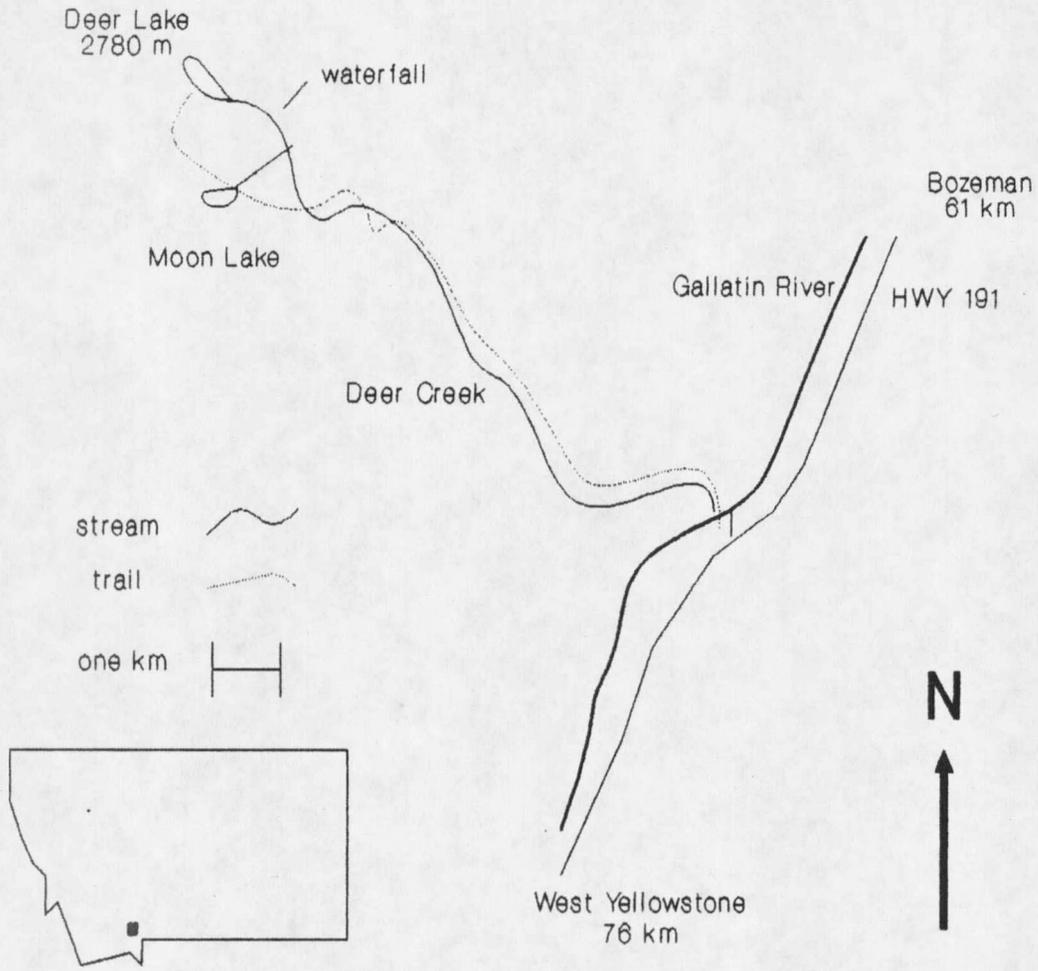


Figure 1. Location of Deer Lake, Montana.

stream. The width of the outlet stream ranges from less than 1 m to over 14 m. Within 100 m of the lake outlet, there are at least three springs discharging directly into the outlet stream.

The outlet stream is characterized by two general habitat types. One type consists of runs and riffles with faster water velocities. These areas have the narrowest channel widths and a wide range of substrate sizes, from very fine to boulder. The second type consists of wide, shallow areas of slow flows, and fine substrates. These will be referred to as flats.

The only fish species in Deer Lake is the Arctic grayling. Although the origin of the population is not known, it probably was started through stocking. Deer Lake grayling are genetically similar to other lacustrine populations originating from plants of Madison/Red Rock grayling (R. Leary, University of Montana, pers. comm. 1990).

Dense concentrations of spawning grayling appear in the outlet stream sometime between late May and early July (Kaya 1990). Although the adults would be very vulnerable in the clear, shallow water, no eagles, osprey, bears or bear tracks were seen in the area. Later in summer, when young were abundant, a belted kingfisher was seen in the study site. Deer Lake is fished throughout the summer. The daily creel limit is five grayling. Fishermen appear

quite successful, although not all keep fish.

A small inlet stream at the north end of Deer Lake provides potentially 4 m of spawning area between the rock cirque and the lake. However, grayling do not appear to use the inlet stream for spawning (Kaya 1989), perhaps because of its small size and cold temperatures. During the 1989 spawning run, no grayling were seen in the inlet and the water temperature (4.1 C) was lower than that of the outlet (about 11.0 C).

## METHODS

During May and early June of 1989 and 1990, I made repeated trips to Deer Lake to determine when the lake surface thawed and when adult fish entered the stream. In both years, observations began when ice cover melted from the lake and outlet stream, and continued until ice started to form along the margins in October (1990) or early November (1989). Due to the remoteness of Deer Lake, the lightest and smallest equipment available was used. All equipment was carried in backpacks.

### Temperature Measurements

As ice cleared from the stream, I placed a Peabody Ryan thermograph (model D) in the stream roughly 30 m from the lake outlet. This location was known to be used by spawning and young grayling (Kaya, pers. comm. 1989). In 1989, the thermograph was installed on June 8 and in 1990 on June 12. In 1989, a second thermograph was placed near the mid-point of the study site in a riffle known to be a major spawning site (Kaya, pers. comm. 1989).

### Spawning Population

When large numbers of adult fish had accumulated in the outlet stream, a four-person crew sampled fish with a backpack electro-shocker (Coffelt BP-1C). Sampling progressed upstream from the waterfall to the lake outlet. We recorded fish total lengths to the nearest millimeter, fish weights to the nearest gram (Ohaus Lume-o-gram Balance Model D1001-BA), sex, and hook scar incidence. All adult fish captured in 1989 received a permanent adipose clip. Numbers of spawners were calculated using the Petersen method (Ricker 1975). All adult fish captured on the marking run also received a temporary upper caudal clip. The recapture run took place 3 d after the marking run in both years.

During the 1989 spawning run, 136 scale samples were taken from male, female, and juvenile grayling in all size classes present. Scale samples were taken from the area between the posterior end of the dorsal fin and the lateral line. I took scales later in the season from size classes not represented in the spawning run to facilitate identification of age classes. This later sampling was done by dip net or with hook and line. Montana Department of Fish, Wildlife, and Parks personnel formed plastic scale impression from all samples. From these, I determined scale annuli on a microfiche at 72x magnification.

Fecundity measurements were collected by sacrificing ripe females of different sizes. For each individual, total length and weight of the female and the total volume of eggs were measured. From each fish, 25 ml of eggs were preserved in a 10% formalin solution and later counted. The number of eggs in each 25 ml subsample was extrapolated to estimate the number of eggs in the total volume taken from each female.

Incidental observations were made of egg predation by adult grayling. Stomachs of grayling killed during electro-fishing were examined. The stomachs were placed in 10% formalin and examined in the lab. One adult grayling which appeared to be chasing young was captured and sacrificed to determine if it was consuming fry.

#### Movement of Young

I monitored movements of young grayling with traps made from 1 mm plastic mesh (window screen). To determine when fry became free swimming, I used emergence traps of the type described by Fraley et al. (1986). Since grayling are broadcast spawners, emergence traps were placed in areas of heaviest spawning activity, over visible egg concentrations.

To monitor movements of young, I installed three traps (Figure 2). All fish trapped were measured to the nearest millimeter and released in the direction of their movement.

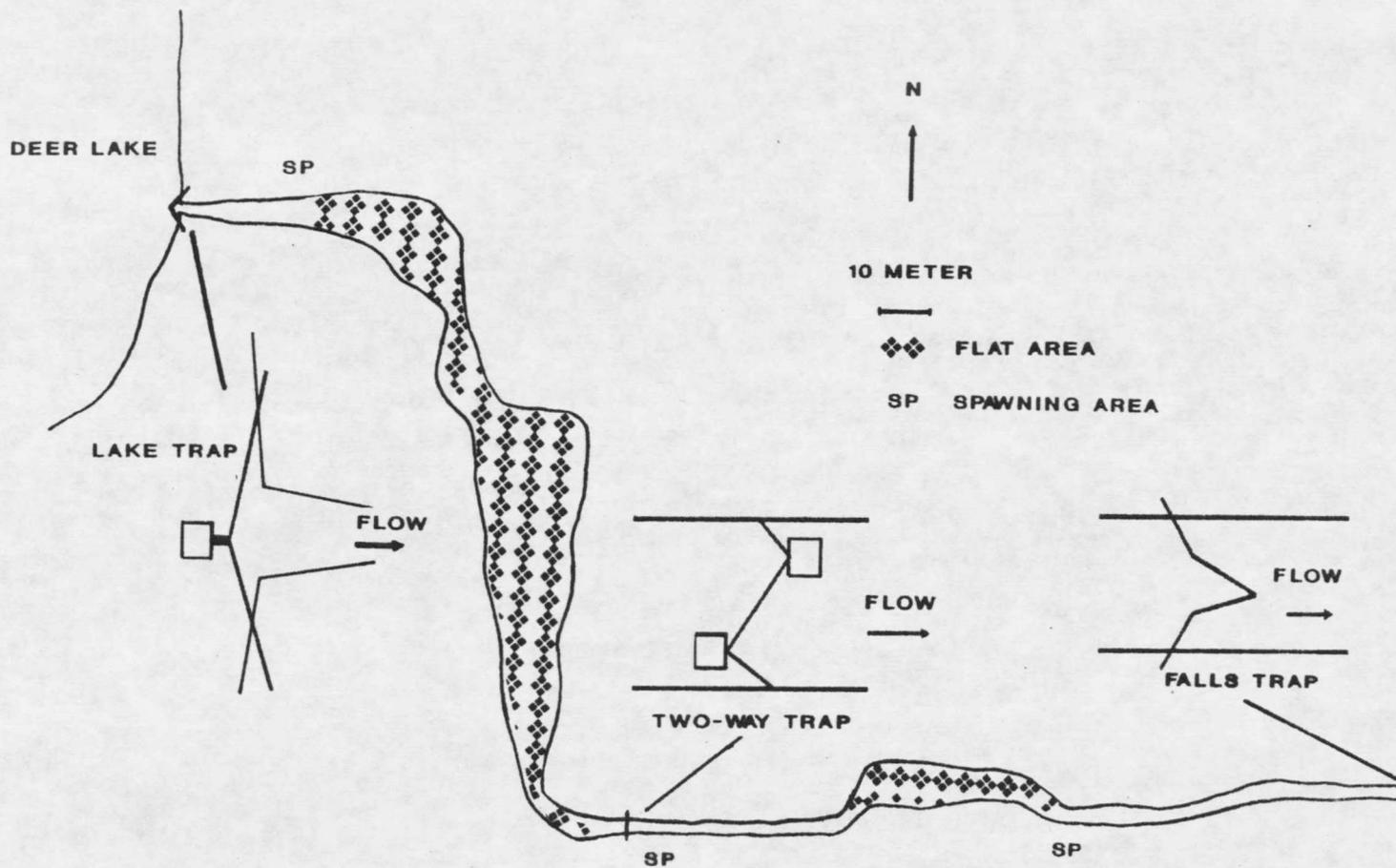


Figure 2. Deer Lake study site, showing three movement traps, major spawning areas, and general water types.

One trap was installed across the lake outlet. This V-shaped, screen barrier leading into a holding trap is referred to as the lake trap. After nearly all adults had returned to the lake, I installed the lake trap which intercepted the movement of all fish from the stream into the lake. In 1989, the leads to the trap extended 1 m into the lake, creating a holding area within the lake. Fish observed in this holding area were captured with a dip net. The trap was modified in 1990 to eliminate this holding area, forcing fish to move into the trap. The trap was framed with lodgepole pine poles and the mesh was weighted with rock at the substrate surface. I made an effort to seal off any potential bypass around the trap.

The second trap intercepted fish moving in both the upstream and downstream directions (to be referred to as the two-way trap). This trap, positioned near the midpoint of the study site about 5 m above a major spawning site (Figure 2), extended completely across the stream, with a continuous screen barrier forming two V-shaped leads.

The third trap (to be referred to as the falls trap) was a drift net placed in the first meter of the waterfall at the downstream end of the study site (Figure 2). In 1989, the falls trap sampled approximately 33 to 50% of the stream flow. In 1990, the falls trap was modified with mesh leads to sample the entire flow. In

1989, the falls trap was continuously in place, while in 1990, it was operated only when an observer was present. During 1990, I emptied the trap at 4 h intervals over 24-h periods.

#### Habitat Use

In 1990, a two-person crew conducted three surveys of habitat use and preference by age-0 grayling. The first day of each survey consisted of visually observing fish positions and measuring habitat characteristics at those positions. On the second day, habitat characteristics were measured along evenly spaced transects to determine habitat availability. Because of their small size, fish could only be observed during periods of bright light and clear skies. If clouds reduced visibility, the observations were discontinued until skies cleared. The three survey periods were July 28 and 29, August 18 and 19, and September 8 and 9.

Fish positions were determined visually, as I moved upstream from the waterfall. For each fish position, I measured the focal point depth (distance of the fish from the substrate), total water column depth, focal point velocity (water velocity at the fish position), mean water column velocity (velocity at 0.6x the depth), substrate type, and distance to cover. Measurements were taken only for fish whose positions were noted before they were

disturbed. The observer made an effort not to measure any fish more than once. This was done by moving forward for the next observation a distance greater than the distance moved by disturbed fish.

I measured depths and distance to cover with a meter stick to the nearest millimeter and water velocities in meter per second with a Montedoro-Whitney digital flow meter. Cover was defined as any aquatic or terrestrial material providing an overhang which could conceal young from overhead view. Terrestrial vegetation within 50 cm of the water surface was considered usable cover. Using a modified Wentworth scale, I visually estimated substrate type within roughly a 10 x 10 cm area (Table 1) (Bovee and Cochnauer 1977). Silt and clay particles as well as fine plant detritus were combined into one category because of the difficulty of distinguishing between these in the field. This category is hereafter referred to as silt. The two or three most common substrate types were noted and weighted evenly due to the difficulty in estimating the percentages of substrate types in such a small area.

An effort was made to search all habitat types and collect as many observations as possible. Extra time was spent in areas with fast current, deeper depths, and overhanging vegetation because of the increased difficulty of observation.

Table 1. Modified Wentworth scale for substrate types and codes used in later analysis for Deer Creek (adapted from Bovee and Cochnauer 1977).

Substrate type	Size (mm)	Code
Silt and Plant detritus	< 0.062	1
Sand	0.062-2.0	2
Gravel	2.0-64.0	3
Cobble	64.0-250.0	4
Boulder	> 250	5
Macrophytes		6

Throughout most of the outlet stream, I searched the entire stream width. In the wider sections, I moved across the stream at roughly a 45 degree angle to the current until close enough to see young at the opposite bank. At this point, I would cross back toward the other bank.

Analysis of variance was used to determine if a significant difference existed between the mean habitat characteristics measured.

#### Habitat Availability

Habitat availability was estimated along randomly selected transects in the outlet stream. The first transect, positioned by the roll of a die, was 3 m downstream from the lake outlet. Downstream transects were then established perpendicular to the thalweg, at 10 m increments, except in the relatively large uniform flat, where four transects were set at 20 m increments. Measurements along these transects were counted twice in

calculations determining habitat availability. Along each transect, at both banks and at 0.25, 0.50, and 0.75 of the stream width, we measured the mean velocity (0.6 depth) and total depth of the water column, substrate type, and distance to cover.

#### Habitat Preference

After classifying and tallying habitat measurements, I determined the proportions of available habitat and use of habitat by the young. Since the availability of both focal point depth and focal point velocity could not be determined by the habitat availability measurements, preference for these characteristics was not determined. Each individual fish position was treated as one observation. Proportions were run through Chi-Squared Goodness-of-Fit comparisons to test the hypothesis that fish use each habitat characteristic in the exact proportion to its availability.

If a statistical difference existed at the 0.05 level, I calculated Bonferroni 95% confidence intervals around the difference between habitat availability and use values to test the hypothesis that habitat availability ( $P_o$ ) was equal to habitat use ( $P_i$ ) (Marcum and Loftsgaarden 1971). If the confidence interval included 0, I assumed the fish were using the habitat in proportion to its availability. If 0 was not included in this interval, I assumed the fish

were not using the habitat in proportion to its availability. The fish were said to prefer the habitat characteristic if both end points of the interval were negative,  $P_i > P_o$ . Likewise, the fish was said to avoid the habitat characteristic if both end points of the interval were positive,  $P_i < P_o$ .

Data were evaluated on a microcomputer. Data were entered on a Lotus 123 spread sheet, and statistical analyses were conducted with the MSUSTAT (Lund 1988) program.

## RESULTS

In 1989, Deer Lake was partially thawed on June 16 and completely thawed by June 22. In 1990, the lake surface was partially thawed on June 25 and completely thawed by July 1. After the lake thawed, temperature at the outlet rose rapidly (Figure 3).

Mean daily water temperatures at the outlet were generally slightly warmer than those at the mid-point of the study site (Figure 4). Water temperature in the lower half of the outlet stream also fluctuated more than temperature at the lake outlet. In comparison to the lake outlet, water temperature at the mid-point tended to be cooler at night, possibly due to greater nocturnal heat loss and influx of cold spring water, and warmer during the day, possibly due to daytime heat absorption in the large flat immediately upstream. In July, the daily high water temperature often exceeded 19 C at the mid-point, but remained below 17 C at the outlet. During this time, the daily low temperature at the mid-point was generally between 9 and 11.5 C, while at the outlet it was 13 to 15 C. Daily temperature range varied 10 C at the mid-point, but only 1 to 2 C at the outlet.

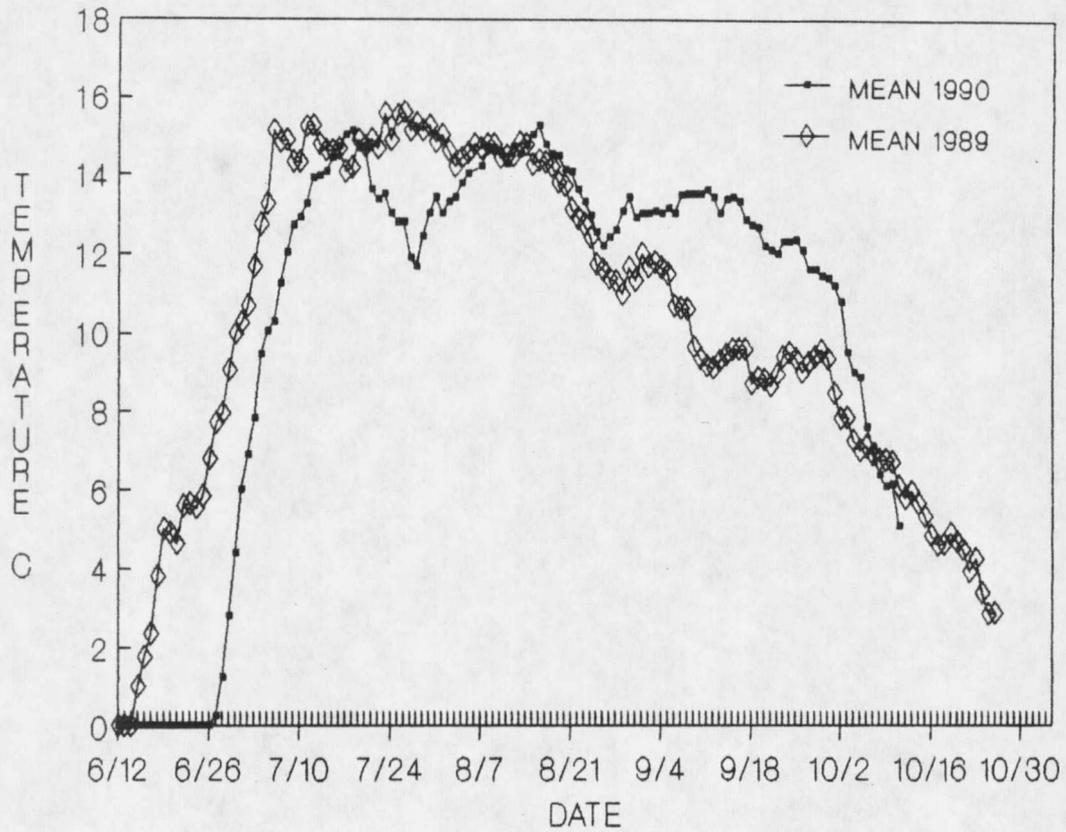


Figure 3. Mean daily temperatures (C) of Deer Lake outlet stream, 1989 and 1990.

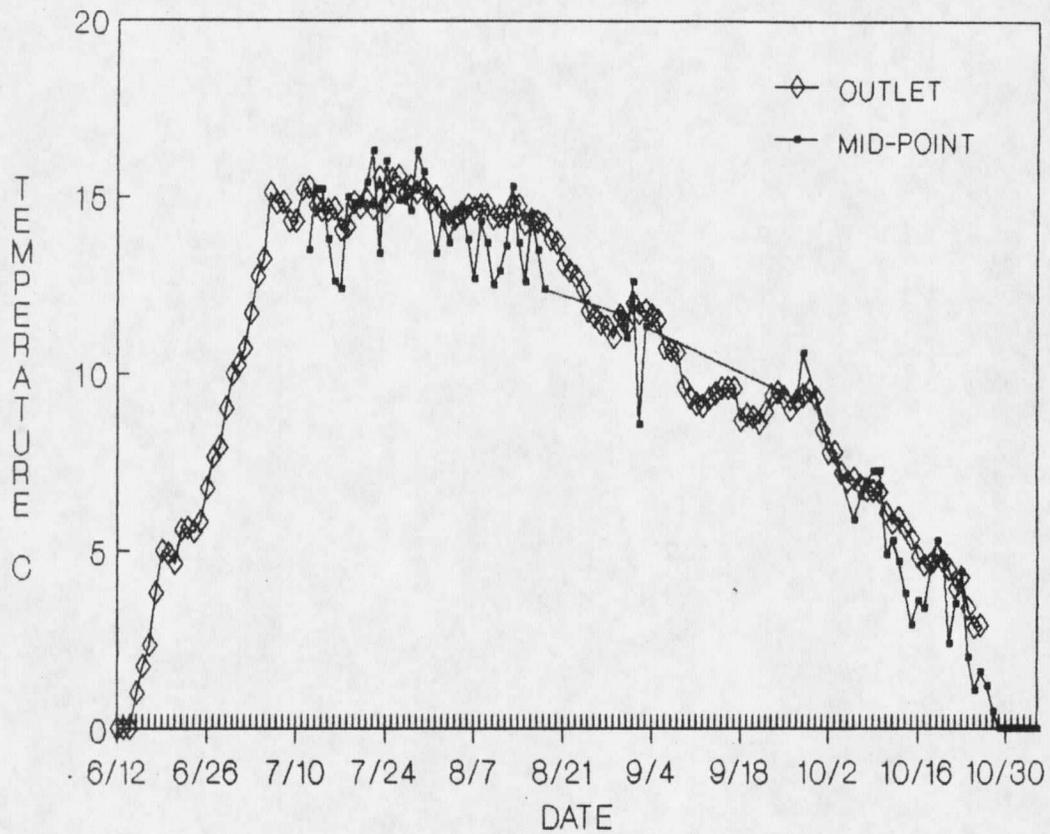


Figure 4. Mean daily temperatures of the Deer Lake outlet stream at two locations, one 30 m from the lake and the other near the mid-point of the study site, 1989.

### Spawning Run

As the lake surface began to thaw, adult grayling began moving into the outlet stream. In 1989, major movement occurred as water temperature rose from 4 to 6 C in the outlet stream. In 1990, hundreds were seen in the stream as water temperature approached 7 C. Numbers increased as adults accumulated in the stream. Hundreds of adult grayling were present in the outlet stream at least a week before peak spawning activity occurred.

### Population Estimate and Sex Ratio

Adult grayling captured during the spawning runs numbered 518 in 1989, and 648 in 1990 (Table 2). Of these, 53% (1989) and 54% (1990) were males. This was a male:female sex ratio of 1.1:1.0 in 1989, and 1.2:1.0 in 1990. The mark and recapture runs gave spawning population estimates with 95% confidence intervals of  $803 \pm 104$  in 1989, and  $1109 \pm 124$  in 1990. Deer Lake grayling appear to spawn each year. Of the adults captured in 1990, 23% of the females and 42% of the males had adipose clips from the 1989 spawning run.

### Length Frequency and Age

In 1989, spawning males averaged 325 mm in total length (TL), ranging from 260 to 404 mm (Figure 5). Females averaged 311 mm TL, ranging from 242 to 384 mm

(Figure 5). Size of spawners was similar in 1990. Males averaged 313 mm TL, ranging from 244 to 393 mm, and females averaged 302 mm TL, ranging from 255 to 380 mm (Figure 6).

Table 2. The maximum likelihood estimate (MLE) for the grayling population of Deer Lake, 1989 and 1990.

Year	Sex	No. of marked fish	No. of fish captured second run	No. of recaptured fish	MLE
1989	M	121	222	69	389
1989	F	107	183	46	426
1990	M	219	218	85	562
1990	F	174	177	55	560

Male grayling in Deer Lake appear to grow slightly faster and reach greater lengths than females. The mean back calculated lengths after the second annulus are generally slightly greater for males (Table 3). The oldest grayling aged was 6 years old.

Deer Lake grayling mature as 3-year olds, toward the end of their fourth year.

#### Fecundity

Estimated number of eggs in the seven ripe females sampled ranged from 2,743 to 3,674 (Table 4). Relative fecundity averaged 12.4 eggs/g of fish and ranged from 7.1 to 15.7, and 9.6 eggs/mm of fish and ranged from 7.9 to 10.7.

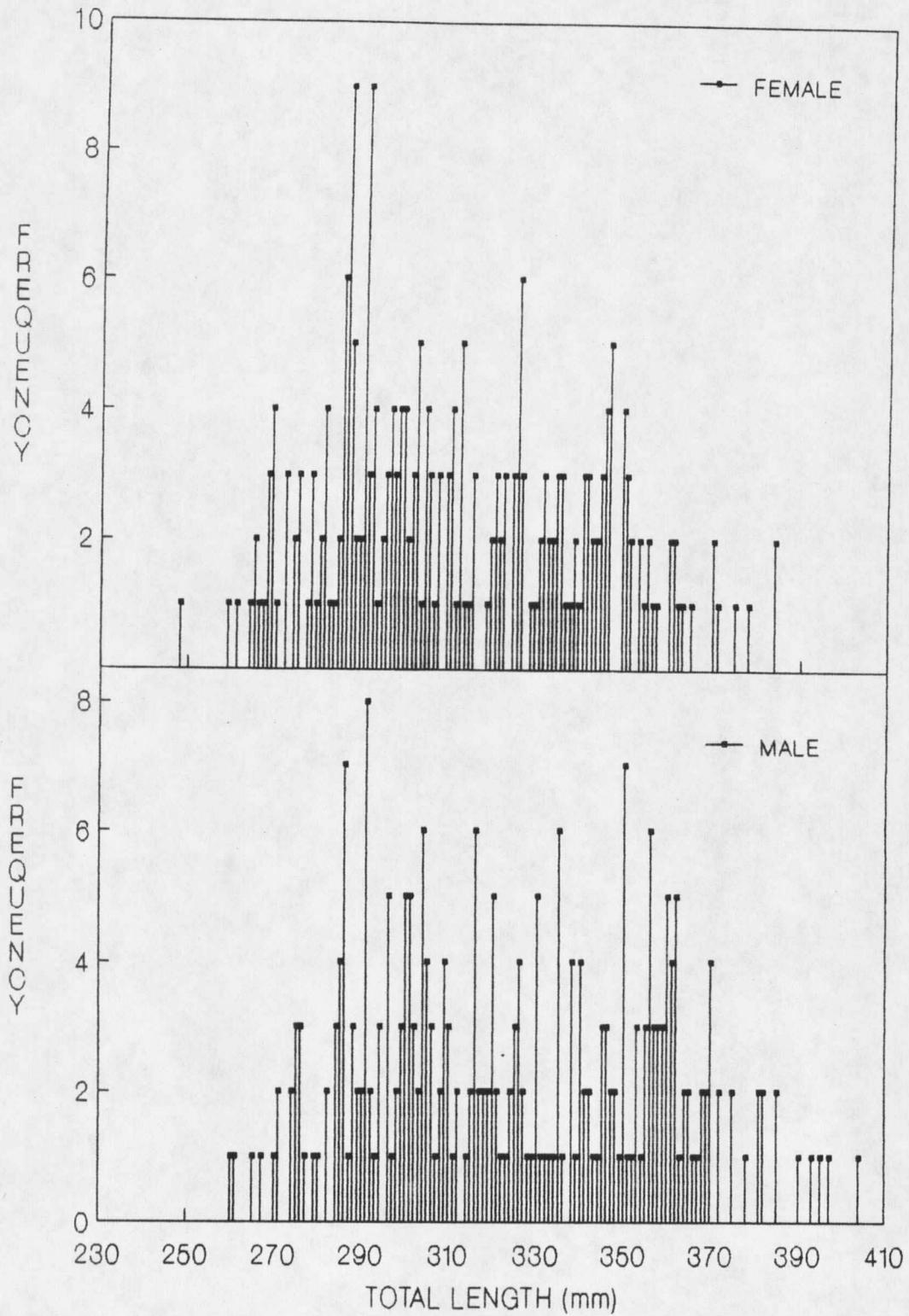


Figure 5. Length frequency of spawning male and female grayling from Deer Lake, 1989.

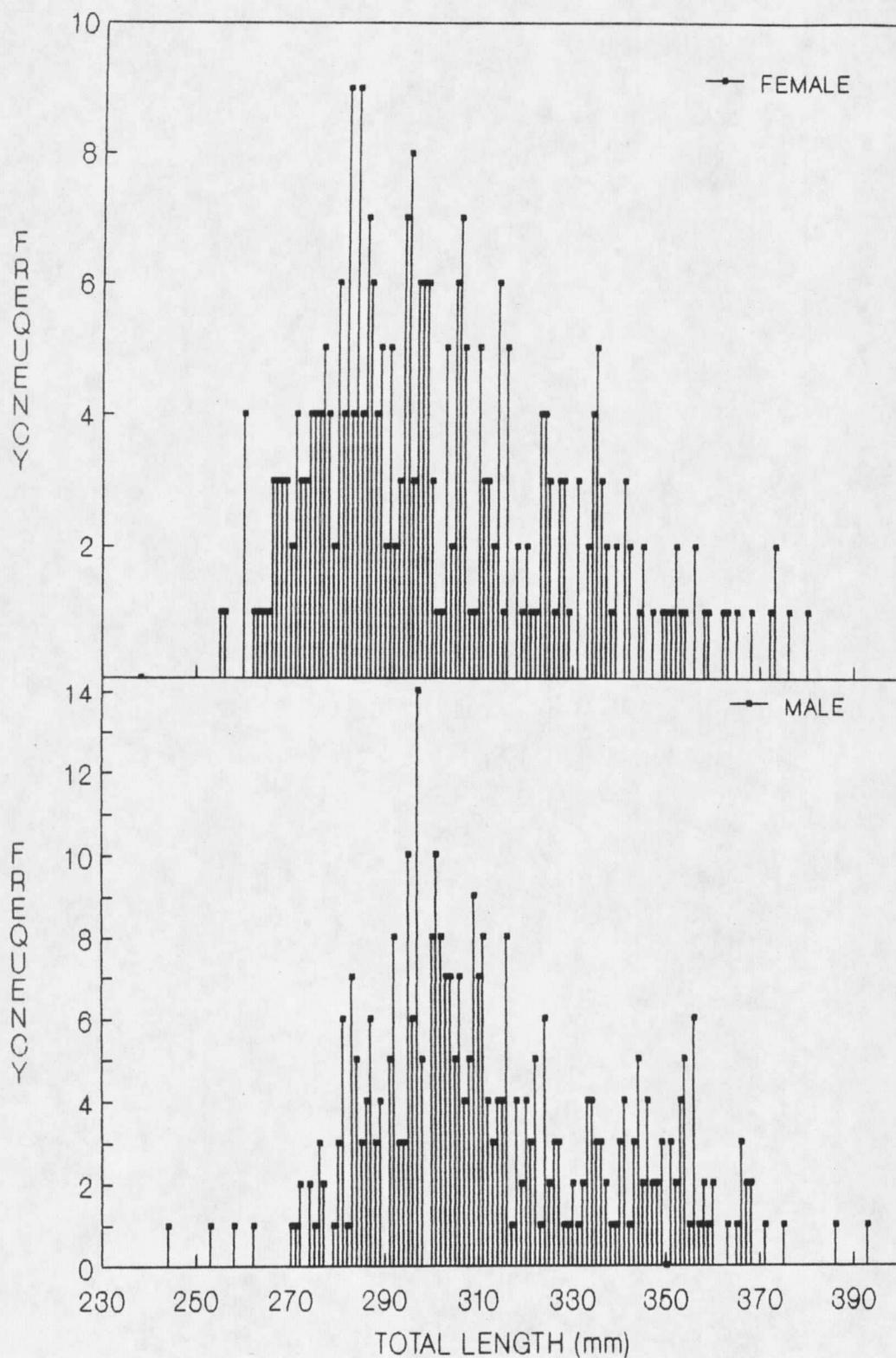


Figure 6. Length frequency of spawning male and female grayling from Deer Lake, 1990.

Table 3. Mean back-calculated lengths of Arctic grayling, Deer Creek, 1989.

Speci- men age	No. of fish in sample	Mean length (mm)	Mean back-calculated length (mm) at age (annulus)					
			1	2	3	4	5	
Females								
1	22	113	70					
2	3	293	61	182				
3	8	292	56	129	227			
4	9	332	66	172	255	312		
5	1	340	61	185	287	311	333	
Mean length			66	156	244	312	333	
Mean annual increment				90	88	68	21	
Males								
1	22	113	71					
2	2	208	58	154				
3	17	301	63	149	258			
4	17	336	66	156	257	313		
5	12	359	62	174	280	320	343	
Mean length			66	158	263	316	343	
Mean annual increment				92	105	53	27	

Table 4. Fecundity estimates for ripe grayling of Deer Lake, Montana, in 1989.

Sample	Total length (mm)	Weight (g)	Estimated no. of eggs		
			per female	per g female	per mm female
1	289	202	2743	13.6	9.5
2	294	198	2857	14.4	9.7
3	296	218	3125	14.3	10.6
4	304	202	3167	10.4	10.4
5	314	248	2459	9.9	7.8
6	340	317	3674	11.6	10.8
7	360	408	2895	7.1	8.0

### Hook Scar Incidence

In 1989, 27% of the fish handled on the recapture run had hook scars. Data on hook scars were not taken during the capture run. In 1990, 30% of the grayling handled during the mark and recapture runs had hook scars.

### Incidental Observations of Predation on Eggs and Fry

In 1989, I observed an adult grayling ingest an egg which passed in front of the fish. Analysis of stomach contents of 13 adult grayling (10 females and three males), which ranged 187 to 375 mm TL, showed that adults did eat some eggs. Of the 13 fish, three had consumed a total of 17 eggs.

During the summer of 1990, six adults remained in the outlet stream. On July 29, I observed these fish in shallow water (5 to 10 cm deep) chasing groups of fry. I was able to capture one of the adults, a 390 mm male, with a dip net and found 12 fry in its stomach.

### Movement of Young

#### Falls Trap

In 1989, the falls trap was installed on July 6 and removed on October 19. This trap sampled about 1/3 to 1/2 of the stream flow. Data collected did not show the total number of young going over the falls but did show a qualitative pattern of fry movement downstream (Figure 7). The greatest number of young went over the falls during and

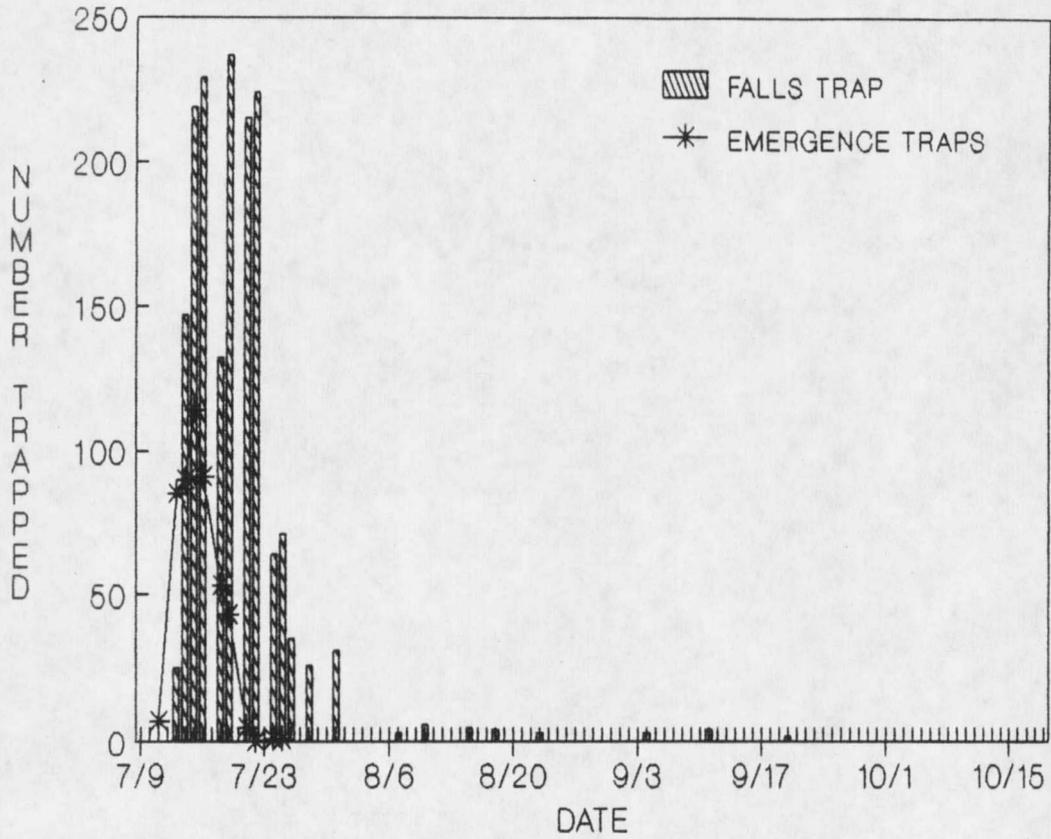


Figure 7. Number of age-0 grayling captured in emergence traps and the falls trap in Deer Creek, 1989.

shortly after swimup, in the early part of summer. In 1989, the peak period of swimup occurred in mid-July and the first young trapped had an average total length of 12 mm and ranged from 12 to 13 mm TL. As summer progressed and age-0 grayling became larger, the number moving over the waterfall diminished. Downstream movement nearly ceased by the end of July. The lowest number went over the waterfall near the end of the season. At this time, their total length averaged 39 mm and ranged from 30 to 48 mm.

In 1990, the falls trap was installed on July 21 and removed on October 11. The 1990 trap sampled the entire stream flow over the waterfall. I monitored the trap at 4-h intervals on sampling dates to collect quantitative information on the numbers of young going over the waterfall at different times of the day. The 1990 falls trap was put in after swimup had begun. As in the previous year, fish movement downstream over the waterfall was greatest during and shortly after peak swimup and diminished as the season progressed (Table 5). In 1990, the average total length of the trapped young was 14 mm (range of 12 to 16 mm) after swimup and 42 mm (range of 36 to 56 mm) in October (Figure 8).

Most downstream movement over the falls occurred in July, at night. Of all the young trapped in the falls trap during 1990, 87% moved during late July and 68% moved between the hours of 10 pm and 6 am (Table 5). In later

weeks, there was not a large difference between the numbers trapped at night and during the day.

Eggs were found in the falls trap during both years. Some of these eggs appeared viable.

Table 5. Numbers and mean total lengths of age-0 grayling in the waterfall trap, Deer Creek, 1990.

Month/day	Time of day	h	No. of young	No. per h	Mean length (mm)
7/23	6am-10pm	16	24	1.5	14.2
	10pm-6am	8	140	17.5	
7/28	11am-10pm	11	92	8.4	14.0
	10pm-6am	8	393	49.1	
	6am-2pm	8	76	9.5	
8/6	11am-10pm	11	29	2.6	18.8
	10pm-6am	8	16	2.0	
	6am-10am	4	4	1.0	
8/17	10pm-6am	8	10	1.3	27.5
	6am-10pm	16	27	1.7	
	10pm-6am	8	0	0.0	
	6am-2pm	8	1	0.1	
8/28	6am-10pm	16	10	0.6	32.3
	10pm-6am	8	5	0.6	
9/8	8am-10pm	14	3	0.2	41.6
	10pm-6am	8	2	0.3	
	6am-2pm	8	0	0.0	
9/19	12pm-2pm	2	0	0.0	
9/25	11am-1pm	2	0	0.0	
10/10	1pm-6pm	5	0	0.0	
	6pm-10am	16	0	0.0	

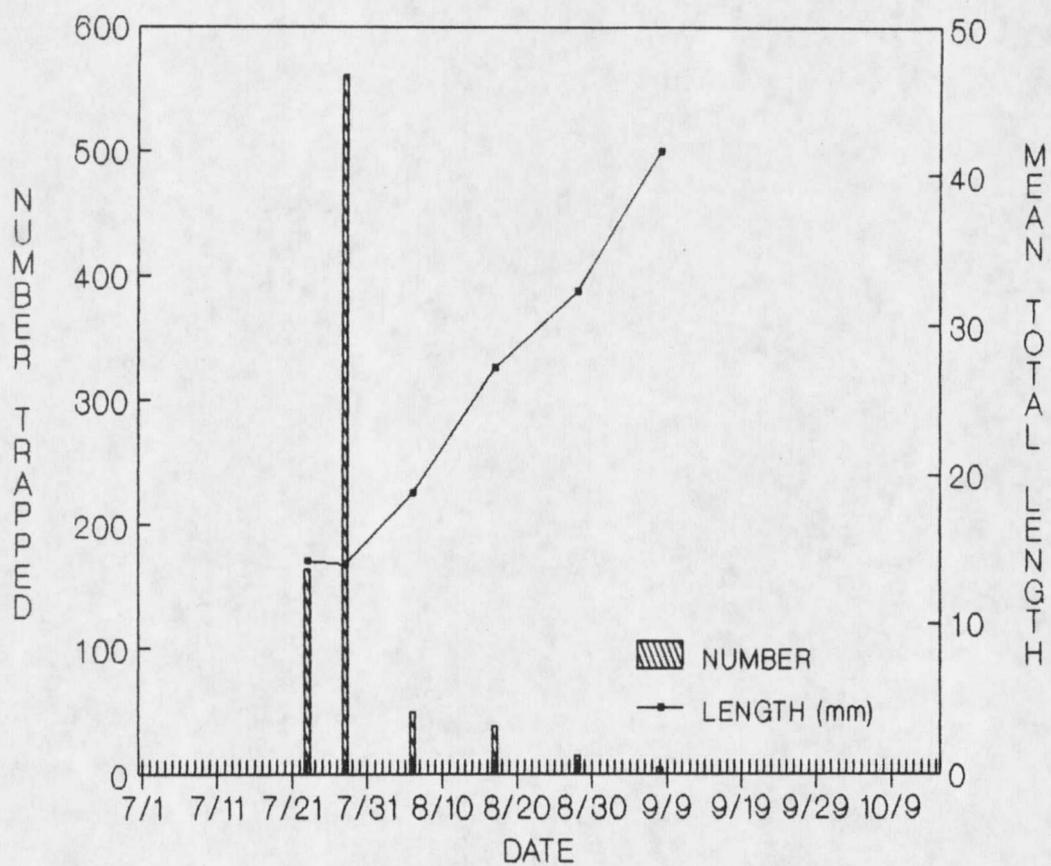


Figure 8. Number and mean total length of age-0 grayling captured in the falls trap in Deer Creek, 1990.

Two-way Trap

The two-way trap was operated from July 12 to November 10 in 1989, and from July 23 to October 11 in 1990. During both years, very few fish moved in either direction through this mid-section of stream. During the second half of July, 1989, 31 young moved into the downstream half of the trap and two moved into the upstream half. Only six other young moved into the trap throughout the rest of the season (Table 6). In 1990, even fewer fish moved between the upper and lower halves of the study site (Table 7).

Table 6. Numbers and mean total lengths of age-0 grayling in the two-way trap, Deer Creek, 1989.

Time period	No. of age-0 caught		Mean length (mm)
	Movement upstream	Movement downstream	
7/12 - 7/31	2	27	15
7/31 - 8/31	0	0	
8/31 - 9/30	3	1	
9/30 - 10/31	0	1	
10/31 - 11/10	0	1	74

Table 7. Numbers and mean total lengths of age-0 grayling in the two-way trap, Deer Creek, 1990.

Time period	No. of age-0 caught		Mean length (mm)
	Movement upstream	Movement downstream	
7/24 - 7/29	0	31	14
7/29 - 8/6	0	1	14
8/6 - 8/28	1	0	48
8/28 - 9/25	2	0	66
9/25 - 10/11	1	0	76

#### Lake Trap

The lake trap operated from July 12 to November 10 in 1989, and from July 23 to October 11 in 1990. In both years, no age-0 grayling were trapped early in the season. The first movement into the lake occurred on August 18 in 1989, and on September 8 in 1990. The average size of the first age-0 young trapped was 52 mm in 1989 and 54 mm in 1990 (Tables 8 and 9). More fish moved into the lake as the season progressed.

In both years, only a small proportion of age-0 young in the outlet stream moved into the lake by the time of trap removal; 104 by November 10, 1989 and 23 by October 10, 1990. Many young were present in the outlet stream on both dates. Traps were removed when cold temperatures made it likely that the lake surface would soon freeze. In 1989, ice had formed on the lake when the trap was removed.

Table 8. Numbers and mean total lengths of young grayling in the lake trap, Deer Lake, 1989.

Date	No. of fish trapped		Mean total length (mm)	
	Age-0	Age-1	Age-0	Age-1
7/12	0	0		
7/18	0	1		
7/24	0	2		
7/25	0	1		
8/4	0	2		
8/18	2	1	52	
9/4	10	4	60	124
9/11	9	5	65	140
9/15	23	10	65	126
9/20	8	7	67	128
9/26	26	5	66	133
10/4	9	4	70	122
10/19	10	3	72	121
11/10	7	0	78	
Total	104	45		

Table 9. Numbers and mean total lengths of young grayling in the lake trap, Deer Lake, 1990.

Date	No. of fish trapped		Mean length (mm)	
	Age-0	Age-1	Age-0	Age-1
7/24	0	0		
7/28	0	0		
8/6	0	0		
8/18	0	0		
8/28	0	0		
9/8	14	1	54	127
9/19	3	0	59	
9/25	2	1	65	119
10/10	4	0	66	
Total	23	2		

#### Movement of Age-1 Juveniles

A few of the age-1 juvenile grayling still present in the outlet stream moved into the three traps. These fish ranged in length from 68 mm in July to 166 mm in September. In the falls trap, three age-1 juveniles were caught in July 1989 and two in July 1990. In the two-way trap, 14 age-1 juveniles were caught moving downstream and three moving upstream in 1989, all in July. In 1990, the two-way trap caught one, moving upstream, in August.

Over the 2 year period, the lake trap caught the most age-1 fish. The first was trapped on July 18, 1989 (Table

8). The greatest number of age-1 juveniles was trapped in September 1989. Only two were trapped in the lake trap in 1990, both in September.

#### Incidental Observations of Young in the Outlet Stream

On June 8, 1989, the surface of Deer Lake had begun to thaw and I saw five age-0 juveniles and five adults in small areas of open water in the outlet stream. Most of the stream was still covered with ice at this time. On November 10, 1989, I saw age-0 and age-1 juveniles in the upper half of the stream when most of the stream and all of the lake was covered by ice.

On June 12, 1990, I saw no adults, 15 live age-0, 2 live age-1, and 59 dead age-0 and age-1 juveniles in the outlet stream, while the lake and most of the outlet surfaces were still frozen. On June 25, 1990, I counted no adults, 56 live age-0, 2 live age-1, and 53 dead age-0 and age-1 juveniles in the upper half of the study site. I also found six live age-0 and one dead age-1 juveniles in shallow, slow water in the lower half of the stream. At this time, there was ice covering the lake and part of the stream.

#### Fry Habitat Use and Preference

In all three surveys, age-0 grayling used some range of measured habitat characteristics at a significantly ( $p \leq$

0.05) greater frequency than the availability of that characteristic. Age-0 Deer Lake grayling were most frequently found over the two finest substrate types, silt (type 1) and sand (type 2). Silt was most heavily used by young on all three surveys (Table 10, Figure 9), with proportions of young over this substrate ranging from 0.44 to 0.59. However, silt was also the most abundant substrate and was not used in greater proportion than available. Sand was the second most heavily used substrate, with proportions of usage ranging from 0.17 to 0.21 among the three surveys. In survey 3, sand was used in significantly greater proportion than available. Use of both gravel (type 3) and macrophyte vegetation (type 6) were low and did not differ from availability on all three survey dates. All macrophytes observed were emergent types. Use of the coarser substrates, cobble (type 4) and boulder (type 5), either did not significantly differ from or was significantly lower than availability.

The age-0 young were most frequently found within the two distance categories closest to cover on all three survey dates (Table 11, Figure 10). However, they appeared to prefer distances farther from cover as they became older and larger. On all three surveys, young were most frequently seen within the closest distance interval to cover (0-20 cm), in proportions ranging from 0.35 to 0.61 (Table 11). However, this was also the most available

Table 10. Bonferroni intervals for substrate type at age-0 grayling positions for surveys 1, 2, and 3, Deer Creek, 1990.

Substrate type	Ni	Expected proportion of usage Po	Actual proportion of usage Pi	Bonferroni interval	Code
<u>Survey 1 (July 28) No=163</u>					
1	90	0.450	0.525	-0.22, 0.7	0
2	29	0.079	0.170	-0.19, 0.003	0
3	9	0.061	0.052	-0.06, 0.08	0
4	25	0.174	0.147	-0.08, 0.13	0
5	10	0.147	0.057	0.003, 0.18	-
6	9	0.089	0.050	-0.03, 0.11	0
<u>Survey 2 (August 18) No=163</u>					
1	96	0.522	0.590	-0.21, 0.08	0
2	29	0.098	0.178	-0.18, 0.02	0
3	9	0.058	0.052	-0.06, 0.07	0
4	14	0.249	0.085	0.06, 0.27	-
5	13	0.068	0.079	-0.09, 0.07	0
6	3	0.006	0.016	-0.04, 0.02	0
<u>Survey 3 (September 8) No=170</u>					
1	63	0.487	0.436	-0.10, 0.20	0
2	31	0.070	0.214	-0.25, -0.04	+
3	14	0.091	0.100	-0.10, 0.08	0
4	26	0.193	0.181	-0.10, 0.13	0
5	8	0.127	0.052	-0.01, 0.16	0
6	3	0.032	0.017	-0.03, 0.06	0

+ indicates Pi is significantly  $>$  Po, at the  $p \leq 0.05$  level.

- indicates Pi is significantly  $<$  Po, at the  $p \leq 0.05$  level.

0 indicates no significant difference exists between Pi and Po, at the  $p \leq 0.05$  level.

Ni= number of fish positions observed.

No= number of locations of availability measurement.

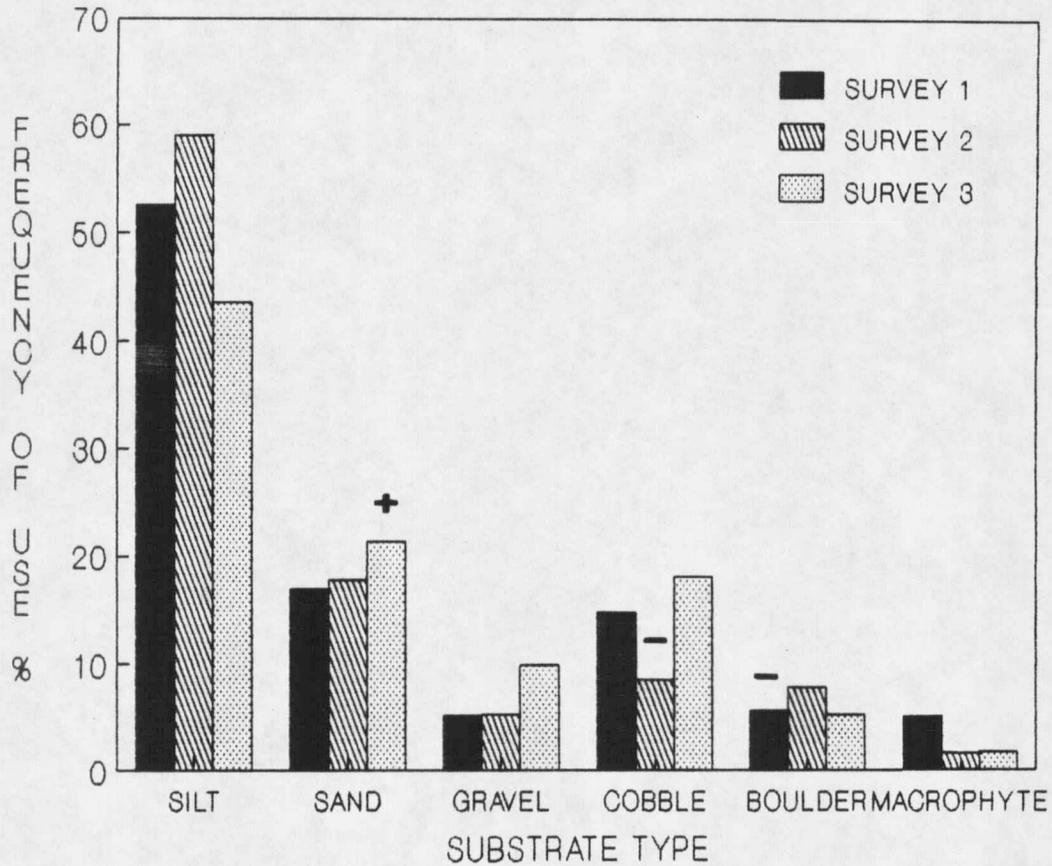


Figure 9. Frequency of use (%) of substrate types by age-0 grayling in Deer Creek, 1990. + indicates proportion of use significantly greater than availability. - indicates proportion of use significantly less than availability.

distance interval (Table 11), and was actually used in significantly lower proportion than available on all three surveys. Use of this closest distance interval progressively decreased from survey 1 to 3.

The next two distance intervals from cover, 21-40 and 41-60 cm, were used in greater proportion than available on all three surveys. Proportion of young in the second distance interval, 21-40 cm, remained relatively constant at about 0.24 to 0.29. Proportions of young using the third distance interval, 41-60 cm, increased from 0.09 in survey 1 to 0.13 and 0.26 in surveys 2 and 3, respectively. Proportions of young that used distance intervals from cover beyond 60 cm were low and were not significantly different from availability.

The preferred range of mean water column velocity increased with time and therefore size of young (Table 12, Figure 11). The average mean water column velocity used by young in survey 3 was significantly greater ( $p \leq 0.05$ ) than the average used in survey 2. On all three surveys, young most frequently occupied the slowest range of water velocities (0-0.05 m/s), which was also the most available (Table 12). However, the proportion of young observed within this slowest range of mean column velocities decreased from 0.91 in survey 1 to 0.54 in survey 3. Proportional usage of this slowest velocity range also changed from being significantly greater than available

Table 11. Bonferroni intervals for the distance to cover at age-0 grayling positions in surveys 1, 2, and 3, Deer Creek, 1990.

Distance to cover (cm)	Ni	Expected proportion of usage Po	Actual proportion of usage Pi	Bonferroni interval	Code
<u>Survey 1 (July 28) No=162</u>					
0-20	104	0.803	0.605	0.07, 0.33	-
21-40	42	0.111	0.244	-0.24, -0.03	+
41-60	16	0.025	0.093	-0.14, -0.001	+
61-80	6	0.012	0.035	-0.07, 0.02	0
81-100	1	0.019	0.006	-0.02, 0.05	0
> 100	3	0.031	0.017	-0.03, 0.06	0
<u>Survey 2 (August 18) No=163</u>					
0-20	83	0.798	0.506	0.16, 0.42	-
21-40	41	0.123	0.250	-0.24, -0.02	+
41-60	21	0.018	0.128	-0.18, -0.04	+
61-80	4	0.012	0.024	-0.05, 0.03	0
81-100	7	0.006	0.043	-0.08, 0.01	0
> 100	8	0.043	0.049	-0.07, 0.06	0
<u>Survey 3 (September 8) No=170</u>					
0-20	50	0.712	0.350	0.22, 0.50	-
21-40	41	0.106	0.287	-0.30, -0.06	+
41-60	37	0.082	0.259	-0.29, -0.07	+
61-80	9	0.041	0.064	-0.09, 0.04	0
81-100	4	0.018	0.028	-0.06, 0.04	0
> 100	2	0.041	0.014	-0.02, 0.08	0

+ indicates Pi is significantly > Po, at the  $p \leq 0.05$  level.

- indicates Pi is significantly < Po, at the  $p \leq 0.05$  level.

0 indicates no significant different exists between Po and Pi, at the  $p \leq 0.05$  level.

Ni= number of fish positions observed.

No= number of locations of availability measurement.

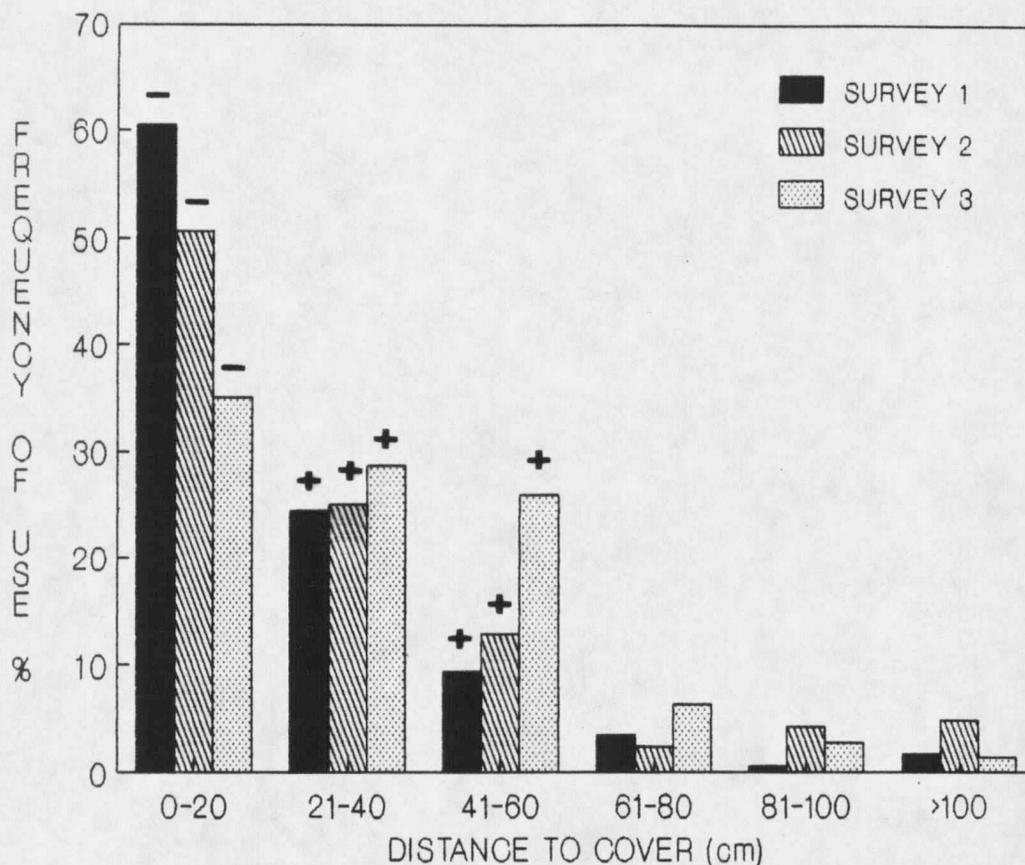


Figure 10. Frequency of use (%) of distance to cover by age-0 grayling in Deer Creek, 1990. + indicates proportion of use significantly greater than availability. - indicates proportion of use significantly less than availability.

in survey 1 to significantly less than available in survey 3.

The next higher range of mean column velocities (0.06-0.10 m/s) was also the next most frequently used and the next most available. The proportion of young within mean column velocities of 0.06-0.10 m/s increased from 0.09 in survey 1 to 0.36 and 0.26 in surveys 2 and 3, respectively. Proportional use was significantly greater than availability in surveys 2 and 3.

Mean column velocities greater than 0.10 m/s were not used by age-0 grayling observed in survey 1, but were used by those seen in surveys 2 and 3. Mean water column velocities 0.11-0.15 m/s were used in greater proportion than availability by those observed in survey 3. Only a few young were observed to use mean column velocities greater than 0.15 m/s in surveys 2 and 3, and proportional use of these velocities did not significantly differ from or was significantly lower than availability (Table 12).

The preferred total water column depth also increased with time and size of young (Table 13). Greater proportions of observed fish positions were in deeper water as the season progressed (Figure 12). The preferred range of total column depth was 6-10 cm in survey 1, 26-30 cm in survey 2, and 16-20 and 26-30 cm in survey 3 (Table 13, Figure 12). In all three surveys, the shallowest, most

Table 12. Bonferroni intervals for mean water column (0.6 depth) velocities at age-0 grayling positions in surveys 1, 2, and 3, Deer Creek, 1990.

Velocity (m/s)	Ni	Expected proportion of usage Po	Actual proportion of usage Pi	Bonferroni interval	Code
<u>Survey 1 (July 28) No=157</u>					
0.0-0.05	155	0.758	0.906	-0.25, -0.05	+
0.06-0.10	16	0.147	0.094	-0.04, 0.15	0
0.11-0.50	0	0.095	0.000	0.04, 0.15	-
<u>Survey 2 (August 18) No=162</u>					
0.0-0.05	95	0.673	0.583	-0.04, 0.22	0
0.06-0.10	58	0.161	0.356	-0.31, -0.08	+
0.11-0.15	10	0.056	0.061	-0.07, 0.06	0
0.16-0.50	0	0.110	0.000	0.05, 0.17	-
<u>Survey 3 (September 8) No=164</u>					
0.00-0.05	77	0.726	0.535	0.05, 0.34	-
0.06-0.10	37	0.104	0.257	-0.27, -0.04	+
0.11-0.15	26	0.049	0.181	-0.23, -0.04	+
0.16-0.20	3	0.043	0.021	-0.03, 0.08	0
0.21-0.25	0	0.012	0.000	-0.01, 0.04	0
0.26-0.30	1	0.012	0.007	-0.03, 0.04	0
0.31-0.50	0	0.054	0.000	0.01, 0.10	-

+ indicates Pi is significantly > Po, at the  $p \leq 0.05$  level.

- indicates Pi is significantly < Po, at the  $p \leq 0.05$  level.

0 indicates no significant difference exists between Pi and Po, at the  $p \leq 0.05$  level.

Ni= number of fish positions observed.

No= number of locations of availability measurement.

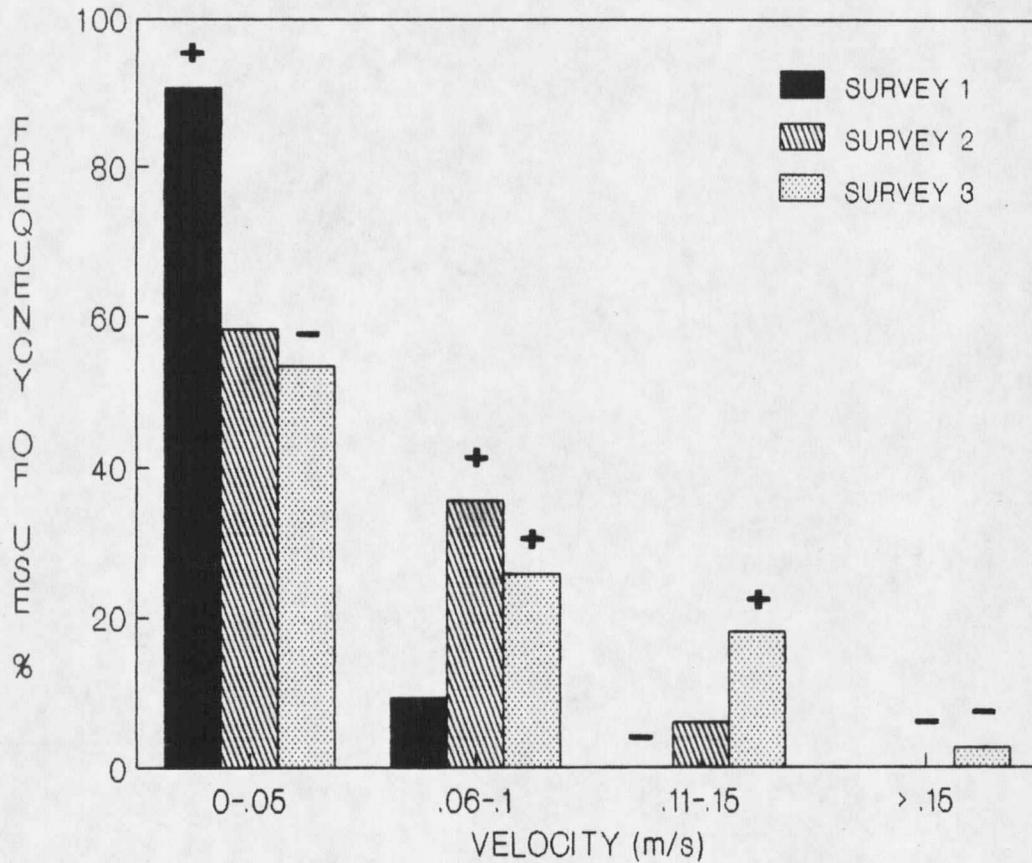


Figure 11. Frequency of use (%) for mean water column velocities by age-0 grayling in Deer Creek, 1990. + indicates proportion of use significantly greater than availability. - indicates proportion of use significantly less than availability.

Table 13. Bonferroni intervals for total water column depth at age-0 grayling positions for surveys 1, 2, and 3, Deer Creek, 1990.

Water column depth (cm)	Ni	Expected proportion of usage Po	Actual proportion of usage Pi	Bonferroni interval	Code
<u>Survey 1 (July 28) No=168</u>					
0-5	14	0.339	0.082	0.14, 0.37	-
6-10	75	0.274	0.439	-0.30, -0.03	+
11-15	46	0.173	0.269	-0.22, 0.02	0
16-20	24	0.125	0.140	-0.11, 0.08	0
21-25	5	0.066	0.029	-0.03, 0.10	0
26-30	4	0.012	0.023	-0.05, 0.03	0
31-40	3	0.012	0.017	-0.04, 0.03	0
<u>Survey 2 (August 18) No=165</u>					
0-5	14	0.346	0.086	0.14, 0.38	-
6-10	53	0.327	0.325	-0.14, 0.14	0
11-15	44	0.164	0.270	-0.23, 0.02	0
16-20	21	0.109	0.129	-0.12, 0.08	0
21-25	14	0.030	0.086	-0.13, 0.01	0
26-30	14	0.012	0.086	-0.14, -0.01	+
31-35	2	0.006	0.012	-0.04, 0.02	0
36-40	1	0.006	0.006	-0.02, 0.02	0
<u>Survey 3 (September 8) No=164</u>					
0-5	10	0.372	0.069	0.19, 0.42	-
6-10	26	0.305	0.181	-0.01, 0.26	0
11-15	37	0.189	0.257	-0.20, 0.06	0
16-20	32	0.092	0.222	-0.24, -0.02	+
21-25	11	0.024	0.076	-0.12, 0.02	0
26-30	12	0.006	0.083	-0.14, -0.01	+
31-35	9	0.006	0.063	-0.12, 0.001	0
36-50	7	0.006	0.049	-0.10, 0.01	0

+ indicates Pi is significantly  $>$  Po, at the  $p \leq 0.05$  level.

- indicates Pi is significantly  $<$  Po, at the  $p \leq 0.05$  level.

0 indicates no significant difference exists between Pi and Po, at the  $p \leq 0.05$  level.

Ni= number of fish positions observed.

No= number of locations of availability measurement.

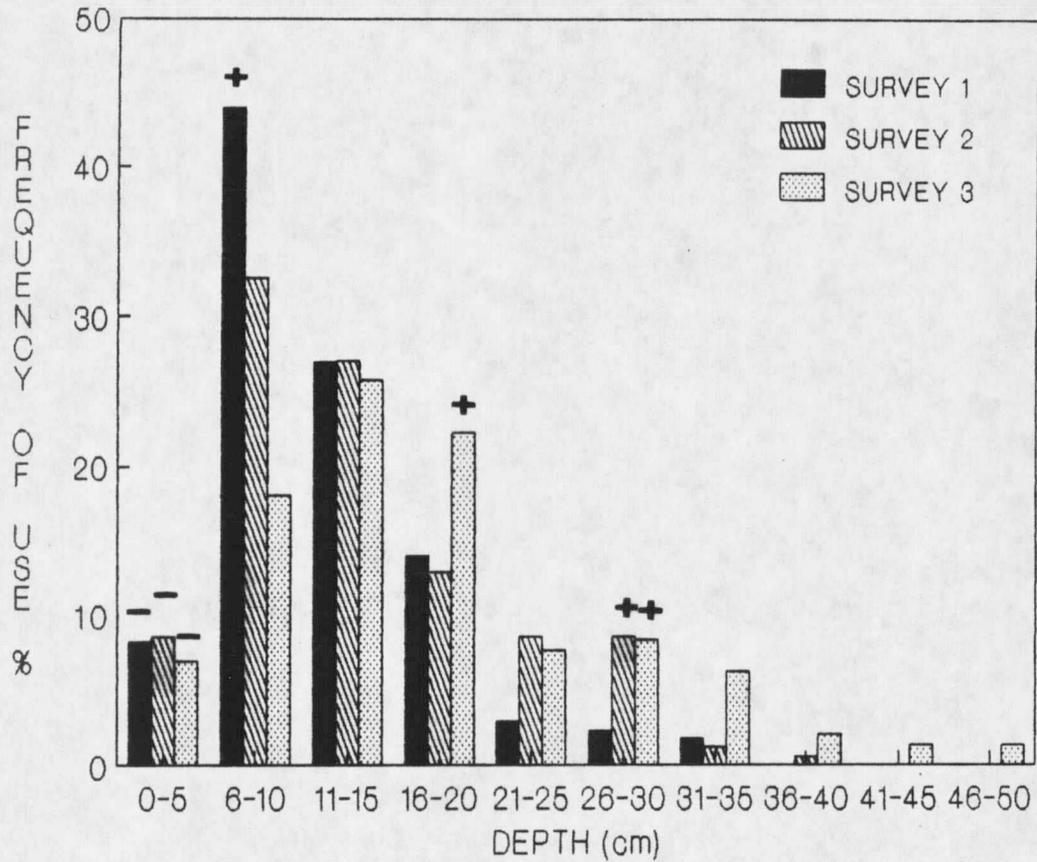


Figure 12. Frequency of use (%) of total water column depth by age-0 grayling in Deer Creek, 1990. + indicates proportion of use significantly greater than availability. - indicates proportion of use significantly less than availability.

available depth interval of 0-5 cm was used in lower proportion (0.07 to 0.09) than available (0.34 to 0.37).

In all three surveys, young used positions near the stream bottom (Figure 13). Over 60% of all focal point depths were 0 to 5 cm from the substrate surface, and over 90% were 10 cm or less from the substrate (Table 14).

Table 14. Focal point depths at positions of age-0 grayling in surveys 1, 2, and 3, Deer Creek, 1990.

Survey date	Approx. mean total length (mm)	N	Proportion at focal depth (cm)					
			0-5	6-10	11-15	16-20	21-25	>25
July 28	15	171	0.626	0.275	0.053	0.041	0.006	0.000
Aug. 18	29	163	0.687	0.227	0.043	0.037	0.006	0.000
Sept. 8	41	144	0.681	0.271	0.028	0.007	0.007	0.007

The focal point velocities at all observed fish positions were less than or equal to 0.1 m/s (Figure 14). In survey 1, 98% of measured focal point velocities were in the range 0.0 to 0.05 m/s (Table 15). For surveys 2 and 3, more than 77% of the velocities fell in this range. The mean focal point velocities of surveys 2 and 3 are significantly ( $p \leq 0.05$ ) greater than that of survey 1.

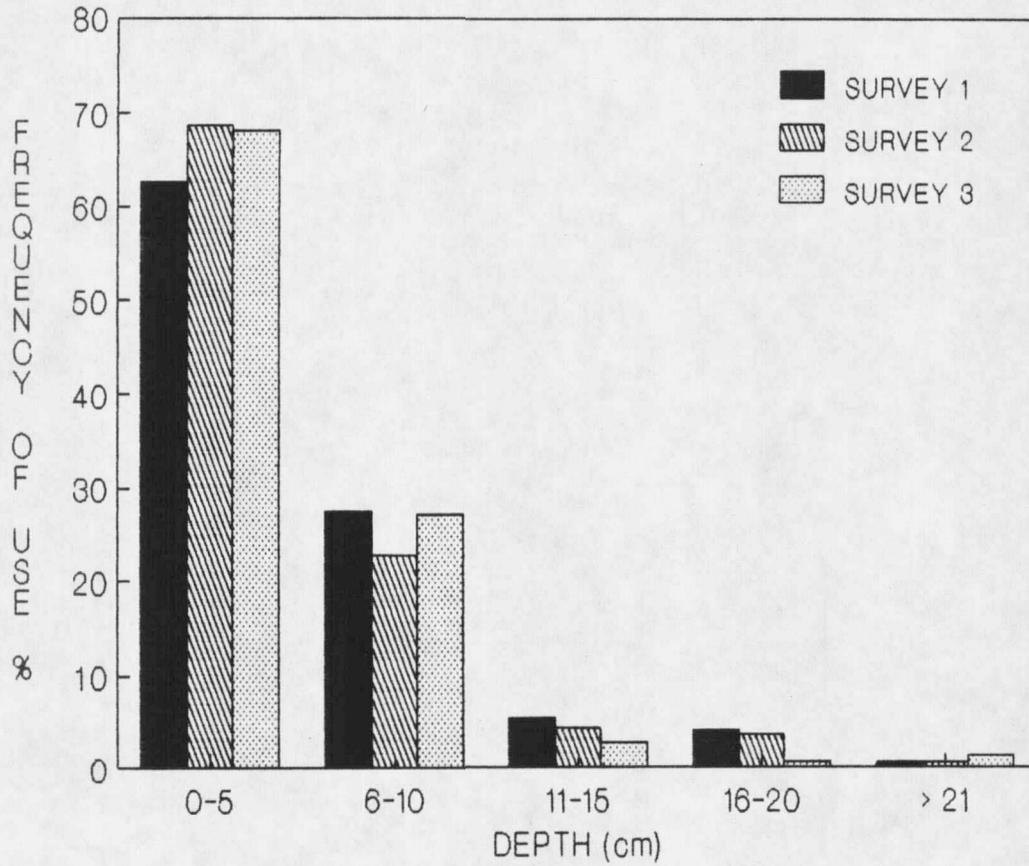


Figure 13. Frequency of use (%) of focal point depth by age-0 grayling in Deer Creek, 1990.

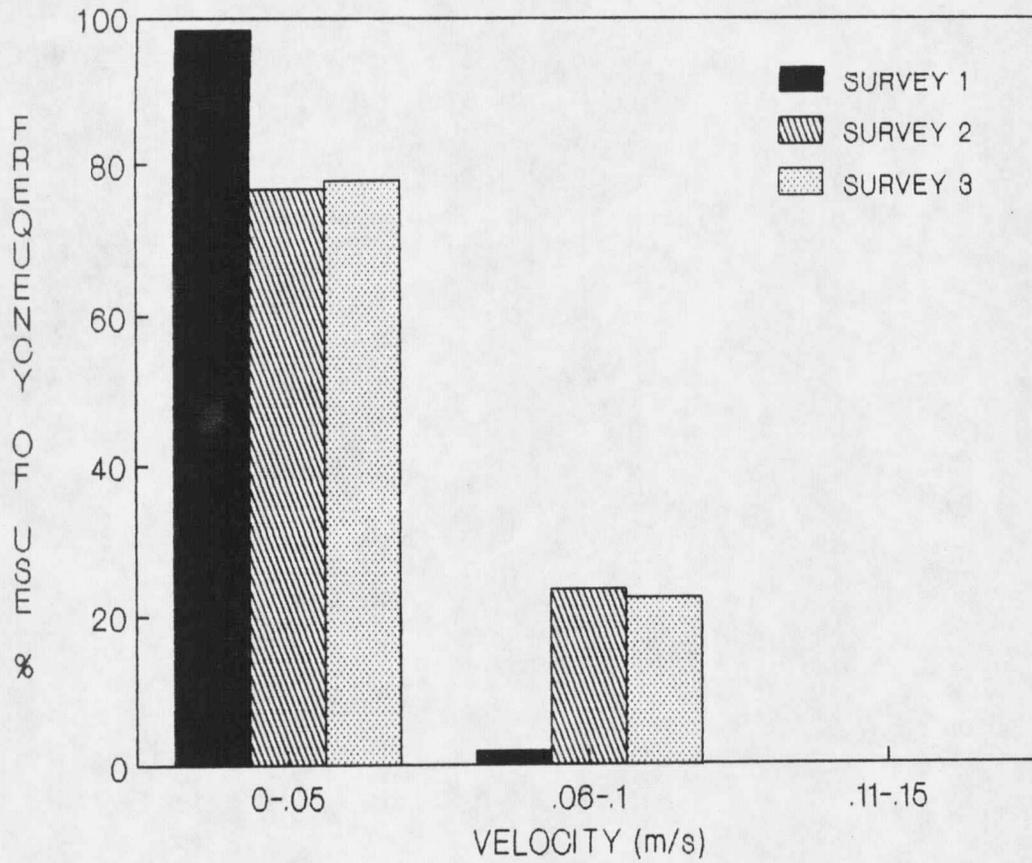


Figure 14. Frequency of use (%) of focal point velocity by age-0 grayling in Deer Creek, 1990.

Table 15. Focal point velocities at positions of age-0 grayling in surveys 1, 2, and 3, Deer Creek, 1990.

Survey date	Approx. mean total length (mm)	N	Proportion at focal velocity (m/s)		
			0.0-0.05	0.06-0.10	0.11-0.50
July 28	15	171	0.983	0.018	0.000
Aug. 18	29	163	0.767	0.233	0.000
Sept. 8	41	144	0.778	0.222	0.000

#### Total Length of Age-0 Young on Survey Dates

The mean total length of age-0 young increased throughout the summer months and between habitat use surveys. Also, young in the upstream areas closer to the lake were generally larger than those farther downstream toward the waterfall. The mean total length of age-0 young in the first survey (July 28, 1990) was 15 mm for the entire study site. Dividing the study site in half at the two-way trap (Figure 2), allows comparison of mean total lengths in the upper and lower sections. In survey 1, the mean total length of age-0 young was 17 mm in the upper half and 14 mm in the lower half. In survey 2 (August 18), the mean total length was 29 mm for the entire study site, 35 mm for the upper half, and 26 mm for the lower half. In survey 3 (September 8), the overall mean was 41 mm, the upper half mean was 48 mm, and the lower half mean was 33 mm.

## DISCUSSION

Spawning Population

The timing of Deer Lake spawning runs appears to be influenced by water temperature. Adult grayling entered the stream as ice melted off Deer Lake. Most spawning adults entered the stream when stream water temperatures approached 6 C in 1989 and 7 C in 1990. This is similar to relations between temperature and the timing of grayling spawning runs in other Montana and Wyoming lakes (Kruse 1959, Peterman 1972, Lund 1974, Wells 1976).

The spawning runs in both years had a male:female sex ratio close to 1.0:1.0, which was also reported by Kruse (1959) for Grebe Lake grayling. However, this is in contrast to disproportionate sex ratios reported among spawning adults from other lacustrine grayling populations in Montana. Peterman (1972) and Wells (1976) reported male:female ratios of about 3:1 and 2:1 among spawners from Lake Agnes and Hyalite Reservoir, respectively. Conversely, Lund (1974) reported that females outnumbered males by about 2:1 among spawners from Elk Lake.

In both years, the mark and recapture runs were conducted during the peak of the Deer Lake spawning run.

Grayling did not have diel movements into and out of the spawning stream, as described for certain inlet-spawning lacustrine populations (Peterman 1972, Lund 1974, Bishop 1971). Since adults probably entered the stream between sampling runs, the assumption of a closed population was not met, and the maximum likelihood estimates should be used cautiously. However, it is assumed that all marked fish were still in the stream at the time of the recapture run, since the adults accumulated in the stream instead of moving in and out on a daily basis. Thus, the spawning population estimates represent the number of adults in the stream at the time of the recapture run.

Deer Lake grayling mature when 3 years old, as they approach the end of their fourth year of life. This is characteristic of southern grayling populations (Kruse 1959, Kaya 1990). Average fecundity estimates, 2,989 eggs per fish and 12.4 eggs/g fish weight, were similar to estimates for other grayling populations. Peterman (1972) found females of Lake Agnes to average 1,750 eggs and 12.6 eggs/g. For one population of Canadian grayling, Bishop (1971) reported an average fecundity of 9,670 eggs and about 11.0 eggs/g. In Elk Lake, Lund (1974) found fecundity averaged 8,170 eggs and 21.9 eggs/mm, which is greater than that seen at Deer Lake.

Age and Growth

Deer Lake grayling are much smaller during their first 2 years than reported for other lacustrine populations (Table 16). Growth during the first year is about one-half that reported for other Montana populations. Back-calculated mean total length at age-1 for spawners was similar to the back-calculated mean total length (70 mm) of age-1 young sampled and also to the total lengths of age-1 young seen in the outlet stream during early summer. Thus, the initial slow growth rate appears related to the extended residence in the outlet stream.

After immigrating to Deer Lake, annual increments of growth were similar to or greater than those of other populations. By the third year, the Deer Lake grayling were similar in length to other populations (Figure 15). The oldest fish I confidently aged was 6 years old. Due to the slower growth rate in later years it is difficult to separate the later annuli and to determine the age of Deer Lake grayling beyond 5 or 6 years.

The growth rate of young grayling in the lower half of the outlet stream was slower than that in the upper half. This was probably due to differences in habitat quality between the two halves. The daily mean temperature in the lower half was generally lower than that in the upper half (Figure 4). The daily mean temperature at the lake outlet more often remained within the optimal range for growth of

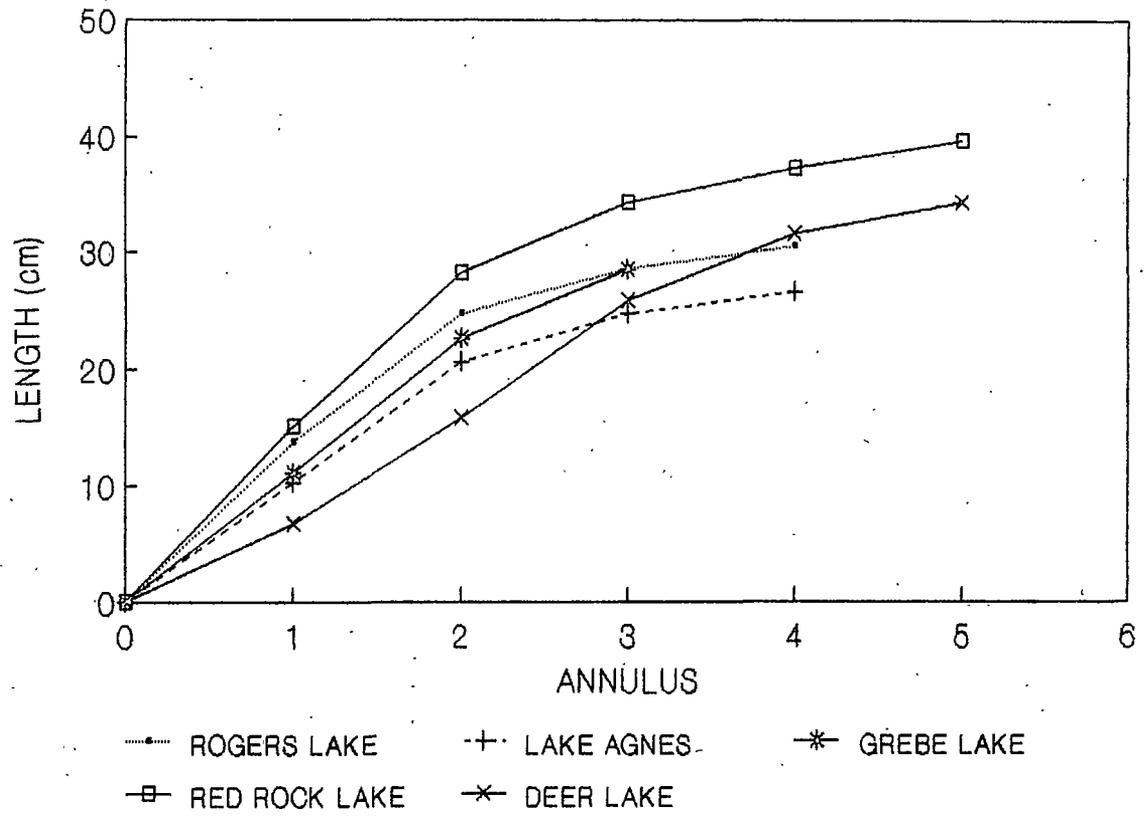


Figure 15. Comparison of back-calculated mean total length (cm) at annuli for grayling of Deer Lake and other lakes in Montana.

Table 16. Back-calculated mean total lengths (cm) at annuli of grayling from Deer Lake and from rivers, lakes, and reservoirs in Montana.

<u>Population</u>	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	<u>Reference</u>
Big Hole River	19.8	26.1	29.2	31.6	38.1	Liknes 1981
Big Hole River	14.5	24.9	29.7	32.2	34.0	Shepard and Oswald 1989
Rogers Lake	13.7	24.7	28.5	30.4		Brown 1943
Lake Agnes	10.3	20.6	24.7	26.5		Peterman 1972
Grebe Lake	11.1	22.6	28.4			Kruse 1959
Red Rock Lake	15.1	28.2	34.3	37.3	39.6	Nelson 1954
Hyalite Reserv.			36.0	39.7	41.7	Wells 1976
Deer Lake	6.6	15.8	25.8	31.5	34.3	

grayling, 12.8 to 15.5 C (Davis 1953), than that of the lower half. There were also greater daily temperature fluctuations in the lower half. The temperature at the two-way trap was both warmer during the day (at times above 20 C) and cooler at night than the outlet temperature. This is possibly due to the addition of cold spring water and the diurnal heat exchange in the slow shallow waters of the upper half. It is also possible that more food is available in the upper half through drift of plankton from the lake. There was also more shallow water with slow current velocities in the upper half.

Fry Movement

The extended residence of young Deer Lake grayling in the spawning stream seems unique to lacustrine grayling populations of Montana and Wyoming. Previous studies, all on inlet-spawning populations, indicate that young migrate down to the lake shortly after becoming free swimming (Nelson 1954, Kruse 1959, Lund 1974, Wells 1976).

Small numbers of fry began moving into Deer Lake in August, 1989 and in September, 1990. Most fry remained in the outlet stream, even as water temperatures dropped and ice began to cover the stream and lake surfaces. There were also age-1 young remaining in the stream at these times.

In June 1990, before the lake and all stream surfaces thawed, both live and dead age-0 and age-1 young from the previous summer were seen in the outlet stream. In the shallower areas, I counted 59 fish, most age-0 and a few age-1, which apparently suffered winter mortality by being trapped in areas without sufficient depth and current. Live young were also seen in the outlet before all ice cleared from the stream surface in 1989. These observations further support the probability that some young remain in the stream over winter and through their entire first year and part of their second year. No adults were seen in the stream before the lake began to thaw.

Each year, large numbers of age-0 young were lost over the waterfall. Most downstream movement occurred in July, at night, during or shortly after the peak period when fry became free swimming. As summer progressed the number of young in the falls trap diminished to zero.

In contrast, fry in the upper half of the site did not move downstream and into the two-way trap. The two-way trap was assumed to have functioned properly, since young were not observed to congregate on either side of the trap.

Loss over the falls may represent deliberate downstream movement of young, or passive displacement. Downstream movement may have resulted from high densities of young in the lower half of the stream, where the major spawning areas are located. Salmonid fry may move downstream while searching for unoccupied and suitable habitat. Moore and Gregory (1988) found that by increasing the amount of lateral habitat in a stream reach, they increased the abundance of cutthroat trout (Oncorhynchus clarki) fry and reduced downstream fry emigration and mortality. Newman and Waters (1989) found that in a resident population of brown trout most movement was by young-of-the-year fish, and retention of young within a stream section was directly related to the availability of suitable habitat. Elliott (1986) felt downstream movement of brown trout fry may have survival value by enhancing food supply and providing cover from adverse conditions.

The greater availability of shallow areas with slow current velocities in the upper section may have kept fry from moving downstream.

Since the two-way trap demonstrated that very few young moved downstream from the upper half of the study site, those that went over the falls must have originated from the lower half. The origins of these young from within the lower half is not known, since local movements were not measured. Possibly, local movements of young within the general stream section, result in some being inadvertently carried over the falls. Also, faster current velocities in the lower stream section could sweep fry downstream. One of the principal spawning areas is within 50 m of the falls, and is separated from the falls by a narrow, mostly fast-flowing reach. It is likely that young passing over the falls originated within close proximity to the falls, from eggs deposited there or from eggs that drifted downstream from upstream spawning areas. Since grayling broadcast their eggs over the substrate, large numbers of eggs are displaced downstream from the immediate spawning areas.

In 1990, 68% of fry moving downstream went over the falls between 10 pm and 6 am. This pattern of downstream movement is consistent with the downstream movement seen in other grayling populations (Kruse 1959, Wells 1976). Lund (1974) found that 94.5 and 79.6% of grayling fry trapped

moving downstream were caught between the hours of 8 pm and 8 am. One explanation is that after dark, salmonid fry may lose visual contact with the physical characteristics of their stream position and fail to maintain their position moving downstream with the current (Hoar 1953, 1958, Northcote 1962, cited in Godin 1981). It has also been proposed that nocturnal movement is an antipredation mechanism (Ginetz and Larkin 1976, Godin 1981, Bardonnnet and Gaudin 1990).

The downstream movement in the lower half, however, could represent drift of unhealthy fish. Elliott (1986) found 81% of young brown trout (Salmo trutta) in an English stream died soon after becoming free swimming and drifted downstream, while those that remained healthy held their position or moved upstream. The slower current velocities in the upper half may be insufficient to transport unhealthy fry downstream.

I do not know whether grayling that moved downstream over the falls were healthy, or what percentage of all the young produced in the lower section they represented. However, many young were present in the stream throughout the study period.

My observations are not conclusive regarding the reason for downstream movement of young Deer Lake grayling. Since downstream movement over the waterfall results in loss from the population, such movement, if intentional,

may suggest that the Deer Lake population has not completely adapted to outlet spawning. Kaya (1989) demonstrated that young Deer Lake grayling have a greater tendency, apparently genetically determined, to swim upstream than those of an inlet-spawning population. However, he also reported that many of the young Deer Lake grayling did move downstream, especially in darkness.

#### Habitat Use

There appear to be specific habitat conditions which are preferred by young grayling. Armstrong (1986), in reviewing grayling research from Alaska, states that fry occurred in quiet water, shallow riffles, backwaters, side channels, pools, and brushy or grassy areas of adjacent sloughs. Optimal rearing areas for fluvial grayling contain at least 30% pools, backwaters, and side channels with average current velocities  $<0.15$  m/s (Hubert et al. 1985, Reynolds 1989). Nelson (1954) found grayling fry were numerous in Red Rock Creek for 2 to 3 weeks in backwaters and areas with slow currents, but did not measure these habitat parameters. Quiet, slow moving water appeared to be most important to the youngest grayling fry of Deer Lake.

The use of substrate type remained relatively constant throughout the study period for age-0 Deer Lake grayling, ranging in total length from 11 to 59 mm. Over 70% of

observed fish positions were over fine substrates. In survey 3, sand bottoms were used in a greater proportion than available. In all surveys, over half of the observed fish positions were over silt. Lee (1985) reported that young grayling in an Alaska stream were predominately found over silt and gravel substrates. In contrast, McMichael (1990) found over 77% of young-of-the-year grayling in the Big Hole River to be in positions over gravel and cobble substrate and that these young preferred large substrate. However, age-0 young of the Big Hole River are much larger than Deer Lake young at a similar time of the season.

In all three surveys, age-0 grayling were most frequently observed within 0 to 20 cm of overhead cover. However, this still represented a lower proportional use than expected. The young used distances farther from cover, 21 to 60 cm, in greater proportion than expected. These observations appears related to their avoidance behavior. When age-0 young were disturbed, they responded by swimming to another location rather than by hiding under cover. This behavior was similar to that described by Lee (1985), where age-0 fluvial grayling in an Alaska stream swam away and did not use available overhead cover when disturbed. In contrast, I observed age-1 grayling to use overhead cover when disturbed.

As age-0 Deer Lake grayling increased in total length, there was an increase in mean water column velocity and

total water column depth at observed fish positions. Lee (1985) also found that grayling young in an Alaska stream used greater mean water column velocities and depths as they increased in length. However, both the velocities and depths used by young in that study were greater than those used by Deer Lake young of comparable size. Since Lee did not evaluate the availability of different depths and velocities, it is not known whether these differences are related to the relative availability of habitat types between the two study sites.

A number of other studies on young salmonids described use of total depths and mean water column velocities similar to those used by young Deer Lake grayling. Elliott (1980, cited in Hubert et al. 1985) reported Arctic grayling young (< 50 mm TL) selected mean water column velocities in the 0.0 to 0.15 m/s range and depths which ranged 9 to 85 cm. Shirvell (1990) found steelhead fry (Oncorhynchus mykiss) averaging 33 mm in length to occupy a mean water depth of 38 cm and a mean water velocity of 0.05 m/s. Grant and Noakes (1988, cited in Grant 1990) suggested that 0.06 m/s is optimal mean current velocity for a 20 to 29 mm brook trout.

Young-of-the-year Arctic grayling of the Big Hole River most often used total water column depths ranging from about 10 to 50 cm and mean water column velocity of 0.0 to 0.27 m/s (Skaar 1989, McMichael 1990). These

grayling selected deeper depths and faster velocities at a higher frequency than available. The depths and velocities used by the Big Hole River young include values which are greater than those preferred by the Deer Lake young.

However, when habitat use was measured, Big Hole young were larger (60 to 110 mm TL) than Deer Lake young (15 to 41 mm TL). Also, the Big Hole River contains a wider range of depths and velocities than the Deer Lake outlet stream.

The higher mean water column velocities preferred by larger young may provide them with better feeding stations. Fausch (1984) proposed that there exist optimal foraging sites which provide maximal food availability and minimal energy expenditure. Everest and Chapman (1972) showed that faster current velocities carried more food than slower ones. Therefore, it would be more beneficial for a fish to be close to fast current if it can position itself so it does not expend excess energy maintaining position in the current (Fausch and White 1981).

Despite the change toward greater total depths and mean water column velocities with increasing size and age, Deer Lake young continued to use similar focal point depths and velocities. Age-0 grayling used the slowest focal point velocities available ( $\leq 0.1$  m/s) in all three surveys. The focal point depth ranged from 0 to 10 cm above the substrate at over 90% of the fish positions. Few age-0 young were observed in the upper portions of the

water column. This close proximity to the substrate may enable the young to avoid greater water velocities.

The change in habitat preference of young Deer Lake grayling is consistent with other studies on young salmonids. Larger fish are better able to use positions with greater water velocity and are found in deeper, faster water. Smaller fish select positions in slower water in which they are better able to maximize net energy gain (Gibbons and Gee 1972, Monshenko and Gee 1973, Jones 1975, Bohlin 1977, Symons and Heland 1978, Kennedy and Strange 1982, Fausch 1984, Degraaf and Bain 1986, Kennedy and Strange 1986, Hearn 1987, Newman and Waters 1989).

## MANAGEMENT IMPLICATIONS

My observations confirm that age-0 Deer Lake grayling remain in the outlet stream for at least 3 months and possibly through their first year. Thus, this population appears to be the most promising, among lacustrine populations of Montana grayling studied thus far, as a brood source for future efforts to reestablish populations in streams. While the last remaining fluvial populations in the Big Hole River would be the obvious choice as a source of fish for reestablishing stream populations, it may not be desirable to have all future stream populations originate from that single stock. It is possible that original stream populations in Montana were genetically divergent (Kaya 1990). Genetic diversity between future stream populations would likely be better accomplished by having more than one brood source, particularly for waters outside the Big Hole River drainage.

My results indicate that age-0 Deer Lake grayling use shallow, slow-moving waters, particularly during their first weeks after becoming free swimming. Thus, availability of shallow waters (6-30 cm), with slow mean column velocities (0.0-0.15 m/s), and fine substrate of silt and sand would be an important consideration in

selecting prospective streams for reestablishment of fluvial grayling populations.

The successful reproduction of the Deer Lake grayling makes this a promising stock for establishing populations in lakes with no inlet spawning streams. The large numbers of spawning adults and the ease with which they can be captured would facilitate spawning operations. Also, there is a well-used U.S. Forest Service trail between the highway and the lake.

Although this study was not concerned with fishermen use of the Deer Lake fishery, my casual observations indicate that many persons hike or ride on horseback to fish the lake during summer. The relatively high occurrence of hook scars (27-30%) suggests the magnitude of fishing pressure. Despite its location in a designated wilderness, 10 km from and 1,000 m above the nearest trailhead, this resource is frequently used by outdoor recreationists. Although the grayling population appears healthy at present, there is the possibility of future problems. The lake is becoming better known for its grayling fishing and grayling are easily caught. Adult grayling are especially vulnerable to exploitation when spawning in the outlet. My estimates of spawning adults, about 800 to 1100, can serve as a baseline for future comparisons. If the population shows evidence of decline, it may be appropriate for the Montana Department of Fish,

Wildlife and Parks to consider regulations to protect the  
spawners, as is already done for fisheries of some other  
lakes and reservoirs.

## SUMMARY

1. As ice melted off Deer Lake and the outlet stream temperatures increased to about 6-7 C, an estimated  $803 \pm 104$  grayling entered the outlet spawning stream in 1989, and  $1109 \pm 124$  in 1990. Both spawning runs had a male:female sex ratio of about 1.0:1.0.
2. Some age-0 and age-1 grayling moved upstream and into the lake in late summer and fall. However, most age-0 young remained in the outlet stream at the time traps were removed and ice was forming. There was very little movement between upper and lower sections of the outlet stream during the periods of observation.
3. Many young moved downstream over the falls, especially during and shortly after the period of peak swimup. Most downstream movement occurred at night. These young originated from the lower section, possibly from spawning sites close to the falls.
4. Over 70% of young grayling positions were over silt and sand. In survey 3, young grayling used sand substrate at a higher frequency than its availability.

5. The preferred total depth and mean water column velocity (0.6 depth) of age-0 grayling increased with fish growth, from 6-10 cm and 0-0.05 m/s when about 15 mm TL, to 16-20 and 26-30 cm and 0.06-0.15 m/s when about 41 mm.
6. All observed age-0 grayling used the slowest focal point velocities available ( $\leq 0.1$  m/s).
7. Over 90% of focal point depths were within 10 cm of the substrate surface.
8. Age-0 grayling did not selectively use positions near overhead cover and did not appear to use cover when disturbed.
9. Deer Lake grayling grow very slowly during their first year of life, apparently as a consequence of stream residence. However, they grow rapidly in the lake and are similar in size to some lacustrine populations by age 3.
10. With their allacustrine spawning and the extended stream residence of the young, the Deer Lake population could provide a brood source for transplants into other lakes with only outlet streams, and possibly also into streams.

11. Despite the lake's location in a designated wilderness, 10 km from and 1000 m above the nearest trailhead, the population supports a popular fishery. It may become desirable in the future to protect adults during the spawning season, when they are particularly vulnerable to capture.

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