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The Distribution, Habitat and Population Characteristics of Fluvial Arctic Grayling (*Thymallus arcticus*) in Montana

Abstract

The only substantial population of native stream dwelling Arctic grayling (*Thymallus arcticus*) in the lower 48 states is located in the upper Big Hole River drainage of Montana. This population, a taxon of special concern, is genetically different from any other Montana or Wyoming population in allele frequencies at variable loci. It represents a unique gene pool which should be preserved. In 1978 and 1979, Arctic grayling were found in three sections of the Big Hole River and in 11 tributary streams. Where Arctic grayling were most abundant, the mean water depth (standard deviation) was 28.4 (22.6) cm, mean width was 12.21 (4.92) m, mean velocity was 0.21 (0.15) m/s, and mean water temperature for the period 21 April to 1 September, 1979 was 13.7 (4.7)° C. In this area, the gradient was 0.29 percent, rubble and gravel comprised 85 percent of the substrate and total shoreline cover was approximately 262 m^2/km of stream.

Growth rates (mean increment of back-calculated length) of Arctic grayling within the study area were greatest (118 mm) during their first year of life and decreased to 23 mm between the 4th and 5th year. Arctic grayling reached sexual maturity at age three at which time they had a back-calculated length of 275 mm.

The core of the population was confined to the Big Hole River itself or the lower portions of tributaries above the mouth of the North Fork Big Hole River. This baseline information will allow future comparisons to asssess the population's status and insure that management actions beneficial to the population can be implemented when necessary. Because the range of this genetically distinctive population has dwindled over several decades, it may be endangered and suitable habitat sites should be identified to which Arctic grayling can be transplanted.

Introduction

At the turn of the century in the lower 48 United States, populations of fluvial Arctic grayling (*Thymallus arcticus*) occurred in northern Michigan and western Montana east of the continental divide and in a small portion of the upper Missouri River drainage within Yellowstone National Park, Wyoming. The Michigan form became extinct around 1936 (Scott and Crossman 1973) and in Montana, Arctic grayling that were widely but intermittently distributed in the Missouri River and its tributaries above the Great Falls (Vincent 1962, Henshall 1906) are now found only in the upper Big Hole River and its tributaries.

The greatly reduced range led to the designation of the fluvial Arctic grayling of Montana as a taxon of special concern by the Endangered Species Committee of the AFS (Deacon *et al.* 1979). Concern for the continued existence of this unique population in the upper Big Hole River drainage has recently increased. Only small numbers of Arctic grayling were found in previous sampling and new biological and physical factors may be impacting the population. Brown trout (*Salmo trutta*) and rainbow trout (*S. gairdneri*) may be pioneering the area and oil exploration has occurred in the drainage.

In this study we examined the distribution, habitat-use, and population characteristics of the relict population of stream-dwelling Arctic grayling in the upper Big Hole River to: (1) provide a database for monitoring the well-being of this unique gene pool and (2) identify Arctic grayling habitat characteristics so suitable areas outside the present range could be identified as areas for possible transplants.

Description of Study Area

The study area encompassed the upper Big Hole River drainage of southwestern Montana and contains tributaries from the Bitterroot and Anaconda Ranges and the Pioneer Mountains. It extended approximately 90 km from the headwaters of the Big Hole River to Sportsman Park (Figure 1). The Big Hole River flows in braided, meandering channels above Pintlar Creek (Figure 1) but is confined to a single channel by a narrow canyon below that point. Grasses, sedges, and willows were present on the extensively irrigated land adjacent to the river and conifers also were present in the riparian zone below Pintlar Creek.

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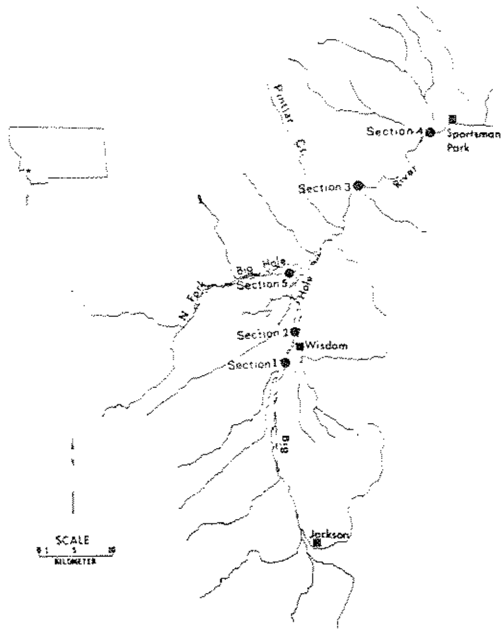

Figure 1. Map of study area showing locations of study sections.

A sagebrush-grassland vegetation type was present on the foothills surrounding the tributary streams.

The maximum and minimum recorded discharges at a site 15 km upstream of Jackson (Figure 1) from 1940-1954 was 26.56 m^3/s and 0.142 m^3/s, respectively (Aagaard 1969). During the first year of the study, the mean discharge at a site approximately 8 km downstream from Jackson was 4.4 m^3/s between 26 July and 15 September, 1978 (Wells and Rehwinkel 1980). National Oceanic and Atmospheric Administration (1977, 1978, and 1979) precipitation records at Wisdom (Figure 1) and summer flow measurements in 1979 indicate that discharges may have been up to 40% lower in 1979 than in 1978.

Methods

The distribution of fluvial Arctic grayling in the upper Big Hole River drainage was determined from collections made at numerous sites by angling and electrofishing for adults and juveniles; seining and drift nets were used to sample for larvae. Four sections on the river (3500-4900 m in length) and one on its principal tributary, the North Fork (2050 m in length), were electrofished to obtain fish population estimates (Figure 1). In areas of the river containing multiple channels, work was confined to the major channel.

Population estimates were calculated using Chapman's modification of the Petersen formula (Ricker 1975). Weights and total lengths of captured Arctic grayling were recorded and scales were taken from an area posterior of the dorsal fin above the lateral line for age-growth analysis. Back-calculated lengths of fish at each age were determined using Hile's (1941) modification of the Monastyrsky method. Predicted and mean weights at each age were computed using the logarithmic form of the standard length-weight relationship equation (Bagenal and Tesch 1978).

Physical habitat features of Sections 1, 2, and 3 were measured to correlate with Arctic grayling abundance. The length of each section, pool, and riffle were measured in the center of the channel. A pool-riffle periodicity (Leopold and Langbein 1966) and ratio were calculated for each section. Pools were defined as areas with reduced water velocities, smooth surfaces, and maximum depths $\geq$ 0.5 m. The remaining portions of the study sections were designated riffles. Gradients for each section were estimated using U.S. Geological Survey topographical maps.

In 1979, 37 transects were established perpendicular to the channel on each section where physical habitat data was gathered; distances between the transects on Sections 1-3 were 45, 100, and 150 m, respectively. Transects were located only on the upper half of Section 1 since the lower half was completely dewatered in 1979. However, the habitat in the upper portion of Section 1 appeared to be representative of the entire section. On each transect, water depth was recorded to the nearest 1 cm at intervals of 0.5 m. Velocities were measured to the nearest 0.003 m/sec at 1 m intervals in Sections 1 and 2 and at 3 m in Section 3 with a Gurley AA current meter. Discharge in each section was calculated from measurements of selected transects.

Shoreline or instream cover 1.5 m to each side of a line transect was measured to the nearest 0.01 m. Shoreline cover was defined as overhanging brush within 1.0 m of the water surface or debris and undercut banks within 0.6 m of the water surface. Instream cover included both aquatic plants and debris. The general condition of banks at each transect was qualitatively evaluated as stable or unstable; unstable banks were defined as those showing recent soil erosion.

Substrate composition was determined by visually estimating the amount of each type of material along each transect. Bottom materials were classified after Wentworth (1922) as bedrock (unbroken, solid rock), boulders (>26.0 cm in diameter), rubble (6.4-26.0 cm in diameter), gravel (2.0 mm - 6.3 cm in diameter), and fines (<2.0 mm in diameter).

Water quality analysis at Sections 1, 2, 3, and 5 occurred bimonthly from 16 June-1 September, 1979. Dissolved oxygen concentrations were determined to the nearest 0.1 mg/l by the azide modification of the Winkler method (American Public Health Association 1976). Alkalinity and hardness were determined by titration with precision to 5 mg/l $CaCO_3$ and the specific electrical conductance was measured with a Beckman RB3-Solu Bridge to the nearest 0.5 μmhos/cm. The pH was determined in the field with an Orion model 407 Specific Ion Meter (resolution = 0.01 pH units). Water temperature was continually monitored to the nearest 0.5 C with Ryan model D-15 thermographs.

Statistical tests were performed according to methods in Snedecor and Cochran (1967) using MSUSTAT (Lund 1979) and SPSS (Nie *et al.* 1975). Values having probabilities of $p < 0.05$ were termed significantly different.

Results

Distribution and Abundance

Arctic grayling were collected at seven locations on the main river and from 11 tributary streams (Figure 2). Fry or young of the year (yoy) were collected at 14 points, 1+ and older fish at four locations and fry and 1+ and older fish together at 12 sites. None were observed in Deep, Warm Springs, Johnson or Fishtrap creeks. Johnson Creek is a tributary of the North Fork Big Hole River.

The relative abundance of Arctic grayling was greatest in Section 1. The average number of Arctic grayling 81-335 mm in total length captured per kilometer on each electrofishing run in Sections 1, 2, and 5 were 16.9, 5.3, and 4.9, respectively. No Arctic grayling were obtained in Sections 3 and 4. In Section 1, the number and standing crop (80 percent confidence intervals) of

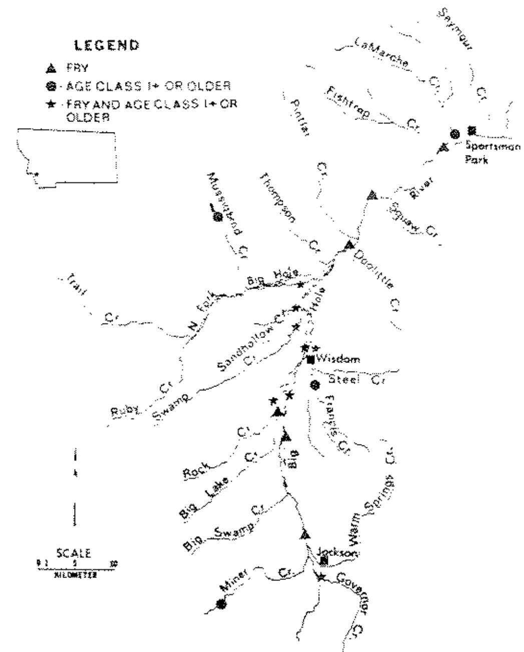

Figure 2. Collection sites of Arctic grayling in the upper Big Hole River drainage, 1978-79.

Arctic grayling 251-297 mm in total length were 35 (±11)/km and 6.7 (±2.5) kg/km or 28 (±9)/hec and 5.5 (±2) kg/hec, resepctively. Population estimates were not obtained in any other section.

Age, Growth, and Spawning

Back-calculated lengths and weights of Arctic grayling from locations throughout the upper Big Hole River drainage were similar, so all the data were combined (Table 1). Their growth rate was most rapid the first year and displayed a pronounced decline between the second and third years. Arctic grayling in the upper Big Hole River attained sexual maturity at age three when their back-calculated length was 275 mm.

The largest number of Arctic grayling captured were obtained in July and August, 1978; these 312 fish allowed us to examine the population's size structure. The dominant age groups were two and three, comprising 47.1 and 30.4 percent of the sample, respectively. Young of the year represented only 7.7 percent of these fish; however, this is due to bias of sampling gear which is more efficient capturing age one and

TABLE 1. Mean total length and weight (standard deviation in parentheses) at time of capture and calculated mean total length and weight at each annulus for Arctic grayling Age 1+ and older captured in the upper Big Hole River drainage in 1978 and 1979.

Age Group	N	Mean total length (mm)	Mean total weight (gm)	Calculated length (mm) at age				
				1	2	3	4	5
1	61	198 (20)	76 (23)	116				
2	190	261 (16)	168 (34)	119	221			
3	167	292 (19)	231 (45)	117	223	275		
4	12	316 (22)	282 (56)	119	230	278	305	
5	1	381	431	150	272	320	356	379
Mean back-calculated length (mm)				118	222	275	309	379
Mean increment of back-calculated length (mm)				118	104	52	28	23
Calculated weight (gm)				27	115	188	247	395

older fish. Age one fish also made up a relatively low portion of the sample, 12.2 percent. Age class four was represented by only 8 individuals (2.6 percent).

Most spawning activity in the Big Hole River during 1979 occurred in late April and early May. A total of 146 age 0 Arctic grayling were collected throughout the upper Big Hole River drainage from 27 May-27 July, 1979. The mean total length of yoy increased from 12.2 mm during 27-31 May to 55.2 mm for the period 11-15 July. Some fry apparently left the spawning streams and moved into the main river shortly after hatching, while others remained much longer, even in intermittent streams such as Sandhollow Creek (Figure 2). Most yoy Arctic grayling captured moving out of Sandhollow Creek were obtained from overnight drift net sets.

Sympatric species

Eleven species of fish coexisted with Arctic grayling in the study area. Mountain whitefish (*Prosopium williamsoni*) and brook trout (*Salvelinus fontinalis*) were the most abundant game fish present throughout the study area. Longnose suckers (*Catostomus catostomus*), burbot (*Lota lota*), mottled sculpin (*Cottus bairdi*), longnose dace (*Rhinichthys cataractae*), rainbow trout (*Salmo gairdneri*), cutthroat trout (*S. clarki*) and rainbow-cutthroat trout hybrids (*S. gairdneri* X *S. clarki*) were also found in the study area. Only one brown trout (*S. trutta*) was collected during this study. Brook, rainbow and brown trout are introduced species in Montana. Also, mountain (*C. platyrhynchus*) and white suckers (*C. commersoni*) have been reported to inhabit the area (Wells and Rehwinkel 1980), but none were observed during this investigation.

Habitat Characteristics

Stream Morphology and Cover

Morphological measurements made on Sections 1-3 showed that mean, pool, and riffle width increased in a downstream direction (Table 2). Analysis of variance showed significant differences in some habitat parameters between the sections. Comparison of sample means (Q test; $P<0.05$) showed that Section 1, with the greatest density of Arctic grayling, was significantly narrower than Section 3, significantly shallower than Sections 2 and 3, and had a significantly slower mean thalweg velocity than Section 2. Also, the percentage of stable banks and the pool-riffle periodicity were lower than in the two downstream sections. The pool-riffle ratio was greatest in Section 1 and decreased in a downstream direction through the study sections, as did the gradient. The composition of bottom materials in all three sections were similar, consisting primarily of rubble and gravel. The area of shoreline and instream cover per kilometer in

TABLE 2. Mean values and standard deviations (in parentheses) of physical habitat parameters measured in study sections on the upper Big Hole River between 16 July and 20 August, 1979.

Parameter	Section 1	Section 2	Section 3
Width (m)	12.21(4.92)	15.95(5.02)	48.09(14.75)
Riffle width (m)	10.83(4.77)	12.62(4.46)	51.50(15.81)
Pool width (m)	8.95(5.23)	13.40(5.30)	40.00(7.60)
Thalweg depth (cm)	54.7(24.0)	77.3(33.5)	61.8(22.0)
Depth (cm)	28.4(22.6)	39.7(30.6)	37.3(23.1)
Thalweg velocity (m/s)	0.27(0.18)	0.42(0.28)	0.32(0.15)
Velocity (m/s)	0.21(0.15)	0.33(0.23)	0.21(0.15)
Stable banks (%)	70.3(5.0)	78.4(4.8)	93.2(2.9)
Pool-riffle periodicity	6.3(4.2)	7.2(4.5)	11.6(7.6)
Pool-riffle ratio	1.51	1.29	0.27
Gradient (%)	0.29	0.23	0.11
Flow (m^3/s)	0.68	2.07	3.50
Bottom materials (%)			
Boulders	0.9(5.5)	0.0	0.1(0.8)
Rubble	41.5(19.8)	38.8(14.2)	51.4(15.6)
Gravel	42.8(16.2)	39.3(12.9)	33.0(11.3)
Fines	14.8(17.7)	21.9(20.3)	15.5(15.5)
Shoreline cover (m^2/km)	261.4	456.2	8.4
Instream cover (m^2/km)	51.0	92.8	0.0

Section 1 was 57 and 55 percent of those respective features in Section 2. Both shoreline and instream cover were virtually absent in Section 3.

Water Temperature and Quality

Analysis of variance on water temperatures of Sections 1-3 showed significant differences. The mean water temperature (Table 3) in Section 1 was similar to that in Section 2, but significantly lower than in Section 3 (Q test; $P < 0.05$). Mean water temperatures in Sections 1 and 2 were also significantly lower than in Section 5 for comparable periods of time (Q test; $P < 0.05$). The recorded number of hours water temperatures exceeded 17° C was similar in both Sections 1 (895) and 2 (727), and was significantly lower than in Section 3 (1342) for comparable periods of time (Chi square; $P < 0.05$). More hours of water temperatures above 17° C were recorded in July than any other month. During this month, temperatures were above 17° C about 60, 60, and 83 percent of the time on Sections 1, 2, and 3, respectively.

There were no significant differences among other parameters from any section on the main river (Table 3). The water in the upper Big Hole River was soft, its pH was nearly neutral, it had a fairly low capacity to neutralize acids and had a low electrical conductance. Mean values of dissolved oxygen were similar throughout the study area. Each individual value was above 85 percent and mean values were all > 100 percent saturation. Data from Section 5 on the North Fork showed that the principal tributary had lower mean alkalinity, hardness and conductivity values than the main river.

Discussion

Virtually all of the fluvial Arctic grayling collected during this study were from locations in the Big Hole River itself or from sites in tributaries near the river. The only Arctic grayling found far upstream in tributaries were in Miner and Mussigbrod creeks. They were captured upstream and downstream, respectively, from lacustrine populations and probably do not represent portions of the fluvial population. Furthermore, the core of the Arctic grayling population was located in the drainage above the mouth of the North Fork Big Hole River. Twelve collections (excluding those from Miner and Mussigbrod creeks) were made in this area, while only four collections were made below this point. However, in previous years, Arctic grayling have also been found at sites below the North Fork (Peterson 1974, Wells and Rehwinkel 1980) and individuals have appeared as far as 85 km downstream from the study area. (J. Wells, Montana Department of Fish, Wildlife and Parks, Bozeman, MT, personal communication).

The relative abundance of Arctic grayling also was greater upstream from the mouth of the North Fork. In this study, densities above the North Fork were about 5-17 fish/km per electrofishing run, while those below were 0 fish/km in the study area and 0.6-2.8 Arctic grayling per electrofishing run/km in other surveys (Peterson 1974, Wells and Rehwinkel 1980).

Summer water temperatures may be an important limiting factor for Arctic grayling in the

TABLE 3. Mean and ranges (in parentheses) of water quality parameters and temperatures from study sections on the upper Big Hole River, 21 April-1 September, 1979.

Parameter	Section 1	Section 2	Section 3	Section 5
Temperature (°C)	13.7 (0-24)	13.6 (1-25)	15.2 (2-25)	18.0* (12.5-23)
Total alkalinity (mg/l $CaCO_3$)	51 (35-60)	51 (40-60)	56 (35-70)	37 (30-40)
Total Hardness (mg/l $CaCO_3$)	43 (40-50)	41 (40-50)	36 (30-45)	26 (15-30)
Calcium hardness (mg/l $CaCO_3$)	32 (25-40)	34 (30-40)	30 (20-40)	22 (15-30)
Magnesium hardness (mg/l $CaCO_3$)	11 (0-20)	7 (0-10)	6 (0-10)	3 (0-10)
pH	7.44 (7.22-7.64)	7.38 (6.78-7.80)	7.56 (7.26-7.72)	7.24 (7.04-7.38)
Conductivity (μmhos/cm)	94.1 (50-120)	100.3 (52.5-120)	105.8 (52.5-140)	71.7 (55-90)
Dissolved oxygen (mg/l)	8.7 (7.7-10.2)	8.7 (7.6-10.3)	8.8 (6.5-11.6)	8.8 (7.9-10.0)

*Based on data collected from 23 June-25 August, 1979.

river downstream of the North Fork. Although the thermal tolerance of Arctic grayling is not precisely known, Vincent (1962) reported that the range of temperature tolerance for Arctic grayling was usually between 10 and 18.3° C. Furthermore, water temperatures of 17 ° C and above exceed the physiological optimum for growth and food conversion efficiency of salmonids (Brett *et al.* 1969, Wurtsbaugh and Davis 1977). The high summer water temperatures measured in the lower portion of the study area may have been largely responsible for the absence of adult Arctic grayling there during this study.

Arctic grayling in the upper Big Hole drainage underwent rapid growth during the first two years of life with a large reduction between the second and third, which was similar to that of Arctic grayling from the Red Rock drainage (Nelson 1954). However, their growth rates were less than those in two other Montana streams outside the Big Hole drainage (Peters 1964). The minimum age and back-calculated length at sexual maturity for individuals found during this study was three years and 275 mm, respectively. In other Montana populations, a few individuals have been reported to mature at age two (Lund 1974, Peterman 1972, Nelson 1954, Brown 1938) while in the northern portion of their range, Arctic grayling usually reach sexual maturity between age four and six (Bishop 1971, Wojcik 1955). The minimum length at maturity was similar to the 270 mm length suggested by Wojcik (1955) for Alaskan Arctic grayling.

Reverse Lee's phenomenon is present in the back-calculated lengths. Older fish have a larger calculated length for a given age than younger fish at the same age. Possible causes of this include incorrect back-calculation or scale reading procedures, non-random sampling of the stock, and selective natural mortality that affects smaller fish in a particular age group more. Such natural mortality may result from either interspecific or intraspecific competition.

Management Applications

The data obtained on the distribution, relative abundance, and biological parameters of Arctic grayling in the upper Big Hole River provide baseline information for future comparisons. Any significant and persistent decrease in range, relative numbers, growth rates or increase in age at sexual maturity should be a stimulus for additional and immediate management action on this population, which has been determined to be genetically different than any other Montana or Wyoming population sampled to date in allele frequencies at variable loci (Everett and Allendorf 1985).

One of the most pressing management actions needed to be addressed is the identification of suitable habitat sites outside the Big Hole River for transplants from this unique population. In that portion of the river where Arctic grayling were most abundant, the mean depth (standard deviation) was 28.4 (22.6) cm, mean width was 12.21 (4.92) m, mean velocity was 0.21 (0.15) m/s, mean water temperature for the period 21 April to 1 September, 1979 was 13.7° C, and the maximum water temperature was 24° C. In this area, the gradient was 0.29 percent, rubble and gravel comprised 85 percent of the substrate and total shoreline cover was approximately 261 m^2/km of stream. Transplant sites having similar physical habitat characteristics to these should be sought, while areas more like Section 3 should be considered less desirable. However, since yoy Arctic grayling were found in the river near Section 3, is should be considered suitable habitat for use at some point in their life history.

The presence of other fish at the potential transplant sites is another factor which must be considered. Sites with only cutthroat trout and mountain whitefish should receive highest priority since Arctic grayling evolved in sympatry with these species. Competition with introduced fish has often been suggested as a major reason for the reduction in the Arctic grayling's range in Montana and Michigan. While this may be accurate, the competitive interactions responsible for the Arctic grayling's decline have not been identified. The possibility that non-native fish simply replaced Arctic grayling populations depressed by other factors should be investigated. Vincent (1962) believed that interspecific competition with exotics would manifest itself in 40 years. However, brook trout were introduced into the upper Big Hole drainage around 1929 and have not eliminated the Arctic grayling. Perhaps this portion of the river is optimal habitat for Arctic grayling and they have thus been able to hold their own against the introduced competitors. Nevertheless, this indicates suitable locations with brook trout also might be considered, although as less desirable sites.

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