



The biology and population characteristics of the Arctic grayling in Lake Agnes, Montana
by Larry George Peterman

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:

The biology and population dynamics of the grayling in Lake Agnes were studied during the summers of 1970 and 1971. In 1971, the ice cleared from the lake on May 28, and the peak of spawning migrations occurred from June 15 to 24. A diurnal movement of spawning grayling into and out of the inlet stream was closely correlated to daily fluctuations in stream temperatures. The sex ratio of 9,364 fish captured in the spawning run was 2.5 females for every male. Intensive territorial behavior between spawning males was noted along the shoreline and at the mouth of the inlet and probably deterred many males from entering the stream. Male grayling generally averaged larger in size and grew faster than females. Grayling from Lake Agnes showed the slowest average growth rate of any reported in Montana. A few grayling matured at age II, however, most matured at age III. Only one adult grayling out of 559 was aged as over 6 years old. The number of eggs per female increased with the size of the fish and averaged 356 eggs per ounce of fish. The adult population was estimated using the Peterson method and the Schnabel method. The total estimate based on the Peterson method was 24,214 with a standing crop of 72.8 kg/ha.

Total population estimates were in close agreement between both methods, however, male and female estimates based on the Schnabel method were 47.5 percent higher and 18.1 percent lower, respectively, than comparable Peterson estimates. Reasons for past fluctuations in numbers and size of fish are discussed.

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LARRY GEORGE PETERMAN

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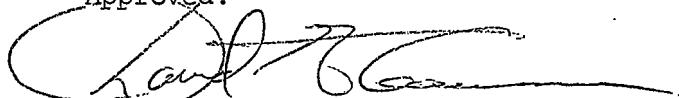
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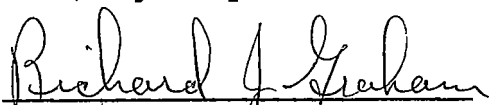

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Approved:



Head, Major Department


Chairman, Examining Committee
Graduate Dean

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ABSTRACT

The biology and population dynamics of the grayling in Lake Agnes were studied during the summers of 1970 and 1971. In 1971, the ice cleared from the lake on May 28, and the peak of spawning migrations occurred from June 15 to 24. A diurnal movement of spawning grayling into and out of the inlet stream was closely correlated to daily fluctuations in stream temperatures. The sex ratio of 9,364 fish captured in the spawning run was 2.5 females for every male. Intensive territorial behavior between spawning males was noted along the shoreline and at the mouth of the inlet and probably deterred many males from entering the stream. Male grayling generally averaged larger in size and grew faster than females. Grayling from Lake Agnes showed the slowest average growth rate of any reported in Montana. A few grayling matured at age II, however, most matured at age III. Only one adult grayling out of 559 was aged as over 6 years old. The number of eggs per female increased with the size of the fish and averaged 356 eggs per ounce of fish. The adult population was estimated using the Peterson method and the Schnabel method. The total estimate based on the Peterson method was 24,214 with a standing crop of 72.8 kg/ha. Total population estimates were in close agreement between both methods, however, male and female estimates based on the Schnabel method were 47.5 percent higher and 18.1 percent lower, respectively, than comparable Peterson estimates. Reasons for past fluctuations in numbers and size of fish are discussed.

INTRODUCTION

The Arctic grayling *Thymallus arcticus* (Pallas), commonly occurs throughout northwestern Canada in and north of the Peace, Athabaska, and Churchill Rivers, and in Alaska. As a result of glacial activity which is believed to have extended their range southward, relict grayling populations historically have been present in Michigan and Montana (Vincent 1962). Although once fairly abundant in both of these locations, the grayling has become extinct in Michigan and has had its range and numbers greatly reduced in Montana.

The original range of the grayling in Montana encompassed the headwaters of the Missouri River above Great Falls. Here they were chiefly found in the Jefferson, Madison, Gallatin and Smith Rivers and their tributaries, and in the Sun River.

Today, the only important remnant of these original populations occurs on the Red rock Lakes National Wildlife Refuge in southwestern Montana. Latest records indicate that there are 39 self-sustaining grayling populations in lakes and 14 in streams throughout western Montana. With the exception of the Red Rock Lakes area and the Upper Big Hole Drainage, most of these populations are the result of introductions (Holton 1971).

Lake Agnes is considered one of the best grayling lakes in Montana. In the past, the grayling of this lake have shown considerable fluctuation in numbers of fish and size of individuals. The principal

objectives of the present study, conducted during the summers of 1970 and 1971, were to determine the present status of the population and gather additional information on the biology of the species.

DESCRIPTION OF STUDY AREA

Lake Agnes is located in the Pioneer Mountains of southwestern Montana, approximately 40.2 kilometers north of Dillon. It lies in a high mountain basin at an elevation of 2.3 kilometers and is surrounded by conifer-covered hills which slope steeply to the shore. In the early 1930's, grayling were introduced into the lake which was originally devoid of fish. The introduction was successful and from 1940 until the early 1960's, these grayling were the primary source of eggs for the Montana Fish and Game Department. The number of eggs taken per year varied from 300,000 to almost 4,500,000.

Lake Agnes is one of three natural lakes in the Rock Creek Drainage which are used for irrigation purposes. The natural outlet of the lake was modified through the installation of a headgate to regulate the withdrawal of water which usually begins in late summer. In 1970 and 1971, drawdown began on August 22 and 15, respectively. During both years, the lake level was lowered approximately 1.5 meters, but a 2.1 meter drawdown is possible when the lake is filled to capacity. At high water in 1970 and 1971, the lake contained 40.9 hectares (101 surface acres) of water and after drawdown, 37.5 hectares. At high water, the lake has a shoreline development of 1.54.

The maximum depth of Lake Agnes at high water was 17.7 meters (58 feet). At this time, 22 percent of the lake area was 6.1 meters deep or less and 44 percent was 12.2 meters deep or more. During July and August of 1971, a thermocline was present at the 6.1 meter depth. By August, there was a progressive decline in the amount of dissolved oxygen below 9.1 meters and at a depth of 12.2 meters or more, the concentration was less than 1 ppm. Other chemical and physical characteristics of Lake Agnes for the summer of 1971 are listed in Table 1.

Table 1. Chemical and physical properties of Lake Agnes - summer 1971.

	Range	Average
pH	7.56 - 8.05	----
Total Alkalinity (ppm CaCO ₃)	71.4 - 71.8	71.6
Total Hardness (ppm CaCO ₃)	28.0 - 31.8	29.7
Conductivity (micro ohms)	80.0 - 82.0	80.7
Turbidity (JTU)	7.0 - 8.0	7.5
Water Temperatures 0.6 meters below surface (Maximum)	10.0 C - 19.0 C	15.4 C
Water Temperatures 0.6 meters below surface (Minimum)	6.0 C - 13.0 C	10.8 C

The primary inlet stream enters the lake from the west and is the major spawning area. It has its source, principally from runoff, in the surrounding hills and meanders through several abandoned beaver impoundments before reaching the lake. The period of high flow for the inlet stream occurs in June and coincides with the spawning season of the grayling. At this time, the stream flows as much as 3.4 to 5.1 m³/min (2-3 cfs), however, by the end of July the flow is much reduced. In the past when beaver were active during a low water year, little or no water flowed below the dams and available stream spawning area was practically eliminated (Robert A. Mitchell - personal communication). The stream is still in the process of eroding its way through old beaver impoundments. As a result, the stream bed and banks are very unstable and bank cave-ins during the period of high flow are not uncommon. Due to the changing nature of the stream, natural obstructions for migrating grayling periodically occur and the portion of the stream available for spawning may vary greatly from year to year. Brown (1938) found that in 1936, about 91.4 meters (100 yards) of stream adjacent to the lake were available for spawning. In 1970, 181.0 meters were available for spawning, but only 43.9 meters in 1971. The stream bottom consisted of a coarse, granular sand; 57 percent of the particles being from 10.0 to 1.981 mm in diameter, 28 percent from 1.980 to 0.833 mm, and the remainder made up of smaller material. Two small tributaries enter the lake along the south shore, but only about 3.1 to 6.1 meters of each

were available for spawning. These ceased flowing by the beginning of August.

The major aquatic plants of Lake Agnes were *Potamogeton praelongus*, *Potamogeton nodosa*, *Potamogeton robbinsii*, and *Myriophyllum* sp. These occurred in thick beds along the shore, many of them at depths of over 1.5 meters. Also present in lesser quantities were *Potamogeton pectinatus* and *Potamogeton* sp. *Chara* sp. was quite common throughout much of the lake and *Nitella* sp. was also present.

METHODS

The grayling population of Lake Agnes was estimated during the summer of 1971 by two mark and recapture methods. Population estimates using the Peterson method were based on data obtained by marking fish in the inlet and recapturing fish in the lake by trapping. Population estimates using the Schnabel method were based entirely on data obtained by trapping fish in the lake. Formula 5 of the Michigan Institute for Fisheries Research (1960) was used for population estimates based on the Peterson method (Bailey modification) with confidence intervals computed using formula 6. Population estimates based on the Schnabel method were made using formula 3.12 of Ricker (1958) with confidence intervals computed using formulas 3.13 and 3.14.

Spawning grayling were captured at random in the inlet throughout the spawning runs of 1970 and 1971 by herding them downstream into live boxes. Capture runs were started in late morning when sufficient

numbers of fish had concentrated below the barrier and were repeated throughout the day until the number of marked fish exceeded the number of unmarked fish in the sample. Length, weight, and sex were recorded and scale samples were taken from each fish captured in 1970. Due to the large number of fish handled in the 1971 spawning season, lengths, weights, and scale samples were taken from approximately 50 fish of each sex for each centimeter size interval. In addition, lengths were taken on about 30 percent and sex was determined on all fish captured. In 1970, a variety of artificial tags were used, but in 1971 all fish were marked by clipping the adipose fin.

Determination of sex of mature fish was based on the size and shape of the dorsal fin (Ward 1951). Immature grayling were separated from mature fish by visual inspection. Immatures had silvery bodies and small, light colored dorsal fins. Adults had larger, more brilliantly colored dorsal fins and darker bodies. In addition, many mature males still exuded a small amount of milt when handled and females had very flaccid abdomens.

Grayling were trapped in the lake with modified fyke nets. Each net consisted of a 3.7-meter long hoop net with a 0.9-meter diameter opening, preceded by a 0.9 x 1.8 x 0.6 meter box of mesh covered steel frames. Leads, 1.2 meters high, were attached to the box and varied in length from 7.6 to 15.2 meters. In 1970, two modified fyke nets were used and only a small portion of the lake was sampled. In 1971,

four modified fyke nets were used and the traps were moved to a new location each day until all of the suitable portion of the shoreline, about 75 percent, was sampled. Portions not trapped were primarily three areas where the bottom sloped too steeply (Fig. 1).

All trapped fish were measured, sexed, marked, and released near their point of capture. In 1971, the lake was divided into five areas and the fish captured in each area were marked with a distinctive partial fin clip. Holes punched in the anal fin were used to indicate the number of times a fish had been recaptured in a particular area. While traps were in operation, a partial creel census was conducted to determine the proportion of marked to unmarked fish harvested.

Prior to and during the early part of the spawning run in 1971, females were collected to obtain egg samples. Females were preserved in 10 percent formalin and the eggs later removed and stored in 40 percent isopropal alcohol until counted. Fry and fingerlings were collected by dip netting along the shore and electrofishing the shoal areas.

A constant recording Taylor thermograph was placed in the inlet in 1971 to monitor stream temperatures during the spawning run. Taylor maximum-minimum thermometers were placed in two positions 0.6 meters below the surface of the lake during the summer months. Temperature profiles were obtained with an ARA model FT3 All-Weather Hydrographic Thermometer. Water chemistry analysis followed procedures outlined in Standard Methods for the Examination of Water and Waste Water (1971).

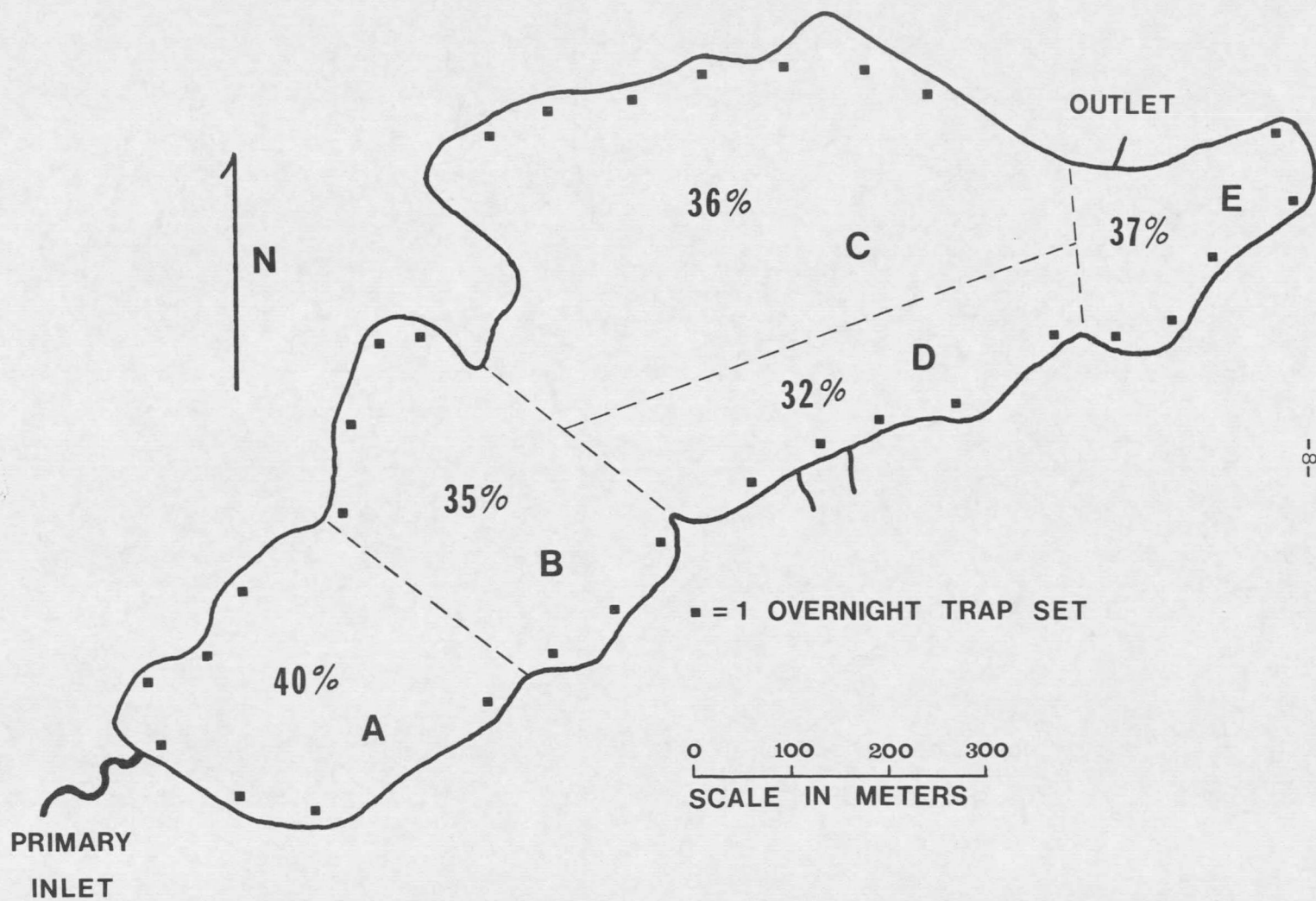


Figure 1. Map of Lake Agnes showing trap locations and the percent of the total number of grayling caught in trap nets in each area that had been marked in the spawning run.

RESULTS

Spawning

The ice cleared from Lake Agnes on May 28, 1971. Grayling first appeared in the inlet for spawning on June 7. The peak of the spawning run occurred from June 15 to 24, and gradually tapered off until July 6, when few fish were seen. Fish apparently began moving into the inlet when the average daily stream temperatures approached 2.8 C (37 F) (Table 2). The surface lake water warmed more rapidly than the stream

Table 2. Summary of spawning stream temperatures and average catch per day of unmarked grayling, 1971.

Time Period	Maximum Temp.	Minimum Temp.	Average Daily Temp.	Average hours/day Over 4.4 C	Average Catch Per Day
5/28-5/31	6.8 C (44.5 F)	0.6 C (33.0 F)	1.9 C (35.5 F)	1.3	----
6/1-6/4	5.3 C (41.5 F)	0.6 C (33.0 F)	1.8 C (35.4 F)	0.7	----
6/5-6/8	6.7 C (44.0 F)	0.6 C (33.0 F)	2.4 C (36.7 F)	4.4	----
6/9-6/12	6.7 C (44.0 F)	1.1 C (34.0 F)	2.4 C (36.7 F)	1.6	548
6/13-6/16	7.2 C (45.0 F)	1.1 C (34.0 F)	2.9 C (37.6 F)	6.4	1,240
6/17-6/20	8.3 C (47.0 F)	1.3 C (34.5 F)	3.4 C (38.4 F)	7.5	935
6/21-6/24	10.6 C (51.0 F)	2.2 C (36.0 F)	5.1 C (41.3 F)	11.6	906
6/25-6/28	8.3 C (47.0 F)	2.2 C (36.0 F)	3.9 C (39.0 F)	6.0	133

and may have influenced movements of the grayling prior to and during the run. From June 11 to 24, the maximum and minimum temperatures of the lake water were 2.8 C° (5 F°) to 4.4 C° (8 F°) higher than stream temperatures. Ice cleared from the lake on June 2, 1970, and the peak of the run occurred from June 11 to 20.

Grayling exhibited a marked diurnal fluctuation in numbers present in the inlet during the spawning run both years. Around mid-day, large schools were observed entering the stream and peak numbers were reached by late afternoon. Fish began moving downstream in early evening and only a small number of fish remained in the stream overnight. Bishop (1971) found a similar diurnal movement of spawning grayling in Providence Creek, Canada, with no fish observed in the creek during the night and large numbers moving upstream around noon. On larger or longer tributaries, similar diurnal movements have not been reported (Nelson 1954, Kruse 1959).

The diurnal movement in and out of the spawning stream was closely related to temperature. Large numbers of fish entered the inlet when stream temperatures were 4.4 C (40 F) or higher, and this seldom occurred before noon. Maximum temperatures were reached between 3:00 and 6:00 p.m. and fell below 4.4 C by late evening. Cold, cloudy days with rain or snow lowered maximum stream temperatures and this in turn, had a depressing effect on the numbers of fish moving upstream. Fabricius and Gustafson (1955) concluded that the daily rhythm of water temperatures

was very marked in shallow streams and was the most important stimulus affecting the grayling's rhythm of spawning and defense of territory.

Spawning fish were also observed in the two small tributaries. Several of these fish had been previously caught in the primary inlet stream and marked. In addition, spawning activity was noted along the shoreline of the lake. This appeared quite intensive at times with as many as six observations in 30 minutes. All of the observations were made in shallow water over small gravel or coarse sand bottoms, however, visibility was limited in deeper waters and over darker mud-bottom types.

During the spawning season, certain male grayling appeared to establish territories and actively defend them against intruding males. This antagonistic behavior was most frequently observed along the shoreline and at the mouth of the inlet. Little or no antagonism was noted in the stream at the peak of the run when spawning densities were extremely high, however, considerable conflict was observed at the mouth of the inlet at this time. This may have deterred many males from entering the stream. No aggressive behavior of males towards females or between females was noted.

A total of 9,364 grayling from the 1971 spawning run was marked from June 11 to 28. The sex ratio of these fish was 1 male to 2.5 females. The sex ratios by days of capture show a marked increase in the proportion of females during the latter part of the run (Table 3).

Table 3. Catch statistics and sex ratios of grayling in the 1971 spawning run.

Date	Total Number of Fish Marked	Sex Ratio σ/ϕ	Total Number of Recaptures	Sex Ratio (Recaptures) σ/ϕ
6/11/71	370	1/2.7	---	-----
6/12/71	727	1/2.3	207	-----
6/15/71	976	1/2.3	277	-----
6/16/71	1,503	1/2.1	627	1/2.7
6/17/71	733	1/3.0	612	1/3.1
6/19/71	1,055	1/2.5	498	1/3.0
6/20/71	1,017	1/2.8	354	1/4.2
6/22/71	871	1/2.1	498	1/1.9
6/23/71	1,035	1/2.3	622	1/3.0
6/24/71	811	1/3.1	717	1/3.0
6/27/71	208	1/4.5	178	1/3.1
6/28/71	<u>58</u>	1/6.2	<u>48</u>	1/2.7
Total	9,364	1/2.5 ¹	4,638	1/2.9 ¹

¹Average

In 1970, a sample of 512 fish revealed a sex ratio of 1 male to 1.8 females. Both of these sex ratios are significantly different from an expected 1:1 ratio (χ^2 values 1695 and 45 respectively). Brown (1938) reported a male-to-female ratio of 1.5:1 in his study section on the inlet to Lake Agnes. Kruse (1959) found a sex ratio of 1:1 in the spawning run of grayling in Grebe Lake, Wyoming. Bishop (1971) found

a male-to-female ratio of 1.3:1 in a sample of 168 grayling from the spawning run in Providence Creek, Canada, but did not consider this statistically different from a 1:1 ratio. The higher proportion of females in the samples of recaptured fish would indicate that females entered the stream more frequently or stayed longer than males (Table 3).

The length-frequency of adult fish captured in the 1971 spawning run is shown in Figure 2. Females averaged 26.3 cm in total length and ranged from 22.4 to 33.5. Males averaged 27.9 cm and ranged from 24.0 to 35.8.

Population Estimates

Trapping fish in the lake in 1971 began on July 2 and was discontinued after July 16. During June and the first week of July, large schools of grayling were observed swimming along the shore. The average catch per overnight trap set in shallow water from July 2 through 9 was 142 fish. After this period, few fish were observed frequenting the shoal areas and the average catch per overnight set fell to 69. Warm surface water temperatures were believed to have forced the grayling into deeper waters. Gill nets set on the bottom at 12.2 to 15.2 meters on July 20 and 21 yielded no grayling, however, one set at about the 9.1 meter depth caught 83 fish. Abundant dissolved oxygen was present at 9.1 meters but less than 0.5 ppm at the deepest sets.

