Original: Jour. of Wildlife Management
cc: Fish Division
Education-Game
Dr. Brown

(W)

February 10, 1943

REPORT NO. 847

THE AGE AND GROWTH OF MONTANA GRAYLING

(*Thymallus signifer montanus*)*

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*Contribution from the Institute for Fisheries Research, Michigan Department of Conservation.

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by

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Introduction

A growth-rate study of the Montana grayling was initiated in the summer of 1936 and continued through the following spring while the writer was associated with the Zoology Department of Montana State College. This investigation was part of a general study aimed at the conservation of the Montana grayling. Reports on the feeding and breeding habits have already been published (Brown 1938a, 1938b). The expenses involved in making collections were largely defrayed from a grant made by the National Research Council.

The data collected in Montana and in Yellowstone National Park have been substantially supplemented by studies of Montana grayling of known age planted in Michigan during the past 5 years.

The writer is indebted to Prof. M. H. Spaulding of Montana State College, to Mr. Elmer G. Phillips, Superintendent of Fisheries, Montana State Fish and Game Commission, who assisted in making the Montana collections, and to Dr. A. S. Hazzard who made the continuation of this study possible in Michigan and who along with other Institute staff members helped with the Michigan collections. I also wish to acknowledge the assistance of L. E. Perry and F. E. Locke in aging the fish and tabulating growth rate information and of Dr. Ralph Hile who has given helpful suggestions in the interpretation of data.

Materials and Methods

A total of 460 grayling were used for the growth-rate study. The Michigan collections included 315 specimens from five different localities while those from Montana contained 114 specimens from five different places. In addition 31 specimens came from Yellowstone National Park. A summary of the various localities and collections is given in Table 1.

Insert Table 1

Grayling were collected by means of nets and angling at all seasons. However, most of the collections were taken during the spring and fall. Specimens were weighed and measured while in a fresh condition. The Montana collections were for the most part measured to the nearest 1/8 inch, standard and total length, and weighed to the nearest ounce while the Michigan specimens were measured to the nearest millimeter, standard and total length, and weighed to the nearest gram. The scales

Table 1

COLLECTION LOCALITIES AND NUMBER OF GRAYLING

Place	County	State	Number of grayling
Wolf Lake State Fish Hatchery	Van Buren	Michigan	31
Ford Lake	Otsego	"	259
O'Brien Lake	Alcona	"	21
East Fish Lake	Montmorency	"	2
Suttons Pond	"	"	2
Ennis Hatchery, U. S. Fish and Wildlife Service	Madison	Montana	6
Rogers Lake	Flathead	"	44
Meadow Lake	Madison	"	39
Agnes Lake	Beaverhead	"	10
Georgetown Lake	Deer Lodge	"	15
Grebe Lake	Yellowstone National Park	Wyoming	31

for this study were collected from the left side of the fishes' body between the lateral line and the dorsal fin.

Ordinarily five typical scales from each specimen were cleaned and then mounted in a glycerine-gelatine medium. The scales were examined and measured by means of a microprojection machine at a magnification X 44.3. The average measurements of all the scales of each sample were used in later computations.

Annuli were determined by the presence of incomplete circuli formed at the close of each growing season followed by the formation of complete circuli at the beginning of the next growing season and by other characteristic marks such as erosion, crossover, etc., familiar to all workers on the subject. There was erosion on the scales of many fish during the arrested period, so that some of the circuli of the preceding growing season were obliterated. This erosion, however, was superficial and not peripheral and therefore did not affect the accuracy of growth calculations.

These criteria for determining annuli were verified by the study of fish of known age. Accessory year marks or "false annuli" were common in some collections. In the fish of known age these checks were identified by studying collections made throughout the growing period.

The anterior scale radius was used for all calculations of body length. This measurement was chosen because the annuli could be more easily distinguished in the anterior region than in other portions of the scales. It was not possible to locate annuli on the posterior portion of some scales.

The relationship between the standard length of the fish and the anterior radius of the scales was treated as linear. A line fitted to the data on fish of known age satisfied this assumption reasonably well. Similarly the relationship between body length and the total diameter of the scale was found to be linear. Svetovidov (1936), in a study of the grayling of Lake Baikal, reported that the annual increments of body length and of the scales are not strongly proportional, but rather that the relationship between body length and scale length was found to be parabolic (described by an equation of the type, $\underline{L} = \underline{c}\underline{S}^{\underline{n}}$).

The relationship between the anterior scale radius and the standard length of Montana grayling may be expressed by the equation $\underline{L} = 51.5 + 2.08\underline{S}$, where $\underline{L}$ = standard length of fish in millimeters and $\underline{S}$ = measurement in millimeters of the anterior radius of the magnified scale. Scale measurements were marked on paper strips. As the first step in the computation of the growth history, "uncorrected" calculated lengths were determined (by means of a nomograph) on the assumption that the body-scale ratio is constant at all lengths of fish after the formation of the first annulus. The averages of these direct-proportion calculated lengths then were corrected by means of the following formula:

$$\underline{L}^{\underline{n}} = \frac{\underline{L}^{\underline{t}} - 51.5}{\underline{L}^{\underline{t}}} \underline{L}^{\underline{c}} + 51.5$$

where $\underline{L}^{\underline{n}}$ = standard length at end of $\underline{n}^{\underline{th}}$ year,

$\underline{L}^{\underline{t}}$ = standard length at time of capture,

and $\underline{L}^{\underline{c}}$ = length computed by direct proportion at the end of $\underline{n}^{\underline{th}}$ year.

This method is a modification of the one proposed by Fraser (1916).

Length of Fish at Time of Scale Formation

An examination was made of young grayling fingerlings taken from Grebe and Rogers Lakes in order to determine when scales are formed. The smallest fish with scales had a total length of 35 millimeters (Table 2). A greatly enlarged scale with 2 circuli is shown in Figure

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Insert Table 2

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1. The inset at the right of this figure is the same scale magnified to the same degree as those in Figures 2-14, inclusive. As has already been observed for certain other fishes, scales first appeared in the region along the lateral line. In slightly older specimens the lateral-line scales and those immediately above and below had a larger number of circuli than those near the dorsal and ventral regions.

Time and Factors of Annulus Formation

There is little doubt that annulus formation on grayling scales is related to, if not directly the result of temperature and food conditions. However, our present knowledge does not permit us to assume that these are the only influencing factors. Almost any unfavorable circumstance during any regular growing period could cause the cessation of growth and leave its mark on the scales. The location and intensity of these marks naturally would depend upon the time and extent of the influencing factors. Individual fish might be variously affected. It is conceivable that some extreme or unusual condition of food or temperature

Table 2

THE SIZE OF GRAYLING FROM GREBE LAKE AND ROGERS LAKE DURING

THE PERIOD OF SCALE FORMATION AND EARLY GROWTH

Standard lengths millimeters	Total lengths millimeters	Scales absent or Number of circuli
20.0	23.0	absent
20.0	23.5	"
20.5	24.0	"
20.5	24.0	"
25.0	29.0	"
26.5	32.0	"
29.0	35.5	1?
30.5	37.0	2-3
31.0	37.0	2-3
32.0	39.0	1-2
32.5	39.5	2-3
33.5	40.0	2
33.5	40.5	2
34.0	41.0	2-3
34.0	41.0	3-4
35.0	41.5	2-3
36.0	42.5	2-3
37.5	44.0	3-4
37.5	45.0	3-4

similar to that producing the true annulus, might exist during the regular growing season and affect the whole fish population in a lake or stream so that the scales of all are marked. It is much more probable, however, that only part of the fish population would be affected—perhaps one species or even a small percentage of one species depending upon the nature and extent of the factor involved. For example, unusually warm temperature in a lake containing both cold- and warm-water species of fish might well be the cause of a summer mark on the scales of the cold-water fish without affecting the normal growth of the others, and conversely, unseasonably low temperature might affect the warm-water species without greatly influencing the cold-water species.

If the true annulus of fish scales is the result of arrested or retarded growth then the maintenance of uniformly favorable conditions for growth in any species would eliminate these scale characters. Hassard (1932) noted the absence of annuli on certain brook trout scales and attributed this condition to the more or less uniform temperature conditions under which these fish lived. Other workers have reported similar findings for other species of fish. Grayling kept under more or less uniform temperature and food conditions by Mr. Charles Fuqua at the Ennis station of the U. S. Fish and Wildlife Service lacked annuli on their scales.

These fish were artificially hatched and held in a spring-fed pond, the temperature of which remained more or less constant the year around. Supplemental feeding was moderate and regular throughout the period in which these fish were confined. Scale samples from six 2-year-old fish showed no recognizable annuli (Fig. 2).

Checks or false annuli were not uncommon on scales of the grayling studied. These accessory year marks were identified positively on fish of known age and with considerable confidence on some wild specimens from Montana waters.

One false annulus was found on the scales of all the grayling of known age from Ford Lake in Michigan. This check was formed in the second summer of life, possibly in late August or early September. It has all of the characteristics of a true annulus (Figs. 9-14) and might well have been interpreted as such in other than known-age fish. No other outstanding irregularities were observed except on malformed scales of a very few individual fish.

Insert groups of figures: Figs. 1-6, Figs. 7-12, Figs. 13-14, Figs. 15-19

Editor please note: It is desirable to keep these figures all together so that comparisons can be made in size and character of scales. Each sheet may be reduced to page size but should not be reduced further. A comparable reduction on Figs. 1-14 is desirable.

We can only conjecture as to the cause of the false annulus appearing in the second summer (August or September, 1937) since no limnological studies were made on Ford Lake during this period. An examination of air-temperature data, however, taken at the Pigeon River Forest headquarter about a mile away, gives evidence that the month, August 15 - September 15, was unusually warm. The air temperature and very probably water temperatures were considerably higher during this period than for the same time in any other year while grayling were present in the lake. Since Ford Lake has thermal stratification with the usual accompanying deficiency of oxygen in late summer, it is probable that the grayling were forced into warm water

Description of Figures

Fig. 1. Grayling scale, soon after formation showing two circuli, taken from a six weeks old (39 m.m. total length) fish from Rogers Lake. Insert at right, same scale of comparable size to Figures 2-14.

Fig. 2. Grayling scale showing no annuli taken from a two year old specimen from the Ennis Hatchery ponds.

Fig. 3. Grayling scale showing five annuli from a specimen taken in Grebe Lake (308 m.m. standard length, 359 m.m. total length, 312 grams weight).

Fig. 4. Grayling scale from fish of known age (28 months) captured in O'Brien Lake (224 m.m. S.L., 262 m.m. T.L., 118 grams wt.).

Fig. 5. Grayling scale from fish of known age (28 months) captured in East Fish Lake (203 m.m. S.L., 245 m.m. T.L., 102 grams wt.); F = false annulus.

Fig. 6. Grayling scale from fish of known age (27 months) captured in Suttons Pond (158 m.m. S.L., 193 m.m. T.L., 40 grams wt.).

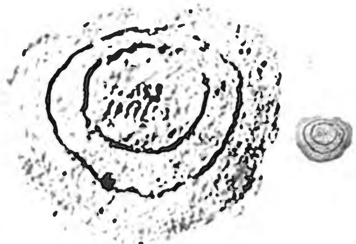

FIG. 1

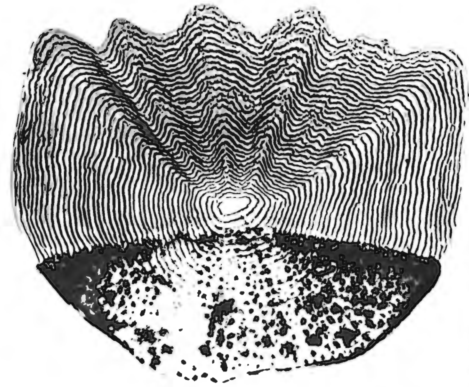

FIG. 2

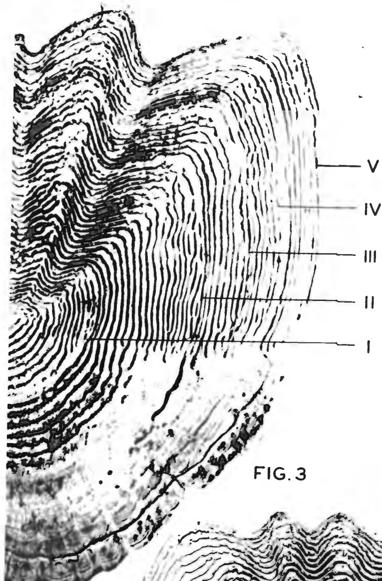

FIG. 3

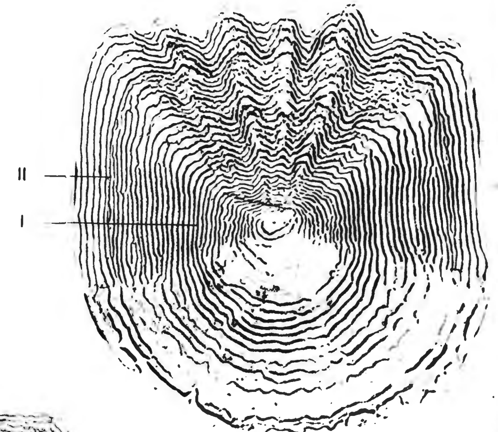

FIG. 4

FIG. 5

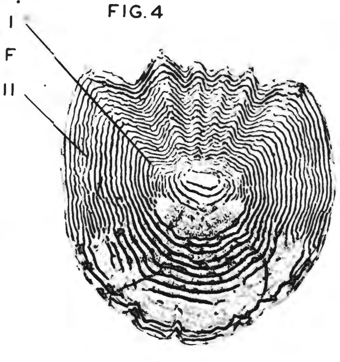

FIG. 6

Description of Figures

Fig. 7. Grayling scale from fish of known age (16 months) taken from the Wolf Lake Hatchery (153 m.m. S.L., 183 m.m. T.L.).

Fig. 8. Grayling scale from fish of known age (11 months) taken from Ford Lake (89 m.m. S.L., 107 m.m. T.L.).

Fig. 9. Grayling scale from fish of known age (16 months) taken from Ford Lake (157 m.m. S.L., 183 m.m. T.L., 84 grams wt.).

Fig. 10. Grayling scale from fish of known age (22 months) taken from Ford Lake (172 m.m. S.L., 199 m.m. T.L., 58 grams wt.).

Fig. 11. Grayling scale from fish of known age (24 months) taken from Ford Lake (218 m.m. S.L., 262 m.m. T.L.).

Fig. 12. Grayling scale from fish of known age (28 months) taken from Ford Lake (250 m.m. S.L., 290 m.m. T.L., 179 grams wt.).

FIG.7

FIG.8

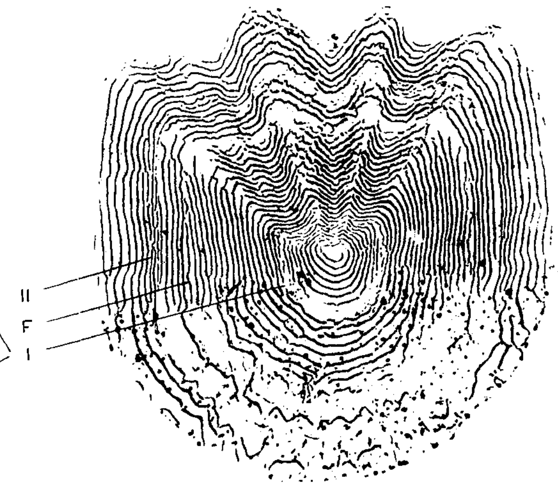

FIG.11

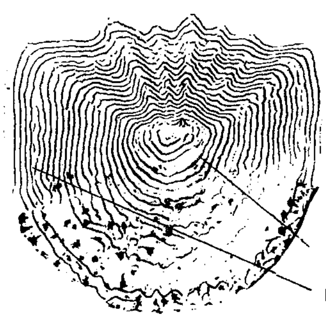

FIG.9

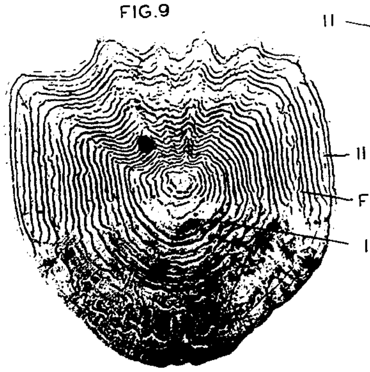

FIG.10

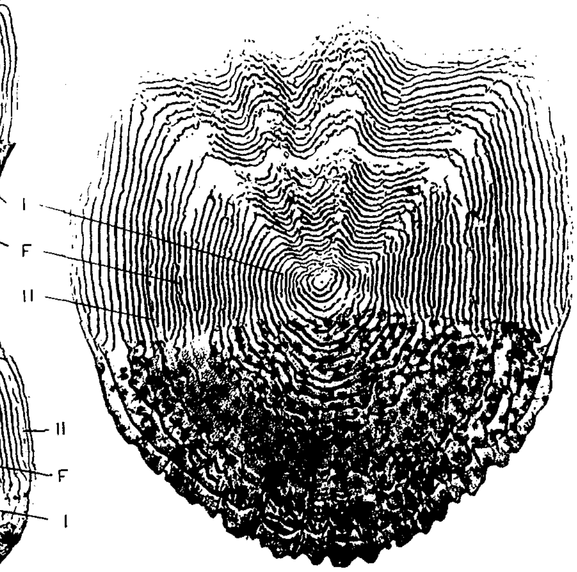

FIG.12

Description of Figures

Fig. 13. Grayling scale from fish of known age (36 months) from Ford Lake (280 m.m. S.L., 334 m.m. T.L., 312 grams wt.).

Fig. 14. Grayling scale from fish of known age (47 months) from Ford Lake (286 m.m. S.L., 343 m.m. T.L., 312 grams wt.).

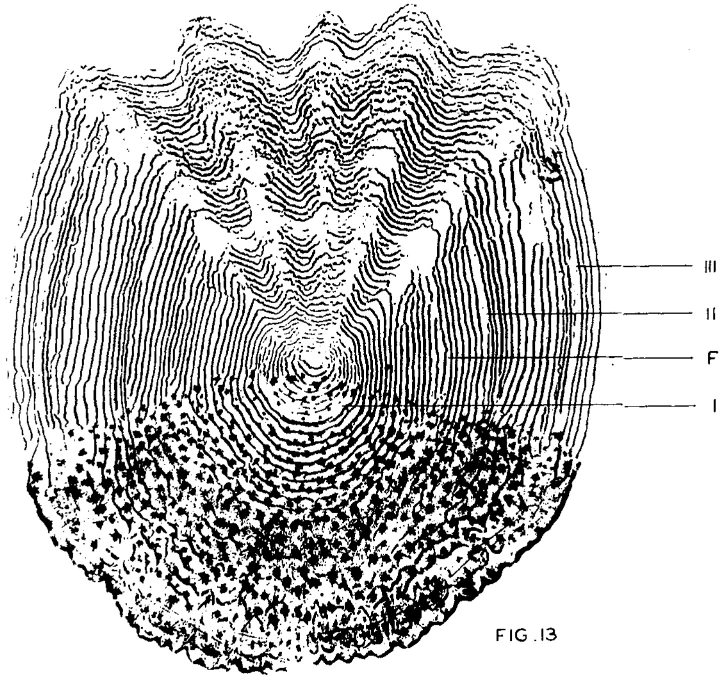

FIG. 13

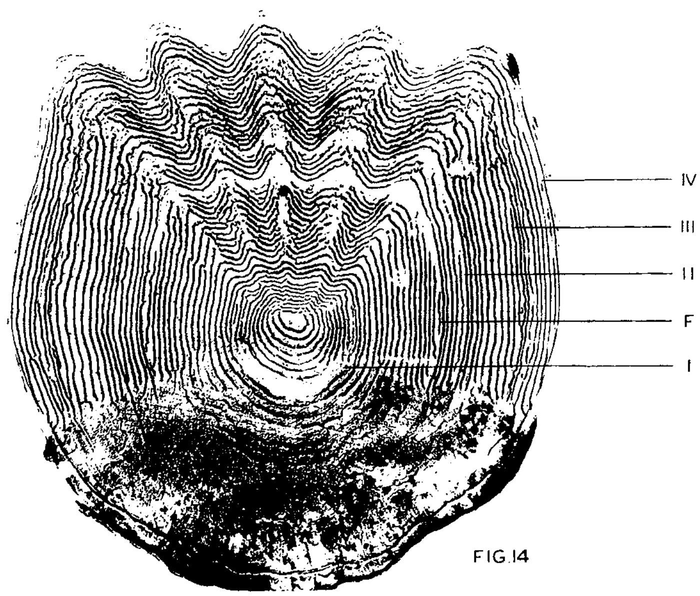

FIG. 14

Description of Figures

Fig. 15. Grayling scale showing four annuli taken from a fish collected in Rogers Lake (326 m.m. S.L., 375 m.m. T.L., 465 grams wt.). False annuli indicated by inner legend line.

Fig. 16. Grayling scale showing four annuli taken from a fish collected in Meadow Lake (330 m.m. S.L., 381 m.m. T.L., 454 grams wt.).

Fig. 17. Grayling scale showing four annuli taken from a fish collected in Agnes Lake (326 m.m. S.L., 371 m.m. T.L., 341 grams wt.).

Fig. 18. Grayling scale showing four annuli taken from a fish collected in Grebe Lake (305 m.m. S.L., 346 m.m. T.L., 285 grams wt.).

Fig. 19. Grayling scale showing four annuli taken from a fish collected in Georgetown Lake (349 m.m. S.L., 384 m.m. T.L., 765 grams wt.).

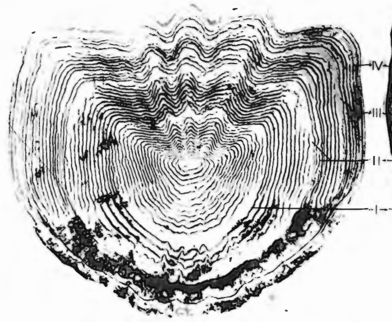

FIG 15

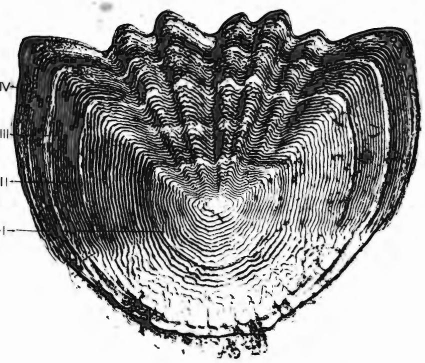

FIG 17

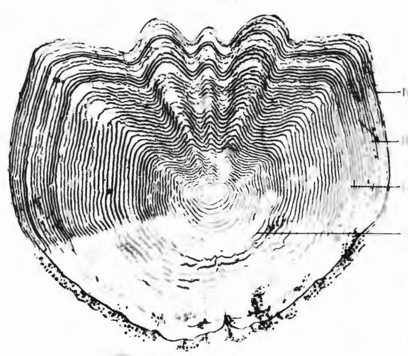

FIG. 16

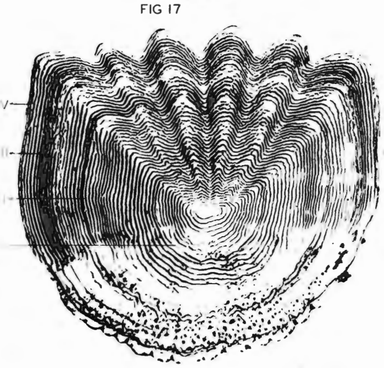

FIG 18

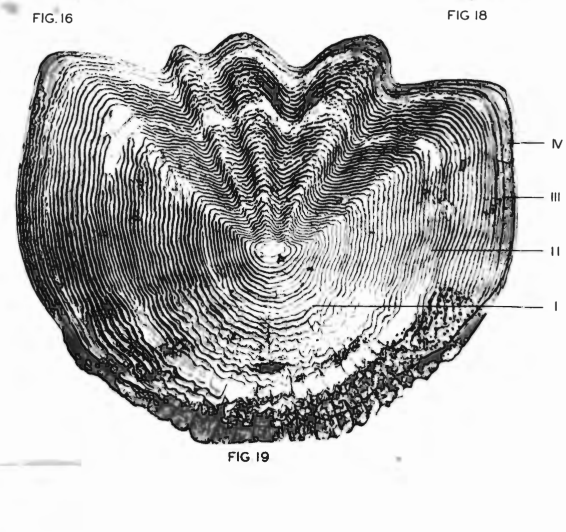

FIG 19

which although not fatal caused a cessation of feeding and growth, and thus brought about the formation of a false annulus.

Water temperatures unsuitably warm for cold-water fish are known to exist in late summer both in Rogers and Meadow Lakes, Montana. In these lakes also a large majority of the grayling collected showed marks interpreted as false annuli (Figs. 15 and 16—the inner legend line). Except possibly for the first year our Rogers Lake material showed the more or less regular formation of a check mark each summer. No evidence of these false annuli was found in the colder lakes, such as Grebe, Agnes, and Georgetown, which remain cold by virtue of their rather high elevations.

That environmental factors largely determine the characteristics of scale markings is shown on the scales of grayling from East Fish Lake and Suttons Pond, Montmorency County, and O'Brien Lake, Alcona County, Michigan. These lakes were stocked at approximately the same time (April, 1940) from the same batch of fish that had been retained in the hatchery over their first winter. Those grayling reaching East Fish Lake did so more or less by accident having migrated up the outlet into the lake. Collections from these lakes were made in 1941 as follows: East Fish Lake, August 26; Suttons Pond, September 12; and O'Brien Lake, October 23. In each lake the fish had completed most of two growing seasons. The size difference of the fish and consequently of the scales was considerable. Growth was the greatest in East Fish Lake (Fig. 5), intermediate in O'Brien Lake (Fig. 4) and least in Suttons Pond (Fig. 6). No consistent irregularities were found on the scales of grayling from

Suttons Pond or O'Brien Lake but both specimens taken from East Fish Lake showed a distinct false annulus which was formed sometime during the second summer. The lack of information on the waters in which these fish lived, makes it impossible to explain this irregularity.

In a study of the European grayling, Hutton (1923) claimed to have found "spawning marks" on certain grayling scales but was somewhat skeptical of his interpretation. It is not likely that such marks could be distinguished even if they did occur since the spawning period and time of annulus formation are practically concurrent.

The true annulus forms on grayling scales in early spring. An examination of the Ford Lake fish of known age showed no trace of a newly formed annulus in the February or March collections. By April 21, however, at least one circulus of new growth was present on the scales of two fish. Collections during the first half of May showed the annulus to be completed in all but one or two specimens. As many as three circuli beyond the annulus were present by this time. By July 1 the number of circuli beyond the annulus averaged about 10. Our collections indicate that the annulus is generally formed sometime between April 15 and May 15 in the Ford Lake and O'Brien Lake grayling.

A study of the western specimens reveals that the time of annulus formation in the different waters is approximately as follows:

Meadow Lake	April 20 - May 20
Rogers Lake	May 20 - June 20
Grebe Lake	May 30 - June 30
Agnes Lake	June 1 - July 1

The variation existing among these lakes is quite probably the result of temperature differences.

Growth Rate of Grayling of Known Age

All of the Montana grayling introduced into Michigan during the past five years were of Yellowstone stock. The eggs were taken from spawning fish in the small inlet to Grebe Lake sometime between May 15 and June 20 (Brown, 1938b), depending on the season, and were held at the small hatchery located on this lake for conditioning. Eyed eggs from this source were shipped to the Wolf Lake Hatchery in Michigan where hatching and subsequent development took place. Very restricted experimental plantings have been made in Michigan waters with fingerling and yearling grayling handled in this manner.

The most extensive data on the growth of grayling in Michigan waters were obtained from the Ford Lake experiment. Approximately 5,000 grayling were introduced into Ford Lake, Otsego County, on October 22, 1937, after all other fish had been removed by poison. These grayling were hatched on June 24 and at the time of planting ranged between 2½ and 3 inches (63-76 millimeters) in total length. The first collection was made the following May, and subsequent collections were taken at intervals (Table 3) thereafter until grayling could no longer be found.

Insert Table 3

The suitability of Ford Lake as a grayling water was demonstrated by the fact that at least some fish of this planting survived there for 3 full years (to an age of nearly 4 years). No additional plantings were made and we are certain that there was no natural propagation.

Ford Lake has a surface area of 11.7 acres and a maximum depth of 33 feet. Water temperatures are suitable for cold-water fish the year

Table 3

COLLECTION DATES AND AGE OF GRAYLING TAKEN FROM FORD LAKE

REPRESENTATIVE PHOTOGRAPHS OF SCALES MAY BE FOUND IN

THE FIGURES (RIGHT COLUMN)

Date	Number of specimens	Age (months)	Figure
May 18, 1937	44	11	8
October 18-20, 1937	32	16	9
February 27, 1938	1	20	-
April 21, 1938	9	22	-
May 8, 1938	22	22	10
July 6, 1938	38	24	11
October 29-30, 1938	17	28	12
March 13, 1939	8	32	-
May 10, 1939	1	35	-
May 24, 1939	2	35	-
June 24, 1939	1	36	13
May 19, 1940	3	47	14

around, at least in the thermocline and immediately below, although, in unusually hot summers conditions in this region may become near the upper limit of toleration for cold-water species with respect to both temperature and concentration of dissolved oxygen.

Shallow water is relatively scarce, and because of this and the soft nature of the bottom, aquatic plants are limited both as to kind and quantity. Except possibly for plankton the abundance of fish food was decidedly below the average of small Michigan lakes but possibly equal to or slightly better than that of the small, cold, deep-basin lakes of the region. There are no inlets or outlets and obviously no place where grayling could spawn successfully. This condition, although it prevents the permanent establishment of the species, is a boon to any study of fish of known age.

If each year of life is assumed to end in May, the grayling from Ford Lake showed the following average lengths for each year:

First	- 86	millimeters	standard	length,	4.1	inches	total	length;
Second	- 199	"	"	"	9.2	"	"	"
Third	- 267	"	"	"	12.3	"	"	"
Fourth	- 288	"	"	"	13.5	"	"	"

A curve based upon this series of collections is shown in Figure 20. There seems to be some evidence of growth throughout the winter although our collections were inadequate to prove this point.

Insert Figure 20

The average lengths and weights at capture and the average calculated standard lengths are shown in Table 4. Representative scales from these collections are shown in Figures 8-14, inclusive. The average calculated

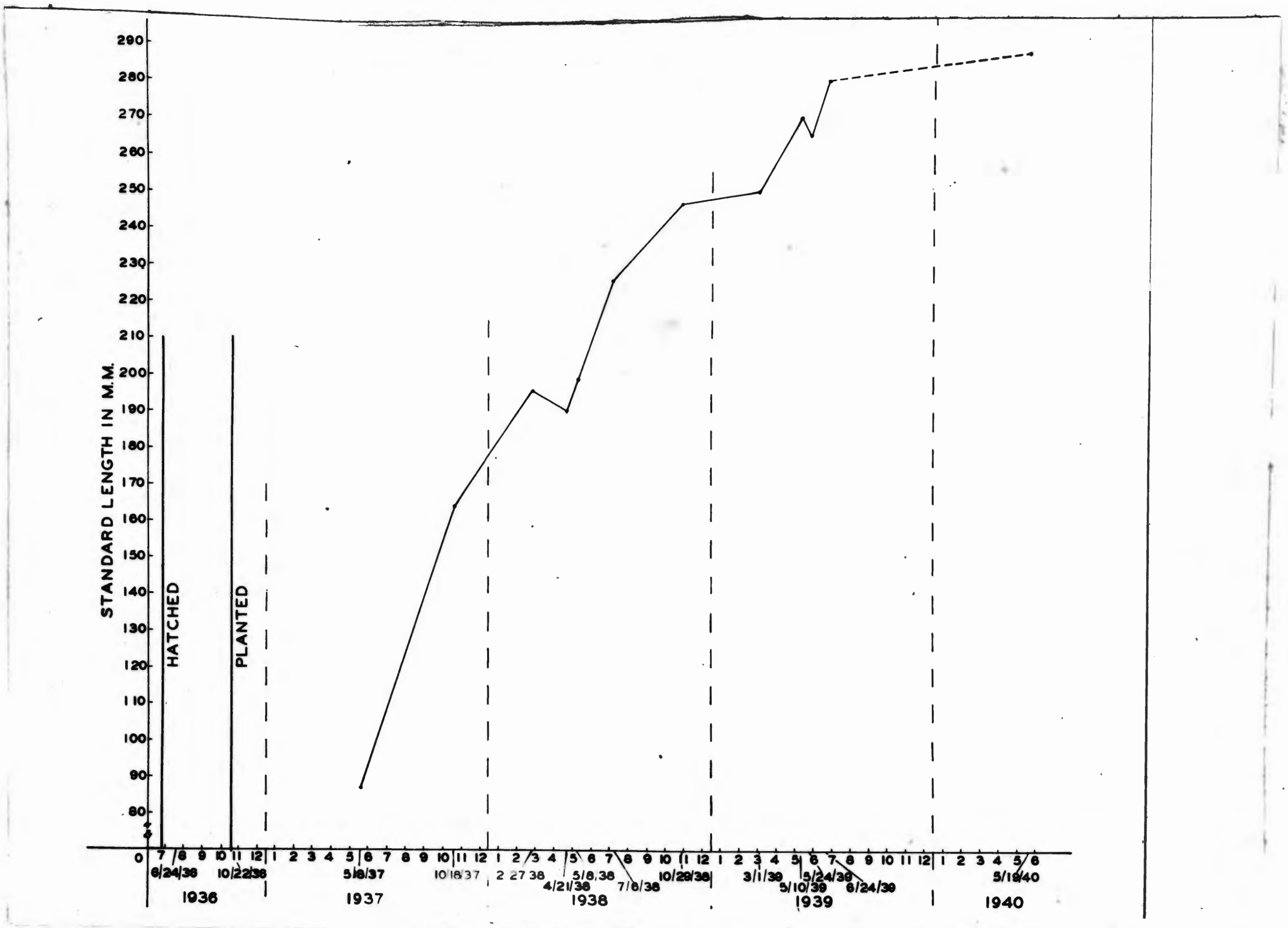

Fig. 20. Average lengths of grayling in the various collections from Ford Lake. The actual individual collection dates are given.

standard lengths of all grayling collections from Ford Lake were as follows: first year — 76 millimeters; second year — 185 millimeters; third year — 258 millimeters; fourth year — 284 millimeters.

Insert Table 4

Creaser and Creaser (1935) in a study of 13 Michigan grayling, mostly from the Otter River, gave calculated standard lengths for the various years of life as follows: first year — 86 millimeters; second year — 178 millimeters; third year —232 millimeters; fourth year (one specimen from the Au Sable River) — 242 millimeters. No significant comparison can be made between these figures because the methods employed in making calculations were probably not comparable. At any rate Creaser and Creaser gave no adequate description of the method they used and their collections were unreliably small. The difference at the end of the first year might be due, at least in part, to the fact that the Ford Lake specimens spent their first summer of life under hatchery conditions not altogether favorable for good growth.

A study of the scales of 21 Montana grayling taken from O'Brien Lake in Montmorency County, Michigan showed the average calculated standard length to be only 43 millimeters at the time the first annulus was formed and 171 millimeters at the end of their second year. Here again all of their first year was spent under hatchery conditions. A comparison between the size of 1-year-old Montana grayling kept in the Wolf Lake hatchery and wild stock of the same age from Montana showed that the former grew only about one-third as fast as the latter. A

Table 4

THE AVERAGE LENGTHS, WEIGHTS AND CALCULATED STANDARD LENGTHS OF FORD LAKE GRAYLING

Date	Number (specimens)	Known age (months)	Weight (grams)	Standard length (millimeters)	Total length (inches)	Calculated standard length in millimeters at end of year of life			
						1	2	3	4
5/18/37	44	11	-	86	4.1	74	-	-	-
10/18-20/37	31	16	67	164	7.6	74	-	-	-
2/27/38	1	20	100	196	8.9	85	-	-	-
4/21/38	9	22	72	190	8.6	75	-	-	-
5/8/38	22	22	91	199	9.2	79	189	-	-
7/6/38	30	24	-	227	10.6	73	179	-	-
10/29-30/38	17	28	-	246	11.5	76	183	-	-
3/1-3/39	8	32	206	250	11.6	78	180	-	-
5/10/39	1	35	-	270	12.6	73	188	-	-
5/24/39	2	35	239	265	12.1	75	188	259	-
6/24/39	1	36	312	280	13.1	76	185	259	-
5/19/40	3	47	356	288	13.5	81	188	255	284
Average						76	185	258	284

difference in growth under hatchery and lake conditions can be seen by comparing the scales of grayling kept at the Wolf Lake hatchery (Fig. 7) until October of their second year with those of fish planted in Ford Lake in October of their first year and recovered during October of their second year (Fig. 9). This comparison does not necessarily mean that conditions in the hatchery were not as good as could be attained in the light of our present knowledge of grayling requirements, but it does show that ordinary hatchery methods for trout are not entirely successful when applied to grayling.

The length-weight relationship of grayling from Ford Lake is shown in Table 5. These figures do not include four collections from this lake which lacked weight information. The series is fairly complete except for the groups of 220-229 and 270-279 millimeters standard length. With each increase in standard length of 10 millimeters these fish showed an increased average weight of over 4 grams. The largest fish (four years of age) having a standard length of 280 millimeters weighed 312 grams or 11 ounces.

Insert Table 5

Growth Rate of Grayling from Montana and Yellowstone National Park

The grayling of Montana and Yellowstone National Park are most abundant, not in their native waters, i.e., the tributary streams of the Missouri River above the Great Falls, but in certain small mountain lakes into which they have been introduced. Collections were made from five different localities as shown in Table 1. Meadow Lake is the only water which can be considered as native to this species. While this lake

Table 5

FORD LAKE GRAYLING—AVERAGE LENGTHS AND WEIGHTS FOR EACH 10 MILLIMETER INTERVAL OF STANDARD LENGTH

Number of specimens	Size group (millimeters)	Standard length (millimeters)	Weight (grams)	Total length (inches)	Weight (ounces)
3	140-149	147	51	6.9	1.8
10	150-159	157	58	7.3	2.0
12	160-169	165	68	7.7	2.4
7	170-179	175	80	8.1	2.8
6	180-189	184	69	8.4	2.4
15	190-199	194	84	8.9	2.9
5	200-209	204	95	9.3	3.4
6	210-220	212	108	9.8	3.8
6	230-239	234	166	11.0	5.9
5	240-249	244	179	11.5	6.3
13	250-259	253	204	11.8	7.2
3	260-269	265	240	12.2	8.5
1	280-289	280	312	13.1	11.0

itself is a man-made impoundment, the stream before it was abundantly supplied with grayling. A brief description of these lakes is given in Table 6. The figures for elevation and maximum depths are only approximate.

Insert Table 6

Aquatic vegetation was abundant in all of these lakes except Agnes which had a sharp "drop off" and shoals composed almost exclusively of angular rock. The plant beds in Rogers, Meadow, and Georgetown Lakes cover more than 50 per cent of the lake bottom. Georgetown Lake is especially productive. The high organic content of the bottom has been the cause of occasional severe winter kill of fish. The fluctuation of the water level in Georgetown and Meadow Lakes is sufficient to have a damaging effect on the fisheries. Both of these lakes are artificial impoundments controlled by private companies. It is true, however, that they are extremely productive fish waters in spite of the fluctuation.

The length of the growing season in these lakes varies considerably according to their elevation. Regular thermal and chemical stratification exists in Grebe, Georgetown, and Agnes Lakes but not in Rogers or Meadow Lakes. Maximum summer temperatures are the highest in Rogers Lake. On July 19, 1936, the temperature of this lake was 76° F. at the surface and 71° F. on the bottom (20 feet). Maximum summer temperatures are undoubtedly much higher than these figures. The maximum surface temperature in Meadow Lake probably never exceeds 74° F. In Agnes Lake a well developed thermocline exists throughout the summer. Surface temperatures probably never reach 70° F. and the bottom water probably never rises above 50° F.

Table 6

DESCRIPTION OF WESTERN LAKES WHERE GRAYLING COLLECTIONS WERE MADE

Lake	Elevation (feet)	Area (acres)	Maximum depth	Methyl orange alkalinity (p.p.m.)	Other species of game fish present
Rogers	4500	325	21	72	cutthroat trout
Meadow	5000	5000	12	-	brown trout rainbow trout cutthroat trout whitefish
Agnes	8500	115	40	38	none
Georgetown	7000	2990	25	-	cutthroat trout
Grebe	8000	90	30	23	cutthroat trout rainbow trout

Grebe Lake also shows a well developed thermocline. On July 6, 1936, the water temperature was 66° F. at the surface and 46° F. on the bottom (28 feet). No temperatures were taken on Georgetown Lake but the maximum summer surface temperature is probably between 70° and 75° F. All of these lakes have comparatively soft water (range of methyl orange alkalinity—23-72 p.p.m.) but all are distinctly alkaline at least at the surface (pH—7.4-8.3).

Determinations of calculated growth rate show that grayling from Georgetown Lake had the fastest growth and those from Agnes Lake the slowest growth. A summary of the lengths and weights at capture and of the calculated standard length for each year are given in Table 7.

Insert Table 7

These calculations show that the differences in the rate of growth are not consistent for all years of life. In general the grayling from Agnes Lake (Fig. 17) have slow growth, but the first-year lengths of fish from this lake are greater than those from Grebe Lake or Ford Lake. In other words, a superiority in first-year growth in one lake may not be maintained during subsequent years. A comparison of the calculated standard lengths of the different age groups in the various lakes is shown in Figure 21.

Insert Figure 21

A comparison may be made among the scales of 4-year-old grayling from the following lakes: Rogers—Fig. 15; Meadow—Fig. 16; Agnes—Fig. 17; Grebe—Fig. 18; Georgetown—Fig. 19. Creaser and Creaser (1935),

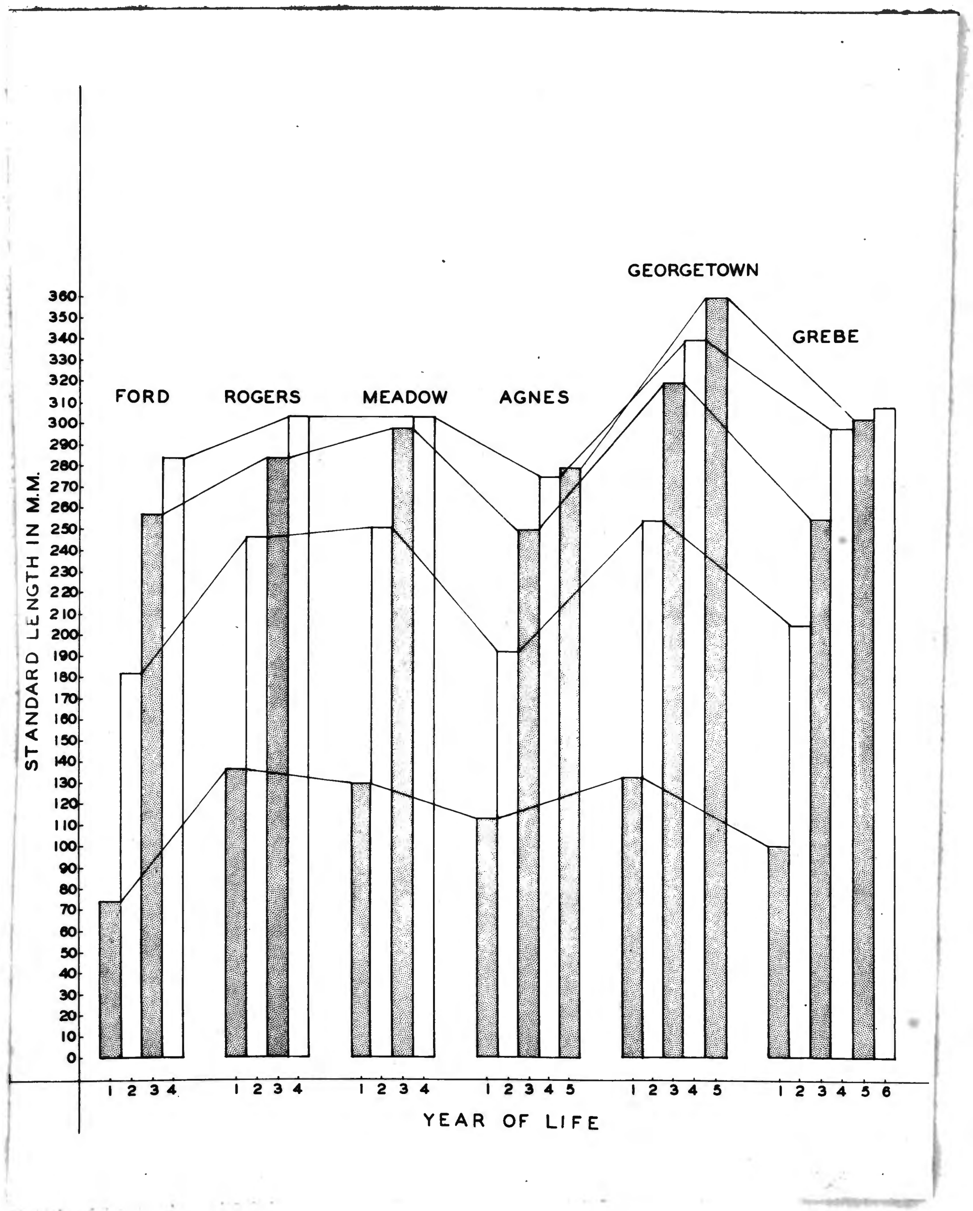

Fig. 21. A comparison of the calculated standard lengths at the end of each year of life of grayling from six lakes.

Table 7

THE AVERAGE LENGTHS, WEIGHTS AND CALCULATED STANDARD LENGTHS OF GRAYLING FROM MONTANA AND YELLOWSTONE NATIONAL PARK

Date	Number of specimens	Annuli	Weight (grams)	Standard length (millimeters)	Total length (inches)	Calculated standard length in millimeters at end of year of life					
						1	2	3	4	5	6
				Rogers Lake							
5/24/36	2	2	198	251	10.8	142	242	-	-	-	-
"	3	3	369	298	13.6	138	242	286	-	-	-
"	3	4	418	314	14.0	152	249	295	312	-	-
7/19/36	10	1	126	198	9.0	123	-	-	-	-	-
"	9	2	291	282	12.9	145	260	-	-	-	-
"	3	3	342	296	13.6	122	244	303	-	-	-
"	3	4	424	311	14.1	152	245	283	303	-	-
5/30/37	4	3	408	307	13.7	135	244	291	-	-	-
"	7	4	418	306	13.7	141	239	274	296	-	-
	44				Average	137	247	285	304	-	-
				Meadow Lake							
4/26/36	1	2	284	264	11.6	167	252	-	-	-	-
"	1	3	342	273	12.8	108	239	268	-	-	-
6/14/36	1	4	454	330	15.0	121	254	297	323	-	-
6/27/36	3	1	132	205	9.1	138	-	-	-	-	-
"	2	2	369	277	12.6	152	248	-	-	-	-
"	4	3	517	314	14.1	137	260	301	-	-	-
7/10,12/36	15	1	135	209	9.4	135	-	-	-	-	-
"	4	2	376	289	13.1	139	254	-	-	-	-
"	8	3	429	298	13.7	128	248	283	-	-	-
	39				Average	135	252	298	323	-	-
				Agnes Lake							
6/6/36	3	1	64	155	7.1	132	-	-	-	-	-
"	2	2	129	240	11.0	105	205	-	-	-	-
"	3	4	246	287	13.0	106	184	248	280	-	-
"	2	5	186	284	12.9	106	194	253	271	279	-
	10				Average	114	193	250	276	279	-
				Georgetown Lake							
6/7/36	1	1	459	286	12.9	201	-	-	-	-	-
"	3	4	756	348	15.7	118	257	323	340	-	-
"	1	5	766	368	16.7	109	244	311	338	359	-
	5				Average	133	254	320	339	359	-
				Grebe Lake							
5/31-6/2/36	6	2	130	231	10.5	104	205	-	-	-	-
"	6	3	153	251	11.3	96	203	244	-	-	-
"	2	4	370	320	14.4	107	225	299	314	-	-
"	2	5	440	319	14.6	108	216	269	295	311	-
"	1	6	459	318	14.3	82	200	245	269	279	307
7/1-6/36	10	1	59	151	6.6	104	-	-	-	-	-
"	2	2	200	235	10.5	112	179	-	-	-	-
"	2	3	259	254	11.6	98	202	236	-	-	-
	31				Average	100	205	255	297	301	307

who had scales from seven grayling from Georgetown and Rogers Lakes, computed the standard lengths of the first year as 91 millimeters and of the second year as 234 millimeters. Our averages for these same two lakes are: 135 millimeters—first year and 250 millimeters—second year. This difference may be due, at least in part, to the methods used.

The length-weight relationship of grayling from western lakes is shown in Table 8. Not all size groups are represented for each lake but

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Insert Table 8

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comparisons are possible for certain groups. The 9-10 inch (total length) group shows that Rogers Lake grayling average 5.2 ounces, Meadow Lake—4.4 ounces and Grebe Lake—3.7 ounces. In the 12-13 inch (total length) group, Agnes Lake fish averaged 6.0 ounces, Grebe Lake—7.7 ounces, Rogers Lake—9.4 ounces, Meadow Lake—12.2 ounces, and Georgetown Lake—16.0 ounces. The grayling from Ford Lake are intermediate in their growth rate and length-weight relationship between the fish from Grebe and Agnes Lakes and therefore show rather poor growth and condition when compared with the other lakes studied. Our collections show no significant length-weight differences which could be definitely attributed to sex. We observed, however, that female grayling seem to be larger and heavier in the spawning runs. It is impossible to suggest what specific factors are responsible for the length-weight differences without a complete study of each lake. It may be said, however, that in general the most productive lakes from the point of view of the aquatic vegetation and general organic content, produce the fastest growing, best-conditioned grayling.

Table 8

MONTANA AND YELLOWSTONE GRAYLING—AVERAGE WEIGHTS FOR EACH ONE INCH INTERVAL OF TOTAL LENGTH

Lake	Number of specimens	Total length (inches)	Average weight (ounces)
Rogers	6	8-9	3.8
	4	9-10	5.2
	1	10-11	6.0
	1	11-12	8.0
	5	12-13	9.4
	19	13-14	12.6
	7	14-15	15.9
	1	15-16	18.0
Meadow	3	8-9	3.7
	13	9-10	4.4
	3	10-11	6.7
	2	11-12	12.0
	4	12-13	12.2
	8	13-14	14.5
	3	14-15	15.7
	3	15-16	19.7
Agnes	2	7-8	2.2
	1	10-11	5.0
	2	11-12	6.0
	2	12-13	6.0
	1	13-14	7.0
	1	14-15	12.0
Georgetown	1	12-13	16.0
	2	15-16	24.0
	2	16-17	29.5
Grebe	8	6-7	1.9
	2	7-8	2.5
	3	9-10	3.7
	4	10-11	4.2
	4	11-12	6.0
	3	12-13	7.7
	2	13-14	11.0
	2	14-15	13.5
	2	15-16	18.0

No very old American grayling have been reported. The oldest fish that we found was a specimen from Grebe Lake which we interpreted to have six complete annuli. A scale with five complete annuli from a fish taken in this same lake is shown in Figure 3. Rapid growth and a short length of life appear, therefore, to be characteristic of this species. The experimental planting made in Ford Lake became greatly reduced during the fourth summer and almost completely disappeared in the fifth summer, thus giving further evidence of a short life span. Other factors, including the competition from bluegills, in this lake may have been partially responsible for the rather sudden disappearance, however.

Conservation and Management

There is real need for concern about the conservation and management of Montana grayling. Its original range, the Missouri River and its tributaries above the Great Falls, has now only a few remnants of a once abundant and thriving population. Although the reduction of this species has been somewhat less spectacular and sudden than that which befell the Michigan grayling, the end result—that of extinction—will be the same unless measures are taken to prevent it.

At the present time grayling are limited in their original range to a scattered few in the Madison River impoundments of Meadow and Hebgen reservoirs, to the main parts of the Big Hole River which is tributary to the Jefferson River and to a few places on the upper Gallatin River. The reported reappearance of grayling in the Gallatin River comes after 10 or more lean years and is attributed to the present stocking program whereby large fingerlings are being planted by the U. S. Fish and Wildlife Service.

Montana grayling are most abundant today in a comparatively few lakes outside their natural range. Such lakes as Rogers, Grebe and Georgetown have been the chief source of grayling spawn for many years and it is significant that all of these waters lack exotic species. This in the writer's opinion is the secret of their success. The absence of competitive species such as rainbow, brown and brook trout seems to be absolutely essential to continued grayling production. On the other hand, the Montana grayling is compatible with cutthroat trout, a companion species of long standing.

Since the beginning of this study, grayling have completely disappeared from Rogers Lake because of low water and increased temperatures resulting from the complete removal of forest cover in the drainage area of the lake. In Meadow Lake, there has been a further depletion so that grayling are taken only rarely.

Georgetown Lake still maintains a reasonably good population of grayling in spite of exceedingly great numbers removed by winter fishermen. This lake is stocked heavily by the Montana Fish and Game Commission. Agnes Lake is at present the chief source of grayling spawn for the Montana Fish and Game Commission and Grebe Lake furnishes the only grayling spawn available to the U. S. Fish and Wildlife Service.

Any program which is undertaken to preserve the Montana grayling must take into consideration the isolation of this species from the competition of exotic fish. The brightest hope lies in their establishment in a considerable number of virgin mountain lakes reserved for this purpose.

Continued propagation will be necessary to replenish the stock of these waters because few of them have inlets of a quality suitable for natural spawning. These lakes, besides offering a reasonable amount of fishing, can serve to supply the hatcheries with the needed spawn. Certain carefully chosen small lakes already stocked with rainbow or brook trout can be cleaned by poisoning (Rotenone) and then stocked only with grayling. It would also be highly desirable to reserve certain suitable streams for grayling if any still remain without introduced species.

It should be pointed out that a careful examination must be made of proposed grayling waters by a competent fisheries biologist before extensive plantings are made if waste and disappointment are to be avoided.

In the light of certain recent studies made on the planting of trout, it is logical to believe that the stocking of large size (7-10 inch total length) grayling into the depleted native waters, now containing rainbow, brown and brook trout, should meet with limited success, not to permanently establish the species but to supply a stock for fishermen. This can be done now at a reasonable cost with improved hatchery methods.

The greatest responsibility for preserving the Montana grayling rests with the Montana State Fish and Game Commission since this species is largely confined to their state, and they alone have authority to make provisions and regulations necessary for its maintenance. A carefully planned program at this time would almost certainly meet with success. On the other hand if the species is further depleted, as it most certainly will be under present practices, there will come a day, not too long hence, when brood stock is no longer available and the final chapter will parallel that of the Michigan grayling—extinction.

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