LIFE HISTORY AND MANAGEMENT OF THE AMERICAN GRAYLING (THYMALLUS SIGNIFER TRICOLOR) IN MONTANA

by

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ABSTRACT

A two-summer investigation was made of the grayling in the Centennial Valley, Montana. Here one of the few remnants of a once abundant grayling population still remains in the headwaters of the Missouri River. The history of the grayling was studied and their present status determined. A life history study was made with special reference to the spawners, eggs, fry, and fingerlings. Age and growth determinations were made on 353 grayling. Some trial management measures were undertaken by removing fish. Approximately 90 beaver dams were removed to enlarge the grayling spawning areas. The control of fishing, irrigation, artificial stocking, and beaver is recommended, and the possibilities for reclaiming waters from exotic fish species for the native grayling are listed.

INTRODUCTION

The American grayling was once abundant in Michigan and Montana--the only areas native to this species in the United States. It has become extinct in Michigan and has progressively declined in Montana (Brown 1943) until this fish now occupies only a small fraction of its original range, which according to Henshall (1906), was the Missouri River and its tributaries above the Great Falls. Grayling have disappeared from the Missouri River and its tributary, the Gallatin River. It is rare in the Madison River drainage and has disappeared in the main stem of the Jefferson River. Two small remnants remain in its tributaries: one in the Big Hole River drainage where it is maintained largely through artificial propagation and the other in the Red Rock Lakes area of the Beaverhead River drainage. This latter area was selected for study of grayling management because it has changed less from original conditions than other areas. Grayling, while greatly reduced in numbers, have maintained themselves here without artificial propagation. A considerable portion of this area lies within the Red Rock Lakes Migratory Waterfowl Refuge. It affords an opportunity for more complete management than would be possible on private lands. Investigations were carried out in the summers of 1951 and 1952. The objectives were to develop a management plan to preserve grayling in at least one area of its original range in Montana, and to determine practices which might be applied in other areas of the state.

Description of the Area

The Red Rock Lakes and tributaries are located in the Centennial Valley approximately 40 miles west of Yellowstone National Park. This valley is bordered on the south by the Centennial Mountains, which form the Continental Divide, and on the north by the Gravelly and Snowcrest Ranges. It is approximately 50 miles long and 8 miles wide. The south slopes and open valley are grassland and sagebrush, with willows along most of the creeks. The north slopes support heavy stands of spruce and fir. Much of the land is privately owned and used for grazing. The Red Rock Lakes Migratory Waterfowl Refuge, established for protection and management of the trumpeter swan, administers approximately 40,000 acres, half of which is lake and marsh. Elevation at the source of Hell Roaring Creek, the most remote headwaters of the Missouri River, is approximately 9,000 feet. The Red Rock River leaves the valley at about 6,450 feet.

Red Rock and Elk Springs Creeks are the principle tributaries to Upper Red Rock Lake (Fig. 1) and Odell Creek is the main tributary to Lower Red Rock Lake. In addition there are many small spring fed tributaries to these lakes. Some are permanently diverted for irrigation, and in others the channels have been greatly altered by beaver dams. Beaver dams were most abundant in the tributaries of Upper Red Rock Lake. In Red Rock Creek, which is the largest of the tributaries (Table I), the highest temperature recorded during the summer of 1952 was 65° F. The greatest monthly fluctuation (24° F.) occurred in September with a maximum of 62° F. and a minimum of 38° F. On September 20 there were 7.2 p.p.m. dissolved oxygen (70 percent saturation) and pH was 7.8 at section 2 (Fig. 1).

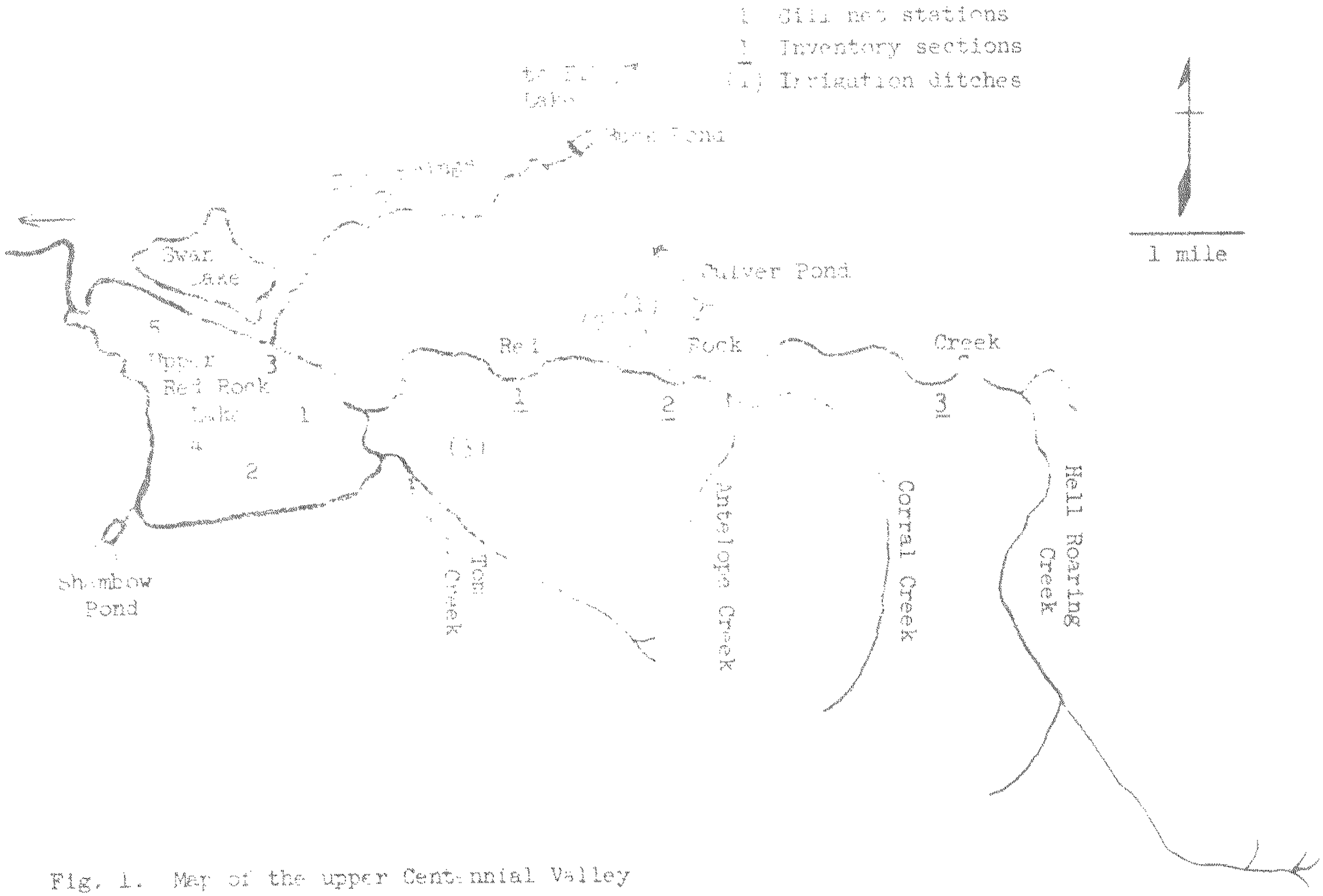

Fig. 1. Map of the upper Centennial Valley

Table I.

Characteristics of main creeks and tributaries in the upper valley. Velocity and volume expressed in feet per second and cubic feet per second.

Main Creek Tributaries	Average gradient (feet per mile)	September average near mouth			
		Width (feet)	Velocity	Volume	Dissolved solids p.p.m.
Red Rock	26	31	1.7	46	129.96
Antelope	150	4			
Corral	386	10			
Hell Roaring	280	11			
Elk Springs	9	15	1.8	20	124.83
Picnic	7	10			
Odell	108	30	1.0	17	78.66

Bottom materials in most of the creeks consist of boulders and rubble in the canyons, coarse to fine gravel in the upper valley, and sand and silt near the lakes and in the lower valley.

Upper Red Rock Lake has an area of 2,206 acres and a maximum depth of about six feet. Temperatures were usually uniform at all depths and the highest surface temperature recorded was 76° F. On September 20, total dissolved solids were 116.28 p.p.m. Lower Red Rock Lake has approximately 1,126 surface acres and a maximum depth of about three and one-half feet. On September 22 the total dissolved solids were 88.92 p.p.m. Swan Lake has an area of 323 acres and a maximum depth of about two and one-half feet. All three lakes have uniform basins with aquatic vegetation throughout. The lake bottoms are all composed of peat except for a small area of marl along the south shore of Upper Red Rock Lake. Shore lines are hard to define due to extensive marsh surrounding the lakes. The only exception is the south and east shore of Upper Red Rock Lake where willows, aspen, and conifers occur. Elk Lake is located in a depression at the head of Elk Springs Creek. It is approximately 235 acres with precipitous shores. No soundings were made but it is known to be deeper than other lakes in the valley.

The Red Rock River drains the Red Rock Lakes and meanders westerly through 12 miles of the lower valley where it empties into the Lima Reservoir. Water from the reservoir leaves the valley via outlet to the Beaverhead River.

Species of Fish Present

Most of the American grayling (Thymallus signifer tricolor) occur in the Upper Red Rock Lake and in Red Rock Creek. Eastern brook trout (Salvelinus fontinalis) is numerous and inhabit many of the creeks and ponds in the study area. Rainbow trout (Salmo gairdnerii) is restricted to Elk Springs Creek Drainage (including Widows Pond and Elk Lake), and Shambow Pond an artificial impoundment near the southwest shore of Upper Red Rock Lake. Cutthroat trout (Salmo clarkii lewisi) is common in the headwaters of the larger creeks, but was rarely observed in the valley streams. Lake trout (Cristivomer namaycush) is restricted to Elk Lake. Mountain whitefish (Prosopium williamsoni) is common in Red Rock Creek. The white sucker (Catostomus commersonii suckli) and longnose sucker (Catostomus catostomus) are abundant in the lakes and in Red Rock and Odell Creeks. Burbot (Lota lota maculosa) is present in the lakes and ponds, and lower portions of the creeks. Longnose dace (Rhinichthys cataractae) is locally abundant in spring fed creeks, and considerable numbers of freshwater sculpins (Cottus sp.) are also present.

History of the Grayling in the Centennial Valley

The history of grayling in the waters of the Centennial Valley was secured by reviewing the literature and by interviewing local residents. Grayling is native to practically all of the lakes and creeks. Upper Red Rock Lake and Elk Lake are reported to have had the largest populations of grayling. Brower (1896) in describing the Centennial Valley wrote, "the waters supply the anglers with superb fishing, mountain trout

and grayling being abundant". Henshall (1907) reported that during the spawning season, Elk Springs Creek was "fairly alive with grayling" in the vicinity of the U. S. Bureau of Fisheries Station. Streams reported to have grayling the year around were Red Rock, Bell Roaring, Corral, Picnic, Elk Springs, and Odell Creeks, as well as the Red Rock River. Many of the small spring fed tributaries harbored grayling during the spawning season. Grayling were caught in the Lima Reservoir for several years after construction of the dam.

About the year 1900 rainbow trout and eastern brook trout were introduced into this area. As late as 1915 grayling and native cutthroat trout were reported abundant in certain areas in the valley. Since the introduction of the eastern brook trout and rainbow trout there has been a decline of the native species.

Beaver became abundant soon after 1935 when they were protected by a state law and establishment of the Federal Waterfowl Refuge. Numerous beaver dams blocked grayling in the lakes from much of their spawning areas. Some of the creeks were converted to marshes by a continuous series of beaver dams.

Red Rock Creek remained partially open because spring runoff was sufficient to open some of the dams. However, at least twice in the last 12 years spawning runs of grayling were stopped by large beaver dams near the lake, and when high water receded in late spring, many grayling were stranded in meadows along the creek.

Irrigation was practised in this area before 1896 (Brower, 1896). With increased settlement in the valley more and more water was diverted

for irrigation. Many spawned-out grayling returning to the lakes were lost in irrigation ditches which originated from Red Rock and Odell Creeks. Water in many of the small creeks was permanently diverted into hay meadows and grazing land, and reached the lakes and river only through seepage. Brower reported a total of 48 creeks in the valley. Although he said nothing of their accessibility to fish, his photographs and the abandoned creekbeds show that most of the small tributaries had well defined channels either to the lakes or to Red Rock River.

In 1951, as a result of beaver dams and irrigation practices, only portions of five tributaries were accessible to spawning grayling from the Red Rock Lakes and Red Rock River. Battle Creek and part of Red Rock Creek were the only tributaries used to any extent in the Upper Red Rock Lake drainage. Before the spawning season (May) of 1952 all of Red Rock Creek and its tributaries were opened by the removal of 25 beaver dams and one-fourth of Tom Creek was opened by removal of 59. As a result grayling spawned successfully in these newly opened areas.

Present Status of the Grayling in the Centennial Valley

The abundance and distribution of grayling in the lakes was determined by gill netting, poisoning, and angling. Over-night sets of graded, 125-foot experimental gill nets were made in Lower Red Rock Lake and Lima Reservoir. Day-sets were made in Upper Red Rock Lake and these were checked at frequent intervals to prevent grayling mortality. The total number of fish caught was recorded. The grayling caught were weighed, measured, fin clipped, scale sample taken, and released. The two species of suckers taken were not separated. Results are expressed in terms of

Table II.

Experimental gill net catches in the Red Rock Lakes and Lima Reservoir

	Grayling	Eastern brook trout	Rainbow trout	Burbot	Suckers	Total
Lima Reservoir (1951-493½ net hours)						
Number	0	0	1	1	972	974
Per cent of total			trace	trace	99.8	
Per cent occurrence			4.2	4.2	100.0	
Catch per hour			trace	trace	2.0	
Lower Red Rock Lake (1951-306½ net hours)						
Number	3	0	0	3	615	621
Per cent of total	0.5			0.5	99.0	
Per cent occurrence	8.3			8.3	70.8	
Catch per hour	trace			trace	2.0	
Upper Red Rock Lake (1951-131½ net hours)						
Number	233	10	0	6	377	626
Per cent of total	37.2	1.6		1.0	60.2	
Per cent occurrence	81.8	27.3		13.6	77.3	
Catch per hour	1.8	trace		trace	2.9	
Upper Red Rock Lake (1952-46 net hours)						
Number	104	0	0	1	72	177
Per cent of total	58.8			0.6	40.7	
Per cent occurrence	80.0			trace	50.0	
Catch per hour	2.3			trace	1.6	

net hours. It is believed that burbot were not taken in proportion to their abundance.

No grayling were taken in the Lima Reservoir, and only three were caught in Lower Red Rock Lake. A fair number of grayling are still present in Upper Red Rock Lake (Table II). In the waters sampled with gill nets, eastern brook trout were limited to Upper Red Rock Lake. All were caught in the immediate vicinity of the mouth of Red Rock Creek. One rainbow trout was caught in Lima Reservoir. A small number of burbot were caught in all of the waters sampled with gill nets. Suckers were the most abundant fish in the lakes and reservoir sampled. No nets were set in Elk Lake but grayling have not been reported since about 1930. Eastern brook trout, lake trout, and rainbow trout were found in fishermen's creels. One cutthroat trout was captured near the mouth of a small creek in Lower Red Rock Lake. Only suckers and burbot were recovered from poisoning selected areas in Swan Lake.

Grayling were most abundant in the lower portion of Red Rock Creek during the spawning season of 1951, but none was found in the upper portion. In 1952, after beaver dam removal, grayling were found throughout Red Rock Creek and in the lower reaches of Hell Roaring, Corral, and Antelope Creeks. They were most abundant in Red Rock Creek in May and June (spawning) and gradually decreased during the summer. The average numbers captured with an electric shocker in 600 feet of stream are as follows: 5.3(June 28-July 1), 2.0(Aug. 12-14), 0.5(Sept. 15-17). In September, 66 per cent of the grayling were young of the year. Eastern brook trout,

suckers, and freshwater sculpin were numerous. Whitefish and burbot were found only in the lower portion of the creek.

Grayling were less abundant in other tributaries of the Red Rock Lakes. Only one was observed in Elk Springs Creek but rainbow and eastern brook trout were numerous.

Spawning grayling were observed in Battle Creek in 1951 and 1952, but no grayling fry were found. The bottom materials in Battle Creek were mainly detritus and peat and were probably not suitable for successful grayling reproduction. Grayling were in Tom Creek during the spawning season (the part opened by beaver dam removal) but disappeared soon afterwards. Fry were abundant in this stream in July. In September an occasional school of fingerlings were observed. Grayling were the only species of fish observed in Tom Creek. Some grayling fry were found in Odell Creek in July. Eastern brook trout, cutthroat trout, and suckers were the only species captured in August (electric shocker and rotenone).

The kinds of fish present in the small creeks and Red Rock River in the lower Centennial Valley were determined by poisoning during September 1952. Grayling were found in only three creeks. The average numbers of grayling recovered in 600 feet of stream were: 2(West Creek), 3(Metzol Creek), 7(Long Creek). All were young of the year (3.4-5.1 in. total length). Burbot, suckers, and freshwater sculpin were also found. Cutthroat trout were found in Long Creek only. Metzel and Long Creeks are tributaries to the Red Rock River and West Creek to the Lima Reservoir. These are the only creeks known to be accessible to fish from the river and reservoir.

Acknowledgments

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LIFE HISTORY OBSERVATIONS

Spawning Movements

Information on the movements of grayling was obtained by marking (fin removal) and subsequent recovery. A total of 370 were marked as follows: 289(Upper Red Rock Lake), 56(Red Rock Creek), and 25(Antelope Creek). Recovery of 14 was accomplished by gill netting, shocking, and angling. Since the same mark was used more than once for a collection at a given station, the exact dates of marking could not be determined from recovered fish. If recovered fish showed movement, the distance traveled was determined by map measurements.

Two grayling were recovered which showed movement during the spawning

season. One marked in Upper Red Rock Lake (Fig. 1, Sta. 1) during the summer of 1951 was recovered in Hell Roaring Creek by angling, July 5, 1952. The total distance traveled was 11.7 miles (upstream). Hell Roaring Creek was not accessible until May 1952, due to the presence of impassable beaver dams. The other grayling was marked in Antelope Creek between May 24-30, 1952. This fish was found dead in an irrigation ditch on June 12, 1952, 4.4 miles down Antelope and Red Rock Creeks, and 0.6 mile down the irrigation ditch from the point where marked. This fish was probably attempting to return to the lake.

One grayling marked at station 1, in the Upper Red Rock Lake sometime between July 27-August 7, 1952, was recovered at section 1, in Red Rock Creek August 12, 1952 (electric shocker). This fish traveled upstream a distance of 3.4 miles.

A total of 11 marked fish were recovered during the summer of 1951-1952 in Upper Red Rock Lake. Ten of these were recovered at the same station where marked, and seven of these ten were recovered within a few hours after having been marked and released. One grayling marked at station 1 was recovered at station 3, a distance of 0.9 mile (Fig. 1).

The exact time the spawning run began in Red Rock Creek was not definitely established. A run was evident in the second week of May 1952, after all ice had disappeared from the lakes. Brown (1938) found the grayling spawning period varied greatly between years, and between different localities in the same year. He reported that the spawning run usually began the day after the ice went off at Grebe Lake, Yellowstone Nat-

ional Park. Here spawning occurred between May 15 and June 20 during the five years previous to 1937. In 1936 at Lower Odell Creek, tributary to the Madison River, Montana, Brown reported the first grayling entered the fish traps on March 15. The peak of the run was April 16, and the last grayling appeared April 24. Gustafson (1948) found that the European grayling (Thymallus thymallus) began the spawning run before the ice went off.

Spawning

Spawning activity was first observed May 19, 1952 in Red Rock Creek. At this time one partially spent female was caught with four others that were still "green". Spawning activity was observed in this creek until June 6. The spawning run in Antelope Creek was more concentrated. It occurred between May 23 and June 1. Water temperatures were generally 5-10 degrees higher in Antelope Creek than in Red Rock Creek.

Grayling were observed to be most abundant in the middle third of Red Rock Creek during spawning. They were also numerous in Antelope Creek. A few were found in Lower Red Rock Creek but turbidity made observations difficult here.

Bottom samples were taken in all spawning areas in order to determine the abundance of grayling eggs in relation to the bottom materials and location. Approximately 50 square foot bottom samples were taken for the egg counts in or adjacent to each of the inventory sections in Red Rock Creek, and in the lower portion of Hell Roaring and Antelope Creeks (Fig. 1). Bottom materials were classified (Roelofs 1944) on the basis of 20 square-foot samples from the same areas where eggs were taken. Grayling

Table III.

Average number of grayling eggs per square foot and the corresponding bottom composition, by per cent of each type of material.

Creek and section	Eggs sq. ft.	Coarse rubble	Fine rubble	Coarse gravel	Fine gravel	sand
Red Rock Creek						
Section 1	0.3					30
Section 2	57.8	13	20	31	29	7
Section 3	6.5		6	35	50	8
Antelope Creek	43.0			43	52	5
Hell Roaring Creek	trace	51	20	17	9	trace

eggs could not be located in bottom materials that were composed of sand and silt. Some eggs were found in pools, but those were always below riffles used by spawning grayling and were probably washed down from the riffle. Grayling were not observed spawning in pools. Since observations showed no grayling eggs in bottoms composed of sand and silt, all quantitative samples were confined to riffles where the bottoms were composed mainly of gravel or rubble. (Table III). Most of Antelope Creek is composed of riffles, and grayling eggs were found in practically every area sampled. About 60 per cent of Red Rock Creek is riffle area. Here the eggs were concentrated on the lower end of the riffle, i.e., the area of transition between a pool and a riffle.

Hatching and Later Stages

Recently hatched grayling fry were found in the bottom materials collected (June 2-7) in Antelope Creek and in sections 1 and 2 of Red Rock Creek. No hatching was observed in the other sections of Red Rock Creek at this time. Grayling fry were observed on the surface of the water on June 12. The yolk sac had been absorbed in most of these. The period between fertilization and hatching was estimated to be 14-19 days in 1952. This agrees with Brown (1938) who found a variation of 11-22 days depending upon the water temperatures and other factors. Water temperatures in Red Rock Creek varied from 38-61° F. during the incubation period.

Fry were numerous for two to three weeks after hatching in back waters and protected areas along the creek, away from strong currents.

During this time they were relatively helpless and made little attempt to hide when disturbed. The abundance of grayling fry was estimated in these areas at two different times by means of quantitative samples. A total of 160 samples from eight stations were taken each year in Red Rock Creek. Results are given as number of fry per cubic foot of water. In 1951, the average was 3.1 fry (June 17-19). Their numbers decreased to 0.6 fry (June 26-July 1). In both sampling periods fry were most abundant between sections 1 and 2(Fig. 1), where there were 11.6 and 1.7 respectively. None was found in the tributaries to Red Rock Creek at this time. All of Red Rock Creek and its tributaries were accessible in 1952. The average number of fry per cubic foot for Red Rock Creek was 1.1 on June 17-19, and 0.2 on June 26-July 3. Fry were most numerous between section 2 and the mouth of Antelope Creek, with 2.8 and 1.7 for those dates. Grayling fry were most abundant in Antelope Creek where the average of two stations (40 samples) was 15.2(June 17) and 2.1 fry (July 3). Only a few fry were sampled in Hell Roaring and Corral Creeks in 1952.

Stomachs of 15 to 25 eastern brook trout were collected at weekly intervals during the 1952 season to see if their stomachs contained grayling eggs, fry or fingerlings. These were secured by means of an electric shocker. Between May 29 and July 1 the contents of 97 stomachs were examined. On May 28, 17 stomachs were examined from trout collected in Red Rock Creek above section 2. The stomach of one trout (3.1 in. total length) contained five grayling eggs, and one (7.1 in. total length) contained 42. The stomach contents of the other trout consisted of mainly aquatic insects.

and earthworms. On June 26, 25 trout were captured between section 2 and the mouth of Antelope Creek. One of these (8.5 in. total length) had 14 grayling fry in its stomach, and five stomachs from small trout (2-4 in. total length) contained 25 fry. Seven other trout stomachs from the collection contained grayling fry remains. No grayling were found in 170 trout stomachs examined after July 1.

Fry are relatively helpless in water currents for about two weeks after hatching and may be carried downstream in large numbers at this time. None was found at the mouth of Red Rock Creek on June 13. Four were captured in this area on June 17, and a noticeable increase was observed July 3.

After the middle of July, fingerlings were no longer observed around the mouth of Red Rock Creek or in protected areas along the creek. On several occasions specimens were observed in weeds along the lake shore near the creek mouth. Some were captured in the riffles and pools in Red Rock Creek with a minnow seine or electric shocker.

Brown (1938) reported that grayling fry were smaller than trout fry but the grayling grew faster in the first year of life. His hatchery reared grayling reached one inch in length at the end of the second month; two and one-half inches by the fifth month; and seven inches at the end of one year. Most of the grayling in Red Rock Creek were over two inches in length at the end of the second month, and were more than two and one-half inches at the end of three and one-half months (Table IV). The average calculated growth at the end of one year was 6.1 inches.

Table IV.

Size of grayling fry and fingerlings in collections from Red Rock Creek.

Date	Number	Total length (in.) * Average	Range
6/14/51	7	0.50	0.43-0.55
7/ 3/51	5	1.84	0.79-0.98
7/16/51	44	1.24	1.06-1.38
7/28/51	13	2.04	1.73-2.28
8/25/51	13	2.63	2.24-2.87
9/17/51	3	3.99	3.82-4.09
6/17/52	27	0.54	0.47-0.59
7/18/52	17	1.40	0.95-1.77
8/12/52	8	2.85	2.70-3.08
9/15/52	3	4.15	4.10-4.22

*measurements from specimens preserved in formalin.

No scales were evident on the 44 fingerlings collected July 16, 1951 (Table IV). The 13 collected July 28, 1951 and one of the specimens (1.77 in.) collected July 18, 1952 had scales.

Age and Growth

Materials and Methods.- Scale samples were collected from 260 grayling captured in the Upper Red Rock Lake and 95 taken in Red Rock Creek during 1951-1952. Total length was determined to the nearest 0.1 inch and weight to the nearest 0.01 pound. Scales were taken from the left side of the body between the lateral line and dorsal fin. Scale measurements were made on the anterior radius of the magnified scale. Uncorrected lengths were determined with a nomograph, assuming a linear relationship between the anterior scale radius and total length of the fish. The averages of the calculated lengths were corrected by the following formula:

$$L_n = \frac{L_t - 2.3}{L_t} L_c + 2.3$$

where L_n = total length at the end of the nth year, L_t = total length at the time of capture, and L_c = total length calculated by direct proportion at the end of the nth year. This was a modification of the formula used by Brown (1943), wherein total length in inches was substituted for the standard length in millimeters used by Brown. Coefficients of condition (C) were calculated for grayling in each age class from the formula:

$$C = \frac{100,000W}{L^3}$$

where W = weight in pounds, and L = total length in inches.

Table V.

Summary of the average calculated total lengths, increments, and coefficient of condition (C) for the grayling collected in 1951 and 1952 (sexes combined).

Age group	Number of fish	Length at capture	(C)	Year of life					
				1	2	3	4	5	6
I	73	9.0	34	6.1					
II	78	12.6	32	6.3	11.2				
III	160	14.2	33	6.4	11.6	13.7			
IV	34	15.4	27	5.9	11.4	14.0	15.0		
V	6	16.3	28	5.6	10.7	13.8	15.2	16.0	
VI	2	16.2	31	6.2	10.5	12.4	14.0	15.1	16.0
Grand averages				6.1	11.1	13.5	14.7	15.6	16.0
Increments				6.1	5.0	2.4	1.2	0.9	0.4
Number of fish	353			353	280	202	42	8	2

Rate of Growth.- Grayling growth rate was greatest the first and second years, and then declined appreciably (Table V).

Brown (1943) reported that a consistent rate of growth for grayling does not always occur in the lakes he studied. A superior growth in one lake the first year is not always maintained in subsequent years. Grayling from the Red Rock area were approximately the same size as those from Georgetown and Meadow Lakes the first and second year. After the third year they were larger than those in Meadow Lake and smaller than those in Georgetown Lake. Grayling in Great Bear Lake (Miller 1946) live longer and maintain growth longer than those in the Red Rock area, although the Red Rock grayling grow faster the first few years.

The oldest grayling found by Brown (1943) in Montana had six complete annuli. Two grayling were interpreted to have six complete annuli from the Upper Red Rock Lake. Seven grayling scale samples were secured from Lower Twin Lake during the spawning season (July 2, 1952). This lake is located at approximately 9100 feet elevation in the Madison River drainage. One grayling was interpreted to have 10 annuli (15.0 in.); four with nine annuli (14.5 in.); one with six annuli (13.3 in.); and one with three annuli (12.3 in.). If the writer's interpretations are correct these grayling approach the age attained by those from Great Bear Lake (Miller 1946).

Age Composition.- A total of 50 spawning fish captured with an electric shocker in Red Rock and Antelope Creeks were aged. Age group II made up 4 per cent; age group III, 92 per cent; age group IV, 2 per cent; and age group V, 2 per cent. Some grayling spawn at the end of their second year.

TABLE VI.

Number and per cent of fish collected in each age group.

Area	Age group						
	I	II	III	IV	V	VI	Total
Upper Red Rock Lake	56	70	102	25	5	2	260
Per cent	21.5	26.9	39.2	9.6	1.9	0.8	
Red Rock Creek	17	11	58	7	2		95
Per cent (all fish)	18.0	11.6	61.1	7.4	2.1		
Red Rock Creek	17	9	12	6	1		45
Per cent (not including spawning fish)	37.8	20.0	26.7	13.3	2.2		

This was also reported by Brown (1938). The bulk of the spawning fish were in age group III. A total of 260 scale samples were taken from Upper Red Rock Lake with experimental gill nets after the grayling spawning season (Table VI). Age group III was also most abundant in Upper Red Rock Lake. In Red Rock Creek after the spawning season, age group I was predominent, not including young of the year grayling.

MANAGEMENT

The fishing season in the study area prior to 1951 was from May 18 to November 15 and the creel limit was 15 grayling. In 1951 the season was changed to open July 1 and the creel limit was reduced to five. Approximately 2,000 rainbow trout were stocked in 1951; eastern brook trout had been stocked also in past years but no stocking records were available. A number of unauthorized plantings are known to have been made.

Experiment in Fish Removal

A quantitative study of grayling and other fish species was made in Red Rock Creek during the summer of 1952. The objective was twofold: to determine the relative abundance of the different fish species and to see what effect the removal of other species would have on the distribution and abundance of grayling.

Red Rock Creek was chosen because it harbored grayling the year around, and because it supplied most of the grayling taken by fishermen. Three sections (Fig. 1) were established. The average water velocity and stream width are compared on the basis of September observations.

Section 1 is in the lower portion where silting and bank erosion was prevalent. Bottom materials on the riffles are mainly of fine gravel and

hardpan, and in the pools, either silt or fine sand depending upon the velocity of the water. The average velocity was 1.7 feet per second and the average width 31 feet. Only a few eastern brook trout were in this area. No fishing was observed during the summer.

Section 2 is in the middle portion of the creek. Bottom materials are mainly coarse and fine gravel, but there is some silt in the pools, resulting from beaver dam removal. The average velocity was 1.8 feet per second and the average width 28 feet. Eastern brook trout and other species were more abundant than in section 1. Most of the fishing occurred in this section.

Section 3 is in the upper portion of the creek. Bottom materials are mainly gravel and some rubble, silt occurred in the deeper pools. The average velocity was 2.2 feet per second and the average width 14.5 feet. Eastern brook trout were most abundant in this section. Very little fishing occurred in the area. This part of the creek was recently made accessible to grayling by beaver dam removal.

Each section was divided into two 600-foot areas which were separated by a 300-foot buffer zone. In the lower 600-foot (control) area, fish were collected, weighed, measured, (inventoried), fin clipped, and returned. In the upper 600-foot (removal) area, all fish were inventoried, but only grayling were marked and returned.

Each of the three sections were inventoried three times during the summer. The original plan was to make the first inventory during the grayling spawning season; however, high water and large quantities of silt

and detritus from newly opened beaver dams made a complete inventory impossible. Some fish were captured by shocking in these areas, nevertheless. More spawning grayling were seen prior to the first inventory than were captured during this inventory.

The electric shock method described by Stefanich (1952) was used to collect fish. Each section was blocked and shocked with alternating-current in 200-foot units. In each inventory 160 volts were used the first trip through each unit, and a maximum of 200 volts was used for subsequent trips. Captured fish were anesthetized in a 0.5 per cent solution of urethane (Ger King 1949). Total length was determined to the nearest 0.1 inch and weight to nearest 0.01 pound. Those fish to be returned were fin clipped and held in pens until they recovered from the effects of handling.

Population Composition in Control Areas.- The control areas were assumed to represent the species composition during the summer. There was a general numerical increase of fish in the second inventory. This was probably due to the increased efficiency of capturing fish. Young fish had reached a more catchable size and water levels were more favorable for the operation of shocking equipment at the time of the second inventory. This increase was pronounced in section 3 where 79 per cent of the eastern brook trout captured were under seven inches total length.

Grayling were captured in all control areas the first inventory, and were most abundant in sections 1 and 2. By the second inventory they had disappeared from section 2. Only one grayling (young of the year) was taken in section 2 the third inventory. Eastern brook trout were captured

in all sections but predominated in section 3. Whitefish were taken in sections 1 and 2 but were most abundant in 2 where they progressively increased each inventory. Only 2 of the 17 burbot captured in section 1 were over 11 inches total length. Longnose suckers were taken in all sections. Although their numbers varied in each section at each inventory, their proportion of the total fish remained relatively constant. In section 2 where longnose suckers were most abundant there was no marked decrease during the summer as was observed by Stefanich (1952) for Prickley Pear Creek. Some decrease in the number of suckers did occur in sections 1 and 3 (Tables VII and IX). White suckers (spawners) were abundant in the spring. The majority of the larger fish probably returned to the lakes before the first inventory. Only three adults and a dozen or so fingerling were captured during the first inventory. No attempt was made to include freshwater sculpins in the inventory but they were observed to be most abundant in sections 2 and 3.

In each control area (total of all inventories) the ratio of grayling, to eastern brook trout, to whitefish, to suckers, to burbot was:

Section 1.	14:	6:	3:	78:	17
Section 2.	8:	59:	37:	155:	0
Section 3.	4:	208:	0:	66:	0

An inverse distribution occurred between grayling and eastern brook trout and between whitefish and eastern brook trout. Grayling and whitefish were most abundant downstream, and eastern brook trout upstream. Section 2 appeared to be the most favorable environment for whitefish and suckers, and section 1 for burbot.

The greatest weight per acre of grayling occurred in section 2 at the

first inventory. Eastern brook trout weight was highest in section 3, where it increased each inventory, but this was never over 31.6 per cent of the total weight of all fish. Suckers comprised over 60 per cent of the weight in all sections. The total pounds per acre during the third inventory had increased over that of the first inventory in sections 2 and 3 and decreased in section 1 (Table VII).

Stefanich (1952) gives a variation of 43.78 to 67.91 pounds per acre of trout for a two year period in Prickley Pear Creek. The averages for individual inventories in Red Rock Creek varied from 10.34 to 18.88 pounds per acre of trout. The highest weight of trout per acre in section 3 (52.58 pounds) was within the Prickley Pear Creek range, but was much less than the 94.40 pounds per acre of eastern brook trout in Hunt Creek, Michigan (Shetter and Leonard 1943). Suckers varied from 74.07 to 140.70 pounds per acre in the inventories of Red Rock Creek, as compared to the 11.20-145.66 pounds per acre in Prickly Pear Creek.

Population Composition in Removal Areas.- There was some difference in numbers and weight of fish in the control and removal areas in each section at the time of the first inventory. These variations were not believed to be significant for the purpose of this study.

Grayling did not occur in sufficient numbers to evaluate the effects of fish removal. Eastern brook trout repopulated the removal areas quickly (Tables, VII, VIII, IX). Forty eastern brook trout were removed from section 2 (plus those removed by anglers), in the first two inventories. Six more were captured in the third inventory than in the first inventory.

Table VII.

Number, weight, and pounds of fish captured in section 1 during each inventory period in Red Rock Creek, 1952.

Species and inventory period	Control area					Removal area				
	Number	Per cent	Weight	Per cent	Pounds per acre	Number	Per cent	Weight	Per cent	Pounds per acre
June 28-July 1										
Grayling.....	9	23.7	3.03	10.4	7.10	4	12.1	0.66	4.4	1.55
Eastern brook..	1	2.6	0.08	0.3	0.19	3	9.1	0.92	6.1	2.15
Whitefish.....	0	—	—	—	—	2	6.1	0.19	1.3	0.44
Suckers.....	26	68.4	25.99	88.8	60.87	23	69.7	13.17	87.7	30.84
Burbot.....	2	5.3	0.16	0.5	0.37	1	3.0	0.08	0.5	0.19
Total.....	38		29.26		68.53	33		15.02		35.17
August 12-14										
Grayling.....	5	7.9	0.84	3.7	1.97	4	14.3	0.04	0.7	0.09
Eastern Brook..	4	6.4	1.68	7.3	3.93	8	28.6	1.85	30.3	4.33
Whitefish.....	3	4.7	0.03	0.1	0.07	7	25.0	0.34	5.6	0.80
Suckers.....	41	65.1	18.50	80.7	43.33	8	28.6	3.74	61.3	8.76
Burbot.....	10	15.9	1.89	8.2	4.43	1	3.5	0.13	2.1	0.30
Total.....	63		22.94		53.73	28		6.10		14.29
September 15-17										
Grayling.....	0					1	25.0	0.01	1.1	0.02
Eastern brook..	1	5.9	0.28	1.7	0.66	2	50.0	0.85	94.5	1.99
Whitefish.....	0	—		—	—	0	—	—	—	—
Suckers.....	11	64.7	15.76	96.6	36.91	1	25.0	0.04	4.4	0.09
Burbot.....	5	29.4	0.27	1.7	0.63	0	—	—	—	—
Total.....	17		16.31		38.20	4		0.90		2.10

Table VIII

Number, Weight, and pounds per acre of fish captured in section 2 during each inventory period in Red Rock Creek, 1952.

Species and inventory period	Control area					Removal area				
	Number	Per cent	Weight	Per cent	Pounds per acre	Number	Per cent	Weight	Per cent	Pounds per acre
June 28-July 1										
Grayling.....	7	11.8	4.40	8.9	11.29	10	14.3	7.80	12.2	20.01
Eastern brook..	10	17.0	1.55	3.1	3.98	10	14.3	2.53	4.0	6.49
Whitefish.....	3	5.1	1.67	3.4	4.28	15	21.4	13.32	20.8	34.17
Sucker.....	39	66.1	41.68	84.6	106.91	35	50.0	40.19	63.0	103.09
Total.....	59		49.30		126.46	70		63.84		163.76
August 12-14										
Grayling.....	0					0				
Eastern brook..	38	38.4	3.00	5.2	7.70	30	30.6	3.83	6.2	9.82
Whitefish.....	14	14.1	9.70	16.7	24.88	19	19.4	8.38	13.7	21.49
Sucker.....	47	47.5	45.41	78.1	116.48	49	50.0	49.04	80.1	125.79
Total.....	99		58.11		149.06	98		61.25		157.10
September 15-17										
Grayling.....	1	1.0	0.01	trace	0.03	1	1.1	0.64	1.6	1.64
Eastern brook..	11	10.8	1.32	1.5	3.39	16	17.2	0.43	1.0	1.10
Whitefish.....	21	20.6	7.20	7.9	18.47	48	51.6	12.91	32.2	33.11
Sucker.....	69	67.6	81.89	90.6	210.05	28	30.1	26.14	65.2	67.05
Total.....	102		90.42		231.94	93		40.12		102.90

Table IX.

Number, weight, and pounds per acre of fish captured in section 3 during each inventory period in Red Rock Creek, 1952

Species and inventory period	Control area					Removal area				
	Number	Per cent	Weight	Per cent	Pounds per acre	Number	Per cent	Weight	Per cent	Pounds per acre
June 28-July 1										
Grayling.....	1	1.6	0.78	4.4	3.82	1	1.1	0.83	1.8	4.07
Eastern brook..	50	79.4	5.48	31.6	26.85	57	62.6	4.51	10.0	22.10
Suckers.....	12	19.0	11.11	64.0	54.44	33	36.3	39.98	88.2	195.90
Total.....	63		17.37		85.11	91		45.32		222.07
August 12-14										
Grayling.....	3	2.1	1.06	1.7	5.19	0		0		
Eastern brook..	102	71.3	8.29	13.2	40.62	87	80.6	8.42	23.7	41.26
Suckers.....	38	26.6	53.55	85.1	262.40	21	19.4	27.18	76.3	133.18
Total.....	143		62.90		308.21	108		35.60		174.44
September 12-14										
Grayling.....	0				0	0		0		
Eastern brook..	56	77.8	18.73	30.9	52.58	33	75.0	3.04	15.2	14.90
Suckers.....	16	22.2	23.98	69.1	117.50	11	25.0	16.97	84.8	83.15
Total.....	72		34.71		170.08	44		20.01		98.05

There was little reduction of eastern brook trout before the third inventory in sections 1 and 3. In section 2, more whitefish were captured each subsequent inventory than were removed in the preceding inventory. Suckers were reduced in numbers in all sections by the third inventory.

The total weight of grayling (third inventory) in the removal areas was slightly higher than in the control areas. The weight of eastern brook trout was reduced in all removal areas by the third inventory (tables VII., VIII., IX.). In section 2, the weight of whitefish was about equal in the first and third inventories, even though 21.7 pounds were removed preceding the third inventory. This may have been influenced by spawning whitefish moving into the removal area. The weight of suckers decreased each inventory in sections 1 and 3. In section 2 there was an increase in the second inventory. At the time of the third inventory most of the fish in the removal areas were of smaller size than those in the control areas.

In sections 2 and 3 the total pounds of all fish per acre decreased in the removal areas and increased in the control areas. In section 1 a decrease in total pounds occurred in both the control and removal areas. Silting and loss of cover due to bank erosion occurred in this section during the inventory periods. In some parts of the lower creek, bank erosion was intensified by cattle which frequented the creek during August and September. An additional 600-foot section was inventoried September 17. This was located about half way between section 1 and the mouth of Red Rock Creek, where erosion resulting from livestock was prevalent. A

total weight of 8.72 pounds of fish were captured.

Effects of Fishing on Grayling Numbers.- The reduction of grayling in both the control and removal areas of section 2 by the time of the second inventory (Table VIII.), resulted partly from removal of grayling by fishermen. The season opened July 1. Most of the grayling caught in Red Rock Creek were taken within a mile on either side of section 2. This was the only part of the creek easily accessible to fishermen. At the end of July, 48 grayling had been checked in creels. Six (35.3 per cent) of the 17 grayling marked in section 2 the first inventory were included in this total number. As near as could be determined from the fishermen, the marked and four unmarked grayling were caught in or near section 2. In August, three unmarked grayling were checked in creels; one of these was taken from the removal area of section 2 immediately before the second inventory. No grayling were taken in this inventory within this section. Few grayling were taken by fishermen after July in 1951-1952.

Proposed Management of the Red Rock River Drainage Area Above the Lima Dam for Grayling

Fishing Season.- It is recommended that the present fishing season (July 1 to Sept. 15) be maintained and that Red Rock and Swan Lakes and that portion of Red Rock Creek on the waterfowl refuge be closed to fishing the entire year. This will give adequate protection for spawning grayling and permit a return to the Upper Red Rock Lake before fishing begins.

Daily Limits.- It is recommended that the present limit of five grayling be reduced to two. The aggregate limit on cutthroat and lake trout should remain at 15 fish, not to exceed 10 pounds and one fish, and not include

more than five fish less than seven inches in length. The size, number, and weight restrictions should be removed on rainbow trout, eastern brook trout, and whitefish.

Irrigation.- It is recommended that an investigation be made of legal "water rights" for creeks entering the refuge. The most important would be Red Rock, Tom, Odell, and Metzel Creeks. The latter three are almost completely dewatered where they enter the refuge for certain periods during the summer.

The control of irrigation on the refuge should be vested in the refuge manager. At the present time water from lake tributaries (mainly Red Rock and Tom Creek) is used to irrigate hay and grazing land leased to ranchers by the refuge. Irrigation should be curtailed wherever possible on the refuge, and no new developments should be permitted. Where permitted, irrigation should not begin before July 15 in order to protect the grayling spawners and fry.

The average number of grayling fry per cubic foot of water was estimated each year in three irrigation ditches originating in Red Rock Creek (Fig. 1). This estimate was based on 120 samples from each ditch, 60 for each of two sampling periods. The sampling period, June 17-19, 1951 had an average of 1.5 fry in ditch 1, 1.0 fry in ditch 2, and 2.5 fry in ditch 3. The second sampling, June 26-July 3, had 1.1, 1.5, and 3.1 fry respectively. While fry decreased in ditch 1, and increased in 2 and 3 between sampling periods, there was a noticeable decrease in Red Rock Creek. In 1952 traces of fry were sampled in ditch 1, 0.6 fry in ditch 2, and 0.5

fry in ditch 3 (June 17-19). The second sampling period (June 26-July 3) there were traces in ditch 1, 0.9 fry in ditch 2, and 0.7 fry in ditch 3. Approximately 100 "spent" grayling were counted dead in ditch 1, in 1951 and seven were found dead in ditch 1 and 14 in ditch 3 in 1952.

Within two weeks after the second sampling period, all of the grayling (young of the year) in the lower part of the ditches were dead. Some survived near the headgates of the ditches. However, all of the fry and adults that entered the ditch were undoubtedly lost. All of the observed adult losses in irrigation ditches occurred between May 24 and June 14. Most of the loss of young of the year grayling was between hatching and the first of July, or when they are relatively helpless in water currents.

Artificial Stocking.- The complete cessation of stocking exotic species in this area was recommended as early as 1950. This recommendation should be strictly adhered to. Only grayling and cutthroat trout should be stocked in the drainage above the Lima Dam. Further experimental stocking of grayling fry may meet with success. Stocking of grayling (six or more inches in length) in the more heavily fished waters such as Elk Lake, Odell and Red Rock Creeks would probably provide some grayling fishing.

Beaver Control.- It is recommended that all beaver and beaver dams be removed from tributaries of the Upper Red Rock Lake. Elk Springs Creek, part of Tom Creek, and six small spring creeks on the south shore of Upper Red Rock Lake have spawning areas not accessible to grayling because of beaver dams. Beaver dam removal above the last springs in Tom Creek is not recommended until a minimum flow of water is established by enforcement of legal water rights. Beaver dam removal without elimination of beaver

on spring fed creeks is useless since dams are rebuilt almost immediately. On Red Rock Creek no repairs to the dams were observed until September. This allowed ample time for grayling to spawn.

Red Rock Creek and its tributaries and part of Tom Creek were made accessible by removal of approximately 100 beaver and 90 dams in 1951 and 1952. Until beaver are eliminated from these areas, beaver dams will need to be removed prior to each year's grayling spawning run in order to keep the stream accessible.

Erosion and Silting.- Number and weight of all fish was lowest in section 1 of Red Rock Creek (Table VII) where erosion of banks, and silting was prevalent. Perhaps after a more complete investigation, fencing of the creeks against livestock in this area might be justified.

Reclaiming Water for Grayling.- Culver (Widows) Pond, Buck Pond, and Shambow Pond (artificial impoundments, fig. 1) contain rainbow and eastern brook trout at present. These fish should be removed by poisoning and grayling introduced. Buck Pond is the only one not at the head of its individual drainage. It has a small runoff from Elk Lake which can be isolated from fish movements by a coarse gravel fill in the canyon at the lower end of the lake. If this is done, these ponds would be isolated and could be managed exclusively for grayling. They have some suitable spawning areas in their short spring inlets.

Two ponds, located off the refuge appear suitable for grayling stocking, if permission can be secured from the owners to poison out the species present.

It may be feasible to poison certain creeks but not without further

investigation.

Grayling Management in Other Areas

Prior to 1951, grayling regulations were applied on a statewide basis. The fishing season extended from May 18 to November 15, and the creel limit was 15. In 1951, the opening of the season was changed to July 1 and the creel limit reduced to five grayling. Between 1950 and 1952, 10½ million fry and 11,894 fingerlings (5-6 in.) were planted in western Montana (Mont. Fish & Game Comm. 1953). Catches of grayling between 1948 and 1952 were reported from 22 lakes and 27 streams (Table X). This fishery is believed to be maintained mainly by artificial stocking. Most of the lakes containing grayling today were originally barren of all fish. Some are known to produce large grayling populations.

It is recommended that the possibilities for enlarging the present grayling range be investigated. All barren mountain lakes which still exist in Montana and which are suitable, should be reserved for grayling only. A number of small mountain lakes already stocked with species other than cutthroat or golden trout might be poisoned out and then stocked with grayling. Headwaters of creeks that are isolated to upstream movements of fish by artificial or natural barriers offer an opportunity to develop grayling water. Over a period of years, it may be possible to reclaim a few entire creeks by poisoning and installing a barrier to keep out other fish.

Table X.

Distribution records of grayling in Montana

River or creek	County	Lake	County
Jefferson River drainage			
Big Hole River	Beaverhead	Browne Lake	Beaverhead
Wise River	"	Agnes Lake	"
Deep Creek	Deer Lodge	Canyon Lake	"
La Marche Creek	"	Mussigbrod Lake	"
Pintler Creek	Beaverhead	Bobcat Lakes	"
Thompson Creek	"	Schwinegar Lake	"
Steel Creek	"	Twin Lakes	"
Trail Creek	"	Miner Lake	"
Warm Springs Creek	"	Lower Red Rock Lake	"
Governor Creek	"	Upper Red Rock Lake	"
Red Rock River(below Lima Dam)	"		
West Creek	"		
Long Creek	"		
Metzel Creek	"		
Odell Creek	"		
Tom Creek	"		
Battle Creek	"		
Red Rock Creek	"		
Antelope Creek	"		
Hell Roaring Creek	"		
Elk Springs Creek	"		
Madison River Drainage			
Madison River	Madison	Meadow Lake	Madison
Grayling Creek	"	Lower Twin Lake	"
Gallatin River drainage			
West Gallatin River	Gallatin	Emerald Lake	Gallatin
Hyalite Creek	"	Hyalite Reservoir	"
Missouri River drainage			
Sun River	Lewis & Clark	Diversion Lake	Teton
Smith River	Cascade and Meagher	Tunnel Lake	"
		Pishkin Reservoir	"
Clarks Fork of the Columbia River drainage			
		Georgetown Lake	Deer Lodge & Granite
		Rogers Lake, Spoon Lake, Lone Lake	Flathead "
Kootenai River drainage		Howard Lake	Lincoln

SUMMARY

1. An investigation of grayling in the Centennial Valley, Montana was made during the summers of 1951 and 1952 to develop a management plan for grayling in one area of its original range.

2. In 1951 grayling were found in two lakes and five creeks. They were most abundant in Upper Red Rock Lake where the catch (1951 & 1952) with 125-foot graded experimental gill nets averaged 2.05 per hour.

3. Grayling were most abundant in Red Rock Creek during May and June during spawning and gradually decreased during the summer. In 1952 the average numbers captured with an electric shocker in 600-foot sections of stream were 5.3 (June 28-July 1), 2.0 (Aug. 12-14), and 0.5 (Sept. 15-17).

4. A total of 370 grayling were marked, and 14 marked fish were recovered.

5. In 1952 spawning was observed between May 19 and June 6 in Red Rock Creek, and between May 23 and June 1 in Antelope Creek. No spawning was observed or grayling eggs found in bottom materials composed of sand or silt.

6. The period between fertilization and hatching of the eggs was estimated to be 14-19 days where the water temperatures varied from 38 to 61°F.

7. The decrease in numbers of grayling fry during June in Red Rock Creek was partly due to predation and downstream movement.

8. The average calculated total lengths in inches for the various age groups of grayling in the Centennial Valley were: age group I, 6.1;

age group II, 11.1; age group III, 13.5; age group IV, 14.7; age group V, 15.6; and age group VI, 16.0.

9. An experiment removing all fish except grayling in sections of Red Rock Creek was tried. Grayling did not occur in sufficient numbers to evaluate the effects of fish removal.

10. At the end of one month's fishing, 6 (35.3 per cent) of the 17 grayling marked in section 2 of Red Rock Creek were checked in creels.

11. A management plan is proposed to control fishing, irrigation, artificial stocking, beaver, and erosion.

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