DISTRIBUTION OF FISH IN A SMALL MOUNTAIN STREAM IN RELATION TO TEMPERATURE

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SOME EXPERIMENTAL FISH HOSTS OF THE STRIGEID TREMATODE BOLBOPHORUS CONFUSUS AND EFFECTS OF TEMPERATURE ON THE CERCARIA AND METACERCARIA*

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ABSTRACT: Experimental studies were conducted on the digenetic trematode, *Bolbophorus confusus* (Krause, 1914) Dubois, 1935, to test host specificity in fish and the effect of temperature on the cercaria and metacercaria. Typical infections followed laboratory exposures of the following fishes: *Salmo gairdneri, Salmo trutta, Salvelinus fontinalis, Prosopium williamsoni, Pimephales promelas, Hybopsis gracilis, Rhinichthys cataractae, Catostomus commersoni, Pantosteus platyrhynchus, Lepomis macrochirus*, and *Gambusia affinis*. Cercarial penetration occurred in *Ictalurus punctatus* and *Cottus bairdi*, but metacercarial development was atypical. Maximum cercarial penetration of fish occurred between 66 and 85 F. Invasive ability was markedly reduced between 55 and 65 F and very few penetrations occurred below 54 F. Metacercariae developed rapidly at 70 F. No metacercarial development was found in fish exposed to cercariae at 70 F and then held at 40 to 42 F. Some metacercariae were observed to develop normally when fish treated in the above manner were returned to 70 F, after being held at 40 to 42 F for 1 month. Water temperature apparently plays a major role in the distribution of the metacercaria of *B. confusus* (common only in one lake) in southwestern Montana.

The digenetic fluke *Bolbophorus confusus* (Krause, 1914) Dubois, 1935, is established in Meadow Lake in southwestern Montana (Fox, 1962). Although this fluke is reported to be common in Europe, the metacercaria had not been previously reported in North America. It has not been found in other lakes in the Meadow Lake vicinity. In Europe, Dubois (1938) reported the metacercaria of this paarsite in the following fishes: rudd (*Scardinius erythropthalmus*), id (*Idus idus*), bream (*Abramis brama*), flat bream (*Abramis blicca*), northern pike (*Esox lucius*), perch (*Perca fluviatilis*), and mullet (*Mugil saliens*). He reported the final hosts to be the pelicans *Pelecanus onocrotalus* and *Pelecanus crispis* in Europe, and the white pelican (*Pelecanus erythrorhynchos*) in North America.

In Meadow Lake, the metacercariae are found in rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), arctic grayling (*Thymallus arcticus*), longnose sucker (*Catostomus catostomus*), and white sucker (*Catostomus commersoni*).

Fox (1962) observed a marked difference in the number of *B. confusus* metacercariae found in brown and rainbow trout from Meadow Lake. All brown trout examined were infected with an average of 194 cysts per fish. Cysts were found in 25 of 30 rainbow trout examined and averaged only 34 per fish. The difference in the degree of infection between the trout and the fact that *B. confusus* metacercariae are not reported in fish from nearby lakes, formed the basis for this investigation. The objectives were to study the host specificity of *B. confusus* metacercariae in fish and to find an explanation for the prevalence of the parasite in Meadow Lake fish.

Although the snail host and cercaria of *B. confusus* were not known at the time the parasite was found in Meadow Lake, the complete life cycle has since been determined by Fox (1965). It is briefly as follows: the adult fluke is found in the anterior intestine of the white pelican. The eggs pass out with the feces into the water and hatch after about 15 days. The resulting ciliated miracidia penetrate the planorbid snail, *Helisoma trivolvis*. Sporocysts develop in the snail producing large numbers of cercariae. After leaving the snail, the cercariae penetrate fish and encyst in the musculature as metacercariae. When eaten by a pelican, the metacercariae develop to patent adults within a few days.

MATERIALS AND METHODS

Numerous attempts were made to collect snails (*Helisoma trivolvis*) from Meadow Lake in the spring and early summer of 1963, but none were

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Vita

The author, Bert Edison Pierce, son of Mr. and Mrs. B. P. Pierce, was born October 22, 1939 in Bell, California. He graduated from Bell High School in 1957. In September, 1957 he entered Montana State College and completed the requirements for a Bachelor of Science degree in Fish and Wildlife Management in 1961. During the summers of 1960 and 1961 he was employed by the Montana Fish and Game Department as an assistant fisheries biologist. In September of 1961 he began graduate studies at Montana State College. He was married to Kay Wessel, of Laurin, Montana in June, 1962.

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Abstract

Fish distribution in relation to temperature was studied in Warm Springs Creek from June, 1962 through December, 1962. Fish were collected by electric shocking. Three 300-foot sections were sampled six times. The upper section was above the influence of warm springs, the middle was within the upper limits of influence of these springs, and the lower was below the warm springs. Longnose dace were scarce above the influence of warm springs, and abundant below. Mottled sculpins were abundant above, occurred in small numbers at the upper limits of influence of these springs, and were completely absent below. Stonecats were extremely rare above the influence of warm springs, and common below. Longnose and white suckers were common both above and below the influence of warm springs. Mountain suckers were scarce above and common below, while rainbow and cutthroat trout were common above and scarce below.

INTRODUCTION

An investigation of fish distribution in relation to temperature in Warm Springs Creek, Madison County, Montana, was conducted from June, 1962 through December, 1962. Warm Springs Creek heads on the divide of the Gravelly Mountains at an elevation of approximately 9,000 feet mean sea level. It flows in a westerly direction for approximately 8 miles to enter the Ruby River about 30 miles southeast of Alder at an elevation of 6,000 feet. This creek drains an area of approximately 40 square miles of steep mountain slopes and valleys. Most of this area lies within Beaverhead National Forest and is used for grazing.

Numerous warm springs, with a constant temperature of 75° F., arise along the lower 2 miles of this stream. These are largely concentrated 1.5 miles above the mouth. The stream volume above the warm springs was about 6 c.f.s. on July 19. The warm springs added approximately 54.5 c.f.s. on this date. Temperatures below the warm springs usually averaged at least 10° F. higher than those above. The lower 2 miles of stream were chosen for study. Three sampling sections, each 300 feet in length, were established (Figure 1). The lower boundary of Section 1 was 2.1 miles from the mouth of the creek and about 600 feet above the entrance of the first warm spring. Section 2 was 1.5 miles from the mouth and situated within the upper limits of the warm springs. Section 3 was 0.7 miles from the mouth and mostly below the warm springs. Average width, depth, and volume were lowest in Section 1 and increased progressively in Sections 2 and 3 (Table 1) while average velocity was lowest in Section 1 followed in order by Sections 3 and 2. Maximum-minimum temperatures were taken at 2-day

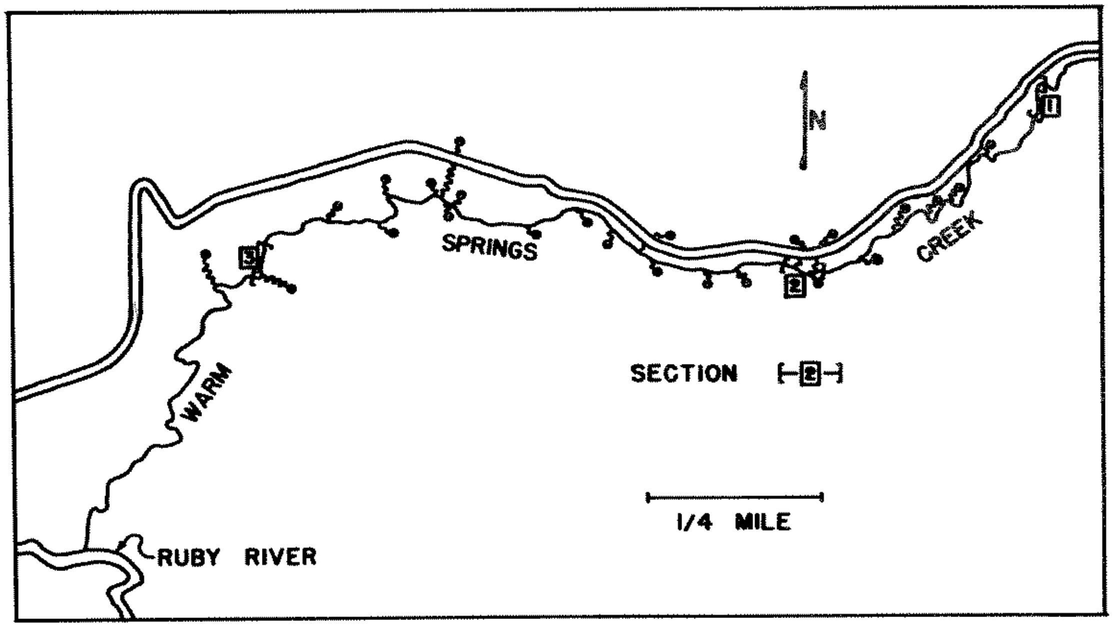

Figure 1. Warm Springs Creek showing study sections.

Table 1. Some physical characteristics of Warm Springs Creek.

Section		1	2	3
Width (feet)	Range Average	4.5 - 14.2 9.1	5.4 - 18.8 14.1	11.2 - 28.2 20.6
Depth (feet)	Range Average	0.1 - 3.5 0.6	0.2 - 4.3 0.8	0.2 - 4.6 1.5
Velocity (ft./sec.)	Range Average	0.2 - 2.4 1.5	0.5 - 4.2 3.2	0.6 - 4.0 2.2
Volume (c.f.s.)		6.1	27.0	60.6

intervals from June 26 until September 30 and then at weekly intervals through December 30 (Figure 2). The inflow of warm water had a definite regulating effect on the temperature of Warm Springs Creek. Temperatures

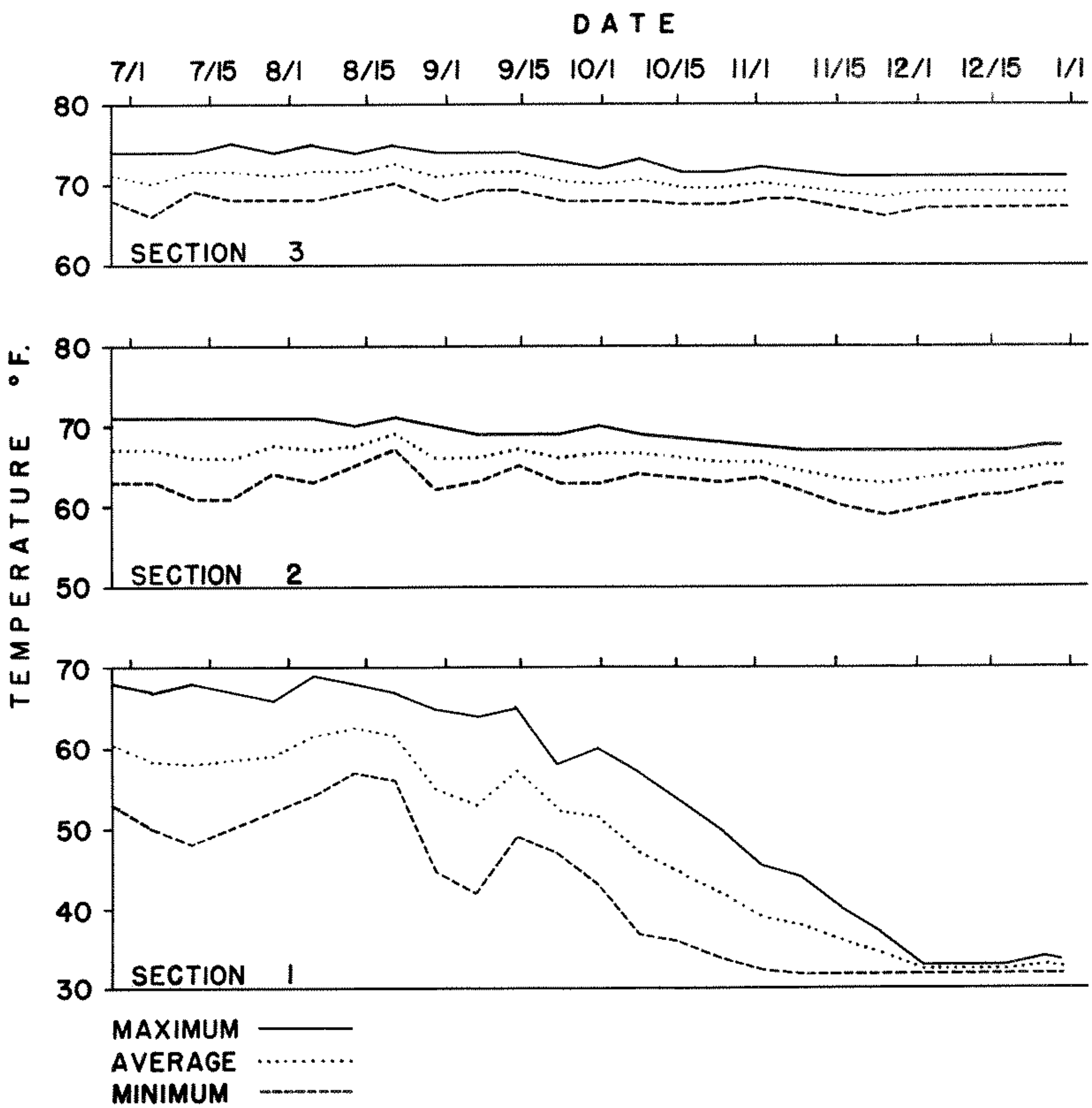

Figure 2. Temperatures of Warm Springs Creek.

became warmer and more stable as the stream progressed through the warm spring area.

Chemical water analyses were made at each section and in the warm springs on January 20, 1963 (Table 2). The warm springs were lower in

Table 2. Chemical analyses of Warm Springs Creek.

Section	1	2	3	Warm Springs
Dissolved oxygen (p.p.m.)	10.7	5.0	6.5	2.8
Free carbon dioxide (p.p.m.)	5.0	7.0	3.0	9.0
Methyl orange alkalinity (p.p.m.)	238.0	185.0	182.0	170.0
Total dissolved solids (p.p.m.)	226.0	304.0	328.0	328.0
pH	7.2	7.4	7.6	7.7

dissolved oxygen and methyl orange alkalinity, and higher in free carbon dioxide, total dissolved solids and pH than the stream above. There was no phenolpthalein alkalinity in either the springs or the stream.

In Section 1, vegetation consisted of small amounts of algae on the rocks during the early part of the study. By late September algae (*Vaucheria* sp.) was abundant and remained so to the end of the study period. *Vaucheria* was not observed in Sections 2 and 3. Section 2 had clumps of moss (*Fontinalis* sp.) dispersed throughout and dense patches of watercress (*Rorippa nasturtium-aquaticum*) adjacent to the stream banks. Pondweed (*Potamogeton filiformis*) was scattered throughout but thick beds were confined to the lower half. In Section 3, large clumps of moss covered many of the rocks and pondweed carpeted most of the bottom. Thick patches of watercress lined the sides, reaching halfway across the stream wherever spring water entered. The kinds and abundance of vegetation remained about the same in both Sections 2 and 3 throughout the study period.

The fish collected from the study area, in the order of abundance, were: longnose dace (Rhinichthys cataractae), mottled sculpin (Cottus bairdi), stonecat (Noturus flavus), longnose sucker (Catostomus catostomus), white sucker (Catostomus commersoni), mountain sucker (Pantosteus platyrhynchus), rainbow trout (Salmo gairdneri), cutthroat trout (Salmo clarki), brown trout (Salmo trutta), and brook trout (Salvelinus fontinalis).

Fish were collected by d.c. electric shocking using a generator with an output of 500 watts and 150 volts. A sample consisted of making one downstream pass through each section, taking as many fish as possible. Six samples were taken at intervals of about one month, except between the second and third which was only one week (Table 3). Each section was blocked at the lower end with a $\frac{1}{2}$-inch square-mesh net. During the first sampling period the nets in Sections 2 and 3 washed out temporarily due to floating vegetation. In subsequent samples a piece of chicken-wire was stretched across the stream immediately above the block net to catch dislodged vegetation and this prevented further difficulty. Shocked fish were collected with dip nets ($\frac{1}{4}$-inch-mesh) and placed in a holding pen located in quiet water away from the immediate shocking area.

All captured fish were measured to the nearest 0.1 inch total lengths. They were released near the middle of the section where taken as soon as possible after capture.

Table 3. Fish taken during the six sampling periods from June, 1962 through November, 1962, in Warm Springs Creek.

Species	Size in inches	Section 1 Sample 1/						Section 2 Sample						Section 3 Sample					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Longnose dace	Less than 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 and over	1	3	2	9	-	-	108	169	252	128	177	197	28	113	192	184	180	243
Mottled sculpin	Less than 2	-	-	-	43	31	38	-	-	4	25	49	48	-	-	-	-	-	-
	2 and over	180	207	168	156	157	115	1	2	4	3	5	4	-	-	-	-	-	-
Stonecat	Less than 2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	14	16	25	21
	2 and over	-	1	-	-	-	-	3	4	2	1	3	2	17	20	27	27	36	36
Longnose sucker	Less than 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 and over	7	15	5	3	-	-	9	6	2	1	2	2	22	6	5	15	4	15
White sucker	Less than 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 and over	14	11	6	8	1	1	10	4	5	1	4	4	9	3	8	6	9	4
Mountain sucker	Less than 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 and over	1	2	1	-	-	-	13	5	1	1	4	2	23	9	7	12	6	5
Rainbow and cutthroat trout	Less than 2	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 and over	5	9	7	27	19	20	1	4	4	8	13	15	4	3	1	2	5	4

1/ Sample 1 was taken June 30 - July 1; sample 2, July 29 - 30; sample 3, August 5 - 6; sample 4, September 14 - 15; sample 5, October 21; sample 6, November 10 - 11.

DISTRIBUTION

The warm springs which are concentrated along a relatively small portion of this creek, undoubtedly influence fish distribution in the study area since they increase water temperatures and volume, which in turn affects the abundance of cover in the form of aquatic vegetation. Temperature, volume, and aquatic vegetation increased progressively from Section 1 through Section 3. The distribution of each species of fish involved is considered in the order of abundance.

Longnose Dace. This species is common throughout Montana on both sides of the Continental Divide. In Warm Springs Creek, only 15 longnose dace were collected in Section 1 (Table 3) during the study period. A total of 1,031 was taken in Section 2, and 940 in Section 3. Nine was the maximum number collected in Section 1 during any of the 6 sampling periods, from June, 1962 through November, 1962, and none were taken during the last two periods. This absence occurred when the average water temperature had declined below 50° F. (Figure 2). The numbers collected in Section 2 ranged from 108 to 252 for the various sampling periods, and those in Section 3, from 28 to 243. Average temperatures were warmer and much more stable in Sections 2 and 3 than in Section 1.

No size distribution analysis of longnose dace was made since small specimens were not collected in proportion to their actual abundance in the population. Many of those smaller than 2 inches in total length readily passed through the dip nets used. Numerous dace less than 2 inches in total length (probably young-of-the-year) were observed in Sections 2 and 3 during the last 2 sampling periods but none were observed in Section 1.

Temperature apparently influenced distribution of the longnose dace in Warm Springs Creek, since they were abundant in the stream below the entrance of warm springs and scarce above. Many were observed in the springs proper. They were always abundant wherever watercress occurred, in or out of the springs. The absence of this species above the warm springs, after water temperatures had declined supports the conclusion that their distribution was influenced by temperature.

Mottled Sculpin. This species is common to all the major drainages east of the Continental Divide in Montana. Bailey (1951) found it to be abundant in dense mats of white water-crowfoot, as well as in rocky streams where little vegetation existed. In Warm Springs Creek, the mottled sculpin was most abundant in Section 1 (Table 3), where 1,095 were collected during the study period. Only 145 were taken from Section 2, and none from Section 3. The numbers of sculpins collected in Section 1 ranged from 153 to 207 for the various sampling periods. The number collected from Section 1 decreased slightly in each of the last two samples. This was probably due to an increase in algae, beginning in late September, which made recovery of small fish more difficult. The numbers collected in Section 2 ranged from 1 to 54. Aquatic vegetation showed little apparent change in this section during the study period.

Mottled sculpins 2 inches or greater in total length are believed to include those one year or older, and those less than 2 inches are presumed to be young-of-the-year. Size distribution was undoubtedly biased in favor of the larger specimens because of collection methods. Sculpins greater than 2 inches in total length made up 100 percent of this species for the first 3 samples in Section 1 and 78 percent, 84 percent, and 75 percent of samples 4, 5, and 6 respectively. In Section 2, they made up 100 percent of the first 2 samples and 50 percent, 11 percent, 9 percent, and 8 percent of samples 3, 4, 5, and 6 respectively. No sculpins of any size were taken in Section 3. Sculpins less than 2 inches in total length constituted only one percent of the total number taken from Section 1, and 87 percent of those taken in Section 2. The length-frequency was determined on 249 specimens collected July 30, 1962, and on 242 specimens collected October 21. An interval of 0.3 inches was used in preparing the frequency polygon (Figure 3). The modes at 3.0 and 3.6 inches, in the July collection, probably represent the I and II year classes. The modes at 1.5, 3.0 and 3.6 inches, in the October collection, probably represent the 0, I, and II year classes. Sculpins of the 0 year class were first collected in Section 2 on August 6 (third sample). They were not collected in Section 1 until September 15 (fourth sample).

Apparently temperature strongly influenced distribution of the mottled sculpin in Warm Springs Creek. It was abundant above the warm springs, occurred in small numbers at the upper limits of influence of these springs, and was completely absent below, although cover, volume and other conditions appeared suitable.

Stonecat. In Montana, this species is found in many of the drainages east of the Continental Divide at lower elevations, and Warm Springs Creek

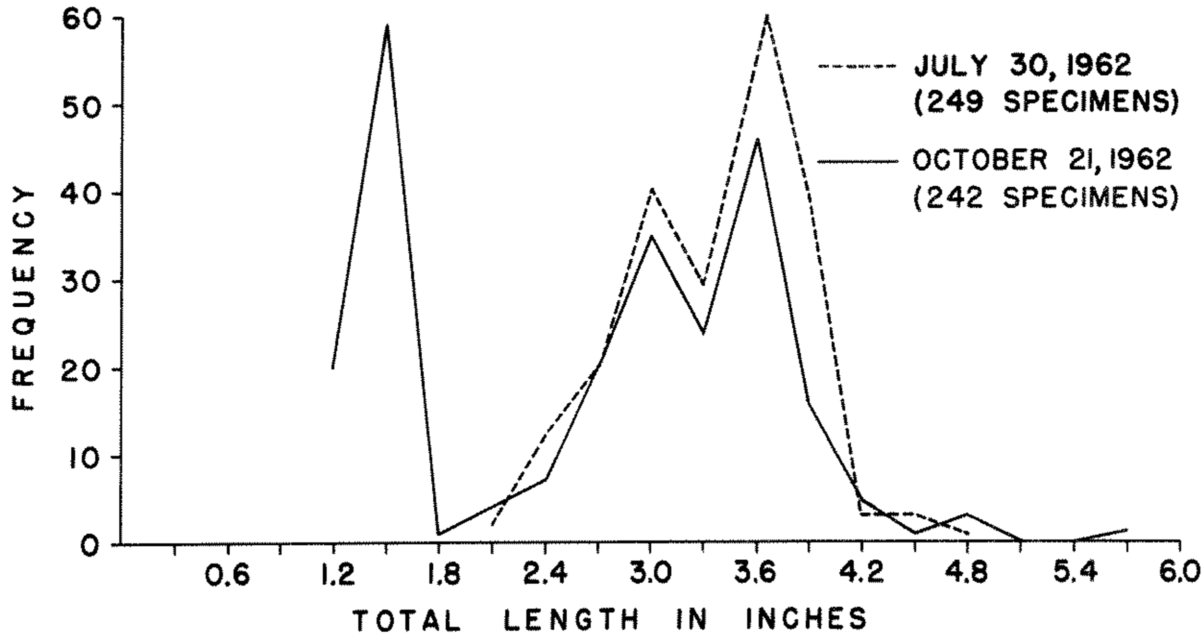

Figure 3. Length-frequency of two collections of mottled sculpins from Warm Springs Creek.

is the only high mountain stream where it has been found. Only one stonecat was taken from Section 1 (second sampling period) during the study period (Table 3). Sixteen were collected from Section 2 and 239 from Section 3. The numbers collected from Section 2 ranged from 2 to 4 for the various sampling periods, while those taken in Section 3 ranged from 17 to 61.

Stonecats 2 inches or over in total length are believed to be one year or older, and those less than 2 inches are considered young-of-the-year. The only specimen taken from Section 1 was 3.9 inches in length. Stonecats greater than 2 inches in total length made up 100 percent of samples 1, 2, 3, 5, and 6 in Section 2, and 50 percent of sample 4 when only two specimens were taken. In Section 3, they made up 100 percent of the first 2 samples, and 68 percent, 63 percent, 59 percent, and 63 percent of samples 3, 4, 5, and 6 respectively. Stonecats less than 2 inches in total length constituted 6 percent of the total number taken from Section 2, and 32 percent from Section 3. These percentages should have been higher since the smaller specimens were not collected in proportion to their actual abundance because of collection methods. A length-frequency study was made on 88 specimens collected September 14 and 15, 1962, using an interval of 0.3 inches in the frequency polygon (Figure 4). Modes at 1.5, 3.0,

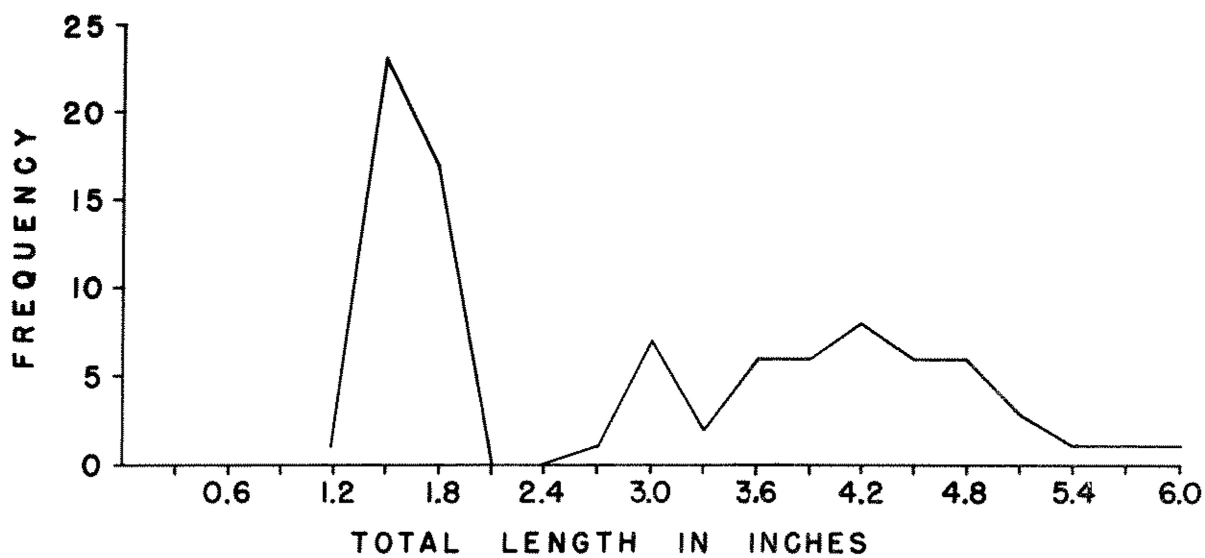

Figure 4. Length-frequency of 88 stonecats collected September 14 and 15, 1962 from Warm Springs Creek.

and 4.2 inches probably represent the 0, I, and II year classes. Gilbert (1953) reported that Noturus flavus usually showed differences in size increment only in the first 3 years. He also found that they generally reach about 2 inches the first year. Stonecats of the 0 year class of Warm Springs Creek were first collected in Section 3 on August 5 (third sample). The only one collected in Section 2 was taken September 14 (fourth sample).

Temperature undoubtedly influences the distribution of the stonecat in Warm Springs Creek since this species was most abundant below the warm springs where water temperatures were highest and extremely rare above the springs where temperatures were lowest, even though cover, volume and other conditions appeared adequate. Gilbert (1953) found the stonecat in rocky riffles of streams. Trautman (1957) classified it as a riffle species, and reported numerous young in aquatic vegetation of sand and gravel riffles.

Longnose Sucker. This species is found in most drainages of Montana. In Warm Springs Creek, 30 longnose suckers were collected in Section 1 (Table 3), 22 in Section 2, and 67 in Section 3. The numbers collected in Section 1 during the sampling periods ranged from 3 to 15. All were taken during the first 4 periods. The numbers collected in Section 2 ranged from 1 to 9, and those in Section 3 from 4 to 22 for the various sampling periods. No size distribution analysis was made because of insufficient numbers.

There was no marked relationship between distribution of longnose suckers and water temperature since they were commonly taken both above and below the warm springs. However, this species was absent in Section 1 during the last two sampling periods when the average water temperature was below 50° F. (Figure 2).

White Sucker. This species is abundant in all major drainages in Montana. In Warm Springs Creek, 41 white suckers were collected in Section 1 (Table 3), 28 in Section 2, and 39 in Section 3. The numbers taken from Section 1 ranged from 1 to 14 for the various sampling periods. Those collected in Section 2 ranged from 1 to 10, and in Section 3 from 3 to 9. No size distribution analysis was made because of insufficient numbers.

There was no marked relationship between distribution of the white sucker and water temperature, since they were commonly taken above and below the warm springs. However, only one specimen was collected in Section 1 in each of the last two sampling periods when the average water temperature had decreased below 50° F. (Figure 2).

Mountain Sucker. This species is common in cold streams east of the Continental Divide in Montana. In Warm Springs Creek, 4 were collected in Section 1 (Table 3), 26 in Section 2, and 62 in Section 3 during the study period. In Section 1, no more than two specimens were collected in any of the first three sampling periods, and none were taken in periods 4, 5, and 6. Those collected in Section 2 ranged from 1 to 13, and in Section 3 from 5 to 23 during the sampling periods. No size distribution analysis of mountain suckers was made since an insufficient number was collected.

Distribution of this species was apparently influenced by temperature since they were collected in greatest numbers below the warm springs and only rarely above, although cover, volume, and other conditions appeared adequate. They were absent in Section 1 during the last three sampling periods when the average water temperature was below 58° F. (Figure 2).

Trout. Rainbow and cutthroat trout are considered together since both are found in Warm Springs Creek and they are known to hybridize readily. The rainbow trout was introduced throughout Montana, and is found in most cold water streams. The cutthroat trout is native and still occurs in some headwater streams. In Warm Springs Creek, 89 rainbow and cutthroat trout were taken in Section 1 (Table 3), 45 in Section 2, and only 19 in Section 3. The numbers collected in Section 1 ranged from 5 to 27, in Section 2 from 1 to 15, and in Section 3 from 1 to 5, during the various sampling periods. No size distribution analysis of rainbow and cutthroat trout was made because of insufficient numbers.

It appears that temperature influenced distribution of rainbow and cutthroat trout in Warm Springs Creek, since they were most common above the warm springs and became progressively fewer below. Other conditions below the springs appeared adequate for both species.

Only 5 brown trout, 3 from Section 2, and 2 from Section 3, and 1 brook trout, from Section 2, were taken.

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Grateful acknowledgement is due to Dr. C. J. D. Brown who suggested the project and aided in the preparation of the manuscript. I am indebted to my wife, Kay, for her constant assistance in the field. Thanks are due to those, especially Fay Wessel, who helped with fish collection. Thanks are also due to Mr. and Mrs. Lester Wessel for their encouragement and financial help during the study. The Montana Agricultural Experiment Station furnished some financial assistance and equipment and the Montana Fish and Game Department supplied the collecting equipment.

SUMMARY

1. Observations were made on the distribution of fish in relation to temperature in Warm Springs Creek, Montana. Three study sections were sampled six times from June, 1962, through December, 1962.

2. Longnose dace were scarce above the influence of warm springs, and abundant below. They were absent above the warm springs when the average water temperature was below 50° F.

3. Mottled sculpins were abundant above the influence of warm springs, occurred in small numbers at the upper limits of influence, and were completely absent below.

4. Stonecats were extremely rare above the influence of warm springs, and common below.

5. Longnose suckers and white suckers were common above and below the influence of warm springs. They were very scarce or absent above the warm springs when the average water temperature was below 50° F.

6. Mountain suckers were scarce above the influence of warm springs, and common below. They were absent above the warm springs when the average water temperature was below 58° F.

7. Rainbow and cutthroat trout were common above the influence of warm springs and scarce below.

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