Life history and ecology of the freshwater sculpin Cottus Bairdii Punctulatus in southwestern Montana
by Jack E Bailey

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
An investigation was made on the life history and ecology of the freshwater sculpin Cottus bairdii punctulatus in the West Gallatin River, Prickley Pear Creek, and Wolf Creek, Montana. The study began in January 1950 and continued until October 1951 Analysis of 903 seulpin stomachs shows that bottom-dwelling aquatic insects comprised 99.7 percent of the total number of food organisms consumed. Biptera and caddis fly larvae and pupae constituted 55.5 and 36.7 percent, respectively. Mayfly and stonefly nymphs made up 5.9 percent of the food items eaten. Caddis were consumed in greatest numbers in the fall and least in spring, while Diptera were taken most in spring and least in fall. The maximum amount of food per stomach occurred during winter months while the minimum was found in summer. Sculpins were most abundant in rubble riffle areas and least abundant where the bottom was entirely sand or clay. Twenty-one of 75 marked sculpins released in Priekley Pear Creek were subsequently recaptured. The 1951 spawning season was from June 5 to 30 and hatching occurred from July 3 to 21, indicating an incubation period of 21-28 days. Some individuals matured at the age of two years and all females over 74 mm. total length were sexually mature. Development of ovaries was determined by calculating ripeness factors based on the ovary volume and the cube of the total body length. The number of eggs per female averaged 203 and many nests were used by more than one female. The nests were prepared and attended by the males. Average total lengths of young sculpins were 7.8mm. in July, 31.4 mm. in October, 32.6 mm. in the following May, and 52.9. in August. Average total lengths of five age groups were determined for 151 specimens by a study of the otoliths. Length-frequency data in general agreed with growth data based on otolith studies. The relationship between length and weight, and also between standard and total lengths, were also determined.

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at

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Abstract

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Introduction

An investigation on the life history and ecology of the freshwater sculpin Cottus bairdii punctulatus was stated in January 1950 and continued until October 1951. This study was centered mainly on the West Gallatin River in the vicinity of Shedds Bridge, $5\frac{1}{2}$ airline miles downstream from the village of Gallatin Gateway, Montana. During the summer of 1950, observations were made on the sculpins of Prickley Pear Creek which empties into the Missouri River about six miles upstream from Craig, Montana. The area studied included the lower 13 miles of Prickley Pear Creek and the lower $1\frac{1}{2}$ miles of Wolf Creek, which is a small tributary of the latter.

Description of the Sampling Areas

The West Gallatin collecting station was 2300 feet long. The maximum width of this section during flood stage (May-June) was approximately 150 feet and the maximum depth approximately 8 feet. In September 1951, at the low water period, the maximum width was approximately 70 feet. Practically all of the collections were made in water between the shoreline and the 2-ft contour. Neither the 2-ft contour nor the shoreline occupied fixed positions as their locations were dependent on water levels. In 1951 the water level dropped approximately three feet from its flood stage peak in May to near normal summer level recorded June 10. This caused the shoreline to move in as much as 100 feet in certain places. By September 17 the water level was down another 6 inches. Gradients of the sampling section were measured with a hand level at 100 foot intervals.

The mean gradient for the section was 0.70 feet per 100 feet with a maximum of 1.94 and a minimum of 0.22. The maximum surface velocity measured, in the area where sculpins were collected, was 4.6 feet per second. Bottom materials in the sampling area consisted of approximately 30 percent boulders, 55 percent rubble, and 15 percent sand and gravel. Both banks of the section are bordered by cottonwoods, aspens, and willows. Algae was the only abundant aquatic vegetation.

Water temperatures for the West Gallatin station were taken at irregular intervals throughout the collecting period. They were usually secured between 2:30 and 3:30 p.m. Minimum temperatures (32-36°F.) occured during December, January, February, and March of both years with a definite "warm up" period beginning in late March. No temperatures were taken in the summer of 1950 but in 1951 the maximum temperature of 65°F. occurred on July 31.

In Prickley Pear Creek, sculpins were collected in riffle areas which had a maximum summer width of approximately 45 feet and a minimum of 21 feet. The maximum depth varied from 14 inches in shallow riffles to about 8 feet in deep pools during September 1950. The maximum surface velocity recorded during September was 4.3 feet per second in areas where collections were made. Bottom materials of riffle areas were exceedingly variable. Rubble was predominant with varying mixtures of gravel, sand, and boulders. Pool bottoms were mostly of clay or sand. After the spring run-off, green algae and white water-crowfoot (Ranunculus aquatilis) became abundant and persisted through most of the summer. The minimum water temperature for the period June 9 to September 27 was 43°F. (June 9) and the maximum was 67°F. (July 26). Variations in temperatures throughout any 24 hour period ranged from 3° to 16°F.

Wolf Creek is similar to Prickley Pear Creek except that it is much smaller. On June 17, 1950, the maximum width was 38 feet and the maximum depth was 18 inches in riffle sections.

Fish Present

The freshwater sculpin (*Cottus bairdii punctulatus*) was the most abundant fish in the sampling area on the West Gallatin River. Brown trout (*Salmo trutta*), rainbow trout (*Salmo gairdnerii*), cutthroat trout (*Salmo clarkii*), rainbow-cutthroat hybrids, eastern brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersonii*), and longnose dace (*Rhinichthys cataractae*), are known to occur in the same general area. Except for suckers, all of the above species were observed in the sampling area. Suckers may have been present but no attempt was made to collect them.

The freshwater sculpin (*Cottus bairdii punctulatus*) was also the most abundant fish in both Prickley Pear Creek and Wolf Creek. (One albino sculpin with a total length of 62 mm. was found in Wolf Creek.) Associated species of trout, whitefish, and suckers were the same as in the West Gallatin River. Carp (*Cyprinus carpio*) and American burbot (*Lota lota maculosa*) were present in small numbers in Prickley Pear Creek.

Acknowledgments

Thanks are extended to those who assisted in this study. Dr. C. J. D. Brown suggested and directed the investigation and assisted in the preparation of the manuscript. Observations on time of spawning and incubation period of sculpins from the West Gallatin River during the 1950 summer season were made by George Holton. Raymond Hays gave many hours of valuable assistance in the determinations of food organisms. Charles K. Phenicie, fisheries biologist for the Montana State Fish and Game Department, furnished the electric shocking equipment for making collections and assisted in the analysis of certain data. The species of sculpins from the West Gallatin River and Prickley Pear Creek were determined by Dr. Leonard P. Schultz. The writer wishes to express appreciation to fellow students who helped in making collections.

Collections and Preservation of Samples

Most collections of sculpins were made with a screen 3 by 4 feet similar to that described by Needham and Needham (1941). The screen was held in an inclined position against the stream bottom and the rubble and gravel immediately upstream was disloged by kicking. Sculpins that collected on the screen were lifted from the water. This method was adequate for small samples of all sculpins except those less than 20 mm. in total length. Small sculpins were most abundant in shallow slow water and were more readily collected with a tea strainer. The collecting screen and the tea strainer were both provided with screen having 16 mesh per linear inch. Two electric shockers were used for taking large samples. One was a 500 watt AC generator used at voltages of 160 to 200, and the other a 250 watt, DC generator used at 125 volts. Each machine was equipped with two portable electrodes.

The DC generator appeared to be more efficient on the larger sculpins. The positive electrode of the DC shocker was maniuplated so as to attract sculpins upwards from the stream bottom thus making it easy to recover them. Sculpins shocked by alternating current were more subject to the flow of the stream which often carried them under rocks where they lodged out of sight. The smaller sculpins were easily collected because they remained near shore where water currents were not effective in carrying them under rocks.

The majority of sculpins collected were preserved in 10 percent formalin at the time of capture. However, when otoliths were to be taken, specimens were weighed and measured in fresh condition. The relationship between total lengths of fresh and preserved sculpins was determined for a sample of 75 specimens. The fresh total lengths ranged from 60 to 121 mm. These fish were then placed in 10 percent formalin for 3 months and measured again. Total lengths after preservation ranged from 57 to 115 mm. The resulting formula for conversion from fresh total length (Y) in mm. to total lengths of preserved fish (X) in mm. was $X = 0.960Y$. When converting from preserved to fresh total lengths, the formula becomes $Y = 1.037X$. Similar factors were obtained for 101 small sculpins (fresh total lengths 25-42 mm.). The conversion factor from fresh to preserved total length for this sample was 0.990 and from preserved to fresh total length was 1.010.

Food Habits

Twenty-three separate collections were obtained from the West Gallatin River and three from Prickley Pear Creek for the food habits study. No definite collecting schedule was followed except to secure at least one sample for each calendar month. Collecting began January 21, 1950, and ended August 31, 1951. Almost all collections were made in the afternoon. A total of 903 specimens were examined, 821 from the West Gallatin River and 82 from Prickley Pear Creek. The West Gallatin River specimens included 53 young (less than three months old, 6.8-26 mm. total length) and 768 old (more than three months old, 21-118 mm.). The Prickley Pear Creek specimens ranged in total length from 42 to 118 mm.

All lengths and weights were taken after specimens were preserved (10 percent formalin) except for 36 fish which were measured while fresh. The length measurements on fresh specimens were converted to preserved lengths by the factor 0.960. Sex and maturity were determined whenever possible by careful examination without making micro-sections of the gonads.

Stomachs were removed by slitting the sculpins from anus to throat, cutting the esophagus at the posterior end of the oral cavity and breaking off the intestine at the pyloric valve which forms a convenient and definite posterior demarcation between stomach and intestine. Stomachs were then placed in 70 percent alcohol before the contents were removed and classified. Food organisms were generally determined to family. Some specific identifications were made. Insect fragments were recorded as unidentifiable insects.

Due to the small amounts of food present in sculpins, it was not practical to measure volumes of individual stomachs. In order to obtain the volumetric measurement of food eaten, total volumes were determined by alcohol displacement of the stomach contents of 17 separate collections. The average volume of food per stomach was 0.09 ml. and the maximum volume was 2.30 ml.

Composition of Food

Food studies on Cottus bairdii by Ricker (1934), Koster (1936), and Dineen (1947) indicate that this species feeds mainly on bottom dwelling aquatic fauna and is not a serious predator of game fish species. The present study agrees with these findings (Table I). Bottom dwelling aquatic insects made up 99.7 percent of the total number of all food items in the stomachs of the older sculpins from the West Gallatin River. Items such as snails (Physa), fingernail clams (Pisidium), water mites (Hydrachnidae), sculpin eggs, and fish composed the other 0.3 percent. The only terrestrial insect taken was an adult ground beetle.

Dipterous larvae and pupae, the most abundant food items, comprised 55.5 percent of the total and occurred in 60.3 percent of the stomachs. Tendipedidae (Chironomidae) was the most important family. Chironomid larvae and pupae accounted for 95.6 percent of the Diptera. Larvae made up 99.6 percent of the Tendipedidae while pupae constituted only 0.6 percent. Chironomid larvae were also the most abundant Diptera in the stomachs examined by Ricker (1934), Koster (1936), and Dineen (1947).

Table I

List of foods found in sculpin stomachs from the West Gallatin River

- Mollusca
  - *Physa*
  - *Pisidium*
- Insecta
  - Ephemeroptera (nymphs)
    - Heptageniidae
      - *Heptagenia*
      - *Rhithrogena*
    - Baetidae
      - *Paraleptophlebia bicornuta*
      - *Ephemerella doddsi*
      - *Ephemerella flavilinea*
      - *Baetis*
  - Plecoptera (nymphs)
    - Pteronarcidae
      - *Pteronarcys californica*
      - *Pteronarcella badia*
    - Taeniopterygidae
    - Nemouridae
    - Capniidae
    - Perlidae
      - *Classenia sabulosa*
    - Perlodidae
      - *Arcynopteryx parallela*
    - Chloroperlidae
    - Isoperlidae
      - *Isoperla*
  - Coleoptera (larvae and adults)
    - Carabidae
    - Haliplidae
    - Dryopidae
      - *Helmis*
  - Hemiptera
  - Trichoptera (larvae and pupae)
    - Rhyacophilidae
      - *Rhyacophila*
      - *Glossosoma*
    - Hydropsychidae
      - *Arctopsyche*
      - Hydropsyche
    - Hydroptilidae
    - Limnephilidae
    - Lepidostomatidae
    - Brachycentridae
      - *Brachycentrus*
    - Helicopsychidae
  - Diptera (larvae and pupae)
    - Tipulidae
      - *Tipula*
      - *Antocha*
    - Tendipedidae (Chironomidae)
    - Ceratopogonidae
    - Blepharoceridae
      - Bibiocephala
    - Simuliidae
- Arachnida
  - Hydrachnidae
- Fish
  - *Rhinichthys cataractae*
  - *Cottus bairdii*
- Fish eggs
  - *Cottus bairdii*

Caddis fly larvae, second only to the Diptera in numbers consumed, accounted for 36.7 percent of all food items and occurred in 58.3 percent of the stomachs. Lepidostomatidae and Hydropsychidae were the most important families constituting 69.8 and 24.4 percent, respectively.

Mayfly nymphs made up only 3.8 percent of the total number of food items but occurred in 32.8 percent of the stomachs. Plecoptera nymphs with 2.1 percent of the total number of food items, occurred in 16.8 percent of the stomachs. Despite the fact that mayfly and stonefly nymphs comprised a low percentage of the total number they were an important food because of their large size and rather regular occurrence. Fish and fish eggs comprised 0.1 percent of the food items eaten and occurred in 0.8 percent of the stomachs.

Snails, fingernail clams, beetles, true bugs, and water mites collectively constituted only 0.2 percent of the total number of food organisms and occurred in only 2.6 percent of the stomachs. Unidentifiable insects made up the remaining 1.6 percent of the food items.

Sticks and stones which were presumed not to be parts of caddis fly cases were found in 5.2 percent of the stomachs.

Food of Small Sculpins

The smallest sculpins which had food in their stomachs were collected July 21, 1951, from the West Gallatin River. Only three specimens (total lengths 9.1-10.0 mm.) of a sample of 15 ranging in total length from 6.8 to 10.4 mm. contained food. Unabsorbed yolk sacs were still present in 12 of the fry. The only identifiable food items were a chironomid larvae and one water mite.

The yolk sacs were completely absorbed in 23 sculpins (total lengths 9.1-14.8 mm.) taken July 31, 1951. All had been feeding on chironomid larvae and in addition, two specimens had one mayfly nymph each, another had a fingernail clam, and a fourth had an unidentifiable insect larvae. Chironomid larvae accounted for 128 (97.7 percent) of the total number of food organisms.

Stomach examinations were made on 15 young of the year (total lengths 14-26 mm.) collected on August 31, 1951 (Table II). Chironomid larvae occurred in all but one and comprised 92.6 percent of the total number of food organisms. Fingernail clams accounted for 3.8 percent of the total. Other items included mayfly and stonefly nymphs. These findings are generally in agreement with Ricker (1934).

Table II

Stomach contents of 15 West Gallatin River sculpins (total lengths 14-26 mm.) collected August 31, 1951

	Number of fish with organism	Average number per stomach	Percentage of total number of organisms
Mollusca (Pisidium)	5	1.4	3.8
Ephemeroptera			
Baetidae	2	1.0	1.1
Paraleptophlebia	1	1.0	0.5
Heptageniidae			
Heptagenia	1	1.0	0.5
Plecoptera	1	1.0	0.5
Diptera larvae	1	1.0	0.5
Chironomid larvae	14	12.4	92.6
Unidentifiable insects	1	1.0	0.5

<u>Food of Large Sculpins</u>

Sculpins were divided into three size groups (total lengths 21-50 mm., 51-80 mm., and 81-118 mm.) in order to facilitate comparison of food habits (Table III).

In the West Gallatin River, mollusks occurred in the stomachs of all three size groups. Fingernail clams were taken by the smallest size group and snails by the two larger groups. In Prickley Pear Creek, however, the larger sculpins took both fingernail clams and snails.

Stonefly nymphs were consumed in greatest numbers by the largest size group and least by the smallest. The smallest size group utilized only small nymphs of the families Capniidae, Perlodidae, Chloroperlidae, and Isoperlidae while the two largest size groups contained in addition nymphs of the families Pteronarcidae, Taeniopterygidae, Nemouridae, and Perlidae. Caddis fly larvae were consistently more abundant in the stomachs of the larger sculpins. Diptera larvae and pupae were used most by small sculpins. Chironomid larva was the most common diptera found in all sizes of sculpins. However, cranefly larvae (<u>Tipula</u>) occasionally contributed more to the total volume due to their large size.

Fish and fish eggs were not important items in the diet of West Gallatin River sculpins. Only five specimens had fish in their stomachs. The smallest was a female with a total length of 80 mm. Four males (total lengths 86-111 mm.) each contained one fish. Only two of the fish eaten were identified; one was a longnose dace and the other a yearling sculpin. One male (total length 105 mm.) taken June 30, 1951, had seven fungused sculpin eggs in its stomach. Eyed sculpin eggs were found in

Table III

Food in relation to size of 768 sculpins from the West Gallatin River 1950-1951

	222 stomachs total length 21-50 mm.				324 stomachs total length 51-80 mm.				222 stomachs total length 81-118 mm.			
	Greatest number in any fish	Average number of organisms in stomachs containing them	Percent of fish with organism	Percent of total number of all foods taken	Greatest number in any fish	Average number of organisms in stomachs containing them	Percent of fish with organism	Percent of total number of all foods taken	Greatest number in any fish	Average number of organisms in stomachs containing them	Percent of fish with organism	Percent of total number of all foods taken
Mollusca	1	1.0	0.4	0.1	3	1.3	1.8	0.2	3	1.7	0.1	0.1
Ephemeroptera	4	1.3	32.9	6.7	10	1.8	33.3	4.3	12	2.0	32.0	2.7
Plecoptera	6	1.2	9.9	1.9	7	1.5	15.4	1.7	29	2.4	25.7	2.5
Coleoptera	1	1.0	0.4	0.1	...	...	...	...	1	1.0	3.2	0.1
Hemiptera	...	...	...	...	...	...	...	...	1	1.0	0.4	0.0
Trichoptera	7	2.3	36.5	13.3	57	6.9	64.2	31.3	194	15.9	71.6	47.2
Diptera	57	8.0	58.1	74.4	149	13.5	63.3	60.8	290	19.2	58.1	46.2
Unidentifiable insects	1	1.0	21.6	3.5	5	1.2	18.8	1.6	2	1.1	21.6	1.0
Arachnida	...	...	...	...	5	5.0	0.3	0.1	...	...	...	...
Fish	...	...	...	...	1	1.0	0.3	0.0	1	1.0	1.8	0.1
Fish eggs	...	...	...	...	...	...	...	...	7	7.0	0.4	0.1

the stomachs of two adult males taken June 28, 1950, from Prickley Pear Creek.

In a total of 17 Prickley Pear Creek sculpins (total lengths 98-118 mm.) collected September 21, 1950, three were found to contain fish, two of the items were rainbow trout approximately $2\frac{1}{2}$ inches long. These trout may have been from fingerlings (2-5 inches total length) planted September 18, 1950.

Predation by freshwater sculpins on game and commercial fishes has been investigated by several fisheries workers. Forbes (1883) reported that 25 percent of the food of six Cottus bairdii was fish. Lincoln (1933) stated that muddlers had been observed to take recently planted trout $1\frac{1}{2}$-2 inches long. Dineen (1947) examined the stomachs of over one thousand Cottus bairdii bairdii and found only one fish, a small sculpin. Simon and Brown (1943) reported a small male (Cottus semiscaber) gorged with sculpin eggs and fry. Dence (1928), Greeley (1932), Ricker (1934), and Surber (1920) reported no evidence of Cottus bairdii eating fish or fish eggs. Koster (1936) concluded that sculpins do not destroy large numbers of trout eggs or fry. This species apparently is not a serious predator of game fish although it may take trout under certain conditions and occasionally eats small individuals of its own kind.

Seasonal Variations in the Food of Sculpins from the West Gallatin River

The volume and number of food items per stomach was compared for the various seasons of the year (Fig. 1). The calendar year was divided into four periods of equal length. On the basis of water temperatures,

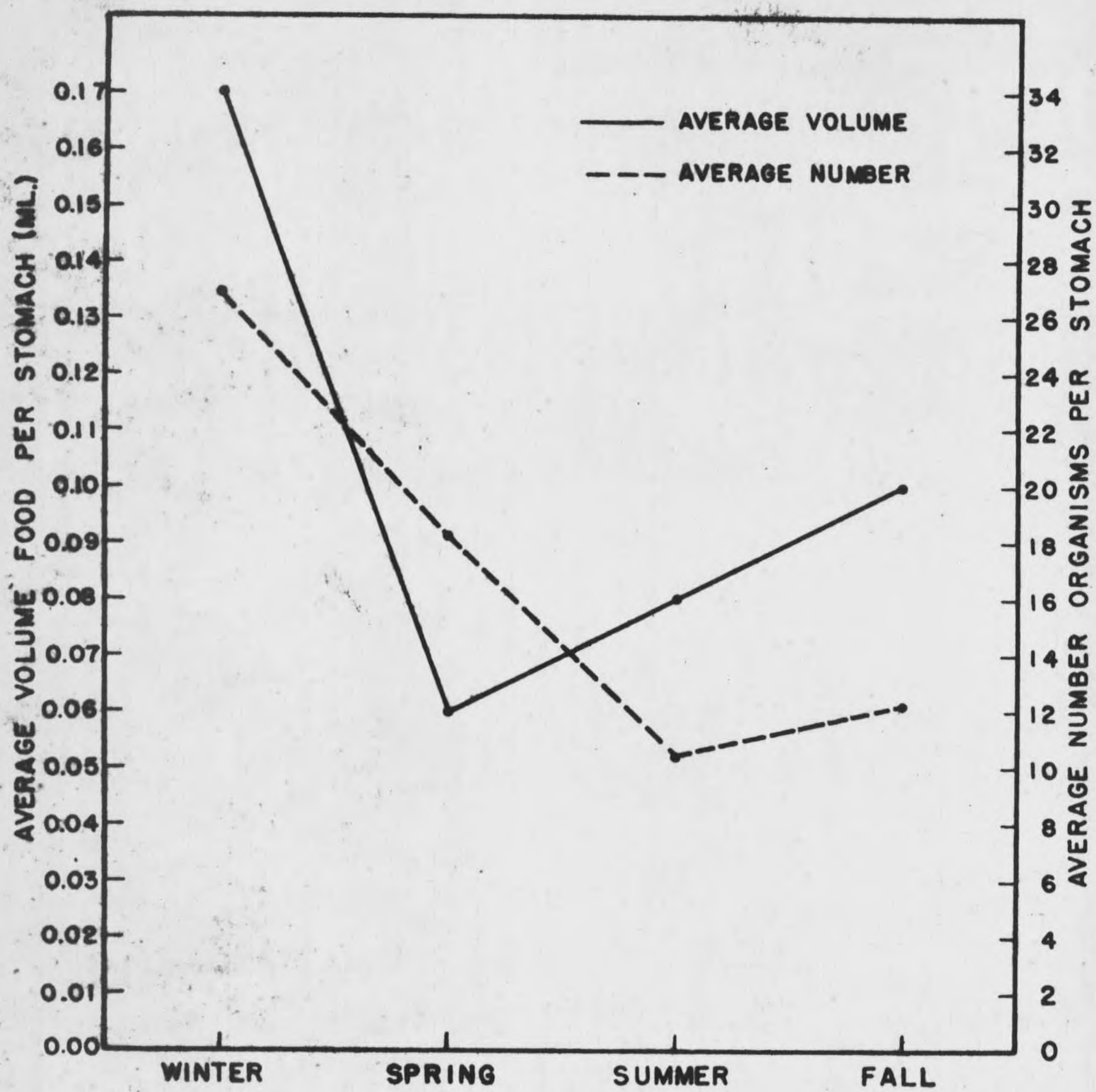

Fig. 1. Amount of food in sculpin stomachs at various seasons from the West Gallatin River.

December through February was designated as the winter season.

There were fewer empty stomachs and the quantity of food per stomach was greatest in the winter samples. The percentage of empty stomachs ranged from 4.0 percent in winter to 10.3 percent in summer and the average volume offood per stomach ranged from 0.06 ml. in spring to 0.17 ml. in winter.

An examination of 62 specimens collected when water temperatures were very low (32-33°F.) showed the average volume per stomach to be 0.25 ml. while the winter average was 0.17 ml. Only one stomach was empty and the average number of food items per stomach was 31.6, which is higher than the winter average of 25.9.

There were obvious variations in the kinds of food consumed. Snails were found only in the summer and fall collections. The number of stomachs containing stonefly nymphs was more than five times greater during the winter than in summer. Caddis fly larvae occurred in greatest numbers in fall collections and least in spring while Diptera were taken more often in spring and least in fall (Fig. 2). Tipulidae larvae were consumed during all seasons but were most important in the stomachs of large sculpins collected in the fall.

Distribution within Sections

Sculpins were abundant in riffle areas where rubble and boulders were predominant and wereusally absent from pools where the bottom was entirely sand or clay. They were numerous in the dense mats of white water-crowfoot in Prickley Pear Creek.

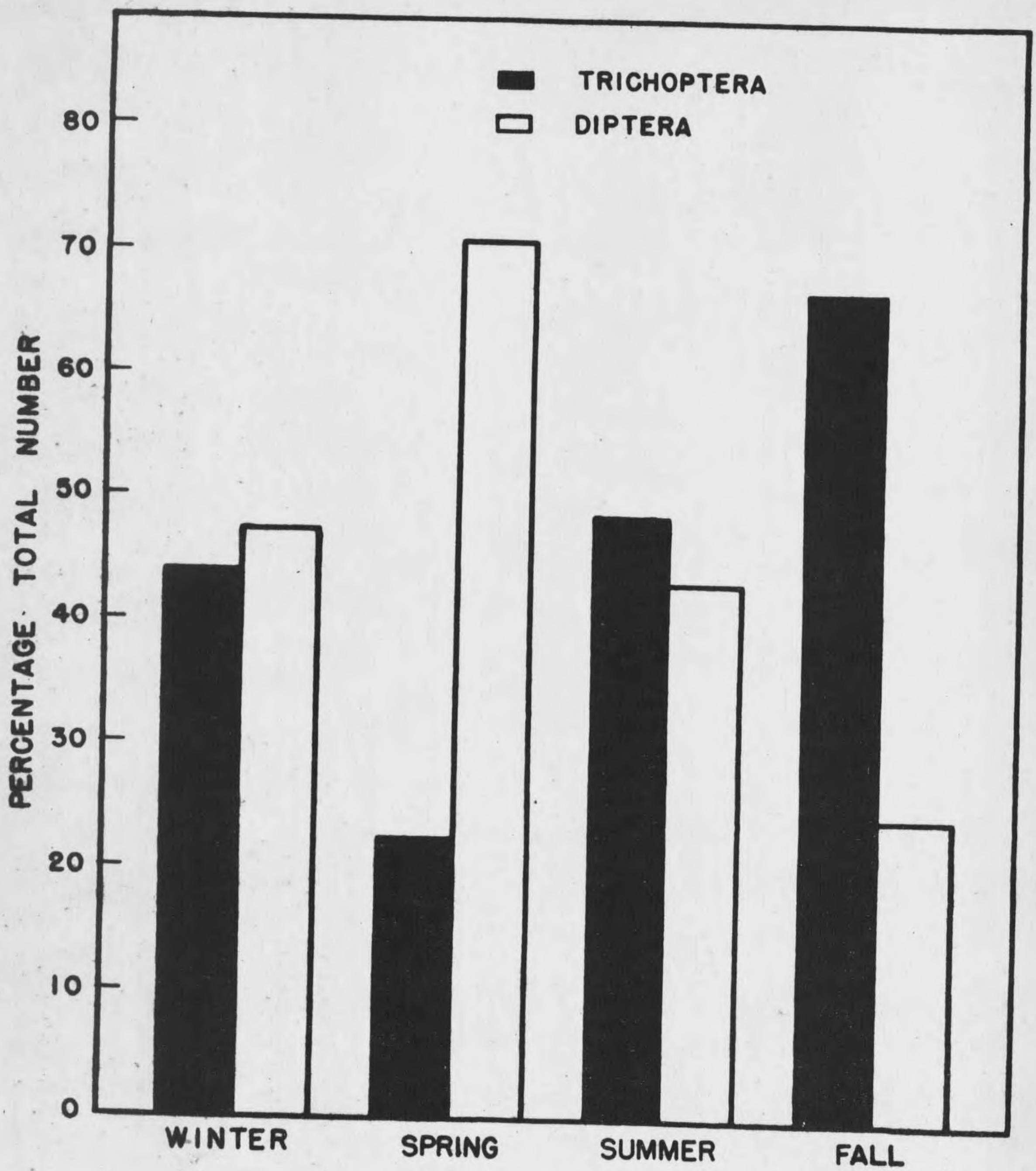

Fig. 2. Number of Trichoptera and Diptera at various seasons in stomachs of sculpins from the West Gallatin River.

Some small sculpins were observed to hide in the quiet water near shore by stirring up clouds of silt which settled and covered them. Larger individuals were found most commonly in rubble riffle areas where the water was more than 4 inches deep but some were present in the shallow quiet water near shore. Distribution was not noticeably affected by surface velocities because sculpins spend much of their time under gravel and rubble on the stream bottom. However, sculpins were scarce in areas where currents were slow enough to allow deposits of sand and silt, probably due to the absence of hiding places.

Movements in Prickley Pear Creek

A total of 75 sculpins (total lengths 50-140 mm.) captured with the assistance of an AC electric shocker were marked with serially numbered jaw tags and released in the same 600 foot section from which they were captured. In four successive shockings, 21 marked specimens (total lengths 70-140 mm.) were recovered (Table IV). Only one marked fish was captured more than once. This specimen was tagged June 30, 1950, and recaptured on August 15 and again on September 25 of the same year. Fifteen (71.4 percent) of the 21 sculpins recovered were within 150 feet of the point where first captured. The greatest distance which a recovered sculpin had moved from the point of release was 470 feet.

Spawning Season

The 1950 spawning season was not definitely established, but eyed eggs were collected in the West Gallatin River on June 17 and in

Table IV

Recoveries of tagged sculpins in Prickley Pear Creek

Date	Number tagged	Number recovered	Number of days between shockings
June 30, 1950	36		
August 15, 1950	39	9	46
September 25, 1950		6	41
November 24, 1950		3	60
June 17, 1951	—	3	205
Totals	75	21	352

Prickley Pear Creek on June 15. The 1951 spawning season in the West Gallatin River covered most of the month of June. On June 5, 1951, one spent female was found in a sample of 147 gravid females. The first two nests with eggs were found on June 9. One nest had 104 eggs and the other 148. First eyed eggs of the 1951 season were found on June 23. All eggs were eyed in the 14 nests located on July 6. The last females (four specimens) to contain numerous eggs were found on June 23. One collected June 30, 1951, had eight eggs.

Ricker (1934) gives the middle of May as the spawning period. Hann (1927) and Gage (1878) observed eggs in April, and Smith (1922) found them in April and May. Simon and Brown (1943) reported the spawning season of Cottus semiscaber as February 20 to May 26.

Males were ripe in advance of the females and some were still capable of producing milt after all females had deposited their eggs. Milt was obtained from males as early as March 25 in the 1950 season. In 1951, the first ripe males were found April 25. Females were also slower to begin ripening in 1951 than in 1950. The last ripe male of the 1951 season was found on August 31.

Afternoon water temperatures during the 1951 spawning season ranged from 46° to 55°F. Hann (1927) observed sculpins spawning in an aquarium at a temperature of 55°F. and reported stream temperatures of 41° to 61°F. during the spawning season.

Age and Size at First Spawning

Hann (1927) stated that sexual maturity was attained at two years of age when sculpins were 45-70 mm. standard length and that males were larger than females. In a sample of 390 females collected from the West Gallatin River during the period of May 27 to June 10, 1951, all individuals over 74 mm. total length were sexually mature (Table V). The smallest one which was sexually mature had a total length of 57 mm. Of 25 females collected during May and June, 7 were sexually immature and 2 years old, 9 were mature and of the same age, and 9 were mature and 3-5 years of age. Maturity of males was not easily determined from the appearance of the testis. The smallest male which produced milt by application of pressure to the abdomen had a total length of 70 mm. and was 2 years old.

Sexual Characteristics

Mature females in the gravid condition are easily recognized by their distended abdomens. Adult males have a prominent genital papilla (Hann 1927) which originates at the posterior margin of the anal fin. The

Table V

Number and percentage of mature female sculpins

Total length in mm.	Total fish observed	Number mature	Percentage mature
50 - 54	44	0	0.0
55 - 59	101	1	1.0
60 - 64	72	12	16.7
65 - 69	38	21	55.3
70 - 74	46	42	91.3
75 - 79	43	43	100.0
80 - 84	24	24	100.0
85 - 89	15	15	100.0
90 - 94	4	4	100.0
95 - 99	2	2	100.0
100 - 104	1	1	100.0

genital papilla can be seen without magnification on most preserved males as small as 60 mm. total length. The sex of 177 preserved sculpins (total lengths 57-113 mm.) was determined first by inspection for the presence or absence of the genital papilla and then verified by examination of the gonads. Sex was correctly determined by the use of the papilla in 96 percent of the specimens. This sample contained 89 males and 88 females. Hann (1927) stated that sex may be determined by the shape of the head in specimens three or more years of age--that of the male being broader. A comparison was made between the greatest head widths of 30 males and 15 females ranging in total length from 82 to 95 mm. The average width for the males was 23.9 mm. and for the females was 21.9. The accuracy of this method of determining sex was about 80 percent. Simon and Brown (1943) stated that in <u>Cottus semiscaber</u> the differences in coloration of the first dorsal fin could be used to separate the sexes. This characteristic was not diagnostic for <u>Cottus bairdii punctulatus</u>.

Development of Ovaries

Ovaries were obtained from 146 specimens collected at frequent intervals between January 21 and May 31, 1951, and December 26, 1950, to June 5, 1951. No samples were taken after fish began to spawn. Ovary volumes after preservation were determined to the nearest 0.01 ml. by alcohol displacement. The object of this study was to determine the stages of ripeness. Volumes of the ripening ovaries were influenced by the size of the female as well as by the state of ripeness. Ovary volumes had an approximate straight-line relationship to the cube of the total body length. Ripeness factors were calculated by dividing the ovary volumes by the cubes of the total body lengths. The resulting factors were arbitrarily multiplied by 10^8 to obtain more convenient figures. Average ripeness factors for each of the small samples were plotted on semilog graph paper. The resulting curves were drawn by inspection (Fig. 3). The average ripeness factor for the 1950 collections increased from 40.4 (January 21) to 209.7 (May 31). In the following year the factor increased from 22.8 (December 26, 1950) to 329.0 (June 5, 1951). The 1950 curve is not complete as no ovaries were measured in the period immediately before spawning.

Number of Eggs

Egg counts were made on 118 preserved females (57-95 mm. total length). The average number of eggs per female was 203. The minimum was 69 in a 57 mm. specimen and the maximum was 406 in a 94 mm. fish. Hann (1927) counted the eggs from nine females which were 51 to 71 mm. standard

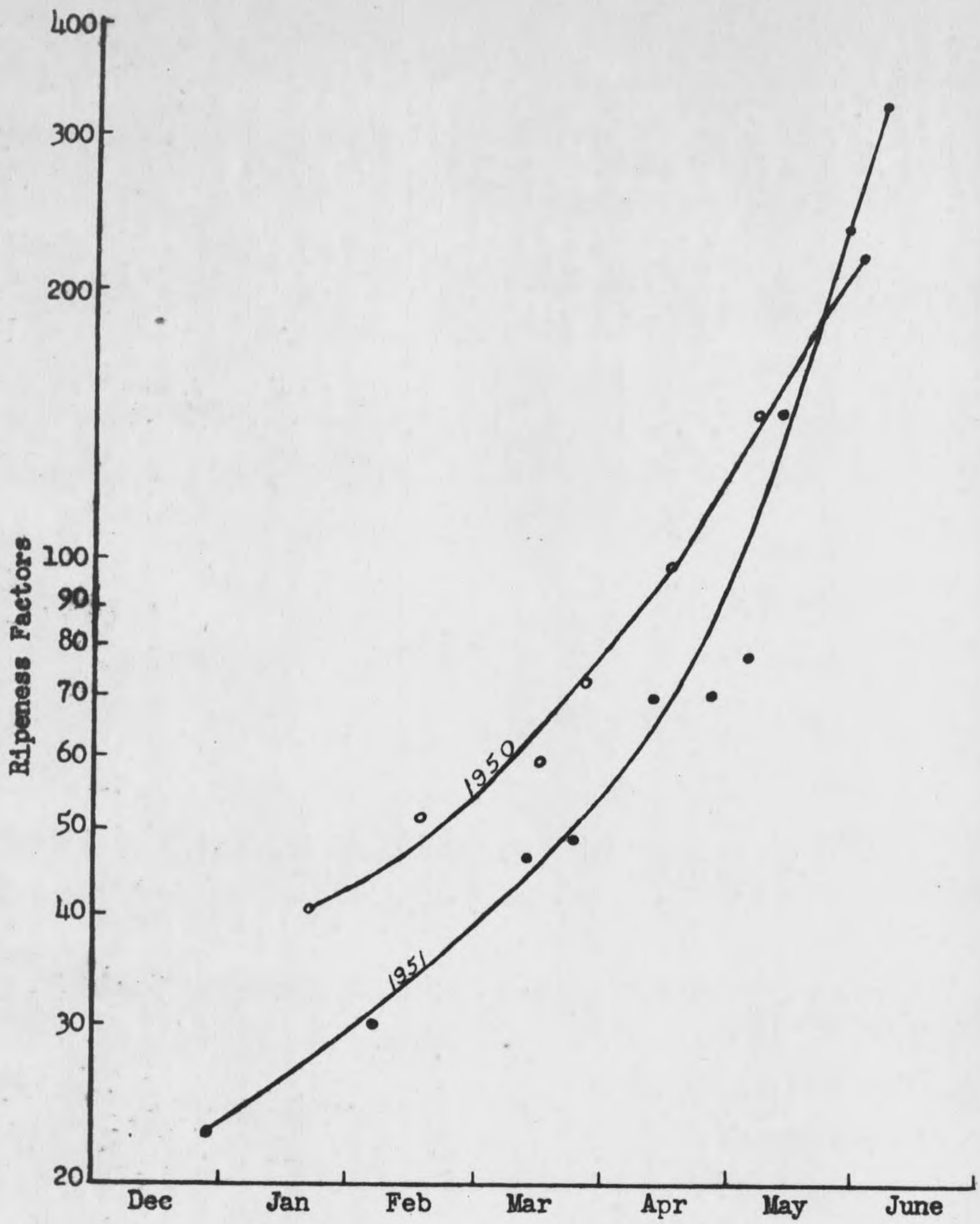

Fig. 3. Average ripeness factors for 146 female sculpins

length. These ranged from 120 to 395 eggs per female with an average of 257. Simon and Brown (1943) found an average of 629 eggs per female (Cottus semiscaber).

Preparation and Distribution of Nests

The nests consisted of holes under rocks or other suitable objects. Preparation of nests was not observed but was presumed to have been done by the males (Hann 1927). There was a greater abundance of adult males in the deeper areas where the first nests were found. Adult females were most abundant in shallow water near shore at that time. In a sample of 12 specimens taken May 27, 1951, from water less than 18 inches deep, the ratio of males to females was 1:5. On June 5 a collection of 30 specimens from the same area showed a ratio of 1:9. In water more than 18 inches deep, 22 adults collected June 5 showed a ratio of 1:0.7. On June 10 females were caught near shore in shallow water, while males were found only in deep water. This segregation of sexes was not noticeable during any other season of the year. The first eggs deposited were found in water over one foot deep.

The rocks under which nests were prepared varied in diameters from about 5 to 15 inches. Egg clusters were sometimes attached to materials other than rocks. Hann (1927) reported the use of aquatic vegetation, C. J. D. Brown found clusters on a piece of submerged wood in the Madison River, Montana, and the writer observed eggs on a rusty piece of sheet iron in Prickley Pear Creek.

Surface velocities over nests varied from 0.0 to 4.6 feet per second.

Simon and Brown (1943) found nests in areas where currents varied from rapid to almost non-existent. Most nests were originally located in areas where surface velocities were high but which became much reduced as water levels dropped. Observations indicated rather gentle water movements within the nests but limitations of available equipment prevented accurate determinations.

Description of Eggs and Egg Clusters

The size of eggs was determined from preserved materials. Such measurements, although they may not give a true picture of size, are useful in comparing egg diameters of different individuals and at different times. Diameters were secured by counting the eggs which would lie side by side on a millimeter linear scale. Eggs from 48 females collected from the West Gallatin River in 1951 varied from 1.3 mm. in diameter in April to 2.2 mm. by June 5. Eggs collected from 11 nests had diameters of 2.5 to 2.9 mm. Simon and Brown (1943) found that eggs from females ready to spawn had a diameter of 2.2 mm. and eggs from nests averaged 2.47 mm. in diameter.

Egg colors ranged from pale yellow to orange-yellow. However, all eggs from a single individual were the same color (Hann 1927). The eggs became progressively darker as the embryos developed. The larger egg clusters were usually composed of small component clusters (Fig. 4) in which the eggs often differed in size, color, and stage of development (Smith 1922).

The number of eggs from twelve nests, collected June 21-July 5, 1951,

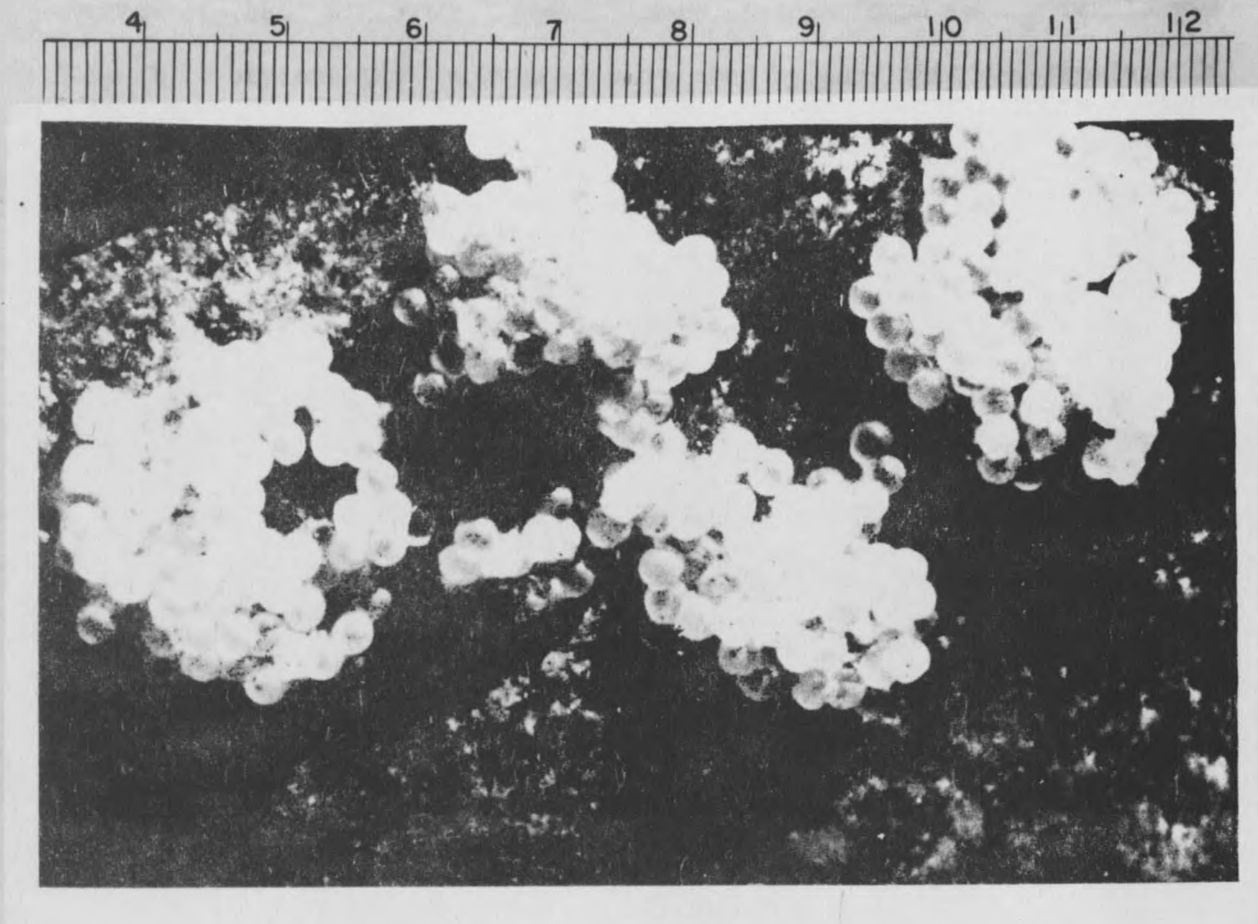

Fig. 4. Sculpin eggs attached to under surface of rock.

Scale graduated in mm.

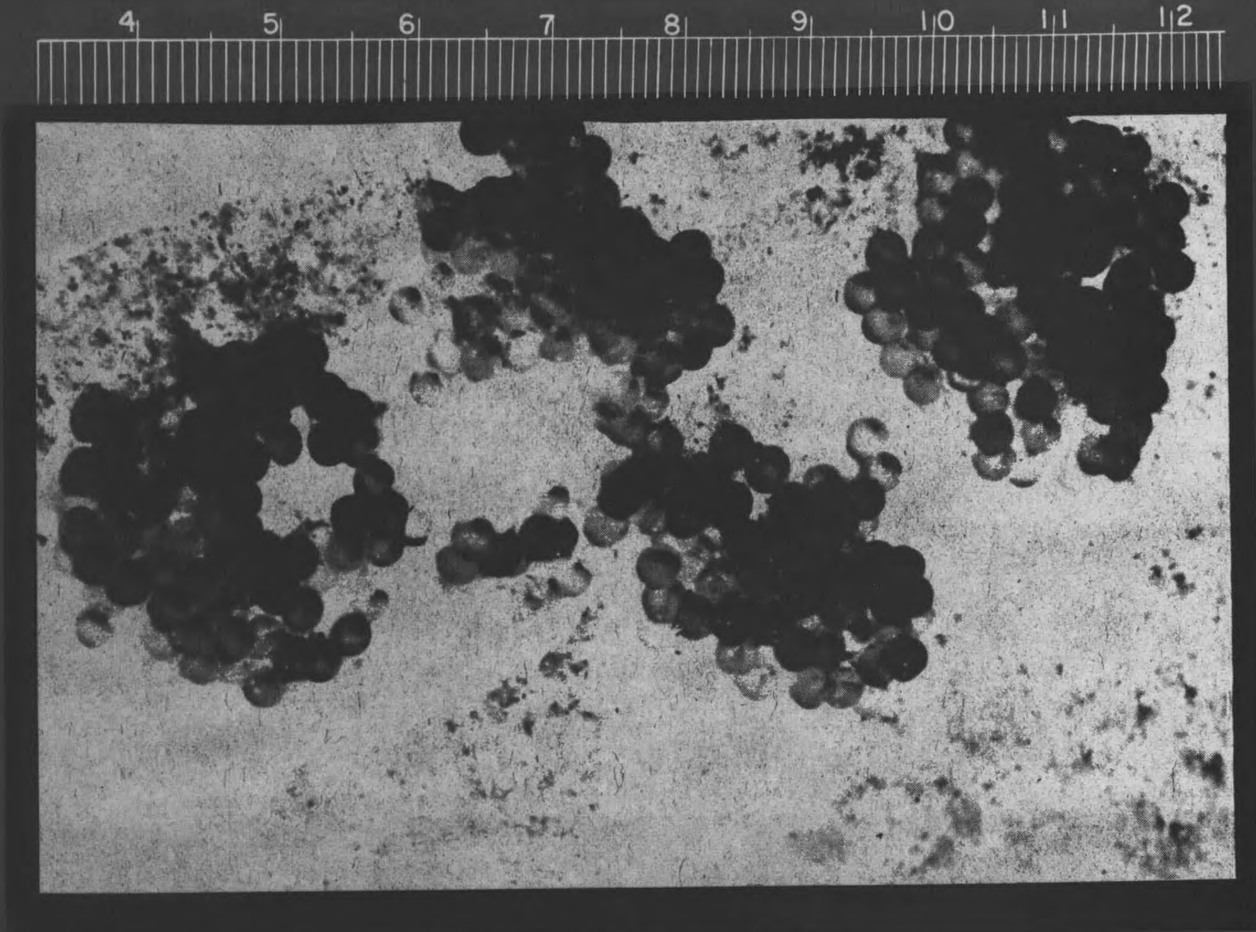

Fig. 4. Sculpin eggs attached to under surface of rock.
Scale graduated in mm.

from the West Gallatin River, ranged from 54 to 1587 eggs per nest with an average of 744. Since the largest number of eggs found in any female was 406, it is obvious that many nests were used by more than one female. In Prickley Pear Creek the largest number of eggs found in any female was 437 and the maximum number in any nest was 1884.

Incubation Period

On the basis of 1951 spawning dates (June 5-30) and hatching dates (July 3-21), the incubation period in the West Gallatin River was 21-28 days. Afternoon water temperatures during this period ranged from 46 to 63°F.

Eggs taken artificially and fertilized with sperm from macerated testes were placed on hatching trays in water at a temperature of 48-50°F. Hatching began 30 days after fertilization but was not complete until 10 days later. These eggs became heavily fungused and were given frequent treatments with copper sulfate. Hann (1927) found that eggs, taken artificially, hatched in twenty days at temperatures of 55 to 59°F.

Care of Nests

It was observed that an adult sculpin was present in almost every nest found. Sculpins captured from 11 nests in Wolf Creek and 5 nests in the West Gallatin River were all males. Smith (1922) observed that almost all nests had guardians and caught four which were males. Hann (1927) stated that the male guards the nest while the eggs are incubating. On the basis of observations made to date, however, the writer does not believe that males actually guard the nests, and prefers to refer to them as attendants rather than guardians. Simon and Brown (1943) observed that the nests were rarely unaccompanied by the male fish. Females were found in nests only during the spawning season and were usually accompanied by the male. Three West Gallatin River nests were visited twice weekly during the incubation period. The attendant parents were not observed on every occasion but it was evident that attendance was continued until hatching was nearly complete.

Attendant males apparently served to keep the nests clean. Nests were remarkably free of silt, debris, and aquatic organisms which would otherwise be expected to accumulate. Very few fungused eggs were found in the nests. The presence of seven fungused eggs in the stomach of an attendant male might indicate that such eggs are sorted from the clusters.

Stranded Nests

No eggs were observed to be left above the receding water level in Prickley Pear Creek, but 14 West Gallatin River nests were found stranded above the water level in 1951. Hann (1927) found no nests left above changing water levels and Gage (1878) felt that the fish had forethought as the eggs were never laid above the low water mark of July.

Age and Growth

Sac Fry

All sculpins used in the aging studies were from the West Gallatin River.

Egg clusters were incubated in hatchery troughs. Fry were held at temperatures of 51-56°F. until their yolk sacs were completely absorbed. Total length measurements of fry were made on preserved specimens. Fry ranged from 5.8 to 8.1 mm. and averaged 7.1 mm. on their first day of life (Table VI). Hann (1927) reported the standard length to be about 6.4 mm. at the time of hatching, and Simon and Brown (1943) found the average total length of artificially hatched fry was 6.9 mm. On the 14th day the yolk sacs were completely absorbed and total lengths ranged from 9.0 to 9.9 mm. with an average of 9.5 mm. After the yolk sac was absorbed, young sculpins closely resembled their parents except for size.

Table VI

Total lengths of hatchery incubated sculpin fry

Age (days)	Total lengths (in mm.)			Number of specimens
	Minimum	Maximum	Average	
1	5.8	8.1	7.1	43
2	6.9	8.0	7.6	3
4	8.4	9.1	8.7	3
7	7.7	9.5	8.8	3
9	8.8	9.0	8.9	3
14	9.0	9.9	9.5	3

Young Sculpins

Juvenile sculpins up to about 14 months of age could usually be distinguished from other age classes on the basis of size. Average total lengths of preserved young sculpins increased from 7.8 mm. on July 16, 1951, to 19.5 mm. on August 31.

The average total length of 110 specimens collected in October 1950 was 31.4 mm. (Table VII) and the average total length of 54 yearlings collected in May 1951 was 32.5 mm. This would indicate very slow growth during the winter months. From June to the end of August, the average total lengths increased from 35.9 mm. (245 specimens) to 52.9 mm. (7 specimens).

Table VII

Total lengths of juvenile sculpins collected from West Gallatin River

Date of collection	Number of specimens	Total lengths (in mm.)		
		Minimum	Maximum	Average
October	110	23	41	31.4
December	55	23	41	29.0
February	14	22	34	29.4
March	14	21	34	28.4
April	17	27	39	30.9
May	54	25	41	32.5
June	245	26	51	35.9
July	13	38	53	45.5
August	7	48	60	52.9

Older Sculpins

Otoliths were taken from 151 fresh specimens. These were stored in 95 percent alcohol and then examined by the use of reflected light (magnifications 9X-36X) while immersed in oil of cloves. Narrow translucent rings alternating with wider opaque zones were visible. The white opaque zones were presumed to represent summer growth while the translucent rings represent winter marks or annuli. The core of each otolith was generally opaque white surrounded by a somewhat translucent band. The area immediately outside the core was an opaque zone representing the first summer's growth.

Ages were determined from the otoliths of specimens collected a few at a time from February 25, 1950, to August 5, 1951. Total length measurements were made on fresh fish before the removal of otoliths. The smallest sculpins from which otoliths were taken (total lengths 22-34 mm.) were collected February 6, 1951. These had only one annulus and this was located on the outer edge of the otoliths (Table VIII). The largest specimen from which otoliths were taken, was a 119 mm. male collected November 11, 1950. It had four annuli. Three specimens had five annuli. Two were females (total lengths 93 and 94 mm.), and one was a male (total length 110 mm.). Average total lengths in mm. for the five age groups ranged as follows: I - 29.6-56.7; II - 64.4-79.3; III - 80.5-98.0; IV - 84.0-118.5; and V - 93.0-110.0.

Table VIII

Average total lengths of each age group of sculpins collected in West Gallatin River. (Lengths in mm., number of specimens in parentheses.)

Number of annuli	February	March	May	June	July	August	September	November
I	(14) 29.6	(1) 31.0	(16) 31.7	(6) 33.3	(3) 40.7	(6) 51.5	(3) 56.7	...
II	(6) 69.2	(5) 67.6	(11) 64.4	(17) 67.5	(4) 70.2	...	(3) 79.3	...
III	(8) 80.5	(8) 81.2	(3) 83.0	(7) 80.9	(2) 87.5	...	(1) 98.0	...
IV	(4) 102.2	(9) 98.7	(8) 96.9	(1) 84.0	...	...	...	(2) 118.5
V	(1) 94.0	...	...	(1) 93.0	...	...	...	(1) 110.0

Sex was determined for 112 specimens and average total lengths of males and females were compared in each age class (Table IX). The males were consistently larger than the females (Hann 1927 and Simon and Brown 1943).

Table IX

Number and average total lengths of males and females in each age group

Number of annuli	Number of males	Average total length (in mm.)	Number of females	Average total length (in mm.)
I	5	57.0	2	48.5
II	20	70.7	29	66.1
III	10	83.1	19	81.6
IV	17	103.7	7	90.0
V	1	110.0	2	93.5

Length-frequency Distribution

A length-frequency study was made on 1681 specimens collected on the following dates: 503, June 3; 288, October 28, 1950; 899, June 5, 1951, A length interval of 2 mm. was used in preparing the frequency polygon (Fig. 5). Age group I showed a mode at 39.5 mm. in the June 3 collection and at 61.5 in the October sample. The mode at 31.5 mm. in the October polygon represents sculpins hatched during the summer of 1950. The peak of the first mode in the June 5, 1951, collection was at 35.5 mm.

Fish two years old and older did not show clearly defined modes in any of the collections. However, a comparison of the June 3, 1950, length-frequency polygon with the mean total lengths of June specimens aged by otoliths (Table VIII) indicated satisfactory agreement between

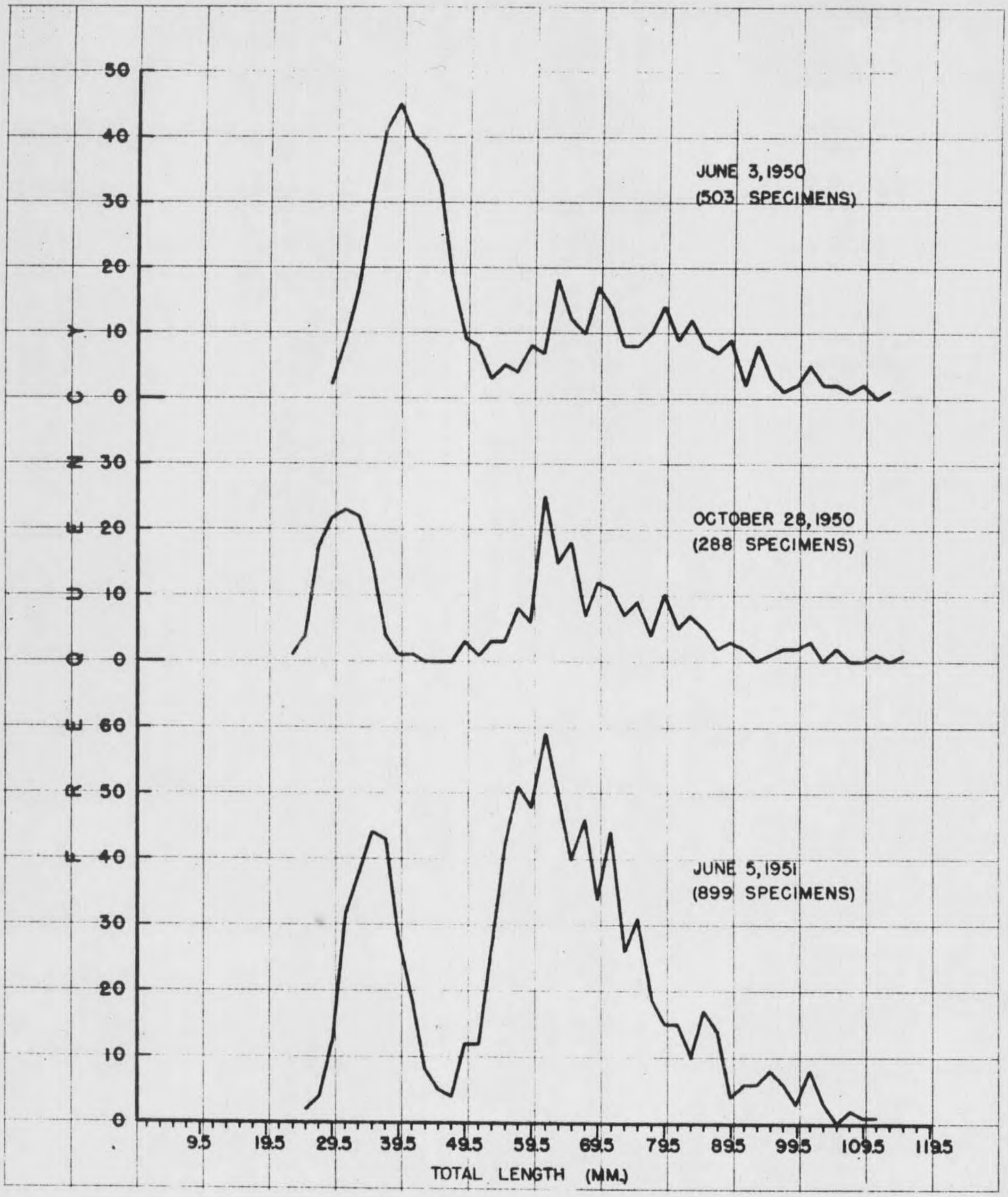

Fig. 5. Length-frequency of three collections of sculpins from the West Gallatin River.

the two methods.

Maximum Growth

The largest sculpins obtained for this study were collected by William D. Clotheir in irrigation canals which originate in the West Gallatin River. One male had a total length of 140 mm. after preservation and a female measured 124 mm. The largest sculpin found in Prickley Pear Creek was a male 139 mm. in total length. The largest sculpin reported by Hann (1927) was a male with a standard length of 113 mm.

Length-weight relationship

The relationship between fresh total lengths and weights for the sexes combined was obtained for 206 West Gallatin River sculpins collected as follows: 179 specimens October 28, 1950; 3, November 9, 1950; 19, July 3, 1951; and 7, August 5, 1951. The weight-length data were fitted to the equation $W=CL^n$ where W = weight in grams, C = a constant, and L = length in mm. The resulting equation expressed in logarithmic form was $\log W = \bar{5}.202 + 3.16(\log L)$. A calculated length-weight curve was prepared which satisfactorily fitted the average length-weight values computed for 5 mm. class intervals except for specimens over 109 mm. total length. This discrepancy may be explained by the fact that only five fish larger than 109 mm. were available for the calculations.

Relationship between total length and standard length

The relationship between total lengths and standard lengths of preserved sculpins was determined for 147 (total lengths 10-124 mm.) specimens selected to give nearly equal representation to all sizes. The equation representing the least-squares line of relationship was $Y = -1.032 + 0.827X$ where Y = standard length in mm. and X = total length in mm.

Summary

1. An analysis of 903 sculpin stomachs showed that bottom-dwelling aquatic insects comprised 99.7 percent of the total number of food organisms consumed.

2. Diptera larvae and pupae constituted 55.5 percent of the total number of food organisms consumed, caddis fly larvae and pupae, 36.7 percent; mayfly nymphs, 3.8 percent; stonefly nymphs, 2.1 percent; unidentifiable insects, 1.6 percent; fish and fish eggs, 0.1 percent; all others, 0.2 percent.

3. Caddis flies were consumed in greatest numbers during fall and least in spring while Diptera were taken most in spring and least in fall.

4. The maximum amount of food per stomach occurred during the winter months (temperatures 32-33°F.) while the minimum was found in the summer.

5. Sculpins were most abundant in riffle areas where rubble and boulders predominated and least abundant where the bottom was entirely sand or clay.

6. Twenty-one marked sculpins from a total of 75 released in Prickley

Pear Creek were recaptured within 470 feet of the point of release.

7. The 1951 spawning season was from June 5 to 30 and hatching occurred from July 3 to 21, indicating an incubation period of 21-28 days.

8. Sexual maturity was attained by some individuals at the age of two years. All females over 74 mm. total length were sexually mature.

9. An attempt was made to determine sex by such external characters as: distended abdomens of females, genital papilla of males, and head widths, and these methods of sex determination were verified by examination of the gonads.

10. Development of ovaries was determined by calculating ripeness factors based on the ovary volume and the cube of the total length of the fish.

11. The number of eggs per female averaged 203 and ranged from 69 to 406. The number of eggs per nest ranged from 54 to 1587 and averaged 744, indicating that many nests were used by more than one female.

12. The nests, which were merely holes under rocks or other suitable materials, were prepared and attended by the males.

13. Total lengths of fry one day old or less ranged from 5.8 to 8.1 mm. and yolk sacs were completely absorbed after two weeks when lengths ranged from 9.0 to 9.9 mm.

14. Average total lengths of young sculpins increased from 7.8 mm. in July to 31.4 mm. in October. The same age group averaged 32.6 mm. in the following May, and 52.9 mm. in August.

15. As a result of otoliths studies on 151 specimens, average total lengths of five age groups were as follows: age group I, 29.6-56.7 mm.;

II, 64.4-79.3 mm.; III, 80.5-98.0 mm.; IV, 84.0-118.5 mm.; V, 93.0-110.0 mm.

16. Length-frequency data in general agreed with growth data based on otolith studies.

17. The length-weight relationship for 206 sculpins was expressed by the equation $\log W = \bar{5}.202 + 3.16(\log L)$.

18. The equation $Y = -1.032 + 0.827X$ represents the relationship between total length (X) and standard length (Y) of 147 preserved specimens.

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