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FOOD INTERRELATIONSHIPS OF THE MOTTLED SCULPIN, *COTTUS BAIRDI*, AND JUVENILES OF THE RAINBOW TROUT, *SALMO GAIRDNERI*, IN A TRIBUTARY OF LAKE SUPERIOR [1]

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ABSTRACT

Young rainbow trout and sculpins occupy similar habitat in many Michigan streams, and thus may compete for available food. To examine this possibility, I investigated the production and food habits of coexisting populations of the mottled sculpin and juveniles of the rainbow trout, in relation to the standing crop of bottom fauna in a small tributary of Lake Superior. Production of age-0 and age-I rainbow trout from June to August 1970 was 2.8 g/m^2. Mottled sculpins, of ages I and II, produced 1.5 g/m^2 during the same period. The bottom fauna was composed mostly of Tendipedidae, Hydropsychidae, Rhyacophilidae, Limnephilidae, Baetidae and Gastropoda. The mean standing crop of bottom fauna was 9.4 g/m^2. The rainbow trout and the mottled sculpin had similar diets; bottom organisms were eaten in approximate proportion to their abundance in the stream. No mutual predation occurred between the two fishes. The low total food consumption of 1.9 times the mean standing crop of benthos indicated that detrimental food competition probably did not occur between rainbow trout and mottled sculpins.

INTRODUCTION

Many Michigan tributaries of Lake Superior are nursery streams that support substantial populations of juveniles of the rainbow trout (Salmo gairdneri). Most of these streams also contain large populations of sculpins (Cottus bairdi and/or C. cognatus). During the first 1 to 3 years of life, young rainbow trout are in close association with sculpins. Thus, trout and sculpins may compete for available food and may even prey upon each other.

Prior investigations of food interrelationships have been done on various species of salmonids and cottids. However, to my knowledge, none has been done on the rainbow trout and mottled sculpin (C. bairdi) combination. Dineen (1951) found that the brook trout (Salvelinus fontinalis), brown trout (Salmo trutta), and mottled sculpin eat the same food. But he, as did Koster (1939), contended that food competition was lessened by the fact that trout feed in all planes of the water from top to bottom, whereas sculpins are essentially bottom feeders. Brocksen, Davis, and Warren (1968) concluded that the reticulate sculpin (C. perplexus) could influence the food consumption and production of the cutthroat trout (Salmo clarki) by cropping the benthic food supply. They concluded that this reduced the supply of drift organisms (which are important to trout, Hunt, 1965), as well as the benthos of the substrate.

The evidence regarding sculpin predation on juvenile trout and salmon is conflicting. Koster (1939) and Patten (1962, 1971) concluded that trout and salmon fry make up only a negligible portion of the diet of several species of sculpins. Conversely, significant predation by the reticulate sculpin on rainbow trout sac fry (Phillips and Claire, 1966) and by slimy sculpins (C. cognatus) on brown trout sac fry (Clary, 1972) has been demonstrated in aquaria. Juvenile rainbow trout in streams reportedly do not prey upon fish (McAfee, 1966).

To provide information on food interrelationships of populations of the rainbow trout and mottled sculpin coexisting in one stream system, I investigated their food habits and production in relation to the standing crop of bottom fauna.

STUDY SITE

This study was conducted on the Little Garlic River, a rainbow trout nursery stream tributary to Lake Superior in Marquette County, Michigan. Field data were collected during 10-13 June, 8-9 July, and 5-7 August 1970, from a 300-m long stream section some 2 km upstream from the river mouth.

The Little Garlic River flows for most of its length through rugged terrain characterized by steep hills forested mainly with mature hardwoods and some conifers. However, the study site was in that portion of the stream which flowed through an area of relatively low relief. The stream banks were lined with alder (Alnus), aspen (Populus), and willow (Salix). Emergent vegetation was lacking in the study section. Submerged vegetation consisted of green and blue-green filamentous algae that sparsely covered the stream bottom.

The stream bottom in the study section was estimated to be 47% rubble, 35% gravel, and 18% sand. Seventy per cent was riffle area, while pools made up the remaining 30%. Between June and August, the stream became narrow and shallow because of receding water levels. Mean width decreased from 6.5 to 4.8 m, mean depth from 26 to 17 cm, mean volume of flow from 0.4 to 0.1 m^3/sec, and the area of submersed bottom from 1,950 m^2 in June, to 1,770 m^2 in July, and 1,440 m^2 in August.

Conductivity was 153 μmho/cm^3 in August at 18 C. Mean water temperature increased from 13 C in June to 18 C in August.

In the study section, age-0 and age-I rainbow trout and mottled sculpins were abundant, and adults of the longnose dace (*Rhinichthys cataractae*) were common. Rare species included the brook trout, young (age-0) coho salmon (*Oncorhynchus kisutch*), age-II and older rainbow trout, and the mottled sculpin. Young-of-the-year of the rainbow trout and of the mottled sculpin began to emerge in early June. The other age groups of these two species were present during the entire study.

Aquatic insect nymphs and larvae, snails, and oligochaetes were abundant in the stream substrate.

METHODS

Fish Populations and Production

Population estimates of age-0 (August only) and age-I rainbow trout and of age-I and age-II mottled sculpins were made in June, July, and August using the methods described by Shetter (1957). The fish were captured, marked by excising part of a fin, released on one day, and recaptured the following day to determine the ratio of marked to unmarked fish. Calculations followed those of Bailey (1951). All fish captured for the population estimates were measured to the nearest millimeter, total length. Ten fish from each 10-mm length group were weighed to the nearest 0.1 g to obtain average weights of the age groups for calculating production.

Two random samples of unmarked rainbow trout and mottled sculpins were preserved in 10% formalin for determining age and growth and food habits--35 rainbow trout and 53 mottled sculpins in June, and 78 rainbow trout and 54 mottled sculpins in August. These preserved fish were measured to the nearest millimeter, total length, and weighed to 0.1 g. Scales were removed from the rainbow trout at an area between the origin of the dorsal fin and the lateral line, and otoliths were excised from the mottled sculpin for age assessment. Otoliths, cleared in hot xylene (Larsen and Skud, 1960), and scales, impressed on plastic slides, were enlarged with a microprojector to a magnification of 107X to determine the age of the fishes (Lagler, 1956).

Production of fish flesh was determined graphically by plotting standing crops of rainbow trout and mottled sculpins in numbers on the ordinate and corresponding mean weights on the abscissa (Allen, 1951; Chapman, 1965). Areas under the resulting production curves were measured for the period 11 June to 6 August 1970. Estimated production of age-0 rainbow trout was low because the August population estimate was used as the estimate (minimal) of their numbers in June and July.

Bottom Fauna

Ten randomly selected samples of benthos (Hildebrand, 1971) were collected on 12 and 13 June, and ten more were collected on 6 and 7 August, with a 0.1-m^2 modified Hess sampler having size-30 mesh netting (Waters and Knapp, 1961). In collecting, the sampler was set on the sample site and forced into the substrate as deeply as possible. Large rocks within the sample site were individually cleaned of fauna. Fine substrate was sifted by hand, causing the fauna to drift into the mesh bag of the sampler.

The organisms were preserved in 40% isopropyl alcohol. The sugar flotation method of separating fauna from inadvertently collected substrate and debris (Anderson, 1959) was attempted, but filamentous algae hampered the technique. Manual sorting of the bottom samples proved most feasible. Identification of the organisms followed Pennak (1953), with individuals being sorted into the appropriate taxonomic group and counted.

To get standing crop, average weights of individuals in each taxon were calculated for the two sampling periods in the following manner. Four bottom fauna samples were randomly selected from each of the two sets of 10 bottom samples collected in June and August. A known number of individuals in each taxon were centrifuged for 2 minutes at 2500 rpm and weighed to 0.001 g. Trichoptera were weighed without cases. An average weight for individuals in each taxon was calculated. This average was used to calculate the weight of each taxon present in the stream, and the weight of food at the time of ingestion.

Fish Food Habits

Stomach contents of the preserved rainbow trout and mottled sculpins were identified mostly to family (Pennak, 1953; Ross, 1965), sorted into appropriate taxonomic groups, and counted. A three-way analysis of variance (Freund, 1952) was used to detect any differences between food habits of juvenile rainbow trout and mottled sculpins. I tested the hypothesis that there was no difference between the diets of the two fishes. Sources of variation were the sampling dates, six food categories (classes and orders) with families as replicates, and the two fish species.

Fish Food Consumption

Total food consumption during my study was calculated by summing the daily maintenance and the growth ration. The maintenance and growth factors were adapted from other investigations. Allen (1951) and Hopkins (1970) used a daily maintenance ration for brown trout of 1.2% of the standing crop of fish and a growth ration of 4.2 times brown trout production. Bonham (1949) found the growth ration for rainbow trout to be three times rainbow trout production. For purposes of this study, I used 1.2% of the average standing crop of the rainbow trout and of the mottled sculpin as the daily maintenance ration for each, and three times the production of these fishes as the growth ration.

Stream Measurements

Stream width in meters, depth in centimeters, and rate of current flow in meters per second (No. 622 Gurley current meter) were measured at each randomly selected bottom sampling site. Also, the substrate was classified as rubble, gravel or sand, and the area of each type was estimated as per cent of the total area.

RESULTS

Fish Populations and Production

Several changes occurred during the study in the populations of rainbow trout and mottled sculpin (Table 1). Young-of-the-year rainbow trout were just beginning to emerge from their redds in June; by August all had emerged and their population amounted to 2,845 individuals. Numbers of age-I rainbow trout were similar in June and July, but had decreased significantly by August. This was probably due to downstream, lakeward migration (Stauffer, 1972). Age-0 rainbow trout nearly doubled their length, and increased their weight five-fold during the study. Growth of age-I rainbow trout was apparently slower; their length increased by only 19%, and their weight by only 70%. This growth was very likely minimal for the original rainbow trout population because larger individuals of a year class have a greater tendency to migrate downstream than do smaller fish (Shapovalov and Taft, 1954). Biomass production of the rainbow trout during the study was approximately 2.4 kg for each of the two age groups (Table 2).

Only a few very small young-of-the-year mottled sculpins were observed in June, whereas many were present in July and August, but they were too small for me to estimate their numbers. Although the point estimates for mottled sculpins differed among the three monthly population estimates within both age groups I and II, the 95% confidence limits overlapped widely (Table 1). This indicated that there was no significant change in numbers within the two age groups. During the course

Table 1.--Estimated numbers of rainbow trout and mottled sculpin, and their mean length and weight, in the Little Garlic River, June-August 1970

Species, age and month	Population estimate and 95% confidence limits	Density (m^2)	Biomass (g/m^2)	Mean length (mm)	Mean weight (g)
Rainbow trout					
Age 0					
June[1]	2,845	1.5	0.3	23	0.2
July[1]	2,845	1.6	0.7	35	0.4
August	2,845 ± 320	2.0	2.0	44	1.0
Age I					
June	724 ± 206	0.4	2.6	91	6.9
July	464 ± 112	0.3	2.6	99	9.7
August	263 ± 45	0.2	2.1	108	11.7
Mottled sculpin					
Age I					
June	1,930 ± 624	0.9	1.6	49	1.6
July	2,879 ± 955	1.6	3.3	55	2.0
August	1,770 ± 440	1.2	3.2	61	2.6
Age II					
June	70 ± 74	<0.1	0.4	92	10.9
July	26 ± 16	<0.1	0.2	93	12.3
August	24 ± 29	<0.1	0.2	95	13.1

[1] These values were derived from a sample of young-of-the-year in June and July, and the August population estimate.

Table 2.--Mean standing crop, production, and food consumption by rainbow trout and mottled sculpin in the Little Garlic River, June-August 1970

Species and age	Mean standing crop		Production		Food consumption	
	g	g/m^2	g	g/m^2/day	g	g/m^2/day
Rainbow trout						
Age 0	1,517	0.9	2,292	0.02	7,914	0.1
Age I	4,191	2.5	2,480	0.03	10,307	0.1
Total	5,708	3.4	4,772	0.05	18,221	0.2
Mottled sculpins						
Age I	4,483	2.6	2,460	0.03	10,446	0.1
Age II	466	0.3	80	<0.01	559	<0.1
Total	4,948	2.9	2,540	0.03	11,005	0.1

of the study, age-I mottled sculpins increased in length by 24% and in weight by 62%, while age-II mottled sculpins increased their length by only 3% and their weight by 20%. Biomass production of mottled sculpin from June to August was 2.5 kg for age-I fish and 80 g for age-II fish (Table 2).

Bottom Fauna

Thirty-five taxa were found in the bottom samples. The most abundant groups were Tendipedidae, Hydropsychidae, Limnephilidae, Rhyacophilidae, Baetidae and Gastropoda. These taxa made up 82% of the total number of organisms and 83% of the total weight (Table 3). A comparison of the mean number of principal invertebrates (± 2 S.E.) found in bottom samples revealed that there was little change in species composition between June and August (Table 4). The main exception was gastropods which were rarely found in June, but were abundant in August. Bottom fauna biomass at 16.1 kg (8.2 g/m^2) in June changed little, to 15.3 kg (10.7 g/m^2) in August.

Food Habits

Both rainbow trout and sculpins fed primarily on immature invertebrates, although rainbow ate a few adult insects. An analysis of variance of the total diets of the rainbow trout and the mottled sculpin showed that there was no significant difference between their diets (Table 5). All observed values of F for sources of variation and their interactions were non-significant.

As shown above, neither the bottom fauna nor food habits of trout and sculpins were greatly different between June and August. Hence, the data were combined in Table 3 to examine the possibility of food selectivity. Number and weight of bottom organisms eaten by the two species of fishes usually were in approximate proportion to

Table 3.--Percentages of total number and weight of organisms found in bottom samples and in the stomachs of rainbow trout and mottled sculpin, Little Garlic River, June and August 1970

Taxa	Percentage of total number in			Percentage of total weight in		
	Bottom samples	Rainbow trout	Mottled sculpins	Bottom samples	Rainbow trout	Mottled sculpins
Diptera						
Tendipedidae	49.2	37.2	47.1	4.4	5.8	4.2
Other	5.6	10.0	7.4	1.8	6.4	3.8
Trichoptera						
Hydropsychidae	6.7	4.7	14.7	62.5	32.1	55.0
Limnephilidae	3.5	1.8	2.2	2.6	1.0	1.7
Rhyacophilidae	3.8	0.5	0.0	6.0	3.8	0.0
Other	3.1	2.4	5.4	1.8	2.8	5.5
Ephemeroptera						
Baetidae	13.6	28.3	8.0	5.8	24.5	3.2
Other	2.3	1.2	4.2	1.9	1.4	6.7
Other insecta	6.1	5.6	2.9	9.5	10.0	8.0
Gastropoda	4.5	7.0	6.4	1.5	7.2	5.9
Oligochaeta	1.6	1.3	1.7	2.2	5.0	6.0

Table 4.--Mean number of the principal food items in ten bottom samples each month and in stomachs of rainbow trout and mottled sculpin, ± 2 standard errors, Little Garlic River, June and August 1970

Taxa	June			August		
	Bottom samples	Rainbow trout	Mottled sculpin	Bottom samples	Rainbow trout	Mottled sculpin
Diptera						
Tendipedidae	344 ±114	5.0 ±2.0	1.0 ±0.4	207 ±152	4.0 ±1.5	1.5 ±0.9
Trichoptera						
Hydropsychidae	20 ±10	1.0 ±0.4	0.6 ±0.2	69 ±99	0.2 ±0.2	0.3 ±0.2
Limnephilidae	26 ±12	0.1 ±0.1	0.1 ±0.1	14 ± 6	0.2 ±0.2	0.1 ±0.1
Rhycacophilidae	7 ± 4	0.2 ±0.0	0.0	57 ±41	0.0	0.0
Ephemeroptera						
Baetidae	100 ±37	9.0 ±6.0	0.3 ±0.2	52 ±22	0.4 ±0.3	0.1 ±0.1
Gastropoda	0.4 ±0.8	0.0	0.1 ±0.1	50 ±64	1.0 ±1.0	0.4 ±0.2

Table 5.--Analysis of variance of the total diet of rainbow trout and mottled sculpin in the Little Garlic River, June and August 1970

Source of variation	Degrees of freedom	Sums of squares	Mean square	F Observed	F Expected[1]
Months	1	2.14	2.14	0.72	4.35
Food groups[2]	5	19.38	3.88	1.32	2.71
Fish species	1	5.28	5.28	1.79	4.35
Months X orders	5	9.76	1.95	0.66	2.71
Months X species	1	5.36	5.36	1.82	4.35
Orders X species	5	10.81	2.16	0.73	2.71
Months X orders X species	5	29.56	5.91	2.00	2.71
Error	20	59.06	2.95		
Total	43	141.35			

1/ $p = 0.05$.

2/ See Table 3 for food groups, with families as replicates.

bottom fauna abundance, suggesting that the fish were not selective. Exceptions were that rainbow trout selected baetid nymphs to some degree, and the mottled sculpin did the same for Trichoptera naiads.

Even though rainbow trout fry were present in ever-increasing numbers in the study section of the stream during June to August, no fry were found in stomachs of either rainbow trout or mottled sculpins. The only fish encountered as a food item of another fish was a young-of-the-year mottled sculpin eaten by an age-II mottled sculpin.

Food Consumption

Total food consumption during the 57 days of the study was 29.2 kg, of which rainbow trout accounted for 18.2 kg, and mottled sculpins, 11.0 kg (Table 2). Rainbow trout consumed 319.7 g of food per day (0.2 g/m^2) which was 2% by weight of the mean standing crop of benthos. Mottled sculpins ate 193.1 g of benthos per day (0.1 g/m^2) or 1.2% of the mean benthic biomass.

DISCUSSION

Production of the rainbow trout in the Little Garlic River was within the range of values found elsewhere by others, particularly in salmonid nursery streams (Table 6). Only one report (Allen, 1951) had substantially greater salmonid production, but he was able to compute values for more age groups than I did. Production values for salmonids of corresponding age groups (Goodnight and Bjornn, 1971; Chapman, 1965) are similar to my findings. Information on sculpin production is scant, but Goodnight and Bjornn (1971) reported much lower production values for *Cottus* sp. than I found for the mottled sculpin (Table 6).

Table 6.--Production of trout, salmon, and sculpins in various streams, 15 June - 15 August

Investigators	Stream	Fish species	Age groups	Production (g/m^2)
Present study	Little Garlic R., Michigan	Rainbow trout	0-I	2.8
		Mottled sculpin	I-II	1.5
Goodnight and Bjornn (1971)	Big Springs Cr., Idaho	Rainbow trout	0-I	3.8
		Cottus sp.	I-II	0.5
	Lemhi R., Idaho	Rainbow trout	0-I	0.6
		Cottus sp.	I-II	0.3
		Chinook salmon	0-I	1.7
Chapman (1965)	Deer Cr., Oregon	Coho salmon	0-I	1.5
	Flyn Cr., Oregon	Coho salmon	0-I	1.3
	Needle Branch, Oregon	Coho salmon	0-I	1.2
Hunt (1966)	Lawrence Cr., Wisconsin Section A	Brook trout	0-IV	1.6
	Lawrence Cr., Wisconsin Section B	Brook trout	0-IV	2.9
Allen (1951)	Horokiwi Stream, New Zealand	Brown trout	All	9.0

An analysis of variance test confirmed that the diets of rainbow trout and mottled sculpin were similar. A comparison of food habits and bottom fauna abundance revealed that the two fishes fed on the various bottom organisms in approximate proportion to their abundance in the stream.

No occurrence of mutual predation between rainbow trout and mottled sculpins was found during this study. Even though large numbers of the fry of both fishes were available for predation, only one young mottled sculpin was eaten by a larger sculpin. This supports the contentions by Koster (1939) and Patten (1962, 1971) that sculpin predation on trout and salmon fry in streams can be negligible. My finding of an absence of predation by the rainbow trout on young of the mottled sculpin is augmented by McAfee (1966) who contended that in general, juveniles of the rainbow trout in freshwater eat mainly aquatic and terrestrial insects.

I could not accurately measure the extent of food competition. My experimental design provided me with data only on standing crop of bottom fauna. Total food consumption by the rainbow trout and mottled sculpin for 57 days was 1.9 times the mean standing crop of bottom fauna. Bottom fauna production values reported by other investigators indicate that this level of consumption probably was much less than the amount of benthos produced in the Little Garlic River. Allen (1951) estimated that the total annual production of bottom fauna in the Horokiwi Stream must have been 40-150 times the average standing crop, based on fish production. Allen's production estimates are regarded as being too high by Mann (1967). Mann reported that in the littoral zone of lakes and in streams where the fish population is at the maximum level permitted by food resources, annual food production may be 10 or more times the average standing crop of food. In support of this view, annual productivity of bottom fauna living on a rock-outcrop in a southern Piedmont stream was reported by Nelson and Scott (1962) to be 11-12 times the mean standing crop.

Daily food consumption by the rainbow trout was 2.0% of the mean biomass of bottom fauna; the mottled sculpin consumed 1.2%. This rate of cropping was substantially lower than that which Hopkins (1970) found for fish in a brown trout nursery stream. He concluded that a 5 to 20% daily consumption of the standing benthic population represented a high rate of cropping.

Based on the low total consumption and low daily cropping rate, food competition between rainbow trout and mottled sculpins in the Little Garlic River probably was not detrimental to either species, because more food was produced than the fishes could consume.

CONCLUSIONS

Populations of the rainbow trout and the mottled sculpin in the Little Garlic River exhibited production comparable to salmonids in other waters, particularly salmonid nursery streams. With minor exceptions, the food habits of the trout and sculpins in the Little Garlic River were similar. Mutual predation did not occur between or among the age and size groups studied. Detrimental food competition probably did not occur, because of the low rate of food consumption compared to the abundance of food organisms.

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