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FOOD PREFERENCES OF THE BROOK STICKLEBACK, *CULAEA INCONSTANS*, BASED ON FISH SIZE[a]

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Abstract. FOOD PREFERENCES OF THE BROOK STICKLEBACK, *CULAEA INCONSTANS*, BASED ON FISH SIZE. An investigation of the macroinvertebrate food preferences of the brook stickleback based on fish size was made. For all size groupings, the sticklebacks were selective in their feeding behavior. The most noted trend was an increase in the percentage of snails in the diet as fish size increased, with an accompanying decrease in the percentage of Ceratopogonidae and nematodes. No trends were observed in the occurrence of empty stomachs or the occurrence of plant material in the stomachs as fish size increased.

Several studies have determined the foods of the brook stickleback, *Culaea inconstans*. Notable are Cahn, 1924 (small, non-aquatic insects that fall into the water), Dymond, 1926 (midge and caddisfly larvae and ostracods), Nurnberger, 1928 (algae, sponges, entomostracans, insects and their larvae), and Winn, 1960 (aquatic organisms, with insects, principally larvae, and crustaceans being the two most abundant kinds of food with the following being taken in lesser quantities: snails, water mites, algae, fish eggs, and oligochaetes). The present study was conducted to investigate how the brook stickleback's feeding habits were influenced by fish size, with determinations made as to whether the fish were random or selective feeders within selected size groupings.

MATERIALS AND METHODS

Brook sticklebacks were collected for analysis on October 5 and 18, 1973 in a small pond adjoining Coon Creek, 9.7 miles east of Genoa on Hwy. 72, Kane Co., Illinois at approximately 11:00 a.m. each day. The dominant vegetation in the pond was *Elodea* sp. with an abundant covering of *Lemna minor*. Water temperatures were 11 and 12°C. respectively.

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Fish were collected with a six foot minnow seine with one-quarter inch mesh. Upon capture fish were placed in a 10% formalin solution. The fish were transferred to and stored in 40% isopropyl alcohol in the laboratory until analyzed.

Prior to removal of the stomach contents, the standard length of each fish was taken to the nearest 0.05 mm by use of Helios dial calipers following the procedure of Hubbs and Lagler (1970). The portion of the digestive tract from behind the gills to the pylorus was dissected from each fish, and the contents removed and identified.

Types and numbers of each food item were recorded for each fish. Identification of stomach contents was made to the lowest practical taxonomic level using Pennak (1953). Contents were grouped into six general categories: 1) *Gyraulus*, 2) *Physa*, 3) Ceratopogonidae, 4) Chironomidae, 5) Nematoda, and 6) Miscellaneous.

For size analysis the fish were grouped into seven size classes: 1) less than 20.00 mm, 2) 20.00 to 24.95 mm, 3) 25.00 to 29.95 mm, 4) 30.00 to 34.95 mm, 5) 35.00 to 39.95 mm, 6) 40.00 to 44.95 mm, and 7) greater than or equal to 45.00 mm. The number of fish analyzed for each group respectively were: 9, 76, 56, 17, 33, 42, and 13.

The relative abundance of food items was calculated for each fish size class. In addition summaries of the percentages of fish in each size class with plant material in their stomachs and with empty stomachs were made to observe if these factors differed with increasing fish size. The mean number of organisms per stomach for each size class was also calculated.

To test whether each size group fed randomly or selectively, chi square analysis was made comparing the relative abundance of the macroinvertebrates in stomachs to their relative abundance in the habitat.

The habitat of the sticklebacks was sampled on October 5 and 12, 1973. A random sample on each date of approximately three gallons of the water and aquatic vegetation was collected by vertically lifting a bucket from the pond bottom obtaining a sample of the water and vegetation in the water column. The samples were brought back to the laboratory where identification of the macroinvertebrates was made and the numbers of each recorded. Relative abundance of macroinvertebrates in the pond community was calculated and compared to the stomach contents.

RESULTS

The relative abundance of the macroinvertebrates found in the pond is listed in Table 1. The community was dominated by snails (60%), Chironomidae (12.56%), Ceratopogonidae (11.73%), and nematodes (3.54%). The remainder of the macroinvertebrate species encountered were in such low numbers that for analysis were grouped into the Miscellaneous class totaling 12.44% of the macroinvertebrate fauna.

TABLE 1. Relative Abundance of Macroinvertebrates

Organism*	Number	Relative Abundance
Gyraulus (Gastropoda)	1299	49.42%
Chironomidae (Diptera)	333	12.67
Ceratopogonidae (Diptera)	311	11.83
Physa (Gastropoda)	256	9.74
Gammarus (Amphipoda)	127	4.83
Argia (Odonata: Zygoptera)	126	4.79
Nematoda	93	3.53
Nymphula (Lepidoptera)	33	1.25
Haliplus (Coleoptera)	24	0.91
Lymnaeidae (Gastropoda)	8	0.30
Veliidae (Hemiptera)	5	0.19
Dugesia (Turbellaria)	4	0.15
Ephemeroptera	1	0.03
Mesoveliidae (Hemiptera)	1	0.03
Gerridae (Hemiptera)	1	0.03
		99.6%

**Isopoda, Naucoridae, Anisoptera, and Tabanidae not considered due to their large size.*

The values for relative abundance of organisms in the stomach contents with accompanying number of individuals for each size class are listed in Table 2. The major observable trends are an increase in the abundance of snails in the sticklebacks' diet as fish size increases with an accompanying decrease in ceratopogonids and nematodes. Chironomids remained at about the same level of abundance for all fish size classes, due to the abundance of midges in the pond and due to the different sizes of midge species and instars which can be consumed by all sizes of sticklebacks.

The individuals consumed from the Miscellaneous group consisted largely of small *Argia* and *Haliplus* larvae which were fairly easy to obtain and small enough to be consumed. The group shows minor fluctuations through the size classes, but essentially maintains a minor role

TABLE 2. Relative Abundance and Number of Food Items for Each Size Class of Stickleback

Size Class (mm)	Number of Fish Examined	*Gyraulus* R.A.*	*Gyraulus* #**	*Physa* R.A.	*Physa* #	Ceratopogonidae R.A.	Ceratopogonidae #	Chironomidae R.A.	Chironomidae #	Nematoda R.A.	Nematoda #	Misc. R.A.	Misc. #
<20.00	9	0.00	0	0.00	0	0.50	7	0.21	3	0.29	4	0.00	0
20.00 - 24.95	76	0.10	22	0.00	0	0.49	112	0.16	36	0.23	52	0.03	7
25.00 - 29.95	56	0.20	55	0.01	1	0.47	128	0.15	40	0.11	31	0.07	19
30.00 - 34.95	17	0.44	45	0.00	0	0.23	24	0.26	27	0.00	0	0.06	7
35.00 - 39.95	33	0.69	81	0.03	3	0.08	10	0.19	22	0.01	1	0.01	1
40.00 - 44.95	42	0.63	173	0.05	16***	0.08	21	0.19	52	0.02	6	0.03	7
≥45.00	13	0.61	52	0.09	8	0.04	3	0.21	18	0.00	0	0.05	4

*R.A. = Relative abundance.

**# = Number of food items found in all fish stomachs for a given size class.

***Includes one Lymnaeidae.

in the diet of the sticklebacks due to several factors: some of the macroinvertebrates were too large for the sticklebacks to consume; some of the invertebrates, such as *Elophila*, lived in cases which made them difficult to obtain; and finally, some of the species, such as *Gammarus*, were too mobile for the sticklebacks to readily obtain.

Table 3 presents the species observed in the sticklebacks' diet by size class.

TABLE 3. Species Observed in the Diet of the Brook Stickleback by Size Class

	Organisms Observed in the Sticklebacks' Diet											
Size Class (mm)	*Gyraulus*	*Physa*	Lymnaeidae	Ceratopogonidae	Chironomidae	Nematoda	*Argia*	*Haliplus*	*Nymphula*	Cicadellidae	*Gammarus*	Isopoda
<20.00	-	-	-	+	+	+	-	-	-	-	-	-
20.00 - 24.95	+	-	-	+	+	+	+	+	+	+	-	-
25.00 - 29.95	+	-	-	+	+	+	+	+	+	-	+	+
30.00 - 34.95	+	-	-	+	+	-	+	+	-	-	-	-
35.00 - 39.95	+	+	-	+	+	+	+	-	-	-	-	-
40.00 - 44.95	+	+	+	+	+	+	+	+	-	-	-	-
≥45.00	+	+	-	+	+	-	+	-	+	-	-	-

- = Not observed.

+ = Observed.

Table 4 presents the values for the mean number of organisms per fish, percentage of empty stomachs, and percentage of stomachs with plant material for each size class. Except for one class the numbers of

TABLE 4. Mean Number of Organisms/Stomach, Percentage of Empty Stomachs and Pecentage of Stomachs with Plants Related to Fish Size

Size Class	# Org./ Stomach	% Empty Stomachs	% Stomachs with Plants
<20.00 mm	1.56	33.3	0.0
20.00 - 24.95 mm	3.37	23.7	5.3
25.00 - 29.95 mm	5.17	16.1	7.1
30.00 - 34.95 mm	6.44	5.9	5.9
35.00 - 39.95 mm	3.58	30.3	36.4
40.00 - 44.95 mm	6.55	14.3	19.0
≥45.00 mm	7.08	23.8	7.7

organisms per stomach increased with increasing fish size. The percentage of empty stomachs per size class did not show any definite trends. No trends were observable in the percentage of stomachs with plant material as fish size increased. Except in one case, the occurrence of plant material in the stomachs was low. The plant material probably was not a food item, but was only secondarily consumed along with more preferable, closely-associated organisms.

Table 5 gives the chi square values for each size class, comparing the abundance of macroinvertebrates in the stomachs to their abundance in the habitat. In all cases there are highly significant differences at the 0.01 level, indicating that the sticklebacks were selective in their feeding habits.

DISCUSSION

It is clear that the brook stickleback is a selective feeder, and that the selectivity differs between size classes of the fish. Hynes (1950) stated that the differences in the diets of fish feeding in the same habitat are sound evidence that they select their food and do not merely eat what is there. One can look at the different size classes of sticklebacks in the same manner. It is especially evident that the diets of the smaller and larger size classes differ, and it is statistically evident that the choice of food for each class differs from the relative abundance of invertebrates in the habitat. Selectivity is forced upon the smaller sticklebacks due to their inability to consume many of the larger invertebrates; it is more voluntary on the part of the larger classes of fish which can select against smaller invertebrates

TABLE 5. Chi Square Analysis of Abudance of Organisms in Stomach Contents Compared to Stickleback's Habitat

Size Class	Chi Square Value
<20.00 mm	52.55**
20.00 - 24.95 mm	617.31**
25.00 - 29.95 mm	408.71**
30.00 - 34.95 mm	43.39**
35.00 - 39.95 mm	34.69**
40.00 - 44.95 mm	49.33**
≥45.00 mm	19.27*

**Highly significant (probability ≤0.01, df = 5).*

***Very highly significant (probability ≤0.001, df = 5).*

such as the Ceratopogonidae. All size classes are forced to select against overly large and/or mobile species. The change in dietary habits as fish size increases is probably related to the increase in mouth size accompanying the increase in body size. Keast (1965) found that increasing body size and mouth aperture width permitted a change in food niche. He demonstrated this in the rock bass; and it appears to be the case for the brook stickleback.

The findings in this study do not agree with those of Cahn (1924), who found 50% of the stickleback's diet to be non-aquatic insects, in that only one of 246 fish had consumed non-aquatic organisms (Cicadellidae). Lagler et al. (1962) stated that fish are highly adaptable in their feeding habits and utilize the most readily available foods. Due to dense vegetation cover in the present study, non-aquatic insects were not readily available, and thus the sticklebacks fed almost entirely on aquatic organisms.

Daiber (1956), in a feeding study on a sculpin and darter, found that the number of species ingested increased from the smallest to the intermediate size groups, and that in the largest size groups the number of species ingested decreased with an accompanying increase in the size of the organisms consumed. Similar results were observed for the sticklebacks (Table 3). The smallest size group ingested only three species, and the next two size classes ingested eight and ten species respectively; the number of species ingested was from five to eight in the remaining size groups. In the first class only the smaller species were consumed

(Ceratopogonidae, Nematoda, and smaller Chironomidae), but as the size of the sticklebacks increased so did the size of the food organisms. For example, the snail genus *Physa* was consumed only by the larger size classes.

It should be clear that feeding studies performed on smaller fish species should include observations of the food consumed by various sizes of the fish. Changes in the diet with increasing size is well documented for large fish species; but significant differences in the feeding activities of many small fish species also occur within the species related to differences in fish size. These differences could have a significant influence on many aspects of the ecology of a species and should thus be investigated.

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LITERATURE CITED

Cahn, A. R. 1924. An Ecological Study of Southern Wisconsin Fishes. PhD. Thesis. Zoology Lab., Univ. Ill., 151 p.

Daiber, F. C. 1956. A Comparative Analysis of the Winter Feeding Habits of Two Benthic Stream Fishes. Copeia, 3:141-151.

Dymond, J. R. 1926. The Fishes of Lake Nipigon. Univ. Toronto Stud. Biol. Ser. 27, Publ. Ont. Fish. Res. Lab., 27:1-108.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes Region. Univ. Mich. Press, Ann Arbor.

Hynes, H. B. N. 1950. The Food of Fresh-Water Sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a Review of Methods Used in Studies of the Food of Fishes. J. Animal Ecol., 19:36-58.

Keast, J. A. 1965. Resource Subdivision Amongst Cohabiting Fish Species in a Bay, Lake Opinicon, Ontario. Proc. 8th Conf. Great Lakes Res. Div., Univ. Mich., Ann Arbor, 106-132.

Lagler, K. F., J. E. Bardach, and R. R. Miller. 1962. Ichthyology. John Wiley and Sons, Inc., Ann Arbor.

Nurnberger, P. K. 1928. A List of the Plant and Animal Food of Some Fishes of Jay Cooke Park. Trans. Amer. Fish. Soc., 58:175-177.

Pennak, R. W. 1953. Freshwater Invertebrates of the United States. Ronald Press Co., New York.

Winn, H. E. 1960. Biology of the Brook Stickleback, *Eucalia inconstans* (Kirtland). Amer. Midl. Nat., 63:424-438.