ASPECTS OF THE FEEDING ECOLOGY OF *FUNDULUS ZEBRINUS KANSAE*

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Fundulus zebrinus kansae fed on a wide variety of organisms, with insects, primarily chironomid larvae, as the major animal items. Bottom materials (mainly sand and debris) represented a large portion of the diet which, compared to other ingested materials, seemed more important at night than during daylight. Feeding activity increased gradually from early morning until nightfall and then declined; however, there appeared to be a significant level of night feeding. Evidence is presented for a proposed competitive feeding relationship between *F. zebrinus* and another cyprinodontid, *Cyprinodon rubrofluviatilis*.

Available information on the feeding ecology of *Fundulus zebrinus* consists primarily of brief treatments by Minckley and Klaassen (1) and Echelle *et al.* (2,3). Our purpose was to extend these observations and to examine further the ecological role of this species. The foods and feeding periodicity of the plains killifish, *Fundulus zebrinus kansae* (Cyprinodontidae), at a single locality on two separate days in the summer of 1971, are described in this report.

METHODS

Observations of feeding activity and collection of specimens for intestinal analysis were conducted on 27 June and 12 July 1971 at Coffeepot Creek, one mile east of Rubottom, Love Co., Oklahoma. This is a shallow, sand-bottomed, freshwater stream which is fed by seepage from the surrounding area. There was little rooted vegetation and water flow was nearly zero. Observations were made from a sharply incised bank of the stream 2 to 3 m above the water. At hourly intervals from 0700 to 2000 hr on both days, the frequency of feeding acts in one-minute periods was recorded individually for five females by each of two observers; this was easily accomplished due to the clarity and shallowness of the water and the conspicuousness of the feeding acts "nipping" and "digging" (2).

Specimens were collected by seine at two-hour intervals from 0630 to 2230 hr on 27 June and from 0100 to 2300 hr on 12 July; each collection was immediately preserved in 10% formalin. Ten specimens were selected for gut analysis from each of the bi-hourly samples; this was done in such a way as to minimize differences in size distribution between the samples. Excepting five individuals (51-55 mm, TL) all specimens were between 30-50 mm in total length. For analysis the entire gut was removed from the fish, placed in a petri dish with a small amount of water, and examined with a dissecting microscope. Both the foregut (esophageal opening to first intestinal loop) and hindgut (posterior one-third of intestine) were assigned an "index of fullness" value based on the

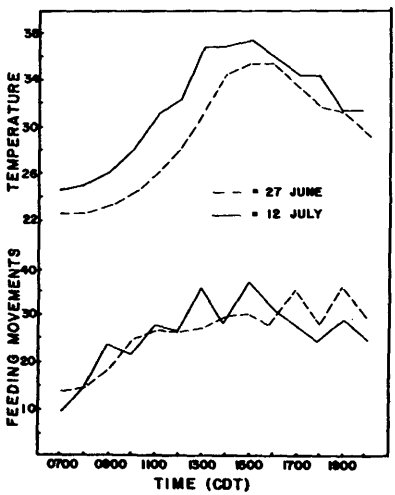

FIGURE 1. Average number of feeding movements (nipping and digging) counted in 10 *Fundulus zebrinus* in one-minute periods at hourly intervals on two separate days in June and July 1971. Temperature is recorded in degrees Centigrade.

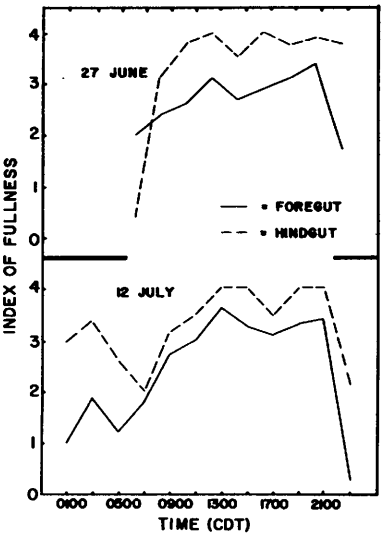

FIGURE 2. Average gut fullness for two sections of the intestine in *Fundulus zebrinus* at bi-hourly intervals on two days in June and July, 1971. Heavy horizontal lines represent approximate periods of darkness.

following code: 0 = empty, 1 = ¼ full, 2 = ½ full, 3 = ¾ full, and 4 = full. The foregut was then dissected; the contents were removed and divided into three categories: (a) sand and miscellaneous debris, (b) filamentous algae, and (c) macroscopic animal food items, *e.g.*, cladocerans and larger forms. The percentage of each category in relation to total foregut contents was estimated, and animal forms were identified and enumerated.

RESULTS AND DISCUSSION

Based on the frequency of observed feeding acts (Fig. 1) and relative gut fullness (Fig. 2), feeding increased gradually from shortly after sunrise until early afternoon and remained high until it was too dark for accurate observation. By gut fullness criteria, feeding activity was relatively low during nighttime hours; however, the data suggest that a certain level of feeding was maintained during the night, particularly on the night of 11-12 July (Fig. 2). At 0300 hr on 12 July the moonlight was sufficiently bright that seining was accomplished without the aid of artificial light. Cyprinodontids, in general, are sight oriented in their behavior (4), and it is pos-

TABLE 1. *Contents of the foregut of 210 specimens of* Fundulus zebrinus *taken from Coffeepot Creek, 27 June and 12 July 1971.*

Food items	Date 27 June	12 July	Total
Nematoda	37 (18.9)[a]	15 (6.7)	52
Ectoprocta (statoblasts)		4 (3.3)	4
Gastropoda	4 (4.5)	4 (2.5)	8
Oligochaeta	11 (11.1)		11
Cladocera	27 (15.7)	1 (0.8)	28
Copepoda	164 (37.8)	23 (13.3)	187
Ostracoda	22 (16.7)	10 (4.2)	32
Hydracarina		1 (0.8)	1
Insecta[b]	241 (70.0)	89 (33.3)	330
Collembola	2 (1.1)	1 (0.8)	3
Zygoptera (N)[c]	2 (2.2)		2
Anisoptera (N)	1 (1.1)	1 (0.8)	2
Ephemeroptera (N)	1 (1.1)	2 (0.8)	3
Chironimidae			
L[c]	134 (57.7)	65 (26.6)	199
P[c]	5 (5.6)	1 (0.8)	6
A[c]	3 (1.6)		3
Ceratopogonidae (L)	76 (20.0)	9 (5.0)	85
Coleoptera (A)	1 (1.1)		1
Corixidae	2 (2.2)		2
Formicidae	1 (1.1)		1
Pisces			
Fundulus zebrinus		1 (0.8)	1
Sand & misc. debris	(85.7)	(66.7)	
Filamentous algae	(70.0)	(44.2)	

[a] Numbers in parentheses = % frequency of occurrence; numbers not in parentheses = number found.
[b] Includes unidentifiable insect material.
[c] N = nymph; L = larva; P = pupa; A = adult.

sible that *F. zebrinus* feeds more actively on bright moonlit nights than on darker nights. Figure 1 suggests a positive relationship between water temperature and feeding activity. In another cyprinodontid, *Cyprinodon macularius,* Kinne (5) found that the energy expenditure increased to high levels at temperatures near those measured in midafternoon during our study (Fig. 1). The evidence suggests that our observed chronology of feeding activity was reflective of metabolic needs.

A wide variety of animal items had been ingested by the *F. zebrinus* we examined (Table 1), and, as noted by Minckley and Klaassen (1) for a Kansas population of this species, insects, primarily chironomid larvae, were predominant. Entomostraca were second in abundance, followed by nematodes. Fish and terrestrial arthropods were uncommon food items. The single fish found in the intestines, a 25 mm (TL) *F. zebrinus,* occurred in a 50 mm (TL) female. The entire length of the gut of one individual was filled with small snails (*ca.* 3 mm long).

The "sand and miscellaneous debris" category of food items (Table 1) consisted primarily of sand and flocculent substrate material; other items included here were diatoms, insect eggs, bits of vegetable debris, and the protozoan *Difflugia.* Although not quantified, *Difflugia* was common in this material as attested to by the presence of large numbers of the characteristic vase-like cases constructed of sand grains. At all hours this category of food items made up a large portion of the gut contents, but, relative to animal items and filamentous algae, it represented larger proportions of the diet at night than during daylight hours (Fig. 3). Since this material could be ingested indiscriminantly and the amount would not seem to depend on light intensity, it may be a major source of nutrients at times when the light is inadequate for effective sight feeding, *e.g.,* at night or under conditions of high turbidity.

The occurrence of animal items in the intestines was much greater on 27 June than on 12 July (Table 1; Fig. 3). This finding may have reflected a decline in the productivity of the stream as a result of midsummer temperatures. There was a distinct diurnal pulse in the occurrence of

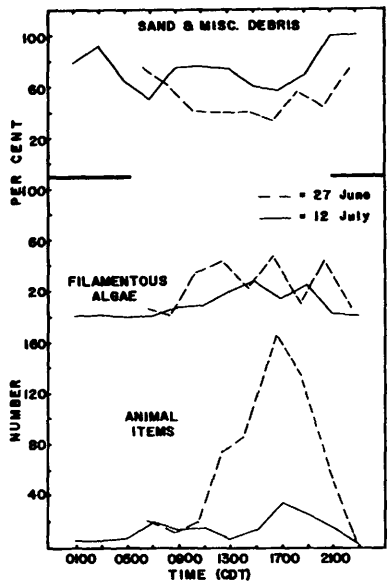

FIGURE 3. Total number of animal items and percentage contribution of two other categories to the foregut contents of 10 *Fundulus zebrinus* at bi-hourly intervals on two days in June and July 1971. Heavy horizontal lines represent approximate periods of darkness.

animal items in the foreguts of specimens collected on 27 June, and a similar, but damped, trend occurred on 12 July. This shows rough correspondence with the feeding trends depicted in Figures 1 and 2. The virtual absence of animal items from the nighttime diet may be the result of both the depressed feeding activity and the above postulated dependence upon light for sight feeding. An increase in the amount of filamentous green algae occurred with the increased abundance of animal items in daylight hours (Fig. 3). Martin (6) presented evidence that although another cyprinodontid, *Cyprinodon variegatus,* ingests large masses of algae, there is little digestion of algal material; large amounts of apparently undigested algae were found in the hindguts of the *F. zebrinus* examined. Some of this material could have been ingested in the process of removing animal items from algal mats.

However, certain individuals spent long periods of time pulling at, and ingesting, algal strands, and filamentous algae represented 50-90% of the intestinal content in 36 of the *F. zebrinus* examined. The evidence suggests that much of the algae was deliberately ingested. It is possible that "animal-like" movement of the algal strands stimulated the fish to grasp and ingest them.

The diurnal chronology of feeding activity depicted in Figure 1 is similar to data presented by Echelle (7) for *Cyprinodon rubrofluviatilis* except that maximum levels of activity were somewhat higher in the latter. The gut contents (Table 1) also resemble those of *Cyprinodon rubrofluviatilis* (7). These observations, in conjunction with similarities in the usual microhabitats of these two species, support the argument that direct competition for food with *C. rubrofluviatilis* partially accounts for the depression of *F. zebrinus* in saline waters supporting both species (3). On the basis of gut contents, Thomerson and Wooldridge (8) suggested a similar relationship between *Fundulus notatus* and *Fundulus olivaceus*.

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