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PREDATORS OF FORAMINIFERA IN THE INDIAN RIVER, FLORIDA

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ABSTRACT

Gut contents of macrofaunal specimens collected from inside an exclosure with 1-mm openings, and from other locations in the Indian River estuary, Florida, were examined to determine what animals ingest foraminifera. One species of goby (fish) several species of decapods, molluscs, and some species of polychaetes were found to contain foraminifera in their guts. Almost all the animals containing foraminifera had been previously described in the literature as deposit feeders.

INTRODUCTION

Interest in the role of foraminifera in the benthic food web has increased in the past few years (Lipps and Valentine, 1970; Sliter, 1971; Lipps and Ronan, 1974; Mageau and Walker, 1976; Wefer and Lutze, 1976; Daniels and Lipps, 1978; Buzas, 1978a, 1978b). Although a wide variety of organisms are known to ingest foraminifera, data on gut analyses are still woefully scant. This is not surprising because the systematic dissection of many individuals belonging to many species is a time-consuming and often unrewarding task. Here, we present some observations which add to this small data base.

To examine the importance of predation on benthic foraminifera, an enclosure with 1-mm openings containing 30 l of abiotic sediment was placed in the Indian River estuary at Link Port, Florida, in February, 1976 and 1977 (Buzas 1978a, 1978b). Four replicate samples were taken inside and outside the cage in March, April, May and June each year. In both years foraminiferal densities were significantly higher inside the exclosure vs. outside.

In both years maximum densities occurred in April and declined in May and June. This was true both inside and outside the exclosures. We cannot be certain whether or not the synchronous decline in densities inside and outside was due solely to predation, other environmental variables, or to a combination of both. Examination of samples inside the cage indicated larvae of the macrofauna had entered the cage and a substantial macrofaunal component was present by the end of the experiment in June.

In June, 1976, a single 6-l sample was taken from the exclosure and examined for its macrofaunal content. Examination of the guts of 71 individuals yielded only one foraminiferal test.

Consequently, in 1977, we decided to examine a larger portion of the macrofauna within the exclosure. To do so, we removed the exclosure in December, 1977, and examined the gut contents of about 27% of the 827 macrofaunal inhabitants.

The purpose of the present paper is to report on the specific results of the gut contents from the 1977 experiment, and on some other similar observations of animals from elsewhere in the Indian River estuary.

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TABLE 1

Gut contents of macrofauna from inside of exclosure Link Port, Florida 1978.

Taxonomic group	Number in sample	Number examined	Major components of gut material	Number of foraminifera
FISH				
Archosargus probatocephalus	1	1	algae, bivalves, bryozoans, tunicate	
Lagodon rhomboides	1	1	algae, crustacean fragments, bryozoans, diatoms, bivalves	
Bathygobius soporator	2	2	vegetation, crustacean fragments, ostracod, caprellid, gastropods	
DECAPODS				
Crabs				
Panopeus herbstii	1	1	copepods, ostracods, nematodes, diatoms	1
Eurypanopeus depressus	1	1	algae, $CaCO_3$ fragments, diatoms, copepods	6
Eurypanopeus sp.	1	1	diatoms, algae	
Microvanopeus sp.	8	8	algae	
Xanthidae juveniles	4	4	algae, detritus, diatoms, $CaCO_3$ fragments	1
Shrimp				
Palaemon floridanus	5	5	detritus, crustacean fragment, copepods, diatoms	3
Alpheus heterochaelis	4	4	detritus, algae, copepods, diatoms, crustacean fragments	1
Alpheus sp.	3	3	algae, detritus, copepods	3
GASTROPODS				
Cerithium muscarum	2	2	detritus, diatoms, $CaCO_3$ fragments	2
Bulla striata	1	1	diatoms, algae, $CaCO_3$ fragments	
Mitrella lunata	10	5	diatoms, algae	
Plyrgocythara plicosa	5	5	diatoms, detritus	
Vitrinella sp.	1	1	detritus, algae, diatoms	
Tricolia affinis	1	1	algae, diatoms, ostracod, micromollusc	2
Turbonilla sp.	3	3	detritus, algae	
Cerithiopsis greenii	24	6	detritus, algae	
Marginella apicina	1	1	empty	
Nassarius vibex	3	3	detritus, algae, diatoms	2
Diastoma varium	53	13	diatoms, algae, detritus, $CaCO_3$ fragments	1
BIVALVES				
Chione cancellata	7	2	detritus	
Lyonsia hyalina floridana	24	6	detritus, algae, diatoms, $CaCO_3$ fragments	
Tellina tampaensis	5	5	micromolluscs, diatoms, algae	17
POLYCHAETES				
Ampharetidae	4	4	diatoms, algae, detritus	
Arenicolidae	1	1	detritus, diatoms, algae	1
Capitellidae	10	10	diatoms, algae, detritus	
Cirratulidae	383	38	detritus, diatoms, micromolluscs	156
Dorvilleidae				
Dorvillea rudolphi	11	6	diatoms, detritus	
Eunicidae				
Marphysa sanguinea	10	5	diatoms, detritus, algae, ostracods	1
Goniadidae				
Glycinde solitaria	1	1	empty	
Hesionidae				
Gyptis vittata	1	1	detritus, sand	
Podarke obscura	4	4	algae, detritus, diatoms	
Maldandidae				
Branchioasychis americana	4	4	detritus, diatoms	3

TABLE 1
Continued.

Taxonomic group	Number in sample	Number examined	Major components of gut material	Number of foraminifera
Onuphidae				
Diopatra cuprea	7	7	diatoms, detritus, crustacean fragments, $CaCO_3$ fragments	1
Orbiniidae				
Scoloplos rubra	1	1	detritus	
Sabellidae				
Branchiomma nigromaculata	32	8	detritus, algae, diatoms, copepods	2
Sabellestarte sp.	6	6	diatoms, algae, detritus	
Syllidae				
Paraprionosyllis longicirrata	1	1	empty	
Trypanosyllis zebra	10	10	detritus, algae, diatoms	
Terebellidae				
Pista quadrilobata	39	19	detritus, diatoms, algae, copepods, micromolluscs	11
Terebella rubra	2	2	detritus, algae, diatoms	
SIPUNCULA				
Phascolion cryptus	4	4	detritus, diatoms, nematodes, algae, micromolluscs	
TOTALS	827	224		213

METHODS

The sample removed from the exclosure was washed over a 1-mm sieve in the field. Monthly sampling had removed from 1–4 l of sediment which were probably replaced, at least in part, by sedimentation in the exclosure. After sieving, the sample was placed in 15% propylene phenoxytol in seawater (McKay and Hartzband, 1970) for 15 min to relax the animals and prevent regurgitation and then fixed in a 5–10% solution of formalin in seawater for 24 h.

The sample was stored in 75% ethanol, stained with rose Bengal, and the animals removed and identified. All of the rarer individuals and a percentage of each abundant species or taxon was dissected, the gut contents examined and recorded.

Other animals examined were obtained from the collections of Harbor Branch Foundation biologists and had received the same type of treatment when collected from similar areas in the Indian River estuary.

RESULTS

Of the 827 animals captured inside the exclosure, 224 were examined for gut contents, and 43 of these contained a total of 213 foraminifera (Table 1).

Four small fish belonging to three species captured inside the exclosure did not contain foraminiferal tests in their guts. Five taxa of crabs were encountered, and three of these contained foraminifera. All three shrimp taxa observed contained foraminifera. More taxa (six of eight) of decapods contained foraminifera than any of the other taxonomic groups. Eleven species of gastropods were recorded, and only four contained foraminifera. Among the three species of bivalves recorded only *Tellina tempanensis* contained foraminifera.

Most polychaete taxa did not contain foraminifera. However, about half the dissected individuals of the Cirratulidae contained foraminifera. Most of these cirratulids were larger than 45 mm.

In addition to examining the macrofauna found inside the exclosure, we examined several other species from various areas in the Indian River estuary, on the adivce of biologists on the staff of the Harbor Branch Foundation. Table 2 lists the results obtained from a single species of fish, two species of polychaetes, and two species of gastropods.

The small fish *Gobionellus boleosoma* consistently contained foraminifera. This deposit-feeding fish ranges in size from about 15 to 40 cm (SL).

Specimens of the polychaete *Branchioasychis americana* outside the exclosure contained a large number of foraminifera. In the three specimens examined outside the exclosure, 135 foraminifera were recorded; however, 104 of these were in a single individual worm. Of the four specimens examined, from

TABLE 2
Gut contents of macrofauna from the Indian River, Florida.

Taxonomic group	Number examined	Major components of gut material	Number of foraminifera
FISH			
Gobionellus boleosoma	10	nematodes, ostracods, diatoms, copepods, detritus	708
POLYCHAETES			
Branchioasychis americana	3	ostracods, diatoms, molluscs, algae, detritus, egg cases, sponge spicules	135
Pectinaria gouldii	3	ostracods, diatoms, $CaCO_3$ fragments, detritus	23
GASTROPODS			
Acteocina candei	11	nematodes, $CaCO_3$ fragments	6
Acteocina canaliculata	10	nematodes, gastropod, $CaCO_3$ fragments	11

inside the exclosure, two contained a total of three foraminifera. Similarly, 20 of the 23 foraminifera found in three specimens of *Pectinaria gouldii* occurred in a single individual.

We examined *Acteocina candei* and *A. canaliculata*, gastropods which range in size from about 2 to 4 mm. Most specimens had one or two foraminifera in their guts and other $CaCO_3$ fragments possibly belonging to foraminifera (Table 2).

DISCUSSION

Analyses of gut contents of animals found inside the exclosure and at other locations in the Indian River estuary indicate that a substantial number of foraminifera are ingested by certain predators. In their list of invertebrates found in the Indian River estuary, Young and Young (1976) classified the polychaetes and molluscs by feeding type. With the exceptions of *Diopatra cuprea* and *Branchiomma nigromaculata*, named as suspension feeders, and *Acteocina*, whose feeding mode is in question, all the polychaetes and molluscs in which foraminifera were found are listed as deposit feeders. Lipps and Ronan (1974) have discovered that the suspension feeder *Diopatra ornata* also ingests foraminifera in Bodega Bay, California. *Branchiomma nigromaculata* has not, to our knowledge, been previously reported as ingesting foraminifera. Hurst's observations (1965) on another species of the genus *Acteocina* indicates that it uses a deposit-feeding strategy which may be shared by *A. candei* and *A. canaliculata*.

That the majority of animals found ingesting foraminifera are deposit feeders is not surprising because foraminifera and nematodes are often the most abundant constituents in the meiofaunal size range and an organism browsing through the sediment would readily encounter them. There are, however, many animals, especially polychaetes (see Table 1), which are deposit feeders and yet did not contain any foraminifera. We suggest that the reason for this apparent anomaly is a combination of size of the individual predator, morphology of its feeding apparatus, and other, more fortuitous, factors. For example, only cirratulids over 45 mm in length contained foraminifera in their guts, indicating either that smaller specimens reject the foraminiferans as too large to be considered a food item, or that the size of the foraminifera simply prohibits their ingestion.

There was some evidence of a relationship between size of a worm specimen and the presence of foraminiferans in the gut (e.g., *Pectinaria gouldii* and *Branchioasychis americana*) with more foraminifera found in the larger worms. Generally, the distribution of foraminifera in the guts of polychaetes examined appeared more arbitrary than in some of the other predators examined, and is probably the result both of inadequate sample size and unknown factors in the feeding behavior of the polychaetes. The feeding mode of the predators does bias the results of a gut analysis study. While a deposit-feeding bivalve like *T. tampanensis* ingests whole food particles and usually contains many intact specimens, the food items of many gastropods are impossible to identify after passing through a digestive tract which may include a scraping radula or a grinding gizzard (Mageau and Walker 1976).

The small fish *Gobionellus boleosoma* feeds mostly on meiofaunal elements and the guts of ten individuals examined contained over 700 foraminiferans. Lee (personal communication) has observed that the fish *Fundulus* ingests up to 3,000 foraminifera per day un-

der laboratory conditions. Although foraminifera probably do not play a significant role in the diet of most fish (Daniels and Lipps, 1978), they may be an important part of the diet of some small bottom feeders and juveniles of larger fish.

The deposit feeders encountered in the Indian River do not feen feed selectively upon foraminifera, but rather ingest organisms in the meiofaunal size range. In keeping with such behavior, we found no evidence of selective predation on particular foraminiferal species. Those species which are commonly found in the Indian River, an *Ammonia-Elphidium-miliolid* assemblage, are commonly found in the guts of deposit feeders.

The importance of the meiofauna as a good food source for the macrofauna is controversial. Some researchers (McIntyre, 1969; Coull, 1973) believe the principle role of the meiofauna is to assist in the recycling of nutrients. In contrast, calculations made on the Link Port data indicate a substantial number of foraminifera are consumed by deposit feeders. At Link Port, we calculated wet-weight biomass estimates of foraminiferal populations that range from 0.9 to 6.0 g/m^2 and averaged 3.2 g/m^2 outside exclosures in 1977–78 [Buzas (1978b), using a procedure suggested by Saidova (1967) and used by Wefer and Lutze (1976)]. Our figures show a foraminiferal biomass from 3 to 12 g/m^2 greater inside exclosures than outside. These estimates may represent a considerable portion of the food supply exploited by macrofaunal deposit feeders and bottom-feeding fish.

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REFERENCES

Buzas, M. A., 1978a, Community unity? patterns in molluscs and foraminifera, *in* Wiley, M. L., ed., Estuarine Interactions: New York, Academic Press, p. 173–190.

———, 1978b, Foraminifera as prey for benthic deposit feeders: results of predator exclusion experiments: Journal of Marine Research, v. 36, p. 617–625.

Coull, B. C., 1973, Estuarine meiofauna: a review: trophic relationships and microbial interactions, *in* Stevenson, L. H., and Colwell, R. R., eds., Estuarine Microbial Ecology, Columbia Univ. South Carolina Press, p. 499–512.

Daniels, R. A., and Lipps, J. H., 1978, Predation on foraminifera by Antarctic fish: Journal of Foraminiferal Research, v. 8, p. 110–113.

Hurst, A., 1965, Studies on the structure and function of the feeding apparatus of *Philine aperta* with a comparative consideration of some other Opistobranchs: Malacologia, v. 2, p. 281–347.

Lipps, J. H., and Ronan, T. E., Jr., 1974, Predation on foraminifera by the polychaete worm, *Dioptara*: Journal of Foraminiferal Research, v. 4, p. 139–143.

———, and Valentine, J. W., 1970, The role of foraminifera in the trophic structure of marine communities: Lethaia, v. 3, p. 279–286.

Mageau, N. C., and Walker, D. A., 1976, Effects of ingestion on foraminifera by larger invertebrates. First International Symposium on Benthonic Foraminifera of Continental Margins. Part A. Ecology and Biology: Maritime Sediments Special Publication 1, p. 89–105.

McKay, C. R., and D. J. Hartzband, 1970, Use of propylene phenoxetol in narcotizing unsorted benthic invertebrate samples: Transactions of the American Microscopic Society, n. 89, p. 53–54.

McIntyre, A. D., 1969, Ecology of marine meiobenthos: Biological Reviews, v. 44, p. 245–290.

Saidova, K. M., 1967, The biomass and quantitative distribution of live foraminifera in the Kurile-Kamchatka trench area: Doklady Akad Nauk SSR, v. 174, p. 216–217.

Sliter, W. V., 1971, Predation on benthic foraminifers: Journal of Foraminiferal Research, v. 1, p. 20–28.

Wefer, V. G., and Lutze, G. F., 1976, Benthic foraminifera biomass production in the Western Baltic: Keiler Meeresforschungen, no. 3, p. 76–81.

Young, D. K., and Young, M. W., 1977, Community structure of macrobenthos associated with seagrass of the Indian River estuary, Florida, *in* Coull, B. C., ed., Ecology of Marine Benthos: Columbia, Univ. South Carolina Press, v. 6, p. 359–381.

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