FOOD HABITS OF FISHES ASSOCIATED WITH MARSHLAND DEVELOPED ON DREDGED MATERIAL

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Abstract: The food habits of *Micropogon undulatus, Leiostomus xanthurus, Fundulus similis, Cyprinodon variegatus, Menidia beryllina* and *Membras martinica* were studied in conjunction with the development of a man-made salt marsh planted during 1976 on Bolivar Peninsula, Galveston Bay, TX. Each of the fishes studied fed to a considerable extent on the benthos community, and utilized at least some zooplanktonic and terrestrial insect foods. The dominant food organisms in the fish stomachs examined corresponded, in general, with those previously reported by other investigators. The artificially created salt marsh on Bolivar Peninsula appeared to provide habitats, both for fishes and their foods, similar to those of natural marshland areas along the coasts of the Gulf of Mexico and the southeastern United States.

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Salt marshes are major sources of detritus in coastal regions of the Gulf of Mexico and the southeastern United States. Detritus may play an important role as a food energy source in certain areas (Odum and de la Cruz 1963, 1967), although the relative contributions of detritus and phytoplankton may vary considerably among coastal environments. Regardless of their importance in primary production, salt marshes are widely recognized as nursery areas for small fishes and invertebrates. In addition, they are highly regarded for their esthetic value.

The Texas coast is characterized by a series of highly productive bays and the large, often hypersaline, Laguna Madre. Salt marshes occur in conjunction with protected waters within the state, but are of limited areal extent because of low tidal range. Smooth cordgrass (*Spartina alterniflora*) occurs intertidally along with marshhay cordgrass (*S. patens*) and other species supratidally.

Material removed from the Atlantic and Gulf Intracoastal Waterways, harbors, ship channels and other areas by hydraulic dredging is often deposited on salt marshes, removing them at least temporarily from production. Salt marshes can be established on dredged material (Woodhouse et al. 1972, 1974a, 1974b; Seneca 1974) with the result that sediment erosion is retarded and natural estuarine habitats are created (Cammen et al. 1974).

When a salt marsh is planted on dredged material, a period of several years may be required for stem and root densities to approach those of natural marshlands. During 1976 and 1977, a project was undertaken to establish a salt marsh on dredged material in Galveston Bay, TX. Plant growth, water and soil chemistry, and the utilization of the study area by aquatic and terrestrial animals were monitored. As a portion of the study, the food habits of several common fish species were determined. The purpose of this paper is to present the findings of the food habits study and compare these findings with published information on the same species of fishes collected from natural habitats. The study was designed to determine the dependence of selected fish species on established marshland habitats by examining if preferred foods were available in a newly-planted marsh area or if fish food habits were modified to any extent from those reported for natural marshlands.

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MATERIALS AND METHODS

The study was conducted on Bolivar Peninsula along Galveston Bay, TX, in an area of approximately 8 ha (Fig. 1). Sediments of the study site were derived from the Gulf Intracoastal Waterway during hydraulic dredging operations in 1974. Prior to initiation of the study, the area was leveled with earth-moving equipment and sloped to a grade of 0.69% leaving a barren sand beach. A fence was constructed around most of the marsh development site to keep out goats and other terrestrial herbivores. Within the fence, a sandbag dike of PVC-coated nylon bags each 0.5 x 1.4 x 2.9 m in size was constructed along 305 m of the seaward portion of the study site (Fig. 2). The dike served as a primary breakwater to protect a portion of the study site from wave erosion. Two secondary dikes 114 m long were constructed perpendicular to the primary dike (Fig. 2).

Maximum tidal fluctuations observed during the study ranged from slightly above the elevation of the most landward portion of the secondary dikes to several meters seaward of the front dike. Supratidally, an area of upland vegetation was planted during the summer 1976. Intertidally, the marshalnd area was divided into a large area protected by the sandbag dike and smaller unprotected areas (Fig. 2). Within the protected area, 270 plots, each 3 x 10 m in size, were established. Treatments within the 270 plots consisted of no planting, sprigging or seeding with *Spartina alterniflora* and sprigging or seeding with *S. patens*. In addition, various rates of fertilizer were applied in plots receiving each treatment. Selected areas within and outside of the sandbag dike received mixed plantings of *S. alterniflora* and *S. patens*.

Transects were established across the study site for sampling fishes, benthos and sediments(Fig. 2). Only information associated with the fish collections is included in this paper. The habitats sampled were as follows:

Transects Z and J - Reference area (unplanted)
Transects A and I - Unprotected, unplanted
Transects B and H - Unprotected, mixed plantings
Transects X and Y - Protected, unplanted
Transects C and D - Protected, mixed plantings
Transects D and F - Protected, unispecific marsh plots
Transect E - Unplanted alley between unispecific marsh plots

Fish samples were collected with a 7.6 m long, 7.6 mm bar mesh beach seine pulled from the level of elevation 5 (Fig. 2) to the shoreline (often corresponding with elevation 3 in Fig. 2). Monthly seine samples were collected along transects Z, A, X, Y, I and J from July 1976 through December 1977 with the exceptions of December 1976 and August 1977 when no samples were obtained. Fish samples were preserved in 10% formalin for later examination.

No species was common to every collection, however, fairly comprehensive data were obtained on spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogon undulatus*), sheepshead minnow (*Cyprinodon variegatus*), longnose killifish (*Fundulus similis*), rough silverside (*Membras martinica*) and tidewater silverside (*Menidia beryllina*). The latter 2 species were pooled for food habit analysis.

Stomach content analyses were conducted utilizing the method of Borgeson (1963). All individuals of each species captured monthly were pooled. If available, 25 individuals of each species were selected monthly from selected size classes. The fish were dissected and the stomach contents removed. The occurrence of an empty stomach was noted and an additional fish, if available, was added to the sample. Material recovered from the stomachs was examined microscopically and all food items were classified to the lowest identifiable taxon and enumerated. No attempt was made to compare the food habits

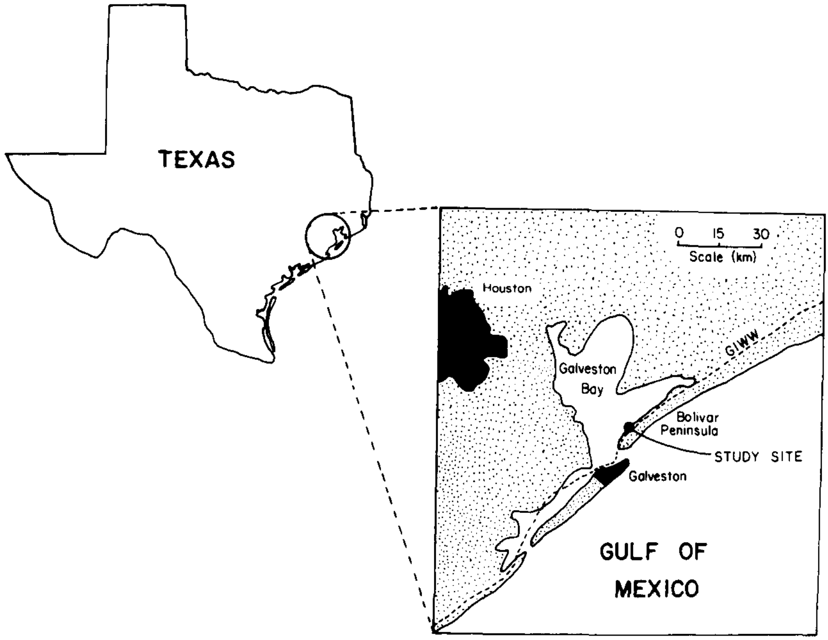

Fig. 1. Map of the study area

among stations because the individual sample sizes normally would have been less than the desired 25. In addition it could not be assumed that food items recovered were consumed in close proximity to the capture site.

RESULTS AND DISCUSSION

A total of 1861 fishes were examined during the study with the largest number of individuals represented by *Fundulus similis* and the fewest by *Leiostomus xanthurus* (Table 1). Over 70% of the stomachs examined (at least 200 stomachs from each species category) contained food.

Food items identified from the stomachs examined are presented in Table 2. In addition to the organisms listed, unidentifiable organic matter and sand grains were frequently found, especially in *Cyprinodon variegatus*. Of the food organisms identified, only foraminifera, ostracods, harpacticoid copepods, barnacle larvae (cyprids) and fish eggs were recovered from all species examined. Few food taxa were limited to only 1 or 2 of the species studied.

Micropogon undulatus

Four size classes of *Micropogon undulatus* were collected and examined for food habits. In addition, Atlantic croaker were captured during each season of the year (Fig. 3). Fish less than 20 mm SL were collected only between November and March. Over 95% of the diet of the smallest group of *M. undulatus* was composed of copepods, with about 25% of the total food quantity represented by benthic harpacticoids. Over 70% of the total food was pelagic copepods (predominantly calanoids, with a few cyclopoids).

With increasing length, fewer copepods were present in the diet of *Micropogon undulatus*. Stomachs examined from fish within the largest size class (greater than 100

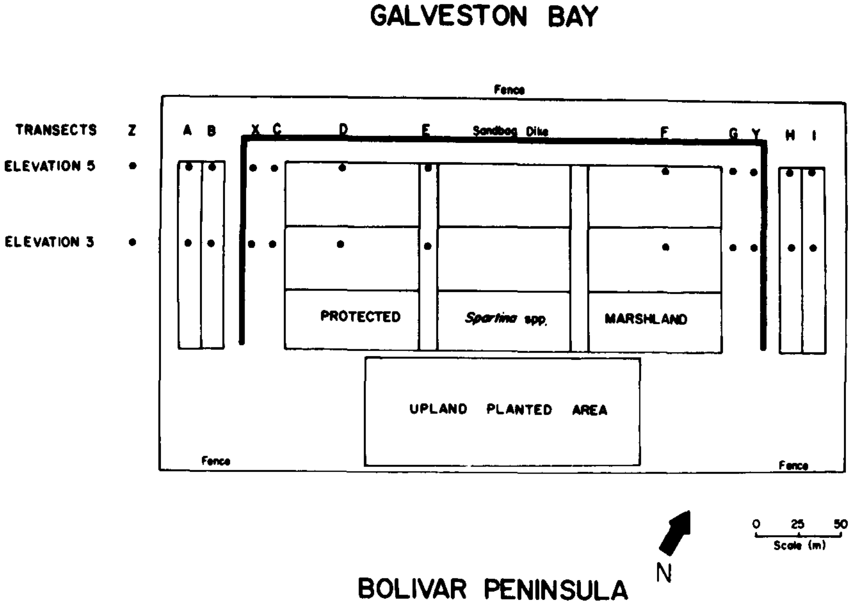

Fig. 2. Bolivar Peninsula marsh development site indicating location of the fence, sandbag dike, transects for aquatic sampling and elevations between which seine hauls were made. (Elevation 5 was approximately the mean low tide mark; elevation 3 was approximately the position of neap high tide.)

Table 1. Fish examined for stomach contents at the Bolivar Peninsula marsh development site.

Fish species	*Total number of fish examined*	*Percentage with food in stomachs*
Micropogon undulatus	454	89.4
Leiostomus xanthurus	269	94.4
Fundulus similis	525	73.3
Cyprinodon variegatus	341	72.7
Membras martinica and *Menidia beryllina*	272	85.7

Table 2. List of organisms recovered from fish stomachs at the Bolivar Peninsula marsh development site. (X - denotes presence of the food item in the fish species indicated.)

Food organism	*Fish species*				
	Micropogon undulatus	*Leiostomus xanthurus*	*Fundulus similis*	*Cyprinodon*[1] *variegatus*	*Membras martinica* + *Menidia beryllina*
Foraminifera	X	X	X	X	X
Oligochaeta	X				
Polychaeta					
Eteone heteropoda	X	X	X		X
Aricidea sp.	X	X	X		
Capitella sp.	X	X			
Heteromastus filiformis	X		X		
Parandalia fauveli	X		X		
Nereis sp.	X	X	X		X
Diopatra cuprea	X				
unidentified remains	X		X		X
Ostracoda	X	X	X	X	X
Insecta					
Coleoptera larvae and adults	X		X		
Diptera pupae, larvae and adults	X		X		X
Hymenoptera adults			X		X
Unidentified pupae, larvae and adults		X	X	X	X
Formicidae			X		
Copepods					
Harpacticoida	X	X	X	X	X
Calanoida	X	X	X		X
Cyclopoida	X				X
Cirripedia (cyprid barnacle larvae)	X	X	X	X	X
Isopoda					
Xenanthura brevitelson	X	X	X		
Amphipoda					
Gammaridae	X	X			X
Caprellidae			X		
unidentified	X		X		X
Decapoda					
Shrimp	X	X	X		X
Uca sp.			X		
Callianasidae	X	X			X
Crab magalops and zoeae					I
Unidentified crabs	X		X		
Crustacean larvae (unidentified)	X		X	X	X
Invertebrate eggs	X				
Mollusca					
Pelycepoda	X	X			
Ensis minor	X				
Osteichthys					
Fish eggs	X	X	X	X	X
Juveniles	X	X	X		X

[1]Most individual *Cyprinodon variegatus* stomachs contained only unidentifiable organic matter and sand.

mm SL) contained no copepods (although these data were based on the examination of only 3 stomachs). *M. undulatus* larger than 20 mm SL ingested a variety of food organisms including cyprid barnacle larvae, oligochaetes, various species of polychaetes, amphipods, shrimp (primarily mysis stages of penaeids) insects and the eggs of fish and invertebrates. Fish remains were found only in *M. undulatus* of the largest size class.

Seasonal food habits appeared to be based largely upon availability. The least variety in Atlantic croaker stomachs occurred during the fall (September through November) when the 32 individuals examined fed almost exclusively on copepods. Approximately two-thirds of the *Micropogon undulatus* collected during the fall were less than 20 mm SL, a fact which contributed to the dominance of copepods in the stomachs during that season. A more diverse assemblage of food organisms was

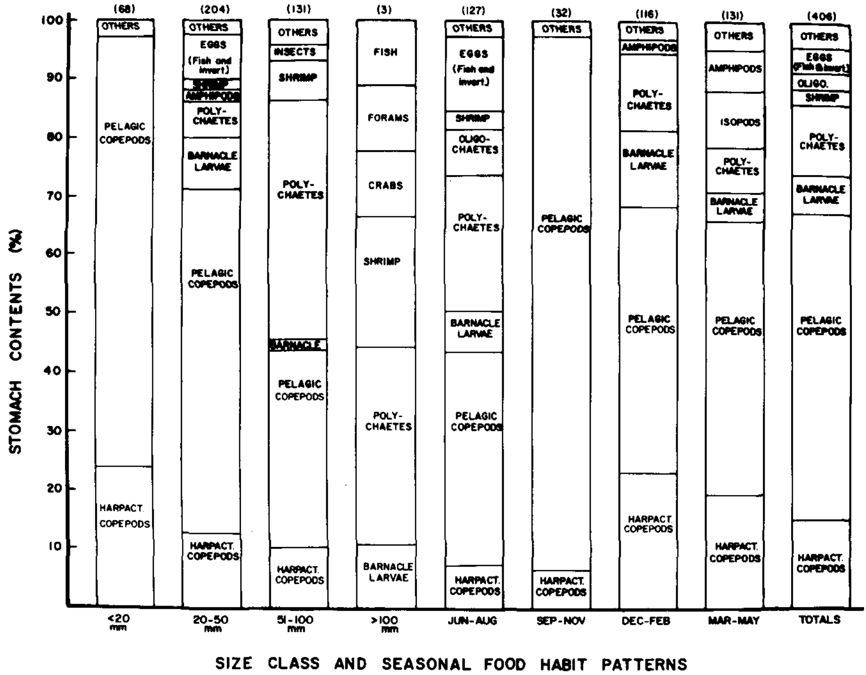

Fig. 3. Numerical abundance (percentage of total) of food organisms in the stomachs of *Micropogon undulatus* from four size classes and four seasons of the year. (Numbers in parentheses above each bar indicate the number of food-containing stomachs examined.)

recovered from the stomachs of *M. undulatus* during other seasons of the year. Of the *M. undulatus* from which food was recovered, over 65% of the food items were copepods. The next largest food group was polychaete annelids.

Data presented in Fig. 3 indicate that *Micropogon undulatus* fed to nearly the same extent on both the zooplankton and benthos communities associated with the Bolivar Peninsula marsh development site, assuming that calanoid copepods found in the stomachs were not actually associated with the sediments. The dependence of *M. undulatus* upon planktonic food organisms appeared to decrease as the fish grew. Selectivity among food organisms appeared to decrease as the fish grew. Selectivity among food organisms was not pronounced; rather, the fish appeared to utilize whatever appropriate sized food items were available (Fig. 3, Table 2). The results agree, in general, with those of other studies on the food habits of *M. undulatus*. Other reports indicated that Atlantic croaker feed primarily on the benthos community and that this dependence increases with increasing fish size (Linton 1904; Welsh and Breder 1923; Gunter 1945; Roelofs 1954; Darnell 1958; Diener et al. 1974; Stickney et al. 1975; Roussel and Kilgen 1975).

Leiostomus xanthurus

Four size classes of *Leiostomus xanthurus* were collected during spring and summer at the Bolivar Peninsula marsh development site (Fig. 4). A total of 254 out of the 269 individuals examined contained food (Table 1). Harpacticoid copepods were the most abundant food items present in spot of all sizes during both seasons. Only 3 fish larger than 100 mm SL were captured and each contained only harpacticoid copepods. The presence of approximately 2% polychaetes in *L. xanthurus* from 50 to 100 mm SL indicated that larger organisms were being taken as the fish grew in size, although the number of spot examined from the largest size class was insufficient to document this trend. No large differences in food habits among size classes or seasons were observed. During both spring and summer harpacticoid copepods accounted for over 90% of the food organisms observed in the stomachs, regardless of size (Fig. 4).

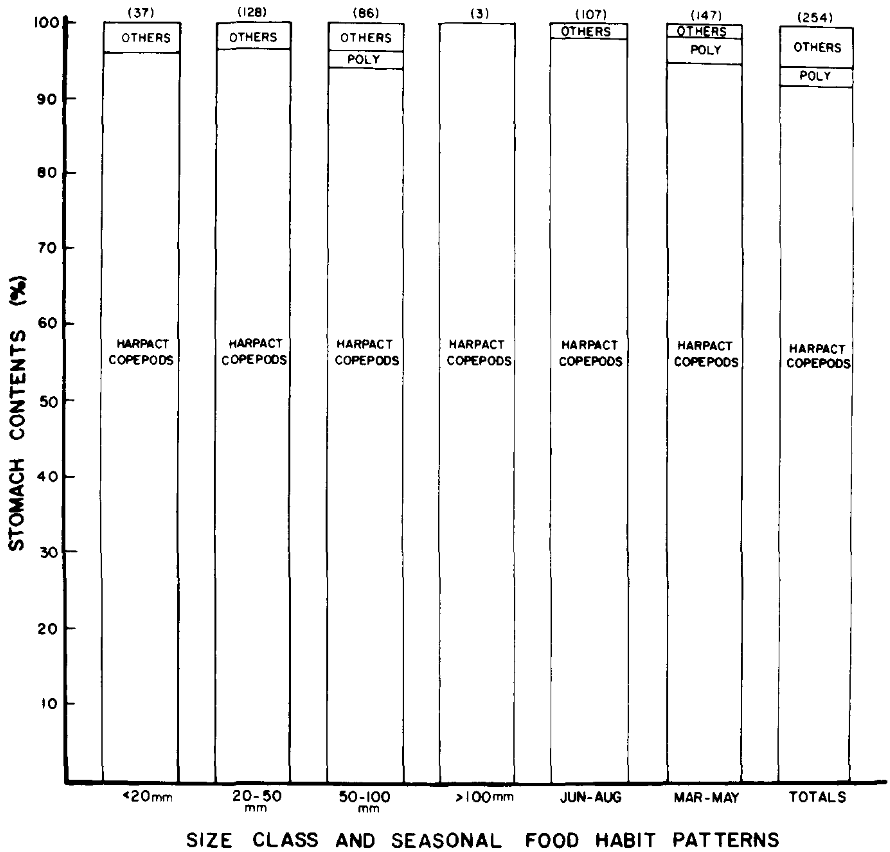

Fig. 4. Numerical abundance (percentage of total) of food organisms in the stomachs of *Leiostomus xanthurus* from four size classes and two seasons of the year. (Numbers in parentheses above each bar indicate the number of food-containing stomachs examined.)

In addition to harpacticoid copepods and polychaetes, various other benthic as well as a few planktonic animal species were present in the stomachs of *Leiostomus xanthurus* (Table 2). Since harpacticoid copepods accounted for the highest percentage of stomach contents in all categories, spot can be assumed to have been feeding primarily on the benthos community at the study site. This feeding pattern has been documented in earlier studies in various estuarine environments (Linton 1904; Welsh and Breder 1923; Hildebrand and Cable 1930; Reid 1954; Roelofs 1954; Darnell 1958; Diener et al. 1974; Stickney et al. 1975).

Roelofs (1954) indicated that both *Micropogon undulatus* and *Leisotomus xan[thurus* of the larger size classes often feed by taking bites from the sediments after which they expectorate inorganic materials and swallow the food organisms present. The position of the mouth in these 2 species is ideal for feeding behavior of the type described. This activity pattern would explain, in part, the diversity of food organisms found in those species. The high percentage of pelagic copepods in *M. undulatus*, especially those within the smallest size class (Fig. 3), and dominance of harpacticoid copepods in *L. xanthurus* of all size classes (Fig. 4) indicated that small fishes of both species were somewhat restricted in selection of food items. Selection of copepods and other small invertebrates may have been largely associated with the small size of the fishes captured. While the diversity of food items in the stomachs of *M. undulatus* increased considerably with increasing fish size [suggesting adoption of the feeding pattern outlined by Roelofs (1954)], *L. xanthurus* of the sizes captured during this study maintained a high degree of food selectivity.

Fundulus similis

Only 2 size classes of *Fundulus similis* were captured (Fig. 5). The stomach contents of eight individuals less than 20 mm SL revealed that over 85% of the organisms ingested were harpacticoid copepods with the remainder being ostracods and insect larvae. *F. similis* larger than 20 mm SL continued to feed largely on harpacticoid copepods (over 75% of the food organisms identified), although the diversity of food items increased appreciably from that of the smaller size class (Fig. 5, Table 2). The presence of polychaetes, isopods and other larger organisms in the stomachs of *F. similis* larger than 20 mm SL may be associated with the ability of the larger fish to ingest those foods as a result of increased mouth size.

Harpacticoid copepods accounted for over 70% of the food items recovered from *Fundulus similis* stomachs during each season of the year (Fig. 5), although some seasonal variations in other organisms were apparent. Cyprid barnacle larvae were recovered from the stomachs of longnose killifish during the spring, summer and fall but accounted for more than 2% of the total abundance of food only during the summer. Similarly, terrestrial insects (adults, larvae and pupae) were consumed in appreciable numbers only during the summer and fall (Fig. 5). Polychaetes became increasingly common food items during the fall, winter and spring as the apparent availability of barnacle larvae and insects decreased. Isopods, while not consumed in appreciable numbers during the summer, accounted for 5% or more of the stomach contents of *F. similis* during the other 3 seasons of the year.

Fundulus similis collected at the Bolivar Peninsula marsh development site fed primarily on benthic organisms, although the presence of insect adults, barnacle larvae and a few other planktonic forms (Table 2) indicated that feeding was not restricted to the benthic community. *F. similis* appeared to be somewhat opportunistic in its feeding behavior, ingesting organisms that were commonly available rather than selecting specific types. Diener et al. (1974) examined the stomach contents of 2 *F. similis* captured from Texas estuarine waters and recovered oligochaetes and portunid crabs, neither of which were important in fish collected during the present study.

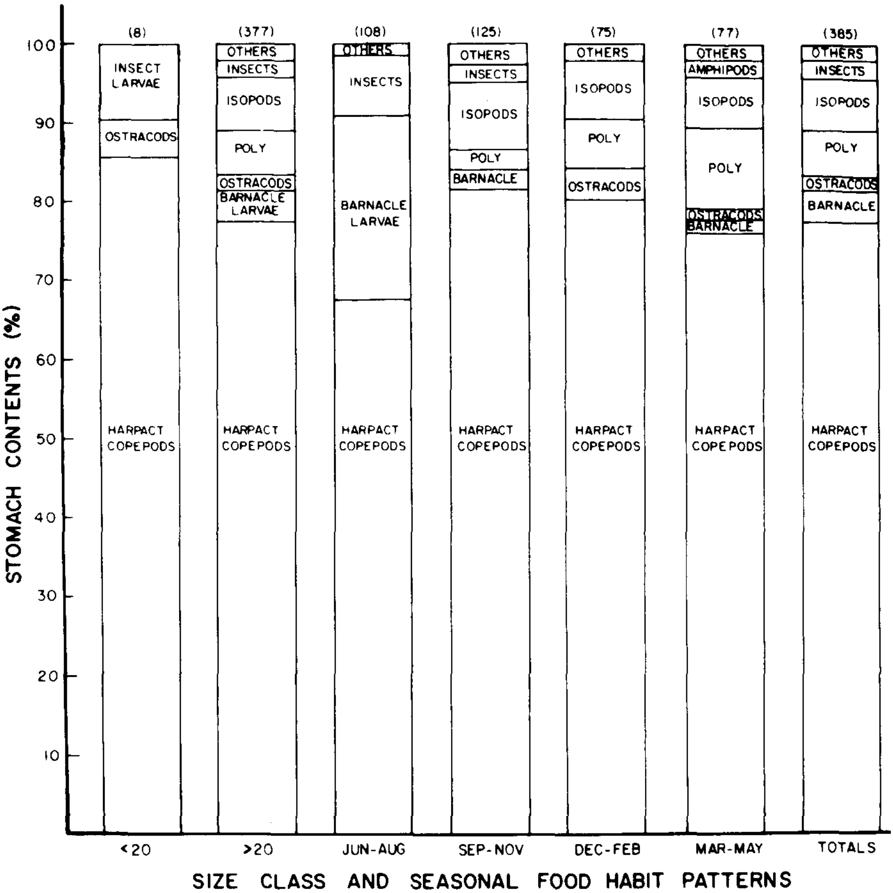

Fig. 5. Numerical abundance (percentage of total) of food organisms in the stomachs of *Fundulus similis* from two size classes and four seasons of the year. (Numbers in parentheses above each bar indicate the number of food-containing stomachs examined.)

Cyprinodon variegatus

Over 70% of the 341 *Cyprinodon variegatus* collected at the Bolivar Peninsula marsh development site contained food (Table 1). Unidentifiable organic matter and sand were present in virtually every individual, although identifiable food organisms were recovered from fish of both size classes (smaller and larger than 20 mm SL) and during every season of the year, except summer (Fig. 6). *C. variegatus* were less dependent upon either pelagic or benthic copepods as a primary food item than were any of the other fishes discussed thus far. Of the copepods recovered from the stomachs of *C. variegatus*, all were harpacticoids (Table 2, Fig. 6). Harpacticoid copepods exceeded 30% of the total number of food organisms recovered in fish larger than 20 mm SL and during the fall. Foraminifera were important in sheepshead minnows of both size classes and in fish captured during the fall. Insects were present in the stomachs of fishes larger than 20 mm

SL, and were important only during the winter, unlike the pattern established in *Fundulus similis* where insects were important only during summer and fall (Fig. 5).

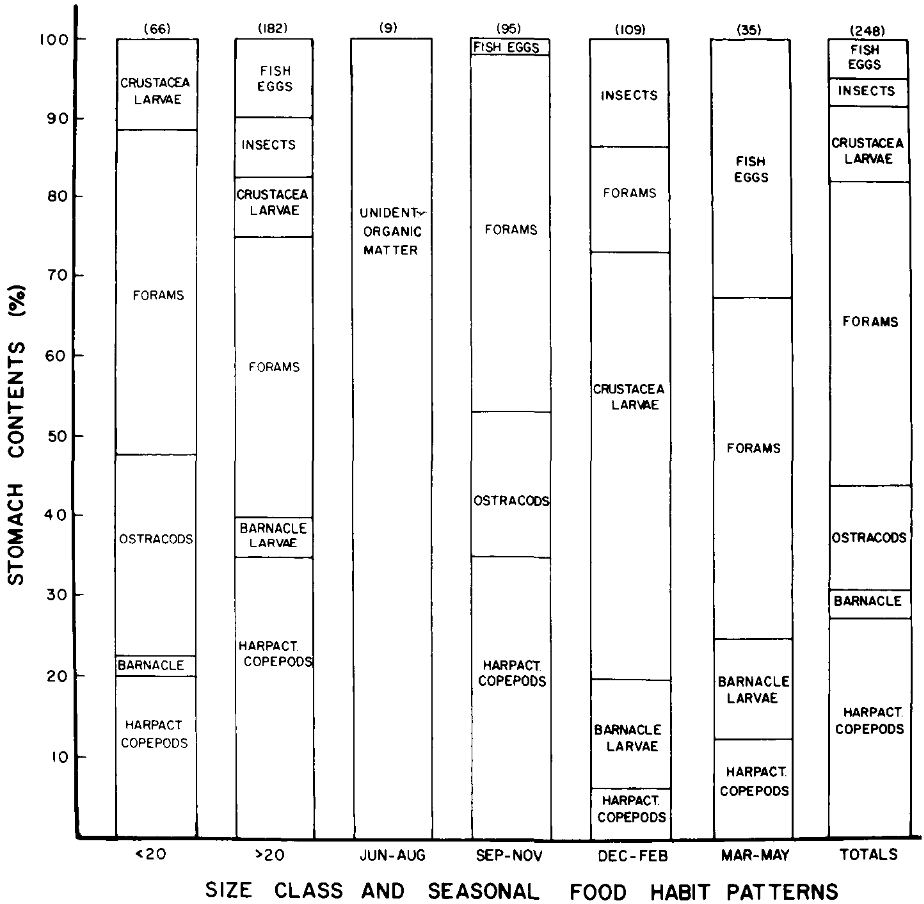

Fig. 6. Numerical abundance (percentage of total) of food organisms in the stomachs of *Cyprinodon variegatus* from two size classes and four seasons of the year. (Numbers in parentheses above each bar indicate the number of food-containing stomachs examined.)

Odum and Heald (1972) examined the food habits of *Cyprinodon variegatus* in a Florida mangrove community and concluded that sheepshead minnows fed predominantly on detritus. These authors discovered that algae, harpacticoid copepods and small arthropods were the most commonly identifiable food items. Hildebrand and Schroeder (1928), Reid (1954) and Springer and Woodburn (1960) all found detritus, algae and sand to be the most abundant items in the stomachs of *C. variegatus*. Harrington and Harrington (1961) reported that *C. variegatus* would consume mosquitos if available. Our findings indicated that *C. variegatus* associated with the Bolivar Peninsula marsh development site consumed a great deal of detritus, but that the diversity of identifiable organisms was also high. Similar to the findings of Odum and Heald (1972), our study indicated that *C. variegatus* consumed harpacticoid copepods and a variety of small arthropods. The relatively high percentage of foraminifera in the stomachs of *C. variegatus* in Galveston Bay has not been reported in other studies on this species.

Menidia beryllina and *Membras martinica*

Menidia beryllina and *Membras martinica* captured at the Bolivar Peninsula marsh development site all exceeded 20 mm SL and were available for collection throughout the year (Fig. 7). Food habits varied considerably on a seasonal basis with the stomach contents being fairly evenly divided among harpacticoid copepods, barnacle larvae and

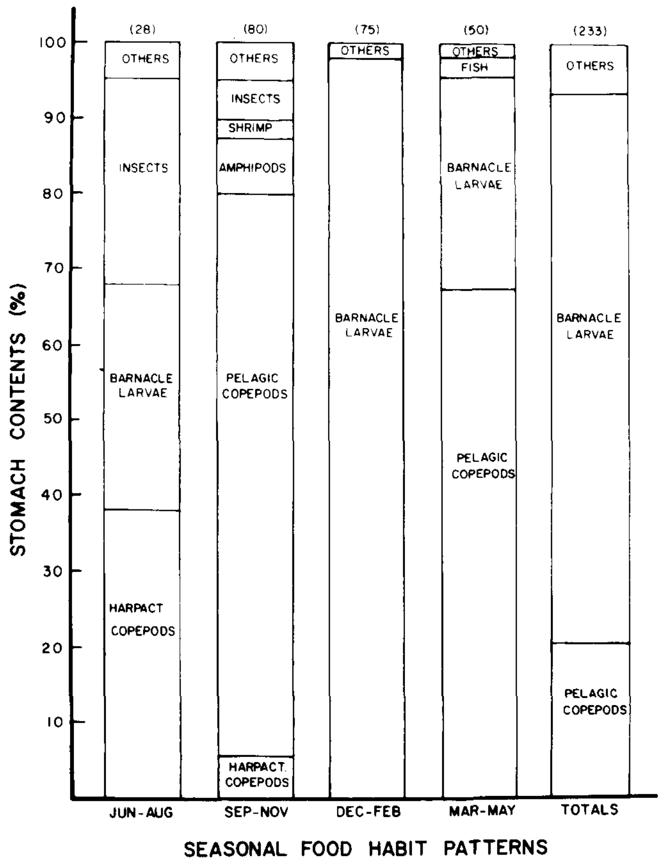

Fig. 7. Numerical abundance (percentage of total) of food organisms in the stomachs of *Menidia beryllina* and *Membras martinica* greater than 20 mm SL during each season of the year. (Numbers in parentheses above each bar indicate the number of food-containing stomachs examined.)

insects during the summer. Pelagic copepods were important during the fall and spring, while barnacle larvae dominated the stomach contents during the winter. Annually, pelagic copepods and barnacle larvae were the most important food items, with other organisms accounting for only about 5% of the total. *M. beryllina* and *M. martinica* appeared to feed nearly equally between the benthic and zooplanktonic communities, and appeared to be fairly selective in their food habits as demonstrated by the small numbers of polychaetes and other benthic forms (Table 2, Fig. 7). Benthic organisms, present in relatively high numbers, included juvenile penaeid shrimp and shrimp mysids, amphipods and harpacticoid copepods, all of which could be selectively ingested.

Dixon (1974) conducted a study on the food habits of both *Menidia beryllina* and *Membras martinica* in Upper Galveston Bay, TX, and determined that both were opportunistic omnivores. He found that small (less than 50 mm) *M. beryllina* fed primarily on the pelagic copepod *Acartia tonsa*, copepod nauplii, polychaetes and harpacticoid copepods, while *M. martinica* of the same size class fed on *A. tonsa*, copepod nauplii, insects, algae and invertebrate eggs. Larger *M. beryllina* were found to feed on insects, polychaetes and small fish while *M. martinica* larger than 50 mm fed primarily on insects and insect larvae. Dixon (1974) found that both species had late morning feeding peaks and that *M. beryllina* also demonstrated a late afternoon peak in feeding activity. Odom and Heald (1972) reported that 74% of the *M. beryllina* stomachs examined during the daytime in a Florida study were empty while most were full at night. Insects, insect larvae and copepods dominated the stomach contents during the day and mysids along with some copepods and amphipods were dominant in night samples (Odum and Heald 1972). Samples from the Bolivar Peninsula marsh development site were obtained during both day and night but were pooled for evaluation, thus no distinction in the feeding behavior patterns at these two times of day was possible.

Other studies of *Menidia beryllina* have demonstrated that planktonic crustaceans are heavily relied upon as a food source, with the dominant organisms being pelagic copepods. Insects and insect larvae also seem to be important in fishes collected from marshland habitats (Hildebrand and Schroeder 1928, Reid 1954, McLane 1955, Springer and Woodburn 1960). In addition to copepods, isopods and amphipods were found to be important food in studies conducted by Darnell (1958, 1961). Harrington and Harrington (1961) determined that copepods were the dominant food of *M. beryllina* in subtropical waters. Veliger larvae were found to be important as food for this fish in the size range 11 to 48 mm by Carr and Adams (1973) who also found copepods, cyprid barnacle larvae, crab megalops, mysids and insect larvae in the stomachs of fish examined.

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