The Journal of the Elisha Mitchell Scientific Society, 113(4), 1997, pp. 171–182

DIEL FEEDING PERIODICITY OF ATLANTIC SILVERSIDE, *MENIDIA MENIDIA*, IN THE YORK RIVER, CHESAPEAKE BAY, VIRGINIA

HOLLY SPRAKER[1] and HERBERT M. AUSTIN

School of Marine Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, VA 23062

Abstract: The feeding habits of the Atlantic silverside, *Menidia menidia*, were examined over a 24 hr period on 20–21 July 1994 at Gloucester Point, Virginia, U.S.A. Most active feeding took place during daylight, as indicated by an index of stomach fullness, but feeding continued all night. The principle daylight forage components were unidentified material followed by plants, crustaceans, and insects, as indicated by an Index of Relative Importance (IRI). When unidentified material was excluded, nocturnal feeding became more important. Important nocturnal prey included horseshoe crab larvae, crustaceans (barnacle cyprids and copepods), polychaetes, and winged ants. Absence of crab zoea and mysids was also considered important. The silverside, reported as a visual diel feeder, can also be an opportunistic nocturnal predator feeding on transient concentrations of larval arthropods.

Key Words: Silverside; *Menidia menidia;* feeding periodicities; horseshoe crab larvae; *Limulus;* barnacle larvae; shore zone fishes; diel foraging; Index of Relative Importance.

INTRODUCTION

The Atlantic silverside, *Menidia menidia*, is an Atlantic estuarine shore fish found from Canada to northern Florida (Kendell, 1901; Hildebrand and Schroeder, 1928; Bayliff, 1950; Bigelow and Schroeder, 1953; Lucas, 1985; Warkentine and Rachlin, 1989). It is the most common of several Atlantic coast *Menidia* species and is found in all saline regions of the Mid-Atlantic coast where it feeds on small crustaceans and polychaetes (Mulkana, 1966; Morgan, 1989, 1990; McDermott, 1983). *M. menidia*, in the Chesapeake Bay, is reported to be an omnivore feeding on small crustaceans, worms, insects, and algae (Hildebrand and Schroeder, 1928). The authors cited above summarize that during summer the silverside is an opportunistic surface oriented shore-zone feeder, and spatial variations in diet are generally the result of habitat differences (sandy beach, mud shore, and marsh grass). Atlantic silversides move off-shore in the winter where the diet becomes more dependent upon the benthos (Warkentine and Rachlin, 1989). Several authors have reported changes in food habits with changes in size (Mulkana, 1966; Austin, 1973; Cadigan and Fell, 1985; Morgan, 1990), but nothing is known of diel patterns of feeding (Mulkana, 1966). This study determines the diel vari-

[1] Current Address: Department of Biology, College of William and Mary, Williamsburg, VA 23185.

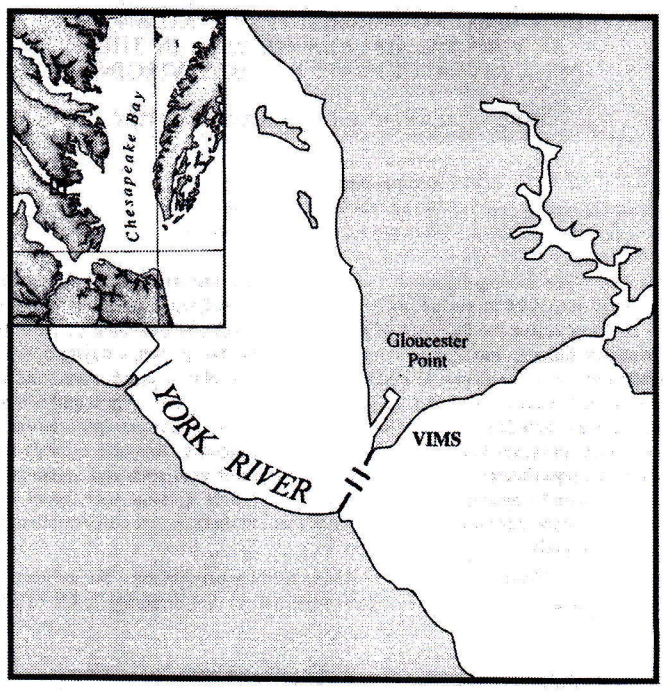

FIG. 1. VIMS Beach, York River, Gloucester Pt., VA, U.S.A.

ability in feeding activity, and stomach contents over a 24-hr diel cycle and two concurrent tidal cycles.

METHODS

Samples were collected with a 15 × 1.5 m beach seine (6 mm mesh) on a sandy York River beach at the Virginia Institute of Marine Science, Gloucester County, VA at 1500, 1945, 0015, and 0645 hr on 20–21 July 1994 (Fig. 1). Three hauls were made during each time period. All silversides were collected and placed in a 10% formaldehyde solution. Other species were returned to the water. Water temperature and salinity were recorded.

Following preservation for 24 hrs in formaldehyde the samples were soaked for six to 12 hrs in freshwater and re-preserved in 40% alcohol. All fish were weighed (0.01 g) on an electric balance, fork length measured (0.1 mm) with Vernier calipers, and the stomach excised. No attempt was made to sex the fish. The stomach contents were removed and weighed to the nearest 0.001 g. Individual prey items, identified under a dissection scope to the lowest possible taxon,

were weighed and counted. In some cases very small items were measured in a group according to prey type or taxon.

Data were formatted on a PC spread sheet for analysis. An index of fullness was computed from the ratio of the stomach content weight to the weight of the fish. The ratios were multiplied by 10^5 to make them whole numbers.

An index of relative importance (IRI) was computed for the individual gut contents to estimate the contribution of major food groups to the diet (Pinkas et al, 1971; Manooch and Mason, 1983; Ruderhausen, 1994). It accounts for the weight (or volume) of each prey category, its numerical abundance, and the frequency or number of times in occurs in all stomachs examined. The index is expressed as: IRI=(N + W)F, where N = numerical count, W = the weight (g), and F = the frequency of occurrence.

RESULTS

Silverside stomachs contained the most food during mid-afternoon (Index = 65.3), then decreased from mid-afternoon through sunset (38.9), and midnight (22.8), reaching lowest levels at sunrise (17.0). Unidentified material and sand were the dominant stomach contents (Table 1, Fig. 2). Of the identifiable contents, barnacle larvae (cyprids) and horseshoe (*Limulus*) crab larvae were most important, being found in 14 and 13% of the fish and comprised 14 and 18% of the diet weight respectively, and ranked first (%IRI=26%) and second (%IRI=17%) in the diet (Table 1). Copepods, mostly harpacticoids, ranked third among identifiable stomach contents (%IRI=14). Flying ants, probably swarming and having dropped on the surface of the water, were found in 10% of the fish (%IRI=6). Grammarid amphipods and polychaetes (*Glycera*) had a %IRI of 3.

Diel variations

Examination of stomach contents (%IRI, Fig. 3), over the four sampling periods, showed that the most striking feature was the dominance of unidentified material (%IRI=91, Table 2) in the guts during the 1500 hr sample, followed by plant material (%IRI=7), insect parts, *Limulus*, and amphipods (Table 2). Barnacle cyprids and copepods dominated during the early evening (1945) sample (67%, Table 3). Their importance continued through the night (0015 hr) when *Limulus* and the polychaete, *Glycera*, became the most important contents (%IRI=55% and 14%, respectively; Table 4). Horseshoe crab larvae and crustaceans were no longer as important, by sunrise (0645 hr), having been replaced by flying ants (%IRI=37) (Table 5).

DISCUSSION

M. menidia is an omnivorous visual feeder. The fullness index indicates feeding activity appears to be greatest during daylight, decreasing after dark. The high fullness index at 1500 hr, results from the large volume of amorphous unidentified material, at least some of which was benthic diatoms and jellyfish, in 15 of the 16 stomachs examined. Discounting this unidentified material, vascular plants became the dominant daylight food along with only a few additional crustaceans and horseshoe crab (*Limulus*) hatchlings. Barnacle cyprids, hatchling *Limulus*, and copepods became significant dietary components after dark, not only in numbers but in frequency of occurrence.

Table 1. Index of Relative Importance (IRI) for all samples 1500 20 July–0645 21 July 1994, VIMS Beach, Gloucester Pt., VA, N = 104.

Item	F	%F	N	%N	W	%W	IRI	%IRI
Unidentified	24	23	24	17	0.17	30	580	30
Limulus (hatchlings)	13	13	25	17	0.10	18	326	17
Crustaceans								
Barnacles (cyprids)	14	13	37	26	0.08	14	519	26
Copepods	12	12	23	16	0.03	5	276	14
Amphipods	8	8	7	5	0.05	9	56	3
Isopods	2	2	2	1	0.02	4	4	<1
Mysids	1	1	1	1	0.01	2	1	<1
Crustacean parts	3	3	3	2	0.01	2	9	<1
Insects								
Flying ants	10	10	11	8	0.03	5	110	6
Unidentified parts	1	1	1	1	0.01	2	1	<1
Polychaetes								
Glycera	8	8	8	5	0.03	5	64	3
Pelecepods	1	1	1	1	0.01	2	1	<1
Plant material	7	7	2	1	0.02	4	14	1
Totals	104	100	145	100	0.57	100	1963	100

F = Frequency of occurrence; N = number (count); W = weight.

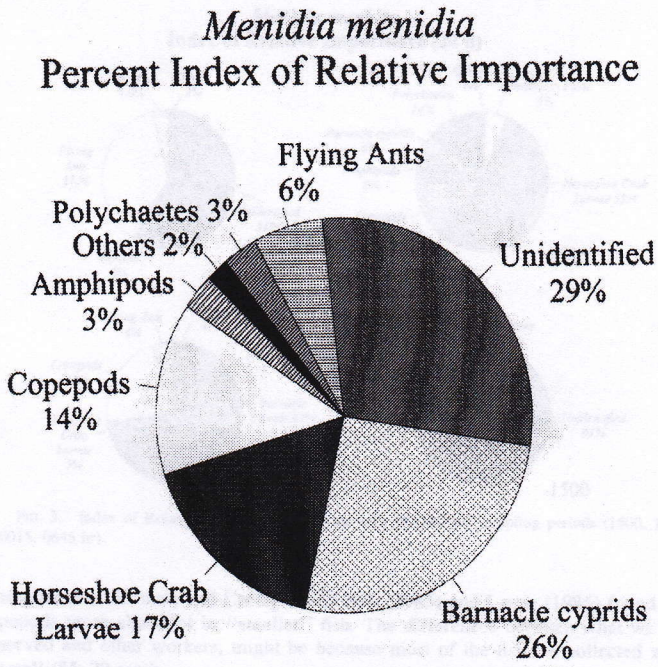

FIG. 2. *Menidia menidia* stomach contents expressed as an Index of Relative Importance (IRI).

The larval *Limulus* ingested were undoubtably swarming after escaping their nests. Rudloe (1979) reported that *Limulus* larvae hatch and emerge from supralittoral nests on nocturnal summer spring tides, when they exhibit a "... strong nocturnal activity rhythm." The July full moon in 1994, and resultant spring tide, was 22 July. The highest IRI (%IRI=55%) was measured at 0015 h, three to four hours after the high tide, and at the time of our first sampling after the high tide.

Similar to the *Limulus* larvae, barnacle cyprid larvae are photonegative (Crisp and Ritz, 1973) and can be found in swarms near the surface at night. Such behavior would bring them into the same nocturnal habitat as the silverside. Our findings might be the result of this cyprid behavior. Insects, copepods, and mysids were the other most important prey, and this was consistent with that reported by Mulkana (1966), Austin (1973), Cadigan and Fell (1985), and Lucas (1985). Winged ants often swarm on still summer nights, some falling on the water surface, which accounts for their nocturnal presence in the food contents.

We found no size relationship between predator and prey in this study. Mulkana (1966), on the other hand found undifferentiated *Balanus* larvae were more common in *Menidia* over 80 mm, and that benthic diatoms were most common in smaller fish. Morgan (1990) found barnacle larvae were more common in *Menidia*

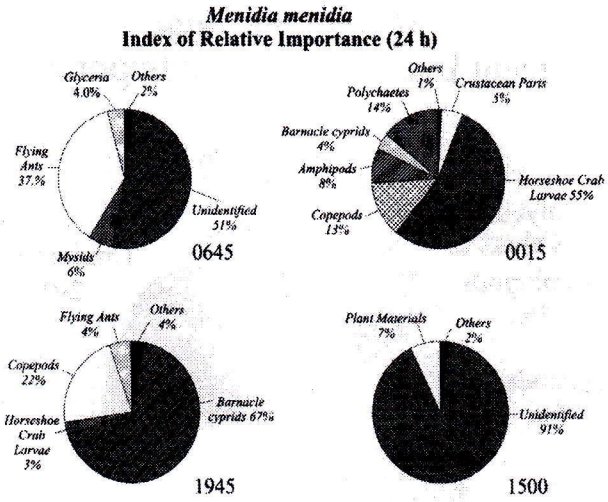

FIG. 3. Index of Relative Importance (IRI) for each of the four sampling periods (1500, 1945, 0015, 0645 hr).

smaller than 55 mm; and Cardigan and Fell (1985) and Lucas (1985) found copepods more abundant in "smaller" fish. The differences between what we observed and other workers, might be because most of the fish we collected were small (55–70 mm).

Of equal significance to the abundance of barnacle and horseshoe crab larvae was the absence of mysids and other estuarine crab larvae, particularly smaller zoea stages. Studies by Morgan (1989, 1990) suggested that the morphology of the zoea, with their carapace spines, make them undesirable prey to the silverside. He also suggested that "poorly-defended zoea," those with no spines, *Uca* for example, hatch on nocturnal spring tides to take advantage of strong spring ebb tidal currents to avoid planktivorous fishes. While this latter point may be true, it does not appear to be applicable to horseshoe crab larvae.

Mysids have been reported as important constituents of the silverside diet (Mulkana, 1966; Austin, 1973; Cadigan and Fell, 1985; Lucas, 1985). Few were found, although we have collected them from silverside stomachs in other shore areas (Spraker, 1994). Lasiak (1983) and Lasiak and McLachlan (1987) found that the mysid shoaling behavior in a dynamic environment produces short-term, patchy concentrations of mysids to shore-zone fishes. This causes heavy predation by some fishes, while other fishes miss the shoals completely (Wooldridge, 1983). Lasiak (1983) suggested that the patchy schooling behavior of prey organisms, and the patchy distribution of some surf-zone fishes, makes their role as energy transformers an opportunistic event.

There was no apparent relation between feeding and tidal stage since the sampling was designed around the 24 hr diel clock, and we did not sample appropriate

Table 2. Index of Relative Importance (IRI) 1500, 20 July 1994, N = 23.

ITEM	F	%F	N	%N	W	%W	IRI	%IRI
Unidentified	15	65	15	62	0.13	27	226.9	91
Limulus (hatchlings)	1	4	2	8	<0.01	2	2	<1
Crustaceans								
Barnacles (cyprid)	0		0		0		0	
Copepods	0		0		0		0	
Amphipods	1	4	1.0	4	<0.01	2	1	<1
Mysidacea	0		0		0		0	
Isopods	0		0		0		0	
Crab zoea	0		0		0		0	
Crustacean eggs	0		0		0		0	
Crustacean parts	0		0		0		0	
Insects								
Flying ants	0		0		0		0	
Unidentified parts	1	4	1	4	0.01	2	1	<1
Polychaetes								
Glycera	0		0		0		0	
Pelecepods	1	4	1	4	<0.01	2	1	<1
Plant material	4	17	4	17	0.31	65	17	7
Totals	23	100	24	100	0.48	100	249	100

Table 3. Index of Relative Importance (IRI) 1945, 20 July 1994, N = 33.

ITEM	F	%F	N	%N	W	%W	IRI	%IRI
Unidentified	1	3	6	9	0.02	2	6	1
Limulus (hatchlings)	4	12	4	6	0.02	2	16	3
Crustaceans								
Barnacles (cyprid)	11	33	33	49	0.43	57	368	67
Copepods	8	24	15	22	0.20	27	122	22
Amphipods	2	6	2	3	0.05	6	4	<1
Mysidacea	0		0		0.00		0	
Isopods	2	6	2	3	0.01	2	4	<1
Crab zoea	0		0		0.01		0	
Crustacean parts	0		0		0.00		0	
Insects								
Flying ants	3	9	8	12	0.02	2	24	4
Unidentified parts	0		0		0.00		0	
Polychaetes								
Glycera	0		0		0.00		0	0
Pelecepods	0		0		0.00		0	0
Plant material	2	6	2	3	0.01	2	4	<1
Totals	33	100	72	100	0.75	100	547	100

Table 4. Index of Relative Importance 0015, 21 July 1996, N = 30.

ITEM	F	%F	N	%N	W	%W	IRI	%IRI
Unidentified	1	3	1	2	<0.01	6	1	<1
Limulus (hatchlings)	7	23	20	41	0.07	48	141	55
Crustaceans								
Barnacles (cyprid)	3	10	4	8	0.01	6	12	5
Copepods	4	13	8	16	0.01	4	32	13
Amphipods	5	17	4	8	0.01	5	20	8
Crustacean parts	3	10	3	6	0.01	5	9	4
Mysidacea	0		0		0.00		0	
Isopods	0		0		0.00		0	
Crab zoea	0		0		0.00		0	
Crustacean eggs	0		0		0.00		0	
Insects								
Flying ants	1	3	3	6	0.01	7	3	1
Unidentified parts	0		0		0.00		0	
Polychaetes								
Glycera	6	20	6	12	0.03	19	36	14
Pelecepods	0		0		0.00		0	
Plant material	0		0		0.00		0	
Totals	30	100	49	100	0.15	100	253	100

Table 5. Index of Relative Importance (IRI) 0645, 21 July 1996, N = 18.

ITEM	F	%F	N	%N	W	%W	IRI	%IRI
Unidentified	7	39	7	39	0.02	<1	49	51
Limulus (hatchlings)	1.0	6	1.0	6	0.01	<1	1	1
Crustaceans	0		0		0.00		0	
Barnacles (cyprid)	0		0		0.00		0	
Copepods	0		0		0.00		0	
Amphipods	0		0		0.00		0	
Crustacean parts	0		0		0.00		0	
Mysidacea	1	6	1	6	5.00	99	6	6
Isopods	0		0		0.00		0	
Crab zoea	0		0		0.00		0	
Crustacean eggs	0		0		0.00		0	
Insects								
Flying ants	6	33	6	33	0.01	<1	36	37
Unidentified parts	0		0		0.00		0	
Polychaetes								
Glycera	2	11	2	11	0.00	<1	4	4
Pelecepods	0		0		0.00		0	
Plant material	1	6	1	6	0.00	<1	1	1
Totals	18	100	18	100	5.04	100	97	100

high/low tidal stages. Also, the sandy beach environment at Gloucester Point may not fluctuate sufficiently between high and low water for a recognizable variation in silverside diet to be evident. The large number of horseshoe crab larvae eaten just after the nocturnal high tide however, may have been the result of the coincidence of a spring high tide and their hatchling lunar cycle. Nocturnal full moon feeding by *M. menidia* on transient crustacean shoals composed of meroplanktonic larval barnacles, horseshoe crabs, or winged ants, demonstrated the importance of opportunism in a plastic dynamic trophic environment such as the shore-zone.

Acknowledgments: The authors wish to acknowledge the Virginia's Governor's School program and Ms Lee Larkin for support to the first author during a mentorship at the Virginia Institute of Marine Science during the summer of 1994. Ms Meghan Cropper, College of William and Mary, assisted with the field study and parts of the laboratory analysis. Dr. David Evans provided statistical council. The authors wish to acknowledge Richard Holmquist and Lance Garrison for a critical review of the manuscript. VIMS Contribution No. 2100.

REFERENCES CITED

AUSTIN, H., J. DICKINSON, AND C. HICKEY. 1973. An ecological study of the ichthyofauna at the Northport Power Station, Long Island, New York. Final Contract Rept to LILCO, 248 p.

———. 1996. Observations on daylight feeding periodicities of wading birds (Ardeidae) in Sarah's Creek, York River, Virginia. J. Elisha Mitchell Sci. Soc., **111**(3):137–145.

BAYLIFF, W. 1950. The life history of the silverside, *Menidia menidia*, (Linnaeus). Ches. Biol. Lab. Publ. 90, 25 p.

BIGELOW, H. B., AND W. S. SCHROEDER. 1953. *Fishes of the Gulf of Maine*. Fish. Bull. No. 74, Vol. 53. Wash. DC. 577 p.

CADIGAN, K., AND P. FELL. 1985. Reproduction, growth and feeding habits of *Menidia menidia*, in a tidal marsh estuarine system in southern New England. Copeia **1986**:21–26.

CRISP, D., AND D. RITZ. 1973. Responses of Cirripede to light. Part I, Experiments with white light. Mar. Biol. **23**:327–335.

HILDEBRAND S., AND W. SCHROEDER. 1928. Fishes of Chesapeake Bay, 1972. Vol. 53, pt 1, IV, U.S. Bur. Fish. Bull., Doc. 1024, Smith. Inst. Press, Wash., DC. 388 p.

KENDALL, W. 1901. Notes on the silversides of the genus *Menidia* of the east coast of the United States, with descriptions of two new sub-species. Rept. U.S. Fish. Comm. **1901**:241–267.

LASIAK, T. 1983. The impact of surf-zone fish communities on faunal assemblages associated with sandy beaches. Pp. 501–506 in McLachlan, A. and T. Erasmus (eds.), Sandy beaches as ecosystems. Junk, The Hague.

———, AND A. MCLACHLAN. 1987. Opportunistic utilization of mysid shoals by surf-zone teleosts. Mar. Ecol. Prog. Ser. **37**:1–7.

LUCAS, J. 1985. Feeding ecology of Gulf silversides, *Menidia peninsulae*, near Crystal River, Florida, with notes on the life history. Estuaries **5**:138–144.

MANOOCH, C. S., AND D. L. MASON. 1983. Comparative food studies of yellowfin tuna, *Thunnus albacares*, and blackfin tuna, *Thunnus atlanticus*, from the southeastern and gulf coast of the United States. Brimleyana. No. **9**:33–52.

MCDERMOTT, J. 1983. Food web in the surf zone of an exposed sandy beach along the Mid-Atlantic coast of the United States. Pp. 529–538 in McLachlan, A. and T. Erasmus (eds.), Sandy beaches as ecosystems. Junk, The Hague.

MORGAN, S. 1989. Adaptive significance of spination in crab zoeae. Ecology **70**:464–482.

———. 1990. Impact of planktivorous fishes on dispersal, hatching, and morphology of estuarine crab larvae. Ecology **71**:1639–1652.

MULKANA, M. S. 1966. The growth and feeding habits of juvenile fishes in two Rhode Island estuaries. Gulf Res. Repts. **2**(2):97–167.

PINKAS, L., M. S. OLIPHANT, AND I. L. K. IVERSON. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Dept. Fish Game Bull. **152**:1–105.

RUDERSHAUSEN, P. J. 1994. Food, feeding, and length-weight relationships of young-of-the-year striped bass. *Morone saxatilis* and young-of-the-year white perch, *Morone americana*., M.A. Thesis, Sch. Mar. Sci., Va. Inst. Mar. Sci., Coll. William Mary, 118 p.

RUDLOE, A. 1979. Locomotor and Light response of larvae of horseshoe crab, *Limulus polyphemus* (L). Biol. Bull. 157:494–505.

SPRAKER, H. 1994. Spatial and temporal variations in the feeding habits of Chesapeake Bay area *Menidia menidia*. Final Rept., Va. Governor's School for Mar. Sci., Sch. Mar. Sci., Va. Inst. Mar. Sci., Gloucester Pt., VA, 31 p.

WARKENTINE, B., AND J. RACHLIN. 1989. Winter offshore diet of the Atlantic silverside, *Menidia menidia*. Copeia 1989(1):195–198.

WOOLDRIDGE, T. 1983. Ecology of beach and surf-zone mysid shrimps in the eastern Cape, South Africa. Pp. 449–460 in McLachlan. A. and T. Erasmus (eds.), Sandy beaches as ecosystems. Junk, The Hague.

Received 24 July 1997