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Diel Feeding Patterns, Gastric Evacuation Rate and Diets of the Mullet, *Valamugil seheli* (Forskal) in the Mulki Estuary, West Coast of India

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Abstract

Diel feeding chronology of the mullet, *Valamugil seheli* was examined from stomach collections taken in the months of April ’99, July ’99 and December ’99 in the Mulki estuary along the southwest coast of India. Significant differences in mean stomach content weight were found between several consecutive 3 h periods with peak fullness occurring in early morning and evening hours. The rates of gastric evacuation of natural food (decayed organic matter, diatoms, algae and fine sand grains) were measured in the field. Ninety percent evacuation of wet weight contents required an estimated 8.0 h at a temperature of 28.5 ±1.2°C. Stomach content analysis indicated that this species is a herbivore, feeding mainly on decayed organic matter, diatoms, algae and sand grains. Smaller sized fishes preferred higher quantities of decayed organic matter, diatoms and algae and lesser quantity of sand grains compared to bigger sized fishes. The feeding activity of *V. seheli* was influenced by the tidal cycle.

Introduction

Fishes belonging to the family Mugilidae (Order: Mugiliformes) commonly known as grey mullets have a wide distribution in the tropical and subtropical regions. Twenty seven species of grey mullets have been reported from India, of which thirteen species are commonly caught (Luther 1967). Along the Karnataka coast, eight species of mullets are available of which *Valamugil seheli* is the most abundant. This species has a great potential for mariculture because of its ability to feed directly on the first trophic level, its faster growth rate and higher market price. The possibility of culturing this species has been reported by James et al. (1984) in the coastal waters of Karnataka.

Although the details of food habits of grey mullets in estuarine waters have been examined in several studies (Sarojini 1954, Das 1977, Babu & Neelakantan 1983), there have been few studies on the detailed aspects of when and how much food may be consumed by a foraging juvenile grey mullet during the diel period. The purpose of the present study is to describe the diel cycle of feeding, gastric evacuation rate and feeding habits of grey mullets in a tropical estuary.

Materials and Methods

Diel feeding pattern

Experiments were conducted in the Mulki estuary, on the west coast of India during three different seasons viz., pre monsoon (April'99), monsoon (July'99) and post monsoon (December'99). Sampling was conducted in 6 different 24 h sampling periods at different locations in the estuary using a cast net and seine net (Table 1). Between 8 to 13 collections were made during each 24 h sampling period. Surface water temperatures were measured during each sampling.

Grey mullets were sorted from the catch and their total length and weight were measured to the nearest millimeter and nearest 0.1 g respectively after removal of excess water. The stomach contents were excised and the contents were weighed to the nearest 0.01 g and preserved for later analysis. A fullness code between 0 (empty) and 5 (full distanded stomach) was assigned to each stomach at the time of weighing as a measure of feeding intensity. In addition, the stomach contents were also expressed as percentage of body weight.

Estimation of evacuation rate

Juveniles of *V. seheli* (length 90±4.5 mm and weight 14±1.5 g) were obtained from the Mulki estuary during the early monsoon. Approximately 50 fish were placed in each of four nylon net hapas [(# 200 mm), 2 m x 1 m x 1 m)] fixed in a nearby brackishwater pond. They were maintained on natural feed (decayed organic matter, diatoms, algae and fine sand grains collected from the estuary) for 2 to 3 weeks before being used in the experiments.

Prior to an experiment, fish were starved for 14 h to ensure empty stomachs and then fed on natural feed for 30 min, later fish were transferred to food free hapas. A random subsample of 16 fish (a maximum of 4 fish from

Table 1. Sampling dates, number of time periods and number of stomachs included for each 24 h sampling period at Mulki estuary.

Date	Number of time periods	Number of stomachs
8 –9 April 1999	9	74
15 – 16 April 1999	12	66
14 – 15 July 1999	10	70
27 – 28 July 1999	8	88
9 –10 December 1999	13	58
21 – 22 December 1999	11	69

each hapa) were sacrificed immediately after feeding and the stomach contents and fish were weighed as stated earlier and the percentage of food recovered was determined. Dry weights were determined by placing the contents on preweighed aluminium foil at 80°C in an oven until they achieved a constant weight. This process was continued every 2 h until most of the stomachs sampled were empty.

Linear, exponential and square root models (Jobling 1981 & 1986) were used to describe the depletion of stomach contents with time in the evacuation experiment. The coefficient of determination (R^2) was used to evaluate the goodness of fit of the models. The data were statistically analyzed following one way ANOVA and Duncan Multiple range tests.

Qualitative and quantitative analysis

Fortnightly samples were collected from the Mulki estuary using cast net and seine nets to carry out the stomach content analysis from April 1999 to March 2000. The stomach contents were washed into a petridish and analyzed by the points (volumetric) method (Pillay 1952) taking into consideration the extent of fullness of stomach. Points were allotted for each food item based on its relative volume. From the volumes obtained for individual fish, monthly averages and percentages were worked out. The volume index, which is the percentage of volume of each food item, was calculated from the total points of all the food items over the whole period.

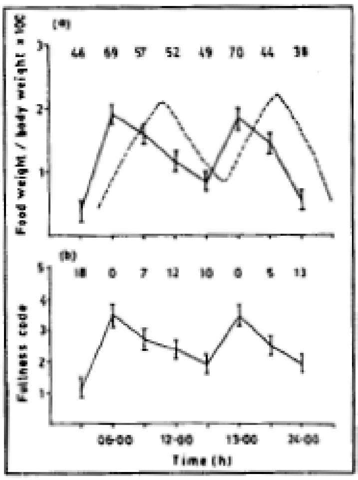

Fig. 1. The relationship between time of the day and (a) the amount of food in the stomachs of *V. seheli* expressed as percentage of wet body weight and (b) the fullness code. The number of stomachs examined in each period is given at the top of (a) and the percent of empty stomachs at the top of (b). The dotted lines indicate the tide.

Results

Diel feeding pattern

The results of the diel feeding activity are presented in figures 1a and 1b. To test for discontinuity in feeding, the sampling times were grouped into eight successive 3 h intervals after adjusting for minor differences in day length between the sampling periods. The stomach weight/body weight ratios were significantly different (one way ANOVA) over the eight intervals tested (Fig. 1a). Similar significant differences were noted for stomach fullness code (Fig. 1b). Feeding indices were generally high during early morning (5.30 to 6.30 h) and evening (17.30 to 18.30 h) hours with fewer empty stomachs. Fullness dropped off after dawn and dusk hours. The tidal cycle had an impact on the feeding intensity of *V. seheli*. The feeding activity of mullet increased with increasing high tide and then decreased with low tide.

Gastric evacuation rate

The mean wet and dry weight proportions of the initial meals recovered from the stomachs clearly decreased with time (Fig. 2). Although the linear model gave a significant fit for both wet and dry relationship, the F-test for linearity indicated that a nonlinear function was more appropriate for both relationships. The exponential model had the highest coefficients of determination for both the wet and dry weight relationships of the three models tested. (Table 2). This model also yielded fairly close approximations of the initial meal size. These fishes required about 8.0 h for the total evacuation of the stomach contents (Fig. 2). The values of the instantaneous rates of evacuation (r) and the time required for evacuation for the exponential model are given in table 3.

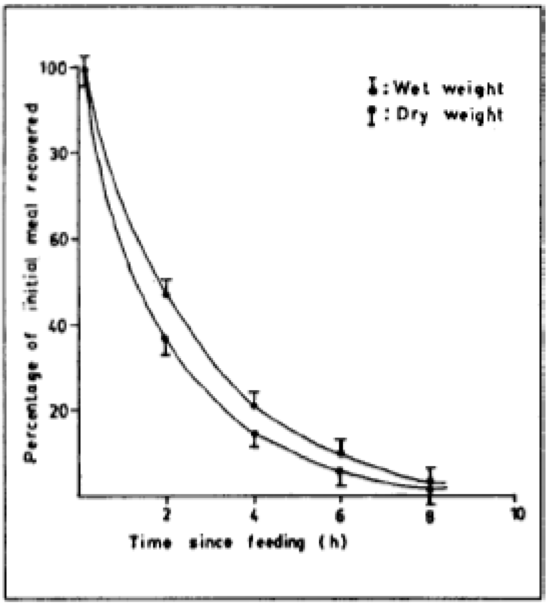

Fig. 2. Wet weight and dry weight recovered from the stomachs of *V. seheli* at each sampling interval.

Composition of the diet

The results of the monthly stomach content analyses are given in table 4. The most frequently occurring components in the diet of *V. seheli* were decayed organic matter, sand grains, diatoms, algae, miscellaneous matter and semidigested matter. Diatoms belonging to 31 genera were recorded. Of these,

Table 2. Regression coefficient for the depletion curves obtained using different models.

Food condition	Model	a(±S.D)	r(±S.D)	R^2	% intercept
Wet	Linear	82.60(±4.17)	0.193(±0.046)	0.85	82.60
	Exponential	4.702(±0.146)	0.007(±0.001)	0.99	
	Square root	9.333(±0.246)	0.017(±0.002)	0.96	
Dry	Linear	77.78 (±6.17)	0.189(±0.024)	0.78	77.78
	Exponential	4.635(±0.207)	0.006(±0.001)	0.99	
	Square root	8.966(±0.311)	0.017(±0.001)	0.93	

Table 3. The instantaneous rate of evacuation (r) and times to various stages of evacuation for the exponential model.

Food condition	r (h-1)(±S. D)	Time (h) to % evacuation		
		50	75	90
Wet	0.007 (±0.001)	1.88	3.53	5.71
Dry	0.006 (±0.001)	2.01	3.93	6.47

Table 4. Monthly percentage composition of different items of diet recorded in the stomachs of mullet *V. seheli*.

Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
No. of fish examined	116	128	132	148	161	122	138	118	106	133	112	122	1536
Stomachs with food	94	104	107	116	128	106	127	106	88	108	94	94	1272
Food item													Mean
1. Decayed organic matter	32.74	35.36	35.13	29.86	28.41	34.41	37.67	32.92	34.26	33.44	34.61	38.25	33.92
2. Sand particles	39.27	39.46	33.25	37.69	40.10	44.41	40.39	48.48	40.10	42.49	35.60	41.34	40.22
3. Diatoms	9.98	8.75	11.68	13.83	11.54	8.03	10.84	7.59	5.60	7.12	10.46	7.60	9.42
Amphora sp.	+	+	-	-	+	+	+	+	+	-	+	+	
Coscinodiscus sp.	+	+	+	+	+	+	+	+	+	+	+	+	
Navicula sp.	+	+	+	+	+	+	+	+	+	+	+	+	
Nitzschia sp.	+	+	+	-	-	+	+	+	+	+	+	+	
Pinnularia sp.	+	+	+	-	+	-	-	+	-	-	+	+	
Rhizosoe lenia sp.	+	+	-	+	+	+	+	+	-	+	+	+	
Synedra sp.	+	+	+	+	-	+	-	+	-	+	+	-	
4. Algae	4.92	4.77	7.77	6.95	7.99	3.49	3.87	4.88	6.44	7.00	9.25	4.36	5.97
Chlorococcus sp.	-	-	-	-	-	+	-	-	+	+	+	+	
Cosmarium sp.	+	+	+	-	-	+	+	-	+	+	+	+	
Merismopedia sp.	+	+	+	-	-	-	+	-	+	+	+	-	
Oscillatoria sp.	-	+	+	+	+	+	+	-	+	+	+	+	
Sphyrogira sp.	+	-	-	+	+	+	+	-	-	-	+	+	
5. Miscellaneous matter	3.75	3.52	3.55	4.46	4.18	4.77	3.82	3.84	4.96	4.15	3.54	3.80	4.03
6. Semidigested matter	9.35	8.16	8.62	7.22	7.79	4.91	3.43	2.28	8.63	5.80	6.56	4.67	6.49

Note : + : Present ; - : Absent.

Amphora sp., Coscinodiscus sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Rhizosolenia* sp., and *Synedra* sp. were abundant in most of the months and the rest of the diatoms were of secondary importance. Algae belonging to 21 genera were identified. The important algae were species of *Chlorococcus, Cosmarium, Merismopedia, Oscillatoria* and *Sphyrogira*. Bryozoa, Cladocerons, copepod remainings, crustacean remains, decapods, dragon fly nymphs, eggs, fish spines, foraminifera, gastropod larvae, ostracods, polychaete remainings, shell pieces, tintinids and leaf pieces were considered as miscellaneous matter. Only very fine sand grains appeared in the gut, invariably seen mixed with other types of food items. Decayed organic matter and sand particles constituted major portions of the diet.

Seasonal variation in diet

Decayed organic matter was highest in March and lowest in August. Higher quantities of sand appeared in November, September and January and lower quantities in June, February and July. Higher percentages of diatoms were observed in July, June and August, and lower percentages in January, November and March. The highest quantity of algae was in February and the lowest was in September. Miscellaneous matter and semidigested matter were recorded in all months in varying proportions. Higher feeding activity was observed from August to December, while lesser feeding activity was noticed during February to July.

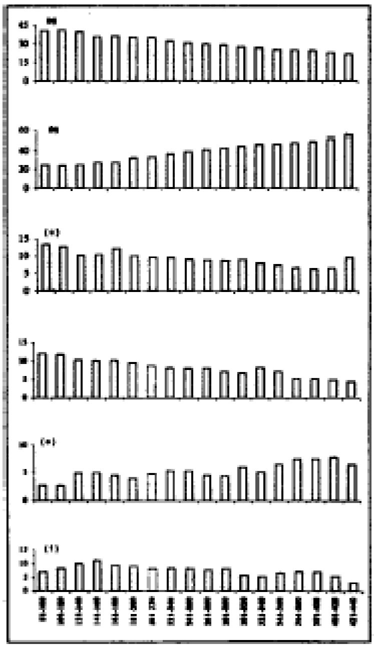

Fig. 3. Percentage occurrence of major food items in the stomachs of 20 mm size groups of *V. seheli* (a) decayed organic matter; (b) sand particles; (c) diatoms; (d) algae; (e) miscllaneous matter; (f) semidigested matter

Relationships between diet and fish size

The percentage occurrence of food types in the diet of 20 mm size groups is shown in figure 3. Decayed organic matter showed a decreasing trend with size, while sand grains showed an increasing trend. Diatoms and algae were found in higher proportions in the smaller size groups (<180 mm). Miscellaneous matter and semidigested matter were recorded in almost all the size groups in varying proportions.

Discussion

The results of the study suggest that the diel feeding behavior of juvenile mullets is characterized by two main feeding periods. The morning feeding period (dawn) begins before sunrise while the evening period (dusk) around sunset. Similarly, a direct relationship between the state of the tide and feeding intensity in *Mugil cephalus* was observed (Odum 1968). In contrary to the present study, there was no relation between the tidal rhythm and diel feeding pattern of *M. cephalus* inhabiting Negombo Lagoon (De Silva and Wijeyaratne 1977).

All three models fit to the data in the study. The exponential model provided the best fit to data obtained in the experiment with mullet at temperatures of 28.5±1.2°C. Although a number of factors including food particle size, food quality, meal size and in some cases predator size, have been shown to affect evacuation rates, temperature appears to be of paramount importance (Fange and Grove 1979, Durbin et al., 1983). Higher temperature can lead to substantially increased evacuation rates (Brett and Higgs 1970; Tyler 1970). One shortcoming of the exponential model is that the stomach contents would theoretically begin to level off when stomachs are nearly empty, but fullness never reaches zero. This leads to overestimates of the amount of food remaining in the stomach at the later stages of evacuation.

Qualitative and quantitative analyses of diet composition of *V. seheli* indicate that this species is herbivorous feeding mainly on decayed organic matter, diatoms, algae and sand grains. The preference for mullet for decayed organic matter may be due to various reasons. The presence of micro organisms such as bacteria and protozoans have been observed in decayed organic matter (Odum 1968; Webb 1973 and Moriarty 1976). Bacteria and protozoa could be helpful as a source of essential nutrients or by providing assistance for breakdown of plant materials (Oren 1971). As in most other species of grey mullets, *V. seheli* appears to browse on the substratum to gather the food. This is evident by the presence of large quantities of sand particles present in the diet, which may be helpful in the grinding of food particles in the thick-walled pyloric stomach which acts as a gizzard (Thomson 1966). It appears that the ingestion of large quantities of sand particles (coated with humus or decayed organic matter) may primarily be associated in deriving nutrients from the sand particle in addition to breaking the cell wall of the diatoms.

The considerable variations observed in the percentage occurrence of different food items may be attributed to factors such as seasonal variation in the abundance of food items, consumption rates, age of the fish and diurnal variation in feeding. The high percentage of decayed organic matter in September, October and December may be due to an abundance of this item in the environment after the southwest monsoon. Diatoms and algae were next in importance after decayed organic matter. It is well known that diatoms and algae occur in large quantities in estuaries and coastal seas (Tung 1971; Payne 1975). The seasonal variations in sand particles cannot be attributed to any particular factor as they are consumed along with other food items. The higher percentages of sand particles from August to January (during monsoon and post monsoon) could be attributed to the disturbance of the estuarine environment by fresh water inflow. High percentages of mud, sand and detritus in the gut of *Rhinomugil corsula* suggested that during the rainy season, the bottom flora in the environment gets disturbed by flood waters which hamper growth of planktonic food (Khan and Fatima 1994). The occurrence of sand grains further emphasizes the bottom feeding habit of the species. The semidigested matter consisted mostly of plant matter in advanced stages of digestion.

There was a direct relationship between sand particles and an inverse relationship between decayed organic matter and length of the fish. In *M. cephalus* from Negombo Lagoon, an increase in percentages of sand and detritus in the food was noticed with increasing size (De Silva and Wijeyaratne 1977). While, there was no change in diet in relation to length of *Liza macrolepis* and *Mugil cephalus* (Blaber 1977). An inverse relationship was observed in *V. spleigleri* between the decayed organic matter and sand grains in relation to the length of the fish (Baburaj 1987). The diatoms and algae were found relatively more in smaller size groups (<180 mm) than the larger size groups (>180 mm). The young ones of *M. cephalus* and *M. curema* feed on planktonic and benthic crustaceans, while the larger ones consume detritus, thus shifting their trophic level with growth (Coin and Dean 1976). It may be said that the variations in the diet of mugilids occur as they grow in different localities.

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