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The Relation of Algal Availability and Food Preferences in the Field Diet of the Equinoid *Echinometra lucunter* on a Rocky Shore in Southeast Brazil

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ABSTRACT

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The diet of herbivorous sea urchins in the field is often determined by algal availability, despite food preferences. This investigation aimed to establish possible temporal patterns and identify the relationhip between the gut contents of *Echinometra lucunter* and local algal community within a 210 m^2 area of a densely populated intertidal rock of the south shore of Peró beach, Vigia's islet, Rio de Janeiro. Fifteen seas urchins were collected monthly and qualitative determinations of algal species occurrence and visual estimates were recorded from May to October 2001. Algal species were ranked into morphological assemblages. Sea-urchins were dissected for the removal and analysis of the gut contents through the "Methodology of Contacts". The preference of a species as food item was given by Ivlev's electivity index. Both the gut contents and the local algal community revealed strong temporal fluctuations. *Echinometra lucunter* presented an essentially herbivorous feeding habit, grazing preferentially upon the available benthic algal species and to a lesser degree upon drift algal material. According to Ivlev's index, the filamentous and corticated foliose algae were the most preferred goups, while the corticated and crustose algae were highly avoided. The foliose corticated *Dictyota dichotoma* and the filamentous *Centroceras clavulatum Sphacelaria brachygonia*, *Ceramium tenerrimum* and *Polysiphonia ferrulacea* were clearly far more preferred as food, whereas *Laurencia obtusa*, *Colpomenia sinuosa*, Corallineacea and *Condracanthus spp.* were consistently rejected as food. The feeding behaviour of *E. lucunter* depends on algal availability, most likely following the temporal occurrence of algae species in the field.

ADDITIONAL INDEX WORDS: *Herbivory, algae assemblages*, *sea urchins.*

INTRODUCTION

The feeding preferences of sea urchins and their effects on benthic communities have been extensively studied in several habitats (PAINE and VADAS, 1969; LAWRENCE, 1975; AYLING, 1978; LAWRENCE and SAMMARCO, 1982). Sea urchins often determine the abundance and distribution of marine plants in shallow water marine environments (LAWRENCE, 1975).

Although sea urchins have preferences, the actual diets in the field are often determined by food availability (LAWRENCE and SAMMARCO, 1982 and authors therein). Selective feeding on a resource at a higher rate than it would be expected from its availability in the field determines food preference (CARPENTER, 1981). Also, food selection can be related to the ability of sea urchins to manipulate and eat their food (LAWRENCE, 1975). Thus sea urchins may select and consume their food in a non-proportional way regarding its availability in the field (JOHNSON, 1980).

Measures of algal availability in the field taken alone are of very limited interest to understand food selectivity, as selectivity and availability are highly interdependant (KREBS, 1989). In order to determine sea urchins food selection, an analysis of gut contents is required and the electivity rate of Ivlev can be applied (GIORDANO, 1986; KREBS, 1989; SOUZA, 1995). This allows for comparison between gut contents and local algal community.

Based on the idea that sea urchins may select their food in relation to food availability, we hypothesized that the algal fraction found in the gut contents of the regular sea urchin *Echinometra lucunter* correlates significantly with temporal fluctuations in algal species composition and dominance in the field. Therefore, this work aims: 1) to characterize the temporal fluctuations in algal composition and dominance on an intertidal rocky shore in southeastern Brazil and in the gut contents of the sea urchin *E. lucunter* found in the same area; and 2) to describe the relationship between gut contents and food availability.

METHODS

Study Area

This study was carried out on the northern rocky shore of Vigia's islet (22º46'S, 042º58'W) at Cabo Frio, Rio de Janeiro State, southeastern Brazil (Figure 1). The region of Cabo Frio is characterized by a rather strong coastal upwelling. This is one of the most important algal regions of the Brazilian coast in terms of its high species richness (YONESHIGUE-VALENTIN and VALENTIN, 1992).

The Vigia' s islet is not a true island, but it is connected to the continent. It is located between the beaches of Peró and Conchas.

The fieldwork was conducted on the highly wave-exposed rocky shore (200 m length) towards the beach of Peró (Figure 1).

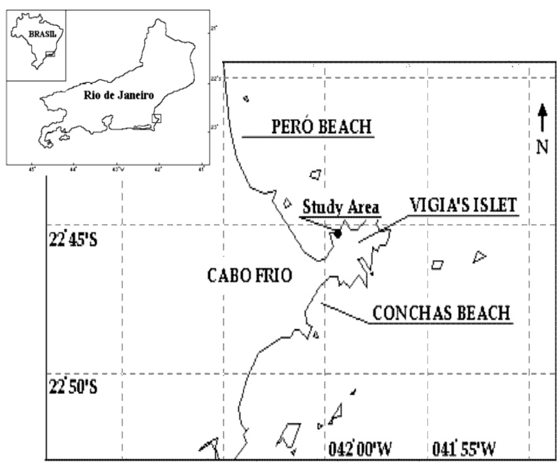

Figure 1. Study area. Vigia's islet at Cabo Frio region, Rio de Janeiro state, Brazil.

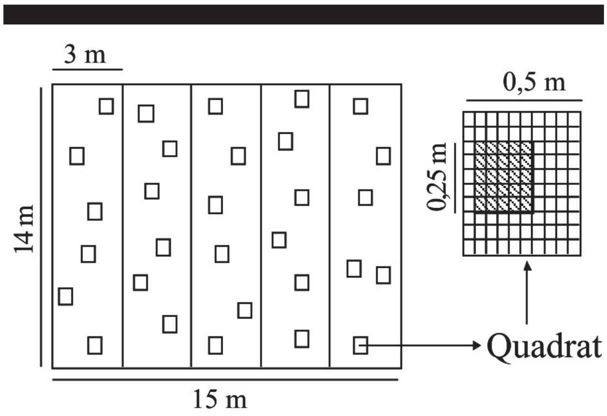

Figure 2. Sampling design performed on the highly exposed rocky shore at Vigia's isle at Cabo Frio.

The chosen study site was a less steep, workable 210 m^2 area (15 x 14 m) in the intertidal zone of this shore with tidal differences of approximately 1 m. This had the co-occurrence of sea urchin and algae, and had some evidence for grazing. The quadrats were sampled randomly but avoiding bare rock. As the objective of this work was to study the effect of algal composition on selectivity by the sea urchins, it seemed reasonable to assume the sea urchins migrate to where the food was more abundant avoiding the naked areas. Although not measured, it was visually observed the presence of sea urchins where there were algae.

Field Work

The fieldwork was carried out monthly from May to October 2001. The established study area was subdivided into 5 equal sub-areas (42 m^2). Each month algae occurrence and total substratum cover were recorded using a 0.25 m^2 quadrat (subdivided into 100 equal quadrats) placed once at random in each sub-area (Figure 2).

Algal turf in the area had an homogeneous appearance. Therefore, a turf area of 0.063 m^2 (within the 0.25 m^2 quadrat) was sub-sampled by scrapping it off from the substratum for further identification and quantification in laboratory.

Sea urchin abundance was estimated from the same 0.25 m^2 quadrat within each sub-area. Fifteen animals were collected each month, preserved in 4 % borax buffered formalin, and subsequently stored in 70% alcohol. These were used for gut contents identification in the laboratory.

Laboratory Methodology

The algae obtained from the field were preserved in 4 %, borax buffered, formalin and sorted into major taxonomic groups. Crustose coralline algae were identified to family level only. The remaining algae were identified to the species level. In order to compare food selection towards different algae associations, algae species were grouped into seven morphologic assemblages: filamentous, corticated, corticated foliose, foliose, leathery, articulated crustose and crustose algae. This classification was adapted from STENECK and DETHIER'S functional groups (1994), not only considering the morphologic but also the textural characteristics of algae.

Each sea urchin was dissected and the gut contents from the whole digestive tract were separated, homogenized and analyzed under an optical microscope using the "Methodology of Contacts" (BOUDOURESQUE and YONESHIGUE, 1987).

The relative abundance of each algal species in the diet of *E. lucunter* was expressed in terms of percentage of occurrence from the total number of contacts which allowed the comparison between the importance of the species as food and its dominance in the field (BOUDOURESQUE and YONESHIGUE, 1987; SOUZA, 1995).

The selectivity of a species as a food item is given by the index of Ivlev's electivity, adapted to consider the relative abundance of an algae in the diet (CC = contact counts) (SOUZA, 1995), as follows:

$$Ei = \frac{(CCi - Di)}{(CCi + Di)}$$

where Ei = Ivlev's electivity measure for species i; CCi = relative abundance of species i in the gut contents; and Di = the abundance of species i in the field (KREBS, 1989). The electivity varies from -1.0 to +1.0, with values between 0 to +1.0 indicating preference and values from 1.0 to 0 indicating avoidance.

The null hyposthsis that there is no temporal variation among algae coverage in the field and among gut contents was tested by one-way analysis of similarity (ANOSIM) permutation test using the Bray-Curtis similarity. Jaccard's index was also calculated in order to determine how similar is algae composition in the field and in the gut contents.

RESULTS

During the studied period a total of 34 algal species were identified in the field, of which 57% were rhodophytes, 26% phaeophytes, and 17% chlorophytes. The highest diversity was observed in August (25 species), whilst June presented the lowest number of algal species (18 species).

In relation to algal assemblages, only one species represented the foliose, leathery and crustose group each, that is *Ulva fasciata*, *Sargassum cymosum* and Corallinaceae, respectively. The foliose *Ulva fasciata* accounted for the highest mean dominance (29%), followed by the corticated (20%), articulated calcareous (18%) and the crustose (17%) groups. The remaining associations accounted for less than 6% of coverage.

According to the ANOSIM test, the intertidal epibenthic algal community on the rocky shore of Vigia's islet is characterized by temporal fluctuations in species percent-cover (Global R= 0.78; p< 6.7%). However, there was a clear trend in the community towards the dominance of the encrusting coralline species from May to July (mean 30% dominance) and the foliose *Ulva fasciata* during the remaining sampling period (mean 46% dominance) (Figure 3a). This trend was also observed in the gut contents of *E. lucunter* during the same period, mirroring a tendency already found in the field (Figures 3b).

In May, the crustose and corticated algae dominated the substrata in terms of percentage cover (Figure 3a), being the latter especially represented by two species: *Gelidium crinale* (9.2%) and *Laurencia obtusa* (7.5%). However, the articulated calcified *Jania cappilacea* and the leathery *Sargassum cymosum* themselves accounted for approximately 16% and 12% of their group average, respectively. In June, *Jania capillacea* held 19.7% of the total articulated calcareous coverage, the second dominant group after the crustose algae (Figure 3a). *Ulva fasciata* accounted for the total foliose coverage in July, following the dominant crustose group. Amongst the dominant morpho-textural groups in August, the corticated *Laurencia obtusa* and articulated *Jania capillacea* were the most dominant species (14.4% and 16.2%, respectively). *U. fasciata* presented the overwhelming dominance in September and October. *Hypnea spinella* accounted for 5.2% and 9.6% of the total corticated algae coverage in September and October, respectively. *Jania cappilacea* also represented the most dominant articulated species in September (13.4%) and October (9.1%).

The gut contents consisted mainly of indefinable small fragments, but also of some easily recognizable small pieces, nearly all of which were algae. A total of 90 sea-urchins were analyzed from Peró beach in whose gut contents 39 species of algae were found, comprising 24 Rhodophyta, 9 Phaeophyta and 6 Chlorophyta. In the guts, the highest diversity of algal species was encountered in May (21 species) and the lowest in July and October (17 species each).

The filamentous algae were the dominant group in terms of

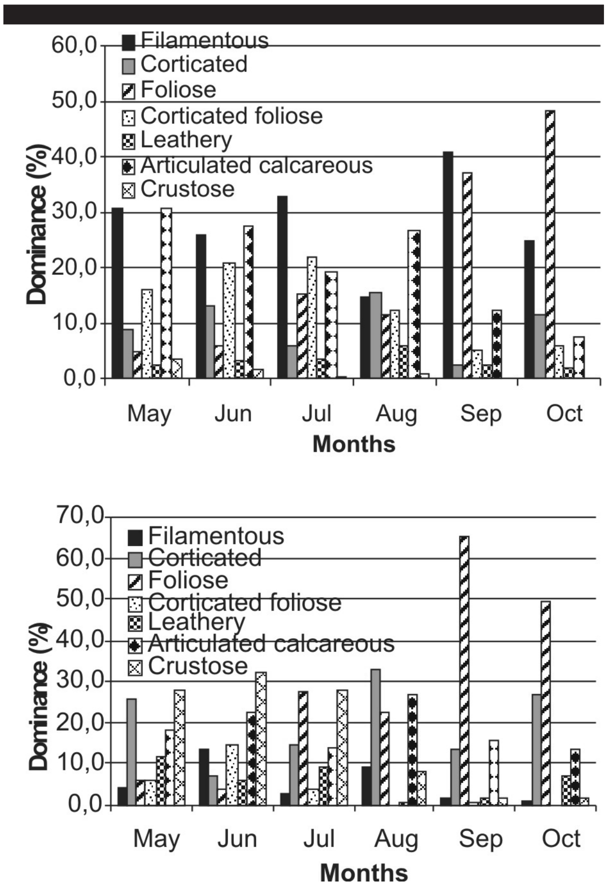

Figure 3. Monthly dominance (%) of the main algae assemblages in terms of (a) percentage cover in the field and (b) contact counts in the gut contents of *E. lucunter*.

contact counts (28.3%) during the studied period, followed by the articulated calcareous (20.8%) and the foliose *U. fasciata* (20.6%). The crustose accounted for less than 1.5% of dominance. Figure 2 shows the monthly dominance of algae assemblages in the gut contents of *E. lucunter* (Figure 3b).

The gut contents of *E. lucunter* varied substantially from May throughout October, according to ANOSIM test (Global R= 0.83; p< 6.7%). *Jania* spp. was clearly the major articulated calcareous component in the diet of *E. lucunter* during the studied period (mean 20.7%). In relation to the filamentous algae, *Sphacelaria brachygonia* was dominant in the diet of *E. lucunter* from May to July (mean 14,4%), whilst *Centroceras clavulatum* overwhelmed in August (7.5%) and *Polysiphonia ferrulacea* in September (17%) and October (6%). *Dictyota dichotoma* was the dominant corticated foliose algae (mean 11.2%). *Gelidium* spp. accounted for 19% of the total corticated algae dominance in June (13.3%) and *Hypnea* spp. was the dominant corticated species in August (9%) and October (8.6%).

Jaccard's index revealed low similarity (SI = 0.25) between the algal community in the field and algal fragments encountered in the guts of *E. lucunter*. A mean of 13 common species were observed for the studied period.

According to Ivlev's electivity index (Ei), food preference of *E. lucunter* varied along the studied period and among species; two patterns emerged clearly as revealed by Ivlev's index. The ranking of each morpho-textural group, from the most preferred to the most rejected, was as follows: filamentous (Ei= 0.6), corticated foliose (Ei= 0.4), articulated calcarious (Ei=0.03), foliose (Ei= -0.1), leathery (Ei= -0.2), corticated (Ei= -0.5) and crustose (Ei= -0.9).

During all the studied period, the foliose corticated *Dictyota dichotoma* (Ei= 0.8) and the filamentous *Centroceras clavulatum Sphacelaria brachygonia*, *Ceramium tenerrimum* and *Polysiphonia ferrulacea* (Ei= 0.7 each) were clearly far more

Table 1. *Variation of Ivlev's electivity index along the months surveyed for the main algal species.*

	May	Jun	Jul	Aug	Sep	Oct	Mean
Filamentous							
Cladophora vagabunda	-0,1	0,2	0,6	-0,6	0,6	0,7	0,2
Enteromorpha sp.	1,0	1,0	1,0	-0,4	1,0	1,0	0,8
Sphacelaria brachygonia	0,8	0,4	0,9	0,3	0,9	0,9	0,7
Centroceras clavulatum	0,8	0,0	0,9	0,8	0,9	1,0	0,7
Ceramium tenerrimum	0,5	0,6	0,8	0,4	0,9	0,9	0,7
Polysiphonia ferrulacea	0,4	1,0	0,4	0,2	0,9	1,0	0,6
Corticated							
Codium spongiosum	1,0	-0,8	0,1	-0,4	1,0	-1,0	0,0
Colpomenia sinuosa	-1,0	-1,0	-1,0	-1,0	-1,0	-1,0	-1,0
Condracanthus acicularis	-0,3	-1,0	-1,0	-1,0	-1,0	-0,9	-0,9
Gelidium spp.	-1,0	0,9	0,8	0,1	0,4	-0,8	0,1
Hypnea spp.	0,2	-0,7	-0,8	0,6	-0,8	-0,1	-0,3
Laurencia obtusa	-1,0	-1,0	-1,0	-1,0	-1,0	-1,0	-1,0
Foliose							
Ulva fasciata	-0,1	0,2	-0,3	-0,3	-0,3	0,0	-0,1
Corticated Foliose							
Dictyota dichotoma	0,5	0,4	0,8	1,0	1,0	1,0	0,8
Padina gymnospora	-1,0	-0,7	0,4	0,9	0,3	0,6	0,1
Leathery							
Sargassum cymosum	-0,6	-0,3	-0,4	0,8	0,2	-0,6	-0,2
Articulated calcareous							
Jania spp.	0,3	0,1	0,2	0,0	-0,1	-0,3	0,0
Crustose							
Corallinaceae	-0,8	-0,9	-1,0	-0,8	-1,0	-1,0	-0,9

preferred as food, whereas *Laurencia obtusa*, *Colpomenia sinuosa* (Ei= -1.0), Corallineacea and *Condracanthus spp.* (Ei= -0.9 each) were consistently avoided as food. The remaining species showed no clear pattern as they were either avoided, indifferent or preferred as food. Table 1 shows the variation of Ivlev's electivity index along the months surveyed for the main algal species.

An evidence of feeding on drift material was pointed out by the presence of *Bostrychia* sp., *Bryocladia* sp., *Champia* sp. and *Polisyphonia* spp. in the guts of *E. lucunter*, especially in May. All of them were algal species other than those reported in the field.

E. lucunter seems to be the dominant benthic herbivore in the studied site, whose mean density showed no great variation from May to October 2001 (mean 19 individuals per 0.25 m^2 ±4.5); the highest density occurred in July (24 individuals per 0.25m^2) and the lowest in the following month, August (11 individuals per 0.25m^2).

DISCUSSIONS

Once aware of the local algae assemblages comprising the epibenthic community of Peró beach, it was possible to establish patterns of food preference of the regular sea urchin *Echinometra lucunter*, the dominant benthic herbivore in the studied site.

E. lucunter consumed the various form groups in accordance with the established patterns described in the literature. According to Steneck and Watling (1982), Littler *et al.* (1983) and Chiu (1988) coarser and tougher species such as thick forms, calcareous and encrusting species are least susceptive to herbivory, while filamentous and foliose algae maximize herbivore accessibility and manipulation. The highest ingestion of filamentous algae by *E. lucunter* througout the studied period and the increasing dominance of the foliose *U. Fasciata* in the guts following its increasing availability in the field (from July on) corroborates these ideas. However, the articulated calcareous assemblage revealed an unexpected pattern, being largely grazed during the first three months of investigation and gradually substituted by the foliose algae, as *U. fasciata* became more dominant in the field during the remainig months. From the data presented here, *U. fasciata* occurred in the diet of *E. lucunter* not by means of a preferred food item, as showed by Ivlev's index. Rather, we especulate that this species dominance in the guts may be attributed not only by its morphological and textural features but especially by its capacity to overgrow other species, thus preventing them from being grazed while becoming more susceptive.

VADAS and OGDEN (1981) once concluded that tropical sea urchin feeding may be governed more by avoidance behavior than by preference. They suggested that tropical algae contain a greater array of defensive mechanisms, which tend to reduce urchin grazing and therefore diffuse feeding over a greater number of species. Such antipredator defenses include chemical defenses, especially in *Dictyota* species and *Laurencia obtusa* (LITTLER *et al*., 1983), and toughness, as in *Sargassum* and calcareous species, leading to low palatability, digestibility and nutritional values (PAINE and VADAS, 1969; LAWRENCE, 1975; STENECK and WATLING, 1982, LITTLER and LITTLER, 1984). Our findings are in close agreement in that concerns the strong rejection of *Laurencia obtusa* and, to a lesser degree, of *Sargassum cymosum*. However, *Dictyota dichotoma* revealed a completely opposite trend, being the most preferred foliose corticated algae.

The variation in the diet of *E. lucunter* in the study area seems to be tied to algal fluctuations in composition and relative abundance. However, macroalgal species not present in the area of collection were also found in the gut contents. This indicates that *E. lucunter* may be probably feeding on drift material. MCCLANAHAN and MUTHIGA (2001) pointed out that the genra *Echinometra* has a relatively limited feeding range and searching ability and may obtain a considerable portion of its diet by trapping drift algae. Another relevant point concerns the dominance of certain algal assemblages. MCCLANAHAN and MUTHIGA (2001) also stated that when leathery and crustose algae are dominant, *Echinometra* would eventually feed upon drift material. This was observed in May, when *Sargassum cymosum* and the crustose Corallinacaea abound in the studied area and the highest contact counts were attributed to drift algal species.

Drift algae are probably more important for those species and individuals which are less agonistic, while benthic algae are more important for agonistic ones (MCCLANAHAN and MUTHIGA, 2001). *E. lucunter* shows an agonistic behavior in sites exposed to wave-action (EBERT, 1980), such as the wave-exposed studied site at Vigias islet. In fact, the benthic algae community at Vigia's islet seems to play a larger role in the diet of *E. Lucunter.*

Echinoid grazing affects not only algal percent-cover, but also algal species composition, implying the echinoids as controlling agents (LAWRENCE and SAMMARCO, 1982). CARPENTER (1981) pointed out a significant inverse relationship between sea urchin density and algal relative abundance. PAINE and VADAS (1969) proposed that algal diversity would be greatest at intermediate levels of grazing. In this study these effects were observed during the month of August, when sea urchin density reached its lowest value, reflecting the highest algal diversity in the same month.

Algal form groups have limitations in the precisions of their boundaries and the level of question they address. It is important to consider other factors, including chemistry, physiology, mechanics and evolutionary history.

CONCLUSIONS

The composition of the gut contents is a reliable indicator of the natural available food ingested by sea urchins. Food preference was defined herein as a selective feeding on a resoure at a higher rate than it would be expected from its availability in the field. Therefore, the application of Ivlev's electivity index was appropriate in determining which species were preferred, avoided or indifferent to the diet of *E. Lucunter*.

In the studied area, *Echinometra lucunter* presented an essentially herbivore feeding habit, grazing preferentially upon the available benthic algal species and secondly upon drift algal material. Our reported findings showed that *E. lucunter* grazed upon algae morphological groups in the following order (from high preference to avoidance): filamentous, corticated foliose, articulated calcarious, foliose, leathery, corticated and crustose. Despite food preferences, the feeding behavior of *E. lucunter* depends on algal availability, most likely following the temporal occurrence of algae species in the field.

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