Journal of Ecology and the Natural Environment Vol. 3(13), pp. 415-423, 12 November, 2011
Available online at http://www.academicjournals.org/JENE
ISSN 2006 - 9847©2011 Academic Journals

Full Length Research Paper

Food preference of the sea urchin *Tripneustes gratilla* (Linnaeus, 1758) in tropical seagrass habitats at Dar es Salaam, Tanzania

Thomas J. Lyimo[1]*, Florence Mamboya[2], Mariam Hamisi[3] and Charles Lugomela[4]

[1]Department of Molecular Biology and Biotechnology, University of Dar es Salaam, P. O. Box 35179, Dar es Salaam, Tanzania.
[2]Department of Science and Laboratory Technology, Dar es Salaam Institute of Technology, P. O. Box 2958, Dar es Salaam, Tanzania.
[3]Department of Biological Sciences, University of Dodoma, P. O. Box 338, Dodoma, Tanzania.
[4]Department of Aquatic Sciences and Fisheries, University of Dar es Salaam, P. O. Box 35064, Dar es Salaam, Tanzania.

Accepted 20 September, 2011

The sea urchin *Tripneustes gratilla* is the most well-known seagrass grazer in the Western Indian Ocean and a few cases of overgrazing have been reported. However, few studies on their feeding preference have been performed in this region. In this study, the food items in the gut contents of *T. gratilla* collected from seagrass beds and in a bare sediment in intertidal areas of Dar es Salaam, Tanzania, were analysed and compared to their availability in the surrounding environment. A total of 59 micro and macro-algae species were identified from the environment and the guts of *T. gratilla,* of which 48 were found in both gut contents and the environment. Gut contents of *T. gratilla* collected from mono specific seagrass habitats were dominated by the species in which they were found. In a mixture of four different seagrass species, *Syringodium isoetifolium* was preferred (with electivity indices (E*) of +0.36) while *Cymodocea rotundata*, *Halodule uninervis* and *Thalassia hemprichii* were slightly avoided (E* = -0.24, -0.22 and -0.22, respectively). We concluded that *T. gratilla* generally feeds on available seagrass species. However, in the presence of different types of seagrasses it showed preference to *S. isoetifolium* possibly due to presence of high epiphyte load which may increase its palatability.

Key words: *Tripneustes gratilla*, seagrass, macroalga, microalgae, food preference, herbivory, Dar es Salaam.

INTRODUCTION

Tripneustes gratilla are known to occur in a wide range of tropical habitats including coral reefs, seagrass meadows, macroalgae meadows and in bare sediment. In these habitats, they are normally found to feed on a variety of seagrasses and algae that are found in their surrounding environment (Klumpp et al., 1993; Beddingfield and McClintock, 1999; Lawrence and Agatsuma, 2001). However, other studies reported some food preference or selectivity in sea urchin feeding habits (de Loma et al., 2002; Vaïtilingon et al., 2003; Stimson et al., 2007). Thus, sea urchin feeding habit may depend on a combination of two factors, that is, food availability and preference. Food selectivity may be due to nutritional value of the food type and/or the presence of chemical substances which repel the sea urchins (Beddingfield and McClintock, 1998).

Seagrass meadows have characteristics that make them suitable habitats for many organisms such as fishes, crustaceans and echinoderms (Coen et al., 1981). This includes their high primary productivity which ensures abundant supply of energy. The three dimensional structure of the vegetation offers hiding places that protect the fauna community against predation. In addition, seagrasses meadows are important due to the fact that they harbour a high biomass of epiphytic algae (Hamisi et al., 2004). Consequently, seagrass ecosystems

*Corresponding author. E-mail: tjlyimo@udsm.ac.tz.

have higher diversity and a larger number of individuals of different species compared to ecosystems without seagrasses (Fortes, 1988).

In seagrass ecosystems, sea urchins have been found to feed on seagrasses, detrital material, as well as epiphytic and epibenthic micro and macroalgae (Klumpp et al., 1993; de Loma et al., 2002). In some cases, sea urchin herbivory on seagrasses has been demonstrated to contribute to the loss of seagrass biomass, shoot density and reduction of growth, which may be a threat especially in tropical areas (Hughes et al., 2004). High densities of sea urchin may result in the overgrazing of seagrasses and complete depletion of seagrass vegetation. This has been reported for example in Florida, USA (Rose et al., 1999), the Gulf of Mexico and the Caribbean (Greenway, 1995; Heck and Valentine, 1995), Kenya (Alcoverro and Mariani, 2002) and Jamaica (Camp et al., 1973). Consequences of overgrazing include loss of habitat, reduction of productivity, erosion of fine-grained sediments, creation of a turbid sediment plume and reduced biodiversity of molluscs (Rose et al., 1999).

The sea urchin *T. gratilla* (Linnaeus, 1758) is the most well-known seagrass grazer in the Western Indian Ocean (Richmond, 2002; Eklof et al., 2008 and the references therein). It plays an important ecological role in various habitats by direct or indirect recycling of nutrients (Lawrence and Agatsuma, 2001). A few cases of overgrazing in Western Indian Ocean seagrass ecosystems have been reported in Kenya (Alcoverro and Marriani, 2002; Crona, 2006). However, few studies on *T. gratilla* feeding habits and behaviours have been performed along the Western Indian Ocean (Maharavo et al., 1994; de Loma et al., 1999; 2002) revealing dietary composition and feeding preferences on various habitats. In Tanzanian coastal waters, Mamboya et al. (2009) suggested that, sea urchins might be the cause of seagrass reductions off the coast of Dar es Salaam but there is no information on the sea urchin feeding habits in these seagrass ecosystems. Understanding food preference by sea-urchins is essential for the prediction of the impact of herbivory on seagrasses and for sustainable management of the seagrass ecosystems (Eklof et al., 2008). The aim of this study was therefore to investigate food selectivity and factors which contribute to food preference of *T. gratilla* among different seagrass species. The question was whether the preferred seagrass species harbor more epiphytic algae. The consequences will be that the preferred seagrass species may be more vulnerable to potential sea urchin out-breaks.

MATERIALS AND METHODS

Study sites

The study was conducted in the intertidal area at Mbweni (06°34′23.7″S and 39°08′09.3″E) in the coast of Dar es Salaam, Tanzania. The climatic condition of Dar es Salaam is tropical and the tidal regime of the coastal water is of a mixed semi-diurnal periodicity with a tidal range of about 4 m during spring tides. The physical and biological details of the studied site have been described previously (Mamboya et al., 2009).

Sampling was done during spring low tides (for easy access to the sites) in August and December 2008 as well as in January, March and October 2009 in seven sampling stations. Six were seagrass community types that contained *T. gratilla* and one was a bare sediment area. The seagrass community were two mono specific habitats composed of: (A) *Syringodium isoetifolium* (Ascherson) Dandy, 1939 and (B) *Thalassia hemprichii* (Ehrenberg) Ascherson, 1871; and four heterospecific habitats composed: (C) *S. isoetifolium* and *T. hemprichii,* (D) *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson, 1870 and *S. isoetifolium*, (E) *Halodule uninervis* (Forsskål) Ascherson, 1882 and *S. isoetifolium*, and (F) all the four species. The seventh sampling station (G) was in bare sediment areas (that is, without seagrass).

Sampling was carried randomly by throwing a 0.5 × 0.5 m quadrat at the pre-identified sampling stations. A total of five quadrat replicates were sampled for each habitat (that is, one quadrat per habitat on every sampling visit). In each quadrat, analysis of seagrass parameters (species composition, cover and density), algal composition and biomass were done as described further. In addition, specimens for laboratory analysis were taken from these quadrats. Sea urchin (*T. Gratilla*) abundance was also determined for each sampling point as described by McClanahan and Shafir (1990). Thus, at each point, counting of *T. Gratilla* were done in a 10 m^2 round quadrats.

Seagrass and algal composition analysis

Seagrass parameters (species name, percentage cover, canopy height and shoot density) were determined as described previously by Duarte and Kirkman (2001). Macroalgal compositions in the quadrats were recorded *in situ*. Five to ten shoots for each seagrass species encountered in the quadrat were collected for analysis of epiphytic microalgae. In the laboratory, the seagrass shoot samples were scraped (using a blunt blade) over GF/F filter papers to remove attached epiphytes. Both epiphytes and seagrasses were dried in an oven at ~60°C to a constant weight. The epiphyte abundance was then reported as gram dry weight of epiphyte per gram dry weight of the seagrass. In addition, about 10 g of surface sediments samples were collected from each quadrat using a syringe corer (30 mm diameter) and kept in 50 ml Falcon tubes. In the laboratory, the sediment and epiphyte subsamples were analysed under a light microscope to identify epibenthic and epiphytic microalgae composition, respectively.

T. gratilla gut content

One specimen of *T. gratilla* was collected from each quadrat and placed in a plastic bag for laboratory analysis. When the quadrat fell in an area without any *T. gratilla*, it was re-thrown. In the laboratory, the specimen were dissected and analysed for food composition visually and with the help of a light microscope. The seagrasses from the guts were separated into species while other materials were separated into detritus, macroalgae and sediment. These were then weighed to obtain their respective wet weights in order to calculate their percentage composition. Epiphytic and epibenthic microalgae from the field samples and the gut content were analysed using light microscope and identified according to Desikachary (1959), Komárek and Anagnostidis (1998, 2005) and Silva and Pienaar (2000).

Sea urchin preference on seagrass species

To compare the sea urchin preference on various seagrass species, relativised electivity indices (E^*) (Vanderploeg and Scavis, 1979) were calculated from the mean percent seagrass biomass in the gut and mean percentage seagrass abundance in the field as follows:

$$E^* = (Wi - (1/n)) / (Wi + (1/n))$$

Where: $W = (ri/pi)/(\sum ri/pi)$; ri = % proportion of the food i in the diet of the animal; pi = % proportion of food i in the environment; n = number of kinds of food items (seagrass species).

When the value of E^* tends towards +1, it indicates that seagrass species are more abundant in the diet (preferred), while values tending towards -1 indicates that seagrass species are more abundant in the field but not in the diet (avoided). When E^* equals 0, it indicates that the food is consumed in proportion to its availability in the field.

Statistical analysis

Data were statistically tested using a parametric two-way analysis of variance with its post hoc, Tukey-Kramer Multiple Comparison test. Where the assumptions for parametric tests were not met, data were analysed using the respective non-parametric Kruskal-Wallis (KW) test followed by the Dunn's Multiple Comparison Test. In all cases, significance was determined at the 95% confidence level. A GraphPad InStat 3 Demo programme was used for the statistical data analyses.

RESULTS

Seagrass parameters and sea urchin density

The seagrass shoot density, percentage cover, and canopy height in the sampling stations, are as shown in Table 1. The shoot density was lowest (931 ± 397 shoots/m^2) in habitat composed of *T. hemprichii* only, and highest (3353 ± 1048 shoots/m^2) in habitats with *S. isoetifolium* only. There was a significant difference in shoot density among habitats (F = 6.792, P = 0.0002) with Tukey-Kramer Multiple Comparison Test showing the significant differences to be between habitat comprising *S. isoetifolium* only and habitat with *T. hemprichii* only (P = 0.001), habitat with *T. hemprichii* only and habitats with mixture of either *S, isoetifolium* and *T. hemprichii* or *H. uninervis* and *S. isoetifolium* (P = 0.01).

Seagrass percentage cover was the lowest (35.8 ± 7.36%) in habitats with a mixture of all four seagrass species and highest (76.6 ± 14.8%) in the station comprising *S. isoetifolium* only. There was a significant difference in seagrass percentage cover among the seagrass habitats (F = 13.64, P < 0.0001) with Tukey-Kramer Multiple Comparison Test showing significantly lower percentage cover in habitat with all four seagrass species compared to the rest of the habitats (P = 0.001). Canopy height was lowest (9.56 ± 2.25 cm) in the mixture of all four species and highest (19.5 ± 3.56 cm) in habitats comprising *T. hemprichii* only. The canopy height was also significantly different among habitats (KW = 22.36, P = 0.0004) with Dunn's Multiple Comparison Test showing the differences to occur between habitat with either *T. hemprichii* only or with *C. rotundata* and *S. isoetifolium* against the habitats with all four seagrass species (P = 0.01).

The density of *T. gratilla* ranged from an average value of 0.18 ± 0.16 individuals/m^2 in habitats without seagrasses (bare sediment) to 0.54 ± 0.21 individuals/m^2 in *S. isoetifolium* habitats (Table 1). However, there were no significant differences among the habitats (KW = 10.76; P = 0.096). When compared to seagrass parameters, there was a significant positive correlation between the shoot density and *T. gratilla* abundance in the study area (r = 0.791; P = 0.034). However, there was no significant correlation between *T. gratilla* abundance and seagrass canopy height (r = 0.278; P = 0.546) or seagrass percentage cover (r = 0.357; P = 0.444).

Algal composition in the environment and the gut content of *T. gratilla*

A total of 59 algal taxa (Table 2) were identified from the environment (on sediment and as epiphytes on seagrasses) and in the guts of *T. gratilla*. Of these, 48 species were found from both gut contents of *T. gratilla* and in the environment, while 11 species were found only in the environment (Table 2). In general, the gut contents of *T. gratilla* from bare sediment had more algal taxa compared to those found in seagrass meadows. This was followed by *T. gratilla* collected from seagrass meadows with mixed species of *T. hemprichii, C. rotundata, S. isoetifolium* and *H. uninervis* while the lowest was observed in monospecific meadow of *S. isoetifolium* (Table 2). There was significant difference in composition of algae in guts of *T. gratilla* from different seagrass habitats (KW 17.76; P = 0.0069) with post hoc results showing the significance difference (P < 0.01) to be mainly between habitats comprising *S. isoetifolium* only and in the bare sediment. *S. isoetifolium* was found to have significantly higher (P = 0.0086) epiphytes dry weight biomass (Figure 1). Significant differences in epiphyte dry weight biomass were found between *S. isoetifolium* and *T. hemprichii* (P < 0.01), and between *S. isoetifolium* and *C. rotundata* as well as between *S. isoetifolium* and *H. uninervis* (P < 0.05).

T. gratilla gut content and preference to seagrass species

The gut content of *T. gratilla* specimens collected from the two different monospecific habitats were dominated by the respective seagrass species from where they were found (Figure 2A, and B). In the mixed meadows with two

Table 1. Description of various habitats in terms of seagrass and sea urchin parameters.

Habitats/sg communities / Seagrass composition (%)	A	B	C	D	E	F	G
C. rotundata	0.00	0.00	0.00	19.6±17.8	0.00	11.7±14.2	0.00
H. Uninervis	0.00	0.00	0.00	0.00	30.1±33.6	14.8±25.0	0.00
S. isoetifolium	100	0.00	89.2±92.8	80.4±82.2	69.9±66.4	66.7±51.6	0.00
T. hemprichii	0.00	100	10.8±7.16	0.00	0.00	6.82±9.24	0.00
Shoot density (m^2)	3353±1048	931.2±397.4	3281±1683	1930±438.0	2972±519.5	1846±654.4	0.00
Percentage cover (%)	76.6±14.8	75.0±6.32	68.0±12.9	74.0±8.76	70.8±8.76	35.8±7.35	0.00
Canopy height (cm)	16.4±5.86	19.5±3.56	13.0±0.63	19.0±2.37	15.3±2.16	9.56±2.25	0.00
T. gratilla (ind./m^2)	0.54±0.21	0.29±0.10	0.50±0.23	0.24±0.18	0.30±0.32	0.40±0.16	0.18±0.16
Electivity index (*E**)							
C. rotundata	-	-	-	-0.15	-	-0.24	-
H. uninervis	-	-	-	-	-0.12	-0.22	-
S. isoetifolium	0.00	-	0.28	0.11	0.10	0.36	-
T. hemprichii	-	0.00	-0.63	-	-	-0.22	-

A = *S. isoetifolium*; B = *T. hemprichii*; C = *S. isoetifolium* and *T. hemprichii*; D = *C. rotundata* and *S. isoetifolium*; E = *H. uninervis* and *S. isoetifolium*; F = all the four species; G = bare areas.

different seagrass species dominated by *S. isoetifolium* (Table 2), the gut contents were dominated by *S. isoetifolium* (Figure 2C, D and E). In the seagrass habitat with a mixture of *C. rotundata, H. uninervis, S. isoetifolium* and *T. hemprichii,* (Figure 2F), *T. gratilla* gut contents were dominated by *S. isoetifolium* (38.2%) followed by *T. hemprichii*, sediment and *H. uninervis*, *C. rotundata* and macroalgae. In bare sediments (Figure 2G), gut content comprised mostly of sediment material, followed by macroalgae, detritus material, *T. hemprichii* and *H. uninervis*.

In general, *T. gratilla* showed some degree of food preference (selectivity) for various seagrass species when found in communities with a mixture of different seagrass species. Thus, different seagrass species were either moderately selected or avoided. For example, in habitats with *C. rotundata* and *S. isoetifolium* or *H. uninervis* and *S. isoetifolium, S. isoetifolium* was moderately selected in both cases (Table 1). However, in habitats with *S. isoetifolium* and *T. hemprichii, T. hemprichii* was found to be highly avoided (*E** = -0.63). In a mixture of four seagrass species, *S. isoetifolium* was more preferred (*E** = +0.36) while other species, that is,., *C. rotundata*, *H. uninervis* and *T. hemprichii* were slightly avoided (*E** = -0.24; *E** = -0.22 and *E** = -0.22, respectively) (Table 1).

DISCUSSION

Seagrass shoot density, canopy height and percentage cover obtained in this study were within the range of earlier investigation reported from the Western Indian Ocean Region and other tropical areas (Agawin et al., 2001; Rollon et al., 2001; de la Torre-Castro and Rönnbäck, 2004; Uku and Björk, 2005; Lyimo et al., 2006; Mamboya et al., 2009). The variations in the seagrass parameters were influenced by the species composition of a habitat. For example, habitats dominated by *S. isoetifolium* species had higher shoot density and percentage cover compared to areas with *T. hemprichii* only or with all four seagrass species. However higher canopy height was recorded in habitat with *T. hemprichii* and *C. rotundata* as compared to habitats dominated by other species. The high seagrass density, canopy height and percentage cover possibly increases surface area for epiphytes to attach thereby increasing food availability to sea urchins.

The abundance of *T. gratilla* was generally low and comparable to previous studies in the area (Mamboya et al., 2009). The significant positive correlation between seagrass shoots density and *T. gratilla* abundance indicates the importance

Table 2. Macro and Micro algae composition in the gut contents of sea urchin (+) and in the environment (x) from various seagrass habitats.

Algal species	A	B	C	D	E	F	G
Bacillariophyta							
Capartogramma spp.	x +	x	x	x +	X	x	x +
Climacosphenia sp.	x +	x +	x	x	X	x	x +
Cymbella spp.	x		x	x		x	x
Cocconeis sp.		x +	x			x +	x
Fragilari sp.	x +		x	x +			x +
Fragilariopsis sp.	x		x	x		x +	x +
Gyrosigma sp.	x +		x +	x +	X	x +	x +
Licmophora sp.	x +	x +	x +	x	X		x +
Mastogloia sp.	x +		x	x +	X		x +
Navicula spp.	x		x	x +	X		x +
Nitzschia spp.	x	x +	x +	x +	X	x +	x
Pleurosigma spp.	x	x +	x +	x +	x +	x +	x
Rhizosolenia sp.	x		x	x	x +		x
Rhopalodia sp.	x +		x	x	x +		
Pseudo-nitzschia sp.					X		
Thalassionnema sp.	x	x +	x +	x			x +
Thalassiothrix sp.							x
Chlorophyta							
Chaetomorpha sp.						x +	x
Cladophoropsis sp.				x +		x +	x
Cladophora sp.		x +					x
Microsopora sp.							x
Palmodictyon sp.						x +	
Chlorodesmis sp.							x +
Protoderma sp.		x +					
Cyanobacteria							
Anabaena sp.	x	x +	x	x	X	X	x
Calothrix sp.	x	x	x	x +	X	X	x
Chroococcus sp.			x +	x	x +	X	x +
Lyngbya spp.		x	x +	x +	x +	x +	x +
Lyngbya majuscule		x	x	x +	x +	x +	x +
Leptolyngbya sp.				x +	x +	x +	x +
Microcoleus sp.						x +	x +
Oscillatoria spp.	x +	x +	x +	x +		x +	x +
Phormidium sp.	x		x	x +	X		x +
Pseudanabaena sp.							x +
Schizothrix sp.		x +	x +	x +	x +	x +	x +
Spirulina sp.					x +		x
Trichodesmium sp.						x +	
Dinophyceae							
Dinophysis sp.						x +	
Amphisolenia sp.						x	
Diplopsalis sp.						x +	x +
Heteraulacus sp.							x +
Protoperidinium sp.		x +	x +	x +	x +		
Phaeophyta							

Table 2. Contd.

Padina sp.							x
Dictyota sp.							x
Rhodophyta							
Ceramium sp.		x +	x +	x +	x +	x +	x +
Feldmannia sp.	x +						x
Jania sp.		x					x +
Herposphonia sp.						x +	
Liogora sp.				x			
Amphiroa sp.							x
Aglaothamnion sp.		x +					
Crouania sp.		x					
Dasya sp.		x					
Heterosiphonia sp.		x +					
Polysiphonia sp.						x +	
Asparagopsis sp.				x +		x +	
Phacelocarpus sp.				x +			
Murrayella sp.				x +			
Hincksia sp.					x +		
Number of species (x/+)	19/9	22/15	25/11	30/20	23/12	28/21	40/23

A = *S. isoetifolium* only; B = *T. hemprichii* only; C = *S. isoetifolium* and *T. hemprichii*; D = *C. rotundata* and *S. isoetifolium*; E = *H. uninervis* and *S. isoetifolium*; F = all the four species; G = bare areas.

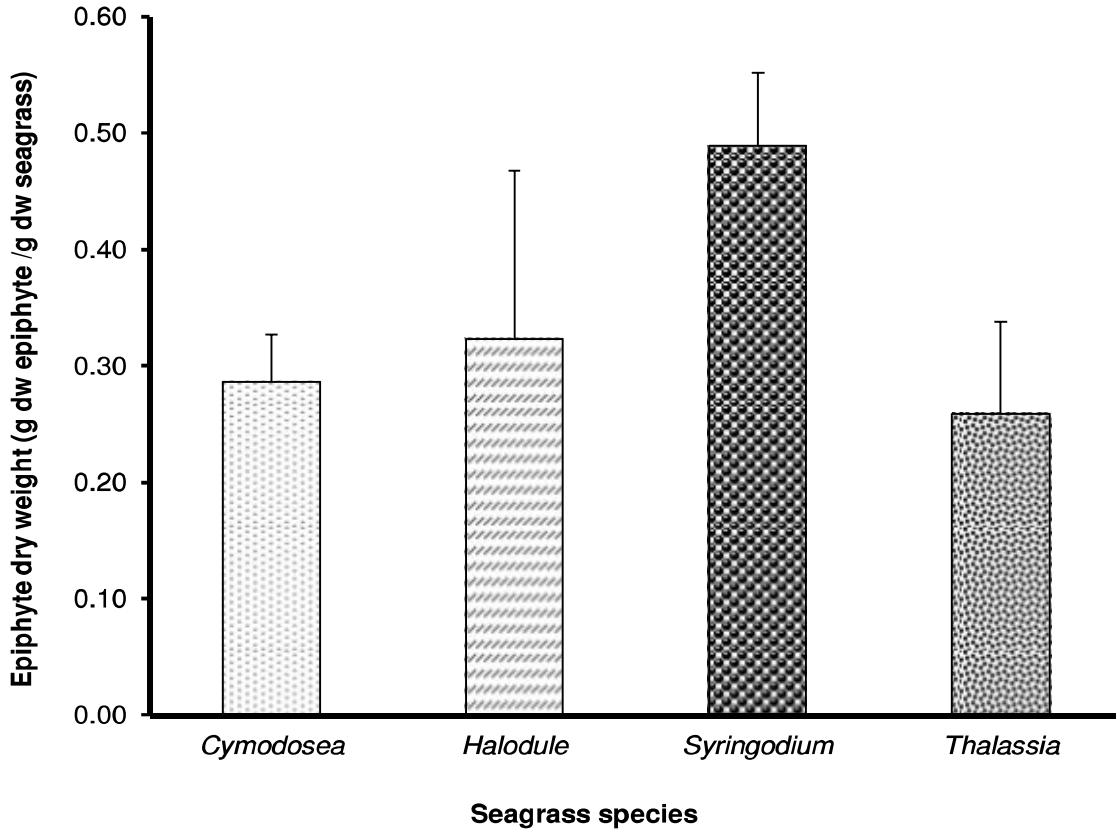


Figure 1. Epiphyte dry weight composition of the four studied seagrass species.

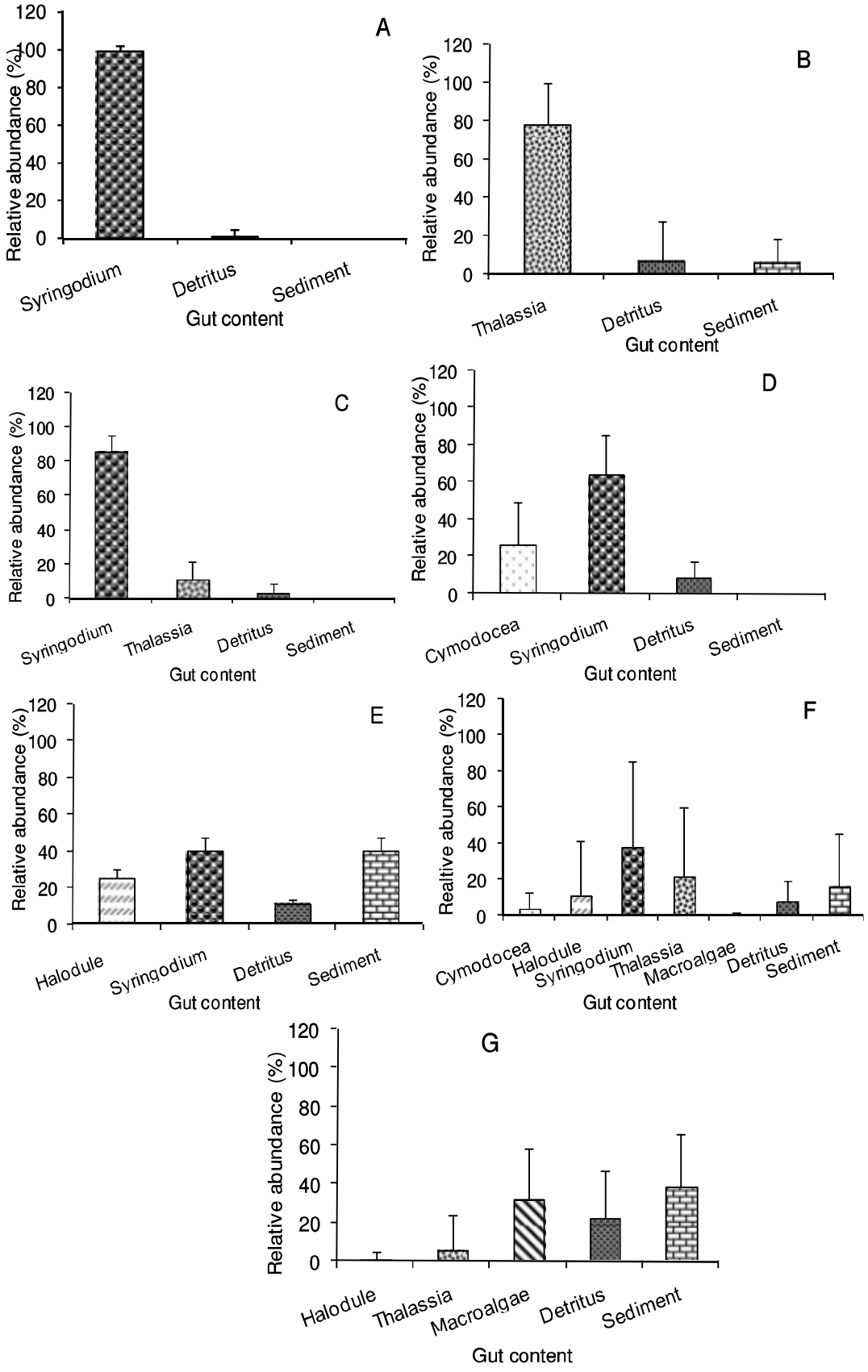


Figure 2. Percentage gut content composition of *T. gratilla* collected from various habitats in Dar es Salaam.

of the seagrass as food to the sea urchins and that the observed *T. gratilla* biomass posed no threat to the seagrass. However, Mamboya et al. 2009 showed no significant correlation between shoot density and *T. gratilla* abundance though the authors observed significant negative correlation between seagrass above ground biomass, shoot density, canopy height, and percentage cover with total sea urchin abundance in the area. They suggested that the grazing impact on seagrass was due to the total sea urchin densities rather than one sea urchin species which corroborate to the current results.

Our results show that *T. gratilla* could eat every seagrass species available in its vicinity. This observation has previously been demonstrated in laboratory experiments (Beddingfield and McClintock, 1999; Stimson et al., 2007). However, in the mixture of four species of seagrasses in the study site, *S. isoetifolium* was the most dominant species encountered in the guts of *T. gratilla* accounting up to 87% of the biomass of the gut content. This may be due to its abundance in the environment as compared to other species which in the mixed meadows averaged 66.7%. Indeed, the calculated electivity index showed that in mixed seagrass meadows, *C. rotundata*, *H. uninervis*, and *T. hemprichii* were avoided while *S. isoetifolium* was preferred. Similarly, Vaïtilingon et al. (2003) reported selectivity by *T. gratilla* favouring *S. isoetifolium* in coastal habitats off Toliara, Madagascar. The morphology and the anatomical features of *S. isoetifolium* could be another factor which contributes for its selectivity by *T. gratilla* (Lowe, 1974; Kuo and McComb, 1989; Stimson et al., 2007). The leaf blades of *S. isoetifolium* are long terete, relatively smooth and soft with loosely arranged cells in which food materials and metabolites are stored, while most of other species, for example, *C. rotundata* and *T. hemprichii,* they are flat, tough and ribbon shaped (Kuo and McComb, 1989). Lowe (1974) suggested that *T. gratilla* prefers terete leaves than flattened leaves found in other seagrass species.

The selectivity by *T. gratilla* on *S. isoetifolium* over other species may also be due to its observed higher epiphyte loads on this seagrass species (Figure 1). Previous studies have indicated that sea urchin densities are generally higher in areas with concentrated organic enrichment (Ruiz et al., 2001) possibly because of the presence of higher epiphytic algae (Yamamuro, 1999; Tomas et al., 2006). However, other studies also show that some macro-algae may produce toxic compounds which deter grazing by sea urchins (Hay, 1996; Cronin et al., 1997). This might not however, be the case for the Rhodophyta of the genus *Feldmannia* which was found in this study to be the most common algae attached to *S. isoetifolium.* Our results show presence of large number of algal species in the gut contents and in the seagrass shoots (as epiphytes) suggesting that epiphytic algae are important additional nutrition source to *T. gratilla*. Thus, *T. gratilla* gets its nutrition from both seagrasses and associated epiphytes. Indeed, epiphytic algae have been reported from other areas to be more palatable than vascular plant tissues to herbivores (Klumpp et al., 1993 and the references therein). The higher algal diversity and biomass observed in the gut content of *T. gratilla* collected from bare sediments compared to other stations suggest that the sea urchins on bare sediment depend primarily on the nutrition gathered from the algae. These include microalgae that may be abundant and sometimes form visible bio-films or microbial mats on sediment surfaces in coastal waters of Tanzania (Lugomela et al., 2005).

ACKNOWLEDGEMENTS

This study was supported by the Marine Science for Management (MASMA) grant for the 'seagrass and sea urchin interactions: overgrazing and resource use in the WIO region' project. We thank Mr. Shamte Sultan, Ms. Winnie Ernest and Mr. Ferdinand Kisoka for assisting field and laboratory works. The University of Dar es Salaam, Department of Molecular Biology and Biotechnology is acknowledged for provision of logistic support including laboratory space, equipment and transport. We wish to thank various anonymous reviewers for their constructive suggestions.

REFERENCES

Alcoverro T, Mariani S (2002). The effects of the sea urchin grazing on the *Thalassodendron ciliatum* seagrass beds of a kenyan lagoon. Mar. Ecol. Prog. Ser., 226: 255–263.

Agawin NSR, Duarte CM, Fortes MD, Uri JS, Vermaat JE (2001). Temporal changes in the abundance leaf growth and photosynthesis of three co-occurring Philippine seagrasses: J. Exp. Mar. Bio. Ecol., 260: 217–239.

Beddingfield SD, McClintock JB (1998). Differential survivorship, reproduction, growth and nutrient allocation in the regular echinoid *Lytechinus variegatus* (Lamarck) fed natural diets. J. Exp. Mar. Biol. Ecol., 226: 195–215.

Beddingfield SD, McClintock JB (1999). Food resource utilization in the sea urchin *Lytechinus variegates* in contrasting shallow-water microhabitats of saint Joseph Bay, Fla Gulf Mexico. Sci. 17: 27–34.

Camp DK, Cobb SP, Van Breedfield JV (1973). Overgrazing of seagrasses by a regular urchin, *Lytechinus variegatas.* BioSci., 23: 37–38.

Coen LD, Heck KL, Abele G (1981). Experiments on Competition and Predation among Shrimps of Seagrass Meadows. Ecology, 62(6): 1484–1493

Crona BI (2006). Supporting and enhancing development of heterogeneous ecological knowledge among resource users in a Kenyan seascape. Ecol. Soc., 11: 32.

Cronin G, Paul VJ, Hay ME, Fenical W, Fenical W (1997). Are tropical herbivores more resistant than temperature herbivores to seaweed chemical defenses? Diterpenoid metabolites from *Dictyota acutiloba* as feeding deterrents for tropical versus temperate fishes and urchins. J. Chem. Ecol., 23: 289–302.

De la Torre Castro M, Rönnbäck P (2004). Links between humans and seagrasses. An example from tropical East Africa. Ocean Coast. Manag., 47: 361–387.

De Loma TL, Conand CL, Harmelin-Vivien M, Ballesteros E (2002). Food selectivity of *Tripneustes gratilla* (L) (Echinodermata: Echinodea) in Oligotrophic and nutrient-enriched coral reefs at La Reunion (Indian Ocean). Bull. Mar. Sci., 70: 927–938

De Loma TL, Harmelin-Vivien ML, Conand C (1999). Diel feeding rhythm of sea urchin *Tripneustes gratilla* (L.) on a coral reef at La Reunion. Indian Ocean. In Caenevali C, Bonasoro (eds) Echinoderm Res. Balkema, Rotterdam, pp. 87–992.

Desikachary TV (1959). Cyanophyta. Indian Council Agric. Res., New Delhi, p. 686.

Duarte CM, Kirkman H (2001). Methods for measurement of seagrass abundance and depth distribution. In: Short, F.T. and Coles, R.G. (eds.) Glob. Seagrass Res. Methods, pp. 141–153.

Eklof JS, de la Torre M, Gullstrom M, Uku J, Muthiga N, Lyimo T, Bandeira SO (2008). Sea urchin overgrazing of seagrasses: A review of current knowledge on causes, consequences, and management. Estuar., Coast. Shelf Sci., 79: 569–580.

Fortes M (1988). Mangrove and seagrass beds of east Asia: Habitat under stress. Ambio, 17(3): 207–213.

Greenway M (1995). Trophic relationship of macrofauna within a Jamaican seagrass meadow and the role of the echinoid *Lytechinus variegatus* (Lamarck). Bull. Mar. Sci., 17(3): 719-736.

Hamisi MI, Lyimo TJ, Muruke MHS (2004). Cyanobacterial occurrence and diversity in seagrass meadows in Coastal Tanzania. Western Indian Ocean J. Mar. Sci., 3: 113–122.

Hay ME (1996). Marine Chemical ecology: what's known and what's next? J. Exp. Biol. Ecol., 200: 103–134.

Heck KL, Valentine JF (1995). Sea urchin herbivory: Evidence for long-lasting effects in subtropical seagrass meadows. J. Exp. Biol. Ecol., 189: 205–217.

Hughes AR, Bando KJ, Rodriguez LF, Williams SL (2004). Relative effects of grazers and nutrients on seagrasses: a meta analysis approach. Mar. Ecol. Prog. Ser., 282: 87–99.

Klumpp DW, Salita-Espinosa JT, Fortes MD (1993). Feeding ecology and trophic role of sea urchins in a tropical seagrass community. Aquat. Bot., 45: 205–229

Komárek J, Anagnostidis K (1998). *Cyanoprokaryota 1. Chroococcales*. Gustav Fisher, Jena, Stuttgart, L¨ubeck, Ulm.

Komárek J, Anagnostidis K (2005). *Cyanoprokarota 2. Oscillatoriales*. Elsevier, M¨unchen.

Kuo J, McComb AJ (1989). Seagrass taxonomy, structure and development. In: Larkum AWD, McComb AJ, Shepherd SA (eds) *Biology of seagrasses*. Elsevier, Amsterdam. pp. 6–73.

Lawrence JM, Agatsuma Y (2001). The ecology of *Tripneustes*. In: Lawrence JM (ed) Edible sea urchins: biology and ecology. Elsevier, Amsterdam, pp. 395–413.

Lowe EF (1974). Absorption efficiencies, feeding rates, and food preferences of Lytechinus variegatus (Echinodermata: Echinoidea) for selected marine plants. M. Sc thesis, University of South Florida, Sarasota.

Lugomela C, Söderbäck E, Björk, M (2005). Photosynthesis rates in cyanobacteria-dominated sub-tidal biofilms near Zanzibar, Tanzania. Estuar. Coast. Shelf Sci. 63: 439–446.

Lyimo TJ, Mvungi EF, Lugomela C, Björk M (2006). Seagrass biomass and productivity in seaweed and non-seaweed farming areas in the East Coast of Zanzibar, Tanzania. Western Indian Ocean J. Mar. Sci., 5(2): 141–152.

Maharavo J, Regis MB, Thomassin BA (1994). Food preference of *Tripneustes gratilla* (L.) (Echinoidea) on fringing reef flats of the NW coast of Madagascar (SW Indian Oceaan). In: David B, Guille A, Féral JP, Roux, (eds.) Echinoderms through time. A.A. Balkema, Rotterdam, pp. 769–774.

Mamboya FA, Lugomela C, Mvungi E, Hamisi M, Kamukuru AT, Lyimo TJ (2009). Seagrass–sea urchin interaction in shallow littoral zones of Dar es Salaam, Tanzania. Aquatic Conservation: Mar. Freshwater Ecosyst., 19: 19–26.

McClanahan TR, Shafir SH (1990). Causes and consequences of sea urchin abundance and diversity in Kenyan coral-reef lagoons. Oecologia, 83: 362–370.

Richmond M (2002). A field guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands. Sida/SAREC – UDSM. 461 pp. ISBN 91-586-8783-1.

Rollon RN, Cayabyab NM, Fortes MD (2001). Vegetative dynamics and sexual reproduction of monospecific *Thalassia hemprichii* meadows in the Kalayaan Island group. Aquat. Bot., 71: 239–246.

Rose CD, Sharp WC, Kenworthy WJ (1999). Overgrazing of a large seagrass bed by the sea urchin *Lytechinus ariegatus* in Outer Florida Bay. Mar.Ecol. Prog. Ser., 190: 211–222.

Ruiz JM, Perez M, Romero J (2001). Effect of fish farm loadings on seagrass (*Posidonia oceanica*) distribution, growth and photosynthesis. Mar. Pollut. Bull., 42: 749–760.

Silva SMF, Pienaar RN (2000). Benthic marine cyanophyceae from Kwa-Zulu Natal, S. Africa. Gebrüder Borntraeger Verlagsbuchhand Lung, Berlin, p. 456.

Stimson J, Cunha T, Philippoff J (2007). Food prefences and related bahavior of the browsing sea urchin *Tripneustes gratilla* (Linnaeus) and its potential for use as a biological control agent. Mar. Biol., 151: 1761–1772.

Tomas F, Alvarez-Cascos D, Turon X, Romero J (2006). Differential element assimilation by sea urchins *Paracentrotus lividus* in seagrass beds: implications for trophic interactions. Mar. Ecol. Prog. Ser., 306: 125–131.

Uku J, Björk M (2005). Productivity aspects of three tropical seagrass species in areas of different nutrient levels in Kenya. Estuar. Coast. Shelf Sci., 63: 407–420.

Vaïtilingon D, Rasolofonirina R, Jangoux M (2003). Feeding preferences, seasonal gut repletion indices, and diel feeding patterns of the sea urchin *Tripneustes gratilla* (Echinodermata: Echinoidea) on a coastal habitat off Toliara (Madagascar). Mar. Biol., 143: 451–458.

Vanderploeg HA, Scavis D (1979). Two electivity indices for feeding with special reference to zooplankton grazing. J. Fish Res. Board Canada, 36: 362–365.

Yamamuro M (1999). Importance of epiphytic cyanobacteria food sources for heterotrophy in a tropical seagrass bed. Coral Reefs, 18: 263–271.