Full Length Research Paper

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

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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 non-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 (Ev) of +0.36) while *Cymodocea rotundata*, *Halodule uninalis* and *Thalassia hemprichii* were slightly avoided (Ev = -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 (Klump 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; Vaillington 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

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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 Mariani, 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, Mamboa 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 outbreaks.

**MATERIALS AND METHODS**

**Study sites**

The study was conducted in the intertidal area at Mweni (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 (Mamboa 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 September 2009 in seven sampling stations. Six were seagrass community types that contained _T. gratilla_ and one was bare sediment area. The seagrass community were two mono specific habitats composed of: (A) _Syringodium isoetilformium_ (Ascherson) Dandy, 1939 and (B) _Thalassia hemprichii_ (Ehrenberg) Ascherson, 1871; and four heterospecific habitats composed: (C) _S. isoetilformium_ and _T. hemprichii_, (D) _Cymodocea rotundata_ Ehrenberg and Hemprich ex Ascherson, 1870 and _S. isoetilformium_, (E) _Halodule uninevis_ (Forsskål) Ascherson, 1882 and _S. isoetilformium_, and (F) all the four species. The seventh sampling station (G) was in bare sediment area (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 m² 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 was 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 Plenaa (2000).
Sea urchin preference on seagrass species

To compare the sea urchin preference on various seagrass species, related values of electrivity indices ($E^*$) (Vanderploeg and Scavia, 1979) were calculated from the mean percent seagrass biomass in the gut and mean percentage seagrass abundance in the field as follows:

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

Where: $W = (r_i/p_i)/(\sum_i r_i p_i); r_i = \%$ proportion of the food $i$ in the diet of the animal; $p_i = \%$ 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/m²) in habitat composed of _T. hemprichii_ only, and highest (3353 ± 1048 shoots/m²) 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/m² in habitats without seagrasses (bare sediment) to 0.54 ± 0.21 individuals/m² 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) epiphyte 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
**DISCUSSION**

(Table 1)

<table>
<thead>
<tr>
<th>Species</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.33</td>
</tr>
<tr>
<td>B</td>
<td>0.15</td>
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<tr>
<td>C</td>
<td>0.22</td>
</tr>
<tr>
<td>D</td>
<td>0.22</td>
</tr>
<tr>
<td>E</td>
<td>0.22</td>
</tr>
</tbody>
</table>

- : 0.22; - : 0.33; 0.00 : 0.00

The significant positive correlation between grassland species diversity and nutrient levels was generally low across the transect, increasing from east to west. However, higher species diversity was observed in the western part of the study area, where higher nutrient levels were recorded. The species composition of the habitat was influenced by the grassland species diversity and nutrient levels, with higher diversity and nutrient levels leading to a more diverse species composition. The results indicate that grassland species diversity and nutrient levels are important factors for maintaining biodiversity in grassland ecosystems.
Table 2. Macro and Micro algae composition in the gut contents of sea urchin (++) and in the environment (x) from various seagrass habitats.

<table>
<thead>
<tr>
<th>Algal species</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillariophyta</td>
<td>X+</td>
<td>X</td>
<td>X</td>
<td>X+</td>
<td>X</td>
<td>x</td>
<td>x+</td>
</tr>
<tr>
<td>Capartogromma spp.</td>
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<td></td>
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<tr>
<td>Climacosphora spp.</td>
<td>X+</td>
<td>X+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x+</td>
</tr>
<tr>
<td>Cymbella spp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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</tr>
<tr>
<td>Cocconeis sp.</td>
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<td>X</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fragilaris sp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>x +</td>
</tr>
<tr>
<td>Fragilaropsis sp.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>x</td>
<td>x+</td>
</tr>
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<td>Gyrosigma sp.</td>
<td>X+</td>
<td>X+</td>
<td>X+</td>
<td>X</td>
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<td>x+</td>
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<td>Navicula spp.</td>
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<td>Nitzschia spp.</td>
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<td>X+</td>
<td>X+</td>
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<td>X+</td>
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<td>x+</td>
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<td></td>
<td></td>
<td></td>
<td>x+</td>
</tr>
<tr>
<td>Protoperidinium sp.</td>
<td>X+</td>
<td>X+</td>
<td>X+</td>
<td>x+</td>
<td>x+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phaeophyta
Table 2. Contd.

<table>
<thead>
<tr>
<th>Species</th>
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</thead>
<tbody>
<tr>
<td>Padina sp.</td>
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</tr>
<tr>
<td>Dicyota sp.</td>
<td>X</td>
</tr>
<tr>
<td>Rhodophyta</td>
<td></td>
</tr>
<tr>
<td>Ceramium sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Feldmannia sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Jania sp.</td>
<td>X</td>
</tr>
<tr>
<td>Herposphonia sp.</td>
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<tr>
<td>Liagora sp.</td>
<td>X</td>
</tr>
<tr>
<td>Amphiroa sp.</td>
<td></td>
</tr>
<tr>
<td>Aglaothamnion sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Crouania sp.</td>
<td>X</td>
</tr>
<tr>
<td>Dasya sp.</td>
<td>X</td>
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<tr>
<td>Heterosiphonia sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Polysiphonia sp.</td>
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<tr>
<td>Asparagopsis sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Phacelocarpus sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Murrayella sp.</td>
<td>X+</td>
</tr>
<tr>
<td>Hinckia sp.</td>
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</tr>
<tr>
<td>Number of species (x+)</td>
<td>19/9</td>
</tr>
</tbody>
</table>

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](image)

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, Mamboy 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 selectivity index showed that in mixed seagrass meadows, *C. rotundata, H. uninervis*, and *T. hemprichii* were avoided while *S. isoetifolium* was preferred. Similarly, Vaillilongon 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 (Yamamura, 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, 1986; 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 (Klump 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).

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