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Feeding, respiration, and excretion by the tropical sea urchin *Tripneustes gratilla* (Echinodermata: Echinoidea) from the Philippines

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The rates of ingestion, egestion, ammonium excretion, and CO_2 respiration of *Tripneustes gratilla* (Echinodermata: Echinoidea) from a shallow water embayment at eastern Mactan Island, central Philippines were examined. There was no significant difference in weight-specific feeding rate with the three macrophytes (*Sargassum polycystum*, *Thalassia hemprichii*, and *Kappaphycus alvarezii*). The power function equation, M=KWb fitted well with the weight-specific egestion rates ((r^2=0.93), weight-specific CO_2 respiration rates (r^2=0.92) and ammonium excretion rates (r^2=0.86). Weight-specific egestion rates, CO_2 respiration and ammonium excretion were indirectly proportional to body weight. For weight-specific egestion rate (in μg DW faeces/g DW urchin-h), the regression coefficient, b and constant, K were −2.31 ±0.68 (mean ±SE) (P=0.02) and 6359.55 ±5394.31 (P=0.29), respectively. The b and K for CO_2 respiration were −1.28 ±0.48 (P=0.04) and 39.72 ±10.59 (P=0.01), respectively. For ammonium excretion, the b and K were −1.03 ±0.46 (P=0.11) and 262.51 ±56.89 (P=0.02), respectively.

INTRODUCTION

Tripneustes gratilla (Linnaeus, 1758) is an herbivore widely found in the tropics and subtropics in sea grass beds, sandy and coral rubble areas (see Lawrence & Agatsuma, 2001). Their abundance and distribution in some coral reefs suggest that they are ecologically important and occupy a key trophic position vital to the flow of matter and energy. They are also considered major consumers of commercially important seaweeds on coral reef platforms (Gomez et al., 1983). Additionally, interest in *T. gratilla* also arises from its potential as a species for mariculture and sea ranching. Lawrence & Bazhin (1998) provide arguments on the suitability of *Tripneustes* for aquaculture based on its life history.

Beddingfield & McClintock (2000) showed that the demographic characteristics of populations of a temperate sea urchin *Lytechinus variegatus* are influenced by the type of shallow-water habitats, local abiotic factors and patchy distribution of plant food resources. Lawrence & Kafri (1979) indicated how the population structure of two species of echinoderms living in high-energy and low-energy environments at Barbados, West Indies differed in their numbers, biomass and caloric content. In view of these observations, it is possible that in areas where the environmental conditions are not optimal, there might be some changes in the physiology of the organism. Therefore the rates of ingestion, egestion, ammonium excretion, and CO_2 respiration of *T. gratilla* were examined in our area. Since *T. gratilla* is widely distributed in the tropics, it is possible that it may have varied physiological responses with regards to its habitat in a specific geographical location. The present study site is a shallow-water embayment in eastern Mactan Island, central Philippines, where the gradual loss of sea grass habitats and artisanal fisheries has reduced the *T. gratilla* population.

MATERIALS AND METHODS

The rates of ingestion, egestion, ammonium excretion, and CO_2 respiration were measured by incubating individual *Tripneustes gratilla* with varying test diameters in glass jars. Additionally, feeding experiments were conducted using three macrophytes, namely *Sargassum polycystum* (the brown alga seasonally occurring in eastern Mactan Island), *Thalassia hemprichii* (the common sea grass in the embayment), and *Kappaphycus alvarezii* (a seaweed commonly cultured in the Philippines).

All laboratory experiments were undertaken at room temperature ranging from 25 to 28°C and at salinity 29–32 psu. The seawater used in the experiments was well aerated in advance. *Tripneustes gratilla* were collected at Maribago, Mactan Island (10°16′N 124°00′E) from November 1999 to January 2000. The temperature and salinity at the collecting site ranged from 28 to 29°C and 31–34 psu, respectively. During transport to the laboratory, the collected specimens were placed in a plastic pail with fresh seawater and provided with adequate aeration. In the laboratory, the organisms were acclimated for 1–1.5 h before experimentation. The study was conducted from October 1999 until January 2000.

Ingestion and egestion rates

Tripneustes gratilla ranging from 3.7 to 6.4 cm in test diameter were placed into individual glass jars with 4 l of seawater. After one hour, 100 g of cleaned, blotted *Sargassum polycystum*, *Thalassia hemprichii*, or *Kappaphycus alvarezii* were placed inside the glass jars. There was only one species of macrophyte inside each jar. After two to three hours, uneaten food was collected, blotted and weighed (in fresh weight—FW). The weight-specific

Table 1. *Ingestion rate (g FW/g DW-h) of* Tripneustes gratilla *feed w/ three types of macrophytes.*

	Ingestion rate		Dry weight (gm) of sea urchin		
Seaweed type	Mean	SD	Mean	SD	N
Kappaphycus alvarezii	0.0552	3.08	6.64	3.08	4
Sargassum polycystum	0.0486	2.06	6.40	2.06	4
Thalassia hemprichii	0.0426	4.87	7.68	4.87	4

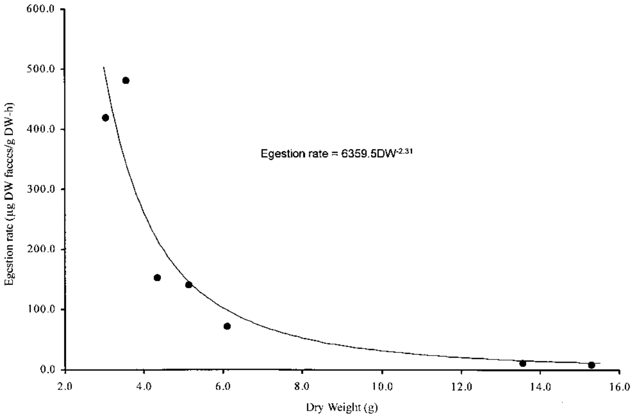

Figure 1. The relationship between weight-specific egestion rate and dry weight of *Tripneustes gratilla* (eastern Mactan Island, central Philippines).

ingestion rate of *Tripneustes gratilla* to the three types of macrophytes was calculated as g FW of the macrophyte/g DW of *T. gratilla*-h.

Tripneustes gratilla ranging from 3.6 to 6.4 cm in test diameter were placed in individual glass jars containing 4 l of seawater. After seven hours, the faeces produced were collected using a Pasteur pipette and preserved with 4% buffered formalin. The sample was filtered using a preweighed gel filtration chromatography filter. The filter residues were dried at 90°C for 48 h and weighed. The weight-specific egestion rate was calculated as μg DW faeces/g DW urchin-h.

Respiration rate

Tripneustes gratilla ranging from 2.9 to 5.0 cm test diameter were placed in individual glass jars containing 1.5 l of seawater. A jar without *T. gratilla* was the control. Respiration rate was determined as an increase in total CO_2 of the incubating medium (Vink & Atkinson, 1985) after one hour. Total CO_2 was derived from pH measurements, temperature and salinity during the inclusive incubation period. Total alkalinity was assumed to be constant during the one-hour incubation period. The weight specific CO_2 respiration rate was expressed in μmol CO_2/g DW urchin-h.

Ammonium excretion

Tripneustes gratilla ranging from 1 to 4 g DW were placed in individual glass jars with 4 l of seawater. A jar without *T. gratilla* was the control. Water samples for ammonium determination were collected before and after one hour of incubation. The samples were immediately analysed for ammonium based on the procedure by Strickland & Parsons (1972). The change in ammonium concentration before and after incubation less the changes in ammonium of the control represents the net amount of ammonium excreted by the individual sea urchin. The weight-specific ammonium excretion was calculated as μmol NH_4-N/g DW urchin-h.

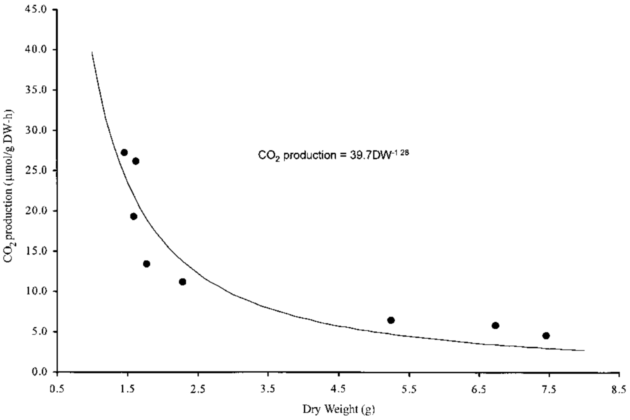

Figure 2. The relationship between weight-specific CO_2 respiration and dry weight of *Tripneustes gratilla* (eastern Mactan Island, central Philippines).

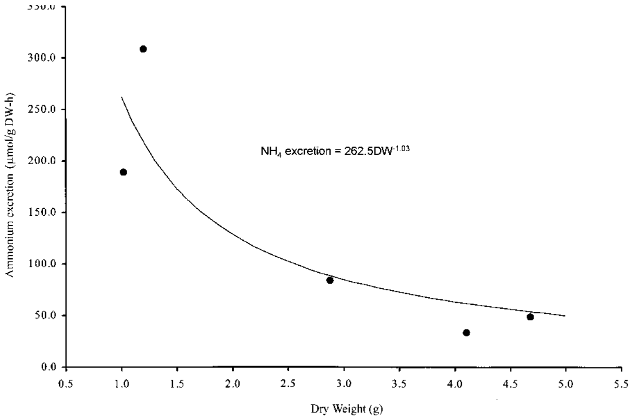

Figure 3. The relationship between weight-specific ammonium excretion and dry weight of *Tripneustes gratilla* (eastern Mactan Island, central Philippines).

Calculations

The relationship between body mass (W) and the physiological or metabolic rates (M) were described using the power function equation (Webb et al., 1977):

$$M = KWb \qquad (1)$$

where M is the metabolic rate; K and b are constants and W is the body weight.

RESULTS

Ingestion and egestion rates

The weight-specific feeding rate by *Tripneustes gratilla* was similar for the three macrophytes (Table 1). There were no significant differences (P=0.86) in weight-specific feeding rate with food type. Weight-specific egestion rate (in μg DW faeces/g DW urchin-h) of *T. gratilla* was indirectly proportional to body weight (r^2=0.93) (Figure 1). The regression coefficient or slope (b) and the constant (K) for weight-specific egestion rate were −2.31 ±0.68 (mean ±SE) (P=0.02) and 6359.55 ±5394.31 (P=0.29), respectively. Assuming a constant egestion rate throughout the day, the daily egestion rate would range from 0.2 to 11.5 mg DW faeces/g DW urchin.

CO_2 respiration and ammonium excretion

Carbon dioxide respiration and ammonium excretion decreased with increasing sea urchin weight. The power function equation, M=KWb fitted well with the weight-specific CO_2 respiration and ammonium excretion rates (r^2=0.92 and 0.86, respectively) (Figures 2 & 3). The b and K values for CO_2 respiration were −1.28 ±0.48 (P=0.04) and 39.72 ±10.59 (P=0.01), respectively. The b and K for ammonium excretion were −1.03 ±0.46 (P=0.11) and 262.51 ±56.89 (P=0.02), respectively.

DISCUSSION

The results on the ingestion rate in this experiment seem to indicate that *Tripneustes gratilla* is a generalist herbivore although it is possible that when presented with a choice, it may prefer some food items. Gomez et al. (1983) noted that *T. gratilla* collected from Calatagan, Batangas, Philippines highly preferred economically important red algae such as *Eucheuma striatum*, *Gracilaria coronipifolia*, *Hypnea cervicornis* and *Laurencia* sp. At Bolinao, north-eastern Philippines, *T. gratilla* consumed small amounts of dead sea grass fronds, avoided the macroalgae *Amphiroa fragilissima* and *Sargassum crassifolium* but showed a feeding preference for live fronds of *Thalassia hemprichii* (Klump et al., 1993). Individuals of *Lytechinus vareigatus* (Lamarck) fed with monospecific diets have significantly lower feeding rates than those fed either mixed or epibiont diets indicating that a generalist diet may be essential to its survival (Beddingfield & McClintock, 1998). Anecdotal observations of seaweed farmers in Danajon Reef, north-western Bohol in central Philippines also indicated that relatively smaller sea urchins have a higher ingestion rate. More feeding experiments on smaller specimens and with other macroalgae will be conducted to confirm its tropic position. The higher egestion rates in smaller sea urchins may be related to the length of their gut. Smaller specimens may have a shorter gut than larger specimens thus would be expected to have higher gut turnover rate.

Carbon dioxide respiration and ammonium excretion rates decreased as body size increased. This corroborates the findings of Koike et al. (1987) who reported a negative correlation between rate of ammonium excretion by *T. gratilla* and its ash-free dry weight, and suggested that smaller sea urchins are metabolically more active. Our value for b (−1.28) for CO_2 respiration of *T. gratilla* is very close to the value reported by Vink & Atkinson (1985) (b=−1.00). A value of 1 for b indicates a constant weight specific metabolic rate for various sizes of organisms (Webb et al., 1977). However, our CO_2 respiration rates were higher (range: 4.5–27.2 μmol CO_2/g DW-h) than the 3.8 μmol CO_2/g DW-h reported by Vink & Atkinson (1985) for *T. gratilla* collected in Western Australia (32°00′S 115°30′E). The higher seawater temperature (range: 27–32°C) in our study area may cause higher CO_2. Vink & Atkinson (1985) used specimens where the temperature ranged from 15 to 20°C. In addition, their frequent exposure during low tide may have also increased their stress and hence, their CO_2 respiration.

The value of b (−1.03) for ammonium excretion of *T. gratilla* further confirms the constancy of weight specific metabolic rate within the size range studied. The range of ammonium excretion rate of *T. gratilla* from 0.03 to 0.31 μmol/g DW-h falls within the range measured by Dy & Yap (2000) for specimens collected in the same study area. Koike et al. (1987) reported values from 0.6 to 2.8 μmol/g ash-free DW-h for *T. gratilla* found on the southern coast of Papua New Guinea. The current data are within the range reported by Bray et al. (1988) for *Centrostephanus coronatus* (0.2 μmol/g DW-h) from a subtidal rocky reef in southern California and by Ryabushko & Propp (1986) for *Toxopneustes chlorocanthus* (0.151 μmol/g DW-h) from Vanphong Bay and Bengoi Bay, Vietnam.

The environmental regime specific to the habitat may be an important factor affecting the metabolic rates of the organism. It is interesting to note that despite adverse environmental conditions characterized by human harvesting, diminishing habitat size, mooring of motor-boats and other anthropogenic disturbances brought about by coastal development, *T. gratilla* are still thriving in the study area. The next investigation will focus on the size–frequency distribution and the reproductive cycle of *T. gratilla* in this area.

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