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Prey Selection and Feeding Rates of *Drupella cornus* (Gastropoda: Muricidae) on Corals from the Jordanian Coast of the Gulf of Aqaba, Red Sea

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Abstract

The corallivorous muricid *Drupella cornus* represents a potential threat to coral reefs. This study aimed to describe and quantify gazing activity and prey selection by *D. cornus* on corals from the Jordanian coast of the Gulf of Aqaba. Field observations revealed that *D. cornus* was mostly found on branching corals such as *Acropora* sp. and *Stylophora* sp. with an average of 13.72 ± 7.4 and 9.8 ± 9.2 individuals per colony, respectively, while only 4.0 ± 2.2 individuals per colony were found on the massive coral *Porites*. Laboratory experiments confirmed our observations in the field in terms of prey selection, where *Acropora* and *Stylophora* attracted most *D. cornus* when several coral species were placed with them in laboratory aquaria. The measured grazing rates of *D. cornus* were greatly influenced by seawater temperature, increasing by five times at 30ºC compared with 18ºC i.e., rates of 1.31 ± 0.19 and 0.27 ± 0.11 cm^2. day^{-1} $individual^{-1}$, respectively. No significant effect between *D. cornus* wet body weight and grazing rate was detected.

Keywords: *Drupella cornus*, corallivorous snails, coral, Gulf of Aqaba, reef health.

1. Introduction

Predators like the crown-of-thorns starfish (*Acanthaster planci*) and corallivorous gastropods as well as disease are common threats to coral populations in many countries around the world (Birkeland, 1989; Schumacher, 1992). Anthropogenic effects and various corallivores are recognized as important factors in structuring reef communities (Baums *et al.* 2003). During the last two decades, gastropod predation by *Drupella* spp. on corals has caused significant destruction to many reefs across the Indo-Pacific region (Turner, 1994a; Johnson and Cumming, 1995; Cumming *et al.*, 1999). Furthermore, gastropod predation, together with coral disease and bleaching, are largely blamed for declines in threatened coral species, e.g., *Acropora palmata* and *Acropora cervicornis*, in addition to interference with recruitment and prevention of juvenile growth (Miller 2001; Schuhmacher *et al*., 2002; Baums *et al*., 2003).

Three species belonging to the genus *Drupella*, i.e., *D. cornus, D. rugosa* and *D. fragum* are recognized. Of those, only *D. cornus* can be found in the Red Sea (Johnson and Cumming, 1995). *Drupella cornus* prey almost exclusively on living coral tissues (Turner, 1994b) and display outbreaks similar to those of *Acanthaster planci* (Turner, 1994a; Black and Johnson, 1994; McClanahan, 1997). Such outbreaks are thought to be due to overfishing of the natural predators and to changes in water temperature and salinity (Lam and Shin, 2006). Outbreaks of *Drupella* spp. can cause significant damage to impacted reefs. For example, it was reported that *D. rugosa* and *D. fragum* outbreaks had a significant impact on scleractinian corals with up to 35% destruction (Moyer *et al*., 1982; Boucher, 1986). *Drupella rugosa* is reported to cause severe bioerosion of certain coral species in Hong Kong (Lam and Shin, 2006). Furthermore, it was suggested that there is a correlation between the abundance of the gastropods and disease and that these can be transmitted between affected and healthy corals by the corallivores (Antonius and Riegl, 1997; Williams and Miller, 2005).

Corallivorous gastropods exhibit prey selectivity in the field, some being restricted to only a few coral prey, while others are more general (Moyer *et al*., 1982; Fujioka and Yamazato, 1983; Turner, 1994a; Shafir *et al*., 2008; Morton and Blackmore, 2009; Schoepf *et al*., 2010). Some corallivorous gastropods are less selective so that they redistribute themselves among the available prey, when the prey of choice decreases in abundance. It has also been shown that *Coralliophila abbreviata* doubled numbers on infested coral colonies with a decrease in coral cover instead of switching to another host (Baums *et al*., 2003).

The relatively small (about 27 km) coastline of Jordan is located on the north eastern part of the Gulf of Aqaba. It has a small total coral reef' area, although it has high biodiversity values that rank among the greatest ever found (Mergner *et al*., 1992; Schuhmacher *et al*., 1995). Jordanian coral reefs are described as being in a good condition (Al-Horani *et al*., 2006) with no major catastrophes recorded that have significantly affected the corals. Some localized damage has occurred through

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industrial, solid waste and ship-based discharges, coral predation and disease, dredging, sedimentation and damage associated with diving and boat anchoring (Mergner, 1981; Walker and Ormond, 1982; Schuhmacher, 1992; Mergner *et al*., 1992; Al-Moghrabi, 1996, 2001; Wilkinson, 2000; personal observations). However, the fast growing city of Aqaba is expected to increase pressure on Jordan's coral reefs and mitigation measures might become necessary in the near future.

The present study was aimed at identifying the coral genera that are influenced by *Drupella cornus* predation in a marine protected area and to study the effect of seawater temperature on the rate of predation on corals. This was done in order to evaluate grazing rates at temperatures prevailing during summer and winter periods in the Gulf of Aqaba. Coral prey selection was also studied experimentally in order to identify the species influenced by the gastropod. Furthermore, and since age categories of *D. cornus* are classified according to size (Turner, 1994b; Black and Johnson, 1994), we have studied the effect of *D. cornus* size on coral grazing rates to identify the most destructive size class. The overall objective of the study was to assess the potential of *D. cornus* to cause significant damage to coral reefs, especially during outbreaks.

2. Materials and Methods

2.1. Study site and sample collection:

Two coral reef sites located in front of the Marine Science Station were selected to collect samples of *Drupella cornus* (Fig. 1). The two sites are part of a marine protected area (classified as class-A MPA) and are characterized by high coral cover and high biodiversity (Mergner *et al*., 1992). The sites are devoid of direct human impacts. Indirect impacts relate to the neighbouring passenger port, where ship movement and solid waste disposed by passengers are partially affecting local reefs (personal observations). *Drupella cornus* individuals were collected during spring and summer using SCUBA from between 0.5-5 m depth along the coast of the Marine Science Station (ca. 700 m long). During the survey, all coral colonies present in an area were inspected for the presence of *D. cornus*. The divers used forceps to pick up individuals from infested corals. The numbers of individuals collected and the infested corals and their sizes were recorded and used to analyze the distribution and natural prey selectivity of *D. cornus* in the field. The collected *D. cornus* were immediately transferred to the laboratory and maintained in flow through aquaria irradiated with HQI lamps (12:12 light dark cycle) and fed with pieces of coral fragments.

2.2. Coral prey selection

Coral prey selection by *Drupella cornus* was studied by incubating individuals with seven coral species that are common to the Gulf of Aqaba. About 100 individuals were placed midway in a 50 L aquarium (dimensions; 60 cm X 30 cm X 30 cm) and small coral samples representing *Acropora* sp., *Stylophora* sp., *Porites* sp., *Turbinaria* sp., *Platygyra* sp., *Fungia* sp. and *Favites* sp. were placed at the edges in the same aquarium. After the movements of the *D. cornus* individuals were completed, the numbers associated with each coral sample were counted. The experiment was repeated three times and averages plotted as percentages of the total number of individuals used in each trial.

2.3. Effect of incubating seawater temperature on coral grazing

Freshly collected *Drupella cornus* individuals were used to study the effects of changing seawater temperature on coral grazing rate. Five different seawater temperatures ranging between 18°C and 30°C at three degree intervals were selected to conduct this experiment. Seawater was maintained at the desired temperature by means of a circulating thermostat. Temperatures were selected to cover the range recorded in the Gulf of Aqaba, which is between 21°C in winter and 27°C in summer (Manasrah and Badran, 2008). In addition, one point below the lowest and one above the highest recorded temperatures were tested. Preliminary tests showed that *D. cornus* is a fast grazer and, therefore, only two individuals were used to study grazing rate. Four replicates were carried out at each temperature, each one comprising two individuals and one small piece of the coral *Acropora* sp. (i.e. the preferred prey). Before the start of each experiment, both the coral and the *D. cornus* were left in seawater at the desired temperature for a few hours acclimatization. The experiments lasted until grazing (i.e. removal of the living tissue of the coral piece) was complete. The grazing rate was calculated by dividing the calculated coral surface area grazed by the time each *D. cornus* individual spent consuming it and expressed as cm^2. day^{-1}. $individual^{-1}$.

The surface area of the coral sample was measured by taking two photographs using an underwater digital camera of the two opposing surfaces. Subsequently, the surface areas of the two photographs were measured using the software Image Tool, and the sum of the two considered as the total surface area of the coral sample.

2.4. Effect of body weight on grazing rate

The collected *Drupella cornus* samples were separated according to their wet body weight into five categories; 0.1-1.0, 1.1-2.0, 2.1-3.0, 3.1-4.0 and 4.1-5.0 g. From each size category, four individuals were maintained at room temperature with a piece of *Acropora* sp. with a known surface area. The experiment lasted until complete coral tissue removal was observed and the grazing rate was calculated for each individual *D. cornus* by dividing the coral surface area by the time needed to complete the grazing. Each experiment was repeated four times and averages plotted.

Statistical analysis of the results obtained was performed using a comparison test (one way Anova at a confidence level of 95%).

3. Results

The field distribution of *Drupella cornus* with regard to the type and size of coral prey are shown in table 1. Most of the collected *D. cornus* were attached to *Acropora* sp., while *Stylophora sp*. and *Porites* sp. had fewer individuals per colony. The average number of individuals were 13.72 ± 7.4, 9.8 ± 9.2 and 4.0 ± 2.2 for *Corpora, Stylophora* and

Porites, respectively. Statistical analysis of the data revealed highly significant differences among the three coral species (P = <0.0001 between *Acropora* and *Porites*, P = 0.0094 between *Acropora*, and *Stylophora*, P = 0.0051 between *Stylophora* and *Porites*). *Drupella cornus* was found on species other than those listed in Table 1 within the study area, although *Galaxea fascicularis* and *Pocillopora damicornis* had *D. cornus* in other localities outside the study area. The depth distribution of *D. cornus* was between 0.5-5.5m for all samples collected. The shell heights of most (about 95%) collected individuals were in the range between 1.1 cm and 3.0 cm with about 75% between 1.1 and 2.0 cm and about 20% between 2.1 and 3.0 cm (Fig. 2).

Maintaining the *Drupella cornus* with seven different coral species that are common to the Jordanian coast of the Gulf of Aqaba showed that 63.5% ± 11.8 of the individuals moved towards the *Acropora* sp. The remaining individuals moved to the other coral species as follows:- 16.4% ± 7.2 towards *Stylophora* sp., 7.4% ± 3.4 towards *Porites* sp., 3.7% ± 3.2 towards *Favites* sp., 4.4% ± 1.5 towards *Platygyra* sp., 3.5% ± 0.8 towards *Turbinaria* sp., and 1.1% ± 0.9 towards *Fungia* sp. (Fig. 3). Statistical analysis of the results revealed highly significant differences between the *Acropora* sp. and all the other coral species (P <0.0001), while the only significant difference among the other species was found between *Stylophora* sp. and *Fungia* sp. (P <0.04). It was also noted that the movement of *D. cornus* was probably affected by crowdedness as some individuals, which did not find space on the preferred coral prey, were attached to the available corals in the aquarium. This is supported by the notion that tissue removal was only recorded for the *Acropora* and *Stylophora* species, while the rest of the incubated corals showed no symptoms of tissue necrosis, although there were some *D. cornus* attached to them.

The results of the effects of seawater temperature on the grazing rate of *D. cornus* on *Acropora* sp. showed that this increased steadily with increasing seawater temperature (Fig. 4). That is, the rate increased from 0.27 ± 0.11 cm^2. day^{-1}. $individual^{-1}$ at 18ºC to 1.31 ± 0.19 at 30ºC. Statistical analysis revealed significant differences among all rates except between 18ºC and 21ºC (P <0.0001).

The effect of *D. cornus* body weight on grazing rate on *Acropora* sp. is shown in Figure 5. Grazing rates for individuals in the size categories 0.1-1.0g, 1.1-2.0g, 2.1-3.0 g, 3.1-4.0 g, and 4.1-5.0 g were 0.52 ± 0.03, 0.56 ± 0.13, 0.57 ± 0.10, 0.57 ± 0.10 and 0.575 ± 0.05 $cm^2.day^{-1}.individual^{-1}$, respectively. No significant differences in grazing rate related to body weight were detected (P >0.05).

Table 1. Field distribution of *D. cornus* on the coral colonies in the study site. Only coral colonies with *D. cornus* are reported upon.

Coral type	No. of colonies sampled	Relative colony size (avg. no. of branches)	Depth range (m)	Total no. of *D. cornus*	No. of *D. cornus* per coral colony (range)	Avg. no. of *D. cornus* per coral colony
***Acropora* sp.**	160	5.22	0.5-5.5	2195	1-50	13.72 ± 7.41
***Stylophora* sp.**	28	4.46	0.5-5.5	247	1-43	9.79 ± 9.22
***Porites* sp.**	23	2.87	0.5-5.5	91	1-10	3.96 ± 2.18

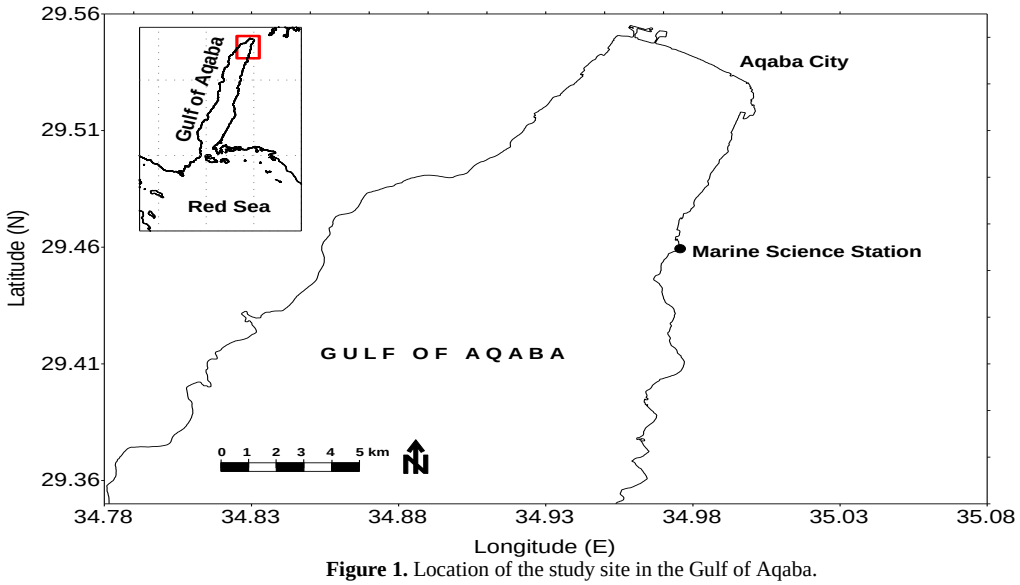

Figure 1. Location of the study site in the Gulf of Aqaba.

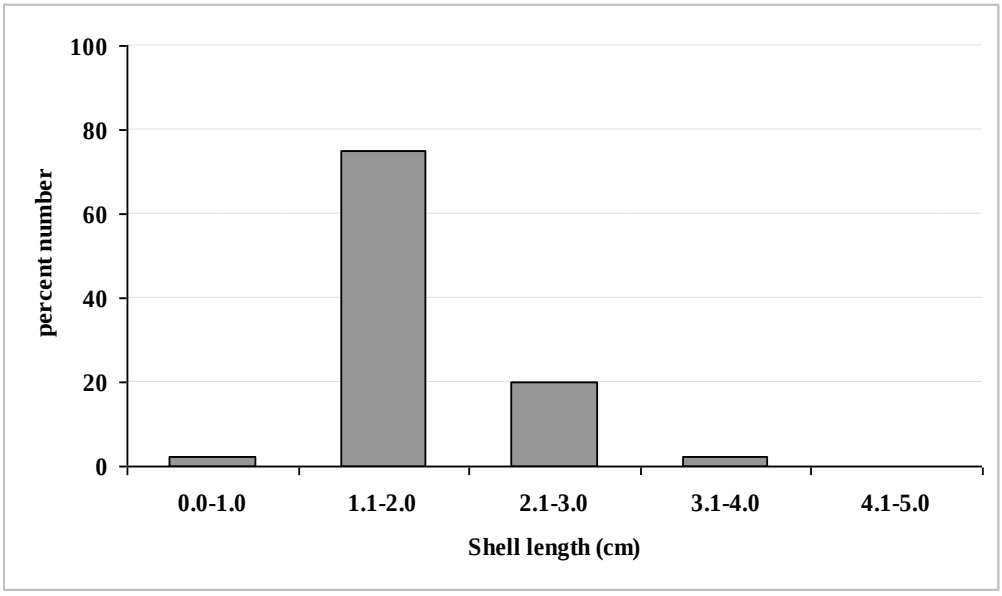

Figure 2. Shell height categories of the collected *D. cornus* individuals. The results are presented as percentages of each category for the total number of samples collected (total number of individuals collected was 2560).

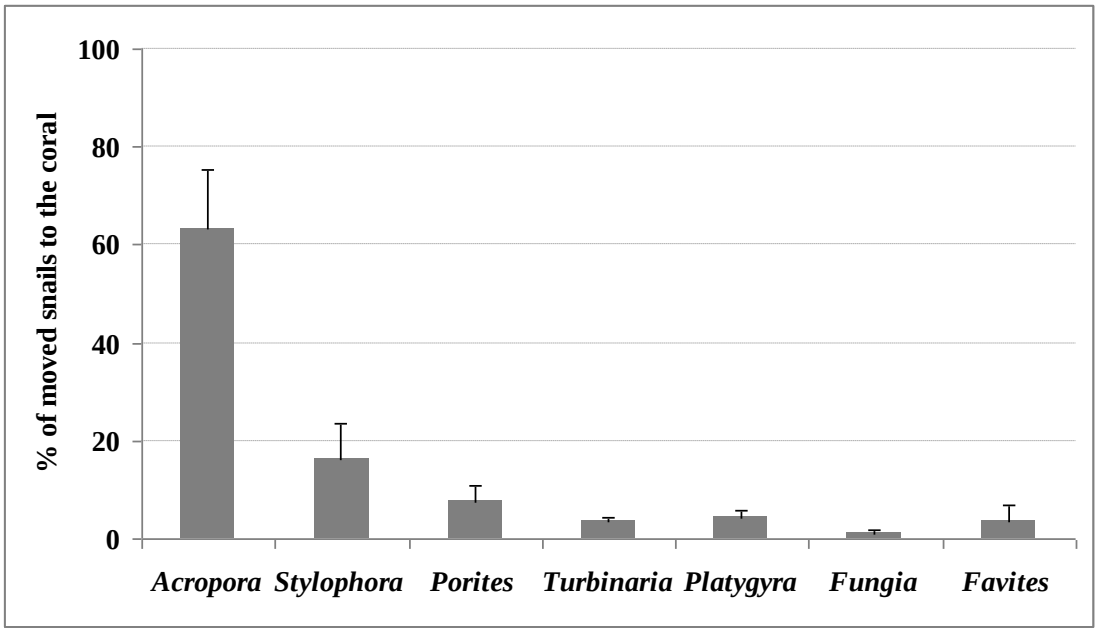

Figure 3. Percentages of the *D. cornus* individuals that moved to the different corals maintained with them. Numbers represent averages ± standard deviations.

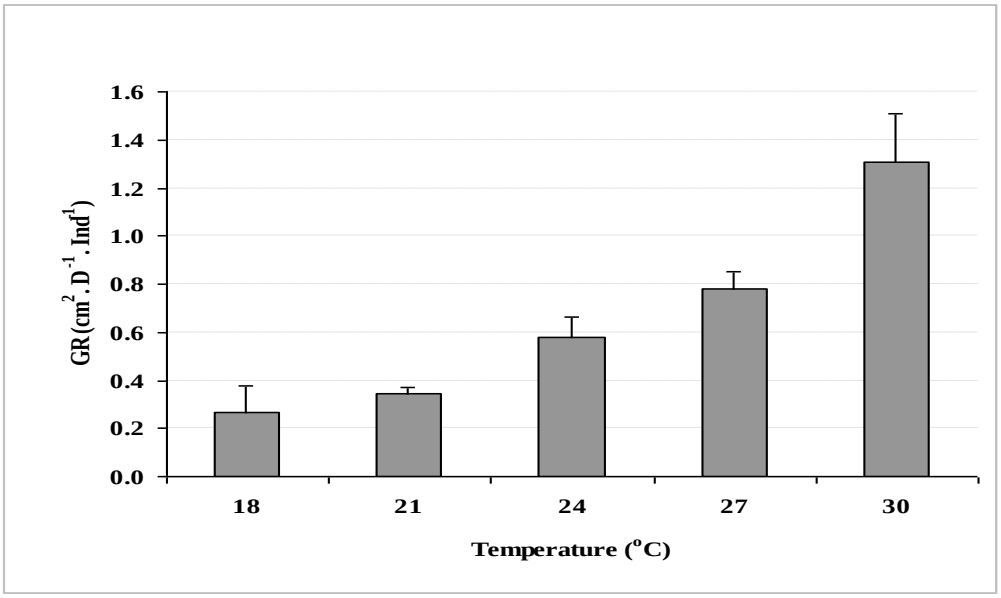

Figure 4. Grazing rates of *D. cornus* on *Acropora* sp. at different seawater temperatures. Numbers represent averages ± standard deviations.

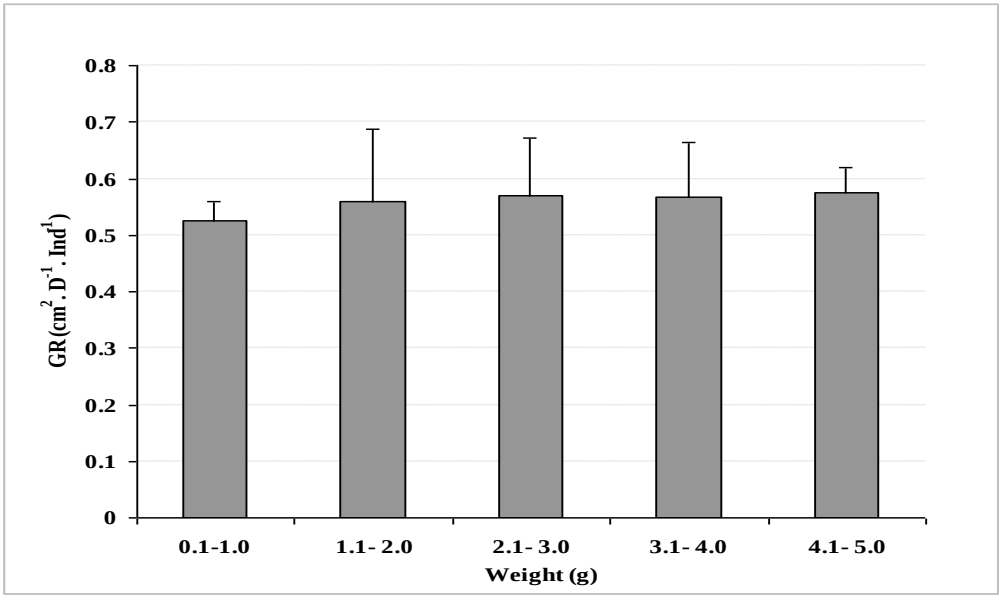

Figure 5. Grazing rates of the different body weight categories of *D. cornus* on *Acropora* sp. Numbers represent averages ± standard deviations.

4. Discussion

Analyses of the field data have indicated that *Drupella cornus* displays selectivity with respect to their preferred coral prey. Most of the collected individuals were associated with branching corals belonging to *Acropora*, suggesting that this genus is preferred over other corals. To a lesser extent, *Stylophora* was second in terms of the number of *D. cornus* individuals associated with it, while few were found with *Porites* sp., which is a massive coral (Table 1). The results obtained are in accordance with previously reported results from the Indo-Pacific and the Red Sea, where *Acropora* was always highly selected by *D. cornus* and other congeners (Turner, 1994a; McClanahan, 1997; Antonius and Riegl, 1997 and 1998; Cumming, 1999; Zuschin *et al*., 2001; Morton and Blackmore, 2009; Schoepf *et al*., 2010; Guzner *et al*., 2010). The selection of coral prey by some *Drupella* species, such *D. rugosa* was described as being complex as it changes according to the relative abundance of each coral taxon (Morton and Blackmore, 2009). Some species also display plasticity with respect to their coral prey, especially when the preferred corals are less abundant (Fujioka and Yamazato, 1983; Shafir *et al*., 2008; Schoepf *et al*., 2010), while others adjust their distributions among the preferred coral prey by increasing their numbers per coral colony (Baums *et al*., 2003).

Acropora in addition to *Stylophora* and *Porites* are important and dominant coral genera in the Red Sea (Riegle and Velimirov, 1994; Riegl and Piller, 1999). Thus, the destruction of species belonging to those genera

might lead to a significant change in the community structure of coral reefs in the area. It was suggested that the impacts of gastropod predation on reef communities will vary with coral species composition, in which case, when the preferred coral species are dominant, then the impact will be more evident on reef structure (Baums *et al*., 2003). The results of this study show that in some instances, about 50 individuals of *D. cornus* were found associated with one *Acropora* colony. This kind of aggregation has been described from Australia and elsewhere in the Red Sea (Johnson *et al*., 1993; Cumming, 1999; Zuschin *et al*., 2001). The field survey of *D. cornus* in the Gulf of Aqaba by Al-Moghrabi (1996) showed that number per square area was higher in industrial areas when compared with reserve areas. *Drupella cornus* can produce more than 150 thousand plankton veligers one month after spawning and which swim to their coral prey (Turner, 1992). Both anthropogenic impacts, such as the increased run-off, over fishing of predators such as triggerfish and increased reef damage, and natural causes such the variable larval recruitment, the existence of branching corals and a lack of competitors like *Coralliophila neritoidae*, have been suggested to explain outbreaks of *Drupella* spp. (Turner, 1994a; b; McClanahan, 1997; Baums *et al*., 2003; Guzner *et al*., 2010).

Age categories of *Drupella* have been classified according to shell height, recruits a being < 1.0 cm, juveniles < 2.0 cm, and adults >2.0 cm, which is about 2.5-3.5 years old (Turner, 1994b; Black and Johnson, 1994). In the present study, about 75% of the collected individuals had a shell height of between 1.1 cm and 2.0 cm and about 20% had a shell height of between 2.1 cm and 3.0 cm. According to the above classification of the age categories, the majority of the *D. cornus* collected for this study were, thus, juveniles with about one fifth being adults with an age of ~2 years. The recruits (<1.0 cm) and larger individuals (>3.0 cm) occurred in small numbers suggesting that the former had not been produced in large numbers during the preceding year, i.e., 2007, and that the latter might have been subjected to predation by, for example, trigger fish.

The maintenance of *D. cornus* in the aquarium together with different species of corals showed that *Acropora* sp. was preferred followed by *Stylophora* sp., both being branching corals. This observation agrees with the field observation, where the *Acropora* sp. had the highest number of *D. cornus* followed by *Stylophora* sp. In a similar experiment, it was found that *D. rugosa* preferred *Acropora* and *Montipora* over other corals like Leptastrea, *Pavona*, *Platygyra* and *Favia* (Morton *et al*., 2002). The results obtained suggest that some corals may have attraction factors for *D. cornus*. Kita *et al*. (2005) isolated montiporic acids from extracts of *Montipora* sp., and which were shown to be potent feeding attractants for *D. cornus*. Similarly, Ochi *et al*. (1992) have isolated calicogorgins from the gorgonian *Calicogorgia* sp. and which posses lethal and repellent qualities against *D. fragum*. It is, therefore, suggested that *Acropora* sp. and *Stylophora* sp. may contain attractants for *D. cornus*, while the rest of the studied corals may not, although biochemical analyses are needed to confirm this. Prey preferences in the field are suggested to depend on factors such as coral genus, colony shape, susceptibility to predators, influence of host tissue nutritional quality and/or secondary metabolite contents, and genetic differences (Baums *et al*., 2003; Schoepf *et al*., 2010). Schoepf *et al*. (2010) suggested that *Acropora* corals provide the best combinations of food and shelter for *D. cornus* and thereby determine its distribution pattern in the field. This hypothesis does not explain why similar coral species like *Pocillopora* or *Seratophora* are much less preferred by *D. cornus* although both of them are highly branching and should provide the necessary food and shelter. The prey selection exhibited by *D. cornus* might lead to changes in reef community structure, especially when outbreaks happen and might also lead to significant decreases in the number of the preferred coral prey as suggested for *Acropora palmata* (Miller 2001; Baums *et al*., 2003). The normal feeding activities of *D. cornus* might not cause significant damage to corals, but when outbreaks occur ecosystem changes might result, especially when this is added to other stressors such as bleaching, diseases and pollution.

When *D. cornus* was maintained with the coral *Acropora* at different seawater temperatures relatively high grazing rates were recorded, especially at warmer temperatures. Although, the mean surface seawater temperature in the Gulf of Aqaba is usually about 21ºC during winter and about 27ºC during summer (Manasrah *et al*., 2004), extreme temperatures might decrease to 18ºC in winter and increase to 30ºC in summer. The results obtained here showed that the grazing rate of *D. cornus* increased by about 5 fold at 30ºC compared with that at 18ºC (Fig. 4). This indicates that the feeding activity of *D. cornus* significantly increases in summer as compared with winter. This observation has important implications for reef health, especially when outbreaks happen as it can lead to destruction of the preferred prey on a coral reef (Turner, 1994a). It is possible that the grazing rate increases at warm temperatures because the corals become stressed as suggested for *D. rugosa*, which is attracted to mechanically stressed corals (Morton *et al*. 2002). The field observations made by Moyer *et al*. (1982) have shown that *D. fragum* caused destruction to *Acropora* reefs during summer with about one third of the reef being impacted in southern Japan (Moyer *et al*., 1982). Similarly, it has been reported that the number as well as the feeding activity of *D. rugosa* showed significant seasonal differences being significantly greater in summer (Morton and Blackmore, 2009). Such results have implications for reef conservation, which must consider mitigation measures during summer when outbreaks of *D. cornus* occur as it was reported that the direct removal of the snail helps preserve the infested corals (Miller 2001).

Body weight is herein shown to have no significant effect on the grazing rate of *D. cornus* (Fig. 5). The reason for this is unknown, but it is reported that the growth rate of *D. cornus* is higher for juveniles than it is for adults (Black and Johnson, 1994). This might be because of the higher energy demands of juveniles.

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