

# POPULATIONS OF A VERMETID GASTROPOD (*DENDROPOMA MAXIMA*) ON BRANCHING AND NON-BRANCHING CORALS ON MOOREA, FRENCH POLYNESIA

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*Abstract.* *Dendropoma maxima* is an unusual gastropods that lives in irregularly coiled shells cemented to the substrate, often coral. The purpose of this study was to determine how coral type affects the population structure in terms of population density and size of individuals, whether or not there is a correlation between population density and individual size, and whether or not branching coral can affect the gastropods mucus net feeding efficiency. To carry out this study, 3 transects of the Temae back reef on Moorea, French Polynesia were mapped out using a handheld GPS unit and a camera. Using this map, individual corals falling into the groups *Porites*, *Pocillopora*, *Montipora*, *Acropora formosa*, and Plate-*Acropora*, a group composed of the two species *Acropora hyacinthus* and *Acropora anthoceris*, were relocated and *D. maxima* populations were counted and individuals' apertures measured to serve as a proxy for size. A flow tank was also constructed to measure quantitative effects of a branching coral obstruction on *D. maxima*'s maximum mucus net radius. I found that *Montipora* and *Porites* corals tended to have the highest population densities of *D. maxima* while *Acropora formosa* and Plate-*Acropora* had the lowest densities. *Porites* corals had the largest individual *D. maxima* while *Acropora formosa* had the smallest individuals. There was found to be no significant correlation between population density and individual size and between mucus net feeding efficiency and maximum net radius. Space for settlement is likely a more important contributor to population density while individual size seems to depend mostly on coral type. Future studies should look into how corallites could shape size of *D. maxima* individuals and into the competitive interactions between corals and vermetids for space.

*Key words:* gastropods; vermetids; interspecific competition; intraspecific competition; population density; coral reef; Moorea, French Polynesia

## INTRODUCTION

Coral reefs are the most diverse ecosystems in the ocean and in terms of number of species per unit area rival even tropical rainforests in biodiversity (Sale 1977). This diversity is largely due to the coral itself. Symbiotic zooxanthellae within corals allow them to act as primary producers within their communities and help to make coral reefs thousands of times more productive than surrounding pelagic systems (Hoegh-Guldberg 1999; Hatcher 1988). Furthermore, the enormous structural variety based upon long-term accumulation of calcium carbonate skeletons across different coral genera can provide a complex habitat for many species of fish, algae, and invertebrates (Veron 1995).

The habitat coral provides is especially important to sessile marine invertebrates, as space on which to live is often the most important limiting resource for early survival. For example, in barnacles the two most common causes of death for juveniles are

predation, which is much more common before settlement, and competition with nearby barnacles for available space during and after settlement (Connell 1961). On a coral reef, live corals and coral rubble together account for a vast majority of settlement space and thus, despite being competitors for space themselves (Jackson 1977) are the most important substrata for sessile invertebrates on reefs.

One common reef invertebrate that utilizes corals for settlement is the vermetid gastropod *Dendropoma maxima* (Keen 1961). Vermetids are unusual gastropods irregularly coiled shells found deep within the substrate with only the shell aperture breaking the surface (Schiaparelli 1999). Unlike many other sessile marine invertebrates that sieve the water column to feed, *D. maxima* feeds on both benthic phytoplankton and zooplankton biofilms using a mucus-net made from continuously secreted mucus spread into the water by its tentacles (Kreitz 2001; Hughes and Lewis 1974; Kappner 2000). The net

remains in the water for 13-minute intervals or until saturated and is then hauled in and ingested along with all of the trapped plankton (Hughes and Lewis 1974; Kappner *et al.* 2000). Wave action has been shown to be extremely necessary to spread the nets across the substratum to maximize feeding efficiency (Hughes and Lewis 1974). Also, contact between mucus nets of two individuals has been shown to stimulate net hauling, reducing feeding efficiency and possibly the size of individuals in more densely packed populations (Hughes and Lewis 1974; Smally 1984).

Competitive interactions between *D. maxima* and corals have come to light in recent years though are still not well understood. Since 2008, several studies have shown strong correlations between *D. maxima* mucus net contact over a period of several months and coral deformities including tissue death; this is thought to give the snails a competitive advantage by preventing the surrounding coral from blocking the current (Zvolini *et al.* 2008; Shima *et al.* 2010; Shima *et al.* 2013). Though previous findings had shown that vermetids grow quickly in order to prevent coral overgrowth (Smally 1984), these findings are the first evidence that vermetids may compete with corals more directly than previously thought.

This study had several goals. The first was to determine how coral type affects *D. maxima* population structure in terms of population density and size of individuals. I hypothesized that: (1) as branching corals have less flat space available for larval settlement and could disrupt water flow necessary for mucus-net spreading, that smaller populations of *D. maxima* will be present on more heavily branching corals (e.g. *Acropora formosa*) while larger populations will be present on non-branching corals (e.g.

*Montipora*) and (2) based on the findings of Hughes and Lewis (1974) and Smally (1984), that larger individuals will be present on branching corals than on flat corals due to reduced competition and increased feeding efficiency. The second goal was to determine whether the inverse relationship between individual size and population density documented by Smally (1984) holds true across the coral genera *Pocillopora*, *Porites*, and *Montipora* and for three species, *Acropora hyacinthus*, *Acropora anthocercis*, and *Acropora formosa*, in the genus *Acropora* rather than just in *Porites lutea*. I hypothesized that this relationship will generally hold true across all of these taxa. My final goal was to determine whether branching coral in the vicinity of *D. maxima* have a significant effect on mucus net spread ability. I hypothesized that branching corals would disrupt water flow significantly enough to reduce the area covered by the mucus nets and thus reduce feeding efficiency in *D. maxima*.

## MATERIALS AND METHODS

### Study site

The field component of this study was conducted on the back reef of the Temae public beach on the island of Moorea, French Polynesia (17° 29' 57.70" S, 149° 45' 27.29" W; Figure 1). Moorea is a high, volcanic island and is one of the windward islands of the Society Island archipelago. The back reef at Temae was selected as a field site due to its easily accessible and abundant Scleratinian corals of the genera *Porites*, *Pocillopora*, *Montipora*, and *Acropora* (Title 2009). All research was conducted between the hours of 0730 and 1300 from 7 October to 11 November 2014.

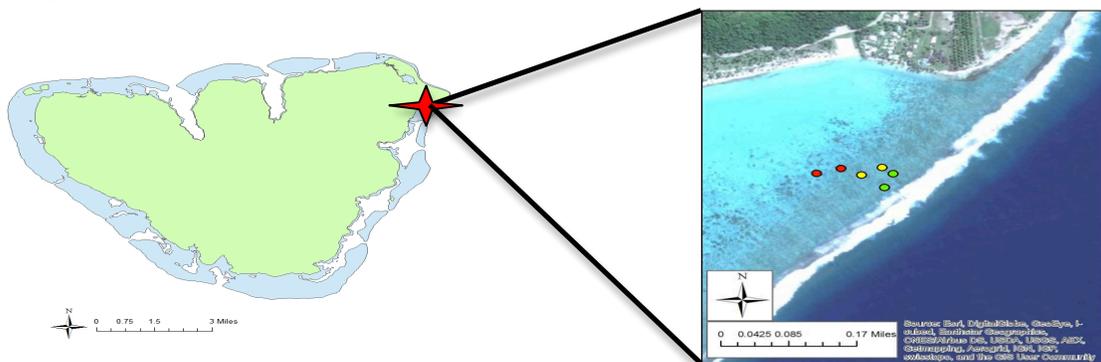


FIG. 1. Map of Moorea, French Polynesia (left) and back reef at Temae (right). The three mapped transects (Table 1) are marked with colored dots. Transect 1 is green, transect 2 is yellow, and transect 3 is red.

TABLE 1. GPS points of transects used to map back reef at Temae.

Transects	GPS Coordinates
1.	S17° 30.020'; W149° 45.384'- S17° 30.042'; W149° 45.394'
2.	S17° 30.010'; W149° 45.396'- S17° 29.999'; W149° 45.422'
3.	S17° 30.011'; W149° 45.443'- S17° 30.018'; W149° 45.471'

#### Field mapping

To obtain a random sample of the corals at Temae, three 50 m transects (Table 1) of the back reef were mapped using a handheld Garmin GPS unit and a Nikon Coolpix underwater camera. For each 50 m strip, GPS points were taken approximately every 10 m or when a major change in the coral environment occurred. As many photos of corals were taken as possible and paired with their corresponding GPS points to make them easier to find later. Photographs were used to identify coral to genus for *Porites*, *Pocillopora*, and *Montipora*, and to species for *Acropora formosa*, *Acropora hyacinthus*, and *Acropora anthocercis* using Veron's (1986) *Corals of Australia and the Indo-Pacific*. The three 50 m. strips mapped the approximate middle of the reef where the current, though not weak, was more consistent throughout. Temae's outer edges were avoided to avoid strong local current differences thus avoiding major abiotic differences between the three transects.

#### Population survey

I divided the mapped corals into five groups, *Porites*, *Pocillopora*, *Montipora*, *Acropora formosa*, and Plate-*Acropora* (**Appendix A**), that I felt sufficiently encompassed most of the Scleratinian structural diversity seen on the Temae reef. While the other four groups were based upon taxonomic relationships, Plate-*Acropora* was based upon morphological similarities and contained the species *Acropora hyacinthus* and *Acropora anthocercis*; both species formed plates parallel to the water surface held up by thin stalks. This morphological similarity and the relative rarity of each at Temae (Title 2009) justified their inclusion into one group. I used a random number generator to select 15 coral heads per group, based on the corresponding picture number in the camera, and then, using these pictures and their associated GPS points, I relocated each of these corals. All 75 coral heads were

randomly distributed across the three mapped transects.

Both density and individual size data were collected at each site. To calculate *D. maxima* densities, a 30-cm<sup>2</sup> quadrat was haphazardly placed on each coral head and all *D. maxima* present within were counted. For corals smaller than 30-cm<sup>2</sup>, the coral's length and width dimensions were taken with a ruler so serve as an estimate of area and all *D. maxima* present on the coral were counted. As a proxy for size of individual *D. maxima*, aperture diameter was also measured for every other individual within each quadrat or on the whole coral head if smaller than 30 cm<sup>2</sup>. A maximum of five individuals was measured at each coral head to minimize sample size differences between sites.

#### Flow-tank experiments

Finally from 10 November to 17 November 2014, I conducted a lab experiment to determine whether *D. maxima* maximum mucus net cover is influenced by branching corals in the vicinity. To accomplish this, a flow tank was constructed using a 75 x 35 x 25 cm tank at a 4° incline with water pumped in down a ramp. Water flowed out through 30 holes between 5-10 mm in diameter drilled into the back of the tank. After tank construction, a block of dead coral with two live *D. maxima* was taken out of a holding tank and placed inside the flow tank. The individuals were allowed to acclimate to the new environment for three hours. After three hours a false branching coral made from epoxy and dead coral rubble was placed into the tank between the flow source and the *D. maxima* individuals. All mucus nets present before the experiment began were removed at 0 minutes to begin each trial. Every five minutes, maximum mucus net radii were measured for both individuals without disturbing the experiment until thirty minutes had passed. As individuals tended to tow every 15 minutes or so (Hughes and Lewis 1974). A control experiment was also conducted in the same manner as before but without any obstructions. Five trials for both the experiment and control were conducted.

#### Statistical analysis

All statistical analyses were done using R. A Kruskal-Wallis one-way analysis of variance test in conjunction with a Dunn's post-hoc comparison test was used to compare means

of *D. maxima* densities between each coral type and to compare *D. maxima* individual sizes between each coral type. Linear regression was used to assess the relationship between individual sizes and population densities both for each coral type and for *D. maxima* populations in general. Finally, I used a Mann-Whitney U test to compare worm snail net radii with and without a branching coral obstruction. A 95% confidence interval was used for all tests.

## RESULTS

### Population survey

*D. maxima* population density was significantly different between coral types ( $p=0$ , Fig. 2). *Acropora formosa* housed the lowest average population density of 5.2 individuals/m<sup>2</sup> (Table 2) but was not significantly different from Plate-*Acropora* which housed an average of 11.3 individuals/m<sup>2</sup>. *Montipora* housed the highest average population density of 288.0 individuals/m<sup>2</sup> though due to high variance in the data was not significantly different from *Porites*. Densities on *Pocillopora* were not significantly different from those seen on *Porites* though were significantly different than those seen on *Montipora*. *Pocillopora*, *Porites*, and *Montipora* all housed significantly higher population densities than both *Acropora formosa* and Plate-*Acropora*.

*D. maxima* individual size was significantly different between coral types ( $p=0$ , Fig. 3). *D. maxima* found on *Acropora formosa* were significantly smaller than on every other coral type. *Porites* had the largest average *D. maxima* individuals and sizes were significantly different from *D. maxima* found on *Montipora* and *Pocillopora* which, had individuals that were insignificantly different in size. *D. maxima* found on Plate-*Acropora* were not significantly different in size from those found on *Pocillopora*, *Porites*, and *Montipora*.

*D. maxima* individual size and population density across coral types were not significantly correlated (Fig. 4). *Acropora formosa* and Plate-*Acropora* were not included for individual linear regression analysis due to insufficient sample size but were still included in linear regression analysis for all coral types. Adjusted  $R^2 = 0.01$  and  $p = 0.16$  for linear regression.

TABLE 2. Mean and standard deviation of population density and individual size for all 5 coral types

Group	Density (#/m <sup>2</sup> )		Individual Size (cm)	
	Mean	Standard Deviation	Mean	Standard Deviation
<i>Pocillopora</i>	88.3	112.4	0.7	0.45
<i>Porites</i>	162.7	176.6	1.1	0.45
<i>Montipora</i>	288.0	165.1	0.7	0.37
<i>Acropora formosa</i>	11.3	20.6	1.0	0.73
Plate- <i>Acropora</i>	5.2	11.8	0.3	0.04

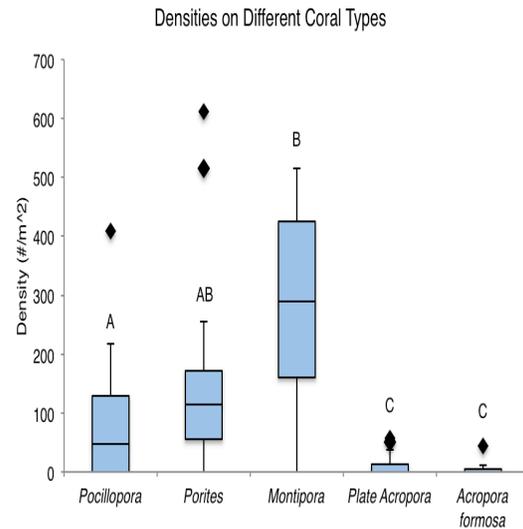


FIG. 2. *D. maxima* densities on five coral types with box-whisker plots (median, box: 25 and 75%, whisker: 2.5 and 97.5%, marked points are outliers). Letters correspond to groups of coral types with similar population densities. Coral types not sharing a letter have significantly different densities.

### Flow-tank experiments

For the flow tank experiment, there was no significant difference between the control trials and the trials with a branching coral obstruction (Fig. 5). Mann-Whitney U tests comparing controls and trials with an obstruction returned  $p$  values of 1.0 for Vermetid 1 and 0.53 for Vermetid 2.

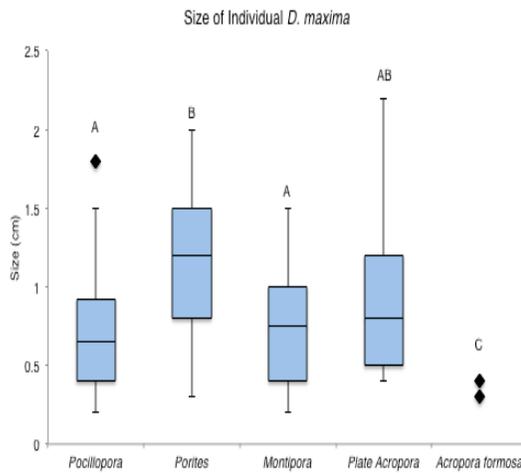


FIG. 3. *Dendropoma maxima* aperture diameters on five coral types with box-whisker plots (median, box: 25 and 75%, whisker: 2.5 and 97.5%, marked points are outliers). Letters correspond to groups of coral types with similarly sized *D. maxima*. Coral types not sharing a letter have significantly different individual *D. maxima* sizes.

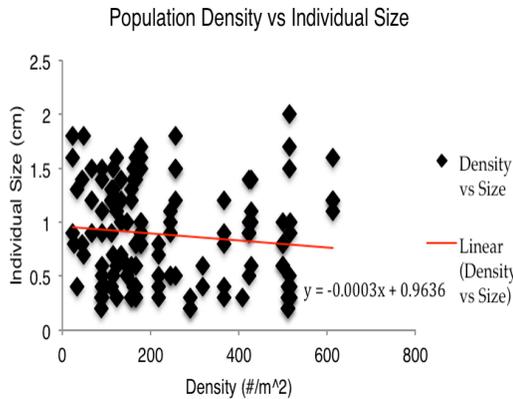


FIG. 4. *D. maxima* population density versus size of individuals for all coral types.

## DISCUSSION

### *Population study*

In general, non-branching corals like *Montipora* and *Porites* tended to have larger population densities of *D. maxima* than branching corals did. Reasons for this could have been simply that *Porites* and *Montipora* corals had more available flat space for settlement than the branching corals and thus

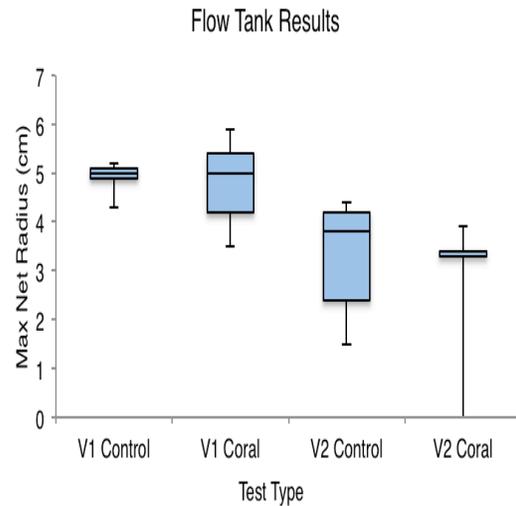


FIG. 5. Maximum net radii in a 30-minute period with and without a branching coral obstruction with box-whisker plots (median, box: 25 and 75%, whisker: 2.5 and 97.5%).

were able to support larger populations. These large flat spaces may have also been better exposed to the current than the interior of some *Acropora formosa* thickets for example and this placement could have assisted in spreading mucus nets and for feeding as was previously shown by Kappner *et al.* (2000). Despite having much larger surface areas than *Porites* and *Montipora* corals, *Acropora formosa* and *Plate-Acropora* had the smallest population densities further suggesting that exposed, flat area plays a large role in determining how large a vermetid population can get as has also been suggested for other sessile invertebrates (Connell 1961).

One unexpected finding was that despite large differences in mean population density (Table 2), *Porites* and *Pocillopora* did not house statistically different vermetid population densities. The low p-value ( $p=0.06$ ) for the Dunn's Test comparing densities on the two genera could have probably been corrected by factoring in surface area for *Pocillopora* as an increase in measured area would have reduced calculated vermetid population density. However, the high variance seen in densities for both groups suggests that sample size may not have been large enough and should be increased for any future study of vermetid populations on *Pocillopora* and *Porites*. Also, despite the drastic differences in shape, population densities on *Acropora formosa* were not significantly different from

those on Plate-*Acropora*. Though this may have simply been coincidental as the irregular plate shape in Plate-*Acropora* and thin branches on *Acropora formosa* could have both reduced area for settlement, the relatively close taxonomic relationship between the two groups suggest other characters such as structural fragility in *Acropora* (Veron 1986) may play a role in vermetid settlement that were not covered by this study.

*Porites* also housed the largest *D. maxima* individuals with similarities between *Pocillopora* and *Montipora* and the smallest individuals observed on *Acropora formosa*. The larger individuals on *Porites* as compared to *Pocillopora* and *Acropora formosa* were probably due to reduced space for growth on *Pocillopora*'s thin blades and *Acropora formosa*'s thin branches. The drastic size difference seen between vermetids on *Acropora formosa* and the other coral types could have also been due to *Acropora formosa*'s relative skeletal fragility (Veron 1986). Greater skeletal fragility could result in greater damage to the corals during a disturbance, a cyclone for example, and destroy any *D. maxima* living on the corals. This could result in smaller populations of vermetids on *Acropora formosa* that do not have time to grow to full size before the coral breaks. The size differences between *Montipora* and *Porites* were less obvious and suggested that differences in corallite morphology between the two genera could have affected vermetid growth (Veron 1986). Future study should be done to take corallite differences into account.

One significant error during this part of the study was an unbalanced sample size between the coral types as greater numbers of individuals were sampled at sites with larger densities. This led to a very small sample size, 5 individuals each, for individuals on both *Acropora formosa* and Plate-*Acropora*. While the standard deviation was quite low for individual size on *Acropora formosa* and did not seem to affect results, it was quite high for Plate-*Acropora* (Table 1) and made it impossible to discern whether the wide size ranges observed on Plate-*Acropora* represent the majority of individuals seen on that coral group or are a result of small sample size. Contrary to my hypotheses and to Smally's (1984) previous findings, population density and individual size were not correlated for any of the coral groups tested in this study. This suggests that food available may not be a limiting resource for vermetids on Moorea and that little intraspecific competition for

resources, at least between settled adults, occurs. This also suggests that differences in coral type, reported by this study, and competition between juveniles for available settlement space, reported by Connell (1961) for sessile barnacles, may be a more important factors in shaping vermetid population structures than competition among adults for food.

#### *Flow-tank experiment*

Flow tank data resulted in not significant differences between mucus net radii with and without a branching coral obstruction to flow. This suggests that settlement area may play a larger role in shaping vermetid populations than feeding efficiency. As the trials were plagued with errors including insufficient sample size, inconstant flow, and bubbly water reducing visibility into the tank, data reported for this study's lab experiment should be taken as preliminary data for future study. Any future studies should improve on flow tank design and attempt to achieve a constant flow through the entire tank as strong current has been reported to be an important component to vermetid feeding (Hughes and Lewis 1974; Kappner 2000).

#### *Future study*

If correlations between *D. maxima* and coral deformation pointed out by Zvolini *et al.* (2008) and Shima *et al.* (2010; 2013) are true, then *D. maxima* could have a disproportionately high effect on flatter corals like *Porites* due to its higher populations on these corals and larger size on individuals within those populations. Although major deleterious effects should not be expected as vermetids have been on reefs since the middle Miocene and are not new players in reef communities (Vescogni *et al.* 2008), Zvolini *et al.* (2008) suggested that their numbers might be increasing. With increasing anthropogenic effects on reefs (Hoegh-Guldberg 1999), it is unclear how competitive dynamics between *D. maxima* and corals might change. Future study should aim to discover any mechanism by which *D. maxima* might deform corals and how vermetids interact with their neighbors in the coral reef community.

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## APPENDIX A

Pictures of coral types identified on the Temae back reef on Moorea, French Polynesia with descriptions. All descriptions and photographs are my own.



FIG. 6. *Porites* sp. forms large bulbous masses of yellow and purple. It is the dominant coral on the Temae back reef.



FIG. 7. *Montipora* is a common and conspicuous coral genus on Moorea. It tends to form a purple or red crust on reef rocks.



FIG. 8. *Pocillopora* sp. has a flower like appearance and is lightly branching. Nodules are easy to see at the end of each blade and they come in a variety of colors.



FIG. 9. *Acropora formosa* is a heavily branching coral and often forms dense thickets.



FIG. 10. Plate-*Acropora* is uncommon and forms a plate parallel to the water's surface held up by a thin stalk. Light branching is present on the plate.