

Effects of herbivore grazing on juvenile coral growth in the Gulf of Mexico

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Abstract. This study demonstrates how herbivore grazing and substrate variations influence coral recruitment patterns at the Flower Garden Banks, Gulf of Mexico, for two brooding coral species, *Agaricia spp.* and *Porites spp.* Three herbivore treatments, two tile textures and two tile orientations were tested. Herbivore grazing significantly affected coral recruit growth for both species. These data suggested that *Diadema antillarum* may be destructively grazing since the recruits for both species were significantly smaller in the sea urchin treatment. *Agaricia* preferred rough textured tiles while *Porites* demonstrated no preference towards either tile texture. Preference for tile orientation differed between species, with *Agaricia* having larger coral recruits on vertical tiles and larger *Porites* were found on flat tiles. Our findings suggest that recruitment and growth of corals is species specific and should be considered as such when developing reef conservation strategies.

Keywords: Herbivory, Coral recruitment, *Diadema antillarum*, Flower Garden Banks, Phase shifts

Introduction

Competition for primary space plays a major structuring role on coral reefs (Lang and Chornesky 1990) and phase shifts from coral to algal dominated communities highlight the importance of this competition. Reports of declining reef resilience and phase shifts towards algal dominated communities appear to be increasing at an accelerated rate (Done 1991; McCook et al. 2001; Hughes et al. 2003, 2007; Aronson and Precht 2006). Caribbean reefs have experienced an average of 40% coral loss since the 1970's (Gardner et al. 2003) and exhibit little recovery as recruitment rates decrease. Many factors affect coral recruitment, however algal competition appears to play a significant role in inhibiting recruitment and growth (McCook et al. 2001; Lirman 2001; Jomba and McCook 2002; Birrell et al. 2005; Vermeij 2006).

Grazing has been suggested as a tool to mitigate coral recruitment since herbivore exclusion experiments have demonstrated that reduced grazing causes declines in coral cover (e.g. Lirman 2001) and increasing grazing enhances coral growth (Omori *et al.* 2006). Caribbean reef communities appear to be highly influenced by the echinoid species, *Diadema antillarum* (Sammarco 1980; Carpenter 1988, Carpenter and Edmunds 2006), which was profoundly demonstrated in 1982 when a natural, species-specific pathogen induced a mass mortality of *D. antillarum* across the entire Caribbean. Mortality rates reaching 99% were observed (Lessios et al. 1984) and reefs were taken over by robust algal species, which caused

a decrease in coral recruitment (Hughes et al. 1989). The recovery of *D. antillarum* has been remarkably slow; however, an increase in juvenile coral recruitment has been associated with urchin resurgence in Jamaica suggesting that these herbivores are a keystone species for coral growth (Carpenter and Edmunds 2006).

The Flower Garden Banks National Marine Sanctuary (FGB) (Fig.1) is an ideal area to study coral recruitment and competition, not only for its pristine conditions, but also for its relatively low species diversity (Gittings, 1992), which offers a simpler approach to understanding the ecology of the system. This study investigates how herbivores influence early coral recruitment and growth in the Gulf of Mexico.



Figure 1: Map the Gulf of Mexico showing the location of the Flower Garden Banks National Marine Sanctuary, approximately 115 miles south of the Texas/ Louisiana border.

Recruitment rate variations can have profound repercussions on the management of corals reefs and low coral recruitment rates currently being observed on Caribbean reefs are likely to result in slow reef recovery after natural or anthropogenic disturbances (Hughes et al. 1999). Using herbivorous species to promote recruitment has been suggested as a solution to reduce the long-term decline of coral communities (Hughes et al. 2005; McCook et al. 2001).

Material and Methods

Experimental setup

A 6m x 6m x 0.6m galvanized steel platform was constructed in June 2007 on a sand patch at 24m depth on the East FGB (27°54'33.0"N, 93°35'59.7"W, Fig.2) to provide a controlled environment to test the effects of herbivores, tile orientation and tile texture on coral recruitment and growth. Nine fiberglass bins (117cm x 36cm x 25cm), each randomly assigned to one of three treatments (1. *Diadema antillarum*; 2. *Cerithium litteratum*; 3. No herbivore control), were attached. Twelve alphas quarry recruitment tiles (15cm x 15cm) were suspended within each bin and served as settlement substrata. Two tile orientations and two textures were tested. Herbivore densities within treatments were determined by conducting herbivore censuses of the surrounding reef area and two *Diadema antillarum* and 50 *Cerithium litteratum* per bin were used. All animals were collected at night using SCUBA and herbivores were retained within bins using 1.3cm² wire mesh.



Figure 2: Coral recruitment platform constructed on a sand patch on the East Flower Garden Banks at 24m depth.

Data analysis:

Natural recruitment took place for nine months and in April 2008 four tiles from each bin were photographed using a high-resolution digital underwater camera with strobe. All images were analyzed using Photoshop 7.0 and ImageJ 10.2. Recruits were divided by genus (*Porites* and *Agaricia*) and individual size was measured and compared between treatment, tile texture and tile

orientation. Coral size data were normalized using log(x+1) to satisfy the assumptions of normality (Shapiro-Wilk) and equal variances for parametric statistical tests. Only main effects are presented here as no significance was observed for interaction terms. All statistics and graphics were performed in JMP 7.0.2.

Results:

Herbivore Treatment

The effect of herbivore treatment was significant for both *Agaricia* (p=<0.0001) and *Porites* (p=0.0343) (Table 1). *Agaricia* recruits were the smallest in the sea urchin treatment, larger in the mollusk treatment and the largest recruits were observed for the control (Table 2, Fig.3A). For *Porites*, recruit size only varied significantly between the mollusk and sea urchin treatments with the mollusk treatment having larger recruits (Table 2, Fig.3B). Control recruit sizes were larger than the sea urchin and smaller than the mollusk treatments; however, these differences were not significant.

Table 1: Analysis of variance (ANOVA) table indicating variation in coral size for *Agaricia spp.* and *Porites spp.*

Source	df	SS	F	P
Agaricia α=0.05				
Treatment	2	31.147846	21.1908	<.0001*
Orientation	1	47.889478	65.1613	<.0001*
Texture	1	6.359544	8.6532	0.0034*
Porites α=0.05				
Treatment	2	2.2692388	3.5318	0.0343*
Orientation	1	7.5842514	23.6078	<.0001*
Texture	1	0.0843076	0.2624	0.6100

*Indicates significant difference α=0.05

Table 2: Tukey's Studentized Range (HSD) Test for variation in coral size with Treatment.

	Tukey Grouping*	Mean	n
Agaricia α=0.05, Q= 2.35			
Control	A	2.6	175
Mollusk	B	2.3	149
Urchin	C	2.0	165
Porites α=0.05, Q= 2.39			
Control	AB	2.4	27
Mollusk	A	2.7	31
Urchin	B	2.3	18

*Levels not connected by the same letter are significantly different

Tile texture:

Tile texture had a significant effect on coral size for *Agaricia* (p=<0.0001), however there was no texture effect for *Porites* (p=0.6100, Fig.4B) (Table 1). T-tests demonstrated that *Agaricia* recruits on rough textured tiles were significantly larger than those growing on smooth tiles and there were also approximately three times as many recruits on rough tiles (Table 3, Fig.4A)

Orientation

The effect of tile orientation was significant for *Agaricia* ($p < 0.0001$) and *Porites* ($p < 0.0001$) (Table 1), however the opposite trends were observed. *Agaricia* were larger on vertical tiles and there were approximately 2.5 times as many individuals on vertical tiles (Table 3, Fig.5A). *Porites* recruits were larger on horizontal tiles and there were over four times as many individuals observed on these tiles (Table 3, Fig.5B).

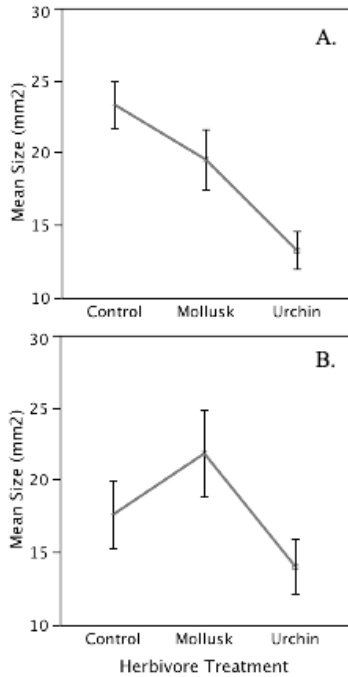


Figure 3: Variations in coral size between three herbivore treatments. A. *Agaricia* spp. B. *Porites* spp.

Table 3: Student's T-test results for variable coral size with tile texture and orientation

	Mean	n
<i>Agaricia</i> $\alpha=0.05$, $t=1.96488$		489
TEXTURE *		
Smooth	2.1	127
Rough	2.4	362
ORIENTATION *		
Flat	1.9	131
Vertical	2.7	358
<i>Porites</i> $\alpha=0.05$, $t=1.993$		78
TEXTURE		
Smooth	2.5	12
Rough	2.4	66
ORIENTATION *		
Flat	2.9	63
Vertical	2.1	15

*Indicates significant difference $\alpha=0.05$

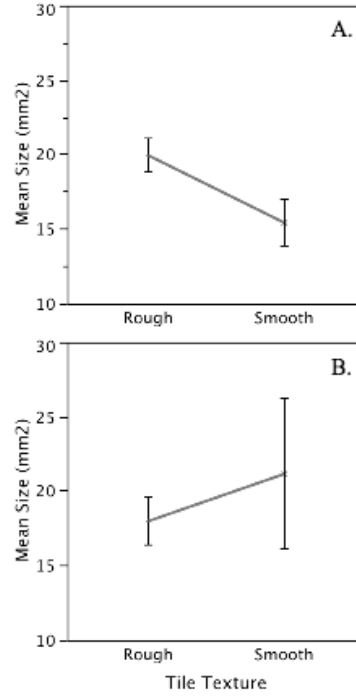


Figure 4: Variations in coral size between two tile textures. A. *Agaricia* spp. B. *Porites* spp.

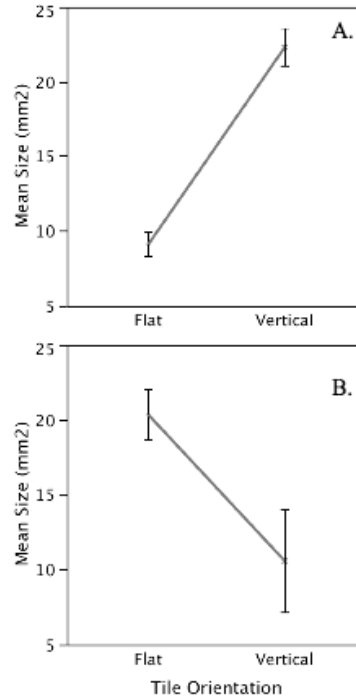


Figure 5: Variations in coral size (mm²) when two settlement tile orientations were manipulated. A. *Agaricia* spp. B. *Porites* spp.

Discussion

This study on juvenile coral growth at the FGB demonstrates that herbivore and substratum variations can have significant effects on recruitment and that these effects vary between coral species. Two types of corals were observed to recruit, *Agaricia* and *Porites*. Both species are brooding corals, where fertilization occurs within the polyp and released larvae are competent to settle almost immediately (Harrison et al. 1984). It is important to note that although these brooding coral species observed here are common on the FGB, they are not the dominant coral species. Coral cover at the FGB is dominated by other scleractinian corals, which reproduce annually in mass spawning events. The results observed here are representative of only one site in the Gulf of Mexico and caution needs to be taken when comparing these results to other coral species and reefs.

Coral recruitment is variable and larvae actively choose suitable substrate on which to settle. Space pre-emption by other benthic organisms can therefore lead to a decrease in local coral recruitment (Vermeij 2006). Research suggests that corals have inferior competitive capabilities and slower growth rates relative to other benthic organisms such as algae, which have been shown to smother young coral recruits (Miller and Hay 1998; Connell 1997; Edmunds and Carpenter 2001; Vermeij 2006). The top-down control of herbivore grazing on algal growth has been previously demonstrated (Carpenter and Pace 1997; McCook 1999) leading to the general hypothesis that herbivores may reduce competition, thereby increasing coral growth.

In this study we found that urchin grazing negatively affected coral growth for both species (Fig 3AB). Birrell et al. (2005) found that coral recruits almost exclusively preferred to settle on surfaces free from sediment and algae. Although urchin grazing has been correlated with an increase in recruitment, we found that corals were significantly smaller in the sea urchin treatment, indicating that experimental sea urchin levels resulted in destructive overgrazing. Destructive overgrazing occurs when echinoid densities are high and algal grazing becomes competitive and abrasive causing a reduction in coral recruitment (Sammarco 1980). For *Agaricia*, coral recruits were the largest in the control, which was not expected as most herbivore exclusion experiments have shown that when algae are released from grazing pressures, algal growth and coral mortality both increase (Sammarco 1980; Tanner 1995; Lirman 2001; Jomba and McCook 2002; Birrell et al. 2005). These unpredicted control results are most likely due to invasive herbivores recruiting to the control bins over the winter months. Several sea urchins were observed to recruit into all experimental bins,

however this recruitment is presumed to be equal across all treatments.

Substrate texture has been shown to have a strong effect on juvenile corals. Peterson et al. (2005) found corals demonstrated a strict preference towards grooves in tiles and Harrison and Wallace (1990) indicated settlement and metamorphosis were generally favored in crevices as well. In this study we demonstrated that texture preference might be species specific. *Agaricia* experienced higher growth rates on rough textured tiles while *Porites* demonstrated no significant preference. However, both species had more recruits on rough textured tiles and this is most likely due to the grooves providing sanctuary for corals from overgrazing and overgrowth by other encrusting species.

Research suggests that scleractinian corals show clear preferences for substrate position. Babcock and Mundy (1996) found that coral settlement on the undersurfaces of tiles was much higher, while Vermeij (2006) found higher survival rates on vertical surfaces. In this study we found that the effect of tile orientation on coral growth was highly species specific. *Agaricia* preferred vertical tiles with almost three times as many corals on vertical tiles and significantly larger sizes as well (Fig.5A). *Porites*, however, showed a higher affinity for flat tiles with significantly larger individual sizes and over five times as many recruits (Fig.5B). Vermeij (2006) has suggested that variations in orientation preference may stem from differences in growth rates. Faster growing species prefer open, exposed habitats while slower growing species prefer cryptic habitats because the faster growing corals may be more dependent on the symbiotic zooxanthellae in their tissues. During storm activity sand accumulated on horizontal tiles, which may have also changed orientation preferences.

The distribution and abundance of corals reflect the patterns of successful recruitment and long-term mortality. Coral settlement and growth is not random but dependent on factors such as light, water circulation, sedimentation, competition, predation and grazing (Rogers et al. 1984). Monitoring coral growth is important since mortality rates decrease considerably as coral recruits increase in size (Wilson and Harrison 2005). Since recruitment is crucial for coral population maintenance, any disruption in coral reproductive output will eventually lead to long-term declines (Omori 2006; Hughes and Tanner 2000; Nozawa et al., 2006). By gaining a more comprehensive understanding of coral recruitment and competition dynamics, research will offer important insights for conservation strategies and management decisions of coral reefs.

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