

AN ABSTRACT OF THE THESIS OF

AnnaRose Adams for the degree of Honors Baccalaureate of Science in BioResource Research presented on March 17, 2011. Title: Response of reef fish assemblages to overgrowth of the hydrocoral *Millepora complanata* by the crustose alga *Ramicrusta* sp.

Abstract approved: _____

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Natural disturbances and human activities can alter the benthic composition of coral reefs and other marine ecosystems. Reef fishes that associate with particular structures on the sea floor, such as coral heads, may be vulnerable to perturbations of those habitats. The spread of a newly discovered crustose alga (*Ramicrusta* sp.) on coral reefs in Lac Bay, Bonaire, has shifted the dominant coral benthos to a crust-covered seascape, posing a potential threat to habitat availability for the local reef-fish community. This study investigated the response of fish assemblages to *Ramicrusta* overgrowth of the hydrozoan fire coral *Millepora complanata*. I conducted visual surveys by snorkel throughout the back reef of the bay which assessed fish abundance and family diversity with respect to a gradient of *Ramicrusta* overgrowth of *M. complanata*. Of 170 observed heads of *M. complanata*, 88% were covered with varying degrees of *Ramicrusta*. Fish abundance differed significantly between high (26-100%) and low (0-25%) levels of overgrowth, yet this trend was likely influenced by larger heads of *M. complanata* having higher levels of *Ramicrusta* coverage. Differences in fish family diversity along a gradient of *Ramicrusta* coverage of *M. complanata* were not statistically significant. Field observations suggest the presence of *Ramicrusta* does not have a substantial impact on the structural complexity of *M. complanata*. Little change in habitat complexity suggests that fishes are capable of using *M. complanata* as habitat regardless of the extent of *Ramicrusta* overgrowth.

Keywords: coral reefs, community ecology, diversity, *Ramicrusta* sp.

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Response of reef fish assemblages to overgrowth of the hydrocoral

Millepora complanata by the crustose alga *Ramicrosta* sp.

by

AnnaRose Adams

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I understand my project will become part of the permanent collect of Oregon State University, University Honors College, and will become part of the Scholars Archive collection for BioResource Research. My signature below authorizes release of my project to any reader upon request.

AnnaRose Adams, Author

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DEDICATION

This thesis is dedicated to my family, Chris, Rosemary, and AmandaMarie Adams.

I would not be where I am today without your love and faith in who I am.

“For whatever we lose (like a you or a me)

it’s always ourselves we find in the sea”

- e.e. cummings

Response of reef fish assemblages to overgrowth of the hydrocoral *Millepora complanata* by the crustose alga *Ramicrusta* sp.

Introduction

Habitat selection and the degree to which organisms associate with specific surroundings strongly influences community structure (McPeck 1996; Morin 1999). The degree of habitat association may affect competition (Schroder and Rosenzweig 1975; Grosberg 1981; Rodriguez 1995; Munday 2001), predation (Sih 1982; Beukers and Jones 1997; Heithaus and Dill 2002), and access to prey (Sebens 1981; McIvor and Odum 1988; Halaj et al. 1998; Ward et al. 1998). Organisms that closely associate with particular habitats are important to consider in conservation management because such specialization may increase vulnerability to environmental change (Munday 2004; Safi and Kerth 2004; Wilson et al. 2008). Dependence upon a specific locale for survival can decrease the likelihood that an organism will adapt by finding another suitable habitat if the original habitat deteriorates. In response to large disturbances, substantial declines in habitat specialists have been documented in coral reef fishes (Kokita and Nakazono 2001; Munday 2004; Prachett et al. 2004; Wilson et al. 2008), bats (Safi and Kerth 2004), insects (Korkeamäki and Suhonen 2002) and mammals (Harcourt et al. 2002), among others. Protecting the associated habitat of specialists is therefore crucial in conserving the community structure of a given ecosystem.

In coral-reef ecosystems, fish assemblages are reliant upon seafloor organisms and structures for their survival (Beukers and Jones 1997; Almany 2004). Benthic structural complexity substantially affects the community structure of obligate coral-dwelling fishes (Luckhurst and Luckhurst 1978; Munday et al. 1997; Friedlander and Parrish 1998; Bergman et

al. 2000; Bozec et al. 2005; Gratwicke and Speight 2005; Wilson et al. 2010). Structurally complex habitats, such as corals, provide a greater number of shelter sites for prey species (Luckhurst and Luckhurst 1978; Hixon and Beets 1993; Friedlander and Parrish 1998) which can decrease predation rates and increase the survivorship of fishes (Hixon 1991; Beukers and Jones 1997; Almany 2004). In addition to shelter, fishes may also depend upon reef-building organisms for food. For example, abundance and species richness of corallivorous (coral-eating) butterflyfish (Family Chaetodontidae) have been positively correlated with the abundance of live coral (Bozec et al. 2005).

A prominent threat to the availability of habitat for reef fishes is overgrowth of corals by macroalgae (seaweeds). In areas such as the Caribbean and Western Pacific, natural disturbances, pollution, and overfishing have altered oceanic conditions to create a favorable environment for algae to outcompete coral (Banner 1973; Maragos 1985; Hughes et al. 1987, Hughes 1994; Stimson et al. 2001; Mosley and Aalsbersberg 2003; Paddock et al. 2009a). Over time, algal overgrowth has led to large declines in live coral cover, habitat complexity, and benthic diversity throughout affected regions (Maragos 1985; Sebens 1994; McCook 1999; Stimson et al. 2001; Alvarez-Filip et al. 2009). Most studies have focused on the response of fish communities to coral bleaching (Kokita and Nakazono 2001; Jones et al. 2004; Munday 2004; Wilson et al. 2008) or crown of thorns starfish (*Acanthaster planci*) outbreaks (Munday et al. 1997; Wilson et al. 2008). Few studies have examined the response of fish-habitat associations to algal overgrowth of corals (Feary et al. 2007). Better understanding of this response would help managers and conservationists better determine the resilience of fish assemblages on algal-dominated reefs.

Within selected areas of the Caribbean, a new alga has been discovered to be outcompeting coral for space. In Jamaica, a recently described crustose red alga, *Ramicrusta textilius*, has been documented overgrowing coral (Pueschel and Saunders 2009). In Lac Bay, Bonaire, an unidentified species of *Ramicrusta* (*Ramicrusta* sp.) has been found overgrowing 14 species of coral (Eckrich et al. in press). It is currently unknown whether this genus of algae is native or invasive to the Caribbean. *Ramicrusta nanhaiensis*, a relative of *R. textilius*, originates from the Pacific Ocean, opening the possibility that the *Ramicrusta* observed throughout the Caribbean could be an invasive species (Pueschel and Saunders 2009). At the present time, no data are available on the extent, causes, and effects of this algal genus overgrowing Caribbean corals.

The ability of crustose algae to compete with coral for living space is currently poorly understood. Naturalist descriptions by Finckh (1904) and van de Hoek (1969) provide evidence that crustose algae can overgrow corals, inducing coral mortality. The presence of *Ramicrusta* overgrowth in Jamaica and Bonaire demonstrates a need to understand competition between crustose algae and corals, as well as the effects of this interaction on other species that rely upon live coral. Overgrowth of coral reefs by *Ramicrusta* could potentially have harmful consequences for reef communities, as previously documented in the Caribbean and Western Pacific (Banner 1973; Maragos 1985; Hughes et al. 1987, Hughes 1994; Sebens 1994; McCook 1999; Stimson et al. 2001; Mosley and Aalsbersberg 2003; Paddock et al. 2009a).

The goal of this study was to examine the effects of *Ramicrusta* sp. overgrowth of coral on associated fish assemblages. Reef fishes associated with the hydrozoan fire coral (*Millepora complanata*) were observed over a gradient of *Ramicrusta* overgrowth of *M. complanata* in Lac

Bay, Bonaire. *Millepora complanata* is a source of habitat structure for multiple Caribbean reef fish species, most notably blennies (Family Blenniidae) (Nursall 1976) and damselfishes (Family Pomacentridae) (Clarke 1977; Waldner and Robertson 1980). *Millepora complanata* is also a structurally diverse coral (Clarke 1977), making it capable of supporting high abundance and diversity of fishes (Friedlander and Parrish 1998).

I predicted that increases in *Ramicrusta* overgrowth of *M. complanata* would have negative consequences on the abundance and diversity of associated reef-fish assemblages in Lac Bay, Bonaire. Abundance and diversity were examined over a gradient of *Ramicrusta* overgrowth, and all three components of diversity (richness, evenness, and composite diversity) were measured at the family level (because identification to species was often unavailable). The following specific hypotheses were tested:

H₁: The abundance of nearby fish will decrease as the percent *Ramicrusta* overgrowth of *M. complanata* increases.

H₂: The family richness, evenness, and composite diversity of nearby fishes will decrease as the percent *Ramicrusta* overgrowth of *M. complanata* increases.

Materials and methods

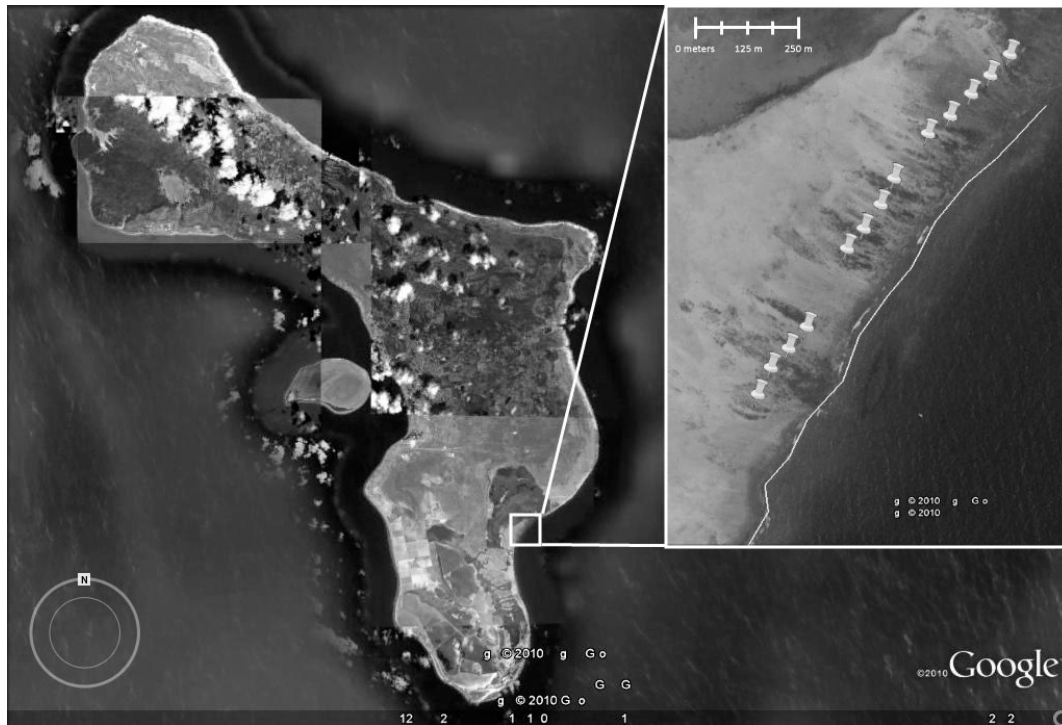


Fig. 1 Image of 13 transect sites (represented as thumbtacks) within Lac Bay, Bonaire (Google Earth 2010). The reef crest is designated by the white line to the east of the transect sites.

Study site

Lac Bay ($12^{\circ} 6' 4.18''\text{N}$, $68^{\circ} 13' 33.01''\text{W}$) is located on the windward (eastern) side of Bonaire, a southern Caribbean island which lies 80 km off the coast of Venezuela (Fig. 1). The back reef of the bay contains an abundance of the fire coral, *Millepora complanata*, near the reef crest. Recently, *Ramicrusta* has been observed overgrowing *M. complanata* throughout the bay (Eckrich et al. in press), making it the second area in the Caribbean where the presence of this crustose alga has been documented.

Observational design

A total of 13 transects were surveyed along the back reef of Lac Bay (Fig. 1). Transect sites were chosen using Google Earth to locate 20 equidistant points (approximately 62 m apart) 125 m northwest of and parallel to the contour of the reef crest. Seven points located in sand patches were subsequently disregarded, resulting in GPS starting coordinates for 13 transects.

During October 2010, surveys were conducted at the 13 transect sites. Data were collected between the depths of 0.5 and 1.5 m during midday (0900 – 1400). At each site, a single 2 m-wide visual belt transect (Brock 1954) was run by following a compass heading toward and perpendicular to the reef crest (approximately 135°). Each transect ended when wave action was too rough to continue data collection (approximately 25-30 m from reef crest), making each transect roughly 100 m in length.

Millepora complanata is abundant in the shallow waters of Lac Bay and is often found in areas of intense wave action near the reef crest (Lewis 2006). Colonies are often densely packed due to the high rate of survival for *M. complanata* fragments (Lewis 2006). A total of 170 coral heads of *M. complanata* were randomly censused along the 13 transects. Random numbers between 2 and 10 (k) were used to determine which heads were surveyed (every k^{th} head).

When an observer came within 1 m of a selected *M. complanata*, a 1-min period would begin to allow fish to recover from any observer disturbances. During this time period, volumetric dimensions of the coral (cm) and percent *Ramicrosta* overgrowth were estimated visually. Percent algal overgrowth was scored as follows:

0 = No Overgrowth (0%)

1 = Minimal Overgrowth (1-25%)

2 = Partial Overgrowth (26-50%)

3 = Moderate Overgrowth (51-75%)

4 = Maximum Overgrowth (76-100%)

After the 1-min recovery period, the number of fish in association with *M. complanata* was recorded at the family level. This study assumed that fish associated with *M. complanata* would live within close proximity of the coral. Therefore, fish association was consequently defined as individuals within 0 to 40 cm of *M. complanata*. The number and family of fishes were recorded from all sides and on top of each coral head.

Data analysis

Total fish abundance was tallied for each censused *M. complanata* and averaged within algal overgrowth categories. Family richness was measured as the total number of families identified at each *M. complanata* head. Composite diversity was calculated using the Shannon-Wiener Diversity Index (Pielou 1966):

$$H' = \sum p_i \ln(p_i)$$

where p_i is the proportion of individuals observed within each family. Evenness was calculated using the Shannon-Wiener Evenness Index (Pielou 1966):

$$E = H' / \ln(S)$$

where S is family richness (number of families present).

Normality was tested for all four variables (abundance, richness, composite diversity, and evenness) using Anderson-Darling tests. Because all data were not normally distributed, each variable was tested for differences across algal overgrowth categories by one-way nonparametric Kruskal-Wallis tests ($\alpha = 0.05$). Differences among categories detected by Kruskal-Wallis tests were followed by pairwise Mann-Whitney U -tests ($\alpha = 0.05$).

The potential influence of *M. complanata* volume (estimated in L) on associated fish assemblages was estimated through correlation analysis. Coral volume was correlated to fish abundance and diversity (richness, evenness, and composite diversity). Differences in estimated coral volume with respect to *Ramicrusta* overgrowth category were also examined through Kruskal-Wallis tests ($\alpha = 0.05$) followed by pairwise Mann-Whitney U -tests ($\alpha = 0.05$). To account for coral volume variability, fish density (fish/L) was calculated and compared among overgrowth categories by Kruskal-Wallis tests ($\alpha = 0.05$). All data analysis was completed using Minitab[®] Statistical Software (V.16).

Results

A total of 170 coral heads of *Millepora complanata* and 11 fish families were observed across a spectrum of algal overgrowth categories ranging from 0 to 100% *Ramicrusta* cover. Damselfish (Family Pomacentridae) and gobies (Family Gobiidae) were the most abundant fish surveyed ($n=199$ and 129) (Appendix A). The majority (88%) of *M. complanata* observed exhibited some degree of *Ramicrusta* overgrowth. The highest proportion (32%) of

M. complanata was found to be maximally overgrown (76 – 100%) by *Ramicrusta*, and the lowest proportion (15%) was observed within the no overgrowth category (Fig. 2).

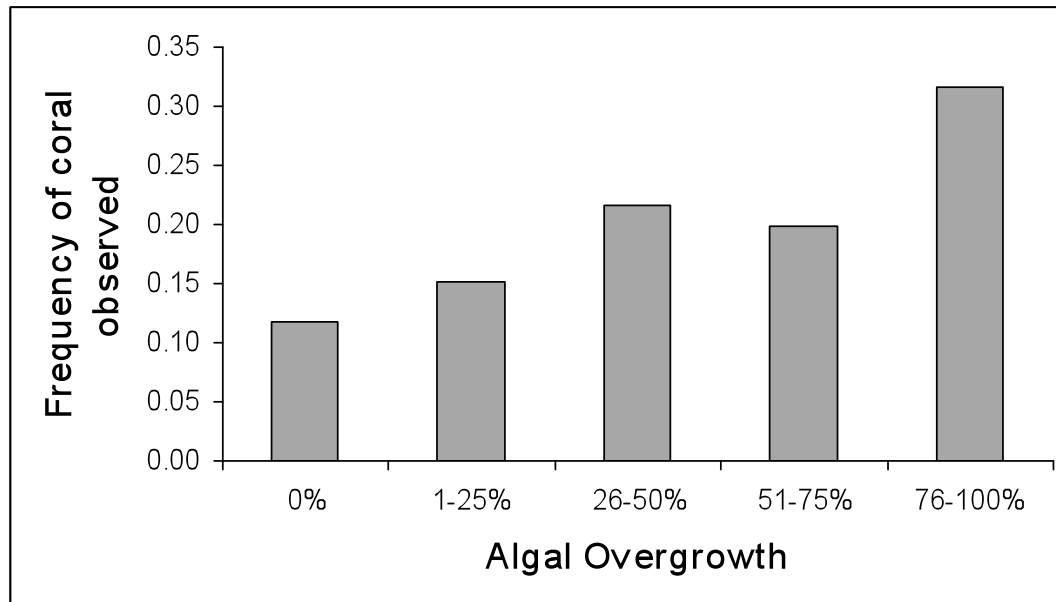


Fig. 2 Frequency distribution of algal overgrowth categories for 170 heads of *M. complanata*.

Fish Abundance

Across the gradient of algal overgrowth, the abundance of fish increased from 0 to 75 % *Ramicrusta* coverage (Fig. 3). At maximal overgrowth (76-100%), fish abundance declined to values similar to those with no overgrowth (Fig. 3). Significant differences in abundance were detectable among algal overgrowth categories (Kruskall-Wallis: χ^2 [4, n = 170] = 13.28, p=0.01). Differences in the median abundance of fish were detected between 0 – 25% and 26% - 100% *Ramicrusta* coverage (Mann-Whitney *U*-test: W=3007.5, two-sided p = 0.001). Coral heads 26 – 100% overgrown by *Ramicrusta* had 1 ± 1 (mean \pm 95% CI) more fish present than coral heads 0 – 25% overgrown.

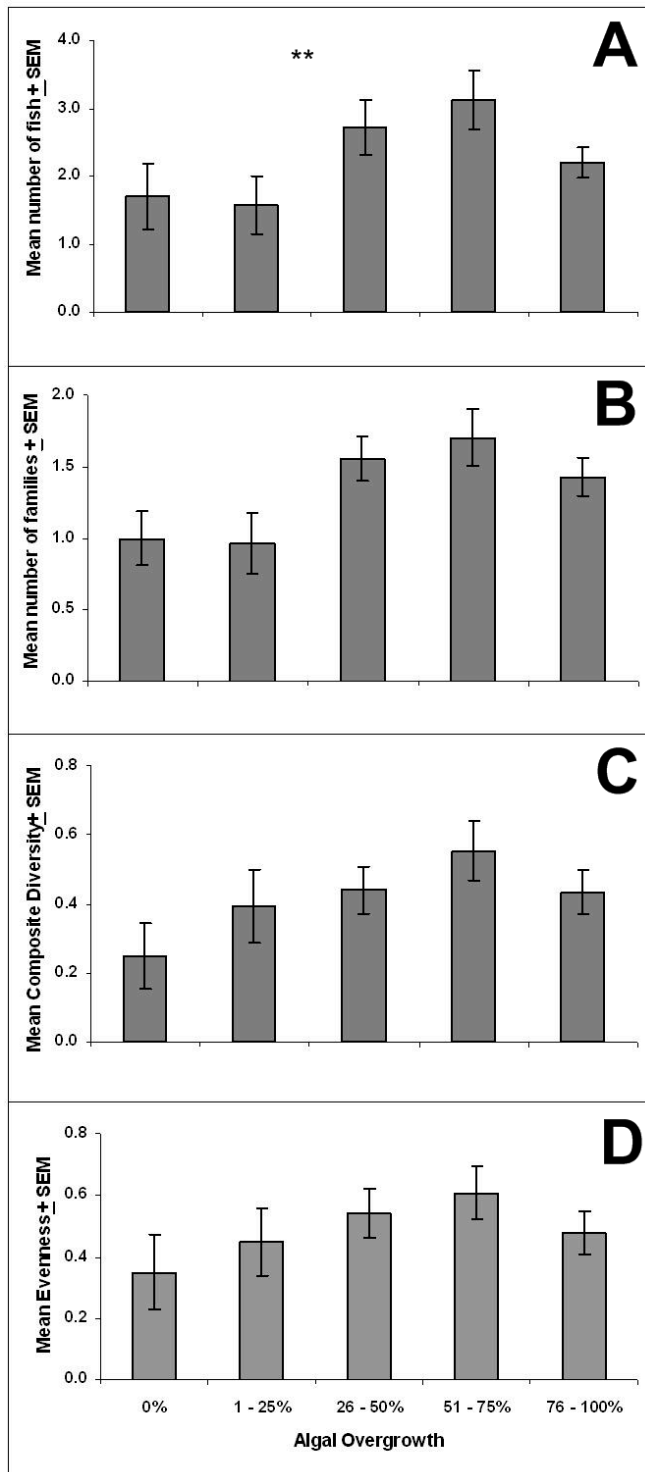


Fig. 3 A) Abundance, B) richness, C) composite diversity, D) evenness (mean \pm SEM) of fish associated with *M. complanata* in Lac Bay, Bonaire, across a gradient of *Ramicrusta* overgrowth. Difference in abundance between 0-25% and 26-100% overgrowth was significant at $p = 0.01$ (**).

Fish Diversity

Fish family richness, evenness, and composite diversity showed trends similar to fish abundance. Mean values of all three measures generally increased from 0 to 75 % *Ramicrusta* overgrowth, followed by a decline at maximal overgrowth (76-100%) (Fig. 3). Significant differences in all three components of diversity were not detected among overgrowth categories (Kruskall-Wallis: richness: χ^2 [4, n = 134] = 6.9, p=0.14; composite diversity: χ^2 [4, n = 134] = 5.9, p=0.21; evenness: χ^2 [4, n = 134] = 4.3, p=0.37).

Influence of Millepora complanata volume

Visual estimates of coral volume were positively correlated with fish abundance, but not with fish diversity (Fig. 4). Abundance was moderately associated with the volume of *M. complanata* (r=0.19, n=131, p <0.0001). While Pearson's correlation coefficients detected a positive relationship between fish diversity and volume, the correlations were not statistically significant (richness: r=0.17, n=100, p= 0.094; composite diversity: r=0.15, n=100, p=0.14; evenness: r=0.12, n=100, p=0.22).

Larger heads of *M. complanata* were observed more frequently at higher levels of *Ramicrusta* overgrowth (Fig. 5). Mean coral volume was significantly different between moderate to high levels of overgrowth (26-100 % *Ramicrusta* cover) and low levels of overgrowth (0-25 % *Ramicrusta* cover) (Mann-Whitney *U*-test: W=962, two-sided p-value <0.0001). *M. complanata* volume was estimated to be 58 ± 23 L (mean \pm 95% CI) larger at 26-100 % *Ramicrusta* overgrowth, than 0-25 % overgrowth. Increasing *M. complanata* volume was also positively correlated with increasing *Ramicrusta* coverage (r=0.25, n=130, p=0.004).

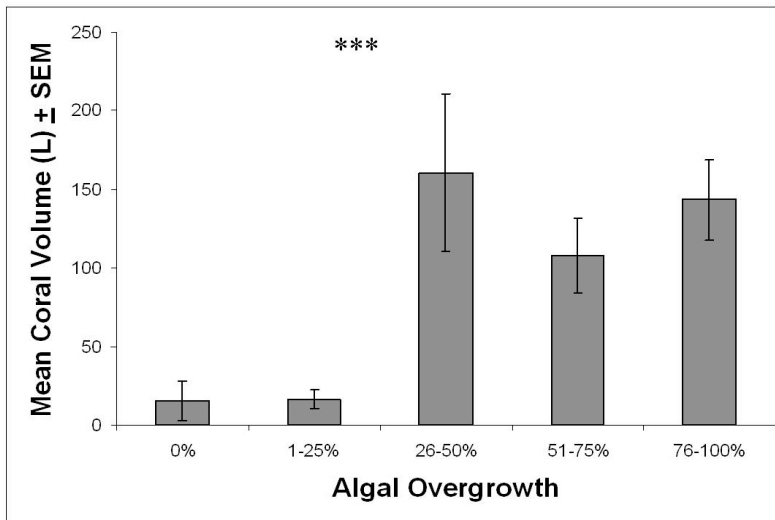


Fig. 4 Comparison of *Ramircrusta* overgrowth categories and estimated *Millepora complanata* volume (mean \pm SEM). Mean *M. complanata* volume was significantly different between 0-25% *Ramircrusta* overgrowth and 26-100% overgrowth at $p < 0.0001$ (***) .

Fish density was inversely associated with *Ramircrusta* overgrowth (Fig. 6). At coral heads where *Ramircrusta* was not present, the greatest density of fish was observed (0.49 fish/L). However, differences in fish density among algal overgrowth categories were not statistically significant (Kruskall-Wallis: χ^2 [4, n = 130] = 1.67, $p = 0.80$).

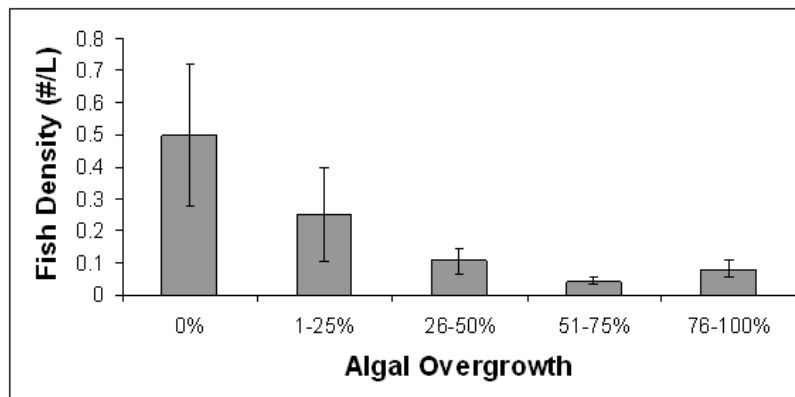


Fig. 5 Fish density (number of fish/L) with respect to *Ramircrusta* overgrowth categories.

Discussion

The predicted decreases in fish abundance and diversity (family richness, evenness, and composite diversity) with increasing *Ramicrusta* overgrowth were not evident in this study. High variance was apparent among algal cover groups, indicating that larger sample sizes would be required to detect whether statistically significant differences exist. Nonetheless, it was common for all response variables to peak at moderate levels (51-75%) of overgrowth. If this trend proved to be correct, then one interpretation would be that habitats which contain an even mix of corals and crustose algae provide higher complexity than habitats dominated by either one. Given that fish abundance and diversity tends to increase with habitat complexity (Friedlander and Parrish 1998; Holbrook et al. 2002), this interpretation would explain the unimodal relationship between *Ramicrusta* and measures of fish abundance and diversity. Alternatively, additional factors not assessed in this study may be involved in structuring fish assemblages associated with *Millepora complanata*. One such factor is the role of coral volume and structural complexity on the number of fish and fish families.

The observational design of this study sampled *M. complanata* regardless of coral head size or structural complexity. This constraint is problematic because it confounded my ability to compare fish assemblages among coral heads of different physical characteristics. Corals that are larger in volume tend to be significantly more structurally complex (Holbrook et al. 2002). Increased structural complexity has been correlated with higher fish abundance and richness (Friedlander and Parrish 1998; Holbrook et al. 2002), which is likely due to the increased number of holes available for shelter (Hixon 1991; Hixon and Beets 1993; Friedlander and Parrish 1998). Visual estimates of *M. complanata* volume completed throughout this study

demonstrated a positive correlation with fish abundance (Fig. 4), which indicates that the size of *M. complanata* may have influenced the composition of fish assemblages. An additional confounding factor was that *M. complanata* heads that were minimally overgrown with *Ramicrusta* were significantly smaller in volume, which could potentially account for the low abundance and diversity of fishes observed in the 0% and 1-25% overgrowth categories. Calculating fish density per unit volume of *M. complanata* accounted for the naturally confounding pattern of *Ramicrusta* overgrowth increasing with coral head size. However, such density comparisons among *Ramicrusta* overgrowth categories were statistically insignificant (Fig. 5). If the observed trend of fish density varying inversely with *Ramicrusta* overgrowth was nonetheless biologically real, then the implication would be that the presence of *Ramicrusta* on *M. complanata* has a negative effect on reef-fish assemblages.

Nonetheless, structural complexity did not appear to differ between colonies of similar size at different levels of overgrowth. In response to changes in seascape, substantial declines in fish assemblages have been largely correlated with reduction of live coral cover and structural complexity (Sano et al. 1984; Kokita and Nakazono 2001; Munday 2004; Pratchett et al. 2004; Graham et al. 2006; Pratchett et al 2008; Wilson et al. 2008; Paddock et al. 2009a). However, Wellington and Victor (1985) found that, in response to the 1982-1983 coral bleaching event associated with El Niño, damselfish abundance was unaffected by declines in live coral cover. This phenomenon was attributed to insignificant differences between the topographic complexity of dead and live coral, implying that these fish use coral as habitat regardless whether it is living or not (Wellington and Victor 1985). Given that damselfish were the most abundant family observed in the present study (199 fish observed), it is likely that differences detected in fish

assemblage characteristics were insignificant because structural complexity was similar between *M. complanata* with high and low *Ramicrusta* overgrowth.

An additional factor in coral structural complexity is how long *Ramicrusta* has been established on *M. complanata*. While this study did not examine the growth rates of *Ramicrusta*, there is evidence that indicates the majority of *M. complanata* observed were recently overgrown. Only one observed *M. complanata* was fully overgrown by *Ramicrusta*. Complete overgrowth by algae induces coral mortality (McCook et al. 2001). Following their death, corals become eroded by biological and physical processes, reducing their overall structural complexity (Sano et al. 1984; Sheppard et al. 2002). Due to this phenomenon, it is difficult to identify *M. complanata* that is completely overgrown in the field. Lac Bay contains large rubble fields which are predominantly covered with *Ramicrusta* (personal observation). It is possible that these fields could contain heads of *M. complanata* that have been eroded to a point where they are no longer identifiable. Since this study focused on *M. complanata* that could be identified visually, there is potential for results to be skewed towards recent algal overgrowth. It is therefore possible that prolonged and complete coverage of *M. complanata* by *Ramicrusta* could have a more substantial effect on fishes associated with *M. complanata*.

The lack of statistical significance between fish assemblages and *Ramicrusta* overgrowth of *M. complanata* does not necessarily negate the potential ecological importance of overgrowth. Initial evidence for the minimal impact of recent *Ramicrusta* on structural complexity corroborates the idea that changes in habitat complexity affect the structure fish assemblages associated with *M. complanata*. While the impact of *Ramicrusta* on fish assemblages remains unclear, this study confirms that the alga has a dominant presence overgrowing *M. complanata*

communities. Much is still unknown about *Ramicrusta* and its ultimate direct and indirect effects on coral-reef ecosystems.

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APPENDICES

APPENDIX A

Table 1. Total number of fish counted in each observed fish family.

Fish Family (common name)	Number of Fish Observed
Pomacentridae (damsel fishes)	199
Gobiidae (gobies)	129
Labridae (wrasses)	41
Blenniidae (blennies)	15
Scaridae (parrot fishes)	9
Acanthuridae (surgeon fishes)	4
Grammatidae (basslets)	2
Holocentridae (squirrel fishes)	1
Serranidae (groupers)	1
Lutjanidae (snappers)	1
Balistidae (trigger fishes)	1

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