# PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2015
Union College, Schenectady, NY

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ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

# KECK GEOLOGY CONSORTIUM
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**ISSN# 1528-7491**

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Funding Provided by:
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The National Science Foundation Grant NSF-REU 1358987
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Funding Provided by:
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The National Science Foundation Grant NSF-REU 1358987
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Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1358987
ExxonMobil Corporation

KECK Geology Consortium
Learning Science Through Research
Published by Keck Geology Consortium
Short Contributions
28th Annual Symposium Volume
25th April, 2015
ISBN: 1528-7491

# GRAZER DYNAMICS ON AN ACROPORID PATCH REEF SYSTEM AND THEIR IMPLICATIONS FOR THE CARBONATE BUDGET AT CORAL GARDENS, BELIZE

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**Research Advisor:** Mark Wilson

## INTRODUCTION

A shift to macroalgae-dominated reefs from coral-dominated reefs has been documented via photographs and data from the 1980's to the present in the Caribbean. The new fast-paced algal growth on reefs can result in a decrease in live coral abundance via competition for space and blockage of space for new coral recruitment (Aronson et al., 2002). Reef herbivores can help control algae abundance on reefs, but die-offs of important species like urchins and parrotfish have been recently and historically documented (Aronson et al., 2002). Changing dynamics between corals and surrounding grazer populations due to overfishing of herbivorous fish and disease outbreaks amongst urchins like *Diadema sp.* have resulted in a decline in living coral in the Caribbean (including Belize) (Aronson et al., 2002).

Bioeroding grazers, such as the sea urchin, *Echinometra viridis,* and parrotfish (*Scaridae*), play a vital role in maintaining the overall health of coral reef systems. Brown-Saracino et al. (2007) found that sea urchins acted as a control on the macroalgae of heavily fished coral reefs in Belize, but could also be a threat to reefs when present in high densities, as they are exceptional bioeroders. Aronson et al. (2002) note that *E. viridis* populations are as abundant as 20-100 urchins/$m^2$ in Belize and Bellwood et al. (2004), McClanahan and Shaffir (1990), and Brown-Saracino et al. (2007) discovered that there were strong correlations between the percentage of live coral cover, macroalgae cover, and urchin densities on coral reefs.

In general, healthy populations of sea urchins and parrotfish help to keep coral cover high and macroalgae cover low, sustaining healthy coral reefs. In this study, it was hypothesized that there would be strong positive correlations between urchin densities and live acroporid coral or macroalgae cover at Coral Gardens, Belize. Using photoanalysis and *in situ* ecological surveys, we compared grazer densities with the percentage of live coral at Coral Gardens and analyzed the correlations for significance.

We found that these relationships were not significant (or even positive) based on the data we collected at Coral Gardens. We concluded that our data were limited by our methodologies. The high urchin densities found at Coral Gardens, in comparison to similar studies, led me to suggest that not all of the macroalgae cover was accounted for through the two-dimensional photoanalysis. This method of data collection could not account for the internal complexity of the coral architecture, which had the capacity to 'hide' macroalgae from our census.

Finally, using standard bioerosion calculations for *E. viridis* and *Scaridae*, a gross carbonate bioerosion rate was determined for Coral Gardens. This rate, combined with the gross carbonate production rate for *A. cervicornis* at Coral Gardens (Peeling, this volume), establishes an overall carbonate budget for Coral Gardens, which can be used to determine whether the reef is in a state of net growth or net erosion.

## METHODS

Using a one square meter quadrat, a team of student photographers documented live coral cover and urchin densities along five transects using SCUBA. Urchin surveys took into account urchin species, density,

test diameter (by three size categories) and any other observations. This was done for all five *Acropora cervicornis* patch transects.

Fish surveys were done along each transect following the belt transect method of the Atlantic Gulf Rapid Reef Assessment (AGRRA). This method consists of a diver swimming at a constant rate along a 30-meter long and two meter wide belt transect for about 6 minutes while counting fish ahead of the diver. A 1-meter T-bar was used to estimate width of survey area and to help estimate fish size.

To determine the percentage of live coral cover along transects at Coral Gardens, we used a computer program (MATLAB) to trace the live *A. cervicornis* in each quadrat photo. After completing each quadrat at each transect, we were able to determine which percentage of the photograph was live *A. cervicornis.* We used this measurement to get average live coral per transect and compared to data from 2012 and 2013. We also used these percentages to compare the health of the reef with other ecological factors like urchin densities and fish counts.

Coral Point Count (CPC), was used to determine benthic cover in the "other" parts of the reef that were not live *A. cervicornis.* 100 points were randomly distributed across each photoquadrat and what the point has landed on was identified. We mainly used CPC to determine macroalgae cover but we also compared live coral cover as determined in MATLAB and CPC and found that the numbers were very similar.

Finally, we used previously determined rates of bioerosion for sea urchins and parrotfish to calculate annual bioerosion rates per $m^2$ at Coral Gardens (Perry et al., 2012). The Atlantic and Gulf Rapid Reef Assessment uses a simple calculation to convert fish size to fish weight, which can be used to find the amount of bioerosion (in kg of $CaCO_3$ per year per $m^2$) for each species of parrotfish in a reef area.

## RESULTS

Photo analysis data were combined with urchin density data to compare important ecological variables in the summer of 2014. Figure 1 shows average coral cover, average macroalgae cover, and average urchin count per $m^2$ per transect at Coral Gardens. At T1 and T2, urchins appear to decrease with increase in coral cover but T5 shows little to no urchin presence and high coral cover. This graph also shows that as urchins increase at any transect, macroalgae increases, and coral cover is lower. Further regression analysis (Table 1) confirmed that the apparent relationships were not statistically significant.

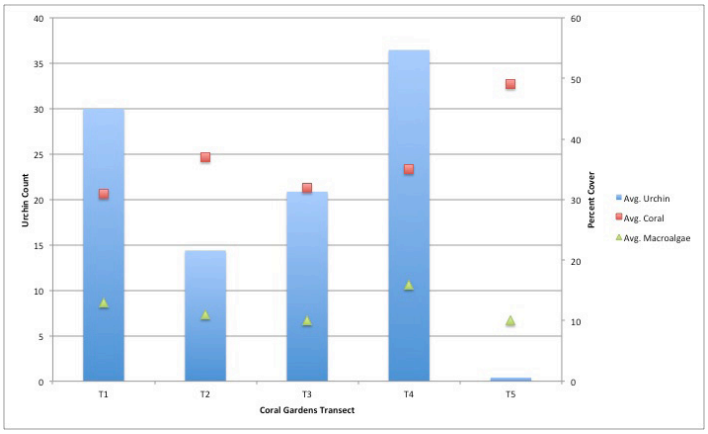


*Figure 1. 2014 Coral Gardens average coral cover, average macroalgae cover, and average urchin count per $m^2$ per transect.*

We found no significant correlation between urchin abundance and macroalgae cover at Coral Gardens (Fig. 2). A negative correlation exists between live coral cover and urchin abundance (Fig. 3). Further p-level analysis supported these findings (Table 1).

| Transect | Urchin vs. Coral p-value | Hypothesis Rejected? | Urchin vs. Macroalgae p-value | Hypothesis Rejected? |
|---|---|---|---|---|
| T1 | 0.00312 | No | 0.33156 | Yes |
| T2 | 0.00655 | No | 0.00272 | No |
| T3 | 0.6772 | Yes | 0.01749 | No |
| T4 | 0.2268 | Yes | 0.09021 | Yes |
| T5 | 0.56713 | Yes | 0.73085 | Yes |

*Table 1. Urchin, macroalgae cover, and coral cover correlation probability testing.*

It is noteworthy that T1 and T2 had significant correlations between urchin density and coral cover. Transect 1 had the second-highest urchin density and the lowest percentage of live coral cover. Transect 2 had low urchin densities and the second highest percent coral cover.

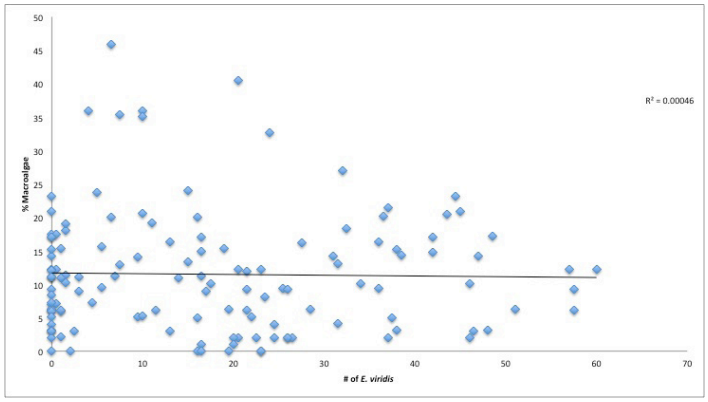


*Figure 2. Urchin counts and macroalgae cover percentages at T1-T5. No correlation; hypothesis rejected.*

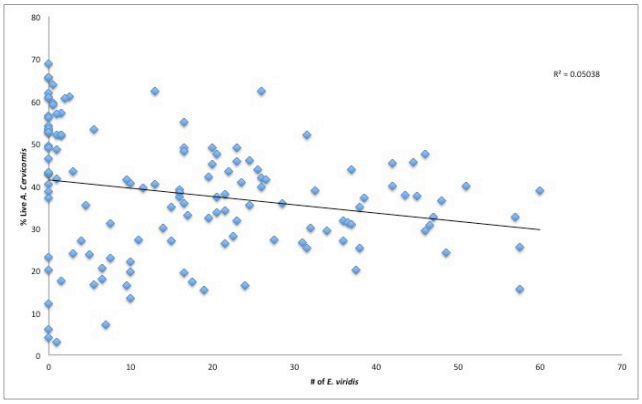


*Figure 3. Urchin counts and live coral cover percentages at T1-T5. No correlation; hypothesis rejected.*

To characterize the relationship of reef grazers and coral through time, we analyzed urchin and live coral cover data from 2012 and 2013 and compared it with data collected at Coral Gardens in 2014. Figure 4 shows how mean number of urchins, percent live coral, and macroalgae abundance per $m^2$ at each transect changed throughout the past three years. Generally, urchin densities increased from 2012 to 2013 and decreased into 2014. Transect 4 was an outlier, as it showed a slight decrease in urchin densities from 2012 and 2013 and a large increase in urchin densities into 2014. The coral cover does not reflect this increase, however, as we see it remains similar to the previous years. Another interesting trend in this graph is the increase in coral cover from 2013 into 2014 for Transect 1-3. Transect 5 is curious as it shows a decrease in coral cover in 2014.

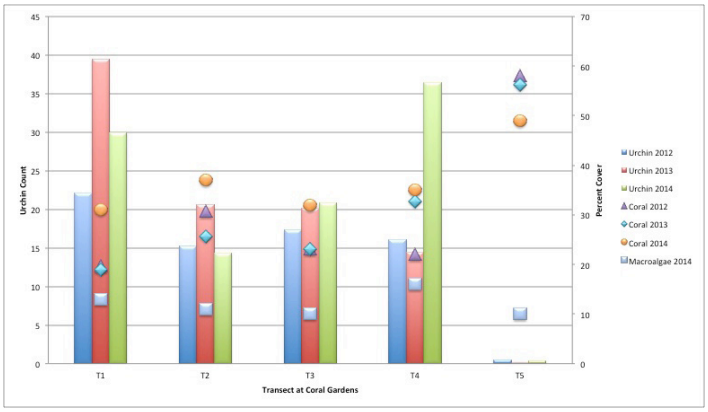


*Figure 4. Average urchin densities per $m^2$ ($Y_1$) vs. average coral cover per $m^2$ ($Y_2$) across transects for all years and macroalgae cover for 2014.*

An additional goal of this study was to determine the rate of bioerosion at each Coral Gardens transect using urchin and fish surveys and a previously determined rate of bioerosion for each species based on size (Perry et al., 2012). The total bioerosion rates for all fish and urchins at the five Coral Gardens transect are displayed in Table 2. Note the relatively high rates of bioerosion from parrotfish at Coral Gardens when compared to urchin bioerosion at the same transect.

| | Urchin Count | Total Urchin Bioerosion (kg $CaCO_3/m^2$/year) | Parrotfish Count | Total Parrotfish Bioerosion (kg $CaCO_3/m^2$/year) |
|---|---|---|---|---|
| **T1** | 960 | 0.412 | 7 | 0.178 |
| **T2** | 446 | 0.198 | 24 | 1.685 |
| **T3** | 396 | 0.287 | 7 | 1.186 |
| **T4** | 510 | 0.501 | No data | No data |
| **T5** | 15 | 0.006 | 19 | 3.791 |

*Table 2. Bioerosion rates at Coral Gardens by transect. Values represent the total amount of calcium carbonate eroded by grazers in kg $CaCO_3/m^2$/year.*

## DISCUSSION

The data from this study indicates that, overall, there are no reliable relationships between live *Acropora cervicornis* and macroalgae in terms of cover and grazer populations at Coral Gardens. Many other studies in the Caribbean have found strong correlations between macroalgae, urchins, and coral cover (McClanahan, 1990). Because we found the opposite, it is important to look at the variations between these studies and ours.

Most modern studies of Caribbean reefs assess massive coral reefs (rather than branching coral in the case of our study) that are highly populated by macroalgae and less populated by urchins. At these massive coral-dominated reefs (such as *Montastrea*-dominated reefs), urchins are exposed at the top of the reef and must move around often to find food, making them easy targets for predators. Massive corals do not provide as much surface area for algae to flourish as branching corals, and urchins will leave if there is not enough food, leading to poor coral health and a transition to an algae-dominated reef.

At Coral Gardens, urchins like *E. viridis* have the opportunity to live within the large branching corals of the acroporids, as compared to other massive coral reefs. They are provided ample protection and food within the crevices of *A. cervicornis* and *A. palmata*. We therefore hypothesize that Coral Gardens is ecologically different from other reefs in the Caribbean and the relationship between bioeroders, live coral, and algae reflect these differences. Therefore we must be mindful of these ecological differences when comparing the relationships and correlations found at Coral Gardens to other studies on bioerosion or herbivory in the Caribbean.

Another conclusion that can be drawn from the lack of relationship between coral and macroalgae cover and sea urchins is that our data is limited by the fact that photo analysis does not account for three-dimensions of real-time data. It is highly likely that the photographs do not accurately represent the macroalgae present at Coral Gardens. We counted all of the urchins living inside the intertwined branches of the coral, but our photo analysis could not account for all of the macroalgae we observed living inside the reef. Thus, it could be that there is enough macroalgae at Coral Gardens to keep the large urchin population fed, but it does not show in our data.

The unique inter-webbed living canopy of *A. cervicornis* –dominated reefs provides protection for urchins and sufficient surface area for macroalgae to exist on the dead branches (rubble) inside the reef. Because of the high acroporid coral cover at Coral Gardens, it may be concluded that the optimum density of *E. viridis* and *Scaridae*, as well as the optimum algal cover, is present here. The grazers provide room for new coral recruits of the fast-growing *A. cervicornis*, and the coral provides protection and food for the grazers.

Finally, no correlations were found between parrotfish and live coral or macroalgae cover. However, it is important to note the high bioerosion rates that scarids produce (in comparison to urchin bioerosion) at Coral Gardens. The total number of observed parrotfish at T1-T5 was 57. The total number of observed sea urchins at T1-T5 was over 2,000 (see Table 2). Yet, the rate of bioerosion from parrotfish was, on average, six times higher than that of urchins per transect. The presence of parrotfish at Coral Gardens, then, is highly influential on the carbonate budget of this reef and the presence of urchins has little effect. To support this claim, grazing and behavioral investigations of the parrotfish at Coral Gardens need to be conducted.

Coral Gardens is not a marine protected area (MPA), however, it lies between two other marine parks, Hol Chan Marine Reserve and Caye Caulker Marine Reserve, which may be responsible for the healthy grazer populations. Establishing protection for Coral Gardens could ensure an environment that fosters healthy parrotfish populations and continued high rates of acroporid coral growth and resilience.

## CONCLUSIONS

(1) According to our data, there is no significant correlation between sea urchins and live coral cover, or sea urchins and macroalgae cover at Coral Gardens. Our data is limited by the photo analysis method; I predict that more macroalgae is present at Coral Gardens than is recorded in the photos.

(2) Coral Gardens displays a distinctive interlocking branching reef system. Fast-growing *A. cervicornis* provides protection and abundant food (macroalgae) for the grazer population, while grazers continuously "work" to open up space for new coral recruits. This is different than what we find elsewhere in Belize and the coral reef literature, thus traditional methods of measuring ecosystem health cannot be used.

(3) Quantifying the fish densities at Coral Gardens and conducting behavioral investigations will be helpful in determining their effects on acroporid reef bioerosion.

(4) Coral Gardens is in a state of net carbonate accretion based on the bioerosion and net growth calculations by Peeling (this volume). However, because we are assessing a different coral reef system and cannot properly quantify macroalgae using photoanalysis, the carbonate budget needs further analysis.

(5) Establishing Coral Gardens as a Marine Protected Area (MPA) could help maintain current grazer-coral relationships (especially parrotfish populations), which may help play a part in sustaining its exceptional Acroporid health.

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