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PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2012
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POST-BLEACHING ENCRUSTATION HABITS IN USVI CORAL REEFS

CLAIRE MCELROY, Otterbein University
Research Advisor: Halard Lescinsky

ABSTRACT

This study examined patterns of encrusting organisms occupying reefs from two bays in the U.S. Virgin Islands, and relates the patterns to encruster contribution to the carbonate budget. External surfaces of coral samples that had died in 2005 were examined under a microscope and the percent cover of each encruster was estimated for tops, transitions, and sides of each sample. Coralline algae was the most prevalent encruster, regardless of depth or location on a coral (top/transition/side) and was most prevalent in shallow water on tops of samples (63%). The coralline algae crust thickness was measured along the tops and sides of samples. When present, average crust thicknesses ranged from 0.022 mm - 0.72 mm on tops, and 0.26mm - .82mm on sides. Average accretion rates on tops of samples was 0.33mm yr^{-1}, while average side accretion was 3.18 mm yr^{-1}. Average total accretion was 3.51 mm yr^{-1}. There was a slight depth-related change in accretion rates (deeper transects had slightly lower rates than shallower transects). Species richness among tops was highest in medium depths at 12.1. The Shannon-Weiner index showed that samples (including transitions and sides), on average, were the most diverse in deep waters (ranging from 0.68-0.8), and least diverse in medium depths (ranging from 0.5-0.72 with no significant depth-related differences). The results indicate that depth isn't as important a factor to species zonation as previously thought, but that encrustation is still an important contributor to the carbonate budget, regardless of depth.

INTRODUCTION

The samples analyzed for this experiment all died during an El Niño event in 2005-2006, in which the water temperature caused the bleaching of coral heads (see Hubbard and Parsons-Hubbard, this volume) This was the most severe bleaching event ever recorded in the area (Miller, et al., 2009). Lameshur Bay was fairly well protected from sedimentation, and one study found that coral cover in Lameshur Bay increased 34% during the study period (1987-1998), indicating that some reefs are more resilient to change than others in the same general area(Edmunds, 2002). Caribbean reefs also saw hurricanes in 2005, and along with disease and bleaching, the USVI specifically experienced a decline in coral cover of over fifty percent. Bleaching itself occurred in over ninety percent of cover (Wilkinson and Souter, 2008).
This study addresses three main questions: 1) Does biont cover differ by depth (shallow=0-8m; medium=9-15m; deep=16-22m)? 2) Does the biont cover differ between two slabs from the same coral sample? And 3) how much do encrusters contribute to the overall carbonate budget of the reef? Other encrustation studies have been done on corals, and resulting patterns analyzed. Successional patterns give indications of time—knowing which organisms are pioneer communities or which are last to colonize substrate can give clues as to how long a particular coral has been dead. Blanchon and Perry (2004) analyzed this as they looked at taphonomic signatures, in part by studying encrustation patterns on Acroporid corals. They discovered that corals found between six and thirty meters had crustose coralline algae several millimeters thick, while samples in less than six meters of water had crusts several centimeters thick, often including *Homotrema* and vermetids in addition to coralline algae (Blanchon and Perry, 2004). Another qualitative pattern is vertical versus horizontal growth (equivalent to sides and tops in this study), and Knott, et al. (2004) observed no difference in algal cover between the two, and also found bryozoans on vertical surfaces/sides. A third pattern is to analyze exposed versus cryptic communities, often done using settling plates. An experiment done by Palmieri and Jell in 1985 used such plates to determine foram successional patterns. They found that Planorbulina

settled on plates in exposed areas, but were later outcompeted by bryozoans and algae. Rasmussen and Brett, in the same year, looked at cryptic communities and found that differences between early and late successional species suggest that early communities are biased in their representation in the geologic record. Soft species (ones that aren't preserved) that colonize corals after pioneer species further break down skeletons. This loss of species richness and diversity in modern reefs most likely occurred in ancient reefs as well, and should be considered when analyzing diversity (Rasmussen and Brett, 1985). Discovering successional patterns on blank plates can be seen as a parallel for succession in struggling, or already dead, reefs. Experiments have been done that look at a fourth pattern of encrustation—depth. Martindale (1992) found that *Carpenteria* were encrusting in waters of similar depths, but were always found in cryptic habitats. These various patterns can be used to determine successional stages in Caribbean reefs. In a reef of unknown origin, the presence of an encruster can indicate relative depth where the coral might have originated. A bryozoan species could indicate that the area it was found in didn't receive direct sunlight. Although these patterns exist, this study indicates that they aren't found in all reef ecosystems, and may not be as important as previously thought.

METHODS

Encrusting patterns were examined on 22 coral that died following the 2005-2006 El Niño warming event. Samples were recovered from depths of 4-22 meters (see Hubbard and Parsons-Hubbard, this volume, Table 1). Coral samples were slabbed to about 1-cm thickness for a range of analyses. Once samples were chosen, the top (area exposed to sunlight), sides (cryptic area, or the area not generally exposed to direct sunlight), and transition (area between top and

					Soft		***Ostreo***		***Homo***	
TOPS										
Shallow										
T15 109	0.7	71.4	6.4	7.0	1.0	0.6	5.7	0.0	0.3	0.6
T15 104	0.0	45.9	38.0	0.5	0.3	0.0	0.0	0.0	2.1	1.0
H08 6	2.5	68.3	15.4	1.8	4.2	0.0	1.3	0.0	0.2	0.3
H08 11	0.0	90.7	2.2	3.2	0.3	0.0	1.4	0.0	0.1	0.1
H14 22	1.3	23.3	50.0	10.0	6.0	1.3	4.0	0.0	0.0	0.4
H14 17	3.8	81.3	1.0	0.3	1.3	0.0	10.0	0.0	0.0	0.1
Medium										
T12 7	2.8	58.0	25.0	5.6	3.2	0.4	2.6	0.0	0.0	0.6
T16 2	0.0	81.3	0.0	1.8	4.5	1.8	3.8	0.5	0.0	2.5
T16 9	0.0	38.2	36.8	4.9	2.2	0.5	2.0	2.1	0.3	0.9
T17 4	7.9	25.4	2.7	1.1	0.8	0.8	61.7	0.0	0.0	0.1
T17 16	1.8	41.3	7.5	1.8	0.8	0.0	42.5	2.0	0.3	0.3
H15 17	4.4	83.6	0.0	3.0	1.0	0.5	1.3	0.0	0.0	0.3
H15 5 (2/2)	0.0	43.8	22.5	13.8	6.3	2.5	4.0	5.0	0.0	0.1
Deep										
T06 24	12.5	70.0	2.5	1.0	2.0	0.0	7.5	0.0	0.0	0.4
T06 25	0.0	51.3	0.0	15.8	0.8	2.0	52.5	0.0	0.0	0.1
T07 2	38.8	12.6	40.8	0.7	0.2	0.0	4.5	0.0	0.0	0.1
T07 5	0.1	75.7	9.3	0.9	1.6	0.6	5.1	0.0	0.5	0.6
T19 3	0.4	77.1	5.1	1.4	0.7	0.3	5.7	0.0	0.4	0.7
T19 9	0.0	43.8	49.5	1.3	1.5	0.3	1.3	0.0	0.0	0.3
T20 1	0.0	10.6	20.6	0.8	0.6	0.1	9.2	55.4	0.2	0.2
TRANSITION										
Shallow										
T15 109	33.0	51.7	8.3	0.0	4.7	0.0	0.0	0.0	0.0	0.2
T15 104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H08 6	1.3	52.5	31.8	1.3	3.8	0.3	2.5	0.0	0.5	0.5
H08 11	2.5	74.5	13.8	0.5	0.0	0.0	5.0	0.0	0.0	0.3
H14 22	2.5	25.0	40.0	1.0	1.0	0.0	17.5	0.0	0.5	1.0
H14 17	0.3	38.8	1.3	1.0	44.0	0.8	11.5	0.3	0.0	0.2
Medium										
T12 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T16 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T16 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T17 4	5.0	41.3	5.0	3.8	2.0	0.3	21.3	16.3	0.0	0.1
T17 16	1.0	40.5	50.0	0.5	0.0	0.0	7.0	0.0	0.0	0.2
H15 17	0.0	80.0	2.5	2.5	2.5	0.0	10.0	2.5	0.0	0.0
H15 5 (2/2)	3.8	47.5	26.3	10.0	5.0	0.8	2.5	0.3	0.0	0.3
Deep										
T06 24	35.0	50.0	2.5	4.0	0.0	1.5	7.5	0.0	0.0	0.2
T06 25	0.0	30.0	27.5	3.0	0.5	0.0	37.5	0.0	0.0	0.0
T07 2	0.0	27.5	3.8	0.3	0.8	0.0	11.3	0.0	0.0	0.1
T07 5	13.8	30.0	33.8	0.3	1.3	0.0	7.5	0.0	0.8	0.9
T19 3	0.0	0.0	10.0	1.0	0.0	0.5	7.5	0.0	1.5	1.9
T19 9	0.0	57.5	22.5	0.5	0.5	1.0	0.0	0.0	0.0	1.5
T20 1	1.3	23.8	18.8	0.8	0.5	0.0	1.5	50.0	1.3	0.0
SIDES										
Shallow										
T15 109	0.0	67.0	23.8	1.3	3.0	0.2	0.0	0.0	0.2	0.3
T15 104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H08 6	1.3	33.3	33.9	0.9	0.3	0.3	0.6	19.4	0.4	0.5
H08 11	0.0	59.9	5.6	0.2	0.6	0.0	8.3	0.0	0.3	0.0
H14 22	24.8	49.2	0.0	11.7	0.3	0.0	13.3	0.0	0.0	0.1
H14 17	6.3	55.0	7.9	0.3	7.8	0.2	16.9	4.2	0.8	0.2
Medium										
T12 7	31.4	44.4	5.0	0.0	0.6	0.0	0.0	0.0	1.7	0.8
T16 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T16 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T17 4	0.7	26.0	8.4	1.2	3.4	0.1	37.3	19.0	0.7	0.2
T17 16	0.9	52.0	16.5	0.7	1.7	0.0	12.7	10.6	0.5	0.4
H15 17	0.1	84.9	6.0	0.9	0.0	0.1	5.0	0.3	0.3	0.2
H15 5 (2/2)	12.0	31.0	51.8	4.2	0.0	0.0	1.5	0.0	0.0	0.0
Deep										
T06 24	0.6	53.5	0.6	0.1	0.0	0.0	35.8	0.0	3.3	0.6
T06 25	0.2	48.4	28.4	0.5	0.7	0.3	13.7	0.0	1.1	0.7
T07 2	17.5	43.3	10.0	0.7	1.3	0.0	21.7	0.0	0.0	0.5
T07 5	6.0	44.4	30.6	1.1	0.6	0.0	10.6	0.4	0.0	0.5
T19 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T19 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T20 1	2.5	56.7	12.5	0.5	0.0	0.0	16.7	8.3	1.0	0.1

Table 1. Total taxa found in study, with average percent cover for tops, transitions, and sides in shallow, medium, and deep depths. Column headings include bare (stony coral), Coral (Coralline algae), Gyps (Gypsina foram), Turf (turf algae), Soft (soft algae), Jania (red algae), Ostreo (Ostreobium), Sponge, Homo (Homotrema), and Other (all taxa with less than 5% total cover).

Sample	Depth (m)	Years Dead	Width (mm)	Height (mm)	Top Thickness (mm)	Side Thickness (mm)	Top Accretion ($kg/m^2/yr$)	Side Accretion (kg/m2/yr)	Total Accretion (kg/m2/yr)
H08-6	4.00	6.00	14.31	55.57	0.33	0.48	0.03	0.49	0.52
H08-11	4.00	6.00	20.28	67.08	0.65	0.74	0.06	0.61	0.67
H14-22	6.70	6.00	13.76	25.38	0.57	0.26	0.06	0.15	0.20
H15-17	11.00	6.00	20.18	54.42	0.26	0.54	0.01	0.14	0.15
T12-7	15.30	5.00	20.25	30.05	0.21	0.70	0.01	0.10	0.11
T17-16	12.00	5.00	19.78	33.20	0.02	0.50	0.00	0.11	0.11
T07-5	16.70	5.00	19.19	34.97	0.34	0.73	0.01	0.09	0.10
T19-9	20.00	5.00	18.01	32.77	0.42	0.73	0.03	0.23	0.27

Table 2. Depth, in meters, of water coral samples were found in, along with years since death, width and height of coral heads, top and side thicknesses, top and side accretion rates, and total accretion rate.

side), of each coral slab were examined separately (Figure 2). Percent cover of each encruster was visually estimated using a Nikon microscope at 10x magnification. Each slab was examined in multiple adjacent frames (the area visible in one viewing window of the scope; the number of frames per sample ranged anywhere from one to fourteen for tops, one frame for transitions, and two to sixteen on sides). Within each frame, an estimated percentage of each biont present was recorded. Averages were calculated for each of the three surface areas on each coral (Table 1). The thickness of a coralline algae crust was also measured using an eyepiece reticule. Not every sample had an algal crust, and for those that did, the thickness was measured on the top of the sample where time since death was known. A student at Oberlin College, Akemi Berry, measured the thickness along sides of certain samples. The average thicknesses of tops and sides were calculated (Table 2).

Both species richness and the Shannon-Wiener Index are measures of biodiversity, and both were calculated in this study. Richness merely counts the number of different species that are present, while Shannon-Wiener calculates diversity based on the proportion of each species relative to the total number of organisms present in an area. T-tests were used to evaluate significant differences.

Calculating Encruster Accretion

The average crust thicknesses were used to calculate the carbonate contribution to the reef by encrusters. The average thicknesses for sides were multiplied by the surface area of the coral head (found by multiplying the width and height of the coral by pi). This number was divided by the number of years the coral had been dead plus the growth interval (how much the coral grew per year, taken from numbers calculated by Benson, this volume). The side accretions were added to the top accretions per sample, resulting in a total accretion rate of encrusters per sample (Table 2). Widths and heights (needed for surface area) were not known for every sample, so those particular transects were left out of the table. Side crust thicknesses were also not known for every sample, and were noted as such in the table.

RESULTS

At all depths and in the majority of samples, coralline algae was the most prevalent encruster on all surfaces (Table 1). It had the highest average percent cover in shallow water on tops of samples (63%), with individual samples having between 10.6%-90.7%. The coralline algae average percent cover values for the tops, transitions, and sides of samples were plotted against the depths the samples were collected from (Figure 1). The foraminiferan Gypsina had the next highest average percentage at 18.8% along tops in shallow depth, with percent cover ranging from 0-51.8%. *Ostreobium* was the third most abundant, with a highest average cover of 16.8% along tops in medium depths.

Samples had anywhere from 0-61.7% cover. Organisms in the 'Other' category were all found either infrequently or in very small percentages.

Average coralline crust thicknesses ranged from 0 - 0.72 mm on tops and 0.26mm – 0.82mm on sides (Table2). Shallow-water samples tended to be more heavily encrusted than medium or deep-water corals. In fact, in deep water two samples had no crust at all.

Top accretion rates averaged 0.33 mm yr^{-1} and sides averaged 3.18 mm yr-1, with total accretion being 3.51 mm yr^{-1}. Sides had an average 9 times more surface area than tops, which contributes to the higher rates for sides than tops.

Species richness, (the number of species present), among tops was highest (12.1) in the medium depths Among transition areas, the middle depths had the

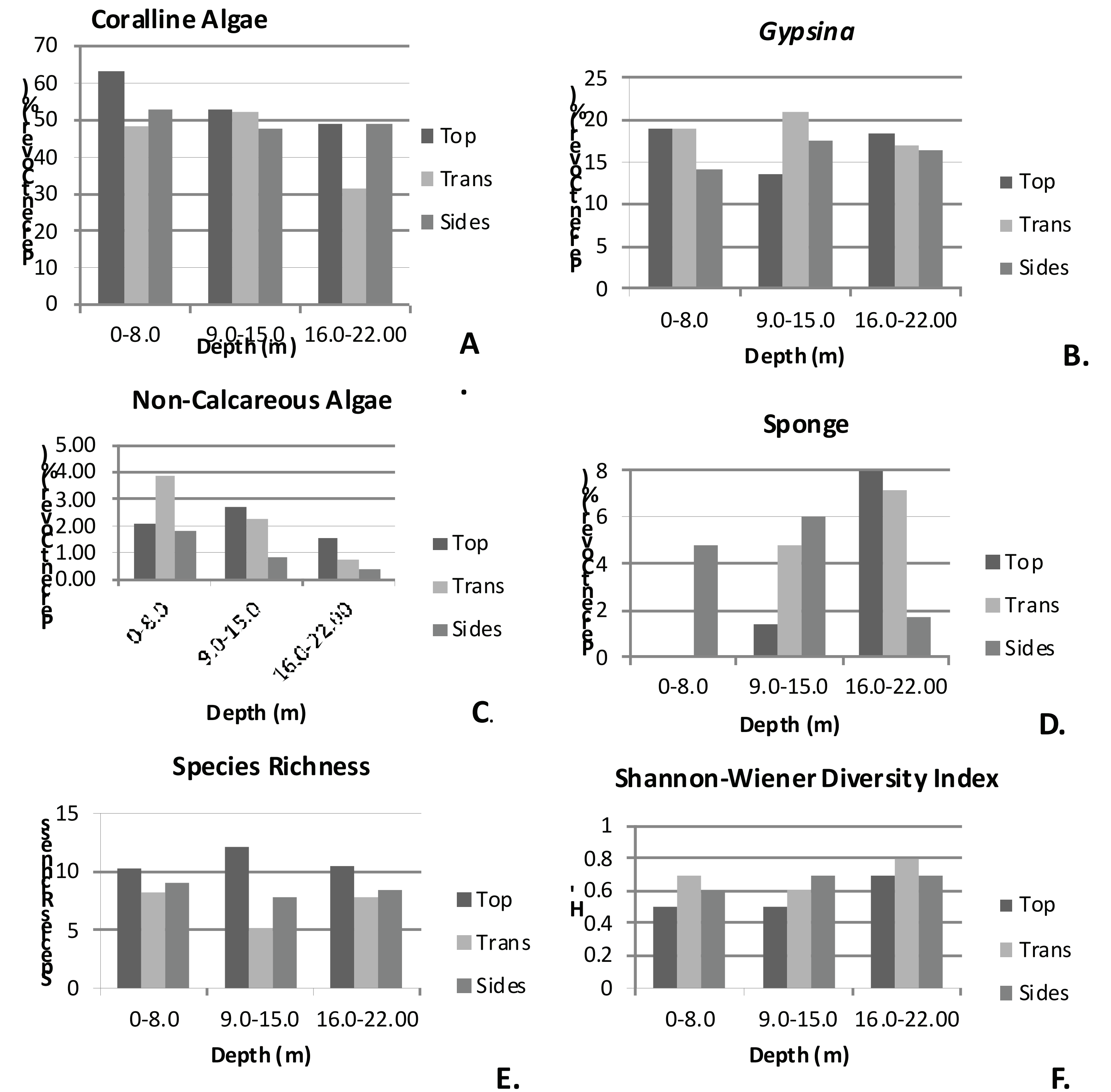

Figure 1. Percent cover of encrusters across depth: A. Coralline algae, B. Gypsina foram, C. Non-calcareous algae (turf, soft, Jania, Ostreobium), D. Sponge, E. Average species richness, F. H' (Shannon-Wiener Diversity Index).

lowest richness (5.1), and the shallow samples had the highest richness (8.3), and the middle depths had the lowest richness (5.1). The Shannon-Weiner index showed that coral samples, on average, were the most diverse in deep waters (ranging from 0.68-0.8), and least diverse in medium depths (ranging from 0.5-0.72) for combined tops, transitions, and sides of samples. In shallow and medium depths, the tops had the lowest diversity value at 0.5 (perhaps due to high coverage by coralline algae/ coralline crust), but tops in deep water showed somewhat greater diversity. The transition areas in deep water had the highest diversity at 0.8, followed by the tops at 0.7, while the least diversity for deep water samples occurred along the sides at 0.68 (Figure 1). However, it must be noted that statistical results from T-tests showed no significant difference in diversity among communities. They were performed on coralline algae data, for example, to see if the differences in cover from depth and also from top, transition, and sides were significantly different. The results show no significant difference in percent cover.

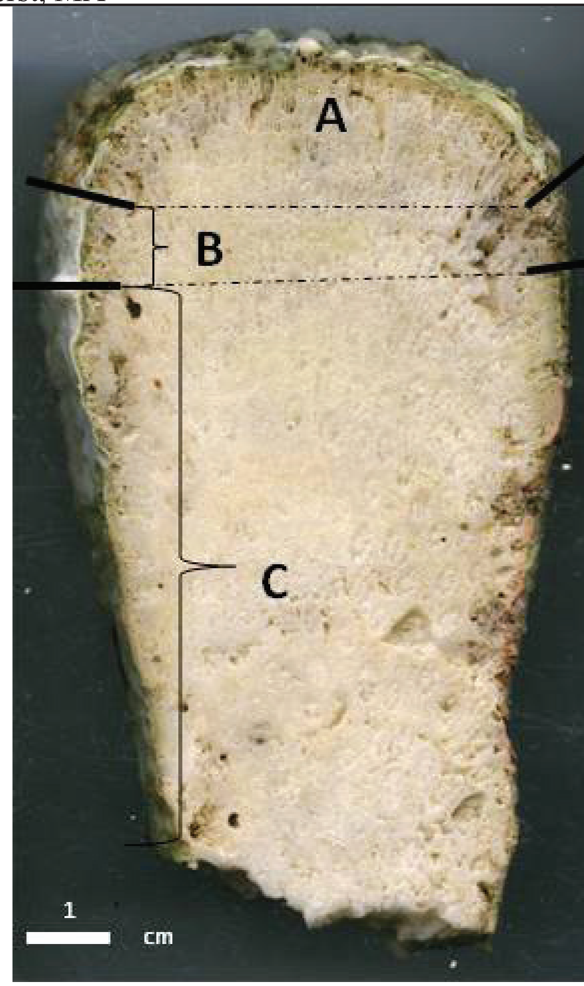

Figure 2. Illustrates a typical top, transition, and side for a coral sample. A. Top area; B. Transition area; C.. Side area.

DISCUSSION

Coralline algae was the dominant encruster found in this study. This is in agreement with a study done by Rasser and Piller (1997), who found the same between 0 and 35 meters, and also found coralline crust thickness decreased with increasing depth (Rasser and Piller 1997). The highest rates of production appear in regions where light is plentiful and easily obtained. Other species, such as Planorbulina, had no clear pattern, while *Carpenteria* had the greatest numbers in deep waters (both of these organisms are included in the 'Other' column of Table 1). This is in agreement with a study done by Sally Walker et al. (1998), who found that forams and bryozoans lived in waters of 73 meters or more. An experiment by Perry, et al. (1999) found that in approximately five meters of water, the coralline crust was thick , and common encrusters included forams, bryozoans, sponge, and various bivalves. In fifty meters, the coralline crust was thin and bryozoans, and *Homotrema* were common (Perry, et al., 1999). The only bryozoans found in this study were in deep waters, while *Homotrema* were found in all depths. The percent cover of algae contradicted what Knott, et. al. found: there were higher percent covers of algae on tops of samples than there were on sides. The areas considered 'sides' could also be considered cryptic, or regions where light doesn't penetrate as easily, while tops were fully exposed to sunlight. The more light that these organisms are able to absorb, the faster they are able to grow, and the more carbonate they are able to contribute to the carbonate budget.

The amounts of carbonate that are being added to the reef each year by the coralline crust are highest along the sides of coral. This could be because bioeroders aren't able to reach the sides, so they graze along the tops of samples, taking carbonate along with the algae they consume. The Blanchon study found that coralline crusts were several cm thick in two meters of water or less (Blanchon, 2004). The thickest crust seen in this experiment was 0.72 mm in thirty feet of water.

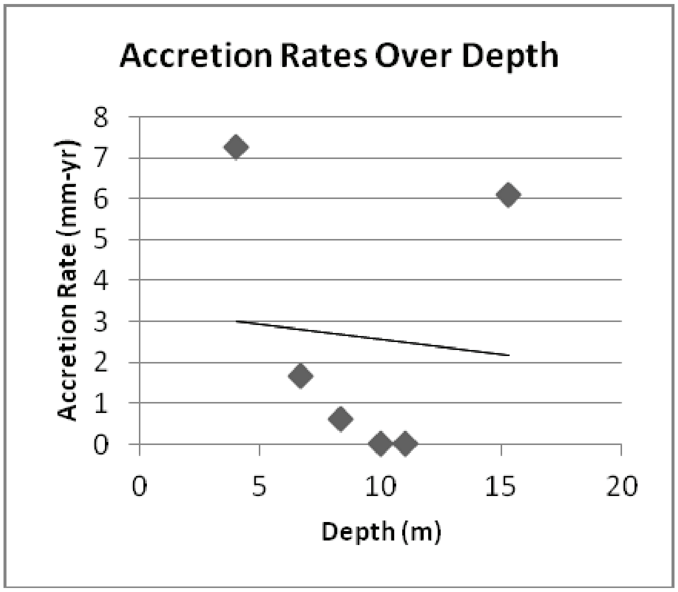

Figure 3. Total accretion rates (side and top accretion rates combined) of coralline algae crusts across depth.

A study by Rasser and Piller (1997) found crusts to be thicker in shallow water, and as the depth increased the crusts got thinner. They suggest this might be due to fewer grazers in deeper waters (Rasser and Piller, 1997). The algae don't have as much light available to them as those in shallow water do, so carbonate production will be lower. The low numbers of grazers also indicate that not as much food is available for them, so they remain in shallow waters and leave the thin algal crusts alone. The shallower transects had several samples with thick crusts, and coral in medium and deep waters had thinner crusts, possibly due to the amount of sunlight available for the algae. The higher accretion rates on the sides of corals could be related to what Rasser and Piller (1997) found in their study, namely fewer numbers of herbivorous grazers in deep waters. Fewer grazers means less carbonate loss due to bioerosion (grazers eating the algae off coral remove carbonate in the process), and in the case of this study, areas considered 'sides' were cryptic and not necessarily within easy reach of predators. Total accretion rates were plotted against depth (Figure 3), and the results are slightly different compared to a study done by Hubbard (2009). At roughly 10 meters, coral growth is relatively steady (no increases or decreases), while growth below 10 meters is greatly reduced. Up to this depth, the growth of coralline algae keeps pace with growth of the coral itself. Overall, a large growth rate difference is not expected (Hubbard 2009). When this data was compared with light intensity, it resulted in a graph with a horizontal line. Figure 3 shows slightly more growth rate change, indicating accretion decreases with increasing depth. The difference in accretion rates is not huge, however, and could reflect elements of bioerosion specific to Tektite and Haulover Bays.

CONCLUSION

The most prevalent encruster, regardless of depth or transect, was coralline algae. Gypsina, *Homotrema*, and *Ostreobium* were also common. Some encrusting habits agreed with previous studies on encrusters, such as Knott, et al. (2004) finding no difference in algal cover between tops and sides, while others disagreed, such as Blanchon and Perry (2004) seeing centimeter-thick crusts in under 6 meters of water. The t-test analyses do not indicate that encrusting patterns are different on tops/transitions/sides. Species richness calculations and Shannon-Weiner values do, however, show that the communities that live on tops, transitions, and sides are variable among transect and depth. The total average accretion rate for coralline algae on tops of samples was 0.33 mm y^{-1}, and for sides it was 3.18 mm y^{-1}, with a total average accretion of 3.51 mm y^{-1}.

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