Coral and Algal Communities in Grape Tree Bay: A Baseline Study

DYLAN D. THOMAS, IAN G. WHEAT, ALEX C. SPINOSO, AND SAMANTHA R. KAPLAN

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Abstract: Phase shifts from coral to algal dominated communities are a major issue in the protection and conservation of coral reefs. Previous studies have shown that Little Cayman's coral reefs are in decline, although the mechanisms remain unclear. We established long-term plots for a study of algal and coral interactions in Grape Tree Bay near the Little Cayman Research Centre. We estimated coral and algal percent cover in twenty 1 m^2 plots along the back reef. Corky sea finger and boulder star were the most common corals, while an unidentified "short green" morphotype was the most abundant alga. Long term monitoring of these plots may help researchers to identify causes of coral decline.

Key Words: coral reef degradation, Little Cayman, Shannon diversity index

Introduction

Coral reefs are declining around the world. Coral bleaching, overfishing, sedimentation, eutrophication, and disease are strongly correlated with human activity (Smith et al. 2006). These changes have facilitated "phase shifts" from coral to macroalgal domination of the communities, a critical step in reef degradation (Connell et al. 1997). Coral disease is often positively correlated with increasing algal cover, and algae can indirectly increase coral mortality by enhancing microbial activity (Smith et al. 2006). Algal cover on dead coral and other hard surfaces also inhibits coral recruitment (McCook et al. 2001). Documentation of long-term trends could help identify mechanisms of coral decline, which would aid in conservation and management.

We studied coral and algal communities near the Central Caribbean Marine Institute, Little Cayman Island, establishing baseline data and permanent plots. Some reefs previously dominated by coral have become dominated by macroalgae within 20 years (Shulman & Robertson 1996). The reefs of Little Cayman are in better condition than those in most of the Caribbean. However, Coelho and Manfrino (2007) showed that, despite low anthropogenic impacts, corals between 9 m and 13 m depth have declined recently on Little Cayman. We decided to complement this study by initiating long term monitoring of coral and algal communities on the back reef (0-2m depth).

METHODS

On February 28 and the March 1-2 2008, we estimated coral and algal cover on the back reef of Grape Tree Bay, ca. 100 m offshore from the Central Caribbean Marine Institute station on Little Cayman Island. Using PVC 1 m^2 quadrats, we established twenty 1 m^2 plots along a ca. 200 m long segment of the back reef. We first placed plot 1 (the most easterly), then proceeded ca. 10m westward to place each successive plot, up to plot 20. We used the following procedure to avoid potential bias in placement of plots. Each time we swam ca. 10 m to the west, we marked that point, then used a randomization procedure to place an individual plot on the back reef within 2m of that point. Detailed instructions for relocating plots are in Appendix A.

We divided each plot into four subplots. We visually estimated the percent of the total substrate surface area within the subplots (i.e. the projected area in the plane of the plot) covered by algae and coral. For this we considered the surface area of both hard and sandy bottom substrates. (We did not take into account the surface area of soft corals or fleshy algae, but rather the area of the substrate they were attached to). In each subplot we estimated percent cover of each genus of algae and each species of coral. Where we could not identify the organism, we used morphotypes (see Results). We also noted the number of colonies of each coral species in each plot. Percentages did not necessarily sum to 100. The sum could be < 100 because of space occupation by organisms other than coral and algae, and unoccupied bare substrate (which was uncommon). The sum was > 100 only if there was some observer error. Coral and algal cover were estimated by two independent observers (one each for algae and for coral).

We mapped the precise position of each plot, for relocation in future (Appendix A). We first measured distance between neighboring plots using distances from a particular corner of plot N (N = 1-19) to each of the 4 corners of plot N+1. We also recorded the compass bearings between neighboring plots, and the inclination of each plot relative to the horizontal plane. We took 6 photographs of each plot: one of the entire plot, one of each of the 4 subplots, and one of the shoreline as viewed from each plot. Appendix B (intended for online access and archived records) contains full-color plot photographs.

In order to compare how similar subplots are to one another, we performed a clustering analysis with JMP, and quantified this result with MRPP in PC-ORD (McCune and Mefford 1999) to avoid the assumption of normality. For the MRPP, we chose the Sorensen (Bray-

Curtis) distance measure, with n/sum(n) weighting of groups, and grouped the subplots according to plot number, and the distance matrix was rank transformed.

RESULTS

We found nine species of coral and twelve genera of algae in our twenty 1 m^2 quadrats. For hard corals, we found boulder star (*Montastrea annularis*), massive starlet (*Siderastrea siderea*), mustard hill (*Porites astreoides*), branched finger (*Porites porites*), boulder brain (*Colpophyllia natans*), sinuous cactus (*Isophyllia sinuosa*), and lettuce (*Agaracia agaricites*). We found one hydrocoral, blade fire (*Millepora complanata*), and one octocoral, corky sea finger (*Briareum asbestinum*). Corky sea finger and boulder star coral were the most common corals, with the greatest number of total colonies, % cover, and frequency of occurrence. For algal genera we found *Halimeda, Dictyota, Ceramium*, *Galaxaura, Valonia, Liagora, Thalassia,* and five unidentified algae, which we refer to as "brown", "short green", "orange encrusting," "long brown," and "stringy yellow." All algae other than "orange encrusting" and "short green" were fleshy. Appendix B (for online access and archived records) contains descriptions and full-color photographs of unidentified algae. The five most common algal groups were unidentified "short green" algae, *Halimeda, Dictyota,* "orange encrusting" algae, and *Ceramium*. "Short green" was very abundant, with a mean cover of 23.5% (Table 1).

To quantify coral and algal diversity, we calculated the Shannon diversity index, separately for coral and algae, for all plots, as: $H = - \Sigma P_i \times \ln P_i$, where P_i = the proportion of each coral/algal species or genus in total coral/algal cover (Begon et al. 1996). For all plots, H ranged from 0 to 1.5720 for coral species and from 0.4412 to1.7094 for algae. Coral diversity and richness (mean H = 0.762 ± 0.075 SE, mean richness = 3.2 ± 0.3211 SE) were lower than for algae (mean H = 1.295 ± 0.075 SE, mean richness = 5.1 ± 0.2800 SE).

Subplots of the same plot were far more similar to one another than to other more distant subplots (MRPP: T = -12.9, observed delta = 0.26, A = 0.48, $p < 0.0001$). This finding was not surprising, since coral colonies often spanned several subplots, and algae were often distributed on patches of dead coral which spanned several subplots of the same plot. A clustering analysis provided graphical confirmation of this result (Figure 1), with subplots often appearing as sister groups in the dendrogram. However, some subplots from different plots were more similar to each other than to subplots within the same plot.

Complete raw plot data (Excel file) are in Appendix D (for online access and archived records).

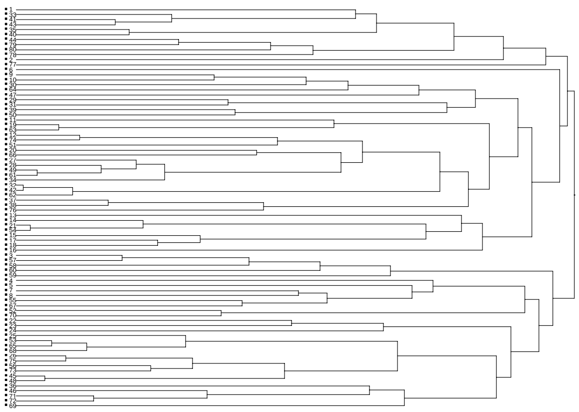

Figure 1. Dendrogram of the 0.25 m^2 (n = 80) subplots belonging to the 1m2 plots (n = 20) sampled on the back reef of Grape Tree Bay, Little Cayman Island. Subplots 1-4 belong to plot 1, 5-8 belong to plot 2, etc.

TABLE 1. Summary of abundances of coral species and algal genera (or morphotypes) from twenty 1 m^2 subplots on the back reef of Grape Tree Bay, Little Cayman Island. The four subplot % cover values were averaged for each plot; mean % cover is the average of those plot means over all plots. Frequency refers to the proportion of plots in which we found each species/genus/morphotype. Relative density of coral colonies = # coral colonies for a species / total # colonies.

Genus or species	**Mean % cover ± 1 SE**	**Frequency of occurrence**	**Total # colonies**	**Relative density of coral colonies**
Unidentified “brown”	0.75 ± 0.58	0.10		
Halimeda	6.62 ± 1.34	0.90		
Galaxaura	0.72 ± 0.34	0.30		
Dictyota	6.41 ± 1.44	0.80		
Ceramium	2.81 ± 0.70	0.65		
Valonia	0.09 ± 0.07	0.10		
Liagora	0.44 ± 0.23	0.20		
Thalassia	0.56 ± 0.28	0.25		
"Short green"	23.50 ± 2.92	1.00		
“Orange encrusting”	4.62 ± 1.31	0.60		
“Long brown”	0.35 ± 0.19	0.20		
“Long stringy yellow”	0.1875 ± 0.1875	0.05		
Total algae	**47.08 ± 2.36**	**1.00**		
Boulder star	11.81 ± 3.64	0.55	76	0.2375
Greater starlet	4.15 ± 3.04	0.15	5	0.0156
Mustard hill	1.56± 0.67	0.30	24	0.0750
Branched finger	1.61 ± 1.01	0.20	9	0.0281
Boulder brain	2.62 ± 1.08	0.30	6	0.0188
Fleshy	0.36 ± 0.36	0.05	4	0.0125
Lettuce	1.55 ± 0.59	0.35	21	0.0656
Blade fire	2.72 ± 1.47	0.20	13	0.1083

Corky sea finger	15.06 ± 2.68	0.90	146	0.4562
Total coral	**42.25 ± 3.28**	**1.00**	**320**	**1**

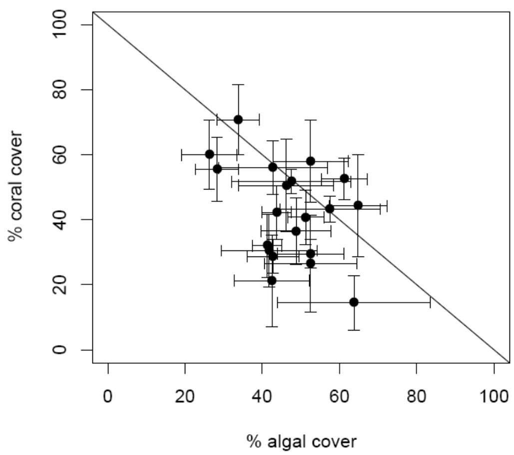

Figure 2. Estimated % coral cover vs. estimated % algal cover in twenty 1 m^2 plots in the back reef of Grape Tree Bay, Little Cayman Island. Each point represents data for one plot; error bars indicate ± 1SE from 4 subplot measurements per plot. Along the line of slope = -1, coral and algal cover sum to 100%; thus points above the line represent plots with sums > 100% due to observer error.

DISCUSSION

Most of the substrate along the back reef of Grape Tree Bay is occupied by coral or algae (Figure 2). We never observed any algae growing on live coral. The total percent cover for each plot ranged from ca. 15-70% for coral and from ca. 25-65% for algae, leaving relatively little space for bare substrates or other space-holding organisms. Thus, in plots with high algal cover, coral cover tended to be low, and vice versa. Plots that lie below the line in Fig. 1, representing 100% combined cover of coral and algae, contain bare substrate or other space-holding organisms that we did not record. It may be useful to record their abundances in future. Plots above the line in Fig. 1 represent plots totally covered by algae and corals, although a sum of > 100% was due to observer error.

Some corals and algae were very common. Corky sea finger was the most common coral, and was the only octocoral in our plots. The second and third most common corals, boulder star and greater starlet, are hard corals that are important in reef building. The unidentified “short green” was the most dominant species in the algal community. Future species identification of “short green” is clearly important.

We found that the coral and algae are spatially aggregated in such a way that adjacent subplots often have similar communities. This pattern could be due to the large size of the aggregations of coral or algae, dispersal limitations, or to unmeasured environmental differences among plots across Grape Tree Bay.

Using these permanent plots, researchers can monitor detailed changes in the algal and coral communities at Grape Tree Bay. We hope that such a long term study will help identify causes of coral decline on Little Cayman Island.

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APPENDIX A. PLOT LOCATIONS

To find all plots, begin with the most easterly 1 m^2 plot (Plot 1) along the back reef as viewed from shore, then move west. Plot 1 is marked by a permanent cement block on the ocean floor on the back reef ca. 5 m east of the furthest east permanent buoy. This buoy is between the bathhouse of the Little Cayman Research center and the first visible telephone pole to the east of the bathhouse (Fig. 2). Plot 1 GPS coordinates are: N 19° 41.809′; W 080° 03.622′, which are accurate to within 5 m. Using a compass, we also triangulated the plot 1 position using 4 permanent positions on the shore: the dining hall of CCMI, the bath house, and the first and second telephone poles to the east of the bath house (Fig. 2). Future researchers should use the information in Figure 2 as well as Plot 1 photographs to locate its position.

Table 2 contains all compass, distance, and inclination data. The compass heading should be taken from the center of each plot, moving progressively west along the back reef, to reach plots in ascending order (Plot 1 to plot 2 is 315 NW, plot 2 to plot 3 is 225 SW, etc.).

Corners of the 1 m^2 plots are numbered 1-4. Facing north (towards the open ocean with the plot in front of the observer), numbers are assigned clockwise, i.e. 1 = top left, 2 = top right, 3 = bottom right, 4 = bottom left (Fig. 3). The plots labeled as "opposite direction", (5 and 19), have the same clockwise number assignments, but are observed facing south (towards the beach with the plot in front of the observer) rather than north (towards the open ocean) (Fig. 4). We included "opposite direction" plots because at some plot locations, it was difficult to work on plots with the observer facing north; at these plots, measurements should be taken from the ocean side, facing south. Plot sides are not oriented along compass directions; they should be determined using the archived photographs of each plot.

Each of the distances between neighboring plots was measured using a synthetic, flexible meter tape, from corner #1 to each of the four corners of the next plot, and similarly from plot 2 to plot 3, etc. We tied the tape measure to corner #1 of each plot to secure the tape for measurements to the next plot. A value of 0.3 m was subtracted from each of the measured distances to account for the tying of the tape measure to the corner of the plot. We made this "tying" length at close as possible to 0.3 m on each measurement, but a few cm of error should be expected in all distance measurements. Of course, in the future, this tying procedure should be eliminated, with one researcher holding the zero position of the tape in place by hand, while another worker takes the measurement. Then the inter-plot distances can be updated in Table 2 to more precise values, with appropriate clear documentation. Plot #20 has no associated compass or distance measurements, as it was the last plot.

Plot inclination data shows whether each plot was approximately in a vertical or horizontal plane. Vertical inclination means an angle > 45˚ and horizontal means an angle of < 45˚ to the horizontal. Those labeled as vertical/horizontal were considered close to 45˚. Photographs for each plot are labeled as "whole" (whole plot), TL (top left corner), TR (top right corner), BL (bottom left corner), and BR (bottom right corner). These labels assume one is facing the plot in the given direction (facing north for most plots, or south for "opposite direction" plots) so TL = corner #1, TR = corner #2, BR = corner #3, BL = corner #4. Each plot also has one photograph labeled "shore", which was taken above water, from that plot towards the shore.

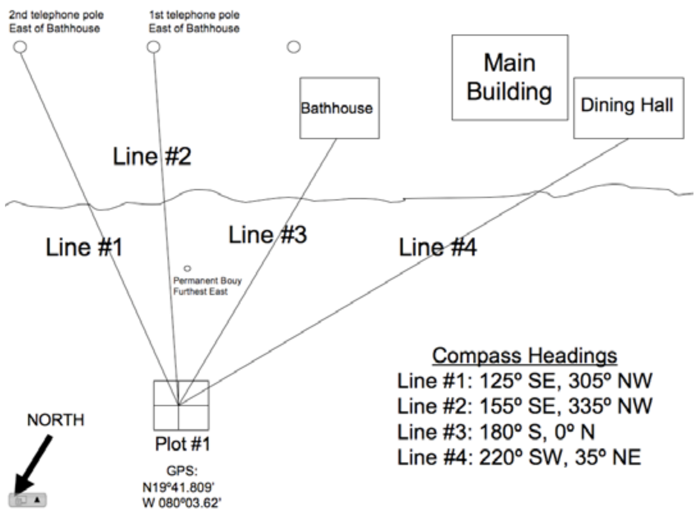


Fig. 2 Location of plot #1 from the ocean-facing deck of the Little Cayman Research Center. Map: Alex Spinoso.

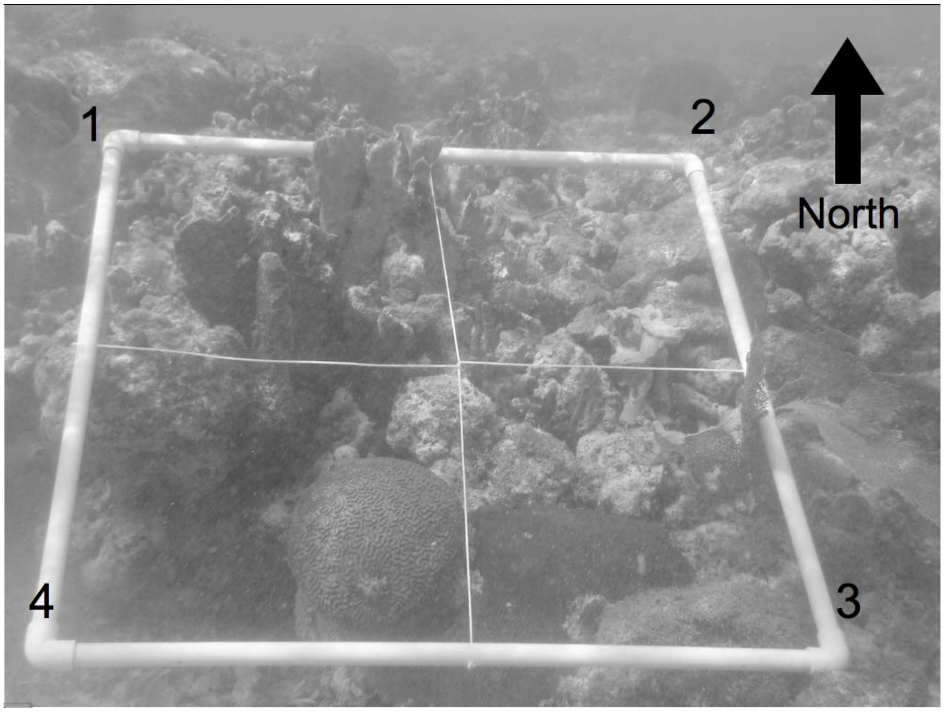


Fig. 3 Numbering system and orientation for plot 1. Photo: Samantha Kaplan.

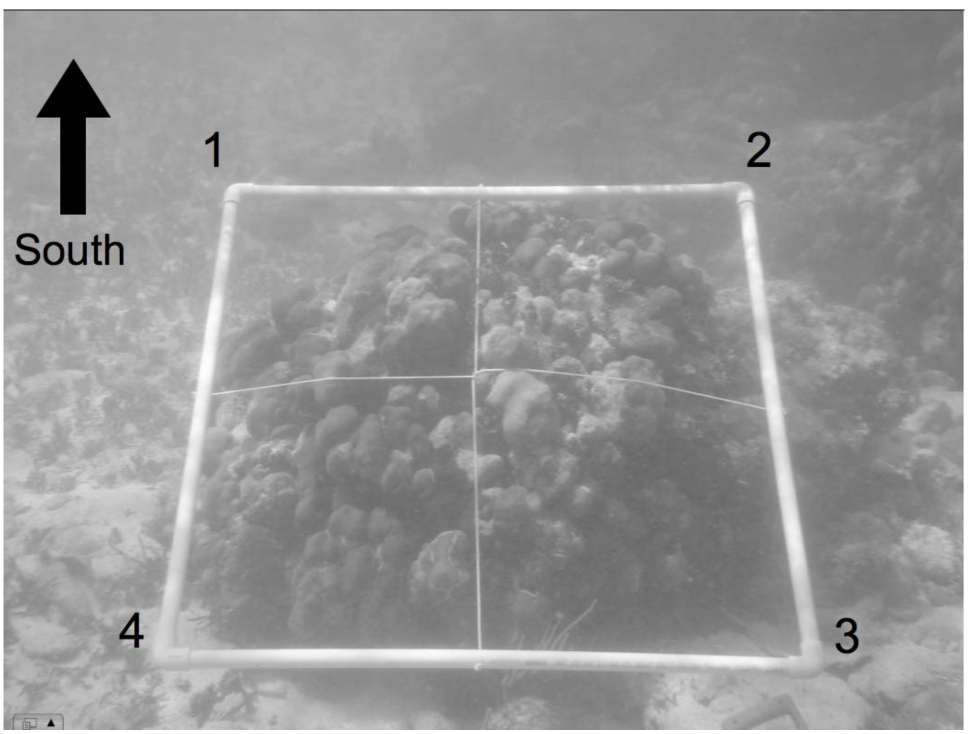


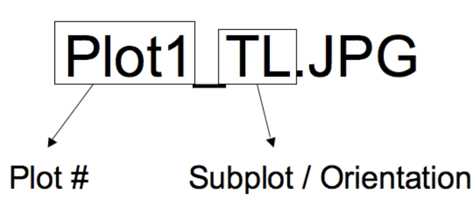
Fig. 4 Numbering system and orientation plot 5 (an opposite direction plot). Photo: Samantha Kaplan.

Table 2. Compass headings, distances between adjacent plots, and inclination of each plot to the horizontal. The observer faces north (toward the ocean with the plot in front of him/her) unless otherwise labeled as “opposite direction”, which assumes one is on the north side of the plot facing south (i.e. facing the beach with the plot in front of the observer). All measurements and directions in each row of the table are from corners of that plot to corners of the next consecutive plot (i.e. from plot N to plot N +1).

Plot #	Compass Heading	Distance between Corner #1 & #1 (m)	Distance between Corner #1 & #2 (m)	Distance between Corner #1 & #3 (m)	Distance between Corner #1 & #4 (m)	Inclination (Vertical/Horizontal)
1	315 NW	9.94	10.94	11.33	11.41	Vertical
2	225 SW	8.96	9.87	9.1	10.07	Vertical
3	235 SW	13.22	12.44	12.59	11.87	Horizontal
4	305 NW	11.71	11.82	11.68	11.7	Vertical
5 (Opposite Direction)	265 W	9.38	8.48	9.65	9.95	Vertical
6	260 SW	11.21	9.84	11.13	10.22	Vertical
7	260 SW	10.51	10.42	10.2	10.32	Vertical
8	285 NW	11.05	10.11	10.55	11.3	Horizontal
9	300 NW	10.56	9.99	9.44	9.96	Vertical
10	240 SW	10.16	9.22	9.48	10.39	Vertical
11	275 W	9.89	8.96	8.93	9.88	Vertical
12	265 SW	9.04	8.24	8.38	9.19	Vertical/Horizontal
13	260 SW	10.85	10.85	9.9	10	Horizontal
14	225 SW	12.85	12.06	11.68	12.59	Vertical
15	260 SW	10.73	12.7	10.55	11.44	Horizontal
16	235 SW	14.01	14.1	13.29	13.42	Vertical
17	255 SW	9.11	8.13	8	8.91	Vertical/Horizontal
18	245 SW	9.94	10.94	11.33	11.41	Horizontal
19 (Opposite Direction)	270 W	8.96	9.87	9.1	10.07	Horizontal
20						Horizontal

APPENDIX B. PLOT PHOTOS

Six photographs for each plot are in the folder labeled “08' FSP Long Term Coral/Algae Study Plot and Unidentified Algae Pictures” Labels for each plot are as follows:



Pictures for each plot are labeled as WHOLE (whole plot), TL (top left corner), TR (top right corner), BL (bottom left corner), and BR (bottom right corner). These assume the observer is facing the plot in the appropriate direction (north for most plots, south for "opposite direction" plots), so TL = corner #1, TR = corner #2, BR = corner #3, BL = corner #4. Each plot also has one picture labeled SHORE, which was taken from that plot towards the shore for orientation. All photos by Samantha Kaplan.

APPENDIX C. UNIDENTIFIED ALGAE DESCRIPTIONS

Photographs for each unidentified alga are in the folder "08' FSP Long Term Coral/Algae Study Plot and Unidentified Algae Pictures".

"Short green alga" - Very common, on dead coral everywhere. Encrusting, with has a few thin hairs (ca. 5 mm long) protruding (ca. 5 per cm^2).

"Brown alga" - Very common, on dead coral everywhere. Very much like the short green alga, but brown in color.

"Orange encrusting alga" - Red/orange; does not appear to have attachment points within the coral, but covers it in a very thick plaque.

"Long brown alga" - Dense mat of brown filaments ca. 1 cm long (with a high density, maybe 20 per cm^2). Rare.

"Stringy yellow alga" - Dense mat of yellow filaments ca. 1.5 cm long (with a high density, maybe 20 per cm^2). Rare.

APPENDIX D. RAW DATA EXCEL FILE

Raw data on coral and algal cover for 2008 in the long-term plots are in the file "08' FSP Long Term Coral/Algae Study Raw Data.xls". All data collected from back reef of Grape Tree Bay, Little Cayman directly behind the Little Cayman Research Institute, from plot locations described above.

ARCHIVED DATA FILES

As noted above, there are two folders of archived data files. "08' FSP Long Term Coral/Algae Study Plot and Unidentified Algae Pictures" contains documentation as described in Appendices B and C. "08' FSP Long Term Coral/Algae Study Raw Data.xls" contains data as described in Appendix D.