4-2010

Differential Damages Sustained from Hurricane Ike on Varying Growth Forms of Coral at Distinct Locations off the Coast of South Caicos, Turks and Caicos Islands

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Abstract:

In September 2008, Hurricane Ike hit South Caicos, Turks and Caicos Islands as a Category 4 hurricane. This study examines the differential damages caused to varying common growth forms, size, locations, and depths of coral by Hurricane Ike on South Caicos reefs. Belt transect techniques as well as line intercept techniques were conducted at nine sites, looking at 14 common species of coral, representing four different growth forms. A total of 9,011 coral colonies were surveyed. 2,832 colonies (31.4%) were found to have at least one type of damage. It was expected that branching and digitate growth forms as well as large colonies would sustain the most damage. The difference in damage between growth forms was found to be highly significant. Large colonies were also found to have significantly more damage (41.1%) than small colonies (29.0%). Colonies located at depths of 9-18m were significantly more damaged(33.3%) than colonies located at depths of 5-8m (28.4%). Coral colonies located at exposed reef sites were found to have more damage (33.5%) than colonies located on protected reef sites (28.4%); however, this difference was not significant. The findings suggests that the intensity of damage sustained by a reef during a hurricane is partially dependent upon the morphology of the species found at the reef and the location of the reef.

Key Words: Hurricane Damage, Coral Growth Forms, Turks and Caicos Islands, Hurricane Ike, Coral Colony Size, Depth, Reef Location

Introduction:

Coral reefs are three-dimensional, shallow water structures that are dominated by scleractinian, or stony, corals and are home to an enormous variety of organisms [1, 2].

Scleractinian coral are the main reef builders because they are able to produce a calcareous skeleton, which functions as the framework for the entire reef [2]. Corals can grow in many different shapes, known as growth forms including: encrusting, plate-like, columnar, massive, branching, and digitate [2]. Almost all the important reef-building corals contain symbiotic zooxanthellae. Zooxanthellae are dinoflagellates that live within the live coral tissue, located only as a thin layer on the surface, and help to create the calcium carbonate skeletons, which forms the base framework. Without the zooxanthellae, corals would not be able to build their skeletons fast enough to make an entire reef [1]. Bleaching, the dissociation of zooxanthellae from their coral host, occurs when corals are under stress and can serve as a sign of deteriorating health [3,4].

Coral reefs, one of the world's most complex ecosystems and the richest of marine ecosystems, are currently undergoing a large scale loss of coral cover [2, 5]. Approximately 58% of the world's coral reefs are classified as threatened and decline in reef health is occurring at even the best-managed reefs in the world [6,7]. In the Caribbean, coral reefs are experiencing phase shifts from coral to algal dominated systems [8]. Among the many factors found to directly cause damage to coral colonies are direct human impacts (overfishing, pollution, sedimentation, etc.), climate change, disease, and natural disturbances such as hurricanes [1,6]. Physical disturbances which alter the reef habitat have the greatest potential to cause harm to these fragile ecosystems [9]. Reefs that are impacted by hurricanes have an average of 6% coral cover decline per year; in comparison, sites that do not have regular hurricane impacts have a declining background rate of coral cover of approximately 2% [6]. Hurricanes are known to cause mass amounts of damage to coral reef communities, changing the coral cover, diversity, and complexity of reef systems [10]; however, the intensity of the damage can be incredibly variable [11]. The outcome of a hurricane impact is affected by factors such as the ferocity, proximity and frequency of hurricanes and, notably, outcome is also determined by the current physical and biological characteristics of the reef [10,12]. Individual coral colonies located on the same reef can sustain variable damages based on characteristics of the colony such as growth form, species, age, size, and orientation [13].

Hurricane impacts on coral reefs in the Caribbean have been well studied. Natural systems, such as coral reefs, are often organized by disturbances [14]. Hurricanes can substantially change the vegetation structure, animal populations, and ecosystem process found on a reef [14]. In the absence of harsh human disturbances, coral reefs are able to gradually repair themselves naturally after routine natural disturbances such as storms [1]; however, it has been shown that human induced effects on a reef can be intensified by natural disturbances, such as strong storms [15-17]. The disturbance history of a reef can play a large role in affecting the outcome of a new disturbance, and the periodic passage of strong storms can increase the resilience of surviving colonies making them better suited to survive future storms [10,18,19]. The average damage sustained at a reef has also been shown to increase as the time since the last storm impact increases [6], which further suggests that reefs can become more resistant to hurricanes if they are impacted regularly.

Reefs at locations directly exposed to wave action during a storm often sustain immense damages as a result. Protected reefs, those sheltered from direct wave force by a landmass, have been shown to sustain worse damages during a storm than exposed reefs because the corals at these locations are more vulnerable to strong wave forces [18]. Corals which are protected from normal current and wave action have been shown to be less adapted to handle storm disturbances, whereas exposed reefs have corals which are more resilient and better adapted to sustain wave action without damage [18]. The greater amount of time that has passed since the last storm, the greater the number of vulnerable species which will be present on a protected reef and, as a result, the amount of possible damage from a disturbance is greater [18]. Massive and head growth forms of coral have also been shown to sustain less damage overall (24% damaged) than branching forms (38% damaged) after hurricane impacts [13]. Scleractinian corals have brittle skeletons making branching corals more vulnerable to fragmentation because of their delicate structure [20,21]. Smaller colonies were also found to have less damage than larger colonies most likely due to less bioerosion and more secure basal attachments[13]. Smaller colonies also have a greater chance of complete mortality, whereas larger colonies more often experience only partial mortality [22].

Depth also plays a large role in the vulnerability of a reef to hurricane damages. Corals living in deep water are less susceptible to wave action than shallow corals [23]. Massive head corals, those most adapted to handle hurricanes, have been shown to have a greater occurrence for toppling in shallow waters [21]. A general decrease in the amount of damage with increased depth agrees with the expected attenuation of wave energy down the water column [13].

The Turks and Caicos Islands are the southeastern extension of the Bahamian archipelago. The Caicos Bank is surrounded by eight large islands and approximately 40 small cays which are scattered across two banks, the Turks Bank and the Caicos Bank [24]. The smallest of the main islands is the southernmost South Caicos [25]. The Caicos Bank is affected by easterly trade winds and extremely low precipitation. Limestone cliffs with the Caicos shelf only 180m offshore characterize the windward eastern side of South Caicos. Conversely, the leeward western side of South Caicos is covered with mangroves and soft sediment banks [25]. The Turks and Caicos Islands are surrounded by over 300km of coral reefs [24].

Many studies have already been conducted on coral status around the Turks and Caicos Islands [25-28]. The Turks and Caicos Islands have some of the healthiest remaining reefs in the Caribbean [26], with only some effects due to pollution visible near the heavily populated islands of Providenciales and Grand Turk [24]. The live coral cover on reefs in the Turks and Caicos Islands was reported to be between 10-12% in 2008[26], which is markedly less than the 18% coral cover reported in 2003 [24]. *Montastrea annularis, Agaricia agaricites,* and *Siderastrea siderea* are the most common species found along the Caicos Bank [25]. *S. siderea* and *Porites astreoides* were found to be the most frequent at all depths on the reefs around South Caicos; comparatively, *A. agaricites* and *M. annularis* were among the most frequent at depths of 18 to 27 meters [28].

The Turks and Caicos Islands provided an excellent location to conduct coral research because they have some of the most pristine reefs remaining in the Caribbean and have low human disturbance compared to many other Caribbean Islands [25,26]. Tourism has become the leading industry in the Turks and Caicos Islands. Tourist activities are also the leading uses of coastal environments, above fisheries, on Providenciales and Grand Turk [28]. South Caicos is the fishing capital of the Islands; however, three large resorts are currently under construction and threaten to severely alter the coastal environments. Local fishermen on South Caicos are reporting decreased catch per unit effort, which suggest the marine environment is already under stress and possibly indicates an algal phase shift is occurring [28].

In September 2008, two hurricanes, Hanna and Ike, hit South Caicos, Turks and Caicos Islands within one week of each other. At the time of impact, Hanna was considered a tropical storm, and caused mainly flooding damage to the island. Hurricane Ike made landfall a week later as a Category 4 hurricane with 135mph winds devastating the island as well as causing considerable damage to the surrounding marine ecosystems. This study examines the effect that Hurricane Ike had on the coral population surrounding South Caicos.

Belt transects will be used for this study because they can cover a large area of space in the short time allotted for data collection, the equipment is easily portable, and techniques are easy to learn, though difficult to carry out in rough surf. Belt transects also allow for coral density to be calculated. A line intercept will also be conducted along each transect in order to provide data on the percent cover of coral at each site, as well as the percent cover of other substrates. The use of quadrats is an alternative method which is popular; however, they cover a much smaller area and consequently the sample studied could be a poor representation of the entire reef site. The methods used in this study are adapted from successful methods used by Bries et al. (2004) when conducting a similar survey of hurricane damage to coral.

Three variables will be the main focus of this study: differential damages sustained by reefs at varying locations (sheltered vs. exposed), varying reef depth (deep vs. shallow), and varying common growth forms of coral. It is expected that branching and digitate growth forms will have more damage than massive and sub-massive growth forms, that shallow reefs will have more damage than deeper reefs due to greater wave action. Sheltered reefs are expected to have greater damage than exposed reefs because they are not often affected by wave action, and therefore will be less resilient. Larger colonies are also expected to have more damage than small colonies.

Materials and Methods:

A survey of the coral population was conducted in April 2009 with the purpose of determining the extent of the damage done when Hurricane Ike passed over South Caicos as a Category 4 hurricane in September of 2008. The survey was conducted at nine strategically selected sites. The sites selected are established dive sites (existing mooring bouys), observed to be heavily damaged by the hurricane, or have high tourist, fishery, or conservation value [24]. Each site is a 200m x 200m area of coral reef preferably encompassing reefs of depths between 5-8m (shallow) and 9-18m (deep) which are of special interest. These sites were easily accessible because they have preexisting mooring lines, and many have had previous research conducted at them, which provided baseline data for our research. The sites are also representative of either protected or exposed reefs to the prevalent winds and currents when the hurricane hit.

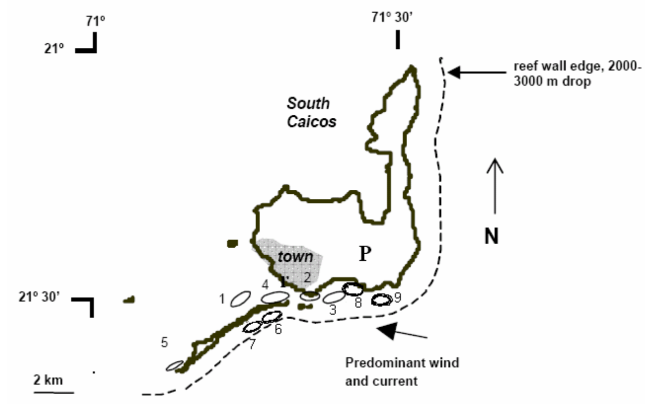

Figure 1. Map of South Caicos, Turks and Caicos Islands, showing nine reef sites surveyed (1=Admirals Aquarium, 2= Cox development, 3=Tuckers reef, 4= Shark alley, 5= South end of Long Cay, 6= The grotto,

The proposed methods for this study have been adapted from successful methods used by Bries et al. (2004)[13]. Fourteen common species of coral were included in this study. These species have been selected because they are reported to be highly prevalent around South Caicos and represent four colony growth categories. The colony categories include massive (*Montastrea annularis* (MA)*, M. Cavernosa* (MC), and *Dendrogrya cylindrus*(DC)), sub-massive (*Colpophylia natans*(CN)*, Porites astreoides*(PA)*, Stephanocoencia intersepta*(SI)*, Diploria strigosa*(DS)*, D. labyrinthiformis*(DL), and *siderastrea sidereal*(SS)), digitate (*Madracis mirabilis*(MM) and *P. porites*(PP)), and branching (*Acropora palmate*(AP)*, A. carvicornis*(AC), and *Agaricia agaricites*(AA)). The size of each colony was recorded within small (10-15cm), medium (25-50cm) and large (>50cm) categories.

Data collection was conducted using SCUBA and snorkeling techniques. A total of five 25 x 4 meter transects were laid at each site. Each transect location was selected randomly over a section of reef that is parallel to shore and avoids areas of the reef with sudden slope change, deep grooves, or large patches of sand or coral rubble. Line intercept technique according to English et al. (1997) was performed to estimate the percent of coral cover present[29]. Divers moved along each transect recording species found directly under the tape. Using the AGRRA method, coral was classified as living, recent dead (one day-one year since death), or old dead (more than one year since death) in situ. The location on the tape was recorded where organism, or substrate changed. Four meter belt transects were also conducted by slowly moving along the belt transect, identifying the 14 species being studied and recording the size and damage present on each colony.

Damage done will be categorized within six damage variables. These six variables are toppling, fragmentation, tissue damage, bleaching, disease and smothering. Toppled corals are those which were shifted away from their growth axis. Corals with fragmentation are those with gross skeletal damage resulting in the colony being broken into two or more parts. Tissue damage is a maceration of the growing surface of the coral. Bleaching are white or pale patches on the growing surface of the colony. Corals with live tissues covered by deposited sand are considered smothered. Diseased coral have the presence of any coral disease. The damages were also categorized by the level of damage shown in Table 1.

	None	Low	High
Toppling	No Toppling	Tilted 0-90º	Tilted >0-90º
Fragmentation	No Fragmentation	1-3 Fragments	>4 fragments
Tissue Damage	No Tissue Damage	<20%	>20%
Bleaching	No Bleaching	<20%	>20%
Smothering	No Smothering	<10%	>10%
Disease	No Disease	<20%	>20%

Table 1. Categories of coral damage used to measure intensity of damage acquired by coral from Hurricane Ike

Calibration of all

participating divers was performed before data collection began. All divers performed data collection on the same transect, in order to compare results to ensure consistent measurements were taken.

Data analysis was done using a Chi-square test to determine if the occurrence of damage was significantly different between growth forms of coral, size of coral colonies and type of damage sustained by size. A Bray-Curtis analysis was also done to compare the distribution of damage by coral species and growth form. Chi-square tests were also used to determine if the occurrence of damage was significantly different between shallow and deep reefs and between protected and exposed reefs.

Results:

A total of 9,011 coral colonies were surveyed within 45 belt transects at nine different sites. 2,832 colonies (31.4%) were found to have damage. Approximately 4% of colonies were found to have more than one damage category (Table 2.). The average live coral cover at all sites surveyed was 8.7%. Digitate corals were found to have the highest occurrence of damage (59.2%), while branching (36.4), sub-massive (33.9%) and massive (22.6%) had far less (Table 3.). There is a highly significant difference in damage sustained by different growth forms of coral ($p = 6.95x10^{-64}$). The Bray-Curtis analysis for the damages sustained by coral species and growth forms shows the sub-massive and massive growth forms were most heavily damaged by smothering (Figure 2.). Digitate corals were most effected by fragmentation and bleaching. There was no strong correlation found between branching species and the damage type sustained.

Table 4. Distribution of damage by coral colony size. Chi-square for occurrence of damage by coral growth form is significant ($p=6.01x10^{-13}$)

Size Category	Total Observed Colonies	# Damaged Colonies	% Damaged
Small	6943	2015	29.02
Medium	1552	605	38.98
Large	516	212	41.08

# Dam Categ Exhib		
0	[illegible]	[illegible]
1	[illegible]	[illegible]
2	[illegible]	[illegible]
3 or more	24	0.26

Table 2. Distribution of damage by coral growth form. Chi-square for occurrence of damage by coral growth form is significant ($p=6.95x10^{-64}$)

Large colonies were found to have more damage (41.1%) than small colonies (29.0%) (Table 4.). The variance in damage sustained by different size categories is highly significant ($p=6.01x10^{-13}$). The difference in the type of damages sustained by different size ca (p were observed to have much less smothering, bleaching and tissue damage than expected and large colonies had more fragmentation

Coral Growth Form	Total # Observed Colonies	# Damaged Colonies	% Damaged
Branching	2319	845	36.43
Digitate	706	418	59.20
Sub-massive	1903	645	33.89
Massive	4083	924	22.63

Table 3. Damage categories exhibited on South Caicos reefs over all reef sites, depths, species and sizes. Total number of colonies observed was 9,011.

	Total # Colonies	# Damaged	% Damaged
Shallow sites	3414	968	28.35%
Deep Sites	5600	1862	33.25%

Table 5. Distribution of damages by depth. Chi square for occurrence of damage by depth is significant ($p=5.75x10^{-5}$)

than expected.

Colonies located at deep sites were found to have more damage (33.3%) than shallow sites (28.4%) (Table 5). The difference in damage sustained at the two depths is statistically significant ($p=5.75 \times 10^{-5}$). Coral colonies located at exposed reef sites were found to have more damage (33.5%) than colonies located on protected reef sites (28.4%). The difference in damage sustained at exposed versus protect Colonies found on exposed sited were most heavily dam and tissue damage. Colonies located on protected sites were most heavily damaged by fragmentation and toppling (Figure 4). The most common coral species found across all sites were *M. annularis* (43.6%), *A. agaricites* (24.6%) and *P. astroidies* (13.7%) (Figure 5).

	Total # Colonies	# Damaged	% Damaged
Exposed	5291	1775	33.5%
Protected	3721	1055	28.4%

Table 6. Distribution of damage by coral location. Chi-square for occurrence of damage by location is not significant (p=0.947)

Discussion:

Live coral cover in the Turks and Caicos Islands is reported to be on average between 10-12% [26]. The average live coral cover at the nine sites surveyed in this study was 8.7%. The decrease in live coral cover could be a result of multiple factors. The background rate of decline of coral cover is reported to be near 2% [6]. It is also likely that Hurricane Ike has drastically reduced the coral cover around South Caicos. On average, a year after a reef is hit by a hurricane, it has a 17% lower coral cover than it did before the hurricane [6].

The damage observed on the reefs of South Caicos is severe, with 31.4% of colonies having sustained damage. Damage caused by Hurricane Ike is similar to that of Hurricane Lenny, which hit Bonaire and Curacao in 1999, because large massive coral heads were overturned during both storms, which is an indicator of especially strong wave destruction [13]. Hurricane Ike caused isolated incidence of *M. annularis* fragmentation due to splitting of the coral head by the wave force. This type of damage has been seen on other severely hurricane damaged reefs [20]. The massive growth forms were the least damaged overall compared to other growth forms, having only 22.6% of colonies damaged, but still experienced the highest percentage of toppling (25.3%). This is consistent with the results of other studies which found that massive and head growth forms sustained less damage than branching forms and agrees with our hypothesis[13,20,21]. *M. annularis* sustained the least amount of damage (21.8%) of all species in this study, and is considered to be very hurricane resistant [23]. *M. annularis* is also an incredibly important species because it is generally the main frame builder or reefs in the Caribbean [23].

A. Palmata, A. cervicornis and *D. cylindrus* were found to be the most damaged species on average over all the sites. This differs from the findings of Bries et al. (2004) who found *M. mirabilis* to be the most heavily damaged by Hurricane Lenny[13]. This could be attributed to the fact that *A. Palmata, A. cervicornis* and *D. cylindrus* were more commonly observed as medium or large colonies, which were found to have sustained a greater amount of damage than small colonies, which was more commonly observed for *M. mirabilis*. *Acropora spp.* were also not prominent on the reefs of South Caicos before Hurricane Ike, this could possibly be attributed to the spread of white band disease throughout the Caribbean [28,26]. The prior presence of disease may have contributed to the high presence of damage on *Acropora spp.* by weakening the colonies before the impact of Hurricane Ike. Disease and hurricane damage are the two leading causes of *Acropora spp.* loss in the Caribbean [19].

The Bray-Curtis analysis of our dataset shows a strong correlation between sub-massive and massive growth forms having been mostly damaged by smothering (Figure 2). This suggests that massive and sub-massive growth forms are more susceptible to smothering, possibly because the round, boulder-like shape of most of these species allows sediment to settle on their live tissue more easily than digitate and branching growth forms. Interestingly, *A. agaricites* was found to behave similarly to the sub-massive and massive growth forms, having been mostly affected by smothering and disease. This result could be because *A. agaricites* was most commonly found in small colonies on the substratum, possibly making it more susceptible to smothering than the larger branching colonies of Acroporids. Both species of digitate coral were found to have a close correlation, being mainly effected by fragmentation and bleaching. Digitate forms were also found to suffer extensive fragmentation after Hurricane Lenny [13]. This is likely caused by the delicate structure of the branches, especially in the case of *M. mirabilis*. The branching forms were found to have no strong correlation.

As expected, large and medium colonies were found to have significantly more damage than small colonies ($p=6.01x10^{-13}$) (Table 4). This is consistent with the findings of Bries et al. (2004)[13]. It is suggested that larger colonies are more susceptible to damage at reef sites which are not frequented by storms, because at these locations corals are able to survive to greater ages and grow larger[13]. Since South Caicos has not been hit by a major hurricane in over 16 years there may be a greater abundance of large and medium colonies susceptible to hurricane damage[27]. The high number of large colonies which were toppled indicates extremely strong wave force and is characteristic of extensive hurricane damage [11]. The difference in type of damages sustained by size categories of colonies was also highly significant ($p=1.32x10^{-28}$). In particular, small colonies sustained less damage from smothering, bleaching, and tissue damage than expected; in contrast, large and medium colonies sustained more fragmentation and tissue damage than expected. A possible explanation for this result is that since small colonies have less surface area, sediment was less likely to settle and cause smothering; similarly, tissue damage from debris during the storm was less likely because of the small size. It is possible that the larger colonies were more susceptible to the increased wave force during the hurricane, and were therefore more likely to fragment or be hit by debris causing tissue damage.

It was unexpected that deep reefs would sustain more damage (33.3%) than shallow sites (28.4%) (Table 5) because previous studies have found shallow reefs to be disproportionately more damaged than deep reefs [13,23]. This finding suggests that the wave force caused by Hurricane Ike was extremely powerful, and extended far down the water column. Colonies located at deep sites are incredibly vulnerable to the effects of such wave force because they are not adapted to handle wave action. This vulnerability may have allowed for greater damage to be observed at deep reef sites during our study. Less damage may also have been observed at shallow sites because many shallow sites were located in protected areas, which experienced slightly less, though not significantly less, damage than exposed sites. The lack of shallow, exposed sites may have caused an inappropriately small number of damages to be observed at shallow locations.

It was expected to find that protected sites would be more damaged than exposed sites because colonies at protected sites are not adapted to handle strong wave force [18]; however, the opposite was true in this study. Exposed reefs experienced slightly more damage (33.5%) than protected reefs (28.4%). This unexpected result may be due to the fact that many protected sites were also shallow. Shallow reefs are normally exposed to greater wave action than deep reefs. The results of this study suggest that although many sites were protected, because they were also shallow the coral colonies located at these sites were more adapted the handle wave action than expected. The protected sites were also located adjacent to the Caicos Bank which is made up primarily of soft sediment and seagrass beds [25]. The coral colonies located on these protected sites may be better adapted to handle sedimentation than colonies on exposed reefs due to the near proximity of the protected reefs to large amounts of soft sediment. The protected reefs experienced greater amounts of fragmentation and toppling than expected, suggesting that the protected sites are most vulnerable to damages caused by direct wave force. The exposed sites also experienced more damage from disease than expected, suggesting that the source of disease may be the currents passing by these locations from other parts of the Caribbean.

Limitations of this study include the exclusion of encrusting species from the study. The majority of the protected sites were also shallow sites. The lack of deep, protected sites may have skewed some of the data using these variables. The exclusion of soft corals and sponges from the study may also have affected the amount of damage observed on protected sites, where these species are often more abundant because of the reduced wave force.

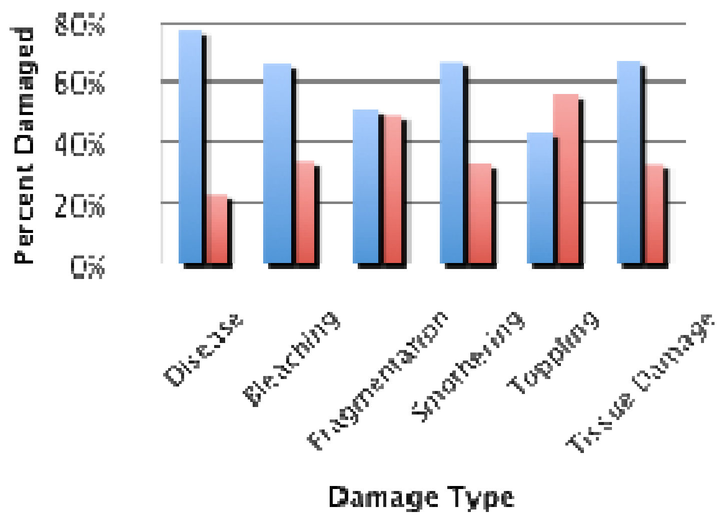

Figure 3. Histogram showing the percent of corals with each damage by location of reef (protected or exposed). Exposed reefs were most damaged by disease, bleaching, smothering, and tissue damage while protected reefs were most damaged by fragmentation and toppling.

The results of this report suggest that the intensity of damage sustained by a reef during a hurricane is partially dependent upon the morphology of the species found at the reef. Reefs primarily made up of large branching or digitate colonies may be more susceptible to damage from wave force during a hurricane and have a greater occurrence of fragmentation. In contrast, reefs made up of small massive and sub-massive colonies may sustain less damage overall with high levels of smothering in a hurricane. Reefs which under normal weather conditions are sheltered from wave action are also more susceptible to fragmentation and toppling damages because colonies on these reefs are unadapted to handle the increased wave force caused by storms. Reefs located in deep water may also be more vulnerable to damage during a storm because colonies at these depths are not accustomed to wave force extending to great depths in the water column.

Further research on the subject of hurricane damages done to varying growth forms of coral is highly recommended. In particular, continued research at South Caicos sites would provide valuable data on the continued recovery of the coral colonies from Hurricane Ike. Small colonies, which are more likely to suffer complete mortality, may become more highly damaged over time; whereas, large colonies, which are more likely to sustain only partial mortality, may begin to recover from the damages sustained [22]. If damaged small colonies do undergo complete mortality, it might be found that small colonies are less frequent over time; however, recolonization of fragments forming new individual colonies may create a greater number of small colonies, so undamaged small colonies may become more prevalent.

While hurricanes cause extensive damage to reefs by altering the physical reef habitat, biological events have the potential to be more destructive because they are less selective than hurricanes which disproportionately affect corals based on growth form and location [23], as this study shows. The effects of anthropogenic factors, such as overfishing, pollution or eutrophication, can be lessen through the establishment of effective reef management. The damage done to coral reefs as a result of climate change may be the most devastating of all because management solutions will not immediately be helpful, but instead will take decades to take effect [7]. The extent of damage caused to reefs by climate change may depend on the amount of degradation already present [7]. Reefs which are currently in poor health will be less able to cope with additional stresses such as changes in salinity, water temperature, UV exposure, disease exposure and storm occurrences due to climate change [30,31]. The ability of coral reefs to return to the same stable state as before a disturbance on its own is not longer guaranteed because reefs are dynamic ecosystems and have multiple stable states [3]. To ensure the health of coral reefs around the world better management practices must be put into place to remove the unnecessary anthropogenic factors placed upon these delicate systems as well as worldwide action to slow and reverse global warming trends.

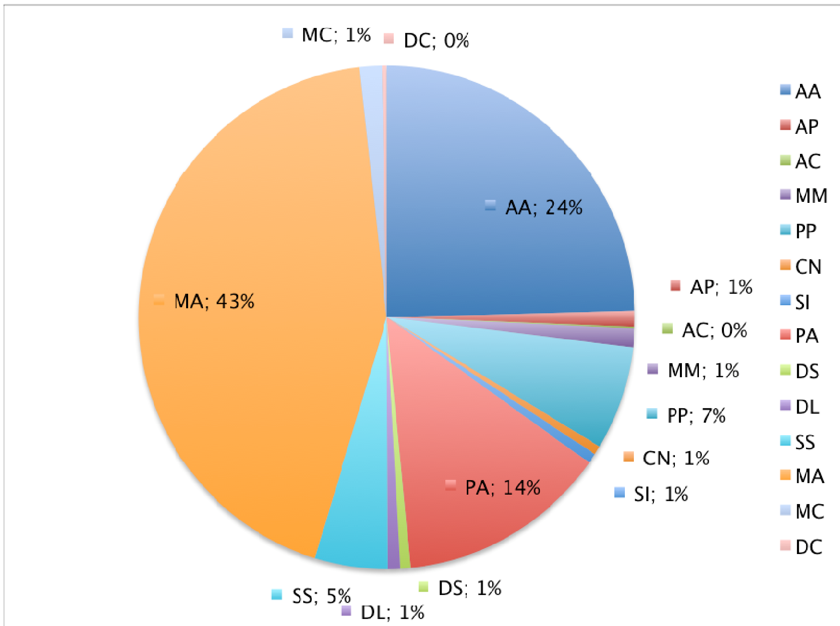

Figure 4. Pie chart showing the relative abundance of coral species present at all sites aorund South Caicos, Turks and Caicos islands.

Acknowledgements:

The author gratefully acknowledges the key financial and field logistical support provided by the School for Field Studies, Center for Marine Resource Studies, South Caicos, Turks and Caicos Islands, as well project design and planning by Dr. Catherine Jadot, the assistance provided during data collection by Will Maclennan, and Annie Loewa and editing advice given by Dr. Zuccarelli and Dr. Matarese.

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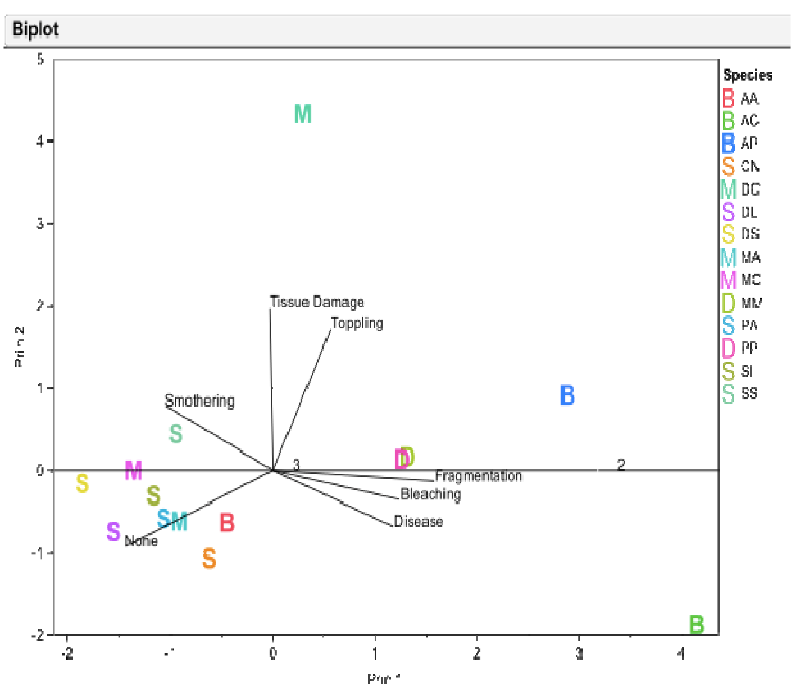

Figure 2. Bray-Curtis polar ordination showing the distribution of damage type by coral species and growth form.