

**Figure 1.** AGRRA survey sites offshore Abaco, Bahamas, with outlines for the Fowl Cay Preserve and Pelican Cays Land and Sea Park.

Abbreviations: LCS = Lynyard Cay south, LCN = Lynyard Cay north, SCB = Sandy Cay backreef, SCF = Sandy Cay forereef, ECSI = Elbow Cay south inner, ECSO = Elbow Cay south outer, ECM = Elbow Cay middle, ECN = Elbow Cay north, SR = Storr's Reef, MOWSS = Man O' War Cay south of south channel, MOWSN = Man O' War Cay north of south channel, FCP = Fowl Cay pinnacles, and FCS = Fowl Cay shallow.

## **A RAPID ASSESSMENT OF CORAL REEFS NEAR HOPETOWN, ABACO ISLANDS, BAHAMAS (STONY CORALS AND ALGAE)**

BY

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### **ABSTRACT**

Coral reefs at 13 sites ranging in depth from 1-16 m near Hopetown, Abaco Islands, Bahamas were surveyed utilizing the Atlantic and Gulf Rapid Reef Assessment (AGRRA) benthos protocol. A total of 35 species of scleractinian corals and 2 species of calcareous hydrocorals were observed. The overall coral cover averaged just over 14%. Among corals that were at least 10 cm in diameter, small colonies (<40 cm diameter) predominated in all sites except for the Fowl Cay pinnacles where 68% were larger than 60 cm in diameter. Large colonies (>40 cm diameter) were also found in the Lynyard Cay spur-and-groove formations and the Sandy Cay fore reef. Zero-4% of the colonies were affected by disease. Total (recent + old) partial-colony mortality ranged from 9-31% (both extreme values being found in outer reef crests). Turf algae were the most common algal functional group overall. Macroalgae were ubiquitous, however, with relative abundance values of about 25-47%. Macroalgal indices (a proxy for biomass) ranged from 64 in the Sandy Cay back reef to 184 in the Fowl Cay outer reef crest.

### **INTRODUCTION**

The AGRRA protocol is being applied throughout the Bahamas and Caribbean to document the condition of reefs with a technique that allows interregional comparisons. This study targeted the reefs of the central Abaco Islands because of their location near the northeasternmost extension of the Bahamas platform. Reefs at the extremes of their geographic range occur near important physiological thresholds for stony corals and may respond earlier to global climate change or anthropogenic impacts than more centrally located reefs. With the exception of Bermuda, Abaco's reefs are nearest the northern limit of shallow reef formation in the wider Caribbean. Additionally, the reefs of central Abaco are near an area of relatively high population density and user pressure from local and tourist fishers and divers.

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The Abaco Islands archipelago, which is composed of middle-to-late Pleistocene eolianites, skirts the eastern margin of Little Bahama Bank (Locker, 1980). Great Abaco itself is of middle Pleistocene age and acts as a barrier to the eastward transport of fine sediments from the Bank interior. A shallow lagoon, the Sea of Abaco, is bounded by Great Abaco to the west and southwest. A string of windward cays to its east and northeast act as a barrier to waves. However, deep tidal channels can act as “energy windows” allowing energy flux (from open-ocean waves and tidal currents) into the lagoon. For example, at Sandy Cay which lies within the lagoon, a well-developed fringing reef thrives on a topographic high where it is exposed to open-ocean waves provided by the wide passes between the string of Lynyard Cay, the Pelican Cays (three islands), and Tiloo Cay. The reef community on the seaward side of Lynyard Cay also lies atop a topographic high; however, the steep slope of the narrow shelf may prevent the reef structure from being well developed (Kenneth Banks, personal observations).

A relatively continuous bank-barrier reef is known to extend just offshore of the eastern cays of Abaco from the northern tip of the Little Bahama Bank, west of Walker’s Cay, southward to the middle of Elbow Cay near Hopetown, a distance of approximately 160 km. Southward of this point the shelf becomes narrow with a steep slope limiting the extent of suitable reef development area. However, spur-and-groove formations have developed at southern reefs offshore of Lynyard Cay on the topographic high spot. Storr (1964) previously described several lines of unusual parallel narrow linear reefs offshore of Johnny’s Cay, several kilometers north of Hopetown on Elbow Cay. Otherwise the Abacos’ reef flora and fauna have not been studied.

Natural impacts on the reefs of Abaco are poorly documented. Frequent hurricane activity (e.g., Hurricanes Erin, 1995, and Floyd, 1999) undoubtedly affects their community dynamics. Moreover, the extent of anthropogenic impacts is not currently known although Woodley et al. (2000) mentioned that overfishing, discharge of human wastewater, and loss of coastline habitat are contributing to degradation of marine ecosystems in the Bahamas. Two of the study areas, Sandy Cay and Fowl Cay, are within marine protected areas (Pelican Cays Land and Sea Park and Fowl Cay Bahamas National Trust Preserve, respectively) where harvesting of marine organisms is not permitted (Dodge, 1999; Woodley et al., 2000). Sandy Cay (in the park) and Lynyard Cay (south of the park and distant from population centers) appear to be relatively undisturbed by direct anthropogenic influences yet development is increasing in the Abacos archipelago. The parks currently do not have staff, and some poaching undoubtedly occurs, but many of the local dive charter operators attempt to aid in enforcement of the park rules. Additionally, all interviewed local inhabitants of Hopetown, including charter boat captains, dive operators, restaurateurs and resort operators, concur that these are “no take” areas. Charter fishing activities are generally targeted on pelagic fish species, or take place in the backwaters and tidal creeks of the Sea of Abaco, and probably don’t impact the reefs significantly. However, preliminary observations in November 1997 at locations of Storr’s (1964) study suggested that fish populations have been reduced (Kramer et al., personal communication). The northerly reefs (Man O’ War, Fowl, and Elbow Cay) surveyed in this investigation are in close proximity to the more developed areas around Marsh Harbour, Hopetown and Man O’ War Cay, locally known as the Hub of Abaco. The residents of this area depend heavily on commercial-scale harvesting of finfish (hook and line and spearguns), spiny lobster

(spearguns) and conch (collected by divers). Catches are exported to the United States or sold locally to supply the tourist industry. Hence, this project provides important data for more effective management of Great Abaco's southern reefs and a baseline for future comparisons.

## METHODS

From August 9-16, 1999 a team of seven divers trained in the AGRRA protocols surveyed reefs near Hopetown on Elbow Cay (Fig. 1). Aerial photographs and discussions with local residents, followed by ground-truthing, allowed the selection of representative reefs along a north-south geographical gradient within small-boat operating distance of Hopetown. The four sites at Sandy and Fowl Cays were strategically located in marine preserves. The Storr's Reef site was located offshore of the linear reef forms studied by Storr (1964).

At each site we focused on areas with the greatest reef development and highest cover of live scleractinian corals. Locations without good reef development (such as the southern end of Elbow Cay and Tiloo Cay) were not visited. Surveyed habitats included a well-developed fringing reef at Sandy Cay (the enormous thicket of dead *Acropora palmata* on its reef crest was not surveyed). The Sandy Cay back reef lacks extensive development of *Acropora cervicornis* but several patches were present in the surveys. Its fore reef, with massive corals on a steep slope extending from near sea level to a sandy plain at 10m depth, resembles comparable habitats in the bank-barrier reef. Surveys on the bank-barrier reef were conducted at: low-relief outer reef crests (e.g., Storr's Reef and Elbow Cay north); low-relief spur-and-groove formations (Lynyrd Cay); a shallow pinnacle reef (Elbow Cay south, outer site); and structurally complex pinnacles that rise from depths of 12-15 m to near the surface (Fowl Cay, where transects circumnavigated the deep pinnacle bases).

The AGRRA benthos protocol Version 2 (see Appendix One, this volume) was followed with the following modifications. Stony corals with maximum widths of 10 cm or larger were included because Abaco's live corals are typically of smaller sizes than those in other Caribbean locations and coral cover was low (personal observations). Coral diameters were measured to the nearest 5 cm. Sediments in the algal quadrats were fanned with quick hand motions prior to estimating the abundance of crustose coralline algae. Coral identifications were aided by reference to Humann's (1996) field guide. Latitude and longitude were determined using a global positioning system (GPS) receiver, Magellan GPS 315. Readings were confirmed or updated as necessary in August 2000 after selective availability (SA) was turned off. Quality assurance surveys of reference transects were initially performed at two sites (Hopetown Reef and Sandy Cay) by all team members who compared results to determine any differences regarding taxonomy, measurements, mortality, etc., and reach a consensus.

## RESULTS

Thirteen sites ranging in depth from 1-16 m were surveyed along the offshore shelf between Lynyard Cay in the south and Fowl Cay in the north (Fig. 1; Table 1). We found the reef morphology at most offshore sites to be typical of bank-barrier reefs (Goreau, 1959; Glynn, 1973). For example, the low-relief spur-and-groove system off Lynyard Cay runs normal to the prevailing wave assault at depths of 6-11 m. Most of these reefs were composed primarily of massive framework builders such as *Montastraea* spp. and *Diploria* spp. The branching elkhorn coral, *Acropora palmata*, was not evident as a primary framework builder except in the Sandy Cay fore reef. However, the deep pinnacle reefs at Fowl Cay have numerous *Agaricia agaricites* and large (up to 400 cm diameter) colonies of *Montastraea faveolata*. Massive corals and *Acropora cervicornis* are found in the back reef of Sandy Cay.

### Stony Corals

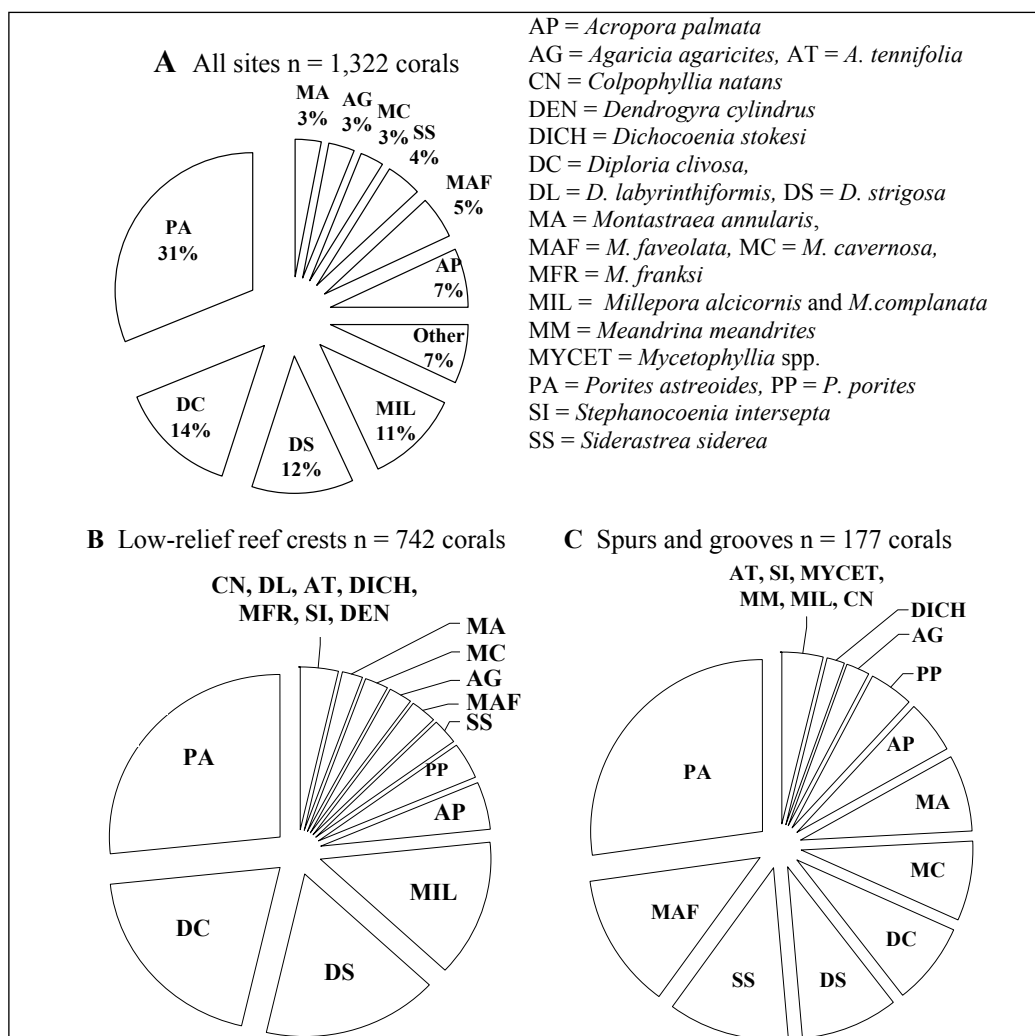
*Density and percent cover.* A total of 1,443 stony corals that were  $\geq 10$  cm in diameter were counted in 186 transects. Coral density averaged 7 colonies/10 m transect (0.7 colonies/m) when all sites were combined (Table 1). Density values ranged from 5.0-8.5 colonies/10 m transect ( $\sim 0.50$ - $0.85$  colonies/m). Two of the three sites with the highest density were in the Sandy Cay protected area.

Live stony coral cover, which averaged over all sites was just over 14% (mean=14.3, sd =7.6, n=13 sites), varied from about 8.5% in the Elbow Cay north outer reef crest to about 22.5% in the Sandy Cay fore reef (Table 1). Two of the three sites with the highest coral cover (Sandy Cay fore reef and Fowl Cay pinnacles) were in marine protected areas.

The pooled average coral density in the four protected sites (Sandy and Fowl Cays) was slightly higher than the pooled density for the nine sites that are not protected (0.78 colonies/m versus 0.68 colonies/m). Similarly, the percent live coral cover averaged for the four protected sites (mean=16.4, sd=4.4) was somewhat greater than that for the nine that are not protected (mean=13.3, sd=2.8). Neither of these differences between protected and unprotected sites was significant (Rank Sum Test, Ambrose and Ambrose, 1995).

*Species.* A total of 36 taxa of scleractinian corals and two species of calcareous hydrocorals were observed including species seen off the surveyed transects (Table 2). *Porites astreoides* was the most abundant species of the  $\geq 10$  cm corals in all sites (Fig. 2A) with the exception of the deep Fowl Cay pinnacles where mounding *Montastraea faveolata* and foliose *Agaricia agaricites* predominated. *Diploria clivosa* and *D. strigosa* were also numerically abundant in the shallow (<6 m) outer reef-crest habitats (Fig. 2B) whereas the spur-and-groove formations at Lynyard Cay had high abundances of *Montastraea faveolata* and *Siderastrea siderea* (Fig. 2C). *Millepora* spp., *Acropora palmata* and *Montastraea faveolata* were regularly observed in most sites.

*Size.* In most (11/13) sites, corals that were smaller than 40cm in diameter (largely comprised of *Porites astreoides* and *Diploria* spp.) made up the largest portion of the  $\geq 10$  cm coral community (Fig. 3A,B). Large corals were infrequently encountered with size classes of over 200 cm comprising 0-10% of the pooled surveyed colonies. At the Fowl

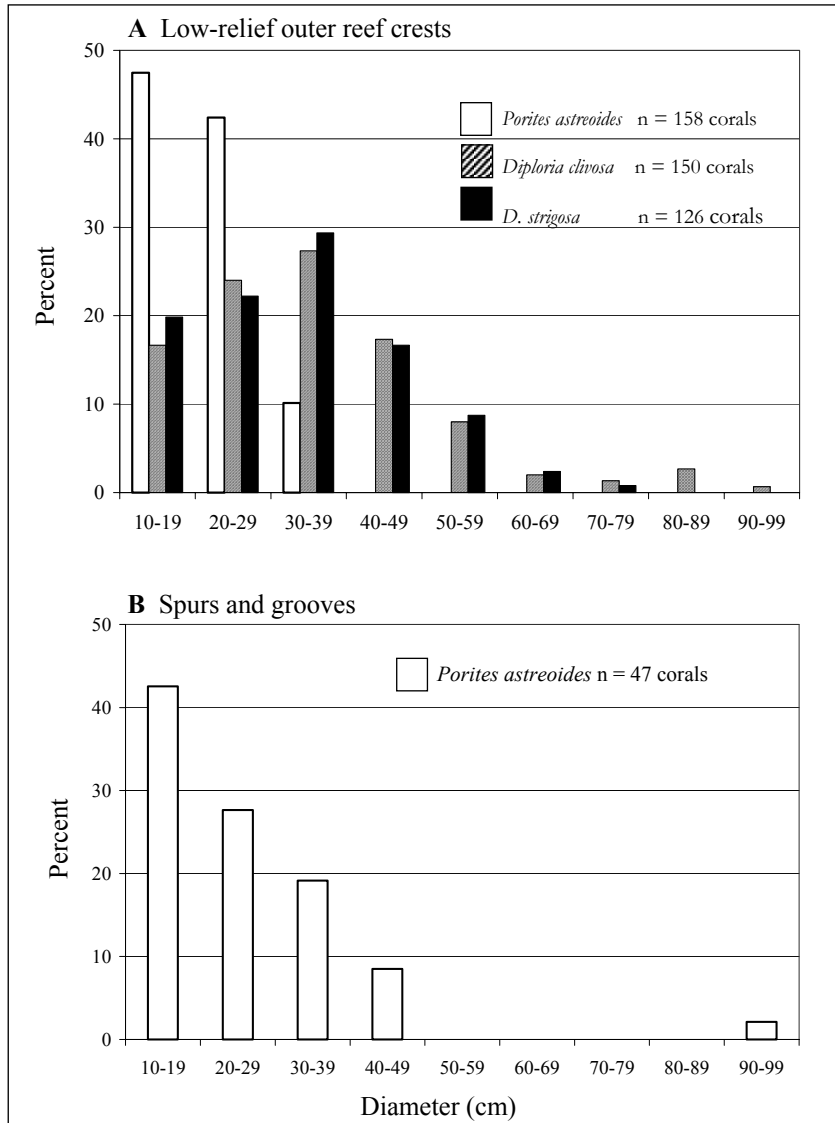


**Figure 2.** Species composition and mean relative abundance of all stony corals ( $\geq 10$  cm diameter) in (A) All Abaco, Bahamas sites, (B) Low-relief outer reef crests (7 sites), and (C) Spurs and grooves (2 sites). Coral species with  $< 1\%$  are placed in a grouped category; Other in (A) = *Agaricia tenuifolia*, *Colpophyllia natans*, *Dendrogyra cylindrus*, *Dichocoenia stokesii*, *Diploria labyrinthiformis*, *Madracis mirabilis*, *Manicina areolata*, *Meandrina meandrites*, *Montastraea franksi*, *Mycetophyllia* spp., *Porites porites*, and *Stephanocoenia intersepta*.

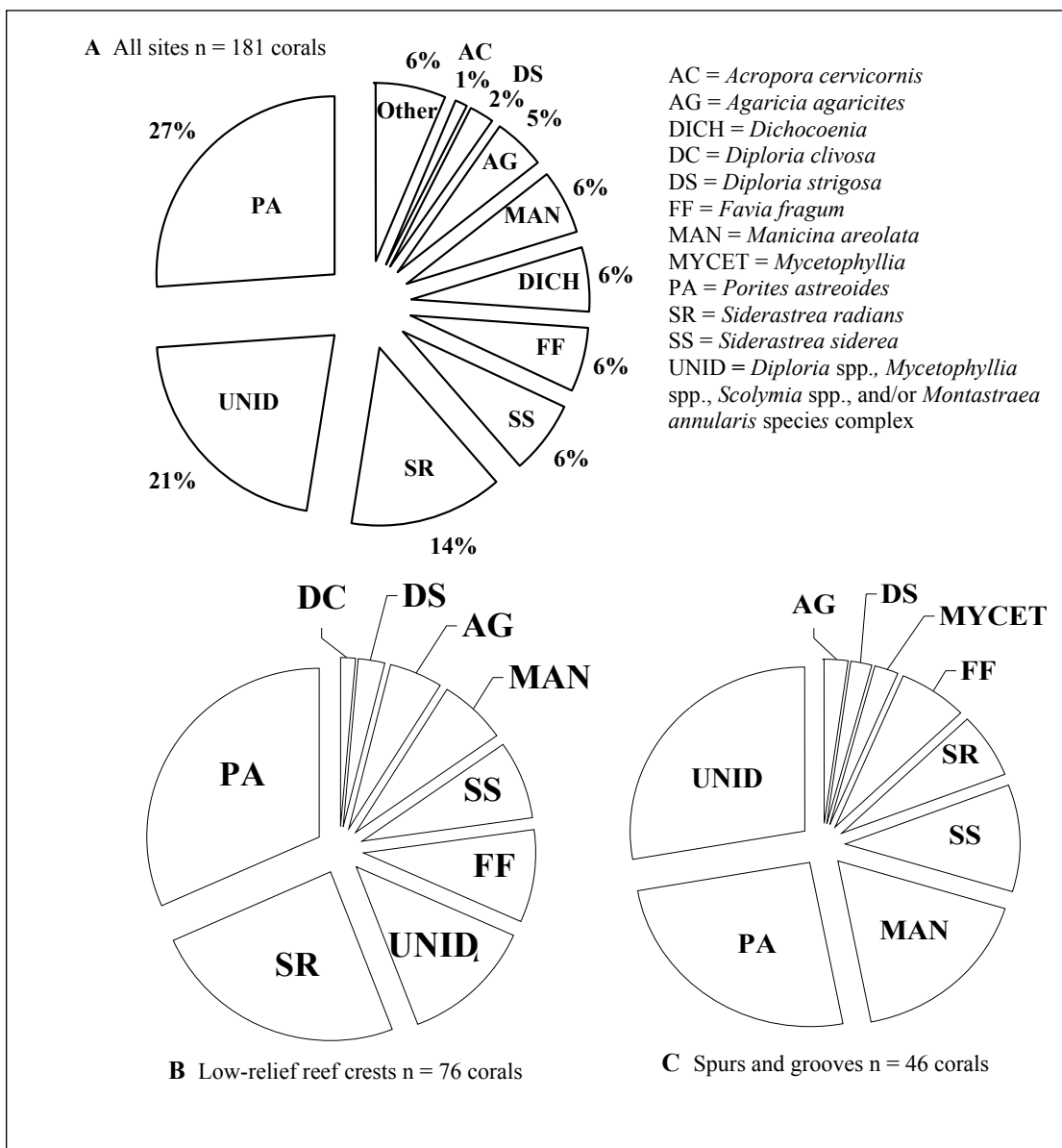
Cay pinnacles, however, smaller ( $< 40$  cm) corals were less than 20% of the total and nearly 20% of all colonies were larger than 150 cm in diameter. Mean colony diameters (Table 3) overall ranged between 32 cm (Man O'War Cay north of the south channel) and 62 cm (Sandy Cay fore reef). The largest size classes ( $> 100$  cm) were mainly comprised of *Montastraea faveolata* (Fowl Cay pinnacles) and *Acropora palmata*; small corals (10-20 cm) were mostly represented by *Porites astreoides*, *Diploria strigosa*, *Diploria clivosa* and *Agaricia agaricites*.

**Recruits.** *Porites astreoides* was the most common coral recruit. Together with *Siderastrea radians* and *S. siderea*, these three species accounted for nearly half (47%) of all recruits observed in the surveys (Fig. 4A). The "unidentified" category accounted for 21% and *Manicina*, *Dichocoenia*, *Favia* and *Agaricia agaricites* composed an additional

23%. The remainder (9%) were mostly reef builders that were only observed once or twice as recruits, including *M. annularis*, *D. strigosa*, *D. clivosa*, *A. cervicornis*, *A. palmata*, and two non-reef-building genera, *Scolymia* and *Mycetophyllia*. Similar recruit frequencies were observed in the low relief-reef crest sites (Fig. 4B), but *Manicina* recruits were more abundant than average at the spur and grove sites (Fig. 4C). Mean coral recruit density ranged from about 0.1-0.5/0.0625 m<sup>2</sup> (~1.6-8 colonies/m<sup>2</sup>) (Table 4).



**Figure 3.** Size-frequency distributions of  $\geq 10$  cm diameter colonies of (A) *Porites astreoides*, *Diploria clivosa* and *D. strigosa* in low-relief outer reef crests (7 sites) and (B) *Porites astreoides* in spurs and grooves (2 sites) off Abaco, Bahamas.



**Figure 4.** Species composition and mean relative abundance of all stony coral recruits ( $\geq 2$  cm diameter) in (A) All Abaco, Bahamas sites, (B) Low-relief outer reef crests (7 sites), and (C) Spurs and grooves (2 sites). Coral species with  $<1\%$  are placed in a grouped category; other in (A) = *Acropora palmata*, *Diploria clivosa*, *Montastraea annularis*, *Mycetophyllia*, *Scolymia*.

### Stony Coral Condition

*Partial Mortality.* Recent partial-colony mortality (hereafter recent mortality) of the  $\geq 10$  cm stony corals was lowest (nearly zero) in the Sandy Cay back reef and averaged  $<3\%$  in eight sites (Table 3). The three lowest mean values for old partial-colony mortality (hereafter old mortality) and total (recent and old) mortality (hereafter total mortality) occurred in the two outer reef crests near Man O' War Cay and in the Sandy Cay back reef ( $\sim 8\text{-}16\%$  and  $9\text{-}16\%$ , respectively). The highest values for both recent mortality (6%) and total mortality (31%) were found in the Elbow Cay north outer



reef crest. Similar patterns of mortality were displayed on corals in the low-relief reef crest and those in the spur-and-groove reefs (Fig. 5A,B). However, more colonies were affected by old mortality than by recent mortality. Also, a greater percentage of the recent mortality occurred on a smaller portion of the affected corals. Old mortality showed a more uniform distribution with respect to amount of the colony affected.

Overall, an average of 3.6% of all the large stony corals were “standing dead” (100% total mortality, still in growth position). Three sites (both near Man O’ War Cay and Fowl Cay pinnacles) had no standing dead colonies while the highest value (8%) was observed in the Elbow Cay north site (Table 3). The species most frequently scored as standing dead were *Acropora palmata*, *Diploria strigosa*, *Millepora complanata*, *M. alcicornis* and *Montastraea annularis*.

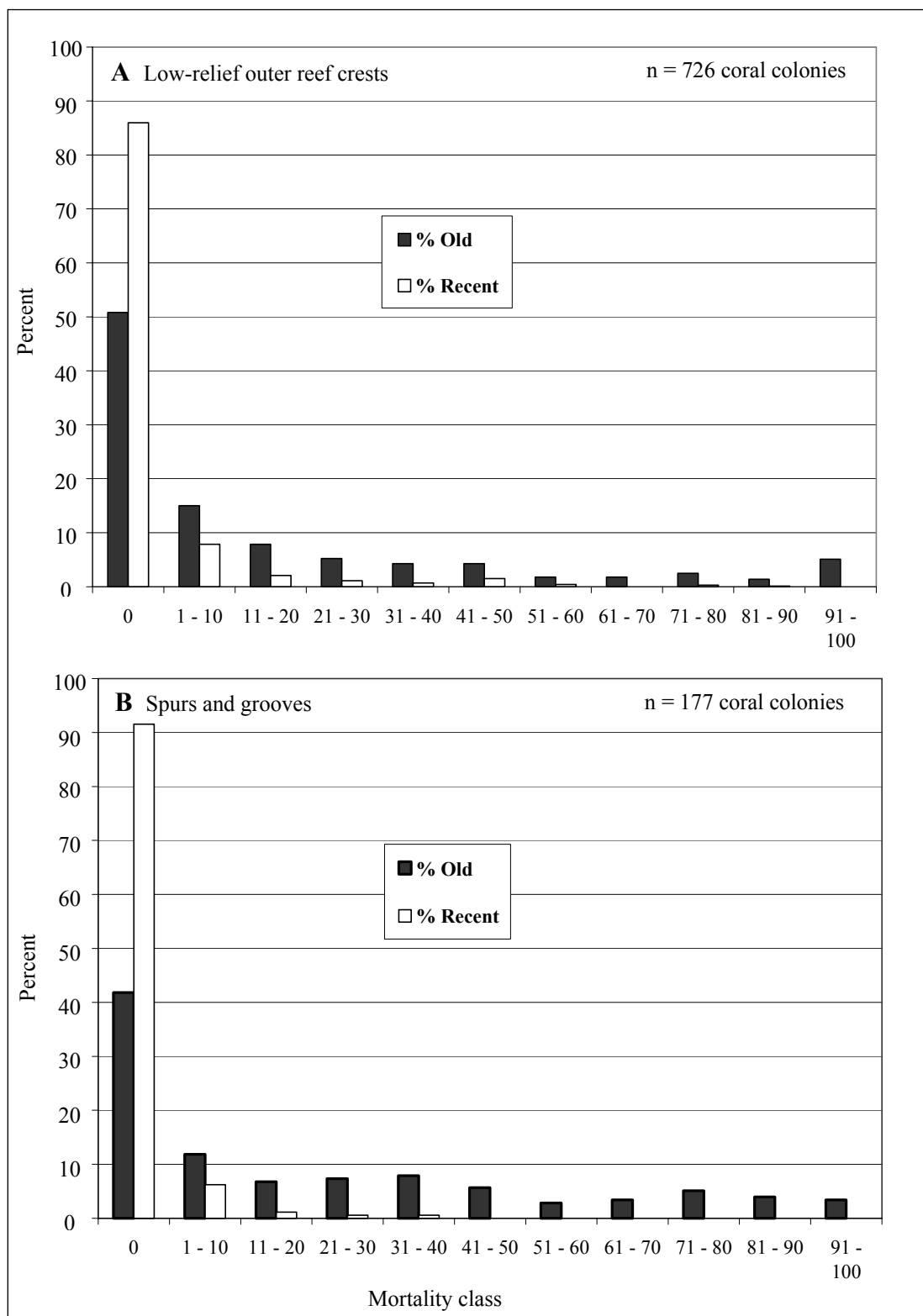
*Diseases.* The overall incidence of coral disease was low, with only 0-1% of all colonies being affected in 11/13 sites (Table 3). Diseased colonies were somewhat more abundant in the Fowl Cay pinnacles (2.5%) and the Sandy Cay fore reef (4%). The most commonly affected species included *Diploria strigosa*, *Montastraea annularis* and *Montastraea faveolata*. Black-band disease affected one surveyed colony each of *M. faveolata*, *Diploria clivosa* and *Colpophyllia natans* and it was noted on two colonies of *Siderastrea siderea* in areas not covered by the transects. Yellow-blotch disease (three colonies) and white plague (two colonies) were also observed. Several other surveyed colonies exhibited tissue sloughing or bands or borders of recently exposed skeleton surrounding live tissues. Due to the unclear etiology it was not possible for us to identify the putative disease agent in these cases and they were classified as “unknown.”

Because the transects did not intercept many of the colonies of *Diploria strigosa* that were sloughing tissues, a haphazard swimming survey was performed in two sites (Elbow Cay middle, outer reef crest and Lynyard Cay north, spurs and grooves). All colonies encountered that were greater than 20 cm in diameter (with some as large as 55 cm) were examined. Of 79 surveyed corals, 26 were dead, 34 were observed to be actively sloughing tissue or with recent partial mortality, and only 19 appeared “healthy.”

*Additional perturbations.* Other incidents of mortality observed in the transects included overgrowth of several coral species by the boring sponge *Cliona* (two colonies of *Porites astreoides* and one colony each of *Diploria labyrinthiformis*, *Montastraea cavernosa*, *Porites porites*, and *Siderastrea siderea*). The hydrocoral, *Millepora alcicornis* was observed to overgrow two colonies of *Porites astreoides* and parrotfish bite-marks were seen on a colony of *Acropora palmata*. Relatively few (0-3%) corals were bleached (Table 3), with entire colonies exhibiting very pale to white tissues.

#### Abundance of Algae and *Diadema antillarum*

Seven hundred fifty-four algal quadrats were examined during the survey. Macroalgal relative abundance values ranged from less than 30% in six sites to nearly 50% in the Elbow Cay north outer reef crest (Table 4). Mean macroalgal heights varied between about 2 cm in the Sandy Cay back reef and 5.5 cm in the Fowl Cay outer reef crest where macroalgal indices (macroalgal relative abundance x macroalgal height, a proxy for macroalgal biomass) were also lowest (64) and highest (184), respectively.



**Figure 5.** Frequency distribution of old and recent partial colony mortality of all stony corals ( $\geq 10$  cm diameter) in (A) Low-relief outer reef-crests (7 sites) and (B) Spurs and grooves (2 sites) off Abaco, Bahamas.

Pp. 58-75 in J.C. Lang (ed.), Status of Coral Reefs in the western Atlantic: Results of initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Atoll Research Bulletin 496.

By a large margin, the highest relative abundance of crustose coralline algae (45%) was in the Sandy Cay fore reef (the only site in which they predominated), whereas the lowest was in the outer reef crest at the Man O' War south of south channel site (10%). Overall, turf algae constituted the most abundant algal functional group in the two spur-and-groove sites off Lynyard Cay and in many (5/7) of the low-relief outer reef crests.

Only a few (<5) individuals of the long-spine sea urchin, *Diadema antillarum*, were seen during underwater operations in Abaco and none was observed in the invertebrate belt transect surveys (Table 4).

## DISCUSSION

Coral cover in Abaco was generally similar to that observed further south in the Exuma Cays by Chiappone et al. (1997). The difference in latitude between Abaco and the Exumas is 3° or approximately 300 km. Chiappone et al. (1997) reported average live stony coral coverage of 22.8% for fringing reefs and 11.2% for windward hard-bottom habitats. In our surveys we found mean coverage of 18.5% in the Sandy Cay fringing reef and 13.5% for all other Abaco sites combined. The relative abundance of species in the studies are different, however, and one should note that the Exuma study included patch reefs (hosting *Montastraea annularis*, not widely documented in this survey) and channel reefs, neither of which type of habitat was examined in Abaco. A total of 39 species of scleractinians and *Millepora* were observed in the Exumas (Chiappone et al., 1997) compared with a similar number of taxa (38) in Abaco (this study).

The only previous examination of the reefs in the vicinity of the Hub of Abaco was carried out by Storr (1964) who examined the linear reefs offshore of the northern end of Elbow Cay between 1948 and 1961. His work was mostly qualitative in nature and his descriptions are of habitats that are landward of our outer reef crest site in Storr's Reef. Nevertheless, comparisons of general reef health between 1999 and the mid-twentieth century are interesting. Storr (1964) noted that *Porites astreoides* was abundant in all sites from offshore to inshore. *Acropora palmata* was abundant in the more seaward, shallow sites (reef flats), becoming patchy inshore. He described the appearance of *A. palmata* as healthy except at an inshore site where the corals were dead and covered with macroalgae. In contrast, *A. palmata* observed in this study showed high values of partial-and/or total- colony mortality but it is unknown when these colonies began to die. *Porites astreoides*, however, is still abundant. The most dramatic difference between the two time periods was the great abundance of *Diadema antillarum* found by Storr compared with the very low densities observed presently, a continuing result of the Caribbean-wide 1983 die-off (Lessios et al., 1984). Storr's (1964) observations of algal cover are too general for detailed comparison with our study (which otherwise might have allowed some correlation between abundance of *Diadema* and algal coverage).

Comparison of the study sites within protected (from fishing) and unprotected areas showed slightly higher coral cover in the protected sites. Moreover, the largest massive corals were found on the Fowl Cay pinnacles, which are protected, and in the Lynyard Cay spurs and grooves, which are distant from human development. Interpretation of these differences should be made cautiously, however, since the protected areas were chosen for their high quality (as observed by divers) and there are

relatively few replicates (four protected versus nine that are unprotected). A number of confounding natural factors, such as depth, substratum, slope, structural complexity and exposure to wave energy can affect coral populations so further study is warranted before the effect on the coral community of protecting these Abaco reefs can be evaluated.

The predominance of corals such as *Porites astreoides*, *Diploria clivosa*, *Diploria strigosa* and, in some cases, *Acropora palmata*, indicates that many of the surveyed sites are chronically exposed to relatively high wave energy and surge. The absence of large mounding corals, except in the deeper habitats on the Fowl Cay pinnacles (where small species, such as *Agaricia* spp., are also very common) and in the spur-and-groove formations at Lynyard Cay, is striking.

The high relative abundance of *Porites astreoides* recruits is consistent with their high frequency as adult colonies in the surveyed reefs and their brooding mode of larval development (Chornesky and Peters, 1987). Due to the ambiguities of coral recruit taxonomic identification, the data are difficult to interpret with respect to relative abundance of species of *Diploria*, *Montastraea*, etc. which, when small, are only identifiable to the genus level. The relatively few recruits encountered (Table 4) also precluded interpretation of patterns of recruitment at the level of site or reef type.

Many colonies of *Montastraea faveolata* and *Diploria strigosa* were observed with pale and dead tissue patches, perhaps due to environmental or biological stressors. Caribbean-wide warming occurred in the summer of 1999 and high-temperature exposure can result in bleaching and partial mortality (Williams and Bunkey Williams, 1990). Alternatively, coral diseases may have impacted these corals. It can be difficult to ascribe tissue necrosis to specific disease conditions (e.g., Richardson, 1998). Black-band disease has the clearest etiology; however, white-band disease, white plague, and other “white-line diseases” are harder to diagnose during snapshot field surveys.

Some of the lowest (both Man O’ War Cay sites) and highest (Elbow Cay north) values for partial-colony mortality and for standing dead were found within the same reef habitat type (low-relief outer, reef crests). There were no apparent differences in terms of anthropogenic impact, either direct or indirect, in any of these reefs, nor were there clear natural impacts that could account for the differences. As few replicates were present for the other habitat types, it is not possible to generalize about coral mortality distribution patterns.

Turf algae were very common but were trapping little sediment and appeared to have caused no stony coral mortality (personal observations). Macroalgal height and relative abundance trends may show some relationship to the degree of human impact in the region, as they are relatively low in the southern Sandy Cay fringing reefs, and some of the highest values occurred in the Elbow Cay reefs near Hopetown (Table 4). Insight into macroalgal biomass trends may be found by examining the role of herbivorous fishes in controlling macroalgae. Large groupers that were observed in the northern Fowl Cay pinnacles are protected from fishing and subjected to fish feeding by the local dive charter operators. Predation by carnivorous fishes off Fowl Cay may locally deplete the herbivorous fish populations leading to an increase in macroalgal biomass. Sandy Cay is similarly protected from fishing but not subjected to significant fish feeding and few large groupers were observed here, which may help to explain its lower macroalgal biomass values.

Pp. 58-75 in J.C. Lang (ed.), Status of Coral Reefs in the western Atlantic: Results of initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Atoll Research Bulletin 496.

The AGRRA methods provide a good snapshot of the reefs of central Abaco and, as the results are compared to those of other Western Atlantic and Caribbean reefs (Kramer, this volume), may reveal large-scale trends in their stony coral, algal and fish communities. Management strategies on a local scale, however, should depend on studies that investigate the processes that affect reef communities. These investigations should include the impacts of anthropogenic factors such as water quality, fisheries and anchor damage, as well as the natural physical processes that may play an important role in controlling reef structure.

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Table 1. Site information for AGRRA stony coral and algal surveys in Abaco, Bahamas.

Site name	Site code/ status	Reef type	Latitude (°' N)	Longitude (°' W)	Survey date	Depth (m)	Benthic transects (#)	≥10cm stony corals (#/10 m)	% live stony coral cover (mean ± sd)
<b><i>Fringing reef</i></b>									
Sandy Cay, Forereef	SCF/MPA <sup>1</sup>	Fore-reef slope	26 23.867	76 59.308	Aug 9 99	1-6	12	8.5	22.5 ± 11.5
Sandy Cay, Backreef	SCB/MPA	Back reef	26 23.867	76 59.308 <sup>2</sup>	Aug 9 99	2-7	15	8.5	14.0 ± 7.5
<b><i>Bank barrier reefs</i></b>									
Elbow Cay, South-inner	ECSI	Low relief outer reef crest	26 31.606	76 57.417	Aug 11 99	4-8	14	8.5	14.5 ± 4.5
Elbow Cay, Middle	ECM	Low relief outer reef crest	26 32.419	76 56.767	Aug 11 99	6-9	13	8	12.0 ± 9.0
Elbow Cay, North	ECN	Low relief outer reef crest	26 33.686	76 56.969	Aug 16 99	6-11	18	5.5	8.5 ± 4.5
Fowl Cay-shallow	FCS/MPA	Low relief outer reef crest	26 38.229	77 02.310	Aug 13 99	8-12	15	8	12.0 ± 4.5
Storr's Reef	SR	Low relief outer reef crest	26 34.654	76 57.538	Aug 16 99	2-6	15	8	14.5 ± 7.5
Man O' War Cay, N. of S. Channel	MOWSN	Low relief outer reef crest	26 36.197	76 58.987	Aug 12 99	6-9	14	5	10.5 ± 6.0
Man O' War Cay, S. of S. Channel	MOWSS	Low relief outer reef crest	26 35.835	76 58.583	Aug 12 99	2-5	14	8	15.0 ± 5.5
Lynyard Cay, North	LCN	Spur and groove	26 21.452	76 58.612	Aug 15 99	6-10	16	5.5	14.0 ± 12.5
Lynyard Cay, South	LCS	Spur and groove	26 21.212	76 58.680	Aug 15 99	6-11	15	6	13.0 ± 6.0
Elbow Cay, South-outer	ECSO	Shallow pinnacles	26 31.937	76 57.023	Aug 10 99	2-6	12	8	18.0 ± 5.5
Fowl Cay-deep	FCP/MPA	Deep pinnacles	26 38.244	77 02.129	Aug 13 99	10-16	13	6	17.0 ± 13.5
<b>All sites</b>						<b>1-16</b>	<b>13</b>	<b>7.1</b>	<b>14.3 ± 7.6</b>

<sup>1</sup>MPA designates that the site was in a marine protected area.<sup>2</sup>Exact GPS coordinates were not obtained. The back-reef site was located approximately 150m ESE of the fore-reef site.

Table 2. Relative abundance of all stony corals seen during AGRRA surveys in Abaco.

Name	Relative abundance <sup>1</sup>	Name	Relative abundance <sup>1</sup>
<b>Milleporidae</b>			
<i>Millepora alcicornis</i>	Abundant		
<i>Millepora complanata</i>	Abundant		
<b>Scleractinia</b>			
<i>Acropora cervicornis</i>	Rare	<i>Montastraea annularis</i>	Abundant
<i>Acropora palmata</i>	Abundant	<i>Montastraea faveolata</i>	Abundant
<i>Agaricia agaricites</i> f. <i>agaricites</i>	Abundant	<i>Montastraea franksi</i>	Rare
<i>Agaricia agaricites</i> f. <i>danai</i>	Common	<i>Montastraea cavernosa</i>	Common
<i>Colpophyllia natans</i>	Common	<i>Manicina areolata</i>	Abundant
<i>Dendrogyra cylindrus</i>	Rare	<i>Meandrina meandrites</i>	Few
<i>Dichocoenia stokesi</i>	Common	<i>Mussa angulosa</i>	Few
<i>Diploria clivosa</i>	Abundant	<i>Mycetophyllia danaana</i>	Few
<i>Diploria labyrinthiformis</i>	Common	<i>Mycetophyllia ferox</i>	Common
<i>Diploria strigosa</i>	Abundant	<i>Mycetophyllia lamarckiana</i>	Common
<i>Eusmilia fastigiata</i>	Common	<i>Porites astreoides</i>	Abundant
<i>Favia fragum</i>	Common	<i>Porites branneri</i>	Common
<i>Isophyllastrea rigida</i>	Rare	<i>Porites porites</i>	Common
<i>Isophyllia sinuosa</i>	Rare	<i>Scolymia</i> spp.	Common
<i>Leptoseris cucullata</i>	Common	<i>Stephanocoenia intersepta</i>	Common
<i>Madracis decactis</i>	Few	<i>Siderastrea radians</i>	Common
<i>Madracis pharensis</i>	Few	<i>Siderastrea siderea</i>	Abundant
		<i>Tubastraea coccinea</i>	Rare

<sup>1</sup>Abundant = seen numerous times on more than half of the 13 dives, Common = seen on less than half of the dives but more than 10 times, Few = seen 4 to 10 times, Rare = seen 3 times or less. Relative abundance categories were determined during debriefings of all Abaco team members following each day of diving and at the end of the expedition.



Table 3. Size and condition (mean  $\pm$  standard deviation) of all stony corals ( $\geq 10$  cm diameter) by site in Abaco.

Site name	Stony corals		Partial-colony surface mortality (% $\pm$ sd)			Stony corals (%)		
	(#)	Diameter (cm)	Recent	Old	Total	Standing dead	Bleached	Diseased
<b><i>Fringing reef</i></b>								
Sandy Cay, Forereef	103	62.0 $\pm$ 60.0	1.0 $\pm$ 3.5	22.0 $\pm$ 32.5	23.0 $\pm$ 32.5	6	0	4
Sandy Cay, Backreef	125	38.0 $\pm$ 33.0	<0.5 $\pm$ 1.0	15.5 $\pm$ 26.0	16.0 $\pm$ 26.0	1.5	1	1
<b><i>Bank barrier reefs</i></b>								
Elbow Cay, South-inner	118	37.0 $\pm$ 29.0	4.5 $\pm$ 14.0	22.0 $\pm$ 30.0	26.0 $\pm$ 32.5	3.5	2	0
Elbow Cay, Middle	105	39.0 $\pm$ 46.5	3.5 $\pm$ 11.5	22.5 $\pm$ 31.5	25.5 $\pm$ 33.5	5.5	1	0
Elbow Cay, North	97	41.0 $\pm$ 41.5	6.0 $\pm$ 14.0	25.0 $\pm$ 35.0	31.0 $\pm$ 37.5	8	0	0
Fowl Cay-shallow	121	33.5 $\pm$ 29.0	1.0 $\pm$ 6.0	19.0 $\pm$ 27.0	20.0 $\pm$ 28.5	6.5	0	1
Storr's Reef	121	43.5 $\pm$ 48.5	2.5 $\pm$ 9.0	19.5 $\pm$ 32.0	22.0 $\pm$ 33.5	7.5	1	0
Man O' War Cay, N. of S. Channel	71	32.5 $\pm$ 22.5	3.5 $\pm$ 10.0	12.5 $\pm$ 20.5	16.0 $\pm$ 23.5	0	0	0
Man O' War Cay, S. of S. Channel	109	35.0 $\pm$ 29.0	1.0 $\pm$ 4.5	8.0 $\pm$ 16.0	9.0 $\pm$ 17.0	0	0	0
Lynyard Cay, North	89	57.5 $\pm$ 72.0	1.0 $\pm$ 2.5	25.5 $\pm$ 31.5	26.5 $\pm$ 31.5	3.5	0	1
Lynyard Cay, South	88	47.5 $\pm$ 63.0	2.0 $\pm$ 6.5	25.5 $\pm$ 31.0	27.5 $\pm$ 31.5	3.5	0	1
Elbow Cay, South-outer	98	38.0 $\pm$ 39.5	1.0 $\pm$ 4.5	20.5 $\pm$ 29.0	21.0 $\pm$ 30.0	1	3	1
Fowl Cay-deep	77	49.0 $\pm$ 60.5	3.0 $\pm$ 13.0	18.0 $\pm$ 23.5	21.0 $\pm$ 26.0	0	1.5	2.5

Table 4. Algal characteristics, and density of stony coral recruits and of *Diadema antillarum* (mean  $\pm$  standard deviation) by site in Abaco.

Site name	Quadrats (#)	Relative abundance (%)			Macroalgal		Coral recruits (#/.0625 m <sup>2</sup> )	<i>Diadema</i> (#/10 m)
		Macroalgae	Turf algae	Crustose coralline algae	Height (cm)	Index <sup>1</sup>		
<b><i>Fringing reef</i></b>								
Sandy Cay, Forereef	60	24.5 $\pm$ 28.0	30.5 $\pm$ 20.5	45.0 $\pm$ 26.5	3.0 $\pm$ 5.0	81	0.3 $\pm$ 0.8	0
Sandy Cay, Backreef	64	28.0 $\pm$ 23.0	51.0 $\pm$ 28.5	21.0 $\pm$ 24.0	2.0 $\pm$ 1.0	64	0.3 $\pm$ 1.2	0
<b><i>Bank barrier reefs</i></b>								
Elbow Cay, South-inner	45	39.0 $\pm$ 24.0	40.0 $\pm$ 22.0	21.0 $\pm$ 20.0	3.5 $\pm$ 2.0	133	0.2 $\pm$ 0.2	0
Elbow Cay, Middle	65	36.5 $\pm$ 24.0	46.0 $\pm$ 23.0	22.5 $\pm$ 19.0	3.5 $\pm$ 1.0	114	0.2 $\pm$ 0.5	0
Elbow Cay, North	60	47.0 $\pm$ 34.5	37.5 $\pm$ 30.5	15.5 $\pm$ 17.0	3.5 $\pm$ 1.0	155	0.2 $\pm$ 0.6	0
Fowl Cay-shallow	60	32.5 $\pm$ 23.0	50.0 $\pm$ 24.0	17.5 $\pm$ 19.5	5.5 $\pm$ 9.5	184	0.2 $\pm$ 0.5	0
Storr's Reef	55	29.0 $\pm$ 27.0	54.0 $\pm$ 30.5	17.5 $\pm$ 21.0	2.5 $\pm$ 1.0	72	0.3 $\pm$ 0.1	0
Man O' War Cay, N. of S. Channel	60	25.0 $\pm$ 21.0	57.0 $\pm$ 28.5	17.0 $\pm$ 22.0	2.5 $\pm$ 1.5	68	0.1 $\pm$ 0.3	0
Man O' War Cay, S. of S. Channel	45	28.5 $\pm$ 15.0	61.5 $\pm$ 21.5	10.0 $\pm$ 16.0	3.5 $\pm$ 1.5	106	0.2 $\pm$ 0.5	0
Lynyard Cay, North	60	29.5 $\pm$ 24.5	53.0 $\pm$ 26.0	17.5 $\pm$ 16.5	4.0 $\pm$ 3.0	124	0.3 $\pm$ 0.6	0
Lynyard Cay, South	60	34.5 $\pm$ 21.5	46.5 $\pm$ 25.0	19.0 $\pm$ 19.5	3.5 $\pm$ 2.0	125	0.5 $\pm$ 0.7	0
Elbow Cay, South-outer	60	44.5 $\pm$ 31.0	38.0 $\pm$ 27.5	17.5 $\pm$ 23.0	3.0 $\pm$ 1.5	130	0.1 $\pm$ 0.4	0
Fowl Cay-deep	60	44.5 $\pm$ 24.0	39.0 $\pm$ 22.0	16.5 $\pm$ 17.0	3.0 $\pm$ 1.0	141	0.3 $\pm$ 0.5	0

<sup>1</sup>Macroalgal index = relative abundance x macroalgal height