PROCEEDINGS OF THE 10TH SYMPOSIUM ON THE GEOLOGY OF THE BAHAMAS AND OTHER CARBONATE REGIONS

Edited by
Benjamin J. Greenstein and Cindy K. Carney

Production Editor:
Dana Bishop

Gerace Research Center
San Salvador, Bahamas
2001

Front Cover: The reef crest indicator species, *Acropora palmata*, on Gaulin's Reef, San Salvador Island. Gaulin's Reef is a classic bank-barrier reef that has shown remarkable resilience following two significant disturbances: El Niño-induced warming of the sea surface in 1998 and Hurricane Floyd in September, 1999 (see Peckol et al., this volume). Photo by Janet Lauroesch.

Back Cover: The oolite shoals of Joulter's Cay, north of Andros Island, Bahamas, site of the pre-meeting field trip. Photo by Ben Greenstein.

ISBN 0-935909-69-9

COCKBURN TOWN FOSSIL REEF: A SUMMARY OF EFFECTS FROM HURRICANE FLOYD

Sally E. Walker, Steven M. Holland, and Lisa Gardiner
Department of Geology
University of Georgia
Athens, Georgia 30602-2501

ABSTRACT

Hurricane Floyd damaged the existing fossil reef (125 ka) at Cockburn Town, San Salvador, Bahamas. The most noticeable damage was vegetation stripping, block removal, block deposition, and sand removal or deposition. Quantitative surveys based on 38 transects laid perpendicular to the exposed fossil reef indicate that ten effects related to Hurricane Floyd were encountered. While 22% of the reef remained relatively undamaged, 78% of the reef was affected by sand and rubble deposition, sand cover, abrasion, rubble deposition, vegetation removal, block or sand removal and rubble and block deposition. During Hurricane Floyd, the sea breached new areas by removing large blocks of reef material. It is imperative that the remnant of this once spectacular fossil reef should be preserved. The Cockburn fossil reef is a fabulous teaching tool for students as well as an excellent repository of historical information concerning reef organisms during the last interglacial period, 125,000 years ago.

INTRODUCTION

Hurricane Floyd is considered one of the strongest hurricanes in the 20th century to have affected the Bahamian Islands. Hurricane Floyd passed over the island of San Salvador on the evening of September 13, 1999, with estimated wind speeds averaging 217 kph (135 mph) and a 3 m (10 ft) storm surge. The eye passed 32.2 km (20 mi) Northof the island as determined by satellite. Extensive beach erosion occurred on both the western and northern tip of the island (T. Goossens, pers. comm., October 1999). Beach profiles were drastically altered and large blocks from beach and subtidal hardgrounds were fragmented and transported inland (K. Buchan, Director, Bahamian Field Station, October 1999).

We examined the damaged caused by Hurricane Floyd at the Cockburn Town fossil reef locality on the island of San Salvador, Bahamas, in January 2000. The Cockburn fossil reef is a repository of important paleoclimatic and paleoecologic information representing a critical point in time: that of the last interglacial (125 ka; Curran and White, 1985; Curran et al., 1989; Greenstein and Curran, 1997; Greenstein and Moffat, 1996). Additionally, the information retained in fossil reefs is important for comparison to modern reefs to assess the amount of biotic change that may have taken place due to human disturbance (e.g., Greenstein and Pandolfi, 1997; Greenstein et al., 1998). In particular, the Cockburn Town fossil reef has provided an important database for students and scientists to compare to the modern reefs (e.g., Hagey, 1991; Noble et al., 1995). Unfortunately, the Cockburn Town reef site was previously quarried for road material and more recently for docking areas for the Shell Oil Company. These human-caused changes have weakened the overall structure of the reef such that a Category 4 hurricane (such as Floyd) could cause substantial damage to the remaining structure of the fossil reef. Therefore, we wanted to document quantitatively the damage to the fossil reef to determine which portions of reef were more damaged than others and the type of damage caused by Hurricane Floyd. A summary of our findings is future protection of this unique fossil reef site.

METHODS

Thirty-eight transects spaced at 5-meter intervals along the reef were completed for most of the exposed Cockburn Town fossil reef. Transects were laid perpendicular to the fossil reef to document damage from the edge of the reef exposed to the oncoming waves to the farthest landward exposed portion of the reef. The wind and wave conditions in January 2000, when these transects were conducted, prohibited a subtidal survey of the fossil reef. A total of 1099.7 meters of exposed reef was examined using the transect method. The linear extent of hurricane damage was noted for each of the transects. The type of hurricane damage was assessed by a preliminary survey of the fossil reef prior to conducting the transects. Eleven descriptors of the fossil reef were compiled in relation to hurricane damage: (1) No discernable damage and the reef remained blackened by lichen and cyanobacteria; (2) vegetation was stripped from the bed rock surface, leaving a cream or tan-colored karstic surface; roots or bioerosion from roots were common; (3) sand cover; (4) sand removal leaving cream to tan color surfaces, some of which were karstic; (5) windrow of plant debris; (6) block (> 1 m in length) removal indicated by white to cream-colored areas on reef where large blocks of limestone were removed intact; (7) block deposition (> 1 m in length); (8) sand and rubble deposition; (9) rubble deposition (< 1m in length); (10) rubble and block deposition; and, (11) abraded, leaving a sand-blasted appearance of bed rock with light gray and white to cream-colored mottling.

RESULTS AND DISCUSSION

The Cockburn Town fossil reef site was greatly affected by Hurricane Floyd. The most noticeable alteration resulted from vegetation and sand removal, sand deposition, and large blocks removed or deposited along the fossil reef (Figure 1). Only 22% of the area surveyed contained the natural black color of the undamaged reef (Figure 2; Table 1), with the remaining 78% displaying some form of hurricane-damage. The most common damage was that of sand cover or sand and rubble deposition behind the seaward edge of the reef (Figure 2; Table 1). While transects were not conducted prior to Hurricane Floyd, there was a considerable amount of sand and rubble in areas where there was no apparent sand or rubble observed in May 1999. Additionally, the rubble was composed of newly removed pieces of coral or other reef facies. Sand deposition was more commonly encountered landward of the reef as the majority of the sand was trapped primarily in the quarried area and on an eolianite knoll (Figure 1).

Abrasion was the next most important agent of damage affecting the fossil reef (Figure 2; Table 1). Abrasion stripped the black surface layer of the reef, producing a mottled effect. Wave scour, sandblasting and the movement of rubble or large blocks most likely produced abrasion across the reef surface. Rubble, composed of angular blocks less than 1 m in length, was also encountered in up to 7% of the transects (Figure 2; Table 1). Rubble was produced by erosion of the reef. Most rubble had fresh surfaces, which had not been colonized by lichen.

Stripping of vegetation from the reef was quite noticeable, especially in the southern portion of Cockburn Town fossil reef (Figure 1). Vegetational stripping accounted for 6% of the hurricane damage encountered in the transect (Figure 2; Table 1). Roots and

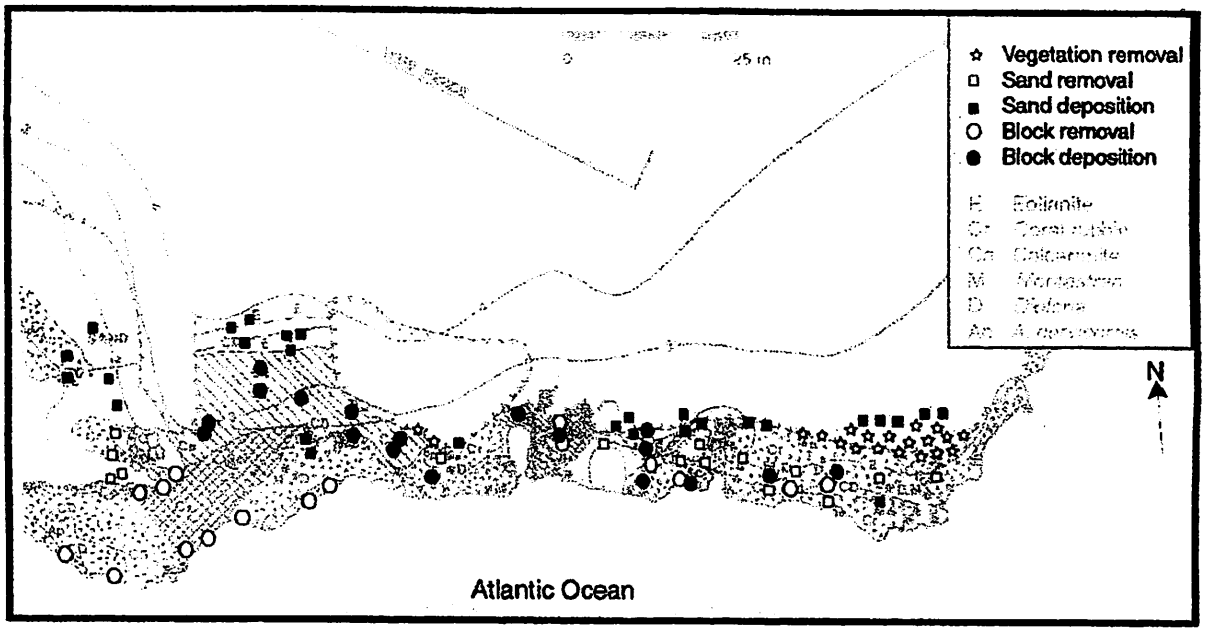


Figure 1. Map of the southern portion of the Cockburn Town fossil reef where damage from hurricane Floyd was examined. Vegetation and sand removal, sand deposition, block removal and block deposition are featured. Map adapted from Curran and White (1985).

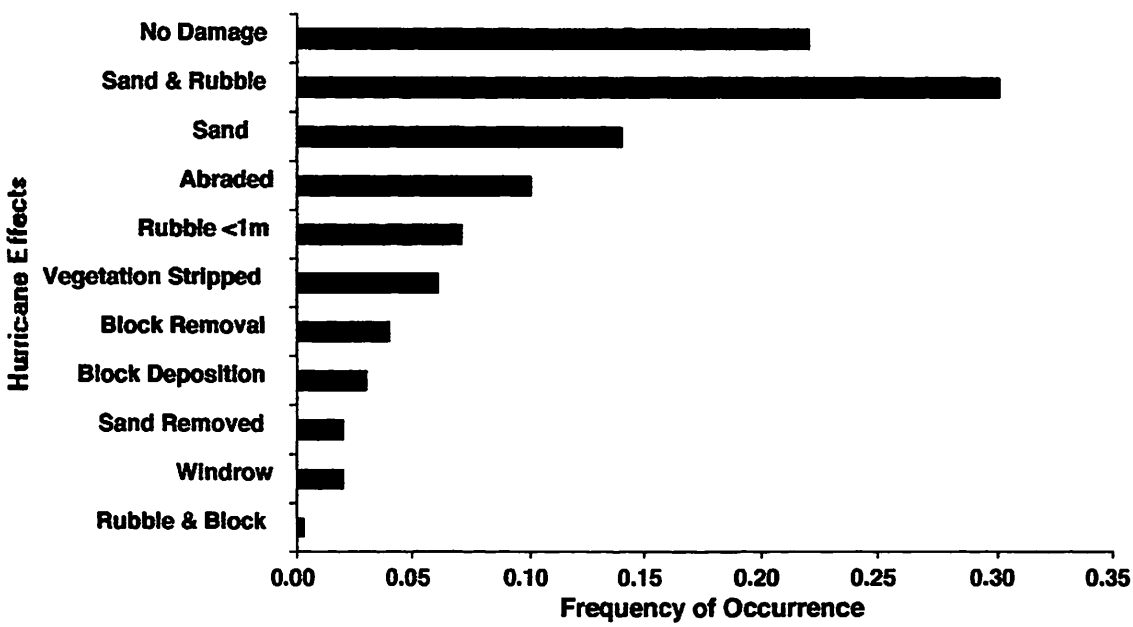
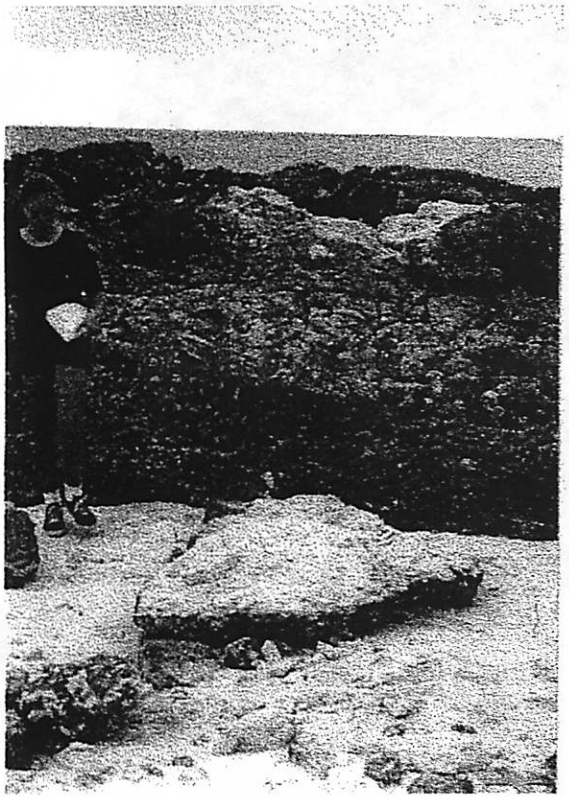


Figure 2. Frequency of occurrence of Hurricane Floyd effects on the portion of Cockburn Town fossil reef examined (as depicted in Figure 1). The frequency was calculated by dividing the length along the transect that each effect represented by the total meters examined for all transects combined.

Hurricane Effects	Total Length Encountered in Transects (m)
No Damage	242.1
Sand and Rubble	321.8
Sand Cover	157.3
Abraded Surface	103.8
Rubble (< 1 m in length)	73.6
Vegetation Stripped	65.4
Block Removal (> 1 m in length)	47.0
Block Deposition	35.3
Sand Removed	26.7
Rubble and Block Deposition	3.6
Total	1099.7

Table 1. Measured distribution of features associated with Hurricane Floyd damage at Cockburn Town fossil reef, San Salvador, Bahamas.



← Figure 3. Reef block removal and subsequent reef block deposition from hurricane Floyd at the Cockburn Town fossil reef site. Lara Buchan, research assistant, for scale.

stripped lower portions of shrubs were commonly encountered. The force of the waves that stripped the vegetation exposed new reef surface, and as much as 5 meters of new reef was exposed in some areas. This new reef area, however, was bioeroded by plant roots and also karstified to a scalloped surface. The vegetation that had been stripped formed a large windrow landward of the fossil reef. The transects ended at the windrow, but the windrow was recorded as 1 meter as it was typically one meter across along the southern portion of the reef (representing 2% of the transects, Figure 2). The windrow acted like a

net by trapping rubble, coral fragments and other eroded debris.

Large block removal and block deposition was quite evident at the Cockburn Town fossil reef (Figure 2, 3). In the measured transects, eroded blocks and block deposition accounted for 4% and 3%, respectively, of the surveyed transects (Figure 2; Table 1). Most eroded blocks occurred on the seaward edge of the reef and most block deposition was recorded landward of that edge (Figure 1). Sand removal occurred more typically in the southern portion of the exposed reef and occurred both on the reef surface and in portions of the quarried area (Figure 1). Sand removal accounted for 2% of the surveyed transects (Figure 2; Table 1). Rubble and block deposition was also noted, but occurred in limited frequency (Figure 2, 4; Table 1).

The damage recorded on the Cockburn Town fossil reef did not appear to be typical of a Category 4 Hurricane. That is, winds would be recorded at 210 to 249 kph with a storm surge up to 5.5 m (18 ft). During a Category 4, trees and shrubs would not be standing (Williams and Duedall, 1997). At the Cockburn Town reef site, small shrubs that were growing in the southern portion of the reef were stripped. However, trees and shrubs landward and adjacent to the fossil reef were, for the most part, intact and still erect. After surveying the island for damage in January, we concluded that the damage to the Cockburn Town fossil reef came from storm waves generated after Hurricane Floyd had passed to the northwest of the island of San Salvador. Therefore, the damage from Hurricane Floyd on the leeward side of San Salvador was more like that expected from a Category 1 or a Category 2 hurricane on the Saffir-Simpson hurricane scale and not a Category 4. Given that, there was still considerable damage to the fossil reef, and it was weakened considerably.

The Cockburn Town fossil reef had previously been quarried and the northern portion was destroyed to make a harbor and

Figure 4. Block, rubble, sand deposition and windrow (in background) from hurricane Floyd, Cockburn Town fossil reef. Lisa Gardiner in foreground for scale.

docking sites. During Hurricane Floyd, the sea breached new areas after large blocks of reef material were removed. Joints and cracks within the existing reef wall were also observed, which will be future areas where hurricane damage can take its toll. It is imperative that the remnant of this once spectacular fossil reef should be preserved. The Cockburn Fossil reef is a fabulous teaching tool for students as well as an excellent repository of historical information concerning reef organisms during the last interglacial period, 125,000 years ago. Future protection of the Cockburn Town reef is essential, and we recommend that the government of the Bahamas, the Bahamas National Trust, and the citizens of San Salvador protect their unique fossil-reef resource. It also would be beneficial if young school children from San Salvador are introduced to this reef, so that they may become more aware of the impact that humans have on their resources. Although once quarried for road gravel, the reef is now much more useful and important for examining the biodiversity of Pleistocene reefs in comparison to other fossil reefs and to the modern. If we throw away our natural heritage, reefal or otherwise, we have no basis from which to assess change. If humans deem that cultural history is important, then so too is the natural history entombed in the Cockburn Town fossil reef.

ACKNOWLEDGEMENTS

We wish to thank Ben Greenstein and Cindy Carney for inviting this presentation for the 10th Annual Geology of the Bahamas and Other Carbonate Regions. We also wish to thank the Directors, Ken and Marge Buchan, and Tom and Linda Goossens for facilitating this research. Lara Buchan was a most helpful field assistant. This research was funded by NSF-SGER grant (EAR-0000894) to Walker and Holland.

REFERENCES

Curran, H. A., and White, B., 1985, The Cockburn Town fossil coral Reef, *in* Curran, H. A., ed., Pleistocene and Holocene carbonate environments on San Salvador Island, Bahamas--Guidebook for Geological Society of America, Orlando Annual Meeting field trip, Bahamian Field Station, Ft. Lauderdale, Florida, p. 147-153.

Curran, H. A., White, B., Chen, J. H., and Wasserburg, G. J., 1989, Comparative morphologic analysis and geochronology for the development and decline of two Pleistocene coral reefs, San Salvador and Great Inagua Islands, Bahamas, *in* Mylroie, J., ed., Proceedings of the Fourth Symposium on the Geology of the Bahamas: Bahamian Field Station, San Salvador, Bahamas, p. 107-117.

Greenstein, B. J., and Curran, H. A., 1997, How much ecological information is preserved in fossil reefs and how reliable is it?: Proceedings of the 8th International Coral Reef Symposium, Panama City, Panama, v. I, p. 417-422.

Greenstein, B. J., and Moffat, H., 1996, Comparative taphonomy of Holocene and Pleistocene corals, San Salvador, Bahamas: Palaios, v. 11, p. 57-63.

Greenstein, B. J., and Pandolfi, J., 1997, Preservation of community structure in modern reef coral life and death assemblages of the Florida Keys: Implications for the Quaternary record of coral reefs: Bulletin of Marine Science, v. 19, p. 38-59.

Greenstein, B. J., Curran, H. A., and Pandolfi, J., 1998, Shifting ecological baselines and the demise of *Acropora cervicornis* in the western North Atlantic and Caribbean Province: A Pleistocene perspective: Coral Reefs, v. 17, p. 249-261.

Hagey, F. M., 1991, Pleistocene molluscan assemblages on San Salvador Island, Bahamas: Preliminary investigations and interpretations, *in* Bain, R. J., ed., Proceedings of the Fifth Symposium on the Geology of the Bahamas: Bahamian Field Station, San Salvador, Bahamas, p. 103-115.

Noble, R. S., Curran, H. A., and Wilson, M. A., 1995, Paleoenvironmental and paleoecologic analyses of a Pleistocene mollusc-rich lagoonal facies, San Salvador Island, Bahamas, *in* Curran, H. A., and White, B., eds., Terrestrial and Shallow Marine Geology of the Bahamas and Bermuda: Boulder, Colorado, Geological Society of America Special Paper 300, p. 91-103.

Williams, J. M., and Duedall, I. W., 1997. Florida Hurricanes and Tropical Storms. University Press of Florida: Gainesville, 147 p.