PROCEEDINGS

OF THE

TENTH SYMPOSIUM

ON THE

NATURAL HISTORY OF THE BAHAMAS

Edited by
Sandra D. Buckner
and
Thomas A. McGrath

Conference Organizer
Vincent J. Voegeli

Gerace Research Center, Ltd.
San Salvador, Bahamas
2005

Cover photograph – "Little Ricky" - juvenile dolphin, San Salvador, Bahamas (courtesy of Sandra Voegeli, 2003)

Printed in the Bahamas

ISBN 0-935909-76-1

VARIATIONS IN SCLERACTINIAN CORAL POPULATIONS ON PATCH REEFS AROUND SAN SALVADOR ISLAND, BAHAMAS 1992 - 2002

Tom McGrath
Biology/Chemistry Division
Corning Community College
Corning, NY 14830
mcgratta@corning-cc.edu

and

Garriet W. Smith
Department of Biology
University of South Carolina at Aiken
Aiken, SC 29801
smithres@aiken.sc.edu

ABSTRACT

Few studies exist that follow long-term changes in hermatypic scleractinian coral populations on permanent study sites. Three patch reefs around San Salvador Island, Bahamas, have been monitored since 1992 with the help of trained volunteers recruited through Earthwatch Institute. Monitoring has enabled variations in these coral populations to be tracked over the past decade. Each of the sites in this study has had less than 10% scleractinian coral tissue cover through most of the period. Rice Bay, a highly compromised site, consistently has had less than 5% live coral tissue cover. Each of the sites has a unique community of coral species as has been found in other studies involving multiple sites. Large coral colonies, those with more than 300 cm^2 live tissue, have been the most likely to exhibit long-term survival and resilience to environmental impacts such as episodes of bleaching, disease, or tropical storms. Small coral colonies, representing recent recruits, vary the most with as much as 30% change in the presence of such colonies occurring each year. While this level of death and recruitment suggests a highly dynamic system, when population distributions of each coral species on each reef are examined, they appear to remain remarkably consistent across the decade. The picture that emerges is one of a system that shows significant and dynamic changes in the short term while exhibiting long-term stability.

INTRODUCTION

Coral reefs around the world have experienced declines since the early 1980s. These declines have been attributed to such events as the loss of significant populations of key organisms on the reefs such as *Diadema* sp. and to coral bleaching events (Grigg and Dollar, 1990; Cook, *et al.*, 1990; D'Elia, *et al.* 1991; Goreau, 1990; Gardner, *et al.*, 2003); Porter and Meier, 1992; Smith and Buddemeier, 1992, Wilkins, 2000). The extent of the declines has been hard to evaluate because few long-term studies have been in place throughout the period (Lang, *et al.*, 1992). A recent metastudy suggested that reefs in the Western Atlantic may have declined in hard coral cover from 50% to 10% (80%) since 1975 with a variety of influences being the cause (Gardner, *et al.*, 2003).

Such declines appear to have affected the reefs of the Bahamas. With much of the Bahamian archipelago surrounded by very shallow banks, patch reefs make up a major portion of the reefal structure important to these islands in a variety of ways (Buchan, 2000). While influences on patch reefs in close proximity may appear to be similar, the reefs may change in strikingly different ways over time (H.A. Curran, P.C.).

In the early 1990s it was suggested that patch reefs around San Salvador Island, Bahamas had experienced decline (H.A. Curran and D. Gerace, PC). In order to characterize the reefs and follow future changes in these systems, three coral patch reefs around San Salvador Island have been monitored three times each year since 1992. (McGrath, 1992; McGrath, *et al.*, 1994; McGrath and Smith, 1999). During this period two major bleaching events, outbreaks of diseases on hard coral and gorgonians, and several hurricanes have occurred (McGrath and Smith, 1998; McGrath and Smith, 2003 [in press]; Smith, *et al.*, 1996; Richardson, *et al.*, 1998). The long-term data make it possible to observe trends in the parameters being monitored on these reefs and to compare these trends with those seen or suspected elsewhere around the world.

The data presented here address two questions regarding hard corals on Bahamian patch reefs:

1. How do reef-building hard corals vary over time?

2. How do environmental challenges impact the hard corals on these reefs?

METHODS

As described in detail previously, 7 permanent transects on three patch reefs have been monitored 3 times each year since 1992 with the aid of Earthwatch volunteers trained on site by project staff. Monitoring has been conducted each February, July, and November. Transects have been mapped and photographed annually in July (McGrath, Gerace, and Smith, 1994; McGrath and Smith, 1998; Wells, 1995).

Haphazard monitoring for substrate cover has been conducted on the same 3 reefs during each expedition. Haphazard surveys and individual colony marking have been conducted during periods of bleaching and disease (McGrath and Smith, 1998; McGrath and Smith 2003 [in press]).

RESULTS

Mean coral cover has remained low, less than 10%, throughout the decade.

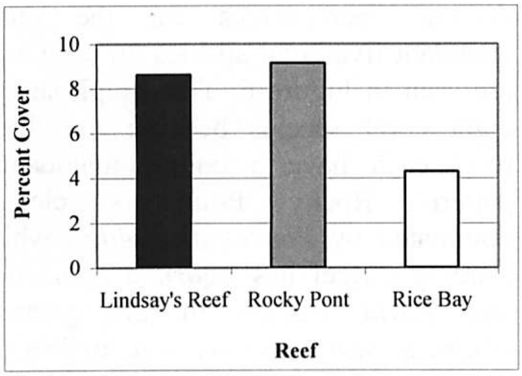

Figure 1. Mean coral cover on the three monitored patch reefs from 1992 through 2002.

The two healthier reefs in the study have lost live coral tissue cover over the period, while live tissue has increased on the more compromised reef with the lowest live coral cover.

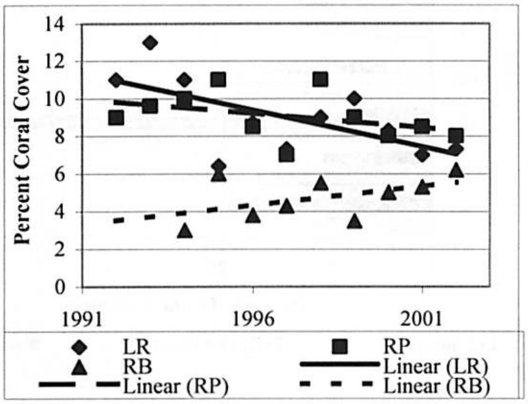

Figure 2. Trends in hard coral live tissue cover from 1992 through 2002.

Only Lindsay's Reef has had a significant decline in total hard coral colony numbers over the decade.

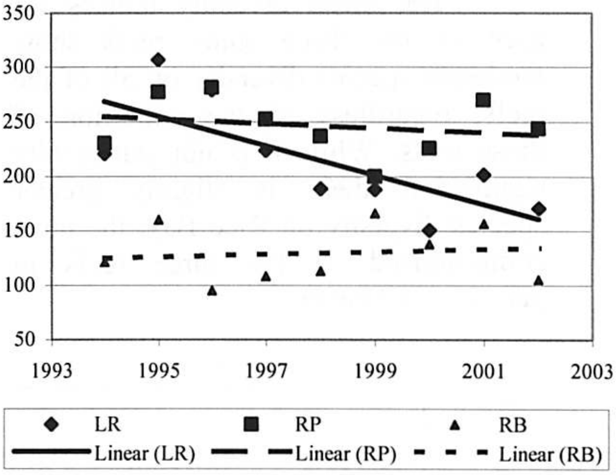

Figure 3. Trends in total hard coral colony numbers from 1993, when Rice Bay Reef surveys were begun, through 2002.

One transect out of the seven established has shown a decline in the number of species represented there over the decade. This transect is the southeastern transect on Rocky Point Reef.

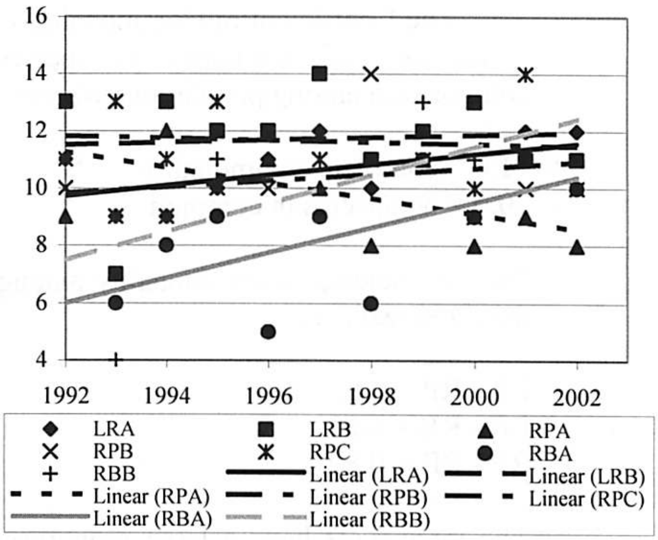

Figure 4. The number of species of hard corals found on each transect from 1992 through 2002.

The mean diversity indices for each of the three study reefs show moderate species diversity on all of the reefs, regardless of the condition of those reefs. While it is not statistically significant, there is slightly greater species diversity on Rice Bay, the most compromised of the three reefs in percent coral cover.

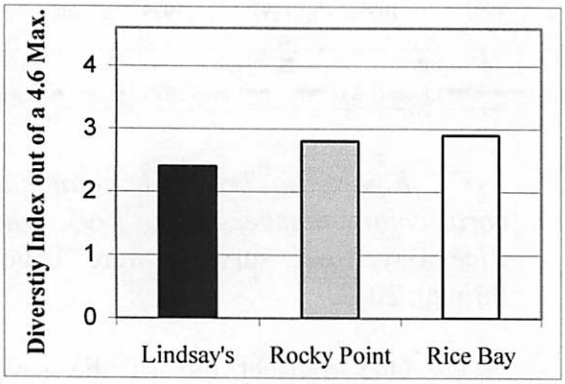

Figure 5. The Shannon-Weaver diversity indices for the three study reefs. An index of 4.6 represents maximum diversity.

The Coefficient of Commonality is a measure of similarity in species composition among populations where:

1.0 = complete commonality
0.0 = no species in common

The coefficients of commonality among the three reefs are:

LR - RP = 0.83
LR - RB = 0.82
RP - RB = 0.89

The three reefs have a large proportion of species in common.

The patterns of species abundance have remained constant over the decade (McGrath and Smith, 2003). Average percentages for the most abundant five coral species on each reef are seen in Figure 6. This graph shows eight coral species because the three reefs each have a unique abundance pattern. Rocky Point is clearly dominated by *Porites asteroides*, while Lindsay's Reef has *Agaricia agaricites* and *Favia fragum* in the greatest numbers. *Manicinia areolata* makes up fewer than 5% of the colonies on Rocky Point transects but accounts for more than 15% of the colonies on the other two reef transects. Colony numbers of all species are much more evenly distributed on Rice Bay transects than at the other two reef sites.

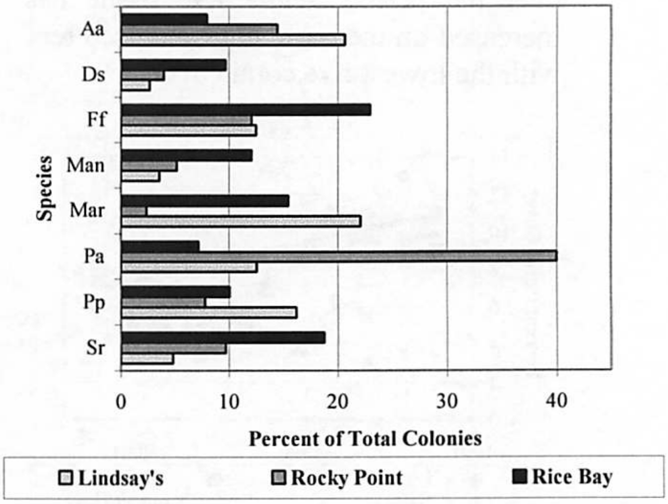

Figure 6. The abundance of the most prevalent five species on the transects on each reef expressed as percentages of the total number of that reef's coral colonies.

Estimated colony size for each coral found in transect maps was determined by calculating the area of the colony "footprint" as seen in the map. For those colonies which had a roughly circular "footprint", the area of a circle was calculated; for oblong colonies the area of an ellipse was calculated.

Colonies with a "footprint" of less than 80 cm^2 represent young colonies (recruits - ≤5 years old), and colonies with a footprint of ≥300 cm^2 represent older colonies (≥10 years old) assuming an average growth rate of all colonies between 2 cm and 10 cm in diameter or length per year.

Figure 7 shows that older (larger) coral colonies have the greatest staying power on the transects over the decade. Such colonies make up fewer than 10% of the total colony numbers on any of the study reefs. As much as 30% colony turnover occurs on these transects from year to year (McGrath and Smith, 2001). Such turnover is occurring primarily in smaller (younger) colonies.

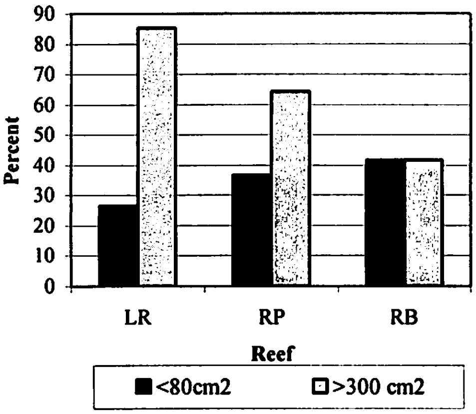

Figure 7. The percentage of all hard coral colonies on the transects of each study site that fall within two size categories.

All transect colonies of these four species remained present through the decade: *Diploria labrynthiformes*, *Montastrea annularis* (cluster), *Montastrea cavernosa*, and *Siderastrea siderea*. Some tissue area was lost from several *M. annularis* colonies, but all colonies remained alive.

All large colonies (over 300 cm^2) of *Porites porites* and *Porites asteroides* remained alive throughout the period.

Two mass bleaching events occurred during the monitoring period, one in 1995 and a more severe event in 1998. A minor and apparently more local bleaching event occurred in 1997. (McGrath and Smith, 1998; McGrath and Smith, 2001). As previously reported and as can be seen in Figure 8, higher than usual sea temperatures contributed only to the 1998 event. A combination of high summer sea temperatures and calm winds allowing for increased insolation were reported to have been the likely cause of bleaching on the Belize barrier reef in 1995 (Burke, 1997). Analysis of wind data available from the Nassau weather station has indicated that local winds were actually higher than normal in 1995 without any influences from tropical storms.

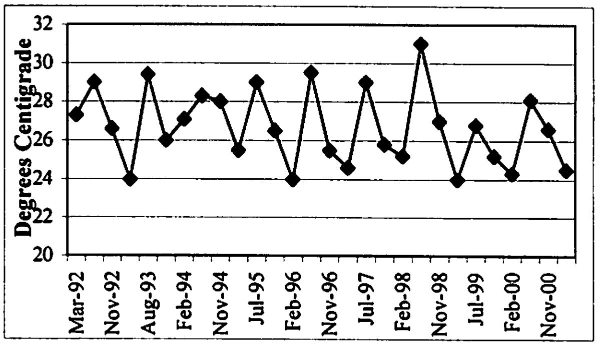

Figure 8. Mean sea temperatures at 1 M depth taken at the study transect sites during each monitoring visit. Note: Low values are February means while high values are July means.

As seen in Figure 9, the three study reefs responded differently to each of the bleaching events, with Lindsay's reef being more significantly affected during the 1995 event than either of the other two reefs (X^2 $p < 0.01$) while bleaching was much more evenly distributed among the reefs during the 1998 event (McGrath and Smith, 2003).

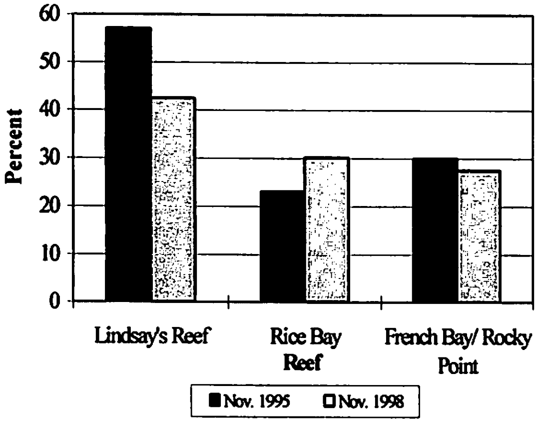

Figure 9. Percent of all bleached corals on each of the three study reefs in 1995 and 1998.

Coral species responded differently to each bleaching event as well. In 1995 *A. agaricites* was the most affected species with *F. fragum* following closely behind, while in 1998 a number of species were affected and to a much more equivalent extent (McGrath and Smith, 2003).

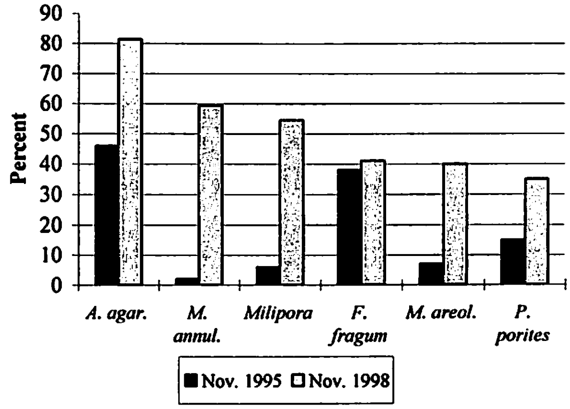

Figure 10. Percent of all corals bleaching during each mass bleaching event by species.

Mean coral cover has declined since bleaching commenced in 1995 at Lindsay's Reef and at Rocky Point. When percent cover is analyzed before and after the mass bleaching events, however, the declines are seen not to be statistically significant (X^2 $p < 0.05$).

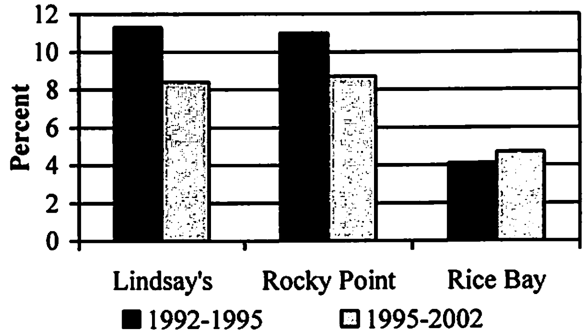

Figure 11. Mean percent coral cover on each study reef before and after bleaching commenced in 1995.

Two species of coral not found on any study transect were severely affected by the 1998 bleaching event, however. *Acropora cervicornis* and *Acropora palmata* seemed to die back completely from the reefs around San Salvador as they appeared to do throughout the Western Atlantic. *A. cervicornis* colonies there had been infected with White Band Type II disease for the entire time prior to the 1998 bleaching but it had not been killed by it. Acroporid recruits have only been found since July 2001 on San Salvador's reefs. Many of these recruits are growing on the dead skeletons of their congeners. A significant proportion of these new recruits are the hybrid forms of the genus, *A. fusiformes*.

Two major hurricanes have struck the Island in the last decade, Lili in 1996 and Floyd in 1999. No greater level of damage was seen during hurricane versus non-hurricane seasons on any of the transect corals.

One outbreak of White Plague Type II was found at Lindsay's reef during the summer of 2000. No transect corals were involved. Fewer than 50% of the colonies of *Dichocoenia stokesii* and one colony of *P. porites* on the entire reef were affected. Ten colonies were marked and followed for one year. Only one *D. stokesii* colony died. All other colonies arrested the disease and have remained alive through the period.

DISCUSSION

Hard coral tissue cover and species number on the reefs in this study is low but seemingly in keeping with what is found elsewhere in the region at this time (Edmunds, 2002; Gardner, *et al.*, 2003). While one of the three study sites, Lindsay's Reef, has lost both live hard coral tissue and species number to a significant degree over the decade, these parameters have changed little on the other two reefs. Development on the dune behind Lindsay's Reef began in the mid-1990s. While none of the physical parameters measured changed significantly after development began, the changes in the biological character of the reef suggest some impact from this development. The exact causes of the changes remain unclear, however.

With each study reef showing only moderate species diversity, it is not surprising that these sites share a significant number of species. Even so, it is clear that each patch reef is unique in the patterns of species abundance of the species present there. This has been seen in previous studies as well and suggests that coral patch reefs are structured as separate habitats, each of which can each respond differently to changes in the environment or other impacts, this pattern was seen in two adjacent reefs around San Salvador Island in the early 1990 when one, Telephone Pole Reef, nearly died off completely, while nearby Snapshot Reef remained healthy (H.A. Curran, PC).

Colony size, and therefore colony age, is clearly a factor in the persistence of a coral head over time. This is not surprising since older colonies are those inhabiting the most advantageous positions on the reef and/or which have been able to withstand environmental assaults over the years because of superior adaptive characteristics.

Bleaching events, disease outbreaks and major hurricanes have failed to produce significant, long-term impacts on the study reefs. Coastal development may produce a different outcome, but further study over a longer term following more physical parameters is needed to determine the nature and fate of any changes that do occur.

CONCLUSIONS

Live hard coral cover on the patch reefs around San Salvador Island, Bahamas, while low, is consistent with that found in other studies (Edmunds, 2002). On two of the studied reefs, Lindsay's Reef and Rocky Point Reef, live hard coral cover is greater than on the more compromised Rice Bay Reef. Hard coral cover seems to be declining at Lindsay's Reef and Rocky Point Reef while it is increasing slightly, albeit not at the level of statistical significance, at the more compromised Rice Bay Reef.

Total transect coral numbers have declined only at Lindsay's Reef over the decade. The number of hard coral species has declined on only one transect through the decade. On all others the species number has held steady or increased.

All three study reefs show moderate levels of species diversity. Hard coral species distributions have remained relatively constant over the decade. Each of the three study reefs has maintained its unique species distribution.

Larger hard coral colonies have endured on the two healthier study reefs. Hard coral species that have not lost colonies over the period are represented by large colonies. The largest colonies of some species have shown greater longevity through the decade than smaller colonies of the same species.

The 1995 hard coral mass bleaching event remains idiopathic on these reefs, while the 1998 event was clearly temperature driven. Hard corals on the three study reefs responded differentially to the bleaching events but with greater similarity in the 1998 event. Bleaching differed significantly among coral species but occurred more equally among species in the 1998 event. Recovery was the norm in both bleaching events.

Two hurricanes that struck the Island during the decade led to no measurable damage on the study reefs.

SUMMARY

While the patch reef hard corals in this study undergo annual changes in colony number and variety and have been exposed to a range of environmental stresses such as bleaching, disease, and storms, they have shown remarkably little change throughout this past decade.

ACKNOWLEDGEMENTS

This work is supported by grants from Earthwatch Institute. Additional in-kind support is provided by the Gerace Research Station, Corning Community College, and the University of South Carolina at Aiken. Dr. Garriet W. Smith of University of South Carolina at Aiken and Dr. Donald Gerace of the Gerace Research Station provided support and funding for startup. Laura McGrath provides field and logistical support. Elizabeth Brill is the project photographer and provides general field support. John Rollino provides added field support. Most important are the Earthwatch volunteers whose contributions of time, energy and money make this work possible.

REFERENCES CITED

Buchan, K.C., 2000, The Bahamas: Mar. Poll. Bull., v. 41, n. 1-6, p. 94-111.

Burke, C., 1997, Abstract on Belize bleaching:

http://coral.aoml.noaa.gov/archive/champ/list-archives/coral-list-1997.txt.

Cook, C.B., Logan, A., Ward, J., Luckhurst, B., and Berg, Jr., C., 1990, Elevated temperature and bleaching on high latitude coral reef: the 1988 Bermuda event: Coral Reefs, v. 9, p. 45-49.

D'Elia, C.F., Buddemeier, R.W., and Smith, S.S., (eds.), 1991, Workshop on Coral Bleaching, Coral Reef Ecosystems and Global Climate Change: Report of Proceedings: Maryland Sea Grant.

Edmunds, P.J., 2002, Long-term dynamics of coral reefs in St. John: Coral Reefs, v. 21, p. 357-367.

Gardner, T.A., Côté, I.M., Gill, J.A., Grant, A., and Watkinson , A.R., 2003, Long-term region-wide declines in Caribbean corals: Science Online, 10.1126/science.1086050.

Goreau, T.J., 1990, Coral bleaching in Jamaica: Science, v. 343, p. 417.

Grigg, R.W., and Dollar, S.J, 1990, Natural and anthropogenic disturbance on coral reefs: Dubinsky, Z editor, Coral Reef Ecosystems, Elsevier, Amsterdam, p. 453-468.

Lang, J.C., Lasker, H.R., Gladfelter, E.H., Hallock, P., Jaap, W.C., Losada, F.J., and Muller, R.G., 1992, Spatial and temporal variability during periods of "recovery" after mass bleaching on Western Atlantic coral reefs: Amer. Zool., v. 32, p. 96-706.

McGrath, Thomas A., 1992, Long-term study of coral bleaching events on the reefs of San Salvador Island, Bahamas in. Proceedings of the 4th Symposium on the Natural History of the Bahamas. W. Hardy Eshbaugh, ed. Bahamian Field Station, Ltd.

McGrath, T.A., Gerace, D.T., and Smith, G.W., 1994, Monitoring the patch reefs of San Salvador, Bahamas for changes due to bleaching and disease: Proceedings of the 26th Meeting of the Association of Marine Laboratories of the Caribbean, San Salvador, Bahamas. Compiled by Donald T. Gerace Bahamian Field Station, Ltd.

McGrath, T.A., and. Smith, G.W, 1998, The effects of the 1995/1996 Western Atlantic bleaching event on the patch reefs of San Salvador, Bahamas: *Rev. Biol. Trop.*, v. 46, n. 5, p. 91-100.

McGrath, T.A., and Smith, G.W., 2001, Monitoring the coral patch reefs of San Salvador Island, Bahamas: Proceedings of the 8th Symposium on the Natural History of the Bahamas.

McGrath, T. A., and Smith, G. W., 2003, Comparisons of the 1995 and 1998 bleaching events on the patch reefs of San Salvador Island, Bahamas: *Rev. Biol. Trop.*, In Press.

Porter, J.W. and Meier, O.W., 1992, Quantification of loss and change in Floridian reef coral populations: Am. Zool., v. 32, p. 625-640.

Richardson, L.L., Aronson, R.B., Goldberg, W.M., Smith, G.W., Ritchie, K.B., Kuta, K.G., Halas, J.C., Feingold, J.S., and Miller, S.L., 1998, Florida's mystery coral-killer identified: Nature, v. 392, p. 557-558.

Smith, G.W., Ives, L.D., Nagelkerken, I.A., and Ritchie, K.B., 1996, Caribbean Sea Fan Mortalities: Nature, v. 383, p. 487.

Smith, S.V. and Buddemeier, R.W., 1992, Global change and coral reef ecosystems: Annu. Rev. Ecol. Syst., v. 23, p. 89-118.

Wells, S.M., 1995, Reef assessment and monitoring using volunteers and non-professionals: Tropical Marine Research Unit, University of York, England. Rosentiel School, Univ. Miami.

Wilkins, C, 2000, Report of the Joint Meeting of the GCRMN Management Group and GCRMN Science and Technical Advisory Committee. ngdc.noaa.gov/paleo/paleo.html