PROCEEDINGS OF THE COLLOQUIUM ON GLOBAL ASPECTS OF CORAL REEFS: HEALTH, HAZARDS AND HISTORY

Compiled by Robert N. Ginsburg

Commemorating the Fiftieth Anniversary of

University of Miami's

ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

and its Founder and Long-Time Dean

F.G. WALTON SMITH

With the cooperation of

THE INTERNATIONAL SOCIETY FOR REEF STUDIES

JUNE 10, 11, 1993

SPONSORED BY

The John D. and Catherine T. MacArthur Foundation

The National Science Foundation

The National Oceanic and Atmospheric Administration

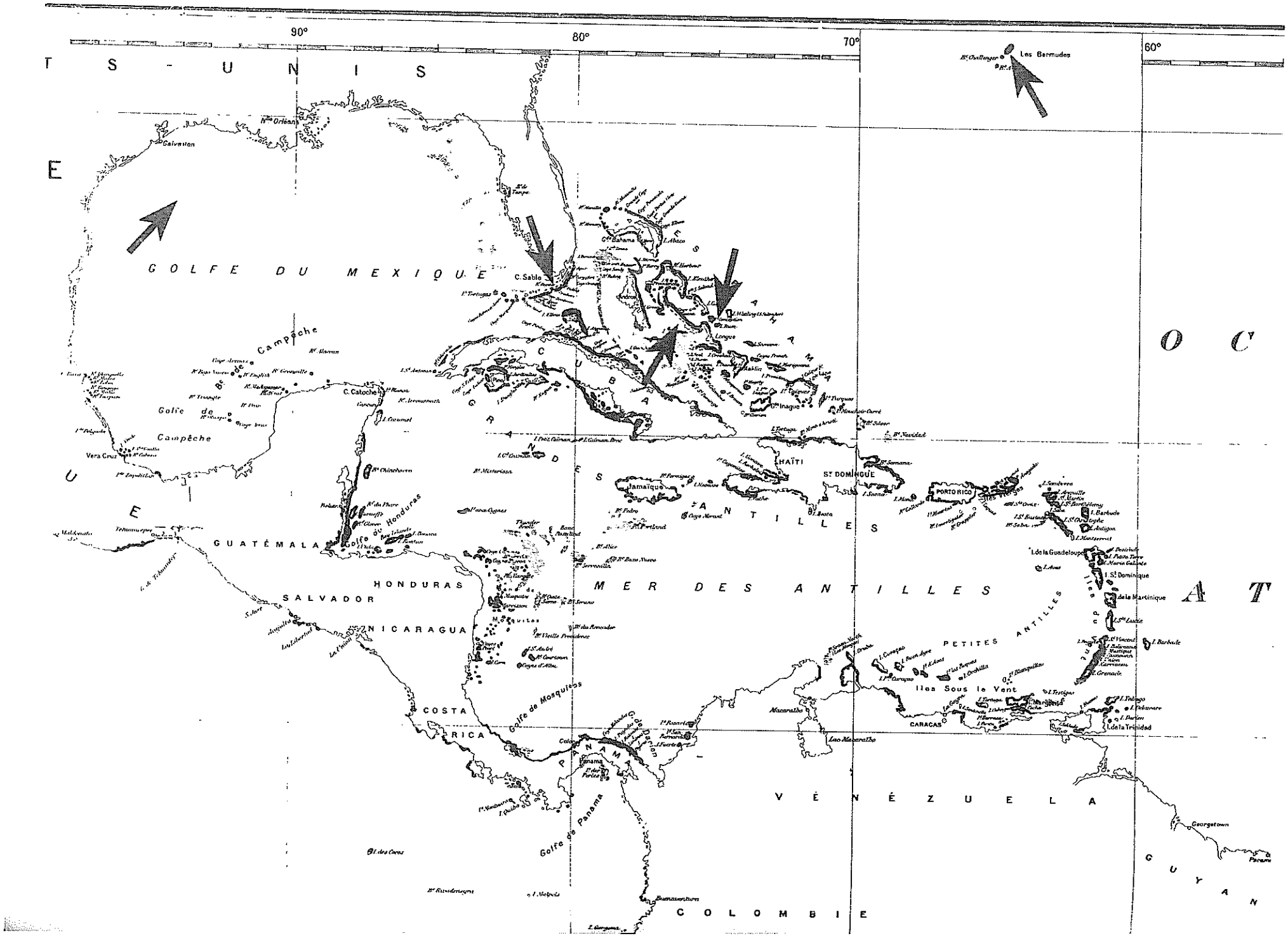
The Minerals Management Service

ORGANIZING COMMITTEE

ROBERT N. GINSBURG, CHAIRMAN

JAMES BOHNSACK ARTHUR MYRBERG JR.

PETER W. GLYNN ALINA SZMANT PETER K.SWART


90°
80°
70°
60°
T S - U N I S
E
Les Bermudes
Galveston
G O L F E D U M E X I Q U E
C. Sable
Campêche
C. Catoche
Golfe de Campêche
Vera Cruz
U E
Golfe du Honduras
G U A T É M A L A
HONDURAS
SALVADOR
N I C A R A G U A
COSTA RICA
Golfe de Mosquitos
Golfe de Darien
P A N A M A
Golfe de Panama
C O L O M B I E
V É N É Z U E L A
G U Y A N
C U B A
Jamaique
HAÏTI
St DOMINGUE
PORTO RICO
G R A N D E S A N T I L L E S
M E R D E S A N T I L L E S
PETITES ANTILLES
Iles Sous le Vent
CARACAS
I. de la Guadeloupe
I. St Dominique
I. de la Martinique
I. de la Trinidad
Georgetown
O C
A T

THE HEALTH AND SHORT-TERM CHANGE OF TWO CORAL PATCH REEFS, FERNANDEZ BAY, SAN SALVADOR ISLAND, BAHAMAS

H. Allen Curran[1], Durelle P. Smith[1], Lucy Chambers Meigs[2], Ann E. Pufall[1], and Mary Lisa Greer[3]

[1] Department of Geology, Smith College, Northampton, Massachusetts 01063. [2] Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, Wisconsin 53706. [3] Department of Geology, Colorado College, Colorado Springs, Colorado 80903

ABSTRACT

Two coral patch reefs on the leeward shelf of San Salvador Island have been studied with surveys in 1983-84 and 1992 to monitor their ecologic health and short-term change. Snapshot Reef covers an area of 50 x 50 m and is dominated by *Montastrea annularis*. The reef was mapped in detail to show the position and size of its coral heads and 64 of these heads were studied in detail. To describe the reef, measurements were made of the height of each head, percent live coral coverage, the dominant coral species, total number of coral species present, *M. annularis* morphotypes present, and the relative occurrence of algae, sponges, octocorals, and dead coral surface. Several types of statistical analyses were performed, indicating a direct relationship between height and number of coral species and also between relative abundance of octocorals and number of coral species. An inverse relationship was observed between relative abundance of algae and amount of bare coral surface. There was a strong correlation between height in 1992 and a combination of percent living coral and number of coral species. An average increase in size of the coral heads of 13 cm from 1984 to 1992 was determined, and there were significantly more coral species, less algae, and less sponge on each head in 1992 than 1984. However, there was not a significant change in the percentage of live coral on the heads. The overall picture is one of a reef in at least a steady state condition. There also is a strong correlation between coral head height in 1992 and a combination of the number of coral species and relative abundance of algae. This relationship may provide a useful means of predicting the future "health" of a given coral head.

The nearby Telephone Pole Reef has been studied by comparisons of transects and photographs made in 1983 and 1992, and they reveal that significant recent change has occurred. In 1983, this reef consisted largely of *M. annularis* heads with dense thickets of *Acropora cervicornis* in its outer parts. Today the *M. annularis* heads remain seemingly unchanged, but virtually all of the *A. cervicornis* has died and collapsed to form layers that now are being covered by rapidly growing heads of *Porites porites*. These surveys have established a baseline for monitoring of the health and short-term change on both of these reefs in the future.

INTRODUCTION

Most previous studies of modern coral reefs have focused on barrier, bank-barrier, and fringing reefs. Surprisingly, there have been few studies devoted to coral patch reefs, although patch reefs commonly are a prominent element of modern reef complexes (Brown and Dunne, 1980). Nonetheless, relatively little is known about the ecologic health and short-term change on such reefs. This study was concerned with two *Montastrea annularis*-dominated patch reefs, Snapshot Reef and Telephone Pole Reef, located in Fernandez Bay on the leeward shelf of San Salvador Island, Bahamas (Figure 1). The purpose of the study was to document the state of the two patch reefs with respect to physical setting, community structure, diversity, and short-term change. Initial surveys of the two reefs were conducted in June of 1983 and 1984, and follow-up surveys using similar methods were made in June, 1992. Analysis of the data from the two surveys has permitted recognition of some short-term changes on the reefs and gives an indication of the present health of the reefs. In addition, a baseline of observations now is in place to permit monitoring of future natural and human-induced change on these two patch reefs, both of which are popular sites for visitation by sport scuba divers. With the recent opening of a large Club Med on San Salvador, possibly the biggest news on the island since its "discovery " by Columbus, these reefs likely will be more heavily used for recreation in the future, and they may provide good test sites for monitoring the effects of sport scuba diver visitation.

San Salvador is located about 600 km ESE of Miami on an isolated carbonate platform, well east of the Great Bahama Bank (Figure 1). The island is bordered by a narrow shelf with an abrupt shelf-edge break leading to a very steep slope. The eastern and southeastern coasts of the island typically are windward to the prevailing trade winds. A well-developed *Acropora palmata*-dominated bank-barrier reef lies off the north coast of the island, and smaller bank-barrier reefs occur along the southeast and southern coasts. Hundreds of small patch reefs dot the

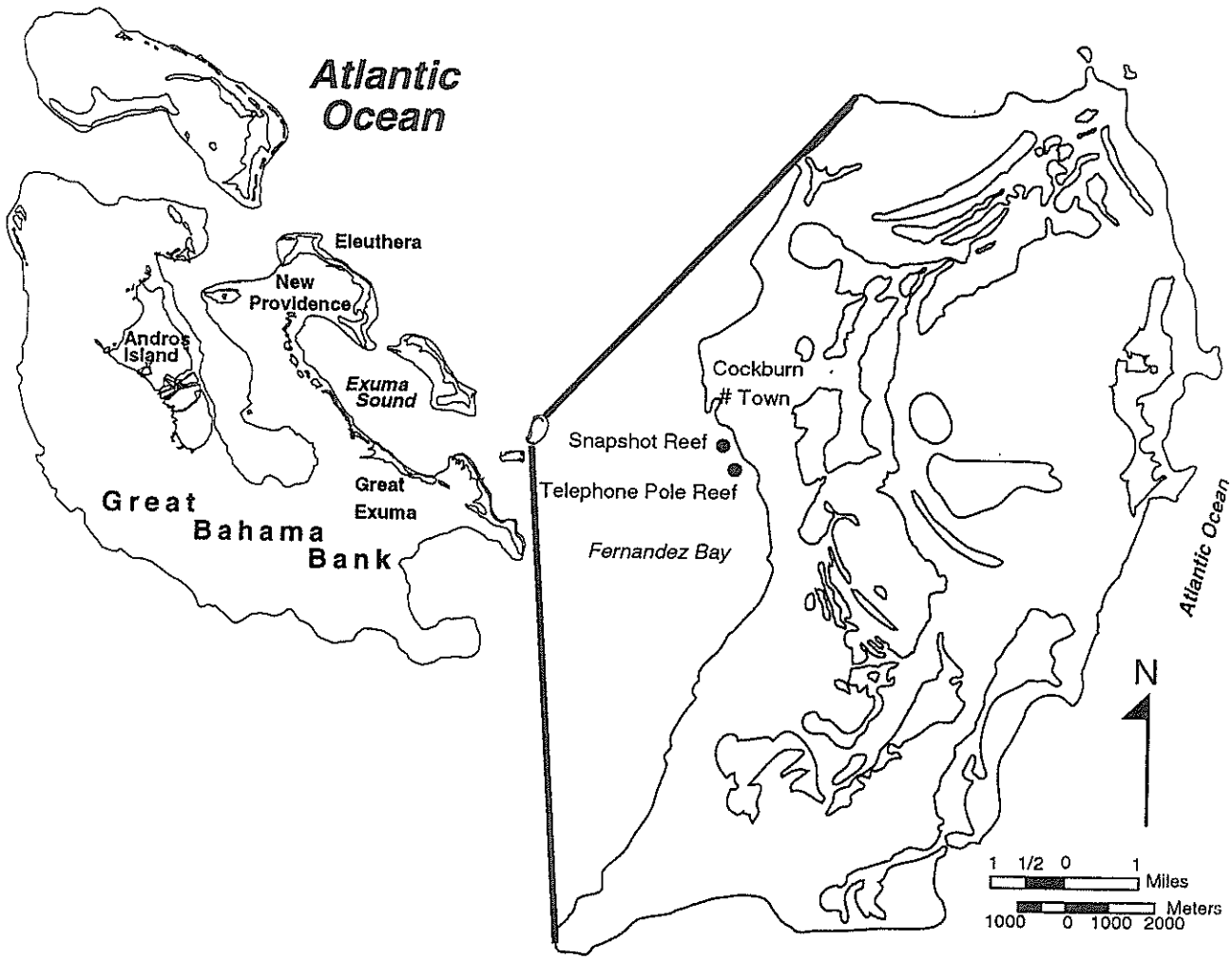


Figure 1. Location of San Salvador Island, Bahamas and Snapshot and Telephone Pole reefs in Fernandez Bay, off the island's leeward coast.

island's eastern shelf, and on the leeward western shelf larger patch reefs occur in the broad embayments of the coast. The Snapshot and Telephone Pole reefs of Fernandez Bay are two of the better developed patch reefs along the island's west coast. Both reefs lie about 200 to 250 m offshore in water depths of 4 to 5 m and are well-bathed by fully oceanic waters. No significant bleaching events have been reported for these reefs. The landward margin of Fernandez Bay is bordered by a road, but the area is only sparcely populated. Both patch reefs can be reached by swimming from the beach or by small boat.

METHODS

The Field Surveys

Snapshot Reef.—Consisting of an aggregation of individual coral heads dominated by *M. annularis*, this patch reef occupies an area of about 50 x 50 m. A detailed, plan view map of the reef (Figure 2) was made by Chambers (1984), with minor revisions made during June, 1992. A set of 64 coral heads were identified, numbered, and studied in some detail in both surveys. A protocol was used during both surveys (modified and expanded in 1992) to provide a means for systematic observations of each head as follows: 1) accurate measurement of coral head height; 2) visual estimate of the percentage of live coral coverage (1=0-20%, 2=21-40%, 3=41-60%, 4=61-80%, 5=81-100%); 3) dominant coral species present; 4) total number of coral species present; 5) relative abundance of non-scleractinian components, i.e. algae, sponges, octocorals, and dead coral surface (1=rare, 2=minor, 3=common, 4=dominant); 6) presence of *M. annularis* morphotypes, as described by Knowlton et al. (1992).

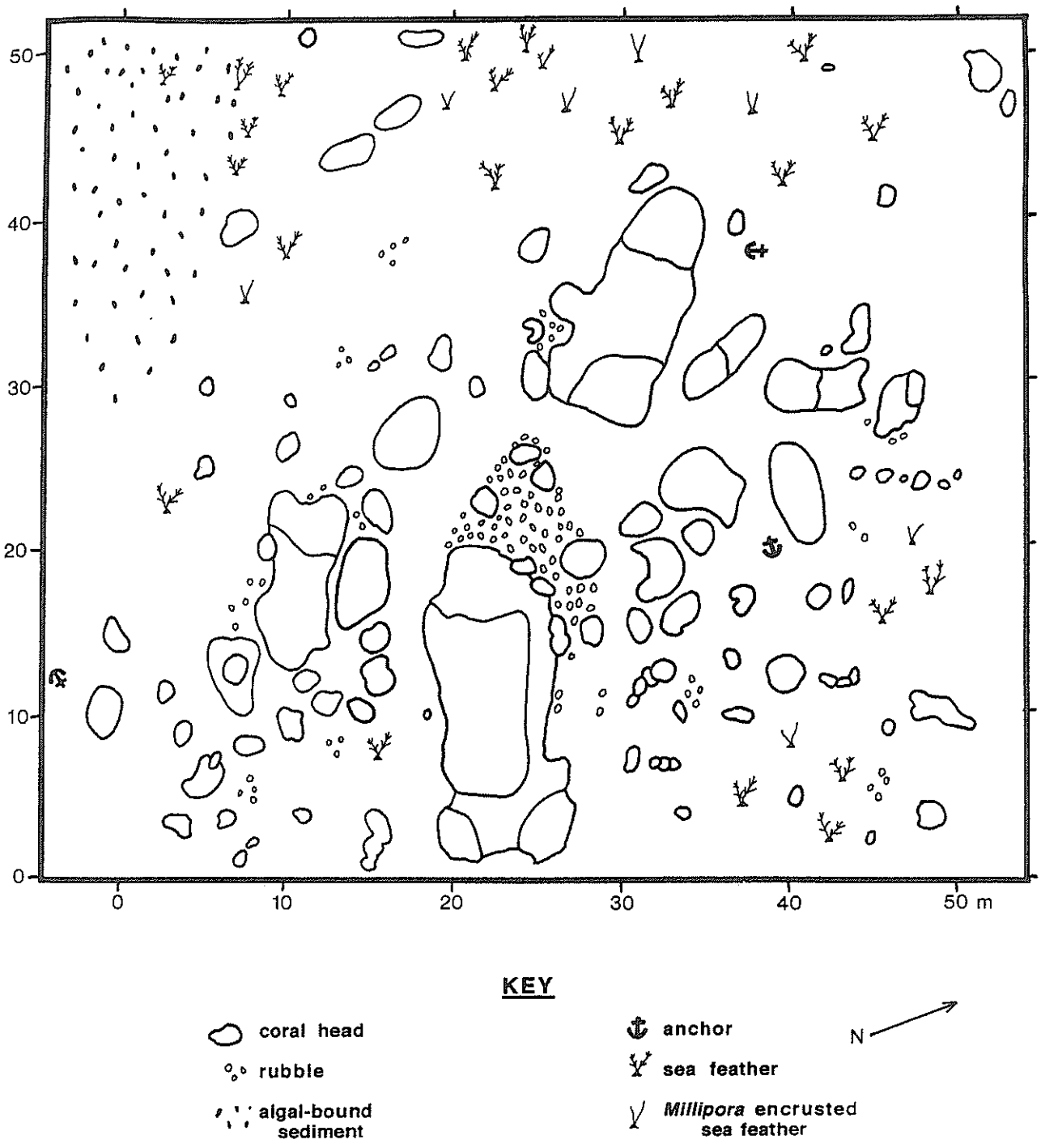


Figure 2. Plan view map of Snapshot Reef. Sixty-four coral heads were identified and described for this study.

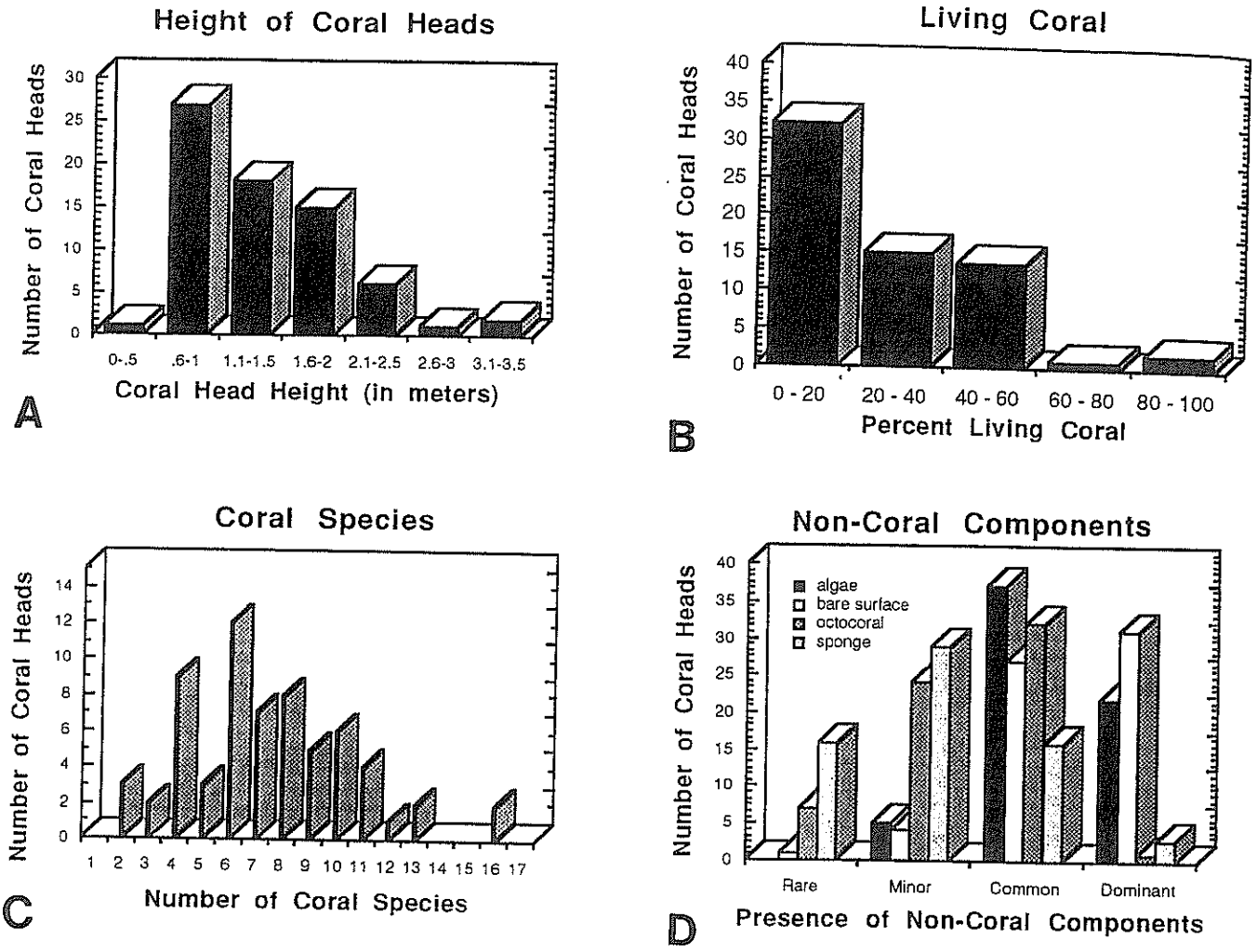


Figure 3. Frequency histograms showing A) height of the coral heads; B) percent living coral; C) number of coral species present; and D) relative abundances of non-coral components.

Telephone Pole Reef.—This is a larger, somewhat irregularly shaped patch reef dominated principally by large *M. annularis* heads separated by areas of smaller corals growing on layers of dead *Acropora cervicornis*. Heads of *Porites porites* now are rapidly spreading over the beds of dead *A. cervicornis*. Because of its larger size, it was not feasible to make a plan map, and this reef has been studied by constructing a series of transects (too lengthy to be reproduced here), beginning with a master transect (Erickson, 1985) that runs from the beach to a distance of 400 m offshore, seaward of the reef proper. Three shorter transect lines paralleling the master transect were constructed in June, 1992, over the main part of the reef to provide more complete coverage of the reef proper. The purpose of these transects was primarily to establish a baseline for the measurement of future change on this reef. A similar protocol as described above was used for collection of data from 32 *M. annularis* heads.

Data Analysis

For Snapshot Reef, frequency histograms (Figure 3) were drawn from the 1992 survey data to illustrate general trends and to form a descriptive definition of the present state of the reef. General descriptive statistics including means, medians, standard deviations, and variances of the variables were calculated. Pearson product-moment correlation coefficients were used to assess relationships between pairs of variables. Multiple regression was used to determine if any of the measured variables were predictors of height or percent living coral on a given coral head. Height and percent living coral were chosen as the dependent variables for the multiple regressions because these variables appear to be our best indicators of the health of the reef. We think that the ability to predict either of these variables may prove to be a useful tool in predicting the health of a given reef. T-tests were used to compare the 1984 survey data with that of 1992 to see if any significant short-term changes on the reef could be

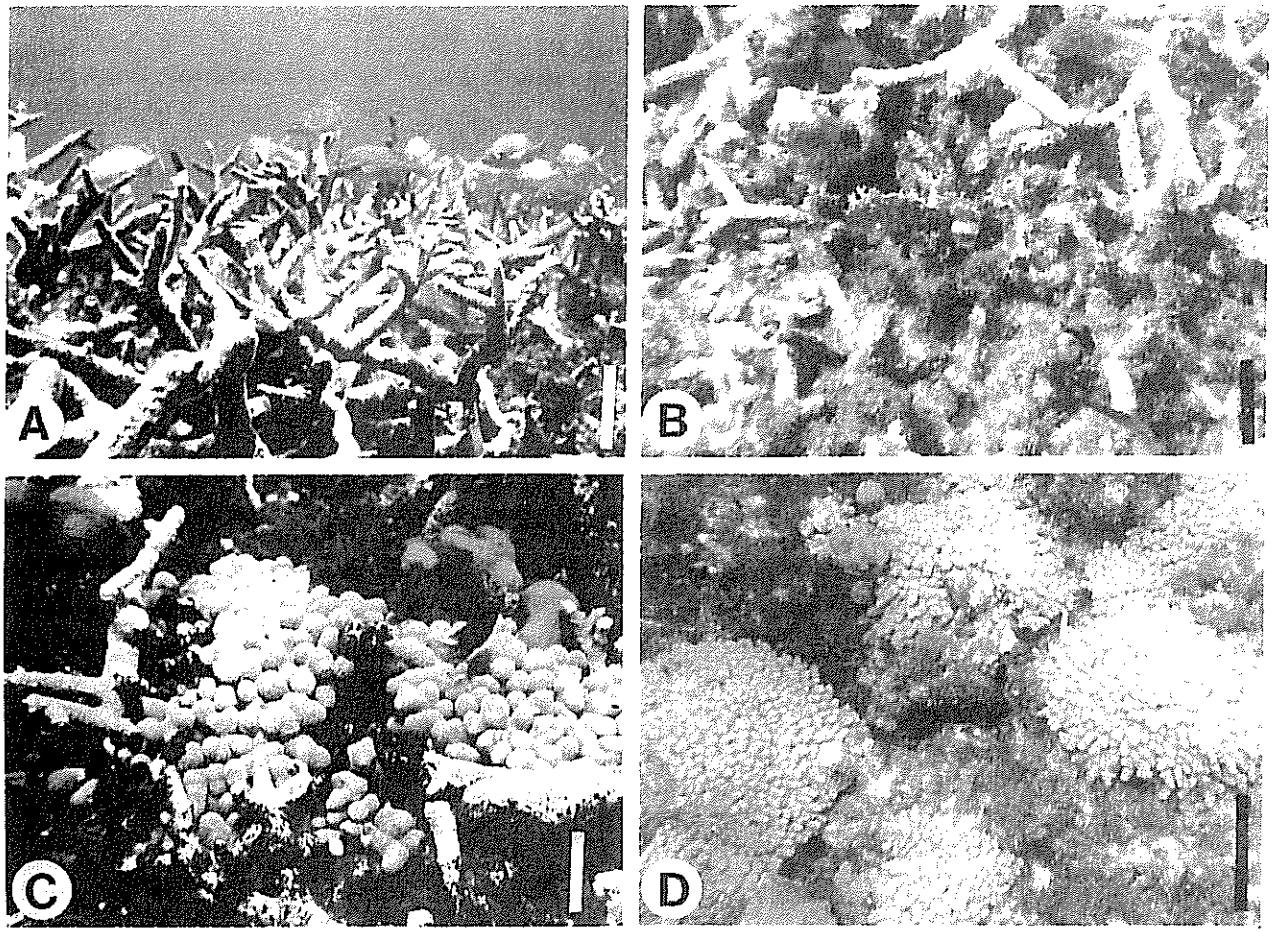


Figure 4. Photographs from Telephone Pole Reef: A) thicket of living *Acropora cervicornis*, 1983, bar scale = 15 cm; B) dead *A. cervicornis*, largely collapsed, 1992, bar scale = 15 cm; C) small head of *Porites porites* growing on *A. cervicornis*, 1983, bar scale = 15 cm; D) large heads of *P. porites*, commonly growing on a layer of dead *A. cervicornis*, 1992, bar scale = 25 cm.

detected. Data histograms similar to those of Figure 3 also have been made for Telephone Pole Reef using 1992 data, but they are not reported here because we have no earlier survey data. Our analysis of Telephone Pole Reef reported here is based on qualitative comparison of transects and photos from 1983 and 1992 surveys.

RESULTS

Present State and Short-term Change of Snapshot Reef

From the histogram data of Figure 3, it can be determined that the mean coral head height for this reef was 1.36 m, mean percent living coral was 37%, mean number of coral species per head was 7, with algae and bare coral surface being the dominant non-coral components and morphotype 1 as the dominant morphotype of *M. annularis*. There was a strong direct relationship between height and number of coral species, r (df=52) = 0.703, and also between relative abundance of octocorals and number of coral species, r (df=52) = 0.488. A fairly strong inverse relationship was observed between relative abundance of algae and amount of bare coral surface, r (df=52) = -0.527. There was a strong relationship between height in 1992 and a combination of the percent living coral and the number of coral species, R = 0.732, R^2 = 0.535. An average growth of the coral heads of 13 cm from 1984 to 1992 was

significant, t (df=60) = 4.968, $p < .0001$. There were significantly more coral species, t(df=56) = 2.679, $p < .01$, less algae, t(df=58) = -2.585, $p < .01$, and less sponge, t(df=58) = -5.543, $p < .0001$, on each head in 1992 than in 1984. However, there was not a significant change in the percentage of live coral on the heads. We also found a strong correlation between height in 1992 and a combination of the number of coral species and the relative abundance of algae in 1984, R = 0.928, $R^2 = 0.860$.

Short-term Change on Telephone Pole Reef

Comparisons of transects and photographs made on this reef in 1983 and 1992 clearly indicated that in the intervening years all of the *A. cervicornis* originally present and seemingly healthy has died (Figure 4). Today there are only two or three small branches of living *A. cervicornis* on this reef. *P. porites* heads, most appearing healthy and many 1 m in diameter or larger, now are common on this reef, and often are growing on the layer of dead *A. cervicornis*. We now have baseline data on many of the large *M. annularis* heads of this reef but cannot yet make historical comparisons. Visually, these heads appear to be in the general same state of health as those of Snapshot Reef.

DISCUSSION

Data from the frequency histograms reveal a picture of Snapshot Reef in 1992. Most of the 64 coral heads are between 0.5 to 2 m tall and have less than 60% living coral, 4 to 11 coral species are found on each head, *M. annularis* morphotype 1 is dominant and 3 is common, and *Agaricia agaricites*, algae, and bare coral surfaces all are common on the heads. Our measurements indicated that the coral heads are growing (mean 13 cm/8years). If calculated as a growth rate, our rate would be somewhat higher than previously reported growth rates for *M. annularis* (10.7 mm/yr., Hoffmeister & Multer, 1964; 10 mm/yr., Hudson, 1979; 7.8 mm/yr., Knowlton et al., 1992), but we were measuring the heights of coral heads, not the true growth rate of individual coral heads, so we suspect that operator measurement error would account for our larger number. Nonetheless, we do believe that the coral heads truly have grown during the study period. We interpret Snapshot Reef to be in at least a steady state condition given that the mean of percent living coral on the heads has not changed and that species diversity is increasing. A recent study of the crinoids on Snapshot Reef (Meyer et al., 1991) indicates that the populations of the two species of *Nemaster* that reside on the large *M. annularis* heads are holding their own or even slightly increasing, and this might also be taken as a sign of the steady health of the reef as a whole. In addition, 86% of the variability of the present height of the heads in 1992 can be predicted from the number of coral species and relative abundance of algae found on each head in 1984. In other words, if the number of coral species and relative abundance of algae is known for a given coral head, 86% of the variability of the height of that coral head can be predicted. This relationship may be a useful means of predicting the future "health" of a given coral head.

Clearly, Telephone Pole Reef is in a state of significant change. The thickets of *A. cervicornis* that were luxuriant here in the late 1970's-early 1980's (and, in fact, gave the reef its other local name, Cervicornis Reef) have died and largely become layered. The cause of death is unknown; we are not aware of any major storm that may have adversely affected the reef, and no disease or bleaching event has been reported. A successional event is taking place with the advent and rapid growth of *P. porites* heads and some other corals over the areas of dead *A. cervicornis*, and we recently have initiated a study to monitor the growth of *P. porites* in a selected area of this reef.

CONCLUSIONS

Through synthesis of field observations and statistical analyses of survey data gathered in the early 1980's and 1992, the ecologic health and short-term changes on two coral patch reefs was determined. Snapshot Reef, dominated by large *M. annularis* heads, has shown the following trends over an eight-year period: 1) overall growth of the coral heads; 2) increase in species diversity of the heads; and 3) a constant percentage of live coral on the heads. This reef has not shown signs of deterioration over the study period and appears to be in at least a steady state. Telephone Pole Reef has undergone rapid change in the past decade. Thickets of *A. cervicornis*, apparently healthy in the late 1970's-early 1980's, have died, and they now are being overgrown by rapidly growing heads of *P. porites*. The large *M. annularis* heads of this reef appear to be in a similar state to those of Snapshot Reef. A data baseline now is in place for the continued monitoring of these two coral patch reefs as they face an uncertain future of accelerating development on San Salvador Island and increased diver visitation.

ACKNOWLEDGMENTS

We thank the directors and staff of the Bahamian Field Station for full logistical support of our field work on San Salvador Island. The Keck Geology Consortium provided funding for the summer 1992 research from a grant from the W. M. Keck Foundation. Patricia Pierce Erickson is acknowledged for earlier research and an unpublished report on Telephone Pole Reef. David White helped greatly with the underwater field work, and Jennifer Christiansen assisted with preparation of the figures.

LITERATURE CITED

Brown, B.E. and R.P. Dunne, 1980. Environmental controls of patch reef growth and development. Marine Biology 56: 85-96.

Chambers, L., 1984. Snapshot Reef: A study of patch reef coral abundance and distribution, San Salvador Island, Bahamas. Smith College, Department of Geology, Special Studies Report. 77 pp. (unpublished).

Erickson, P.P., 1985. Field guide to Telephone Pole Reef (*Acropora cervicornis* Reef), San Salvador Island, Bahamas. Smith College, Department of Geology. 27 pp. (unpublished).

Hoffmeister, J.E. and H.G. Multer, 1964, Growth-rate estimates of a Pleistocene coral reef of Florida. Geol. Soc. America Bull. 75(4): 353-357.

Hudson, J.H., 1979. Absolute growth rates and environmental implications of Pleistocene *Montastrea annularis* in southeast Florida. Geol Soc. America Abstracts with Programs 7(1): 24 (abstract).

Knowlton, N., E. Weil, L.A. Weigt and H.M. Guzman, 1992. Sibling species in *Montastraea annularis*, coral bleaching, and the coral climate record. Science 255: 330-333.

Meyer, D.L., B.J. Greenstein and G. Llwellyn, 1991. Population stability of crinoids at Snapshot Reef, San Salvador, Bahamas. Pages 181-184 *in* R.J. Bain, ed. Proceedings of the fifth symposium on the geology of the Bahamas, Bahamian Field Station, San Salvador, Bahamas.