PROCEEDINGS OF THE 15TH SYMPOSIUM ON THE GEOLOGY OF THE BAHAMAS AND OTHER CARBONATE REGIONS

Edited by
Douglas W. Gamble and Pascal Kindler

Gerace Research Center
San Salvador, Bahamas
2012

Front Cover: *Porites* colony encrusted by red algae in waters of San Salvador, Bahamas; see paper by Fowler and Griffing., p. 41. Photograph by Pascal Kindler, 2011.

Back Cover:. Dr. Jörn Geister, Naturhistorisches Museum Bern, Keynote Speaker for the 15th Symposium and author of "Keynote Address – Time-Traveling in a Caribbean Coral Reef (San Andres Island, Western Caribbean, Colombia)", this volume , p. vii. Photograph by Joan Mylroie.

Press: A & A Printing

ISBN 978-0-935909-93-7

KEYNOTE ADDRESS: TIME-TRAVELING IN A CARIBBEAN CORAL REEF (SAN ANDRES ISLAND, WESTERN CARIBBEAN, COLOMBIA)

Jörn Geister
Naturhistorisches Museum Bern
Bernastrasse 15 CH-3005 Bern Switzerland

ABSTRACT

Based on time-series of underwater photographs, taken between 1968 and 2007 at five distinct observation stations off San Andres Island, the following biotic changes have been documented and dated: partial and total coral mortality, impact of coral diseases, growth and regeneration of coral colonies, fusion and fission of colonies, and bioerosion of a large coral head. From the complete photographic series (not reproduced here) it appears that algal encroachment since the mid-1970s was a gradual process that initiated long before the die-off of algae-feeding *Diadema* sea urchins. Extensive coral death occurred in the 1980s. From the mid-1990s till present there was a gradual but steady process of recovery of most reef sites studied. However, many coral associations fundamentally changed, and extensive algal growth persists till present. Reviewing the pictures, we shall virtually drift with time from 1968 to 2007.

INTRODUCTION

At San Andres, an isolated oceanic coral island in the western Caribbean (see Geister, 1973; Geister, 1975; Diaz et al. 1995; Geister and Diaz, 1997), since 1968, time-series of submarine photographs were taken in a number of "Reef Stations" (Rs) at irregular intervals but over a period of up to 40 years. These sites are situated in or near "Little Reef", an easily accessible shallow fringing reef N of the island, protected from the direct impact of incoming swell by an outer barrier reef. Only Rs J lies off the fringing reef at the bottom of a reef pass, which connects the lagoon with the open sea to the N (Figure 1).

The photographic record provides a rich database for the retrospective analysis of biotic changes that have occurred over a time-span of four decades. Four instructive photographs from each of five sites featuring the state of the reef in one particular year have been selected to document the changes in this paper. Additional photographs taken in intermediate years are not

Figure 1. Panoramic aerial view of Little Reef lining the northern shore of San Andres Island. View to W from a position approximately above the barrier reef (not visible). The dark area between Little Reef and the island shore corresponds to the boat channel, a shallow sea grass belt, 1 to 1.2 m deep. The dark area in front of Little Reef is part of the lagoonal basin with about 6 to 8 m of water depth. The location of Reef Stations A, B, C is marked. Reef Station J lies 1700 m to the NNW from Little Reef on the rocky floor of "Snapper Shoal Channel" connecting the lagoonal basin with the open sea in the N. It is out of the view angle of the picture. August 1970.

published here, but were used to interpret, to date and to support our observations.

By examining successive time slices recorded by the photographs, we are able to detect retrospectively, to monitor and to approximately date the beginning of upcoming major and minor changes in the living reef environment that would otherwise go unnoticed to the casual observer. Time-series of photographs from other sites (thickets of *Acropora cervicornis* at Rs G and *Porites porites* at Rs H), not included in this paper, have been discussed elsewhere (Geister, 1999; Geister, 2001; Zea et al., 1998).

DEGRADATION AND CHANGE IN MODERN CORAL REEFS

In the last more than 30 years, alarming reports have been published focussing on die-offs of reef invertebrates, algal invasions, and general degradation of modern coral reefs (Antonius, 1995; Birkeland, 1997; Ginsburg, 1994; Lessios et al., 1984; Williams and Bunkley-Williams, 1990; Zea et al., 1998). However, most of these studies were initiated after the changes had already occurred. Thus, it was difficult to establish precisely the state of the reef before and at the beginning of degradation. Covering an entire degradation cycle by time-series photographs of particular reef sites is necessarily a study of long breath, which must ideally extend over a time-span of several decades, especially as many permanent changes may only become recognizable towards the end of observations.

Corals die from a variety of causes, most obvious being fragmentation of branching colonies by storm waves and tissue destruction by bleaching events. Complete destruction of polyp tissue irrevocably causes the death of the entire colony. Partial tissue destruction may be regenerated from the living margin of the colony. Under favourable conditions, seemingly dead skeletons may rapidly be recolonized by lateral encroachment of polyps from surviving minute pockets of living tissue.

"Reef Station A": Death and post-mortem degradation of moose-horn coral *Acropora palmata.*

GPS coordinates of Rs A: N12.58179° W81.68444°. View to S

Figure 2/1: Rs A in summer 1968.

This patch of extraordinarily thick-branched colonies of *Acropora palmata* is very conspicuous and for this reason was easily located again during subsequent visits in the fringing reef, even after absences of several years. The blunt ends of the thick, almost cylindrical branches point in direction of the incoming waves, which due to wave refraction approach from northerly to northwesterly directions at this site.

Figure 2/2: Rs A in early May 1977.

The central *A. palmata* branches have fallen down the fringing reef slope (possibly struck by a launch) anytime after 1973. The rest of the biota seems to be untroubled. No major change can be recognized.

Figure 2/3: Rs A on July 30, 1979.

The site seems to be essentially unchanged since 1977. The fallen *A. palmata* branches are still alive.

Figure 2/4: Rs A on August 10, 2006.

The situation has entirely degraded. All the *A. palmata* colonies are dead and encrusted by red algae. Branches lying on the fore-reef slope seem to have diminished in size (effects of grazing?). Soft brown algae (*Dictyopteris* ? sp.) colonize rubble and crevisses. Colonies of the fire coral *Millepora* sp. persist and flourish now even on top of the *in-situ A. palmata* colonies. The death of the *A. palmata* thicket occurred probably during the Caribbean-wide bleaching events in the 1980s (Williams and Bunkley-Williams, 1990). During a visit in 1993 the entire *A. palmata* group was already dead and covered by algal crusts. Standing dead branches of *A.*

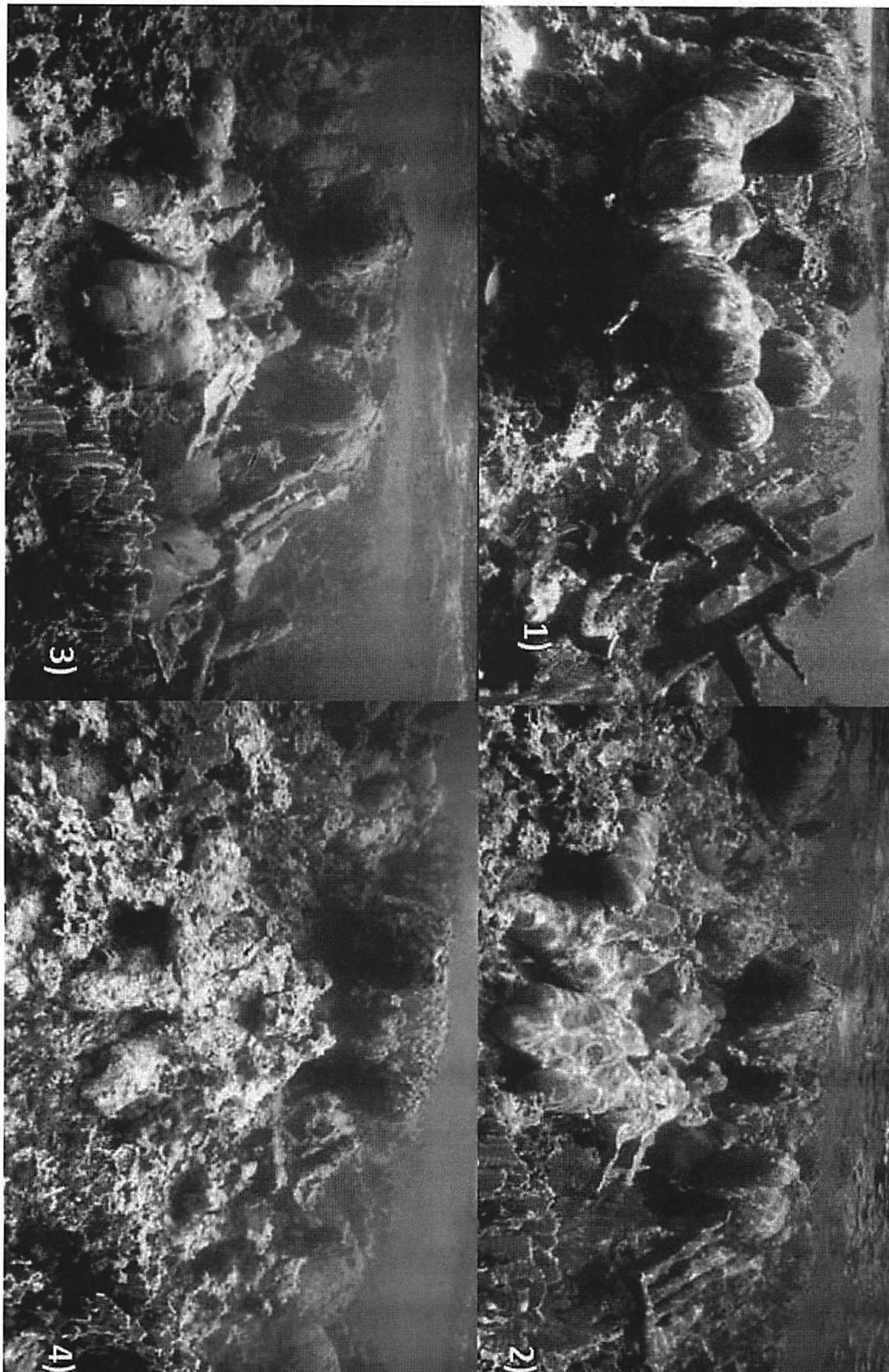

Figure 2. "Reef Station A": Death of Acropora palmata branches. View to SE: 1) 1968. Blunt A. palmata branches point towards incoming waves; 2) 1977. Some branches have broken off but continue to flourish; 3) 1979. Situation essentially unchanged since 1977; and 4) 2006. A. palmata colonies are dead, bioeroded and encrusted.

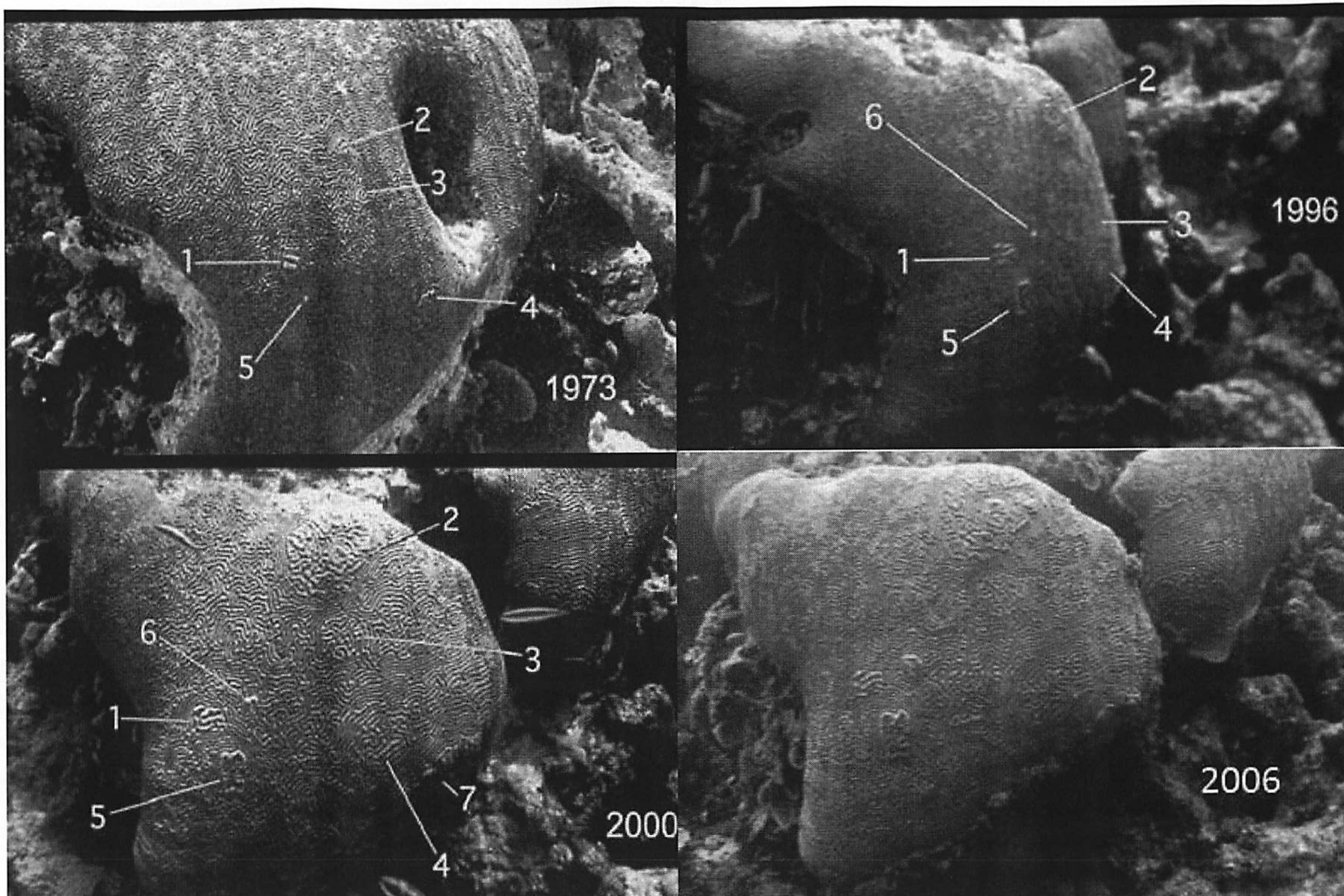

Figure 3. "Reef Station B": Development of tumors in large Diploria strigosa. View to NW: 1) 1973. Numbers 1 to 4 mark existing tumors. 5 will be a future tumor site; 2) 1996. Tumors in progress. 5 marks new tumor. 6 marks future tumor site; 3) 2000. Tumors in progress. 6 marks new tumor, 7 tumor at colony margin; and 4) 2006. Tumors 1-6 in progress. Compare with figures 2/1 to 2/3.

palmata show little impact of bioeroders and storms. They may be found standing upright for more than 10 years, being no more susceptible to breakage than neighboring live branches.

"Reef Station B": Origin and development of tumors in brain coral *Diploria strigosa.*

GPS coordinates at Rs B: N12.58 288° W81.68 507°. View towards N.

Rs B lies on western side of the reef pass opposite to Rs A. For overall photographic views of this particular site, see also Geister (2001: figures 3/1-4).

Figure 3/1: Rs B in early May 1973.

Major colony of the brain coral *Diploria strigosa* shows various growth stages of Neoplasia tumors (Bak, 1983; Loya et al., 1984). Numbers 1-4 refer to various tumors to be followed on succeeding pictures over the years. At number 5 a flake of filamentous algae has grown on the colony surface.

Figure 3/2: Rs B on July 9, 1996.

Existing Neoplasia tumors 2 and 3 have considerably expanded. At 5 a new tumor has formed. At 6 a whitish flake of filamentous algae marks the spot where another small tumor will be found in 2000.

Figure 3/3: Rs B on August 29, 2000.

Expansion of existing tumors 1-5. Number 6 indicates a freshly formed tumor on former site of algal flake. Tumor 6 is already well developed. Number 7 marks a tumor at lower edge of colony where living coral tissue is in contact with dense algal growth.

Figure 3/4: Rs B on August 10, 2006.

Tumors 2, 3 and 4 have expanded considerably within the last six years. Other tumors are still conspicuous but grew more slowly.

The tumors of the Neoplasia type in *Diploria strigosa*, observed since 1973, continued to expand, but some became less distinct with time. Tumors initiate in what appear to be small lesions of the coral tissue (fish bites?) colonized by soft algae. Subsequently, Neoplasia is probably triggered in corals by a toxic shock delivered by these algae. Starting from the former fixing points of algal flakes, tumors are spreading gradually with the years over much of the coral surface area. In addition, tumors are contorting visibly the original meander pattern of the coral thus altering significantly taxonomic characters within the affected area. Here, width of meander valleys may be almost doubled and interseptal spaces may increase notably. Apparently, the general health of the coral colony is not affected by this kind of tumor formation.

"Reef Station C": Impact of "Blackband Disease" (BBD) in brain coral *Diploria strigosa.*

GPS coordinates of Rs C: N12.58378° W81.68609°. View towards SE.

Figure 4/1: RsC in July 1970

Lush growth of massive brain corals *Diploria strigosa*, moose-horn corals *Acropora palmata* and finger corals *Porites porites* facing the boat channel of Little Reef.

Figure 4/2: Rs C in early May 1977.

Most of the *P. porites* colonies from figure 4/1 were still present on pictures taken in April 1973, but had almost disappeared since. Brown algae (*Dictyopteris* ? sp.) replacing sea grass on the left were already present in 1973, but since then became more conspicuous also between coral colonies. Larger corals with the exception of necrose *A. palmata* branches in the center appear healthy and undamaged.

Figure 4/3: Rs C on Oktober 11, 1994.

All of the *A. palmata* colonies have died, presumably by bleaching in the 1980s. The branching *Porites porites* colonies have disappeared. The large *D. strigosa* colony in the foreground is seriously struck by an infection of the Blackband Disease (BBD). The small

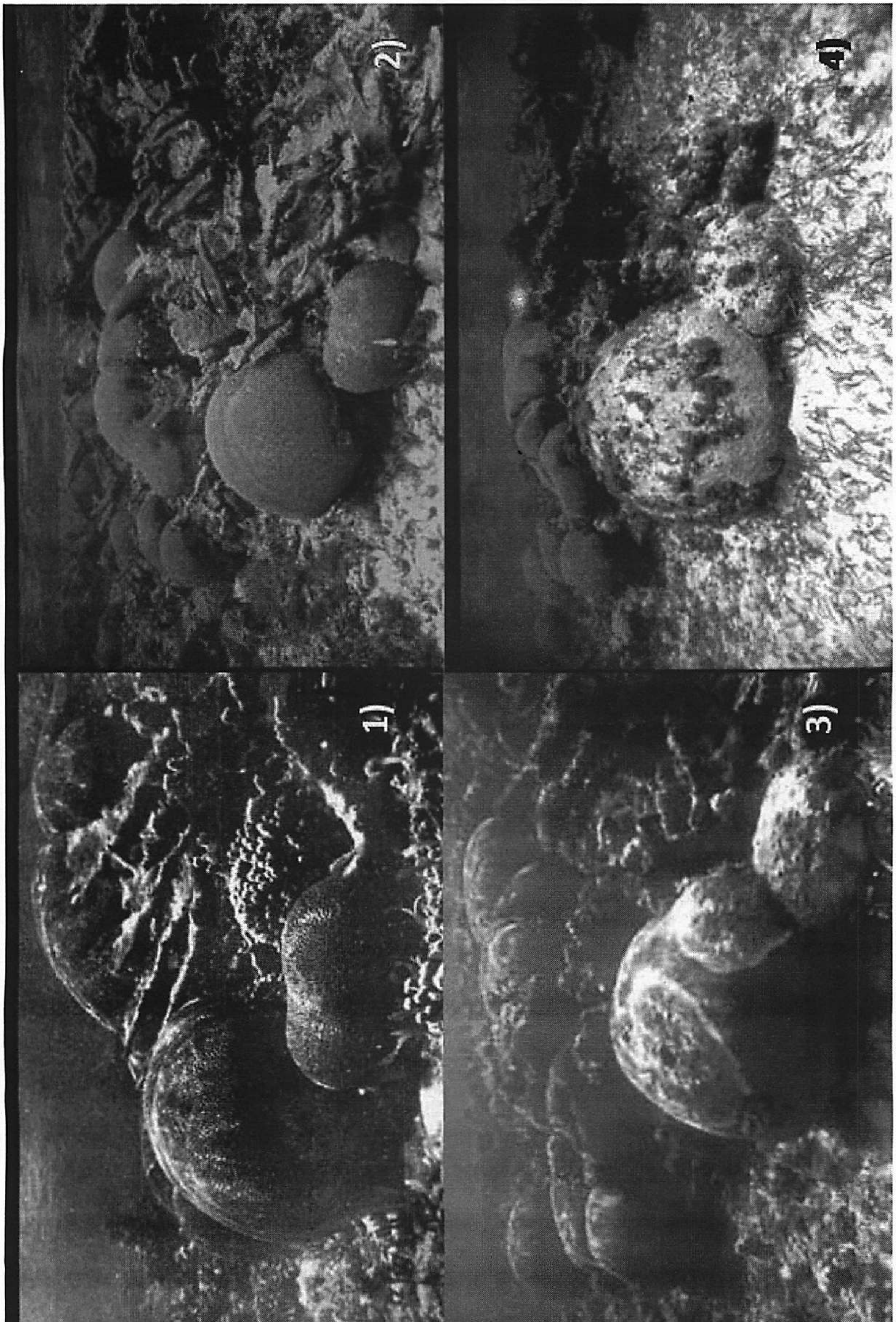

Figure 4. “Reef Station C”: Impact of “Blackband Disease” (BBD) in D. strigosa. View to east:1) 1969. Lush growth of D. strigosa, A. palmata and P. porites; 2) 1977. Most P. porites have disappeared, brown algae Dictyopteris? sp. on left; 3) 1994. A. palmata colonies died. Left D. strigosa struck by BBD, right dead; and 4) 2001. Both D. strigosa in front are apparently dead.

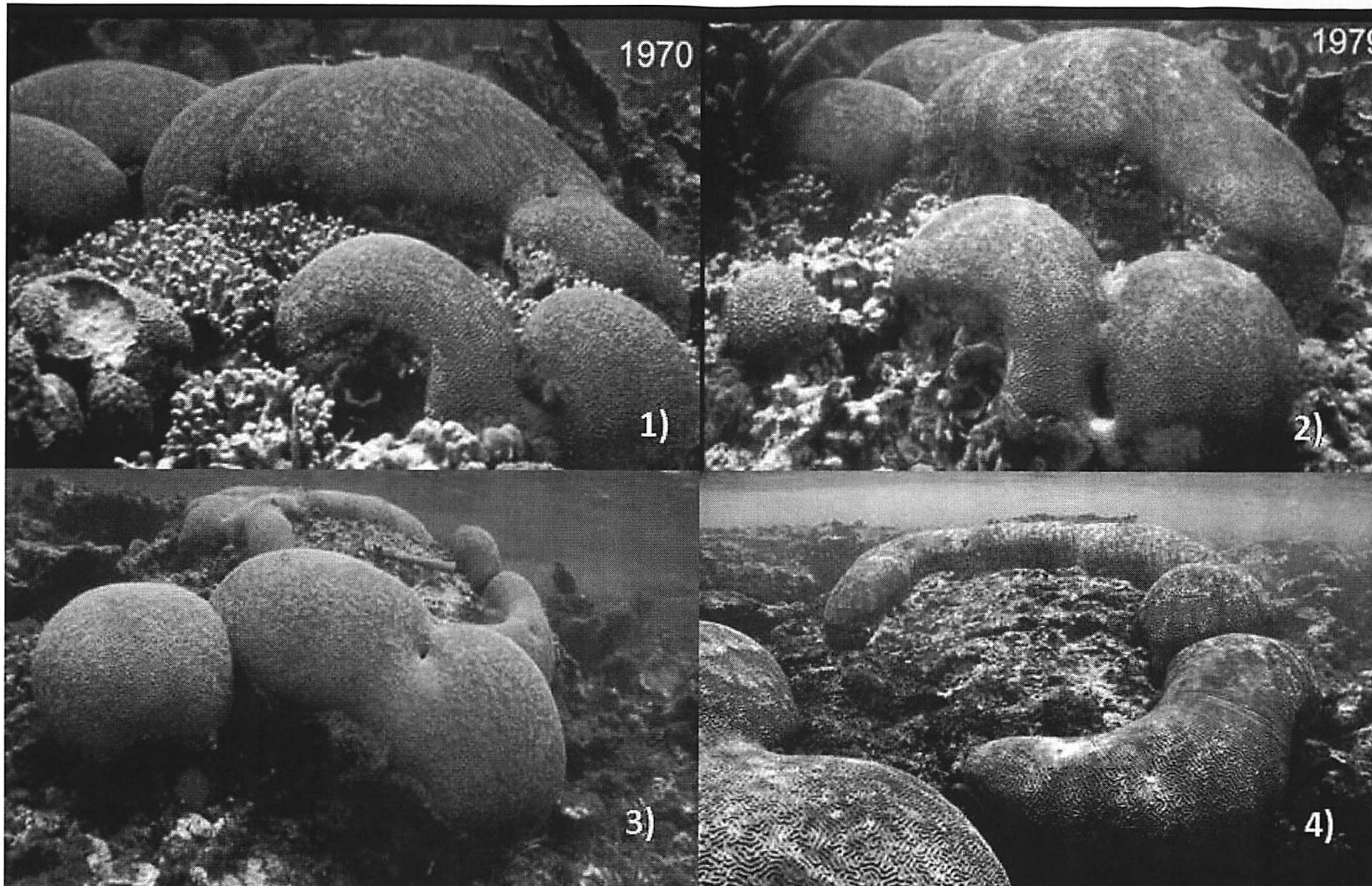

Figure 5. "Reef Station C": Regeneration, fusion and splitting of D. strigosa. View to southeast: 1) 1970. Bioeroded Diploria at left, fusing colonies in front. Note P. porites; 2) 1977. Regenerated Diploria left, continued fusion at right. Less P. porites; 3) 2005. Fusion of regenerated and fused Diploria. P. porites has disappeared; and 4) 2007. Fission of large D. strigosa. Compare to Figures 5/1-3 (background).

Diploria to its right is already dead at this time, presumably, killed by BBD. Revisited in 1995, also the large *Diploria* appeared to be entirely dead.

Figure 4/4: Rs C on September 22, 2001.

Skeletons of both brain corals seem to be covered with patchy growth of brown algae. However, hidden in a cleft of the larger *Diploria* colony, a small patch of living tissue survived and is beginning to recolonize locally the dead skeleton (not seen on this picture!).

"Reef Station C": Fusion and fission of massive brain corals *Diploria strigosa.*

GPS coordinates of Rs C: N12.58378° W81.68609°. Same coral patch as in Figure 4, but view to the NE.

Figure 5/1: Rs C in July 1970.

Massive colonies of brain coral *Diploria strigosa* and branches of moose-horn coral *Acropora palmata* (right). Between the brain corals see lush growth of finger corals *P. porites*. Note bioerosion forming cavity in small brain coral *D. strigosa* in left foreground. Beginning fusion of two brain corals in front right.

Figure 5/2: Rs C on July 30, 1979.

Brain coral in left foreground has completely overtopped bioerosive cavity (already in 1973!) by active growth. Brain corals on the right continue to fuse. Finger corals *P. porites* are less conspicuous. Note healthy state of all the *D. strigosa* heads and *A. palmata* branches (right and left background).

Figure 5/3: Rs C in August 2005.

Fused pair of *D. strigosa* on the right has become a single integrated colony. Regenerated *D. strigosa* (left) considerably accelerated growth and is now in touch and beginning to fuse laterally with the "double colony" on its right. All the *A. palmata* branches within the view field of the picture have died during the 1980s, as did the upper surface area of the large *D. strigosa* colony in center background.

Figure 5/4: Rs C in September 29, 2007.

Close-up of dead top of large *D. strigosa* colony (see Figure 5/3) being slowly regenerated from polyp tissue of the vertical lateral walls. The originally single colony is split into three separate colony segments that became independent colonies, but may fuse again in the future. At left front, note fused double colony of *D. strigosa*. Photo: marine biologist Ana Maria Marquez, Universidad Nacional, San Andres.

As shown by these pictures, adjacent *Diploria strigosa* colonies may fuse over the years to become one single integrated colony. Relic patches of healthy tissue of a single necrotic colony may regenerate to two or more independent coral colonies.

"Reef Station J": Progress of bioerosion in giant brain coral.

Rs J is situated in 6 m-deep "Snapper Shoal Channel" located between Johnny Cay and Top Blowing Rock. No GPS coordinates available to date from Rs J. View to W.

Figure 6/1: Rs J on August 1, 1979.

This healthy coral colony monitored and photographed since 1970, is heavily bioeroded from underneath by parrot fishes, sea urchins and boring sponges. As a result a cave formed and widened and the cave entrance expanded.

Figure 6/2: Rs J on October 12, 1994.

Since 1979, the small hole in the center of the picture widened to a big erosive indentation in the colony margin. Boring and grazing organisms perforated the cave roof from underneath and from above.

Figure 6/3: Rs J on September 13, 2000.

Perforations on top of colony were enlarged and colonized by brown algae. Note further progress of bioerosion around cave entrance.

Figure 6/4: Rs J in August 2005.

Continued destruction of skeleton visible on top and around the cave entrance. The pictures show that progress of bioerosion in massive corals may be roughly quantified by studying time series photographs.

CONCLUSIONS

Retrospective Analysis

Retrospective analysis using time-series of submarine photographs bridging not only weeks or months but decades provides an efficient tool for recognition, follow-up and dating of certain changes in the reef environment by comparing pre- and post-change pictures:

- degradation and regeneration of reef sites;
- causes and initiation of Neoplasia tumor formations in corals;
- development of infections by "Blackband Disease" (BBD) in corals;
- fusion and fission of coral colonies;
- increase of algal proliferation.

Changes Observed in Time

In the past 40 years, the reefs of San Andres underwent a cycle of intense degradation followed by remarkable recovery. Most destructive were the 1980s. As documented by photographs, a slowly increasing death toll of corals in the 1970s was essentially compensated by re-growth and regeneration until the mass bleaching events of the 1980s. After those, coral growth and regeneration remained stagnant at a very low level for about a decade. However, since about 1994, there are encouraging signs of progressive recovery of the reef biocoenosis at San Andres.

It is anticipated that, within a few decades after degradation, many reefs may have regained lush coral growth. But coral associations will look substantially different from those recorded on pictures from the past. At San Andres, *Acropora palmata* already returned to vigorous growth, though not necessarily at the same sites, where it was abundant before. *Acropora cervicornis* disappeared almost completely, already before 1980 and does not show any signs of recovery. Since the mid-1970s, increasing growth of brown algae gradually covered and killed the living tissue of a *A. cervicornis* thicket (Geister, 2001: figure 5). The top surfaces of large massive coral colonies like *Montastraea annularis* und *Diploria strigosa* died within the upper 10 m of water depth suggesting excessive exposure to sunlight. Also the depth of maximum algal proliferation is 0 to 10 m. Corals growing under shaded overhangs, at cave entrances, or relic tissue pockets in clefts of colonies or vertical faces of massive corals show less or no necrotic tissue surfaces at all. This suggests a directional agent, i.e. the intensity of solar radiation, possibly coupled with temporarily increased ultraviolet light incidence. Proliferation of UV resistant algae points in the same direction.

It appears that the present Caribbean reef crisis characterized by the *Diadema* die-off (Lessios et al., 1984), algal proliferation and regional bleaching that aroused scientific interest in the 1980s is part of a major cyclic event. This consisted in a phase of slow but increasing reef deterioration and algal proliferation (1973-1982), which culminated in the mass bleachings in 1983/84. This was followed by a decade of low-level stagnation of reef development and proliferation of algae suffocating individual colonies. Since about 1994, the reef biocoenosis appears to be in a process of slow but accelerating regeneration.

ACKNOWLEDGMENTS

The autonomous corporation CORALINA (San Andres) provided boat transport to reef stations. The Dr. Karl-Bretscher Foundation (Bern) financed fieldwork. Ana Maria Marquez (San Andres) took the

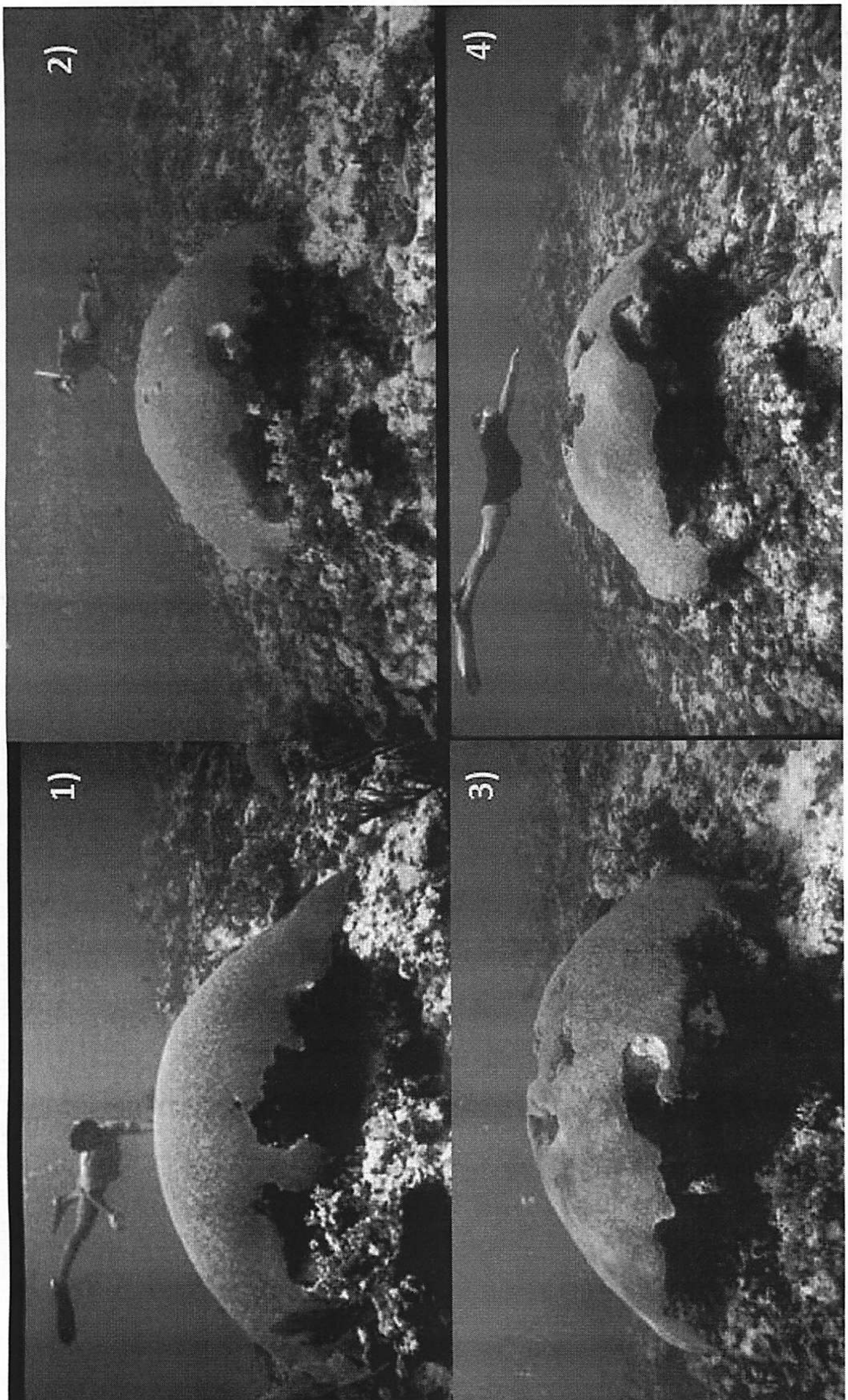

Figure 6. "Reef Station J": Bioerosion of giant brain coral. Water depth = 6 m. View to West: 1) 1979. Excavation of cave below brain coral, retreating colony margins; 2) 1994. Cave roof perforated from underneath. Marginal erosion; 3) 2000. Perforations on colony top are enlarged and colonized by brown algae; and 4) 2005. Further destruction of colony from below, on top and around cave entrance.

photograph series of Little Reef in 2007. Erich Staub (Bern) provided informatic support and Marion Frantz (Köniz) participated in early re-surveys

REFERENCES

Antonius, A., 1995, Pathologic syndromes on reef corals: a review, *in* Lathuiliere, B. and Geister, J. (eds.), Coral Reefs in the Past, Present and Future. Publications du Service Géologique du Luxembourg 29, p. 161-169.

Bak, R.P.M., 1983, Neoplasia - regeneration and growth in the reef building coral *Acropora palmata*: Marine Biology 77, p. 221-227.

Birkeland, C.E. (ed.), 1997, Life and death of coral reefs: Chapman and Hall, New York, 536 p.

Diaz, J.M., Garzon-Ferreira, J. and Zea, S., 1995, Los arrecifes coralinos de la Isla de San Andres, Colombia. Estado actual y perspectivas para su conservacion: Academia Colombiana de Ciencias exactas, fisicas y naturales, Coleccion Jorge Alvarez Lleras 7, p. 1-150.

Geister, J., 1973, Los arrecifes de la Isla de San Andres (Mar Caribe, Colombia): Mitteilungen aus dem Instituto Colombo-aleman de Investigaciones cientificas 7, p. 211-228.

Geister, J., 1975, Riffbau und geologische Entwicklungsgeschichte der Insel San Andrés (westliches Karibisches Meer, Kolumbien): Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie & Paläontologie) 15, p. 1-203.

Geister, J., 1999, 30 Jahre im Leben eines karibischen Korallenriffes (Thirty years in the life of a Caribbean coral reef): Profil 16, p. 1-11.

Geister, J., 2001, Coral life and coral death in a Recent Caribbean coral reef: a thirty-year record in photographs: Bulletin of the Tohoku University Museum 1, p. 114-124.

Geister, J. and Diaz, J.M. ,1997, A field guide to the oceanic barrier reefs and atolls of the southwestern Caribbean (Archipelago of San Andres and Providencia, Colombia): Proceedings of the 8th international Coral Reef Symposium 1, p. 235-262.

Ginsburg, R. N. (ed.), 1994, Proceedings of the Colloquium on Global Aspects of Coral Reefs : Health, Hazards and History, June 10, 11, 1993: Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, 420 p.

Lessios, H. A., Robertson, D.R. and Cubit, J. D., 1984, Spread of *Diadema* mass mortality through the Caribbean: Science 226, p. 335-337.

Loya, Y., Bull, G. and Pichon, M., 1984, Tumor formations in scleractinian corals: Helgoländer wissenschaftliche Meeres-untersuchungen 37, p. 99-112.

Williams, E. H., jr. and Bunkley-Williams, L., 1990, The world-wide coral bleaching cycle and related sources of coral mortality: Atoll Research Bulletin 335, p. 1-71.

Zea, S., Geister, J., Garzon-Ferreira, J. and Diaz, J.M., 1998, Biotic changes in the reef complex of San Andrés Island (southwestern Caribbean Sea, Colombia) recorded during more than two decades: Atoll Research Bulletin 456, p. 1-30.