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Epizoism: a new threat to coral health in Caribbean reefs

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Abstract : Coral reefs around Carrie Bow Cay, Belize, Central America were investigated in 1972 and reefs of the John Pennekamp Coral ReefState Park offKey Largo, Florida in 1973. Both sites were resurveyed in 1997 and a new threat to coral health was found: a rather epizootic occurrence of other organisms overgrowing living coral. On the reef-flat of the Barrier Reef north of Carrie Bow Cay, there are fields of *Acropora cervicornis* and *Porites porites*, scattered over shallow sand-bottom. A large number of these corals show either "tufts" of blue-green algae, or filamentous "flags". Both may cover substantial portions of individual coralla; the living tissue disappeared at the of contact area. Another type of overgrowth on living corals is represented by the red alga *Metapeyssonnelia corallepida*, as well as the brown alga *Lobophora variegata*. Both overgrow mainly *Millepora complanata* and *M. alcicornis*, but also other corals with smooth surface, such as *Porites porites* and *P. astreoides*. This syndrome occurs about equally abundant around Carrie Bow Cay, Belize, and in reefs off Key Largo, Florida. A similar kind of tightly attached overgrowth is represented by the sponge *Cliona caribbea*. It was found regularly in the reefs around Carrie Bow Cay on a wide variety of coral species. An identical type of epizoism is represented by *Chondrilla cf. nucula*, which, so far, was observed only in Belize. All these new syndromes together amount to a considerable coral-degrading factor, which was not found in these reefs 25 years ago.

Key words: Reef corals, space competitors, epizoism, coral death, reef degradation.

Coral reefs around Carrie Bow Cay, Belize, Central America, located at 16° 48' N, 88° 05' W (Fig.1) were investigated in 1972, and reefs of the John Pennekamp Coral Reef State Park off Key Largo, Florida, located at 25° 07' N, 80° 18' W (Fig.2) in 1973 (Antonius 1974). Since 1972 was the year of discovery of the black-band disease (BBD) of reef corals (Antonius 1973), special emphasis in both surveys was put on coral health. Thus, along certain transects, live, diseased, otherwise impacted, and dead corals were recorded. Impacts on live corals other than diseases was found to be mainly feeding damage by the fireworm *Hermodice carunculata* (Antonius 1973, 1975) in these old surveys.

When both reef-sites were resurveyed in early 1997, the most striking differences in comparison to the old surveys were that : 1) much larger portions of reef-crest and back-reef areas are dead today, and 2) a qualitatively new threat to coral health has emerged, consisting of a rather epizootic occurrence of certain Cyanophyta, Rhodophyta, Phaeophyta, and Porifera overgrowing living corals. Thus, subject of this paper is a qualitative description of newly observed phenomena of epizoism degrading coral health.

This does not mean that the "old" maladies have disappeared. On the contrary, BBD and white-band disease (WBD) are still common at both locations (Antonius 1981), coral-tissue-

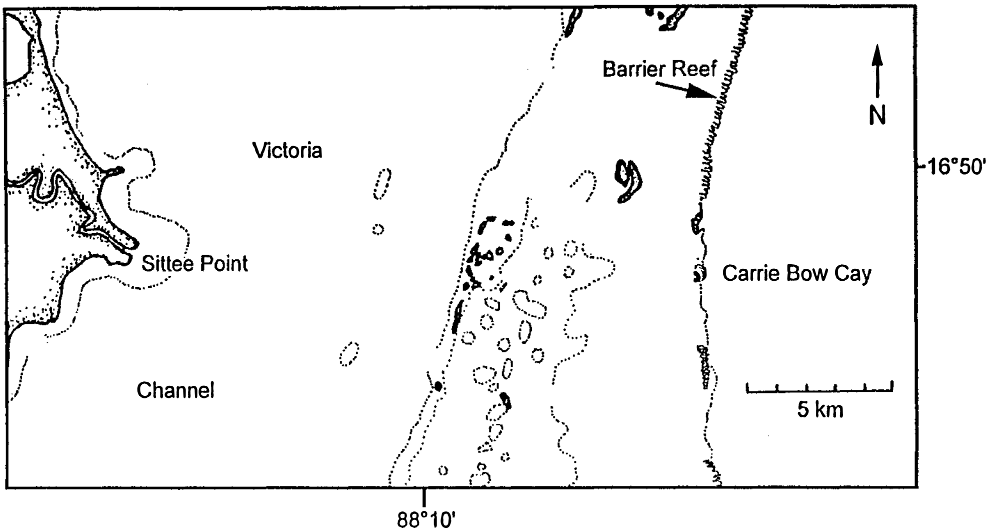

Fig. 1. To the left (= west) the mainland of Belize just south of the town of Dangriga with the mouth of the Sittee River. To the right (= east) the patch-reef system of the lagoon and the barrier reef with Tobacco Reef in the north, Curlew Bank in the south and Carrie Bow Cay in the center.

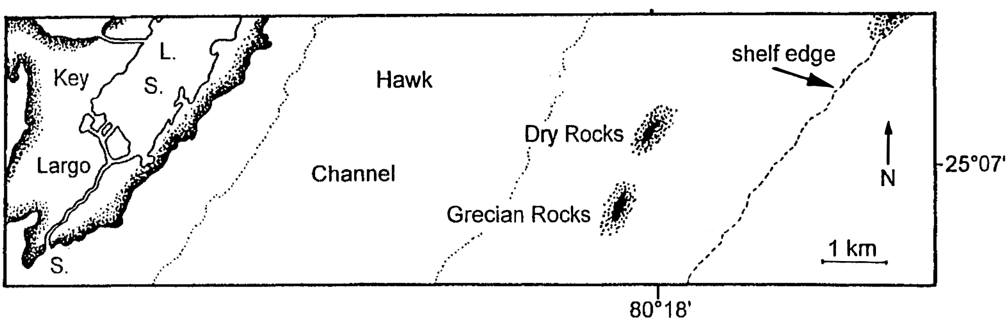

Fig. 2. To the left (= west) Key Largo with Largo Sound (L. S.) and South Sound Creek (S). To the right (= east) the White Banks area with the Key Largo Dry Rocks and Grecian Rocks reefs. The shelf edge marks the 30m isobath.

bleaching (TBL) is rampant especially in Belize (Antonius, in prep.), while Florida is being invaded by an array of previously little or unknown syndromes, such as white-pox, yellow-blotch, white-plague (Goreau *et al.* 1998), white-plague type II (Richardson *et al.* 1998), or rapid-wasting disease (Cervino *et al.* 1997). However, in our opinion, the combined phenomena of epizoism, described in this paper, may pose an even more severe threat to coral health and wellbeing of the entire reef ecosystem.

MATERIALS AND METHODS

Underwater, on-site observations were made along a total of twelve transects: 3 north and 3 south of Carrie Bow Cay, Belize, as well as 3 transects on Key Largo Dry Rocks and 3 on Grecian Rocks, Florida.

The Belt Method was used throughout in order to register all syndromes on corals in the transects as indicators of the health condition of the respective reefs (Antonius 1995a). It is a semi-quantitative time-count technique that uses 30-min scans to quantify frequency of occurrence of coral diseases and other coral-degrading syndromes on a scale from zero to six. However, for the purpose of this paper, percentages of afflicted specimens of the respective coral species were calculated. An overall account of coral (and thus reef) health, dealing with all the presently known syndromes on reef corals (Antonius 1995b), will be published elsewhere (Antonius, in prep.).

Samples taken in the field were preserved in 4% formalin-seawater, as well as in 70% denatured ethanol. All voucher specimens were deposited in the Herbario del Centre d'Estudis Avancats, CSIC, in Blanes, Spain. The respective accession-numbers are listed in the "Results" section.

RESULTS

For somebody who has not been back to these reefs for 25 years, the first sight was a real shock. Especially the reefs around Carrie Bow Cay, in Belize which were teeming with grouper, snapper, triggerfish, other colorful reef fish, and with lobster and conch in the old days, are now ghostly empty. The only larger fish seen during one month of survey was one parrotfish and two barracudas. Fish populations inside the National Marine Sanctuary at Key Largo, Florida, appeared to be in better shape. However, as mentioned under point one in the Introduction, large portions of reef-crest and back-reef, which were documented as alive and in good condition 25 years ago, were found dead today. And this is true for Carrie Bow Reef in Belize, as well as for Grecian Rocks and Key Largo Dry Rocks in Florida. In all of these reefs, large expanses of still standing, relatively undamaged coral skeletons (mainly *Acropora palmata* and *Millepora complanata*) can be found, as well as other areas where these skeletons are weathered down to stumps, and others again where even these are obliterated and reduced to rubble. Carrie Bow Reef was surveyed in 1972 (Antonius unpublished), and the Key Largo reefs in 1973 (Antonius 1974). An accounting of these old (1972/73) results in comparison with the new (1997) ones, containing data on the changes that have taken place in these reefs over time, will be forthcoming at a future date (Antonius, in prep.).

The second point listed in the Introduction, the new phenomena of other organisms overgrowing living coral, is the subject of this paper. We would like to point out that the designation as "new" phenomena shall not suggest that these syndromes had not existed in the past, but merely that they had not been a threat to coral and to coral reef health a few decades ago.

Blue-green algae: The Atlantic Barrier Reef immediately north of Carrie Bow Cay, Belize, consists of an approximately 50m-wide reef crest, made up mainly of *Acropora palmata* and *Millepora complanata*, followed by a

TABLE 1

Summary of percentages of coral populations overgrown by either cyanophytes, or macroalgae, or sponges in reefs of Carrie Bow Cay, Belize and Key Largo, Florida. (n.r. = not registered)

Belize %	Cyanophytes growing on	Florida %
50	*Acropora cervicornis*	n.r.
50	*Porites porites*	n.r.
n.r.	reported on Scleractinia and Gorgonia	80
Belize %	**Macroalgae growing on**	**Florida %**
5	*Millepora complanata*	10
5	*Millepora alcicornis*	10
5	*Porites astreoides*	2
10	*Porites porites*	2
Belize %	**Sponges growing on**	**Florida %**
10	*Dendrogyra cylindrus*	n.r.
5	*Acropora palmata*	1
5	*Millepora complanata*	1
2	*Montastrea annularis*	n.r.
2	*Diploria strigosa*	n.r.
2	*Diploria labyrinthiformis*	n.r.
1	*Agaricia tenuifolia*	n.r.

Fig. 3. The typical "tufts" of *Oscillatoria submembranacea* on branches of *Porites porites*. One of the branches has been completely covered by the cyanophyte.

roughly 200m-wide reef flat that is about 1m deep behind the reef crest and 2m deep toward the lagoon (Rützler and Macintyre 1982). Right behind the reef crest, the bottom is mostly rubble inbetween numerous *Montastrea annularis* and *Porites astreoides* heads. Towards the lagoon, the floor becomes a sand-flat, studded with *Acropora cervicornis* and *Porites porites* colonies.

As mentioned earlier, compared to 1972, the 1997 survey showed a much larger percentage of still standing, but dead coral colonies. This was the case on the reef crest as well as on the reef flat. A substantial part of this coral mortality could be traced to cyanophytic overgrowth. About 50% of all *A. cervicornis* and *P. porites* colonies (Table 1) scattered over the reef flat show either "tufts" of blue-green algae (Fig. 3) or filamentous "flags" (Fig. 4) waving in the current. Both may cover substantial portions of these branching corals. Whether these cyanophytes had grown on the coral branches from minute germs, or whether they were swept in from the outer reef, getting caught in the branches, is not known at present.

Following Drouet's taxonomy, we identified the "tufts" as *Oscillatoria submembranacea* and the "flags" as *Schizothrix mexicana*, while according to classic taxonomy the "tufts" also match the characteristics of *Microcoleus lyngbyaceus,* and the "flags" those of *Oscillatoria margaritifera.* Since the taxonomy of blue-greens is notoriously difficult, definite identification will undoubtedly require further investigation.

Absolutely unequivocal, however, are the effects of this kind of overgrowth on the living coral. There seems to be a positive correlation between the size of the area of contact between alga and coral, and the degree of degradation of coral tissue: with increasing size of the area, the results of this contact become increasingly severe. The coral tissue is usually found bleached when the area of contact is as small as a few square-millimeters; when the alga covers several square-centimeters, the coral tissue is

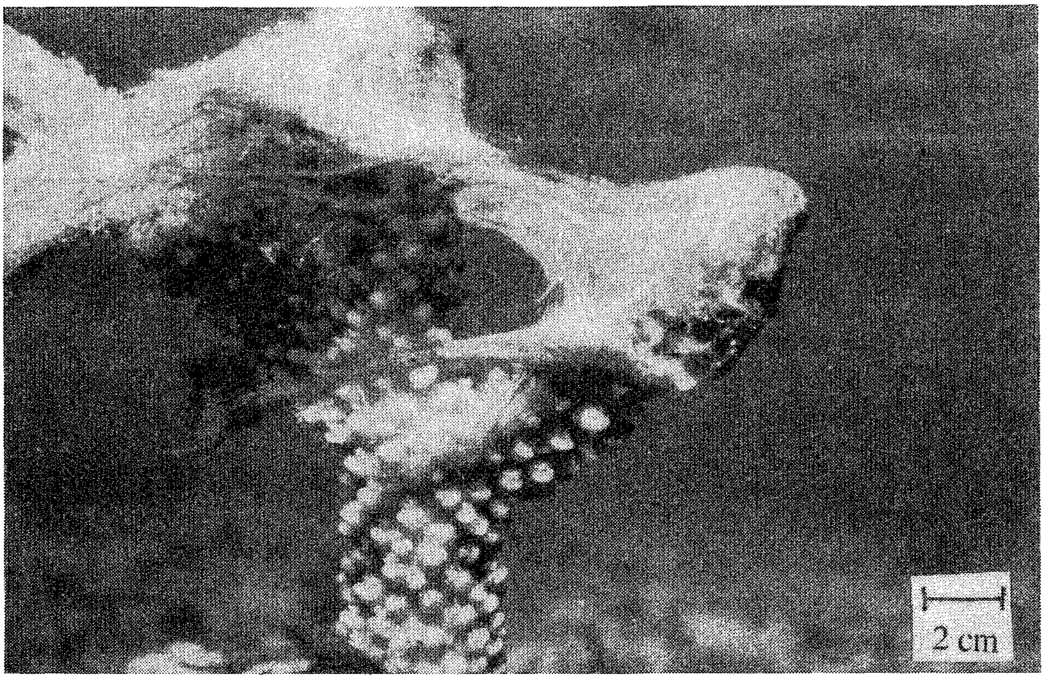

Fig. 4. Waving "flags" of *Schizothrix mexicana* on branch-tips of *Acropora cervicornis*. Coral tissue is being killed by the cyanophytic cover.

mostly encountered in the process of dying; once cyanophytic overgrowth occupies areas in the order of magnitude of square-decimeters, the coral tissue has, in most cases, died off and is completely gone.

This particular problem of cyanophytes invading coral populations was, in February 1997, encountered only to a minimal degree in Florida. However, blue-green algae can be - and have been - a problem in Key Largo reefs (Table 1) and will be dealt with again in the "Discussion".

Samples of *Oscillatoria submembranacea* are deposited as EB-CBC-12 and EB-CBC-13, while *Schizothrix mecicana* is represented by EB-CBC-14.

Macroalgae: Another type of overgrowth on living corals is represented by the red alga *Metapeyssonnelia corallepida*, and the brown alga *Lobophora variegata*. While species determination of *L. variegata* did not pose any problem, systematic evaluation of *Metapeyssonnelia corallepida* is under way, since it is a new species. Both algae overgrow mainly *Millepora complanata* (Fig. 5) and *Millepora alcicornis* from the bottom upwards, but also other corals with smooth surface, such as *Porites porites* (Fig. 6) and *Porites astreoides*. This syndrome occurs about equally abundant around Carrie Bow Cay, Belize, and in the reefs off Key Largo, Florida with percentages of afflicted individuals of these species ranging from 2 to 10 % (Table 1).

Both algae, *Metapeyssonnelia corallepida* as well as *Lobophora variegata* form a tightly attached "skin" on the coral surface, with no trace of living coral tissue left below the algal cover. In the field, the two species are hard to distinguish, since both are very dark with razor-sharp edge. In comparison, however, *M. corallepida* appears even darker than *L. variegata*, with a violet hue and showing rather straight edges, while *L. variegata* is tinted dark olive with more rounded edges. Both algae start to grow at the base of coral colonies which are

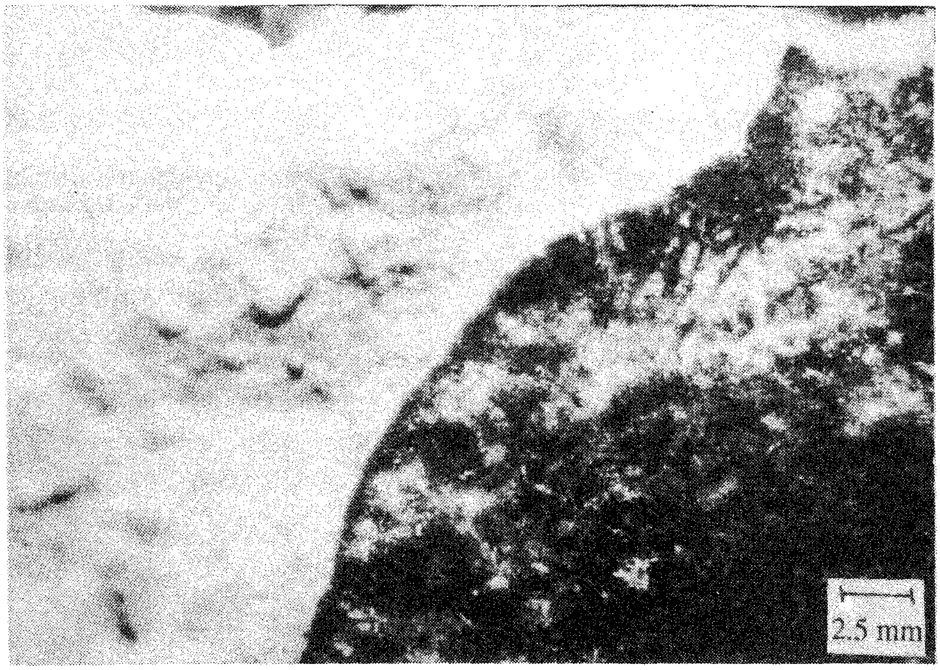

Fig. 5. The rhodophyte *Metapeyssonnelia corallepida* growing over *Millepora complanata.* The edge of the alga is relatively straight and its color is a dark purple.

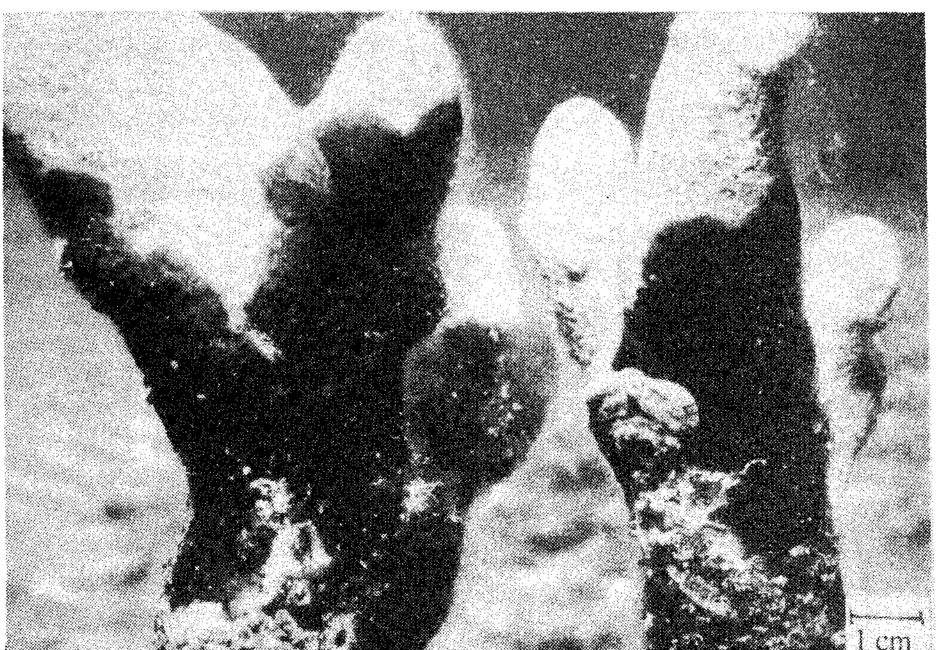

Fig. 6. The phaeophyte *Lobophora variegata* overgrowing some fingers of *Porites porites.* The edges of the alga are usually rounded and its color is a dark, drab olive-green.

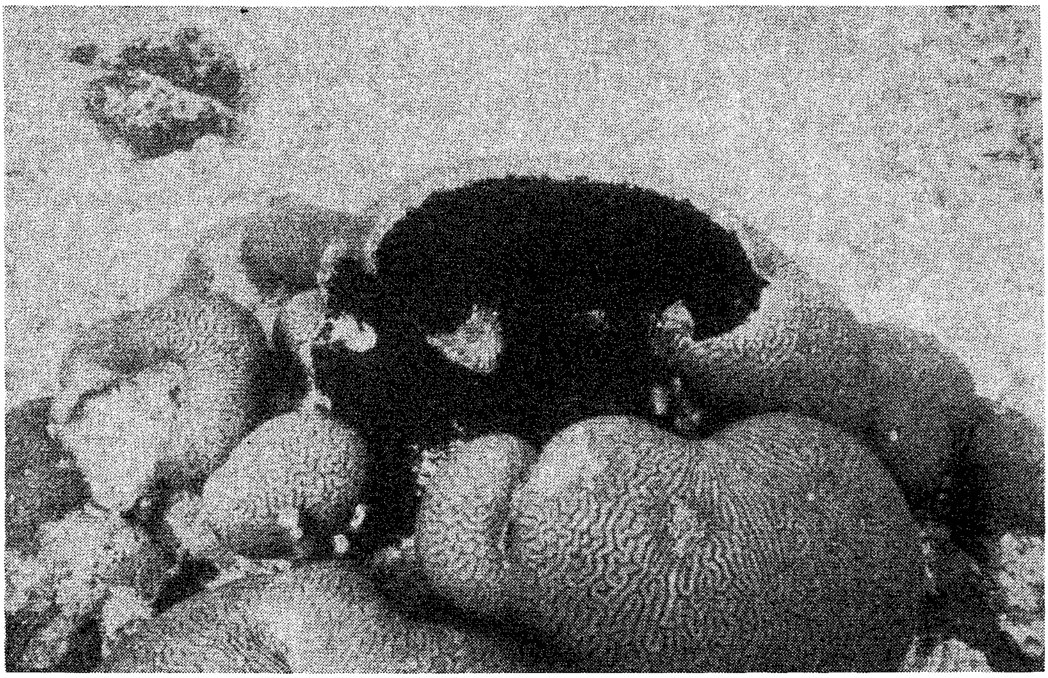

Fig. 7. The hadromerid sponge *Cliona caribbea* growing on a large *Diploria labyrinthiformis*. It probably started out at some spot of denuded coral skeleton, but proceeds to overgrow living coral surface.

"dead", void of coral tissue and thus defenseless. From there they proceed upwards, now overgrowing and destroying polyps and coenosarc.

Lacking observation time, the speed of the process is not yet known, but the impact is evident. Although coral polyps appear undisturbed immediately in front of the advancing alga, there is no trace of coral tissue left below the tightly attached algal cover. In fact, even the surface structure of the coral skeleton appears to be eroded. Quite in contrast to other syndromes, *M. corallepida* and *L. variegata* overgrowing and thus killing off living coral tissue, do not appear to open up the way for other coral bioerosion, such as boring organisms.

However, in some instances these overgrowing macroalgae seem to trigger WBD (Antonius 1995b). This was definitely observed in cases of *Lobophora variegata* overgrowing *Porites porites* and is suspected - but could not be verified beyond a reasonable doubt - in cases of *Metapeyssonnelia corallepida* overgrowing *Millepora complanata.*

This does not mean, however, that *Metapeyssonnelia corallepida* could not be lethal for *M. complanata.* Many cases have been registered of large firecorals totally overgrown by the rhodophyte. Thus, these colonies still perfectly exhibit the shape and growthform of *M. complanata,* but they are now purplish-black instead of the typical live yellow. The same is true for *L. variegata* overgrowing *P. porites* : colonies of this coral showing fingers which are olive-black instead of the normal live, bright greenish-grey, have been killed and overgrown by the phaeophyte.

Samples are deposited under the numbers EB-CBC-7 and 11, as well as EB-KLF-1 through 6.

Sponges: A similar kind of tightly attached overgrowth, also starting at the base of the coral colony is represented by the hadromerid sponge *Cliona caribbea.* It was found regularly in reefs around Carrie Bow Cay on *Acropora palmata* (Fig. 8), *Millepora complanata,*

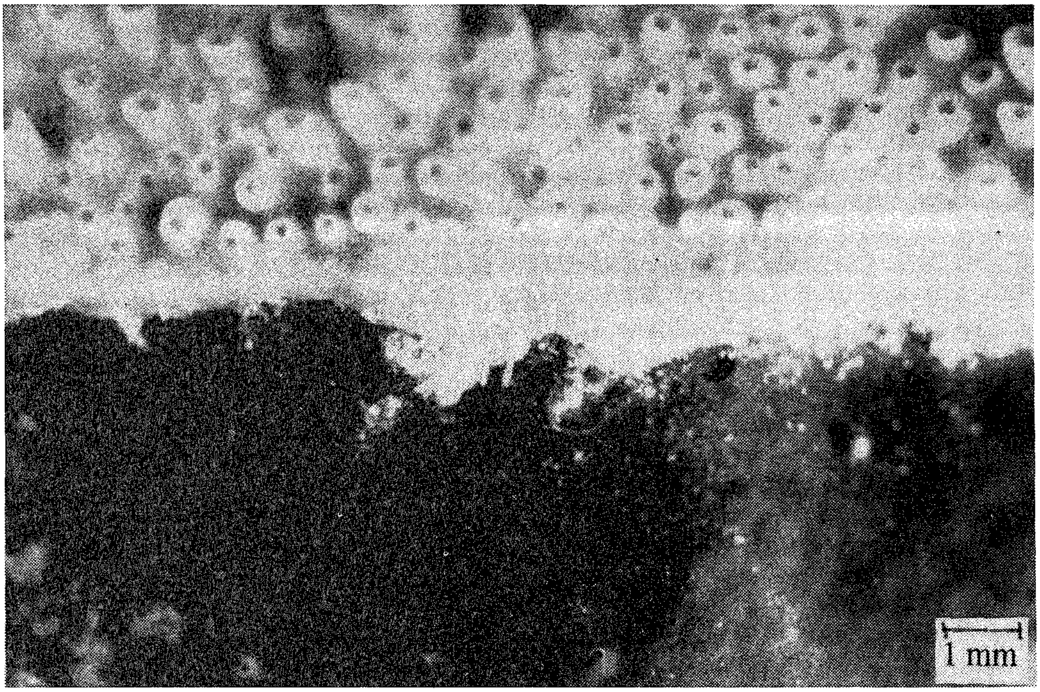

Fig. 8. Close-up of the advancing front of *Cliona caribbea* on an *Acropora palmata*. The sponge not only kills off the coral polyps, but also penetrates the uppermost layer of the skeleton.

Montastrea annularis, Diploria strigosa, Diploria labyrinthiformis (Fig. 7), *Agaricia tenuifolia,* and relatively frequently on *Dendrogyra cylindrus*, but only very rarely on *Acropora palmata* and *Millepora complanata* in Florida (Table 1).

However, *Cliona caribbea* covering live corals may be the second stage of the invasion. The sponge readily grows on dead coral surfaces, often enough with no living coral anywhere near. From these footholds it proceeds to overgrow live portions of the coral colony (Fig. 7). In doing so, *C. caribbea* not only eliminates the coral's polyps and coenosarc, but also erodes the skeletal surface structure and even penetrates the uppermost 1-2 cm of the coral skeleton. However, just as was observed in the case of overgrowing macroalgae, coral polyps appear to be undisturbed immediately in front of the leading edge of the sponge. The speed of advance of *C. caribbea* is not yet known, but the position of several of these leading edges have been marked in the field and will yield results in the future.

Of the substantial *A. palmata* and *M. complanata* populations south of Carrie Bow Cay, an estimated 5% of all colonies may be afflicted, while not more than 1-2% of the other coral species are overgrown by *C. caribbea* (Table 1). The striking exception is *D. cylindrus* which is not a frequent species around Carrie Bow Cay, but under heavy attack by *C. caribbea* (Table 1). Interestingly, this syndrome seems to be much less of a problem in Florida where only very few cases were observed on *A. palmata* and *M. complanata* (Table 1).

Another sponge, *Chondrilla cf. nucula*, apparently is behaving the same way. It starts out at some dead spot of a coral colony, but proceeds from there to overgrow living coral surface. At present it does not seem to be a threat to reef health though, since only three cases were found in Carrie Bow Reef, and none, so far, in Florida. One of these, however, had almost completely enveloped a large colony of *Diploria strigosa* (Fig. 9).

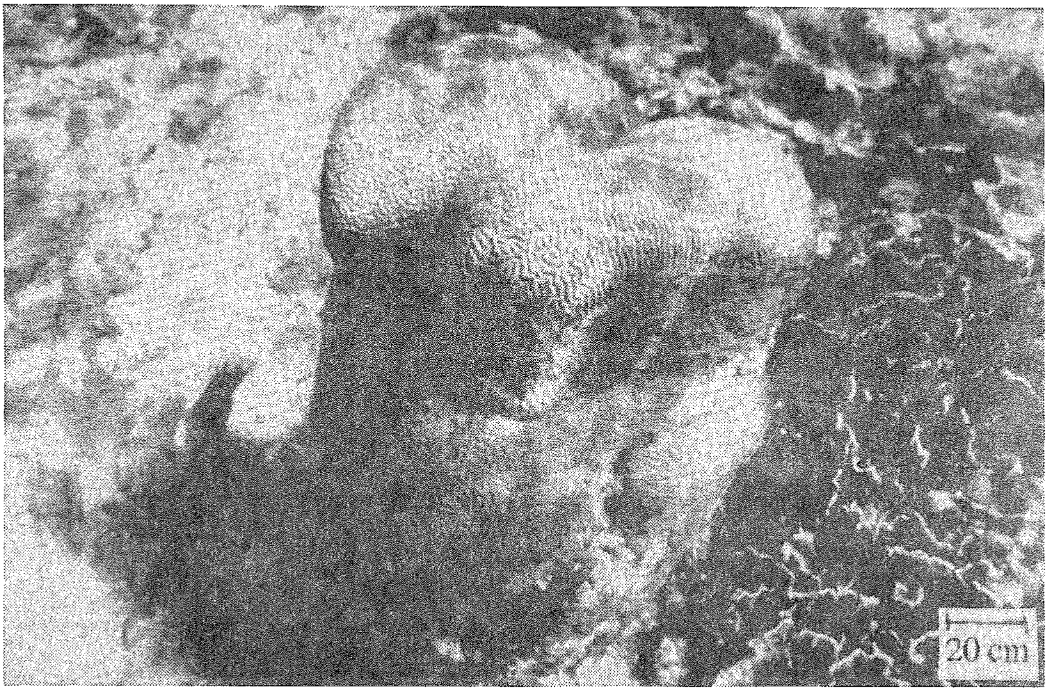

Fig. 9. Another sponge, *Chondrilla cf. nucula*, in the process of overgrowing a large colony of *Diploria strigosa*. Although the sponge will kill living coral surface, polyps in the immediate vicinity appear undisturbed.

DISCUSSION

As summarized before (Antonius 1995b), the fact that different organisms can overgrow and kill reef corals is nothing new. What may be different from previous observations is the fact that these syndromes have now become a factor controlling growth and development, at least of the reefs investigated.

Overgrowing blue-green algae were noticed in the past. For instance, investigations of coral reef decline in Mauritius in the early 1990s, revealed a widespread occurrence of cyanophytes in various reef areas. However, being overshadowed by so many other coral-killing syndromes, they were not recognized as active coral-killers at that time (Antonius 1991a, b; Ballesteros 1994, in press).

Although overgrowing cyanophytes were registered as rampant at Carrie Bow Reef, Belize in the present investigation (Table 1), there was hardly any evidence of this problem in the reefs of Key Largo, Florida, in February 1997. However, just as was noticed in Belize, dead reef areas in Florida have also increased enormously when compared to the situation in the early 1970s. Among several other syndromes, it is not out of the question that cyanophytes too may have contributed to this decline. After all, just as evidenced in case of *Phormidium corallyticum,* the pathogen of the BBD (Antonius 1985), other cyanophytes are also seasonal. These seasons are much more pronounced in the waters of Florida, than in the more southerly Caribbean, such as Belize. BBD, for instance, disappears in Florida in winter, but remains active in Belize (Antonius 1981). Thus, it is entirely possible that overgrowing blue-greens play a major role in Floridian reefs in the hot season of the year.

In the very recent past, for example, spanning several consecutive summer seasons, there has been a massive invasion of filamentous blue-green algae in a large patch reef to the NW of Key Largo Dry Rocks. These cyanophytes grew in dense bushes, up to almost half-a-meter in height and covering large patches, killing off not only stony corals, but also the very frequent sea-fans (J. Halas pers. comm.). Thus, the reef is locally known as the "algae reef" since then, and the cyanophyte was tentatively identified as *Lyngbya sp.* Today, most of the stony corals are dead, and so is the dense population of *Gorgonia ventalina* (Table 1). The large skeletons are still there, waving in the surge, while a new generation of now hand-sized fans has begun to grow.

At Carrie Bow Reef in Belize, which is far away from sources of man-made pollution, we suspect that the problem is related to a decline in Caribbean water quality in general. Where should cyanophyte-promoting water-conditions come from, if not from the open Caribbean Sea? After all, northeasterly trade-winds prevail in Belize during 70% of the year (Rützler & Ferraris 1982).

Of the array of coral-overgrowing organisms, the brown alga *Lobophora variegata* is the only one previously observed by the authors to damage corals. During investigations of coral health in Mauritius, mentioned earlier, *L. variegata* was observed to overgrow small specimens of *Porites sp., Favia stelligera.,* and others (Antonius 1991b, 1995b, Ballesteros, in press). However, even in the partially very sick coral populations of Mauritius (Antonius 1993, Ballesteros, in press), the *Lobophora*-syndrome (LOB) was not encountered as frequently as in the reefs around Carrie Bow Cay. Especially among the *Porites porites* populations of the back-reef area, LOB really amounts to a controlling factor.

While LOB seems to be less of a threat in Florida, another overgrowing macroalga, the rhodophyte *Metapeyssonnelia corallepida* is dominant there. In Florida, this red alga is mainly attacking *Millepora complanata* in reef-crest areas. To the best of our knowledge, *M. corallepida* was an undescribed species (Ballesteros *et al.*, in prep.) and, therefore, it was never observed before or it was misidentified. Just as *L. variegata* can envelope entire coralla, so can *M. corallepida*. It is a striking sight to find totally black, alga-overgrown *Millepora* colonies inside a field of living, bright yellow ones.

What both algae seem to have in common is the fact that they can trigger WBD, a phenomenon previously only observed to be linked with cyanophytes (Antonius 1987, 1988). Through this mechanism *L. variegata* as well as *M. corallepida* may amount to a force much more destructive than any of them would be on their own.

Among coral-overgrowing and coral-killing sponges, the most notorious to date is probably *Terpios sp.* (Bryan 1973, Plucer-Rosario 1987 and Antonius 1991b), or *Terpios hoshinota* respectively (Antonius 1993, Rützler & Muzik 1993). *T. hoshinota* which can infest hundreds of meters of coral reef in Micronesia (Bryan 1973), has also been reported from the northern Pacific, from Samoa to Taiwan (Plucer-Rosario 1987), from southern Japan (Rützler & Muzik 1993), as well as from Mauritius (Antonius 1993) and Sinai (Antonius 1996). But it was never observed in Atlantic waters.

However, there seems to exist a true counterpart in the Caribbean. *Cliona caribbea* turned out to amount to a major coral-killing agent in reefs around Carry Bow Cay, Belize, and also occurring in Florida. *Cliona* species, such as *C. caribbea, C. lampa,* and *C. varians* have been observed as successful competitors for space before (Vincente 1978). However, one species, *C. caribbea,* now occurring in numbers controlling coral reef growth, may be a new development. In contrast to the relatively species-specific coral-overgrowing algae described here, *C. caribbea* does not seem to have preferences, and is overgrowing a wide variety of different coral species (Table 1) in a rather indiscriminate manner.

As mentioned earlier, the sponge does not prey on corals, and probably can not even settle on live, healthy coral tissue. But it flourishes on denuded coral limestone surfaces, and from this secure foothold has no difficulty in subsequently overgrowing the living coral animal. Just as *Terpios hoshinota* is aided by cyanobacterial symbionts in overpowering corals, *Cliona caribbea* harbors large quantities of zooxanthellae which impart the same advantage.

Another true cyanobacteriosponge is *Chondrilla sp.* in Carrie Bow Reef, which could be *C. nucula*, described as coral-overgrowing from Puerto Rico (Vincente 1990), but might be a new species (K. Rützler, pers. comm.). The *Chondrilla* species found in Belize, however, is a whole order of magnitude less frequent than *Cliona caribbea* and does not (yet?) pose a threat to the health of local reefs.

Summing up these observations, it is evident that a substantial perc ntage of the coral populations one of us (A. Antonius) investigated are afflicted with syndromes discussed here (Table 1). Thus, there can be no doubt that these coral-killing phenomena together amount to a considerable factor degrading coral reefs. What should be cause for more concern, however, is the fact that none of these syndromes amounted to a recognizable factor in any of these reefs some 25 years ago. They certainly did not show up in the painstakingly recorded old transects. How this situation is going to develop in the future should be monitored carefully.

ACKNOWLEDGMENTS

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RESUMEN

Los arrecifes coralinos situados alrededor de Carrie Bow Cay, Belice (América Central), y los arrecifes del John Pennekamp Coral Reef State Park, en Key Largo, Florida, fueron explorados en 1972 y 1973, respectivamente. En ambas prospecciones se puso especial atención al estado de los corales puesto que en 1972 se había descubierto la enfermedad de la banda negra (Black Band disease) que ataca a los corales. Ambos lugares fueron visitados nuevamente en 1997 observándose nuevos síntomas de degradación consistentes en el recubrimiento de los corales por parte de diversos organismos bentónicos. Las poblaciones de *Acropora cervicornis* y *Porites porites* situadas sobre los fondos arenosos someros de la plataforma arrecifal del nort de Carrie Bow Cay estaban, en parte, recubiertas por penachos o láminas de las cianofíceas *Oscillatoria submembranacea* y *Schizothrix mexicana*. Aproximadamente el 50% de los corales estaban afec ados, con destrucción del tejido vivo del coral en las áreas de contacto con las cianofí eas. Desconocemos si las cianofíceas se desarrollaron directamente sobre los corales o bien si se engancharon a ellos provenientes del sistema pelágico. Sea como fuere, su asentamiento degrada los corales de forma considerable. Otro tipo de epizoismo es el producido por la rodofícea *Metapeyssonnelia corallepida* y la feofícea *Lobophora variegata*. Ambas especies crecen principalmente sobr *Millepora complanata* y *M. alcicornis*, aunque mbién recubren otros corales lisos como *Porites porites* y *Porites astreoides*. Tanto *Metapeyssonnelia* como *Lobophora* están fijadas fuertemente al coral y destruyen sus tejidos, y avanzan desde la base hacia los ápices de los corales. Ambas especies estan presentes en Carrie Bow Cay y Key Largo. Un tipo de recubrimiento parecido lo constituye la esponja *Cliona caribbea*, recolectada sobre *Acropora palmata*, *Millepora complanata*, *Montastrea annularis*, *Diploria strigosa*, *D. labyrinthiformis*, *Agaricia tenuifolia*, y, especialmente, *Dendrogyra cylindrus*, en Carrie Bow Cay. La esponja *Chondrilla* cf. *nucula* crece sobre *Diploria strigosa* de forma idéntica a *Cliona caribbea*. Todos estos nuevos síndromes no existían hace 25 años y actualmente representan, en conjunto, un importante factor de degradación de los arrecifes.

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