# EXTENSIVE MORTALITY OF' CORALS IN THE COLOMBIAN CARIBBEAN DURING THE LAST TWO DECADES

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## ABSTRACT

Evidence is presented that reefs of the Colombian Caribbean have suffered considerable coral mortality **in the last** 20 years, mostly during the last decade. Live coral cover has declined to about 20-30 % of the hard **substrate.** The **most affected species are branching and foliose corals** from shallow waters, of **which Acropora cervicornis, A. palmata, Agaricia tenuifolia Porites porites, P. furcata** and **Millepora complanata** have reached mortality levels of nearly 100% at several **sites. Massive corals have also been** seriously affected, **in** shallow as **well** as in deep waters, specially **Colpophyllia natans, Diploria strigosa, Montastrea annularis, Siderastrea siderea and Stephanocoenia intersepta. Sea** fans **(Gorgonia)** have also suffered a recent mass mortality of more **than** 90%. Evidences suggest that coral mortality **in** the Colombian Caribbean has had **its origin** principally from agents of wide distribution **(i.e.,** bleaching events **and** pathogenic diseases **like** BBD **and WBD)** as a part of a generalized reef deterioration process occurring **in** the **wider** Caribbean. Nevertheless, local **agents** of stress **(i.e.,** increasing sedimentary load from *rivers,* **fishing with explosives, sewage pollution and nautical activities) have contributed to increase the problem.**

## INTRODUCTION

**Due to continental influence (i.e. terrestrial run-off and major river discharges) the Caribbean coast of Colombia is dominated by sedimentary and estuarine systems and less than** 8% of its coastal areas support coral reef communities. The Colombian insular territories in the Western **Caribbean (San Andrés and Providencia islands and nearby cays and atolls)** make about half of **this ammount (CORPES** C.A., 1992). Distribution, composition, **zonation,** environmental conditions and conservation of **coralline** formations from **Colombia** were recently reviewedby **Prahl and Erhardt (1985) and Wells (1988). Apart from some local damage related to human activities and a minor bleaching event, no** extensive mortality of **corals was** reported **in** these reviews from the Colombian Caribbean. **From** the **beginning of the 1980's, considerable work has been done to quantify the structure of Colombian Caribbean coral** communities, **most of which is not published. Since then, also, extensive mortalities of corals and other organisms became evident at these communities. The purpose of the present work is to review recent information and document the occurrence of these mortalities at the two main coralline areas of the Colombian Caribbean, discussing on possible causes and dates** of occurrence.

## STUDY AREAs

**The Cartagena** area, **located south of the city of Cartagena, has the most extensive shelf reefs of the continental Colombian Caribbean, mainly** at the **coralline** archipelagos of **Islas del Rosario (10"O4-14'N, 75°37-53'W) and Islas de San Bernardo (9°40-50'N, 75°45-55'W) (Fig. 1). The two archipelagos have**

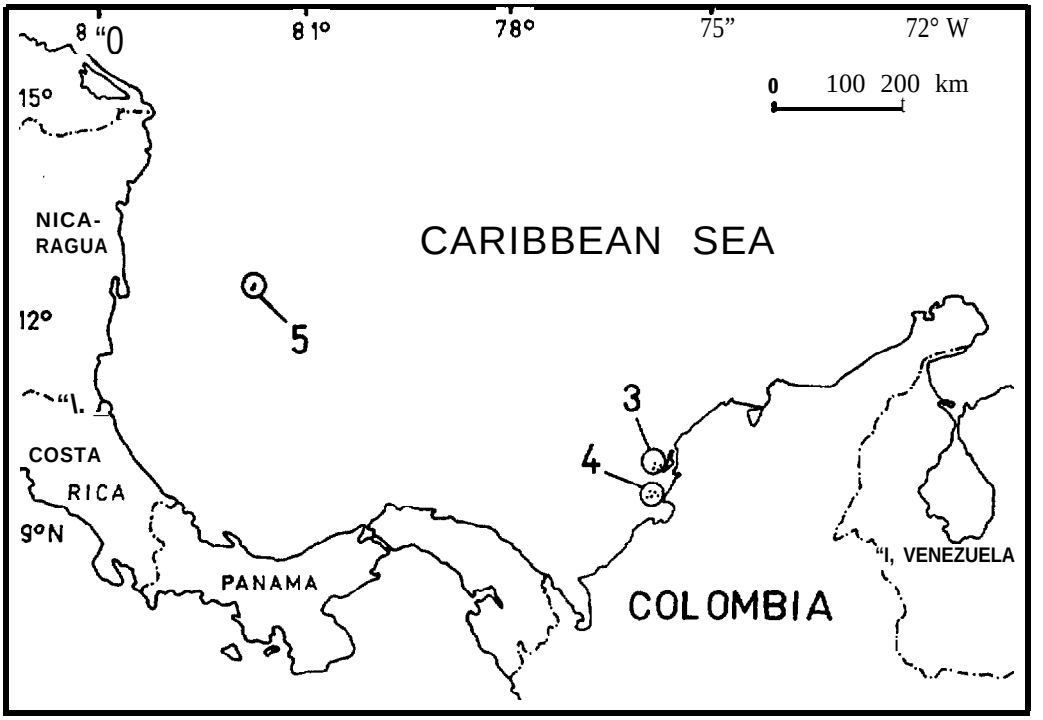


**Figure** 1. Location of **study** areas **in** the Colombian Caribbean: **Islas** del **Rosario** (3), **Islas** de San **Bernardo** (4) and San **Andrés Island** (5).

very similar geological origin, environmental conditions and reefs (Prahl and Erhardt, 1985), with warm (not lower than 26°C) and predominantly clear marine waters, although river discharges influence both archipelagos during *rainy* months. Fifty-seven species of stony corals have been reported from Islas del Rosario and the coral growth extends down to more than 50 m.

The oceanic island of San Andrés is located in the Western Caribbean (12°28-36'N, 81°40-44'W), lying 150 km off the coast of Nicaragua and some 800 km WNW of the Colombian coast. The island, as well as the surrounding shelf, is basically coralline in origin. Marine water is very clear all the year and has a surface temperature higher than 26°C. Coral reefs are well developed, diverse and extensive, and coral growth has been observed deeper than 50 m. Forty-seven species of stony corals are known from San Andrés (Geister, 1975; Prahl and Erhardt, 1985; Diaz et al., 1992).

## METHODS

Two basic methods have been employed to estimate percent cover of corals and other components of the substrate in studies done at Colombian Caribbean reefs. The linear-quadrat method has been used in the Cartagena area. Planar surface areas were visually estimated as percentages within a 1x1 m quadrat placed every consecutive meter on a transect line. The chain-transect method has been used in San Andres. A chain was drapped over the contour of the substrate, along a transect line, and the number of links covering each bottom category was recorded. Specifications on number, length (or covered area), location, *and* depth of transects is given below when presenting data.

Qualitative observations and visual estimates of mortality and reef community structure during fast surveys provide additional information.

## RESULTS

### Cartagena Area

The first evidence of recent coral reef deterioration in the area came from observations made on May 1977 at Islas del Rosario by Werding and Sánchez (1979). They reported a significant extension of dead Acropora cervicornis near the southern coast of Rosario island. No more coral mortality was mentioned at that time, except for local damage caused by dynamite fishing, boat traffic, anchoring and coral mining. Otherwise, coral communities were apparently in a rather healthy condition and great extensions of Acropora palmata, A. cervicornis, Porites porites and Agaricia tenuifolia stands were described from many sites around the islands.

The first quantitative assessment of coral community structure in the Cartagena area was done in 1980 by Ramírez and De La Pava (1981), who studied two stations at the West coast of Isla de Tierra Bombs (10"19-23'N, 75°35-36'W). This island is situated adjacent to the Cartagena Bay and is affected by turbid and polluted waters from the bay. Nearly 560 $m^2$ of fore reef surface were sampled between 5 and 10 m depth, finding a live coral cover of 29-38% (mean 32.2%). No information was given on cover of other dead or live components of the reef bottom. Acropora cervicornis was reported as dominant (more than 50% of coral cover) at two zones and scattered patches of A. palmata were found at one station, but the authors did not mention any mortality on these two species. On the other hand, fore reef slopes were found mostly dead and very eroded (live coral cover less than 10%), suggesting the occurrence of old mortality events.

From observations made during 1982 at Isla Grande (Islas del Rosario) came the first report about extensive coral mortalities in the Colombian Caribbean (Coral and Caicedo, 1983). These authors sampled 800 $m^2$ of reef bottoms from O to 40 m depth, and found a live coral cover of 6.2-75.9% (mean 28.1%). Unfortunately, they did not give information on cover of dead coral and the other components of the substrate nor on mortality proportions of affected species. Great ammounts of dead Acropora palmata and A. cervicornis still in place were noted at the reef crest and the inner fore reef, respectively, in the northern side of the island. Live A. palmata cover at the crest ranged from only 8.2% in the NE to 51.6% in the NW (mean 29.9%). No live A. cervicornis was recorded at transects surveyed in these side of the island. On the other hand, dense stands of live A. cervicornis were found in the southern side of the island, *covering* 65.4% of the substrate at *2-10* m depth. One year after, Ramírez et al. (1986) estimated visually that less than 10% of populations of both species were alive at 10 stations sampled across the archipelago.

Table 1 summarizes data on mean cover of major components of the reef surface (relative to hard substrate), obtained at Islas del Rosario and Islas de San Bernardo by several authors between 1983 and 1990. Apparently, a decline in relative live coral cover from 1983 to 1988, and a stabilization since this year at a value that represents only 20.6-24.6% of the available hard substrate, occurred in the area (including both archipelagos). Changes in relative algal cover are very difficult to evaluate due to seasonality of algal communities and because filamentous algae were apparently included within the dead coral category by some authors. If it is assumed that dead coral was covered by an algal carpet, then relative algal cover may reach mean values of 52.3-75.6% (mean 68.3%) for 1983-1990 at the islands. Within the macroalgae, Dyctiota and Halimeda were strongly dominant and were observed in

Table 1. Mean percentage cover of major components of the reef surface (relative to total hard substrate), recalculated from estimations made at three coralline areas of the Colombian Caribbean by Linear quadrat (LQ), chain transect (CT) and fast survey (FS) methods. Sources: A: Ramirez et al (1986); B: Sarmiento et al. (1989); C: Penereiro et al. (1990); D: this work; E: Laverde-Castillo et al. (1987); F: Ramirez and Viña (1991); G and H: Diaz et al. (1992).

| | Islas del Rosario | | | | Islas de San Bernardo | | San Andres Island | |
|---|---|---|---|---|---|---|---|---|
| Live hard coral | 41.8 | 20.6 | 24.9 | 21.3' | 31.1 | 22.5 | 29.9 | 26.5 |
| Dead coral | 39.5 | 61.0 | 58.0 | -- | 31.5 | 28.7 | -- | -- |
| Algae | 17.6 | 14.6 | 16.5 | 52.3 | 37.4 | 41.5 | 62.0 | 67.8 |
| Other organisms | 1.1 | 3.8 | 0.5 | 26.4 | -- | 7.3 | 8.1 | 5.7 |
| Source | | B | c | D | E | F | G | H |
| Depth (m) | 1-: | 1-20 | 1-30 | 5-25 | 1-10 | 5-10 | 1-20 | 0-22 |
| # of stations | 10 | 89 | 5 | 3 | 7 | 10 | 14 | 50 |
| Method | LQ | LQ | LQ | LQ | LQ | LQ | CT | FS |
| Sample size[2] | 495 | 8560 | 200 | [3] 90 | 670[4] | 6605 | 420 | 5000 |
| Date | 1983 | 1988 | 1989 | 1990 | 1987 | 1989 | 1992 | 1992 |

1: excluding Millepora; 2: all in square meters except G that is given in meters; 3: channel zone data excluded; 4: coastal zone data excluded; 5: community 1 data excluded.



Table 2. Recent mortality of hard corals species at Islas del Rosario (IR) and San Andres I. (SA). Values are maximum and mean (below) percentages of dead cover relative to total cover (live + dead) of the species [recalculated from (1) Sarmiento et al., 1989; (2) Galvis, 1989; and (3) Diaz et al., 1992] . Species: Acr. cervicornis (ACE) ; A. palmata (APA) ; Aga. agaricites (AAG), A. tenuifolia (ATE), Col. natans (CNA), Den. cilindricus (DCI), Die. stokesi (DST), Dip. clivosa (DCL); D. labyrinthiformis (DLA); D. strigosa (DIS); Eus. fastigiata (EPA); Mea. meandrites (MME), Mill. complanata (MCO), Mont. annularis (MAN), M. cavernosa (MCA), Per. astreoides (PAS) , P. furcata (PFU) , P. porites (PPO), Sid. radians (SRA), S. siderea (SS1), Ste. intersepta (SIN).

| AREA | ACE | APA | AAG | ATE | CNA | DCI | DST | DCL | DLA | DIS | EFA | MME | MCO | MAN | MCA | PAS | PFU | PPO | SRA | SS1 | SIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR | 100 | 100 | - | 92 | - | - | - | 18 | - | - | - | - | - | 100 | - | 25 | - | 100 | 26 | 12 | - |
| (1)* | 80 | 89 | - | 31 | - | - | - | <1 | - | - | - | - | - | 4 | - | 1 | - | 37 | <1 | cl | - |
| IR | 100 | 80 | - | 64 | - | - | - | 100 | - | 22 | - | - | - | 63 | 100 | 23 | - | 100 | - | 100 | - |
| (2)* | 78 | 80 | - | 24 | - | - | - | 3 | - | 6 | - | - | - | 10 | 9 | 1 | - | 40 | - | 12 | - |
| SA | *100* | *95* | *80* | - | *70* | *30* | *70* | *30* | *40* | *60* | *80* | 40 | 90 | *90* | *70* | - | 100 | 70 | - | 80 | 50 |
| (3)+ | 75 | 59 | 7 | - | 53 | 8 | 14 | 5 | 17 | 16 | 53 | 9 | 31 | 38 | 22 | - | 26 | 22 | - | 32 | 17 |

*: see Table 1 (B and H) for information on methods. +: *30* stations, linear-quadrat, 943 m2, 1-12 m depth, 1987.

dense patches on coral skeletons as well as covering live coral tissue (Alvarado et al., 1986; Sarmiento et al., 1989; Ramírez and Viña, 1991).

Table 2 lists 14 hard coral species that have suffered considerable recent mortality in the Cartagena area. The most affected are A. palmata and A. cervicornis, which have lost about 80-90% of their live cover, and secondly A. tenuifolia and P. porites that reached mean mortality of 20-40% at Islas del Rosario by 1987-88. These four species [and also D. clivosa, M. annularis, M. cavernosa and S. siderea) reached mortality levels of 100% at some locations, excepting A. tenuifolia that had a maximum of 92% (Sarmiento et al., 1988). Diploria strigosa, M. annularis and S. siderea *were* reported to have intermediate mean mortality values (6-12%). From Islas de San Bernardo, information was given about great extensions of dead A. palmata and A. cervicornis still in place, observed in 1989 at the northern side of the islands (Ramírez and Viña, 1991). Laverde-Castillo et al. (1987) reported also noticeable mortality in P. porites and Tubastrea aurea in 1987 at San Bernardo. Another mass mortality event involving a reef organism was reported from the Cartagena area by Garzón-Ferreira and Zea (1992). Hundreds of eroded skeletons of Gorgonia, still attached to the bottom, were found in 1990 at the inner fore reef in the northern coast of Isla Tesoro (Islas del Rosario).

## San Andrés Island

Coral reefs of San Andrés were qualitatively surveyed in detail between 1968 and 1973 by Geister (1975). At the end of this period, a great proportion of A. cervicornis and P. porites stands in the NE reef lagoon were found dead. Also, some degree of deterioration at a shallow P. furcata patch reef of the lagoon was noted since 1968. Aside from this, coral formations around the island seemed to be in good healthy condition.

No more studies on coral reefs of San Andrés were done until 1992, when Diaz et al. (1992) carried out an intensive survey to evaluate health and present community structure. High levels of recent coral mortality (visually estimated at 47 fast survey stations) were found between 0.5 and 22 m depth, resulting in a overall mean of 52%. More than half of the stations had mortality values higher than 50%. Table 1 presents data on mean cover of major components of the reef surface (relative to hard substrate), estimated by two methods. Both produced very similar results, with mean relative live coral and algae covers of about 28% and 65% respectively. Proliferations of algae (mainly Dyctiota, Halimeda, Lobophora and Padina) were commonly found covering dead coral, as well as adjacent portions of live coral tissue. Thallous algae represented a 26% of the reef surface cover at San Andrés, estimated in chain transects.

Nineteen hard corals species were identified as affected noticeably by recent mortality in San Andrés (Table 2). Among them, 14 species reached maximum mortality levels of at least 50% and A. cervicornis, A. palmata, A. agaricites, E. fastigita, M. complanata, M. annularis, P. furcata and Siderastrea siderea of at least 80%. The most affected species is A. cervicornis, of which probably less than 1% of its recent populations survive at present; only isolated small colonis were found alive at fore reefs and the extensive patches examined at the lagoon were totally dead and fragmented. Two of the most important species in shallow reef construction in San Andrés, A. palmata and M. complanata, showed very high mortalities in the lagoon and adjacent to the inner side of the barrier reef, while at the exposed side of the barrier their mortality levels were comparatively much lower. Furthermore, all populations of the sea fans (Gorgonia) were found mostly dead (60-100%, mean 91.4%) (Díaz et al., 1992; Garzón-Ferreira and Zea, 1992).

## DISCUSSION

This review on changes of coral reefs of the Colombian Caribbean, suggest that extensive recent mortality of corals began sometime between the end of 1980 and the begining of 1982, at least for the continental coast. Previous damage reported by Geister (1975) from 1968-1973 in lagoonal reefs of San Andrés Island were related to hurricane impacts. Colombian mortality events may be part of a generalized process of coral decline, which is occurring in the Wider Caribbean from the begining of the 1980's (Williams and Bunkley-Williams, 1990).

The Rosario and San Bernardo archipelagos are seasonally influenced by turbid waters. Increased sedimentation (resulting principally from anthropogenic modifications in river drainages) has been implicated as the main cause of recent extensive mortality of corals at the islands (Alvarado et al., 1986; Ramírez et al., 1986; Laverde-Castillo et al., 1987; Ramírez and Viña, 1991). The occurrence of a mortality event of similar characteristics at the oceanic island of San Andrés, where marine waters are clear and sedimentation rates very low (Díaz et al., 1992), may indicate that another agent (or several agents) of wide distribution could be responsible. Epidemic diseases and bleaching have been related to high mortality of corals in the Caribbean and other seas during the 1980's (Williams and Bunkley-Williams, 1990). White band disease was probably the main cause of massive die-offs of Acropora spp. in Colombia, as in other Caribbean *areas.* Black band and other diseases are still commonly observed killing massive corals at San Andrés (Díaz et al., 1992) and in the Santa Marta area (pers. observ.). Bleaching events have been reported in San Andrés since 1969 (Geister, 1992) and in the Cartagena area from 1983, 1987 and 1990 (Ramírez et al., 1986; Sarmiento et al., 1989; Solano et al., 1993). Other agents that surely have contributed to increase coral mortality in the Colombian Caribbean during the last 20 years are: hurricanes (only at the San Andrés area), algae proliferation, seawage pollution, eutrophication, over-fishing, boat traffic, anchoring, coral mining, increased sedimentation and dynamite fishing (the last two only at the continental coast) (Werding and Sánchez, 1979; Alvarado et al., 1986; Alvarado and Corchuelo, 1992; Ramírez and Viña, 1991) .

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