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# Health status evaluation of shallow coral reefs in Cahuita and Manzanillo, Costa Rica

Evaluación del estado de salud de los parches arrecifales someros en Cahuita y Manzanillo, Costa Rica

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**Abstract**

Sedimentation, increased tourism, coral diseases and high ocean temperatures have become a permanent threat to reef areas worldwide. The aim of the present study was to evaluate the health status of the shallow reefs in Cahuita and Manzanillo, Limon, Costa Rica. A database, including species of all colonial sessile cnidarians and their known diseases, was created for the studied area. Subsequently, 15 transects were surveyed along the coast in 1-3 m deep bands of 10 x 1 m following the AGRRA V5.4 protocol. Of the 27 species found, 21 were reported from Cahuita and 23 from Manzanillo. The shallow coral reefs' health status in both sites was good in terms of diseases, bleaching and mortality due to their low incidence. Sessile cnidarians' species composition, colonies' sizes and coverage were dominated by massive and lobate scleractinians such as *Pseudodiploria clivosa* and *Siderastrea siderea*. Macroalgal coverage was low (below 20%) and mostly represented by brown algae. Sea urchins' densities were also low (below 1 ind/m$^2$ except for *Echinometra viridis* in Manzanillo) and they trend to continue decreasing as the years go by.

**Key words:** AGRRA, Coral reef, Caribbean, Costa Rica, health status.

**Resumen**

La sedimentación, el aumento del turismo, las enfermedades de los corales y las altas temperaturas oceánicas se han convertido en una amenaza permanente para los arrecifes de coral en todo el mundo. El objetivo del presente estudio fue evaluar el estado de salud de los arrecifes poco profundos en Cahuita y Manzanillo, Limón, Costa Rica. Se creó una base de datos, incluyendo especies de todos los cnidarios sésiles coloniales y sus enfermedades conocidas. Posteriormente, 15 transectos fueron muestreados en cada sitio a lo largo de la costa en bandas de 10 x 1 m, siguiendo el protocolo AGRRA V5.4, y a profundidades entre 1-3 m. De las 27 especies encontradas, 21 fueron reportadas de Cahuita y 23 de Manzanillo. El estado de salud de los arrecifes de coral someros en ambos sitios fue bueno en términos de enfermedades, blanqueamiento y mortalidad debido a su baja incidencia. La composición de las especies de cnidarios sésiles, el tamaño y la cobertura de sus colonias fueron dominados por escleractinios masivos como *Pseudodiploria clivosa* y *Siderastrea siderea*. La cobertura de macroalgas fue baja (inferior al 20%) y mayoritariamente representada por algas pardas. Las densidades de erizos de mar también fueron bajas (por debajo de 1 ind/m$^2$ excepto para *Echinometra viridis* en Manzanillo) y tienden a seguir disminuyendo a medida que pasan los años.

**Palabras Clave:** Arrecifes de coral, AGRRA, estado de salud, Caribe, Costa Rica.

## INTRODUCTION

Current coral reefs have been considered one of the most diverse and productive ecosystems in the world, providing food and shelter for approximately 25% of all marine species (Risk *et al.,* 1980; Cortés & Risk, 1984; Grimsditch & Salm, 2006). Coral reefs also offer important ecological goods and services for tropical coastal communities, such as fishing, protection against coastal erosion, as well as recreation, tourism and even environmental education centers (Risk *et al*., 1980; Cortés & Risk, 1984; Moberg & Folke, 1999).

It has been estimated that reefs provide a net profit of $30 billion per year to the world economy (Grimsditch & Salm, 2006). Unfortunately, coral reefs are among the most fragile ecosystems on the planet and, therefore, have been strongly affected by the increase of ocean temperatures, and constant anthropogenic disturbances such as overfishing, sedimentation and pollution (Grimsditch & Salm, 2006; Kemp *et al.,* 2006; Yeemin *et al.,* 2013). The synergy of these factors has steadily decline coral populations and led to the local disappearance of species due to bleaching and diseases (Rotjan *et al*., 2006; Yeemin *et al*., 2013).

Reef formations cover approximately 970 km$^2$ of the seabed in Costa Rica (Burke *et al*., 2011; Martínez, 2012). Specifically, the Southern Caribbean has one of the highest reef growths in the country, which is reflected mainly in the areas of Moín-Uvita Island, Cahuita and Puerto Viejo-Punta Mona. Some of these places harbor more than 40 species of scleractinian corals and at least three species of hydrocorals in shallow water reefs (Fernández & Alvarado, 2004; Palacios, 2009).

Nevertheless, sedimentation due to deforestation close to the basins, increased tourism, destruction by divers and accelerated development around the Caribbean coast

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during the last two decades have become a permanent threat to reef areas in the Southern Caribbean (Cortés & Risk, 1984; Cortés *et al.,* 2010b). These reefs have also been affected by epidemics of the Caribbean White Band Disease, which additionally impacted their resilience after bleaching/disturbance events reported since June 1983 in Cahuita (Cortés *et al.,* 2010b).

At the same time, opportunistic benthic algae take advantage of the lack of important reef grazers, like sea urchins, and the effects of disturbances to compete and overgrow stressed and weakened coral colonies. This is considered a critical phase in the degradation of the reefs and an important indicator of their health status (McCook *et al.,* 2001).

Considering all the above, the objective of this study was to evaluate the health status of the shallow reefs in Cahuita and Manzanillo, which are the most susceptible to tourism and other anthropogenic impacts due to their proximity to the coast and their easy access in the Southern Caribbean of Costa Rica.

## MATERIALS AND METHODS

This study was conducted in shallow patch reefs located in the Cahuita National Park (9°45' N-82°48' W), specifically around the Perezoso and Eduardo sub-aquatic trails, and in Manzanillo Beach in the Gandoca-Manzanillo National Wildlife Refuge (REGAMA; 9°38’ N, 82°39’ W), Fig. 1. The coral reefs in Cahuita National Park are comprised in three barriers, which are the largest and most developed in the country and has also been the most studied (Cortés & Guzmán, 1985; Cortés & Jiménez, 2003).

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REGAMA is a 9,449 ha wildlife refuge with a land area of 5,013 ha and a water area of 4,436 ha, that includes extensive sandy beaches, rocky cliffs, and carbonate platforms (Cortés, 1992, Krupp *et al.,* 2009). In front of the town of Manzanillo lies an extensive reef with several ridges (Cortés & Guzmán 1985, Cortés & Jiménez 2003). Surveys were conducted between August and October 2013. A database was prepared, including species of all colonial sessile cnidarians found in the reefs, as well as any coral diseases known and signs of loss of zooxanthellae (paleness - bleaching). Based on pre-sampling and considering the most accessible reefs for snorkeling, study areas were subsequently established (Fig. 1), where 15 transects were surveyed along the coast in 10 x 1 m bands, in accordance with the AGRRA V5.4 basic protocol for corals and benthic organisms (Lang *et al*. 2010). Transects were 1 to 3 m deep and were separated by a minimum of 5 m to avoid data overlapping.

AGRRA V5.4 basic coral protocol was modified to include zoanthid and octocoral colonies in order to have a more detailed characterization of the coral reefs from both sites. In addition, the basic protocol for benthic organisms was

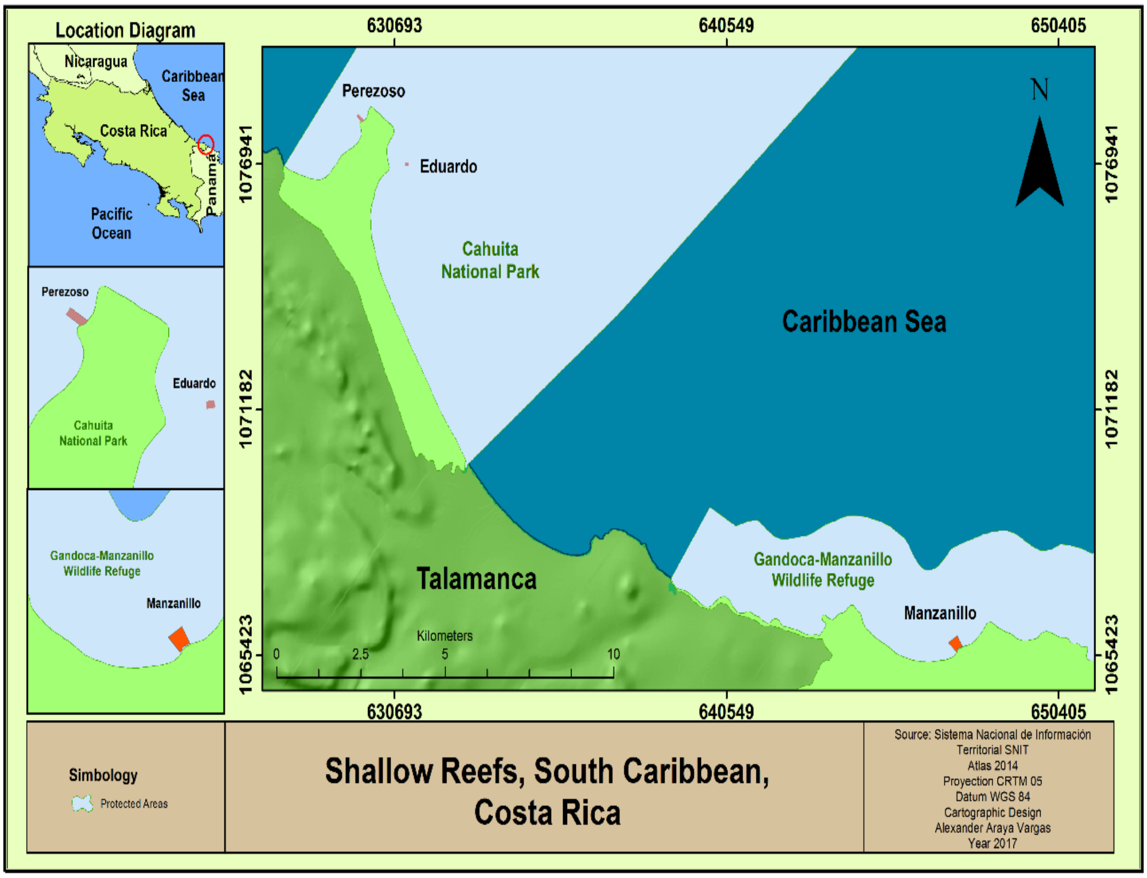


Figure 1: Study areas: the Cahuita National Park and Manzanillo.

Figura 1: Áreas de estudio delimitadas en el Parque Nacional Cahuita y Manzanillo.

Table 1. Sessile cnidarian species identified in Cahuita[C] and Manzanillo[M] shallow coral reefs.

Tabla 1. Especies de cnidarios sésiles identificados en los arrecifes de coral someros de Cahuita[C] y Manzanillo[M].

| Class | Order | Species |
|---|---|---|
| Hydrozoa | Anthoathecatae | *Millepora complanata*[C,M] |
| | | *Stylaster roseus*[M] |
| Anthozoa | Scleractinia | *Acropora palmata*[C,M] |
| | | *Agaricia agaricites*[C,M] |
| | | *Agaricia humilis*[M] |
| | | *Agaricia tenuifolia*[C,M] |
| | | *Stephanocoenia intersepta*[C] |
| | | *Colpophyllia natans*[C] |
| | | *Pseudodiploria clivosa*[C,M] |
| | | *Pseudodiploria strigosa*[C,M] |
| | | *Favia fragum*[C,M] |
| | | *Manicina areolata*[C] |
| | | *Orbicella faveolata*[C,M] |
| | | *Montastrea cavernosa*[C] |
| | | *Mycetophyllia danaana*[M] |
| | | *Porites astreoides*[C,M] |
| | | *Porites porites*[C,M] |
| | | *Siderastrea radians*[C,M] |
| | | *Siderastrea siderea*[C,M] |
| | Zoantharia | *Palythoa caribaeorum*[C,M] |
| | | *Zoanthus pulchellus*[C,M] |
| | Alcyonacea | *Erythropodium caribaeorum*[C,M] |
| | | *Gorgonia flabellum*[M] |
| | | *Gorgonia ventalina*[C,M] |
| | | *Eunicea tournefortii*[M] |
| | | *Muricea atlántica*[M] |
| | | *Plexaura flexuosa*[C,M] |

modified to measure the macroalgal coverage area and record the density of any sea urchin species found.

The following guides were used for the identification of the organisms: Humann & Deloach (2002a, b); Reyes *et al*. (2010) and Borrero-Pérez *et al*. (2012). When identification was not possible in the field, photographs and samples from the specimens were taken to the laboratory for a more detailed examination (specifically for macroalgae and octocorals).

## RESULTS

A total of 27 cnidarian species were found, including two hydroids, 18 scleractinian corals, two zoanthids, and five octocorals. From this species inventory, 21 were reported from Cahuita and 23 from Manzanillo; most of them (17 total) being shared in both places (Table 1).

The order Scleractinia (Anthozoa), followed by the order Anthoathecatae (Hydrozoa), had the highest number of colonies, average length, width and height, as well as the highest coverage percentage, incidence of diseases, bleaching and mortality in both sites (Table 2). Scleractinian corals in Cahuita showed overall higher values than Manzanillo, except for the colonies with new mortality.

The brain coral *Pseudodiploria clivosa* (Ellis & Solander, 1786) presented the highest average length (93.33 ± 25.17) and width (65.00 ± 18.30) in Cahuita, while the massive starlet coral *Siderastrea siderea* (Ellis & Solander, 1786) had the highest number of colonies (63) and the second largest average length (80.34 ± 65.08), providing it with the highest coverage percentage (50.02%). *Acropora palmata* (Lamarck, 1816) was the third largest (75.83 ± 63.12) and the second widest species (60.83 ± 45.65); however, it showed lower number of colonies (6) compared to *S. siderea*, which, consequently, did not allow it to reach high coverage percentages (8.12%). The least represented species in terms of coverage and size were *Manicina areolata* (Linnaeus, 1758), the zoanthid *Palythoa caribaeorum* (Duchassaing & Michelotti, 1860) and the octocoral *Plexaura flexuosa* (Lamouroux, 1821) (Table 3).

On the other hand, *A. palmata* had the highest average length (88.33 ± 71.32) and width (68.33 ± 60.80) in Manzanillo, followed by *P. clivosa* (64.81 ± 31.09 and 47.83 ± 24.07, respectively), which also showed the highest number of colonies (70) and represented more than half of the coverage percentage (59.13%) in this site. *P. flexuosa* and the scleractinians *Favia fragum* (Esper, 1797) and *S. radians* (Pallas, 1766) presented the lowest coverage percentages (Table 3).

In relation to the health of the coral colonies in both sites, the incidence of diseases, bleaching and mortality was low (39 out of 515 colonies). In fact, Dark Spots Disease (DSD) was the only disease reported in this study and was only present in species of the genus *Siderastrea* in Cahuita. Additionally, *S. radians* and *S. siderea* showed the highest number of bleached, pale, and dead colonies for both sites. In addition, Cahuita had the highest number of colonies with old mortality records (5), while Manzanillo had more new mortality records (4).

The percentage of macroalgae coverage was lower in Cahuita (10.47%) and never exceed 20% of total coverage in either site (Fig. 2). The species *Dictyota* sp. 1 and *Halimeda opuntia* (Lamouroux, 1816) had the highest coverage in Cahuita, while *Sargassum acinarium* (Setchell, 1933) and *Dictyota friabilis* (Schnetter, 1972) had the highest coverage in Manzanillo (Fig. 3).

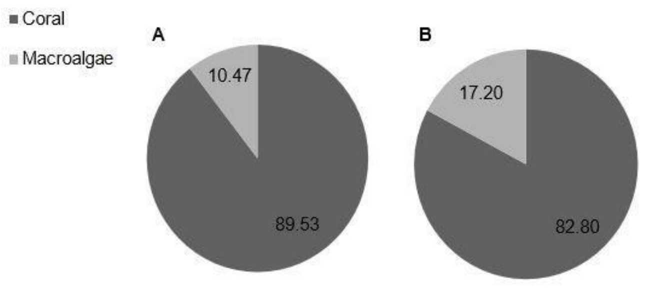


Figure 2: Sessile cnidarians and macroalgae coverage (%) proportions in (A) Cahuita and (B) Manzanillo shallow coral reefs.

Figura 2: Proporción de la cobertura (%) de cnidarios sésiles y macroalgas en los arrecifes someros de (A) Cahuita y (B) Manzanillo.

Table 2: Size and health condition for sessile cnidarian orders found in Cahuita and Manzanillo. NC = Number of colonies. D = Disease (DSD or Dark Spots Disease). B = Bleaching (B = bleached, P = pale, NF = not found). M = Mortality (N = new, O = old, T = total, NF = not found).

Tabla 2. Tamaño y condición de salud para los órdenes de cnidarios sésiles encontrados en Cahuita y Manzanillo. NC = Número de colonias. E = Enfermedad (DSD = siglas en inglés para enfermedad de manchas oscuras). B = Blanqueamiento (B = blanqueado, P = pálido, NF = no encontrado). M = Mortalidad (N = nueva, O = vieja, T = total, NE = no encontrada).

| Site | Order | NC | Average width ± SD (cm) | Average length ± SD (cm) | Average height ± SD (cm) | Coverage (%) | D | B | M |
|---|---|---|---|---|---|---|---|---|---|
| Cahuita | Anthoathecatae | 42 | 15.00 ± 11.37 | 24.00 ± 15.17 | 12.90 ± 9.80 | 2.88 | NF | NF | 1N 1O 1T |
| | Scleractinia | 215 | 30.38 ± 22.41 | 43.90 ± 31.48 | 18.53 ± 16.23 | 95.92 | 2 DSD | 5B 5P | 2N 4O 1T |
| | Zoantharia | 1 | 5.00 ± 0.00 | 10.00 ± 0.00 | 2.00 ± 0.00 | 0.01 | NF | NF | NF |
| | Alcyonacea | 7 | 12.92 ± 11.20 | 25.00 ± 7.07 | 16.25 ± 19.45 | 1.19 | NF | NF | NF |
| **Total** | | 265 | | | | | 2 DSD | 5B 5P | 3N 50 2T |
| Manzanillo | Anthoathecatae | 24 | 8.96 ± 3.90 | 14.17 ± 8.43 | 7.29 ± 3.90 | 1.08 | NF | NF | NF |
| | Scleractinia | 170 | 22.60 ± 20.78 | 30.44 ± 27.80 | 11.96 ± 13.73 | 96.80 | NF | 5B 3P | 3N 3O |
| | Zoantharia | 13 | 12.50 ± 9.64 | 18.13 ± 16.68 | 2.75 ± 1.39 | 0.88 | NF | 1P | 1N |
| | Alcyonacea | 43 | 6.19 ± 1.68 | 16.67 ± 16.50 | 44.88 ± 35.52 | 1.24 | NF | NF | NF |
| **Total** | | 250 | | | | | NF | 5B 4P | 4N 3O |

Densities of sea urchins in Cahuita were below 1 ind/m$^2$ and the most frequent species were *Diadema antillarum* (Philippi, 1845) and *Echinometra viridis* (Agassiz, 1863). In contrast, *Echinometra lucunter* (Linnaeus, 1758) was the most frequent species in Manzanillo, with an average of four individuals per meter square (Table 4). Regardless of the above, the densities of sea urchins in both Cahuita and Manzanillo continue to be low.

## DISCUSSION

The reef-building species identified during this study represent a little over half of the species reported for the Costa Rican Caribbean coast. Previous studies reported three species of hydrocorals, 44 reef building corals, five non-reef building corals, five zoanthids and 26 octocorals (Cortés & Jiménez, 2003; Fernández & Alvarado, 2004).

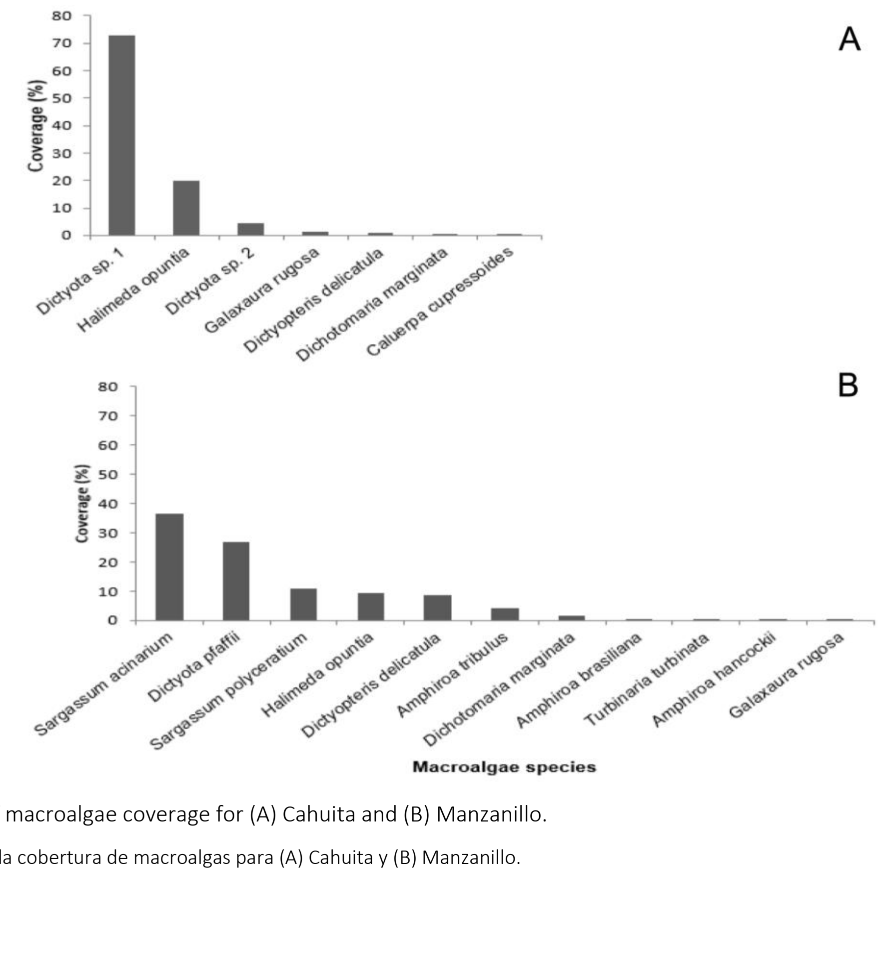


Figure 3: Histogram of macroalgae coverage for (A) Cahuita and (B) Manzanillo.

Figura 3: Histograma de la cobertura de macroalgas para (A) Cahuita y (B) Manzanillo.

Table 3: Size and health condition for the sessile cnidarian species found in Cahuita and Manzanillo. NC = Number of colonies. D = Disease (DSD or Dark Spots Disease). B = Bleaching (B = bleached, P = pale, NF = not found). M = Mortality (N = new, O = old, T = total, NF = not found).

Tabla 3: Tamaño y condición de salud para las especies de cnidarios sésiles encontradas Cahuita y Manzanillo. NC = Número de colonias. E = Enfermedad (DSD = siglas en inglés para enfermedad de manchas oscuras). B = Blanqueamiento (B = blanqueado, P = pálido, NF = no encontrado). M = Mortalidad (N = nueva, O = vieja, T = total, NF = no encontrada).

| Sitio | Species | NC | Average width ± SD (cm) | Average length ± SD (cm) | Average height ± SD (cm) | Coverage (%) | D | B | M |
|---|---|---|---|---|---|---|---|---|---|
| Cahuita | *M. complanata* | 42 | 15.00 ± 11.37 | 24.00 ± 15.17 | 12.90 ± 9.80 | 2.88 | NF | NF | 1N 1O 1T |
| | *A. palmata* | 6 | 60.83 ± 45.65 | 75.83 ± 63.12 | 43.67 ± 30.70 | 8.12 | NF | NF | 1O |
| | *A. tenuifolia* | 22 | 54.09 ± 48.34 | 70.00 ± 49.52 | 24.73 ± 22.89 | 23.86 | NF | NF | 2N 1T |
| | *C. natans* | 1 | 20.00 ± 0.00 | 25.00 ± 0.00 | 5.00 ± 0.00 | 0.10 | NF | NF | NF |
| | *P. clivosa* | 3 | 65.00 ± 18.30 | 93.33 ± 25.17 | 30.00 ± 20.00 | 3.67 | NF | NF | NF |
| | *P. strigosa* | 6 | 50.00 ± 33.47 | 70.00 ± 28.28 | 43.33 ± 20.90 | 4.91 | NF | NF | NF |
| | *F. fragum* | 14 | 6.82 ± 3.37 | 7.27 ± 4.67 | 4.18 ± 1.40 | 0.14 | NF | 2P | NF |
| | *M. areolata* | 1 | 5.00 ± 0.00 | 10.00 ± 0.00 | 2.00 ± 0.00 | 0.01 | NF | NF | NF |
| | *O. faveolata* | 7 | 31.43 ± 14.64 | 46.43 ± 30.34 | 11.43 ± 11.07 | 2.42 | NF | NF | NF |
| | *M. cavernosa* | 2 | 25.00 ± 0.00 | 52.50 ± 3.54 | 30.00 ± 28.28 | 0.51 | NF | NF | NF |
| | *P. astreoides* | 50 | 11.09 ± 6.69 | 15.78 ± 11.65 | 4.19 ± 4.38 | 1.45 | NF | NF | 1N |
| | *P. porites* | 6 | 8.75 ± 7.75 | 11.25 ± 7.75 | 5.00 ± 0.00 | 0.10 | NF | NF | NF |
| | *S. radians* | 34 | 8.80 ± 4.15 | 13.00 ± 7.7 | 2.68 ± 1.82 | 0.62 | 1DSD | 4B 1P | NF |
| | *S. siderea* | 63 | 48.07 ± 40.69 | 80.34 ± 65.08 | 34.66 ± 26.09 | 50.02 | 1DSD | 1B 2P | 3O |
| | *P. caribaeorum* | 1 | 5.00 ± 0.00 | 10.00 ± 0.00 | 2.00 ± 0.00 | 0.01 | NF | NF | NF |
| | *E. caribaeorum* | 6 | 20.83 ± 17.72 | 30.00 ± 25.88 | 2.50 ± 1.22 | 1.16 | NF | NF | NF |
| | *P. flexuosa* | 1 | 5.00 ± 0.00 | 20.00 ± 0.00 | 30.00 ± 0.00 | 0.02 | NF | NF | NF |
| Manzanillo | *M. complanata* | 24 | 8.96 ± 3.90 | 14.17 ± 8.43 | 7.29 ± 3.90 | 1.08 | NF | NF | NF |
| | *A. palmata* | 6 | 68.33 ± 60.80 | 88.33 ± 71.32 | 48.17 ± 42.83 | 17.37 | NF | NF | 1O |
| | *A. agaricites* | 3 | 13.33 ± 5.77 | 18.33 ± 10.41 | 8.33 ± 2.89 | 0.26 | NF | NF | NF |
| | *A. tenuifolia* | 20 | 19.00 ± 14.64 | 25.25 ± 18.67 | 6.35 ± 3.01 | 4.32 | NF | NF | NF |
| | *P. clivosa* | 70 | 47.83 ± 24.07 | 64.81 ± 31.09 | 15.09 ± 14.39 | 59.13 | NF | 1B | 1N |
| | *P. strigosa* | 19 | 25.29 ± 15.56 | 38.82 ± 30.03 | 13.24 ± 13.31 | 6.95 | NF | 1B | 1N 1O |
| | *F. fragum* | 1 | 5.00 ± 0.00 | 5.00 ± 0.00 | 2.00 ± 0.00 | 0.01 | NF | NF | NF |

Although the study areas did not exceed 3 meters depth, the coral species proportion did relate to what has been previously reported in the literature (Risk *et al.,* 1980; Cortés, 1992; Cortés & Jiménez, 2003; Fernández & Alvarado, 2004; Wehrtmann & Cortés, 2009).

Coral colonies were overall larger in Cahuita than in Manzanillo, which coincides with the results of Fonseca (2003) who also used the AGRRA methodology. In contrast, we found smaller coral colonies in both sites compared to what Fonseca (2003) reported, this may be related to the study sites and their depth. While she surveyed 2-7 m depth, we never surpassed the 3 m because of our study objective.

As reported by Cortés & Risk (1984), Fonseca (2003), Palacios (2009) and Cortés *et al.,* (2010a), *S. siderea* is the dominant species in Cahuita and can reach very large sizes, especially along the Eduardo trail. Large sizes have also been reported for *A. palmata*, however, this species has experienced a decrease in its abundance and coverage as a consequence of a massive mortality event during 1983 and its subsequent fragmentation in the 1991 earthquake due to its fragility conferred by this coral's branching morphology (Cortés & Jiménez, 2003).

Another dominant species according to the literature was *A. agaricites* (Linnaeus, 1758) (Cortés & Risk, 1984, Fonseca, 2003, Palacios, 2009, Cortés *et al.,* 2010a); however, this species was not found in any transects of the present study; rather it was *A. tenuifolia* the species with the second highest coverage. This could suggest a mistake in the taxonomic identification during sampling due to the morphological similarities between both *Agaricia* species.

A study in Belize highlighted the opportunistic capacity of *A. tenuifolia* to colonize spaces where other species had dominated for thousands of years (Aronson *et al*. 2002). Therefore, there is also the possibility that *A. tenuifolia* has been opportunistically replacing *A. agaricites*, which has experienced bleaching events affecting more than 65% of its colonies in Cahuita during a warming event in 1995 (Cortés & Jiménez 2003).

Table 4: Composition of sea urchin species and densities for Cahuita and Manzanillo.

Tabla 4: Composición de especies y densidades de erizos de mar para Cahuita y Manzanillo.

| Site | Species | Density (ind/m$^2$) |
|---|---|---|
| Cahuita | *Echinometra lucunter* | 0.01 |
| | *Echinometra viridis* | 0.35 |
| | *Diadema antillarum* | 0.51 |
| | *Eucidaris tribuloides* | 0.01 |
| | *Tripneustes ventricosus* | 0.01 |
| Manzanillo | *Echinometra lucunter* | 4.25 |
| | *Echinometra viridis* | 0.39 |
| | *Diadema antillarum* | 0.08 |
| | *Eucidaris tribuloides* | 0.05 |
| | *Tripneustes ventricosus* | 0.01 |

The least represented species have been deteriorated mainly by tourist activities such as snorkeling, where people and boats can fractionate fragile branching octocorals like *P. flexuosa* or overturn colonies of *M. areolata*, which is characterized for not being attached to a hard substratum and prefer really shallow and sandy habitats to grow (Cortés & Jiménez 2003). In the case of the zoanthid *P. caribaeorum*, studies in Brazil have registered that hawksbill sea turtles (*Eretmochelys imbricata*), commonly observed during the surveys, and coral reef fish feed of these colonies, which might explain their low abundance (Stampar *et al.* 2007, Longo *et al.* 2012).

The Manzanillo reef has been characterized as having a low but diverse coral cover, mainly including the species *P. clivosa* and *A. palmata* colonies in shallow areas and *S. siderea* in deep areas (Cortés 1992). This description coincides with what was found in the present survey. It is important to highlight that the *A. palmata* colonies observed in this study were large, which may be a symbol of recovery after the mortality events that occur in the recent past (Cortés & Jiménez 2003).

As personal observation, it was found that the area sampled in Manzanillo coincides with the dock used by community boat owners, which is very concerning, since during the hours of sampling boats crossed part of the area with their engines on, raising a huge amount of sediments near to sites with high coral coverage.

Between 2000 and 2004 the incidence of diseases in the corals of Cahuita decreased from 24% to 11% (Cortés *et al.,* 2010a); while in this study we found that incidence decreased to 0.93% (2 out of 215 scleractinian colonies). During 2000 and 2004, diseases such as black stripe, white stripe, yellow spot and Aspergillosis were not reported. Cortés *et al.,* (2010a) only observed white plague and DSD mainly in *S. siderea* colonies, which coincides with what we report in this study. An investigation on the Island of Dominica suggested that the DSD may be a phenotypic response of *S. siderea* to high temperatures, since the mortality of colonies after being affected is very low. Therefore, Borger (2005) recommended using the DSD as a stress indicator rather than as a pathology. Curiously, *S. siderea* also was the species most affected by bleaching, although the number of colonies with this condition was low. It is possible that this species shows phenotypic differences in response to thermal stress, and sedimentation, especially on the Perezoso trail where there is fresh water intrusion from the mouth of the Perezoso River (Cortés *et al.,* 1984, Kemp *et al.,* 2006). If this is the case, more physiological, biochemical and thermal stress studies should be conducted with *S. siderea* and its zooxanthellae to determine if it could be used as a potential biomarker of the health status in the Caribbean reefs of Costa Rica.

The assessment of algal composition shows calcareous *H. opuntia* as one of the species with the highest coverage within the green algae group, mainly at coral reef sites in Cahuita, although generally brown algae dominated (Fonseca, 2003; Fernández & Alvarado, 2004). This is the case of genera *Dictyota* and *Sargassum*, which are very abundant and conspicuous in tropical seas and are characterized by forming big meadows in shallow coastal waters with high solar radiation thanks to their low light saturation rates for photosynthesis (Fernández & Alvarado, 2004).

Another crucial factor that was considered, in addition to coral and algal coverage, was urchin density in each site. Densities in Cahuita and in Manzanillo were low for most of the species; only *E. lucunter* presented densities above 1 ind/m$^2$, specifically in Manzanillo, and was found mainly in limestone pavements, near colonies of *M. complanata,* as has been reported in a previous study (Fernández & Alvarado, 2004). The situation is worrisome for this species in Cahuita, as it presented very low densities that confirm its decay in during the last 10 years; from 20 ind/m$^2$ in 2000 to 0.6 ind/m$^2$ in 2008, (Cortés *et al.,* 2010a) and 0.35 ind/m$^2$ in the present study. *D. antillarum* status is also alarming, its populations continue to fail in their recovery, and even decrease, after the high mortality events that critically reduced their densities during 1983 and 1992, from 4 and 33 ind/m$^2$ to 1 ind/m$^2$ (Cortés & Jiménez, 2003, Cortés *et al.,* 2010b), and less than 0.51 in the present study. Research on the dynamic population of these sea urchins is essential to determine the causes of their decrease and to take measures, since this key herbivorous species could contribute to the recovery of reefs if their densities were to stabilize again (McCook *et al.,* 2001; Cortés *et al.,* 2010a, b).

## CONCLUSIONS

The shallow coral reefs' health status in Cahuita and Manzanillo was good in terms of diseases, bleaching and mortality due to their low incidence. Nevertheless, sessile cnidarians' species composition, colonies' sizes and coverage were dominated by massive and lobate scleractinians such as *P. clivosa* and *S. siderea*, which doesn't provide a lot of reef complexity and neither refuge for reef fish, crustaceans and other organisms.

Macroalgal coverage was low in comparison to corals, with brown algae being the most representative group. Sea urchins' densities were low and they trend to continue decreasing as the years go by.

This is the second time that AGRRA protocol has been used to assess the bethic components in the coral reefs of Costa Rica. We recommend using this methodology for future coral reef surveys and monitoring, due to its low cost and fast execution.

A special attention should be given to the *Siderastrea* genus as a possible bioindicator of the health status of coral reefs in the Caribbean. We also recommend complementary researches and mapping on the composition of species in reefs and their ecological relationships with other organisms and the environment, as well as to evaluate aspects such as connectivity between reefs and larvae settlement in order to create effective management and conservation strategies for this ecosystem's recovery.

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