

A REEF UNDER SILTATION STRESS:
A DECADE OF DEGRADATION

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ABSTRACT

The coral reef at **Cahuita** National Park, Caribbean coast of Costa Rica, has been stressed **by** sediments from watersheds of rivers that flow to the sea near the Park. High sediment loads **in** these rivers are due to deforestation on the highlands and to inappropriate agricultural practices on the coastal plains. During the last decade natural disturbances -- coral bleaching in 1983, *Diadema antillarum* die-off **in** 1983 and 1992, a 7.5 earthquake **in** 1991 -- and other **anthropogenic** stresses -- pollution, tourism -- have contributed to the degradation of the coral reef.

A comparison of the reef between the late 1970's - early 1980's and 1993 revealed the following: suspended sediments and the non-carbonate fraction of bottom sediments have increased from 8 to 9 **mg/l**, and from 40 to 48%, respectively; **live coral** cover has decreased, from 40 to 11%, **while** dead coral, algae covered carbonate substrate and coral rubble have increased from 60 to 89%. These changes are attributed to the increase **in** sediment loads **in** the reef, increased **visitation** to the reef, and to natural disturbances. It **is** possible that the reef **will** recover **if** sediment loads **in** the **rivers** are reduced.

INTRODUCTION

The **Cahuita** coral reef **is** located on the Caribbean coast of Costa Rica, Central America (9°45'N - 82°48'W) (Fig. 1). The **fringing** reef **is** part of **Cahuita** National Park. The reef was characterized **in** the early 1980's as **being** under **siltation** stress because of high suspended sediment loads and resuspension of bottom sediments. As a result, **it** had low **live** coral coverage, diversity and coral growth rates (Cortés 1981; Cortés and Risk, 1984, 1985).

Several natural disturbances have affected the reef **since** 1980. In 1983 a bleaching event associated **with** high temperatures, was responsible for the death of corals, **mainly** *Acropora palmata* (Cortés et al., 1984). Also **in** 1983, there was massive mortality of the sea urchin *Diadema antillarum* (Murillo and Cortés, 1984), due to a water-borne pathogen (Lessios et al., 1984). In 1991 a 7.5 earthquake (Richter scale) affected the **entire** Caribbean coast of Costa Rica (Cortés et al., 1992). **Finally**, there was another die-off of *Diadema* **in** 1992 (unpubl. data). Parallel to these natural disturbances, **visitation** to the

Park increased 3 fold between 1982 and 1991. Additionally, during this entire period, siltation has continued.

In this paper I compare data on coral cover and sediments collected in 1993 with the results obtained by **Cortés** (1981), and put forth possible causes for the **degradation** of this coral reef.

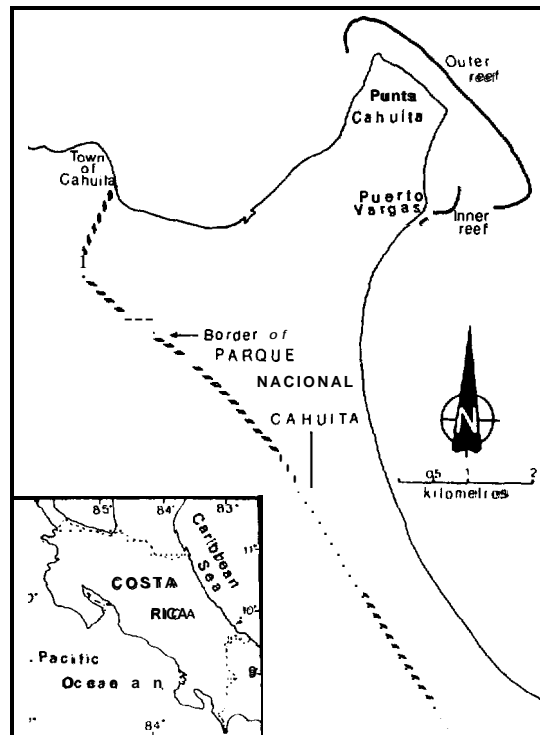


Figure 1: Location of the study reef.

METHODS

To provide comparable data, the methods used by **Cortés** (1981) to study the reef at **Cahuita** were employed in 1993. Transects were done and samples were collected, in both periods, in the same area and depth range. Sixteen line transects (10 m long) were done and the distance covered by each coral species and other substrates was recorded. Coral colony sizes (length) were calculated from the transect data. In the late 70's and early 80's the density of *Diadema antillarum* was determined using 1 m² quadrats. In 1993, all of the individuals encountered were counted and the area covered was calculated. Surface suspended sediments were determined by filtration of 1 liter samples onto preweighed **Millepore** 0.45 μ m HA filters. The non-carbonate fraction of bottom sediments was determined by dissolution of carbonates with diluted **HCl**. Finally, records of visitation to the park expanding from 1982 to 1991 (**Bermúdez**, 1992) were analyzed.

RESULTS

Table 1 summarizes the data from **Cortés** (1981) and the results obtained in this study. Percent live coral coverage is significantly lower in 1993 than in previous surveys by **Cortés** (1981), while other substrates increased, including dead coral, algae covered carbonate substrate and coral rubble. The number of coral species encountered in the transects surveyed was the same (Table 1). However, **Acropora cervicornis** was recorded in 1980, but not in 1993, while the opposite occurred with **Colpophyllia natans** (Table 2). The size of **Porites astreoides** during both surveys is not significantly different (Table 1), but **P. astreoides** is more abundant now than 10 years ago (Tables 2). The average size and abundance of **Agaricia agaricites** have decreased (Tables 1 and 2), but it is still the predominant coral species at **Cahuita** (Table 2). **Siderastrea siderea** is currently represented by larger colonies (Table 1) and its abundance has increased (Table 2). The abundance of **Porites porites** has decreased (Table 2).

The density of **Diadema antillarum** was about 3 orders of magnitude lower in 1993 (Table 1). Suspended sediments are significantly higher in 1993 (Table 1). Percentage of the non-carbonated fraction of bottom sediments is also higher (Table 1).

Visitation to **Cahuita** National Park increased from just over 31,000 in 1982 to over 100,000 persons in 1991.

DISCUSSION

High sediment loads is associated with less live coral and reduced coral recruitment (Rogers, 1990). At **Cahuita**, live coral cover declined in the last decade while sediments loads have increased (Table 1). Also, very few recruits were encountered at **Cahuita**, except for **P. astreoides**. In some localities, e.g. Fanning Island (**Maragos**, 1974), larger colonies are found in more turbid areas. **Cortés** (1981) noted that colonies of some massive species at **Cahuita** were larger than in other areas. In 1993, **Siderastrea siderea** colonies were larger than in the earlier survey (Table 1).

Other factors may also contribute to the degradation of the coral reef at **Cahuita**. The bleaching event in 1983 caused close to 40% coral mortality, especially of **Acropora** spp. (**Cortés** et al., 1984). **A. palmata** abundance is lower now and **A. cervicornis** has not been observed recently (Table 2). Other species have recovered from the bleaching event. The massive die-offs of **Diadema antillarum** in 1983 and 1992 (**Murillo** and **Cortés**, 1984; unpublished data) have resulted in the small surviving populations (Table 1). The reduction in urchin numbers has resulted in an increase in macroalgae cover near or on coral colonies (unpublished data), as was observed, after 1983, in other Caribbean reefs (**Carpenter**, 1990). The increase in macroalgal cover has a negative effect on corals (**Liddell** and **Ohlhorst**, 1986; **Lapointe**, 1989). At **Cahuita**, macroalgae are smothering

Table 1

Comparison between data collected at Cahuita National Park in the late 1970's - early 1980's and in 1993.

	Cortés 1981	This study
1. Percent Cover		
Live coral"	40.4 ± 5.6 (4 - 80)	11.2 ± 2.4 ^b (0 - 34)
Other substrate'	59.6 ± 5.6 (20 - 96)	88.8 ± 2.4 ^b (66 - 100)
2. Corals		
Number of species in transects	10	10
Colony sizes (cm)		
P. <i>astreoides</i>	9.3 ± 1.1 n = 48	9*4 ± 5*4 n = 21
A. <i>agaricites</i>	21.0 ± 1.1 n = 105	14.8 ± 12.2 n = 45
S. <i>siderea</i>	26.6 ± 1.2 n = 32	32.6 ± 24.0 n = 17
3. Density"of <i>Diadema</i> <i>Diadema antillarum</i>	4 - 33 ind/m ²	10 ind/1,000 m ²
4. Sediments		
suspended sediments (mg/l)	8.4 ± 1.6 (0.8 - 54.0) n = 34	9.1 ± 2.8 ^b (3.6 - 22.1) n = 18
% non-carbonate fraction of bottom sediments	40.1 ± 10.4 (2.8 - 68.9) n = 7	47.8 ± 8.9 ^d (4.9 - 81.1) n = 9

a. mean ± standard error of the mean and range in parentheses.
n = 10 linear transects (10 m long)

b. Differences between years are significant (ANOVA p < 0.05)

c. Mainly dead coral, algal-covered carbonate substrate and coral rubble

d. Differences between years are not significant (ANOVA p > 0.05)

Table 2

percentage of each species of the **total live coral** encountered in 16 transects.

	Cortés 1981	This study	% change
<i>Agaricia agaricites</i>	54.6%	39.7%	- 14.9
<i>Siderastrea siderea</i>	15.6	31.1	+ 15.5
<i>Porites porites</i>	13.0	3.8	- 9.2
<i>Porites astreoides</i>	6.5	11.0	+ 4.5
<i>Diploria strigosa</i>	3.4	0.8	- 206
<i>Acropora palmata</i>	3.1	1.9	- 1.2
<i>Millepora complanata</i>	2.4	3.7	+ 1.3
<i>Diploria clivosa</i>	0.7	2.8	+ 2*1
<i>Montastrea annularis</i>	0.4	2.8	+ 2.4
<i>Acropora cervicornis</i>	0.1	0	- 0.1
<i>Colpophyllia natans</i>	0	2.2	+ 2.2

corals and may affect larval settlement. The April, 1991 earthquake caused coastal uplift and slumping of part of the reef front (**Cortés et al., 1992**). Two of the most affected species were *A. agaricites* and *P. porites*, because of their predominance on the reef front (**Cortés and Risk, 1984**). Densities of both species have dropped (Table 2). Large areas of the reef are now covered by rubble of these two species, that is serving as a substrate for *P. astreoides*, which explains its increase in density (Table 2).

The above natural disturbances have affected other reefs on the Caribbean coast of Costa Rica, which are not under siltation stress. These reefs seem to have recovered from these disturbances (**Cortés and Guzmán, 1985; Cortés, 1992; pers. obs.**).

Recreational **activities** may have a deleterious **impact** on coral reefs. Coral trampling by reef walkers, voluntary or involuntary physical contact with corals, and boat damage are causes of coral **stress** and death (**Tilmant, 1987; Neil, 1990**). In the Florida Keys a **significant linear** correlation of reef use and incidence of **physical** damage was found (**Tilmant and Schmahl, 1981**). The number of *visitors* to **Cahuíta** National Park has **increased** dramatically and they walk on the reef, break **corals** and cause boat damages.

Other problems have been detected recently in Cahuíta. Heavy metal concentrations in coral and sediments are higher at **Cahuíta** than at other coral reefs surveyed in both Panama and Costa Rica (**Guzmán and Jiménez, 1992**). These metal pollutants are associated with natural (soil erosion) and anthropogenic (domestic and industrial sewage, oil, pesticides) sources (**Guzmán and Jiménez, 1992**).

The sediment problem at Cahuíta was found to be significant (**Cortés 1981**), and it is now obvious that on top of the siltation

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stress there are natural disturbances and other anthropogenic disturbances degrading the reef. But there is still hope for the Cahuita reef, since there is still some live coral cover and a relatively large number of coral species. Recruitment onto artificial substrate raised above the reef have been obtained (**unpublish. data**), herbivorous fish are present (Phillips and **Pérez-Cruet**, 1984), and *Diadema* has demonstrated that its populations may recover (**pers. observ.**). It is possible that the reef will recover if sediment loads in the rivers are reduced by re-establishing the riverine forest and by reducing deforestation on the highlands.

CONCLUSION

The coral reef at **Cahuita** has been continually stressed by high sediment loads. During the last decade, degradation of the reef has continued, compounded by acute natural events -- coral bleaching, *Diadema* die-offs and earthquake -- and to other anthropogenic stresses -- pollution and tourism. Because of the chronic siltation stress at **Cahuita**, this reef has not been **able** to recover from natural disturbances as has been observed **in** other reefs in the area. If sediment loads at **Cahuita** are reduced, the reef may recover.

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