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SHORT NOTE

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Bleaching and mortality of reef organisms during a warming event in 1995 on the Caribbean coast of Costa Rica

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Abstract: Coral reefs at the Caribbean coast of Costa Rica were affected during a bleaching event associated with the 1995 warming of the Western Caribbean. During doldrum weather in late August 1995, reef organisms at Parque Nacional Cahuita were 62% and 7.4% bleached and dead respectively, whilst 67.6% bleached and 8.2% died in the Refugio Nacional de Vida Silvestre Gandoca-Manzanillo. However, Cahuita had the highest mean number of bleached (257 ± 51.1) and dead (30.5 ± 5.6) colonies in the surveyed transects, and bleaching was observed down to a depth of 20 m. The most affected species (>10% of dead colonies) were the hydrocoral *Millepora complanata* and the scleractinian corals *Montastraea* spp. at Cahuita, and *Porites furcata*, *Porites porites* and *M. complanata* at Gandoca-Manzanillo. Mean seawater temperature was between 30.5 and 31.1°C (0-18 m depth) during four days of observation at the end of August 1995. Coral reefs of the Costa Rican Caribbean coast have shown a rapid decline during the last 20 years due to natural and anthropogenic disturbances. The effect of the 1995 warming added more pressure to the already deteriorated reefs.

Key words: Coral reefs, bleaching, warming, coral mortality, Costa Rica, Caribbean.

The bleaching of coral reef organisms has been observed during the last years with an unprecedented scales in almost all coral reef regions of the world (Glynn 1993, 1996, Hoegh-Guldberg 1999). Higher than normal seawater temperature (SWT) has been pointed out as the triggering factor in mass bleaching events (Goreau & Hayes 1994, Glynn 1996, Brown 1997, Hoegh-Guldberg 1999). In the Caribbean region, mass bleaching events have been observed since at least 1940, as a consequence of the impact of Hurricane Flora on Jamaica (Goreau 1964). Thereafter, coral bleaching was reported in the 1980's in different parts of the Caribbean (e.g. Cortés *et al*. 1984, Williams *et al*. 1987, Williams & Bunkley-Williams 1990), and on a larger scale during the 1990's (Wolfgang 1995, Glynn 1996, Hoegh-Guldberg 1999, Quinn & Kojis 1999), although not all were related with anomalous increase in SWT (e.g. Atwood *et al*. 1992).

In the late summer of 1995, one of the bleaching events occurred throughout the western Caribbean (Rowan *et al*. 1995, Wolfgang 1995, Anonymous 1997, Guzmán & Guevara 1998, Winter *et al*. 1998), with coral bleaching reported for the first time along the Belizean barrier reef (Glynn 1996). At the southern Caribbean coast of Costa Rica, we observed coral bleaching and mortality during 25-28 August 1995 in the Parque Nacional Cahuita and the Refugio Nacional de Vida Silvestre Gandoca-Manzanillo (Fig. 1). The occurrence of bleaching was determined by diving along a 150 m transect parallel to the shore line, and recording bleached and dead coral species within two meters on either side of the transect. At Cahuita (1.5-8 m depth), three transects were laid on the outer reef crest

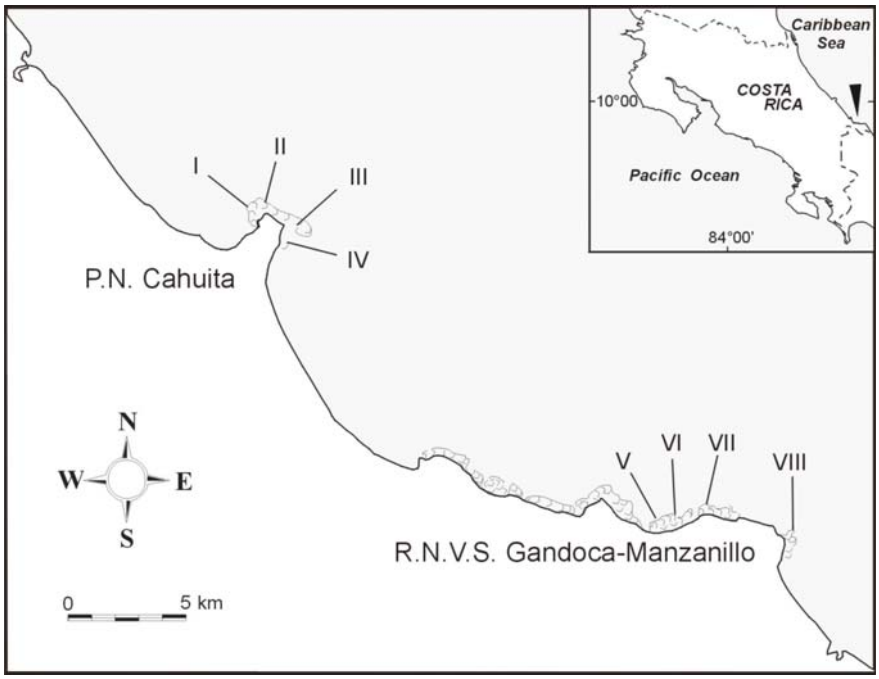

Fig. 1. Study sites at the Caribbean coast of Costa Rica and location of transects (Roman numbers): Parque Nacional (P.N.) Cahuita and Refugio Nacional de Vida Silvestre (R.N.V.S.) Gandoca-Manzanillo.

and lagoon, and one on the inner crest (Fig. 1). At Gandoca-Manzanillo (2-10 m), three transects were laid around the reef bordering the town of Manzanillo, and one at the eastern end of the fringing reefs (Fig. 1). A colony was considered bleached when it had more than 5% of the colony area white, and dead when it had been overgrown by algae. SWT was recorded in the water column down to a depth of 18 m with a calibrated bulb thermometer.

Bleaching and mortality were observed in sixteen scleractinian coral species, one hydrocoral and one zooanthid (Table 1). Corals were pale or white, and bleaching pattern was often in small patches. In shallow waters entire colonies were pale, and only in small size corals whole-colony bleaching was observed. At Cahuita, affected colonies were observed down to a depth of 20 m. In the transects, more than 60% of all colonies were bleached and general mortality was around 7% (Table 1). The most affected species were *Millepora complanata* and *Montastraea* spp. (>10% of their colonies died). At Gandoca-Manzanillo, affected colonies were observed down to a depth of 15 m, and bleaching and mortality were around 67% and 8% respectively (Table 1); *Porites furcata*, *Porites porites* and *M. complanata* being the three most affected species, each with more than 10% of dead colonies.

The occurrence of bleaching and mortality was not randomly distributed in the surveyed sites (Chi-square, $p \ll 0.001$ in all cases). At Cahuita, the highest incidence of bleaching (>60% of all colonies in the transect) and dead organisms (7-9%) was in the transects II to IV (Fig. 2a), that is, in the northeastern sections of the outer barrier and in the inner small barrier (Fig. 1). At Gandoca-Manzanillo, transects around the town (V, VI, Fig. 1) had the highest percentage of bleaching (≈69%) and mortality (8-10%) (Fig. 2b). Significant

TABLE 1

Number of affected coral colonies according to species at Cahuita (1.5-8 m depth, 27-28 VIII, 1995) and Gandoca-Manzanillo (2-10 m, 25-26 VIII, 1995)

Species	Cahuita			Manzanillo		
	Normal	Bleach	Dead	Normal	Bleach	Dead
Agaricia agaricites	34	102	11	6	51	2
Agaricia tenuifolia	29	28	1	--	--	--
Acropora palmata	33	38	2	3	6	0
Acropora cervicornis	2	2	0	--	--	--
Siderastrea siderea	37	69	3	12	32	1
Siderastrea radians	44	55	6	11	35	2
Stephanocoenia intercepta	3	1	0	--	--	--
Porites furcata	92	94	13	6	23	6
Porites porites	31	86	6	23	58	10
Porites astreoides	33	103	13	9	54	3
Colpophylia spp.	2	3	0	2	3	0
Diploria strigosa	32	70	7	5	7	0
Diploria clivosa	32	68	8	19	43	3
Favia fragum	9	60	3	7	21	2
Montastraea spp.	5	10	0	--	--	--
Montastraea cavernosa	1	12	2	2	3	0
Millepora complanata	54	182	46	41	76	22
Palythoa caribbea	35	45	1	4	7	0
Total	508	1028	122	150	419	51
Percent per locality	30.6%	62.0%	7.4%	24.2%	67.6%	8.2%

TABLE 2

Seawater temperature (°C) statistics at Cahuita and at Gandoca-Manzanillo, Caribbean coast of Costa Rica. SD= standard deviation; n= number of temperature readings

Date	Locality	Mean	SD	n	Max.°C	Min.°C	Depth Range (m)
25 VIII 1995	Manzanillo	30.5	1.5	26	32.4	28.0	0-15
26 VIII 1995	Manzanillo	30.5	1.3	23	32.4	27.5	0-18
27 VIII 1995	Cahuita	31.1	1.0	28	32.4	29.5	0-15
28 VIII 1995	Cahuita	30.8	1.2	19	32.4	28.0	0-12

differences were found only in the mean number of bleached and dead colonies when comparing all transects in both surveyed sites (Fig. 2c). Cahuita had significantly more bleached (257±51.1 colonies, $p<0.01$ Student's *t*-test) and dead (30.5±5.6 $p<0.01$) colonies than at Gandoca-Manzanillo. These differences in bleaching and mortality incidence could be related to biological and physical factors within and between sites. For example, local oceanographic settings which may create completely different physical environments, are suspected to be acting with a higher than expected genetic variability in zooxanthellae strains and coral colonies (Edmunds 1994, Glynn 1996, Brown 1997, Muller-Parker and D'Elia 1997, Rowan *et al*. 1997, Winter *et al*. 1998).

Mean SWT in the water column was between 30.5 and 31.1 °C during the four days of observation at the end of August 1995 (Table 2), and on one opportunity it was 29.5 °C at 15 m depth at Cahuita. Local divers and fishermen in the towns of Cahuita and Manzanillo, indicated that SWT was warmer during doldrum weather conditions (when waters are clear and calm) which lasted almost two weeks prior to our surveys, when they observed changes in the coral's coloration. Warm SWT and doldrum weather extended until the end of September 1995 (R. Smikle, pers. com. 1996), though it is not known if

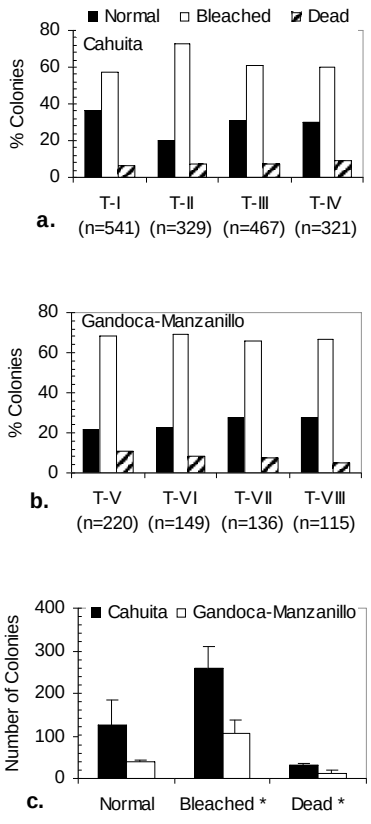

Fig. 2. Percentage of normal (black bars), bleached (white) and dead (stripped) colonies according to transects (T) at (a.) Cahuita and (b.) Gandoca-Manzanillo. (c.) Mean number (bars) and standard deviation (line) of normal, bleached and dead colonies at Cahuita (black) and at Gandoca-Manzanillo (white).

further bleaching and mortality occurred at the surveyed sites.

At a first glance, the mortality recorded here (7-8% of all colonies) could be taken as minimal, particularly if it is compared with the effects of the 1995 warming on the coral reefs of Cayos Cochinos, Honduras (Guzmán & Guevara 1998). There, affected colonies were recorded down to a depth of 28 m, and mortality ranged from 6 to 86% in scleractinian corals (mainly *Montastraea* spp.) and 74% for the hydrozoan *M. complanata*. Furthermore, a high infection rate of the Black Band Disease or BBD (Antonious 1981) observed in those reefs in 1996, seemed to have been triggered by the 1995 bleaching event, increasing partial mortality of the surviving colonies (Guzmán & Guevara 1998). Whereas in subsequent visits to Cahuita during 1996, surviving colonies showed extensive tissue partial mortality (overgrown by calcareous and fleshy brown algae), few dead whole-colonies were observed. Additionally, only two *Siderastrea siderea* and one *Diploria clivosa* colonies were infected by the BBD. Therefore, the extent of the 1995 bleaching and mortality in the two Caribbean localities of Costa Rica, is comparable to what was observed in Puerto Rico (Winter *et al*. 1998), where few corals died during the same warming event. Also, to the same area of Cahuita during a previous warming event in June 1983, when moderate bleaching and death of reef organisms were observed when SWT along the Caribbean coast of Costa Rica was between 29 and 35°C (Cortés *et al*. 1984).

What makes the observed mortality during the 1995 warming event relevant to the coral reefs of the Caribbean coast of Costa Rica? To answer this, we have to consider the actual situation of those reefs and the processes which are influencing them. The Costa Rican Caribbean reefs are under the negative impact of increased terrigenous sediment loads (Cortés & Risk 1984, 1985, Hands *et al*. 1993, Cortés 1992, 1994, Cortés *et al*. 1998), chemical and solid pollution (Cortés & Guzmán 1985, Mata *et al*. 1987, Guzmán & Jiménez 1992, Rojas *et al*. 1998, Cortés & Jiménez in prep.), punctuated uplift of the coast (Cortés *et al*. 1992, 1994, Denyer 1998), mass mortalities of reef organisms (Guzmán & Cortés 1984, Murillo & Cortés 1984), and tourism related activities (Cortés 1994, Cortés & Jiménez in prep., Jiménez, unpublished). All this factors acting in combination have been associated with a significant deterioration of the reefs. Not only near-shore reefs are affected, even offshore submerged banks were observed to have been reached by heavy loads of silt (Cortés & Jiménez in prep.). The consequence is a rampant deterioration of the reefs and it explains the observed decrease in live coral cover from 40% in the 1980's to less

than 10% in the 1990's at Cahuita (Cortés 1994), and from 12 to 7% in less than six years in the northwestern reefs at Gandoca-Manzanillo (Cortés & Jiménez in prep).

Given the poor condition of the coral reefs at the Caribbean coast of Costa Rica, due to the factors cited above, a small to moderate bleaching and mortality could have severe repercussion on the whole reef. That is, the corals which seem to be faring well despite the environmental degradation and which are contributing more to the percentage of live coral cover (Risk *et al.* 1980, Cortés & Risk 1985, Cortés 1994, Cortés & Jiménez in prep.), will be affected significantly by any rate of mortality, such as the one reported here. This will be expressed as a general reduction in live coral cover, which, in its turn, will give algae a chance to flourish and to outcompete corals for substrate and light, as has been recorded in several plots at Cahuita (Jiménez unpublished). Hence the need to implement land management policies in the coastal zone and the protection and study of these reefs.

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RESUMEN

Los arrecifes coralinos de la costa Caribe de Costa Rica fueron afectados por el calentamiento del Caribe occidental en 1995. Durante un período de calma en agosto 1995, colonias de organismos zooxantelados en el Parque Nacional Cahuita, se blanquearon (62%) y murieron (7.4%) mientras que en el Refugio Nacional de Vida Silvestre Gandoca-Manzanillo fueron 67.6% y 8.2% respectivamente. Sin embargo, Cahuita tuvo el mayor número promedio de colonias blanqueadas (257 ± 51.1) y muertas (30.5 ± 5.6) en los transectos de reconocimiento. Las especies más afectadas en Cahuita fueron el hidrocoral *Millepora complanata* y el coral escleractíneo *Montastraea* spp. En Gandoca-Manzanillo fueron *Porites furcata*, *Porites porites* and *M. complanata*. La temperatura promedio del agua de mar estuvo entre 30.5 y 31.1°C (0-18 m profundidad) durante los cuatro días de observación en agosto 1995. Debido al efecto de disturbios naturales y antropogénicos, los arrecifes de la costa Caribe de Costa Rica han sufrido una dramática disminución en la cobertura de coral vivo en los últimos 20 años. La mortalidad de corales asociada al calentamiento de 1995, aumentó la presión que existe sobre los arrecifes que actualmente se encuentran severamente deteriorados.

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