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NOTE

Octocoral bleaching during unusual thermal stress

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Abstract We describe a bleaching event in octocoral communities at four reefs in southwest Puerto Rico during October 2005 following a period of elevated sea surface temperatures. Percentages of colonies bleached varied among taxa, ranging from 0% for *Pseudopterogorgia*, *Eunicea* and *Gorgonia* to over 90% for *Muricea*. Other taxa exhibiting bleaching included *Pseudoplexaura* (22.3%), *Muriceopsis* (36.6%), *Briareum* (46.1%), *Plexaurella* (69.6%) and *Pterogorgia* (84.5%).

Keywords Caribbean · Bleaching · Octocoral · Species-specific

Introduction

Bleaching, the whitening of corals and other taxa due to the expulsion of photosynthetic symbiotic microbes (Brown and Ogden 1993), has been reported since the 1800s (reviewed in Glynn 1993). However, the intensity and frequency of bleaching has accelerated in the last three decades (Donner et al. 2005). For example, during the past century, the 1987–1988 and 1998 bleaching events are regarded as the most severe in the Atlantic and Pacific oceans, respectively, (Williams and Bunkley-Williams 1990; Marshall and Baird 2000). During 2005, the Caribbean region experienced the worst bleaching event on record (http://coralreefwatch.noaa.gov/caribbean2005/) causing extensive bleaching and subsequent death of corals (Whelan et al. 2007).

Hoegh-Guldberg (1999), Donner et al. (2005) and McClanahan et al. (2009), among others have associated bleaching events with increases in sea surface temperature and UV radiation. Subsequent effects of bleaching on coral reef communities may be dramatic because of physiological responses to the stress, including (1) death (Glynn 1993; Brown et al. 1996; Hoegh-Guldberg 1999; Harvell et al. 2001), (2) increased vulnerability to disease (Harvell et al. 2001; Richardson and Voss 2005; Weil et al. 2006), and (3) reduced reproduction (Szmant and Gassman 1990). In addition, because species vary in their susceptibility to bleaching (Lang et al. 1992; Marshall and Baird 2000), shifts in community structure may also ensue (Ostrander et al. 2000; Loya et al. 2001; Aronson et al. 2002; Edmunds 2004).

Previous reports of bleaching have largely concentrated on scleractinian corals (Lasker et al. 1984; Cook et al. 1990; Williams and Bunkley-Williams 1990; Marshall and Baird 2000; Bruno et al. 2001; Harvell et al. 2001; Aronson et al. 2002; Whelan et al. 2007) probably because they form the framework of modern reefs and have suffered the most from bleaching. In contrast, little is known about bleaching in octocorals, despite these animals being visually dominant on most Caribbean reefs (Lasker and Coffroth 1983; Yoshioka and Yoshioka 1989). Previous descriptions of bleaching in Caribbean octocorals are largely limited to Lasker et al. (1984) and Harvell

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et al. (2001), who reported bleaching in the genera *Briareum*, *Plexaurella*, *Eunicea*, *Erythropodium*, *Muricea* and *Pterogorgia*.

In this study, we describe spatial and taxonomical patterns of bleaching in the octocoral community off the southwest coast of Puerto Rico associated with a period of elevated sea surface temperatures in the summer/fall of 2005. The objective of this study is to provide information on the susceptibility and/or resistance of octocoral species to bleaching, which may be useful in identifying changes in this important taxonomic component of Caribbean reef ecosystems.

Materials and methods

Fringing reefs were surveyed in the vicinity of La Parguera, southwest Puerto Rico. These included 2 semi-protected, near shore reefs: Pelotas (17°95.74′N, 67°06.97′W) and Romero (17°56.87′N, 66°59.77′W) and 2 exposed reefs: Enrique (17°57.34′N, 67°02.57 W) and Media Luna (17°56.09′N, 67°02.58′W). The study area is typical of most northern-Caribbean reef ecosystems, with octocorals dominant at depths from about 4 to 10 m.

Octocorals were surveyed during October 2005, about 2 weeks after the highest temperatures recorded in the area in recent years (Table 1) and when >75% of the scleractinian colonies were bleached. Abundance and condition (bleached or non-bleached) of adult octocoral colonies (>20 cm in height, except for encrusting forms such as *B. asbestinum*) were assessed in 20 m^2 (1 × 20 m) band transects at 8–10 m depth. Bleaching was assessed visually following procedures of Lasker et al. (1984) and Harvell et al. (2001). Only completely white colonies (including polyps and coenenchyme) were recorded as bleached (Fig. 1). A few colonies of *Pseudopterogorgia acerosa*, *Eunicea succinea* and *Eunicea laxispica* were observed to exhibit pale coloration but were not classified as bleached. Thus, incidences of bleaching reported here can be considered as conservative estimates that minimize possible observer bias.

Octocorals were identified by their morphological characteristics. A 3-cm piece of each morphotype was collected for verification by sclerite features following Bayer's (1961) method. *Pseudoplexaura flagellosa/wagenaari/porosa*, *Muricea muricata/atlantica*, *Plexaurella nutans/dichotoma*, *Pseudopterogorgia* (other than *P. acerosa* and *P. americana*), and *Pterogorgia anceps/guadalupensis* were recorded as operational taxonomic units due to overall colony similarities and uncertainty in the field identification. Differences in proportions of bleached and non-bleached colonies among species and reefs were analyzed with log–likelihood tests. These analyses were restricted to species where all expected frequencies were ≥5 (Sokal and Rohlf 1995).

Results and discussion

A total of 1,823 colonies from 24 taxa were surveyed at Enrique ($n = 277$), Pelotas ($n = 277$), Romero ($n = 569$) and Media Luna ($n = 700$). *Pseudopterogorgia americana* and *P. acerosa* were the most abundant taxa comprising 24% of all colonies. Other abundant taxa were *Pseudoplexaura* spp., *E. flexuosa*, *E. tourneforti* and *B. asbestinum* representing 14, 9, 7, and 7% of the colonies, respectively (Fig. 2). Relative abundances of species differed significantly among reefs ($X^2 = 206.1$, $df = 18$, $Ps < 0.001$).

A total of 330 colonies (18% of the total) were bleached. Relatively high proportions of bleaching (>50% of colonies) were observed for *Muricea*, *Plexaurella*, *Pseudoplexaura*, *Pterogorgia*, and *Briareum* (Fig. 2). These observations are consistent with previous reports of bleaching in these taxa (Lasker et al. 1984; Lang et al. 1992; Harvell et al. 2001). We also observed bleaching (although at lower frequency) in *Muriceopsis flavida* and *E. flexuosa* (Fig. 2), which has not been reported previously. Interestingly, bleaching was not observed in *Pseudoplexaura*,

Table 1 Sea surface temperature (SST) time series (mean ± SD) at Puerto Rico from 2001 to 2007

	2001	2002	2003	2004	2005	2006	2007
July	28.16 ± 0.4	28.26 ± 0.17	27.71 ± 0.17	28.3 ± 0.12	**28.94 ± 0.34**	28.32 ± 0.15	28.41± 0.31
August	28.61 ± 0.37	28.72 ± 0.13	28.54 ± 0.26	28.68 ± 0.29	**29.39 ± 0.14**	28.64 ± 0.29	28.86 ± 0.05
September	29.1 ± 0.13	28.89 ± 0.17	29.11 ± 0.32	29.04 ± 0.21	**29.81 ± 0.29**	29.27 ± 0.24	29. 05 ± 0.2
October	28.88 ± 0.28	28.83 ± 0.19	29.5 ± 0.11	29.16 ± 0.26	29.2 ± 0.28	**29.33 ± 0.11**	29.13 ± 0.07
Year average	27.48 ± 1.2	27.73 ± 0.93	27.9 ± 0.89	27.68 ± 0.97	**28.1 ± 1.28**	27.94 ±1.06	27.92 ± 0.87
Min	25.65 ± 0.28	26.17 ± 0.19	26.78 ± 0.1	26.39 ± 0.09	25.81 ± 0.3	26.43 ± 0.39	26.71 ± 0.25
Max	29.1 ± 0.28	28.89 ± 0.21	29.5 ± 0.33	29.16 ± 0.12	**29.81 ± 0.29**	29.33 ± 0.24	29.13 ± 0.14

Max and min values are temperature averages calculated from weekly measurements for each indicated month or year. Values in bold are maximum average values for each particular category. Note that for all categories (except min. temperature and October), 2005 has the highest values. Data extracted from NOAA-coral reef watch (http://coralreefwatch.noaa.gov/satellite/data_nrt/timeseries/all_PuertoRico.txt)

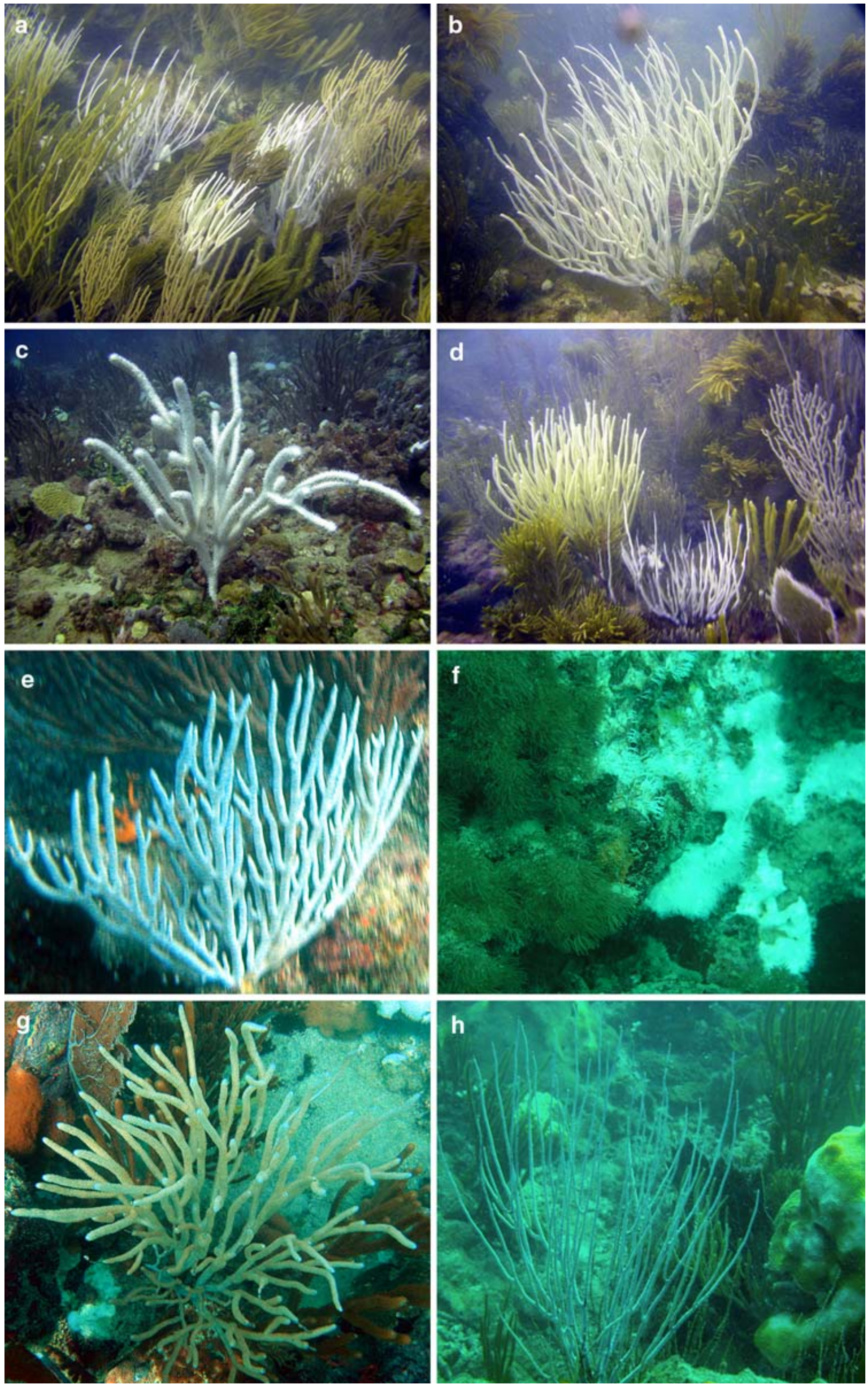

Fig. 1 Bleached octocorals from southwest Puerto Rico. *Pseudoplexaura* (**a**, **b**, **c**, **d**, **g**, **h**), *Muricea muricata* (**e**) and *Briareum asbestinum* (**f**)

Muriceopsis and *E. flexuosa* in previous bleaching events in the study area (P. Yoshioka, personal observation). Finally, several other taxa, notably *P. americana*, *P. acerosa*, *G. ventalina* (except for a single colony in El Hoyo, Southwest Puerto Rico; Yoshioka, per. obs.), *Plexaura* spp., and *Eunicea* spp. (except *E. flexuosa*) showed no definitive indications of bleaching in this (or previous) surveys. Except for observations of *Eunicea* sp. in Panama (Lasker et al. 1984), bleaching in these species has never been reported. A possible reason for non-bleaching in several of

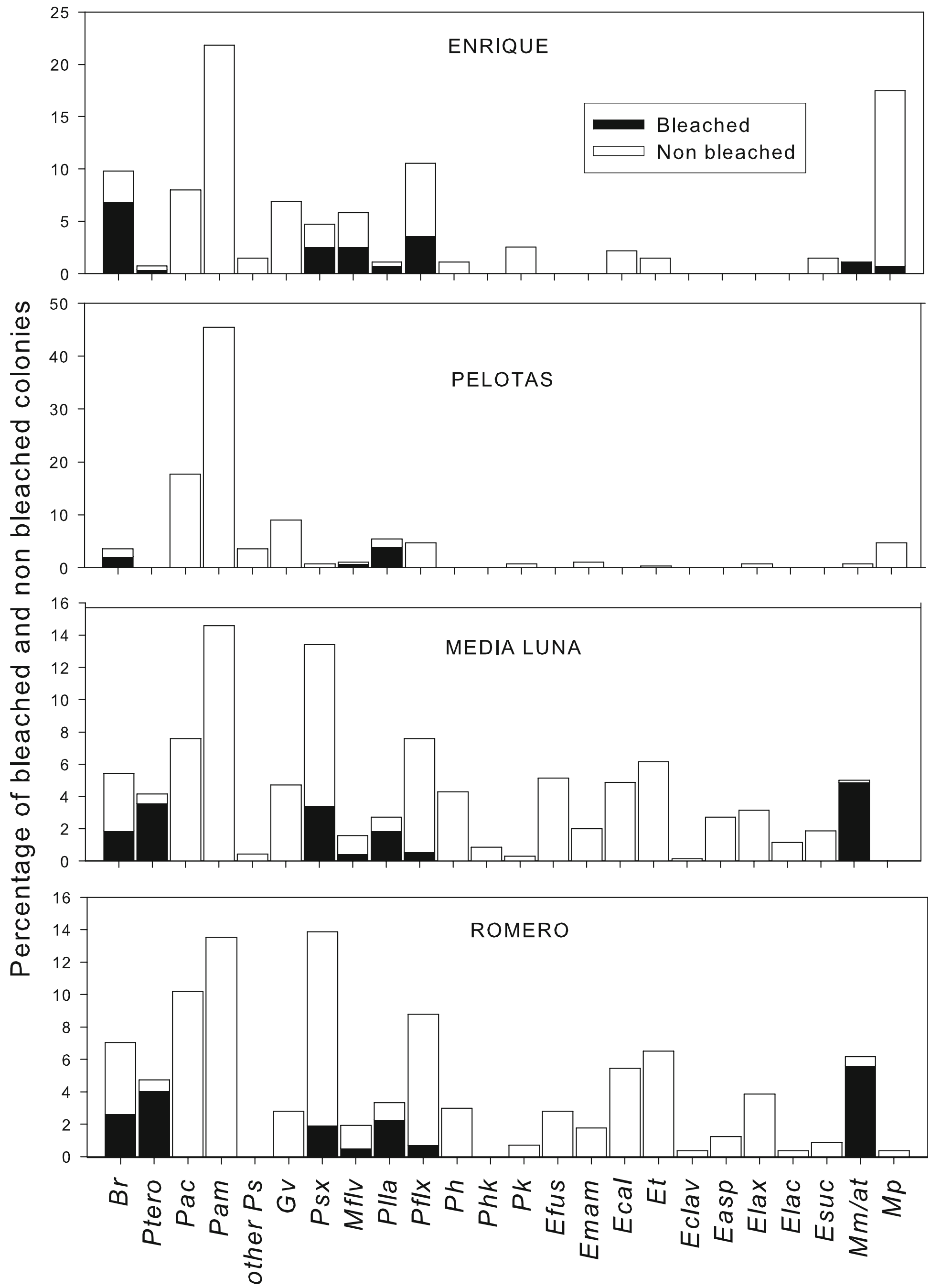

Fig. 2 Percentage of bleached and non-beached colonies per species with respect to the total number of colonies in a location. Abbreviations are: Br = *Briareum asbestinum*, Ptero = *Pterogorgia anceps/guadalupensis*, Pac = *Pseudopterogorgia acerosa*, Pam = *Pseudopterogorgia americana*, Other Ps = *Pseudopterogorgia bipinnata/elisabethae/rigida*, Gv = *Gorgonia ventalina*, Psx = *Pseudoplexaura flagellosa/wagenaari/porosa*, Mflv = *Muriceopsis flavida*, Plla = *Plexaurella dichotoma/nutans*, Pflx = *Eunicea flexuosa*, Ph = *Plexaura homomalla*, Phk = *Plexaura homomalla kükenthali*, Pk = *Plexaura kuna*, Efus = *Eunicea fusca*, Emam = *Eunicea mammosa*, Ecal = *Eunicea calyculata*, Et = *Eunicea tourneforti*, Eclav = *Eunicea clavigera*, Easp = *Eunicea asperula*, Elax = *Eunicea laxispica*, Elac = *Eunicea laciniata*, Esuc = *Eunicea succinea*, Mm/at = *Muricea muricata/atlantica*, Mp = *Muricea pinnata*

these species is that bleaching may be masked by dark pigmentation of octocoral tissues/sclerites.

A likelihood test of Species x Condition was significant ($X^2 = 201.4$, $df = 6$, $P < 0.01$), while a test of site x condition ($X^2 = 1.8$, $df = 3$, $P = 0.61$) was not, suggesting that bleaching is independent of location but dependant on species (Fig. 3). These data analyses indicate that octocoral species differ in their susceptibility to bleaching. Field observations also suggested differences in temporal patterns. Intense bleaching of octocorals was first noted in late September to early October beginning with *Erythropodium caribaeorum*, which was not encountered in our transects but was severely affected by the increased temperature; followed by *Muricea*, *Briareum* and *Plexaurella* and later by *Pseudoplexaura* and *Pterogorgia* (Fig. 1). In addition, bleaching of octocorals was preceded by bleaching in scleractinian corals, hydrocorals, and the zoanthid *Palythoa caribaeorum*. This temporal pattern suggests higher tolerance to thermal stress of octocorals compared to the other major cnidarian taxa.

In late November 2005, these colonies were surveyed again. These observations revealed that the majority of the

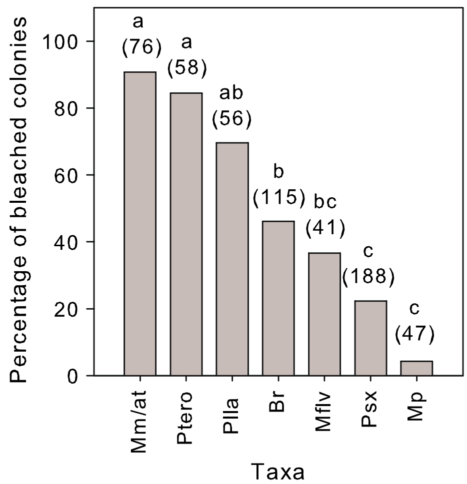

Fig. 3 Percentage of bleached colonies among species. Sample sizes are in parenthesis. Different letters represent differences among groups in *G*-test pairwise species comparisons ($G = 16.812$, $df = 6$, $P < 0.01$) (Sokal and Rohlf 1995, p 722)

affected colonies suffered no mortality. The exceptions were the bleached colonies of *Muricea*, which suffered >90% mortality.

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