DELAYED MORTALITY IN BLEACHED MASSIVE CORALS ON INTERTIDAL REEF FLATS AROUND PHUKET, ANDAMAN SEA, THAILAND

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ABSTRACT: An extreme bleaching event in 2010 in the Andaman Sea caused considerable coral mortality on intertidal reef flats around the south east tip of Phuket, Thailand, which are dominated by poritid and faviid corals. Declines in overall coral cover on the mid-outer reef flats of approximately 40% were noted over a 10 month period with stands of Acropora dying within 7 weeks of initial bleaching while many massive corals showed partial mortality by 7-15 weeks and full colony mortality between 15-44 weeks. The greatest whole colony mortality was evident in Acropora aspera followed by Goniastrea aspera, Coeloseris mayeri, Favites abdita, Goniastrea reitormis, and Platygyra daedalea. The susceptibility to bleaching-induced mortality of G. aspera, which is widely regarded as a hardy coral, is noteworthy as is the delayed whole colony mortality of all the massive coral colonies in this study.

INTRODUCTION

There have been relatively few studies where the mortality of bleached corals has been followed over an extended time frame (Baird and Marshall 2002; McClanahan 2004) though there have been several brief references to delayed coral mortality following bleaching. Glynn (1990) reported that following the 1982-83 bleaching event in the eastern Pacific the massive coral Porites panamensis retained colouration for 2-3 months after other mainly branching species bleached but then died 7 months after the initial bleaching. On the Great Barrier Reef some colonies of the massive coral, Platygyra daedalea, which bleached in 1998 took up to between 4-10 months to die after initial bleaching compared with branching Acropora hyacinthus where over 80% mortality was noted within 10 weeks of the onset of bleaching (Baird and Marshall 2002).

Species differences in bleaching susceptibility and patterns of mortality have long been noted (Brown and Suharsono 1990; Gleason 1993; Marshall and Baird 2000) with branching corals commonly being more severely affected than massive poritids and faviids during bleaching events. In addition, branching corals generally have high rates of whole-colony mortality and relatively little partial mortality following bleaching while massive species show low levels of whole colony mortality and significant tissue loss through partial mortality (McClanahan et al 2009). In the case of P. daedalea from the Great Barrier Reef proportionately more tissue was lost as a result of partial mortality (44%) during the 1998 bleaching than was lost from whole colony mortality (34%) of Acropora millepora (Baird and Marshall 2002). As McClanahan et al (2009) point out, from a population perspective P. daedalea was more severely affected than the branching A. millepora, a result that rather conflicts with the accepted pattern of species susceptibilities.

In the present study advantage was taken of a particularly severe bleaching event in the Andaman Sea in 2010 to evaluate patterns of bleaching, partial and full-colony mortality in both branching and massive corals on intertidal reef flats on the south east tip of Phuket on the west coast of Thailand. The study was carried out over a 12 month period after initial bleaching was noted in late April 2010 – a time scale which allowed the fate of many of the massive corals, which dominate the reef flats in the area, to be comprehensively assessed.
MATERIALS AND METHODS

Detailed accounts of the study site on the SE tip of Phuket island have been published elsewhere (Brown et al 1990; Scoffin et al 1992; Brown et al 2002a) and so only very brief reference will be given here. Data were collected from a reef flat in Ao Tang Khen Bay which has been named as site A in previous publications (Clarke et al 1993; Brown et al 2002a). At this site four permanently marked 10m long transects have been regularly photographed since 1987. These transects (9, 11, 14 and 15) are parallel to the shore and are located at 90, 110, 140 and 150m distances respectively from the shore-line on the outer reef flat. For the purpose of this study belt transect (10m x 0.6m) photographs were taken in March 2010 before bleaching commenced and then again at the onset of bleaching on 1st May, and subsequently on 14th May, 11th June, 10th August and 10th May 2010 and then again on 20th March and 15th May 2011. Percentage living cover was calculated from measuring tapes placed along the transect line on the photographs. In addition the bleaching/mortality status of between 14-40 colonies of different scleractinian coral species, which dominate the reef flats, were tracked over a 10 month period. The species included Acropora aspera (n = 28 colonies); Goniastrea retiformis (n = 28); Platygyra daedalea (n = 40); Coeloseris mayeri (n = 19) and Favites abdita (n = 14). The bleaching/mortality status of 40 colonies of Goniastrea aspera on the inner reef flat was also assessed on the dates shown. Although Porites lutea was a dominant species on the reef flat its irregular and anastomosing growth form in this habitat meant that it was impossible to easily define individual colonies and so this species could not be included in the bleaching/mortality assessment though it was clearly one of the most resilient corals on the reef. The extent of colony bleaching was classified according to Gleason (1993) where the relevant categories for this study were 0-10% bleached, 11-50% bleached, 51-99% bleached, 100% bleached and dead. Two additional categories were added to this scale namely 10-50% partial mortality and 51-99% partial mortality of massive coral species.

RESULTS

Percentage coral cover on all photo-transects combined declined logarithmically ($\ln(\text{cover})=a+be^{-\text{time}}$ adjusted $r^2 =0.67$ $p<0.0001$) from March 2010 to March 2011 (Fig. 1) with live coral cover continuing to fall up to 35 weeks after initial bleaching was noted. Considering the colonies of dominant coral species that were tracked throughout the year it is clear that A. aspera and C. mayeri very quickly succumbed to 100% bleaching within one week of initial bleaching being noted (Fig. 2). Total colony mortality was then evident in A. aspera 7 weeks after initial bleaching while 75% of C. mayeri showed signs of partial mortality at this time. After 44 weeks 71% of C. mayeri colonies had completely died. G. retiformis, F. abdita and G. aspera showed similar bleaching patterns in the early stages of the study with all colonies appearing 100% bleached after 7 weeks. This appearance was followed by considerable partial mortality between weeks 15-44 in G. retiformis and F. abdita and 43% and 57% of colonies showing whole colony mortality respectively by week 44. The majority of G. aspera colonies remained 100% bleached for at least 7 weeks and possibly beyond. However, by 15 weeks 10% of the colonies had died and the remainder showed 51-99% partial mortality. By 44 weeks the majority of colonies of this species had died. P. daedalea appeared to be relatively resistant to bleaching in that at no measuring point were all colonies recorded as 100% bleached though considerable partial mortality of this species was noted by week 15. However, at this time several colonies (21% of the total monitored) began to recover their colouration. By 44 weeks after initial bleaching 46% of P. daedalea colonies were noted as dead.

DISCUSSION

The very severe bleaching event experienced by corals in the Andaman Sea, where sea temperatures exceeded 32°C for 7 weeks (see other papers in this issue) and where cumulative heat stress was reported that exceeded 5 degree
other papers in this issue) and where cumulative heat stress was reported that exceeded 5 degree heating weeks (http://www.osdpd.noaa.gov/PSB/EPS/SST/climohot.html), led to early mortality in branching corals but a delayed mortality (4-10 months after bleaching) in several massive species. In the present study sea temperatures dropped to normal values in August 2010 and thereafter into 2011 (see Tanzil this volume). In addition, no marked sea level depressions were noted during this period (R.P.Dunne – pers comm.) which might have contributed to coral mortality. Hence, it may be concluded that the observed delayed mortalities were a result of the earlier bleaching event rather than subsequent environmental disturbances. Patterns of delayed coral mortality mirror those of Baird and Marshall (2002) and McClanahan (2004) highlighting how mortality estimates of a bleaching event are strongly influenced by the time of sampling.

As in earlier work, the lack of any partial mortality in Acropora species contrasted with extensive partial mortality in massive species (Baird and Marshall 2002). P. daedalea showed some resistance to bleaching when compared with other faviids though estimates of final colony mortality were very similar to those of G. retiformis which showed greater bleaching susceptibility 3 weeks after bleaching was noted. While other studies have shown that massive species are generally less susceptible to bleaching events than branching corals (Brown and Suharsono 1990; Marshall and Baird 2000; McClanahan et al. 2004) there is clearly a hierarchy of bleaching susceptibility within massive species. The present study highlights the bleaching susceptibility and generally high colony mortality of C. mayeri, F. abdita and G. aspera when compared with P. daedalea and G. retiformis as well as the considerable levels of partial mortality exhibited by all massive species at 15 weeks.

Of particular interest was the marked demise of the faviid G. aspera which is one of the highest living corals on the intertidal reef and a coral which might have been anticipated to be a survivor because of its demonstrated tolerances.
Figure 2. Proportion of colonies of six species in various categories (ranging from normally coloured 100% bleaching and 10-50% mortality 100% mortality) when noted on five occasions between May 2010 and March 2011. A. Acropora aspera B. Goniastrea aspera C. Coeloseris mayeri D. Favites abdita E. Goniastrea retiformis F. Platygryra daedalea.
described *G. aspera* as a ‘winner’ during the bleaching of 1998 in Japan because of its increased abundance following the event. However, Stillman (2003) and Somero (2005) have suggested that it is likely that upper inter-tidal species are probably the most susceptible to increases in habitat temperatures compared with species lower on the shore because of their limited acclimation abilities (Stillman 2002). The acclimation potential of *G. aspera* remains unknown but it is possible that the severe bleaching of 2010 was energetically too costly (Anthony et al 2009) for a species already living in highly marginal conditions. Such a result offers a potentially intriguing insight into the relative physiological tolerances of scleractinian corals and suggests that further work is needed on those species which appear to be resistant to environmental stress yet suffer higher mortality than lower shore congeners during an extreme bleaching event.

**ACKNOWLEDGEMENTS**

We should like to thank the Director and staff of the Phuket Marine Biological Center for their continued support and also the Percy Sladen Trust of the Linnean Society for financial support to BEB. Thanks also to Richard Dunne for assistance in compiling figures.

**REFERENCES**


