Coral Reef Impacts of the 2005 Caribbean Bleaching Event

Abstract

Global warming and El Niño have led to an increased frequency of coral bleaching since the 1980s. In late 2005, elevated seawater temperatures resulted in an extensive Caribbean bleaching event. While this event was not as geographically extensive as the 1997-1998 bleaching event in the IndoPacific, regarded as the largest and most damaging bleaching event to date, both maximum seawater temperature and temporal duration of the Caribbean event were similar to those measured in the 1997-98 IndoPacific event. Coral reef surveys conducted in 16 countries by Reef Check teams before, during and after the Caribbean bleaching event revealed that significant coral bleaching but relatively low mortality occurred as compared to the 1997-98 IndoPacific bleaching event. Caribbean bleaching ranged from 4-62% and mortality from 0-27%, whereas bleaching levels neared 100% and mortality reached as high as 95% in many locations following the IndoPacific bleaching event. While bleaching was extensive in Belize, Jamaica, St. Lucia and the British Virgin Islands, mortality was not significant in these areas. By using a standardized approach to monitor and quantify bleaching for the past 10 years, the Reef Check data are useful to help track and compare reef impacts on a regional and global basis. As the threat of global warming to coral reefs increases, it would be wise to invest in a more complete network of surveys to aid in monitoring large-scale environmental stressors and their impacts on coral reefs.

Introduction

Hurricanes, El Nino, disease outbreaks, bleaching and other stressors caused by human impacts have increased coral mortality throughout the world in the past 25 years (Bruno et al. 2001, Mumby et al. 2001, Aronson et al 2002). Although there are many factors responsible for coral mortality, bleaching has been regarded as the major agent of change responsible in both the widespread mortality of corals as well as changes in coral reef community structures (Bruno et al 2001, Diaz-Pulido G and LJ McCook 2002). Large-scale bleaching is predominantly triggered by elevations in sea surface temperatures and in recent years there have been unprecedented increases in sea surface temperatures in many areas of the tropical oceans (Goreau et al 2000, Loya et al. 2001, McClanahan 2004).

The largest global bleaching event on record occurred in 1998 where ocean temperatures reached levels of up to 2.8°C above normal and lasted for periods of days to even months (Goreau et al. 2000, Loya et al 2001). The results of this El Nino related temperature increase were catastrophic for many coral reefs. Coral mortality was near 100% in the Indian Ocean and 80% in areas of the Great Barrier Reef (Wilkinson 1998, Goreau et al. 2000, Obura 2005). Areas of the Caribbean were affected by this bleaching event as well, but escaped the massive estimates of mortality as seen in the rest of the tropical oceans. Although few areas such as Belize and the Cayman Islands experienced extensive bleaching and mortality, coral mortality across the Caribbean ranged from only 5-10% (Wilkinson 1998, Goreau et al 2000, Aronson et al 2002).

In 2005 another large-scale bleaching event occurred, this time centered in the Caribbean Sea. Temperature elevations and temporal duration of the 2005 bleaching event matched those recorded in the 1998 bleaching event (NOAA satellite observations). In this study we attempt to ascertain the impacts of this recent bleaching event. Using standardized Reef Check coral reef survey methods, we will compare bleaching estimates before, during and after this major Caribbean bleaching event to determine the extent of coral bleaching and mortality on two spatial scales: localized, country-based estimates and large-scale estimates of the greater Caribbean Sea.

Materials and Methods

Study Sites:

Over 185 benthic surveys were conducted between January 2004 and June 2006 in 16 different countries and territories. These locations include: Belize, Honduras, Mexico, Brazil, Colombia, Florida, the Bahamas, Dominica, Cuba, the Dominican Republic, Jamaica, the British Virgin Islands, St. Lucia, St. Vincent and the Grenadines, the Netherland Antilles, and the US Virgin Islands.

Survey Design:

Surveys were conducted using the globally standardized Reef Check survey methods. Each site survey contains 4 replicates of a 20x5 meter band transect survey for fish and invertebrates as well as a 20 meter uniform point contact survey for substrate types. Details of the survey design and methodology can be found in Hodgson 1999. Bleaching estimates in these surveys were categorized by both percentage of each coral colony bleached (colony bleaching) and percentage of overall corals bleached (population bleaching) within the band transect. For the purposes of this study, survey depths were categorized into 2 broad reef depths: shallow reefs (2-6 meters) and deep reefs (6-12 meters).

Greater Caribbean bleaching estimates:

To ascertain the impacts of coral bleaching resulting from the 2005 Caribbean bleaching event survey dates were lumped into three distinct time periods. The Before time period determines baseline bleaching levels prior to the major bleaching event; the During time period spans from the onset of elevated seawater temperatures to the time when temperatures resume to normal ranges while the After time period includes all surveys that have taken place once seawater temperatures resumed to normal levels Caribbean wide. The specific dates for these time periods are as follows: Before time period dates range between January 1st 2004 and July 31st 2005; During incorporates surveys from August 1st thru December 31st 2005 and After includes surveys conducted from January 1st thru May 15th 2006.

To gauge large-scale impacts of this bleaching event all locations listed above were lumped to form a greater Caribbean estimate of coral bleaching and mortality. Means of each time period were determined and analyzed using ANOVA with post-hoc Tukey comparisons for estimates of coral population bleaching, colony bleaching and hard coral abundances. Comparisons of the two depth categories were analyzed for both colony bleaching and population bleaching using two-sample T-tests. Mortality estimates were devised using a ratio of recently killed coral (RKC) to total coral cover, where total coral cover is defined as live hard coral cover plus recently killed coral. Estimates of this mortality index were analyzed by ANOVA with post-hoc Tukey comparisons to determine differences among time periods.

Country-based bleaching estimates:

Analyses of bleaching impacts were conducted for specific countries as well as the greater Caribbean. Multiple surveys conducted in Belize, Jamaica, St. Lucia and the British Virgin Islands allowed for bleaching analyses to be conducted by country. Time periods are identical to the greater Caribbean bleaching estimates described previously. All analyses were conducted using ANOVA tests with post-hoc Tukey comparisons to determine differences between time periods. Estimates of mortality follow the same fashion as outlined above.

Results

Greater Caribbean bleaching estimates

On a Caribbean-wide basis, the effects of the 2005 bleaching event were significant. Coral bleaching ranged from 2-62% as a result of the bleaching event. The percentage of coral populations bleached increased significantly as a result of the Caribbean bleaching event (ANOVA $F_{2,187}=26.73$; $P<0.001$). Post-hoc Tukey comparisons revealed that each time period differed significantly from the others. Comparisons of both coral colony bleaching and coral population bleaching by depth category revealed no significant differences between deep and shallow reefs (coral colony t-test: $t_{1,160}=0.82$; $P=0.41$ coral population t-test: $t_{1,169}=0.15$; $P=0.88$). While the bleaching of corals was significant, overall hard coral cover did not differ significantly as a result of the bleaching event (ANOVA $F_{2,182}=0.54$; $P=0.59$). Of the corals that did succumb to bleaching, mortality was significant (ANOVA $F_{2,182}=5.71$; $P=0.004$) with approximately 4-15% mortality Caribbean-wide. Post-hoc Tukey comparisons reveal mortality levels were significantly greater in the after period than in either the before or during time periods.

Country-based bleaching estimates

Belize

Both percent coral colony bleaching and percent coral population bleaching were marginally significant as a result of the 2005 Caribbean bleaching event (coral colony ANOVA $F_{2,23}$=3.25; P=0.06 coral population ANOVA $F_{2,23}$=3.18; P=0.06). Although bleaching among corals was marginally significant in Belize, the percent hard coral cover remained the same among time periods (ANOVA $F_{2,23}$=2.00; P=0.16). Mortality estimates were also non-significant among the time periods (ANOVA $F_{2,23}$=2.16; P=0.14).

Jamaica

The percentage of coral populations bleached in Jamaica were significant as a result of the Caribbean bleaching event (ANOVA $F_{2,42}$=3.32; P=0.05). Post-hoc Tukey comparisons reveal bleaching of the coral populations were significantly higher during the bleaching event than before the event. Coral colony bleaching was also significantly higher during the bleaching event than before (ANOVA $F_{4,41}$=4.97; P=0.01; post-hoc Tukey comparisons). Hard coral cover was significantly reduced after the bleaching event (ANOVA $F_{2,47}$=6.49; P=0.003; post-hoc Tukey comparisons). Although coral cover was significantly reduced, coral mortality as a result of the bleaching event was not significant (ANOVA $F_{2,47}$=1.07; P=0.35).

St. Lucia

St. Lucia experienced massive coral colony and population bleaching as a result of the bleaching event (coral colony ANOVA $F_{1,9}$=52.5; $P<0.001$; coral population ANOVA $F_{1,11}$=51.16; $P<0.001$). Both coral colony bleaching and coral population bleaching were significantly higher during the bleaching event than after the event (post-hoc Tukey comparisons). While bleaching was significant, no significant change percent hard coral cover was observed (ANOVA $F_{1,12}$=0.09; P=0.77). Mortality estimates conducted were also found to be non-significant (ANOVA $F_{1,12}$=0.71; P=0.42).

British Virgin Islands

Coral colony and coral population bleaching was found to be extensive in BVI as a result of the Caribbean bleaching event (coral colony ANOVA $F_{2,21}$=22.0; $P<0.001$; coral population ANOVA $F=_{2,21}$=72.01; $P<0.001$). Bleaching in both individual colonies and the population as a whole was found to be significantly higher during and after the bleaching event than before the event (post-hoc Tukey comparisons). Even though coral bleaching was extensive in BVI, there was no overall change in hard coral cover (ANOVA $F_{2,21}$=1.24; P=0.31). As with hard coral cover, there was no change in the mortality estimates as a result of the Caribbean bleaching event (ANOVA $F_{2,21}$=1.2; P=0.32).

Discussion

The coral bleaching event in 1997-98 resulted in catastrophic coral bleaching and mortality in the Indo-Pacific region. Caribbean regions experienced lesser impacts ranging from severe (Belize) to insignificant (southern and eastern Caribbean) as a result of this event (Wilkinson 1998).

Similar trends in bleaching and mortality were observed in the Caribbean as a result of the 2005 coral bleaching event. While overall bleaching was high (up to 62% overall with some reefs experiencing 100%), mortality was relatively low, ranging from 4-15%. High levels of bleaching with lesser levels of mortality are becoming apparent as a general trend for the Caribbean region with regards to large scale bleaching events, as evidenced in the last two major events.

Proposed mechanisms to this rely on the resistance and resiliency of the coral species themselves. Massive or mounding corals such as poritids and faviids are less susceptible to the effects of bleaching than branching corals such as acroporids and pocilloporids (Marshall and Baird 2000, Loya et al. 2001, Kayanne et al. 2002, Douglas 2003). As the Indo-Pacific is dominated by branching corals and the Caribbean by mounding corals, it is understandable why higher coral bleaching and mortality estimates are found in the Indo-Pacific and comparatively lower levels of mortality in the Caribbean.

Another key mechanism is the frequency in which elevated seawater temperatures that cause bleaching are experienced by the coral colonies. Caribbean corals undergo more frequent increases in temperatures than corals do in the Pacific and it is likely that these Caribbean corals have become more adapted to elevated temperatures and are thus more resistant to bleaching as a result of temperature flux (Aronson et al 2002, Douglas 2003, West and Salm 2003).

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