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Comment

Coral bleaching and disease should not be underestimated as causes of Caribbean coral reef decline

In his recent paper 'A clear human footprint in the coral reefs of the Caribbean', Mora (2008) identifies the drivers of change in Caribbean coral reef communities based on the results of comprehensive analysis. Caution is warranted in accepting some of his major conclusions because, as he himself states, the analysis is a 'snapshot of the potential drivers of coral reef change' and because some of the methods that were used and assumptions that were made seem questionable. In fact, the analysis is a snapshot that looks not at trends, change over time or actual causes of decline but at static measures, and the end result is a misleading picture. Mora concludes 'human activities related to agricultural land use, coastal development, overfishing and climate change had created independent and overwhelming responses in fishes, corals and macroalgae.' In contrast, his analysis indicates that 'thermal stress' and coral diseases have played a minor role in causing reef degradation in the Caribbean. In fact, disease and bleaching have been underestimated as causes of coral reef decline in the Caribbean.

All of the biological data used in the analysis are from one-time surveys conducted between 1999 and 2001 under the auspices of the Atlantic and Gulf Rapid Reef Assessment Project (AGRRA). It is important to note that the factor used in the analysis was not changes in living coral cover over time but rather recent coral mortality. Furthermore, recent coral mortality was calculated as 'the fraction of coral colonies in a transect with 100% of their outward-facing surfaces recently dead'. This approach, which is inconsistent with AGGRA methods, could greatly underestimate mortality by ignoring colonies that are partially dead (even in planar view). Large patches of *Montastraea annularis*, the most abundant species on some Caribbean reefs, are not accounted for accurately when numbers of colonies are counted because they cannot be differentiated into separate colonies. Recent coral mortality exhibits effects of stressors within the last few weeks and would not be expected to reflect possible damage from hurricanes over a 40-year span (as suggested in this paper). This problem with the use of different temporal scales occurs with the treatment of other factors as well.

It is not clear how much of a role Mora attributes to, or at least estimates for, humans in influencing climate change. Coral bleaching associated with elevated seawater temperatures is considered a major indicator of climate change. There is no mention of bleaching at any of the surveyed reef sites, but it is not evident if bleaching was not present at the sites from 1999 to 2001 or if it was intentionally omitted from the analysis. Thermal stress is not defined in the paper or supplementary material, although there is the statement that 'reef sites in warmer environments indeed have had higher coral mortality'. Perhaps thermal stress was calculated as the 'frequency of pentads (i.e. five day periods) in which temperature was 1°C above typical summer temperature'. What is typical? Thermal stress and average temperature are treated distinctly in figure 2 but lumped together in figure 3 (Mora 2008).

Mora also states 'While the effective implementation of marine protected areas (MPAs) increased the biomass of fish populations, coral reef builders and macroalgae followed patterns of change independent of MPAs'. Because this analysis is based on a snapshot that does not reflect changes over time after the establishment of MPAs, particularly marine reserves, it is not valid to use it to support conclusions regarding the effectiveness of MPAs.

In addition, the suggestion that increasing abundance of *Diadema* will help reefs recover is logical, but it is more applicable to shallow depths. All data for the analysis are apparently from fore-reef zones, although the depths are not provided. Note also that herbivory is a rate, and not identical with herbivore biomass.

It would be interesting to see the results of a similar analysis focused on *Acropora palmata* zones. This species, now listed as threatened under the US Endangered Species Act, does not seem to have been included.

Obviously, it is challenging to determine the causes of major changes in complex coral reef ecosystems. The different stressors and their effects vary greatly, and differ in different locations. It is easier to quantify physical damage from a vessel grounding than the effects of overfishing and sedimentation. The characteristics of the major groups of organisms vary widely also. For example, although the analysis in this paper and in many others use single values of macroalgae, macroalgal abundance can vary widely over the course of a year, while coral cover and fish biomass will usually change more slowly. Because of slow coral growth rates, coral cover cannot possibly rebound as quickly as fish biomass.

In this paper, generalizing and extrapolating from the results of one-time surveys carried out over just a few years has created an incorrect and misleading perspective. Although it is irrefutable that human activities have played a major role in causing reef degradation in the Caribbean, it is important to focus not only on better management of more tractable activities such as fishing and anchoring but

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also on support for more research on coral diseases, the links between human activities and diseases, and the synergy between bleaching and (other) diseases (e.g., Muller *et al*. 2008). Losses of over 50–60 per cent of the living coral cover from reefs in the United States Virgin Islands were observed following massive bleaching in 2005 and a subsequent severe outbreak of disease (Miller *et al*. 2006; Rogers *et al*. 2008; Wilkinson & Souter 2008), and similar losses were seen in Puerto Rico (E. Weil 2008, personal communication). None of the factors Mora identified as drivers of Caribbean reef decline has caused such large losses over the course of a single year.

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REFERENCES

Miller, J., Waara, R., Muller, E. & Rogers, C. 2006 Coral bleaching and disease combine to cause extensive mortality on reefs in US Virgin Islands. *Coral Reefs* **25**, 418. (doi:10.1007/s00338-006-0125-6)

Mora, C. 2008 A clear human footprint in the coral reefs of the Caribbean. *Proc. R. Soc B* **275**, 767–773. (doi:10.1098/rspb.2007.1472)

Muller, E. M., Rogers, C. S., Spitzack, A. S. & van Woesik, R. 2008 Bleaching increases likelihood of disease on *Acropora palmata* (Lamarck) in Hawksnest Bay, St John, US Virgin Islands. *Coral Reefs* **27**, 191–195. (doi:10.1007/s00338-007-0310-2)

Rogers, C. S. *et al*. 2008 Ecology of Coral Reefs in the US Virgin Islands. In *Coral Reefs of the USA* (eds B. Riegl & R. E. Dodge), ch. 8, pp. 303–374. Berlin, Germany: Springer.

Wilkinson, C. & Souter, D. 2008 *Status of Caribbean coral reefs after bleaching and hurricanes in 2005*. Townsville, Australia: Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre.