The dynamics of architectural complexity on coral reefs under climate change

Yves-Marie Bozec[1,2], Lorenzo Alvarez-Filip[3] and Peter J Mumby[1,2]

[1]Marine Spatial Ecology Lab, ARC Centre of Excellence or Coral Reef Studies ,School of Biological Sciences, University of Queensland, St.Lucia, Qld 4072, Australia,[2]College of Life Sciences, University of Exeter, Exeter EX4 4PS,UK,[3]Unidad Academia de Sistemas Arrecifales, Instituto de Ciencias del Mar y Limnologia, Universidad Nacional Autonoma de Mexico, Puerto Morelos ,Quintana Roo77580,Mexico

Abstract

One striking feature of coral reef ecosystems is the complex benthic architecture which supports diverse and abundant fauna, particularly of reef fish. Reef-building corals are in decline worldwide, with a corresponding loss of live coral cover resulting in a loss of architectural complexity. Understanding the dynamics of the reef architecture is therefore important to envision the ability of corals to maintain functional habitats in an era of climate change. Here, we develop a mechanistic model of reef topographical complexity for contemporary Caribbean reefs. The model describes the dynamics of corals and other benthic taxa under climate-driven disturbances (hurricanes and coral bleaching). Corals have a simplified shape with explicit diameter and height, allowing species-specific calculation of their colony surface and volume. Growth and the mechanical (hurricanes) and biological erosion (parrotfish) of carbonate skeletons are important in driving the pace of extension/reduction in the upper reef surface, the net outcome being quantified by a simple surface roughness index (reef rugosity). The model accurately simulated the decadal changes of coral cover observed in Cozumel (Mexico) between 1984 and 2008, and provided a realistic hindcast of coral colony-scale (1-10 m) changing rugosity over the same period. We then projected future changes of Caribbean reef rugosity in response to global warming. Under severe and frequent thermal stress, the model predicted a dramatic loss of rugosity over the next two or three decades. Critically, reefs with managed parrotfish populations were able to delay the general loss of architectural complexity, as the benefits of grazing in maintaining living coral outweighed the bioerosion of dead coral skeletons. Overall, this model provides the first explicit projections of reef rugosity in a warming climate, and highlights the need of combining local (protecting and restoring high grazing) to global (mitigation of greenhouse gas emissions) interventions for the persistence of functional reef habitats.

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