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Rapid phase-shift reversal on a Jamaican coral reef

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Abstract Many Caribbean reefs have experienced a phase-shift in community structure, the principle features being a decline in coral cover and an increase in macroalgal biomass. However, one Jamaican reef—Dairy Bull on the north shore near Discovery Bay—is once again dominated by scleractinian corals and several key species have returned. Living coral cover at 6–8 m depth at Dairy Bull has doubled over the past 9 years and is now ~54%. The absolute cover of *Acropora cervicornis* was <1% in 1995, but increased to ~11% by January 2004. During this time the cover of macroalgae decreased by 90%, from 45 to 6%. We speculate that long-lived colonies of *Montastraea annularis* may have facilitated the recovery of this reef by providing structural refugia.

Keywords *Acropora cervicornis* · Coral reef · *Montastraea annularis* · Phase-shift

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Introduction

Since the 1980s, the community structure of most Caribbean reefs has changed dramatically (Gardner et al. 2003). A phase-shift from coral- to macroalga-dominated benthic reef communities has been caused by a variety of factors, of which two of the most important have been the drastic reduction in abundance of *Acropora* spp. (Aronson and Precht 2001) and the decline in herbivory (Hughes 1994).

This phase-shift from coral to macroalgal dominance is widely accepted as a model for the recent dynamics of Caribbean reefs in general and Jamaican reefs in particular (Hughes 1994). Indeed, Jamaican coral reefs often are depicted as a classic example of reef degradation in the Caribbean, in part because multiple agents have acted in concert to create widespread and persistent macroalgal dominance.

Materials and methods

Surveys were performed on the fringing reef at Dairy Bull, located ~2 km east of Discovery Bay, Jamaica. This reef is ~500 m long and ~100 m wide and is part of a discontinuous reef system that spans most of Jamaica's north coast. We conducted our surveys on this reef in 1995, 2003, and 2004.

To estimate the coverage of benthic components such as corals and macroalgae, three transects each 30 m in length were haphazardly placed parallel to depth contours at 6–8 m depth. Benthic community structure was quantified with standard photographic survey techniques. We photographed the substratum within 0.25 m^2 quadrats positioned at random locations along transects ($n = 37$ quadrats in 1995, 73 in 2003, and 38 in 2004). Statistical comparisons of benthic cover components were made between 1995 and 2004 data using unpaired *t*-tests. All data are reported ±1 standard error.

Results and discussion

Benthic cover surveys revealed drastic changes in coral and macroalgal cover from 1995 to 2004. The rapid shift from macroalgal to coral dominance is demonstrated by an inversion in relative percent cover (Fig. 1). Between 1995 and 2004 scleractinian cover nearly doubled from 23.0 ± 3.5 to $53.5 \pm 3.5\%$ while macroalgal cover was reduced by nearly 90% from 44.9 ± 2.8 to $5.7 \pm 1.6\%$. Of the scleractinians *Acropora cervicornis* showed the most dramatic increase in cover from 0.6 ± 0.4 to $10.5 \pm 3.2\%$, appearing in thickets between massive colonies of *Montastraea annularis* reminiscent of the fore-reef community structure that was present at Discovery Bay prior to Hurricane Allen (Rylaarsdam 1983; Fig. 2a). There were no significant differences among sampling periods in cover of *M. annularis*; however, the cover of other reef-building coral species increased significantly, especially *Agaricia agaricites* and *Porites astreoides* (Fig. 2b).

The benthic community at Dairy Bull in 2004 is similar to benthic structure on pre-phase-shift Jamaican reefs of the 1970s when average coral cover was ~55% (Huston 1985). The dramatic reduction in the abundance of macroalgae to only $5.7 \pm 1.6\%$ cover in 2004 is even more striking and is similar to the cover recorded prior to the *Diadema* mortality of 1983–84 (Hughes 1994). The presence of residual populations of living coral at Dairy Bull in the 1990s (Edmunds and Bruno 1996), especially long-lived colonies of *M. annularis*, maintained a high degree of habitat complexity. While habitat complexity was not directly measured in this study, massive corals of the *M. annularis* species complex have been shown to withstand hurricane damage (Woodley et al. 1981), and contribute substantially to topographic complexity (Aronson and Precht 2001). This is a striking contrast to intermediate depths (6–20 m) on the Discovery Bay west fore-reef, where topographic relief has been reduced by coral mortality and bioerosion. At these intermediate depths, coral cover presently is 5–15%, and macroalgae occupy >60% of the substratum (Cho and Woodley 2002). *M. annularis*-generated high structural complexity of the Dairy Bull reef is likely to be an important difference compared to nearby reefs (Bechtel et al. 2006), and it may be that reefs without it are less resilient. If this scenario is accurate, *M. annularis* species complex may function as a foundation taxon (*sensu* Bruno and Bertness 2001) that facilitated the recovery of the Dairy

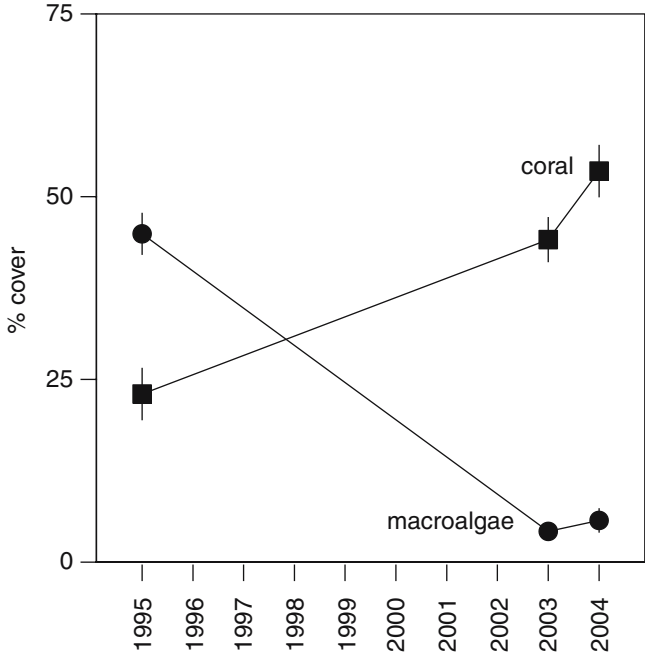

Fig. 1 Percent cover of dominant benthic components in 1995, 2003, and 2004. Data are means ± 1 SE

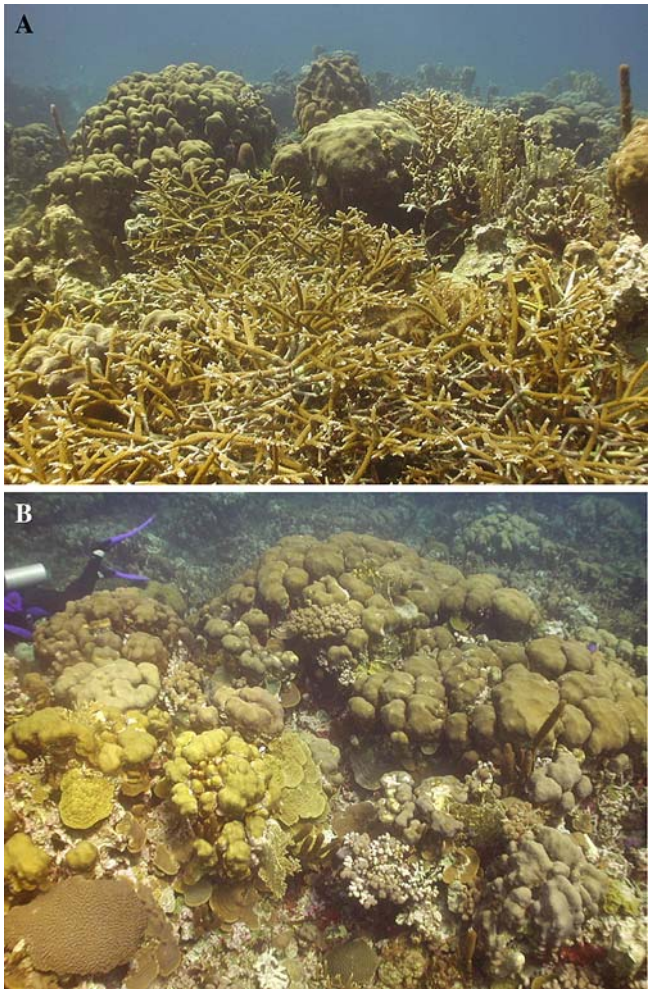

Fig. 2 Underwater photographs of Dairy Bull Reef, Jamaica in February 2003. **a** Underwater photograph of a *Acropora cervicornis* thicket filling in the areas between large, long-lived colonies of *Montastraea annularis* at ~6 m depth at Dairy Bull. View is reminiscent of the coral community of Jamaica in the 1960s and 1970s. **b** Abundance of brooding species *Agaricia agaricites* and *Porites astreoides* within and between large *M. annularis* colonies that form the foundation species of the Dairy Bull Reef complex

Bull reef. At present, the role of *Diadema* as a factor in reef recovery at Dairy Bull is unclear because of high temporal and spatial variance of the data. However, the possibility of high rugosity favoring *Diadema* populations, and hence increased herbivory, could be usefully investigated in future studies (see Bechtel et al. 2006).

While our study is the first to report a phase-shift reversal on a Caribbean reef, our results are spatially restricted to the reef at Dairy Bull. However, when interpreted in conjunction with other studies (i.e., Edmunds and Carpenter 2001; Carpenter and Edmunds 2006), they appear to provide some important clues about the factors responsible for promoting coral reef recovery along the north coast of Jamaica and throughout the Caribbean. This is Discovery Bay Marine Lab publication number 715, and contribution number 128 of the marine biology program of California State University, Northridge.

References

Aronson RB, Precht WF (2001) Evolutionary paleoecology of Caribbean coral reefs. In: Allmon WD, Bottjer DJ (eds) Evolutionary paleoecology: the ecological context of macroevolutionary change. Columbia University Press, New York, pp 171–233

Bechtel JD, Gayle P, Kaufman L (2006) The return of *Diadema antillarum* to Discovery Bay: patterns of distribution and abundance. In: Proceedings of the 10th international coral reef symposium, Okinawa (in press)

Bruno JF, Bertness MD (2001) Habitat modification and facilitation in benthic marine communities. In: Bertness MD, Hay ME, Gaines SD (eds) Marine community ecology. Sinauer, Sunderland pp 201–218

Cho LL, Woodley JD (2002) Recovery of reefs at Discovery Bay, Jamaica and the role of *Diadema antillarum*. In: Proceedings of the 9th international coral reef symposium Bali 1:331–338

Carpenter RC, Edmunds PJ (2006) Local and regional scale recovery of *Diadema* promotes recruitment of scleractinian corals. Ecol Lett 9:271–280

Edmunds PJ, Bruno JF (1996) The importance of sampling scale in ecology: Kilometer-wide variation in coral reef communities. Mar Ecol Prog Ser 143:165–171

Edmunds PJ, Carpenter RC (2001) Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. Proc Natl Acad Sci USA 98:5067–5071

Gardner TA, Côté IM, Gill JA, Grant A, Watkinson AR (2003) Long-term region-wide declines in Caribbean corals. Science 301:958–960

Hughes TP (1994) Catastrophes, phase-shifts, and large-scale degradation of a Caribbean coral reef. Science 265:1547–1551

Huston MA (1985) Patterns of species diversity in relation to depth at Discovery Bay, Jamaica. Bull Mar Sci 37:928–935

Rylaarsdam KW (1983) Life histories and abundance patterns of colonial corals on Jamaican reefs. Mar Ecol Prog Ser 13:249–260

Woodley JD, Chornesky EA, Clifford PA, Jackson JBC, Kaufman LS, Knowlton N, Lang JC, Pearson MP, Porter JW, Rooney MC, Rylaarsdam KW, Tunnicliffe VJ, Wahle CM, Wulff JL, Curtis ASG, Dallmeyer MD, Jupp BP, Koehl MAR, Neigel J, Sides EM (1981) Hurricane Allen's impact on Jamaican coral reefs. Science 214:749–755