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Industrial sedimentation lowers coral growth rates in a turbid lagoon environment, Discovery Bay, Jamaica

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Abstract

Columbus Park is a turbid lagoonal reef site in Discovery Bay, Jamaica, where bauxite is loaded onto ships for transport. In Columbus Park, growth of *Siderastrea siderea* colonies (radial growth rate= 2.0 ± 1.7 mm/yr; n=3) and *Acropora cervicornis* colonies (linear extension rate = 2.51 ± 2.2 cm/yr; n=3) were significantly (p=0.0005 for both) lower than at Dairy Bull (*Siderastrea siderea* radial growth rate= 6.6 ± 2.2 mm/yr; n=3 and *Acropora cervicornis* linear extension rate = 10.95 ± 2.72 cm/yr; n=3) on the Discovery Bay fore-reef . Zooxanthellae from *Acropora cervicornis* samples (n=5) in Columbus Park were all clade A, while zooxanthellae clades A, B, and C were found in *Acropora cervicornis* samples (n=5) at Dairy Bull. The implication of chronic sedimentation and acute extreme events on the coral reefs of Discovery Bay is discussed.

Keywords: clade, zooxanthellae, LSUrDNA, phylogenetic analysis, *Siderastrea siderea*, *Acropora cervicornis*, hurricane Emily, global warming, climate change.

INTRODUCTION

On coastal coral reefs, hard coral cover and biodiversity tend to be low near coastal developments, with sedimentation and pollution causing coral degradation (Crabbe and Smith, 2005; Fabricius *et al.*, 2007). This study documents the impact of sedimentation from an industrial loading terminal on coral colony growth on adjacent coral reefs.

In Jamaica, Bauxite, the ore of aluminium, is the major export, and a key source of GDP for the country (Coke *et al.*, 1987). Total Bauxite production (crude bauxite plus bauxite converted into alumina) was estimated at 11.7 million tonnes in 1996 (Jamaica Bauxite Institute, 2006). Much of this is shipped out from Discovery Bay, on the north coast, where there is a bauxite loading facility (Fig. 1a-c). Several studies have shown the impact of sedimentation in this bay on sediment composition (Perry *et al.*, 2006), bioerosion (Macdonald and Perry, 2003), and carbonate levels (Perry and Taylor, 2004; 2006). We here show the influence of sedimentation of coral colony growth and zooxanthellae clade, and the effects of an extreme acute event (Hurricane Emily in 2005) on sediment transport in the bay.

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MATERIALS AND METHODS

Study Sites

Columbus Park is a lagoonal reef site in Discovery Bay, Jamaica (18° 27.927´ N, 77° 24.827´ W) situated in a semi-protected 1km wide and 56 m deep embayment (Macdonald and Perry, 2003; Perry and Taylor, 2006). Comparative coral growth data is from a fore-reef site, Dairy Bull (18° 28.084´ N, 77°

23.300´W) (Crabbe, 2007). The study period was from July 2003 to December 2006 inclusive.

Fig. 1a

Fig. 1b

Figure 1: Discovery Bay and the bauxite loading terminal. a, The bay and the bauxite loading terminal; b, plume of bauxite dust blown over the Columbus Park coral reef site, during ship loading. Photographs, M.J.C.Crabbe.

Zooxanthellae clade phylogenetic analysis

Sample extraction, preparation and clade analysis using PCR of large subunit rRNA DNA (LSUrDNA) from *Acropora cervicornis* samples at Columbus Park (n=5) and Dairy Bull (n=5) was as described previously (Diekmann *et al.*, 2002; Crabbe, 2003).

Coral growth determination and analysis

This was as described previously (Crabbe *et al.*, 2004; Crabbe and Smith, 2005), for *Acropora cervicornis* and *Sidastrea siderea* colonies, using computer computer digital image analysis using Image Tool software (freely available from the University of Texas Health Science Center, San Antonio, Texas) with probabilities calculated by ANOVA. Three colonies of each species were chosen haphazardly at both Columbus Park and at Dairy Bull, at depths of 10 m at each site.

Fig. 2a

Fig. 2b

Figure 2a,b: Sedimentation on *Siderastrea siderea* colonies in Columbus Park, Discovery Bay, Jamaica. *Depth, 8m.* Photographs, M.J.C.Crabbe.

RESULTS

Fig. 2a and 2b illustrate sediment on *Siderastrea siderea* colonies at the Columbus Park site. Sediment does not appear on colonies at the Dairy Bull fore-reef site. Fig. 3 shows the radial growth rates (mm/yr) of *Sidastrea siderea* and the linear extension rates (cm/yr) of *Acropora cervicornis* at both Columbus Park and Dairy Bull. In Columbus Park, growth of *Siderastrea siderea* colonies (radial growth rate= 2.0 +/- 1.7 mm/yr; n=3) and *Acropora cervicornis* colonies (linear extension rate = 2.51 +/- 2.2 cm/yr; n=3) were significantly (p=0.0005 for both) lower

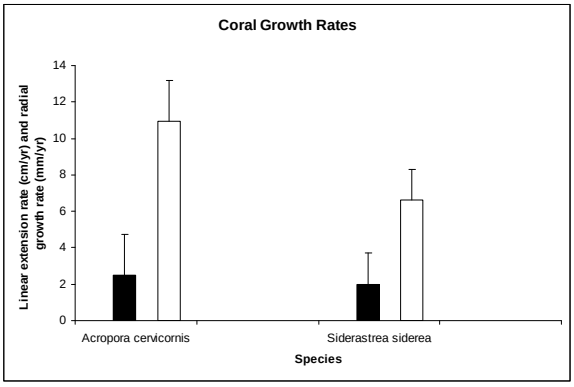

Figure 3. Radial growth rates (mm/yr) of *Sidastrea siderea* and the linear extension rates (cm/yr) of Acropora cervicornis at both Columbus Park * and Dairy Bull.

than at Dairy Bull (*Siderastrea siderea* radial growth rate= 6.6 +/- 2.2 mm/yr; n=3 and *Acropora cervicornis* linear extension rate = 10.95 +/- 2.72 cm/yr; n=3) on the Discovery Bay fore-reef. Clade analysis showed that zooxanthellae from all samples of *Acropora cervicornis* tested at Columbus Park were entirely clade A, while zooxanthellae from *Acropora cervicornis* samples at Dairy Bull were clades A, B and C.

DISCUSSION

Sedimentation rates and light attenuation at Columbus Park are significantly higher than on the fore-reef (Macdonald and Perry, 2003). We show here that they significantly lower growth of *Acropora cervicornis* and *Sidastrea siderea* colonies. Gowth rates found at Dairy Bull were comparable to those found in an earlier study (Huston, 1985). There is no fluvial input into the bay even in the wet season (Macdonald and Perry, 2003), and much of the fine-grained sediment must come from the bauxite loading bay (Fig. 1b), where a ship enters for loading every 7-14 days. Columbus Park has an increase (c. 2-fold) in nutrients (soluble reactive phosphorous, total oxidised nitrogen and ammonia) relative to the fore-reef (Macdonald and Perry, 2003).

It is interesting that only clade A was found in samples of *Acropora cervicornis* taken from Columbus Park while clades A, B and C were found in samples from Dairy Bull. Clade A zooxanthellae may be more tolerant to the high sedimentation/low light conditions than clades B and C.

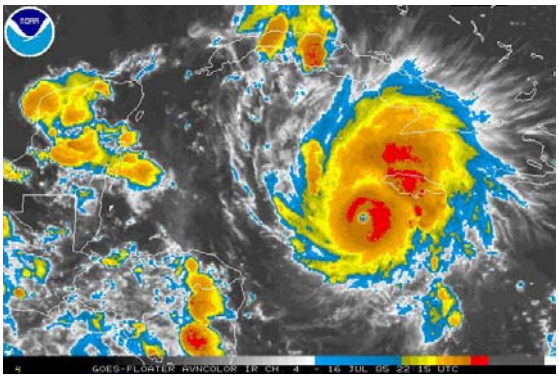

Fig. 4a

Fig. 4b

Fig. 4c

Figure 4:. Sedimentation in Discovery Bay during and after Hurricane Emily, 2005. a, colour enhanced satellite image of hurricane Emily. The eye is to the south west of Jamaica. Picture courtesy NOAA; b, sediment (visible as brown water) in Discovery Bay 12 h after the commencement of the hurricane-force winds and rain (photograph looking East across the bay, M.J.C. Crabbe); c, 15 h after photograph b, looking north towards the reef crest, sediment (visible as brown water) on the shore side of the reef crest. Photograph M.J.C.Crabbe.

Interestingly, one of us (MJCC) was able to observe sediment transfer in the bay as a result of an acute extreme event, Hurricane Emily, in 2005. The hurricane produced high winds and rain along the north coast of Jamaica (Fig 4a). 12 h after the commencement of the hurricane-force winds and rain at Discovery Bay, sediment was distributed throughout the bay, with debris by the shore (Fig. 4b). After a further 15 h, sediment had been transferred through the entrance to the bay, and along the 12m deep ship channel, and was visible on the shore side of the reef crest (Fig. 4c), leaving the bay free of sediment. Such extreme events, which are increasing owing to global warming (Elsner *et al.*, 2006) can only further degrade the Discovery Bay reefs, transporting sediment onto the reef crest and through the ship channel onto the near fore-reefs.

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