Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 16

Is sponge bioerosion increasing?

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Abstract. We tested the hypothesis whether bioerosion is likely to increase on stressed coral reefs, using bioeroding sponges as a key group. A survey was conducted on the central Great Barrier Reef before and after two major bleaching events. While coral cover was slightly reduced, total bioeroding sponge abundances significantly increased from the first to the second survey (by 150%, $p < 0.001$). *Aka mucosa* became more common on the upper reef flat, and symbiotic bioeroding sponges proliferated on the lower reef flat and slope. Both groups are able to attack live coral. As typical after disturbance events, homogeneity of the sponge abundances was more pronounced after bleaching. Due to increased availability of settlement area and reduced space competition, we expect bioeroding sponge abundances and bioerosion rates to rise globally and would like to encourage more intensive field investigations on this group.

Key words: *Cliona*, *Aka*, bioeroding sponges, abundances, community shift

Introduction

On healthy reefs and under normal conditions, bioerosion is balanced or exceeded by carbonate accretion (Goreau and Hartman 1963), but this balance can be upset by shifts in environmental conditions or by disturbance events. As a consequence, reef-building organisms may suffer mortality, sublethal damage or stress (Berkelmans et al. 2004). In contrast, bioeroding organisms appear to continue to function normally or can occasionally even become epidemic (Rose and Risk 1985; Vicente 1990). Disturbance-related, changed conditions involve (i) the creation of suitable substrate for the settlement of larvae of bioeroding organisms, (ii) reduced space competition in favor of bioeroding organisms and (iii) reduced resistance of organisms invaded by bioeroders (Rose and Risk 1985). Considering that endolithic bioeroding organisms are relatively sheltered from otherwise adverse ambient conditions (Schönberg and Suwa 2007; Schönberg et al. 2008) and that many are filter feeders that may benefit from eutrophication (Rose and Risk 1985; Holmes 1997, 2000; Holmes et al. 2000; Ward-Paige et al. 2005), a rise in bioerosion appears to be a logical consequence if present trends of environmental deterioration continue. In extreme cases the positive balance of reef accretion will be overridden and bioerosion may prevail.

Sponges are the leading internal bioeroders on many coral reefs (MacGeachy and Stearn 1976). Many successful and aggressive species of bioeroding sponges harbor symbiotic dinoflagellates (Schönberg and Loh 2005), and have been reported to be more bleaching-resistant than corals (Vicente 1990). Reasons for this observation may stem from differences in the symbiosis of corals and bioeroding sponges: the 3-dimensional body of the sponges shelters symbionts from light more efficiently than coral tissue; the sponge G-type symbionts appear to be comparatively stress-resistant (Schönberg and Loh 2005; Schönberg et al. 2008); and the sponges are able to move the symbionts away from sources of stress (Schönberg and Suwa 2007). Recent observations have reported putative increases of bioeroding sponges in the Caribbean (Rützler 2002). However, to date we had no quantitative data on bioeroding sponge abundances both before and after a major disturbance event.

We report findings of a field study before and after bleaching at Orpheus Island, central Great Barrier Reef (GBR). The same survey was conducted in 1997/98 (Schönberg 2001) and in 2003/04. In 1998 and 2002 two major bleaching events significantly affected the study area, mainly killing branching corals (Berkelmans and Oliver 1999; Baird and Marshall 2002; Berkelmans et al. 2004). This presented an opportunity to investigate whether bioeroding sponges suffer from environmental changes as much as other reef organisms or, alternatively, whether bioeroding sponges tolerate environmental changes or even benefit from them. This study attempts to provide insights into possible future trends of reef bioerosion.

Material and Methods

The present study was conducted in the southern part of Little Pioneer Bay, Orpheus Island, central GBR (18°37'S and 146°29'E), mostly on SCUBA and partly by snorkeling. Methods were consistent in the first and second survey: Sponge occurrences were recorded along five 100 x 0.5 m belt transects perpendicular to the shoreline (see Fig. 2 in Schönberg 2001) using a 50 x 50 cm quadrat subdivided into 100 cm^2 squares. Any 100 cm^2 sub-square that contained bioeroding sponges was counted and then related to the amount of available calcium carbonate (see also Chiappone et al. 2007). Sponge occurrences are here represented as percentages per available substrate per square and then averaged over each reef zone (Table 1). Reef zones and sponge species were categorized as in the first study (Schönberg 2001), with the zones being defined as:

A) sand flat with only very little suitable substrate for bioeroding sponges, substrate often buried
B) mixed zone with sand patches, rubble, blocks and small live, massive corals with dead tops
C) coral pavement where mostly dead corals form a more or less continuous ground cover
D) branching coral zone, mostly reduced to rubble during the second study
E) reef relief, including live corals in patchy distribution

The sponge groups were:

1) the encrusting growth form of *Cliona orientalis* Thiele, 1900 (for information on growth forms see e.g. Schönberg 2008)
2) brown papillate bioeroding sponges with a papillar diameter > 2 mm (dominated by the papillate growth form of *C. orientalis*)
3) brown or orange papillate sponges with a papillar diameter < 2 mm (mainly including *Cliona caesia* (Schönberg, 2000) and *Pione vastifica* (Hancock, 1849), but to a smaller extent also *Cliona mucronata* Sollas, 1878 and *Cliona vermifera* Hancock, 1867)
4) yellow or orange papillate sponges with a papillar diameter of > 2 mm (*Cliona celata* Grant, 1826 *sensu* Schönberg 2000, *Cliothosa hancocki* [Topsent, 1888] and *Cliothosa aurivillii* [Lindgren, 1897])
5) *Aka* spp. (vastly dominated by *A. mucosa* [Bergquist, 1965] *sensu* Schönberg 2000, but also including the rare *A. paratypica* Fromont, 1993)
6) *Zyzzya criceta* Schönberg, 2000
7) other, comparatively rare bioeroding sponge species

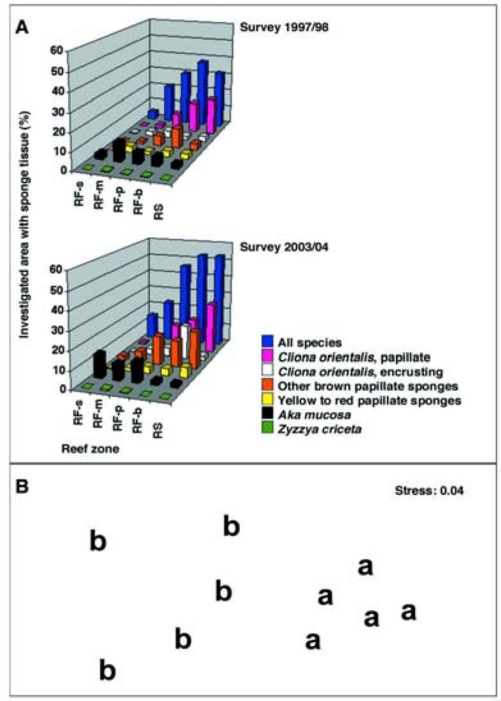

Fig. 1. Bioeroding sponge distributions at Orpheus Island. A: Increase in bioeroding sponge abundances on the central Great Barrier Reef. Abundances and distributions of bioeroding sponges are displayed for the different reef zones during the surveys 1997/98 and 2003/04. Reef zones: RF – reef flat, s – sandy, m – mixed, p – pavement, b – branching corals, RS – reef slope. During the second survey, dead substrate available for sponge settlement was +4, +1, -10, +8 and +11% in the 5 zones, respectively (Table 1). B: Changes in the community of bioeroding sponges represented by multidimensional scaling after an analysis of similarities (MDS; ANOSIM), b – before, a – after bleaching events (5 belt transects 100 x 0.5 m).

Substrate categories were distinguished as:

i) calcium carbonate in form of dead coral, mollusk shells etc.; suitable substrate for bioeroding sponges
ii) substrate covered with live tissue (corals, soft corals, other invertebrates, dense cover of algae); unsuitable substrate for all bioeroding sponges except for *C. orientalis*, which invades such areas laterally (Schönberg and Wilkinson 2001) and *A. mucosa* that may even be able to settle on coral tissue (Rützler 1971)
iii) sand; unsuitable substrate for bioeroding sponges (except for *A. mucosa* that is able to live in a piece of calcium carbonate buried in the sand; Schönberg 2001)
iv) mud; unsuitable substrate for bioeroding sponges (except for *A. mucosa* that is able to live in a piece of calcium carbonate buried in the mud; Schönberg 2001)

Where reference samples were taken with hammer and chisel, preparations were made according to standard procedures (e.g. Schönberg 2000) and included in the reference collection of the first author. Resulting species descriptions can be accessed through other publications (Schönberg 2000; Schönberg 2001; Schönberg et al. 2006; Schönberg and Tapanila 2006; Schönberg and Beuck 2007).

The earlier study was conducted 1997/98 (Schönberg 2001), the later study 2003/04. The first survey yielded data for a putatively largely undisturbed situation. The more recent survey took place two years after two severe bleaching events, which had a significant impact at the sample site and caused severe disturbance that partly resulted in over 60% coral mortality (Berkelmans and Oliver 1999; Baird and Marshall 2002; Berkelmans et al. 2004). To date only the survival of reef builders had been surveyed in this area, but not the survival of bioeroders. The studies reported here represent an unprecedented before-and-after investigation and focused on the question whether bioeroding sponges had suffered to the same extent as corals. 'Before' data were compared with 'after' data with multidimensional scaling for community composition using analysis of similarities (MDS; ANOSIM), and for total area of bioeroding sponges per survey using a paired t-test.

Table 1. Material composition and bioeroding sponge abundances averaged over all survey transects in Little Pioneer Bay, Orpheus Island comparing the situation of 1997/98 with 2003/04. Values in parentheses are standard deviations.

Zone	Material [% transect area]								Sponge abundances			
	Calcium carbonate		Live tissue		Sand		Mud		[% transect area]		[% substrate area]	
	1997/1998	2003/2004	1997/1998	2003/2004	1997/1998	2003/2004	1997/1998	2003/2004	1997/1998	2003/2004	1997/1998	2003/2004
Sand	41.7	45.9 (20.0)	2.0	3.3 (2.1)	56.3	50.8 (20.1)	6.7	0.0 (0.0)	1.9 (2.0)	6.1 (4.3)	4.6	16.8 (13.9)
Mixed zone	70.7	71.5 (6.4)	11.7	12.4 (7.5)	17.6	16.0 (9.9)	9.3	0.2 (0.4)	8.4 (2.6)	9.3 (8.4)	11.9	13.1 (12.2)
Coral pavement	84.2	74.1 (5.8)	15.5	20.2 (5.4)	0.3	5.2 (3.9)	18.9	0.5 (0.5)	12.4 (1.6)	18.9 (2.41)	14.7	25.7 (3.7)
Branching corals	62.9	71.2 (9.0)	36.4	22.8 (5.8)	0.7	5.5 (8.0)	18.8	0.5 (0.9)	13.8 (10.8)	18.8 (7.64)	21.9	27.0 (7.2)
Reef relief	57.5	68.8 (6.7)	32.5	22.7 (9.0)	0.0	0.2 (0.3)	20.7	8.6 (6.2)	12.6 (2.9)	20.7 (6.2)	21.9	29.6 (11.0)

Results and Discussion

Both, the 1997/98 and the 2003/04 survey on bioeroding sponge abundances on the central GBR showed that symbiotic bioeroding sponges dominated over non-symbiotic ones (most common: *Cliona orientalis* and *Cliona caesia*; Fig. 1; latter as *Pione caesia* in Schönberg 2001). Another very common sponge was *Aka mucosa* that can survive on the innermost reef flat and in the mud behind the reef crest, its body being buried in the sediments and cm-long fistules reaching into the water column. *C. orientalis* and *A. mucosa* can attack live corals, while most other bioeroding sponges can only settle on or expand into dead substrates (Rützler 1971; Schönberg 2001; Schönberg and Wilkinson 2001).

Between the first and the second survey (Fig. 1A) a clear escalation in bioeroding sponge abundances occurred, with an overall increase of total bioeroding sponge area of about 150% ($p < 0.001$, paired t-test), and a stronger prevalence of *A. mucosa* on the upper reef flat and the symbiotic bioeroding sponges on the lower reef flat and on the reef slope. For *C. orientalis*, especially the early, papillate growth form became more common, indicating that larval settlement continued unhindered or was even enhanced after the bleaching events by increased availability of suitable substrate (Table 1). Despite clear evidence of the demise of various species of corals and soft corals, the more mature, encrusting growth form of *C. orientalis* had also increased in the zone formerly inhabited by branching corals, suggesting that established colonies of this sponge did not die during the bleaching events, but spread in reef areas where most coral mortality occurred. Using multidimensional scaling, mean bioeroding sponge areas per transect and available substrate clustered separately for both surveys and differed significantly, with the cluster from the first survey more dispersed than the cluster from the second survey (Fig. 1B; ANOSIM $r = 0.804$, $p = 0.008$). This pattern indicated that sponge community composition became more homogeneous, possibly implying the occurrence of a major disturbance (Connell and Keough 1985). We ascribe this disturbance to the recent bleaching events, resulting in an increase of dead surface area available for sponge larval settlement (Table 1) and reduced space competition by other reef organisms (see also Chiappone et al. 2007).

The present study represents a localized survey, but is supported by other reports of increases in bioeroding sponge abundances (Rose and Risk 1985; Rützler 2002). If we accept that bleaching events were the cause for this shift, then we will have to expect globally increasing bioerosion rates on coral reefs. This prognosis appears even more likely when considering that many sponges may benefit from growing eutrophication and pollution (see e.g. Holmes 1997, 2000). We would like to encourage further field studies on bioeroding sponges, and preferably investigations over time.

Acknowledgements

The first author was supported by a Feodor-Lynen Fellowship from the Alexander von Humboldt Foundation, Bonn, Germany and by funding from the Australian Research Council to O. Hoegh-Guldberg. We acknowledge the friendly assistance we received from staff at the Orpheus Island Research Station. H. Cambourn, E. Cebrian, W. Loh and R. Olbrich helped during the field trips and long, long if shallow dives.

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