Journal of Experimental Marine Biology and Ecology 441 (2013) 71–79

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Coral bioerosion by the sea urchin *Diadema setosum* in Hong Kong: Susceptibility of different coral species

Clement P. Dumont [a], Dickey C.C. Lau [b], Juan Carlos Astudillo [a], Kin Fung Fong [b], Solomon T.C. Chak [a], Jian-Wen Qiu [b,*]

[a] *The Swire Institute of Marine Science and School of Biological Sciences, The University of Hong Kong, Pok Fu Lam Road, Hong Kong, China*
[b] *Department of Biology, Hong Kong Baptist University, 224 Waterloo Road, Hong Kong, China*

ARTICLE INFO

Article history:
Received 17 April 2012
Received in revised form 16 January 2013
Accepted 17 January 2013
Available online 13 February 2013

Keywords:
Bioerosion
Coral
Diadema
Platygyra
Porites
Sea urchin

ABSTRACT

This study examined coral bioerosion by the sea urchin *Diadema setosum* at 8 sites along a north–south direction in Hong Kong. Bioerosion rate, estimated from urchin density, size distribution, gut turnover rate and $CaCO_3$ in gut content, varied from 0.12 to 0.66 kg $CaCO_3$ m^{-2} yr^{-1}. The highest bioerosion rate and *D. setosum* density occurred at Moon Island, Hoi Ha Wan (HHW) Marine Park. There was no evidence of segregation by *D. setosum* on a particular substratum. However, of all *D. setosum* found on corals, a large percentage (62%) was found on the two dominant coral genera *Platygyra* and *Porites*. A laboratory experiment was thus run to compare the relative susceptibility of *Platygyra carnosus* and *Porites lutea*, two dominant species of massive corals with different porosity and skeletal density, to urchin grazing. The urchins eroded 3.3 times more dead *P. carnosus* skeleton and 3.6 times more dead *P. lutea* than the live coral of the corresponding species. Bioerosion of *P. carnosus* was also >3 times higher than that of *P. lutea* for both live corals and dead skeleton, which was further confirmed by a higher amount of inorganic content in the feces of *D. setosum* feeding on *P. carnosus* than those feeding on *P. lutea*. Cover of fouling organisms (mainly turf algae) on the dead skeleton was greatly reduced in both species (-49% in *P. carnosus* and -38% in *P. lutea*). Our study has provided clear evidence that *D. setosum* is effective in reducing algal growth as well as causing coral bioerosion, especially the more porous and less dense *P. carnosus*. The results were consistent with the field observation of severe coral damage at HHW where *P. carnosus* dominated the community, and indicated an urgent need for management action to reduce coral bioerosion at the site with a high density of *D. setosum*.

1. Introduction

Sea urchins act as both herbivores and bioeroders in coral reefs. They feed on not only erect macroalgae grown on various solid substrates, but also surficial and endolithic algae associated with coral skeleton (Bak, 1994; Carreiro-Silva and McClanahan, 2001). While an adequate level of urchin grazing removes competitive algae and thus provides suitable substrates for coral settlement and growth (Carpenter and Edmunds, 2006), excessive urchin grazing will result in severe bioerosion, weakening the coral framework and increasing the risk of coral damage by storms (Glynn, 1997). High densities of sea urchins can also reduce coral recruitment, coral juvenile growth rate (Davis and Vize, 2008; Sammarco, 1980), and even consume living coral tissue with the underlying skeleton (Bak and van Eys, 1975).

The rate of bioerosion is influenced by the species, size and density of the sea urchin, as well as site characteristics, such as macroalgal and predator abundance (Brown-Saracino et al., 2007; Carreiro-Silva and McClanahan, 2001; Griffin et al., 2003; Mokady et al., 1996). Among sea urchins, *Echinothrix diadema* (Linnaeus), *Echinometra mathaei* (de Blainville), *Eucidaris thouarsii* (Agassiz and Desor) and several species of *Diadema* can reach high densities (30 to 150 individuals m^{-2}) and have been reported as the main agents of coral bioerosion (see Table 6 in Carreiro-Silva and McClanahan, 2001), often with bioerosion rates higher than any other groups of external grazers including fishes (Table 4–2 in Glynn, 1997). For example, bioerosion by sea urchins can reach 40 kg $CaCO_3$ m^{-2} yr^{-1} (Glynn, 1988), much higher than the typical accretion rates of 0.3 to 12 kg $CaCO_3$ m^{-2} yr^{-1} in tropical reefs (Smith, 1983), and be responsible for up to 80% of the total erosion of reefs (Scoffin et al., 1980).

The present study was conducted to quantify the bioerosion rate by *Diadema setosum* (Leske) at multiple sites in Hong Kong, including Hoi Ha Wan (HHW) Marine Park where erosion by this urchin has been observed (Lam et al., 2007), and to determine how urchin density and size, substrate composition and coral dominancy might affect coral bioerosion. Based on our field surveys that showed a frequent association between *D. setosum* and massive corals *Platygyra* spp. and *Porites* spp. (Fig. 1), a laboratory experiment was conducted to determine whether the susceptibility to grazing differed between the *Platygyra carnosus* Veron and *Porites lutea* Milne-Edwards and Haime, the most

---

* Corresponding author. Tel.: +852 34117055; fax: +852 34115995.
E-mail address: qiujw@hkbu.edu.hk (J.-W. Qiu).

0022-0981/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jembe.2013.01.018

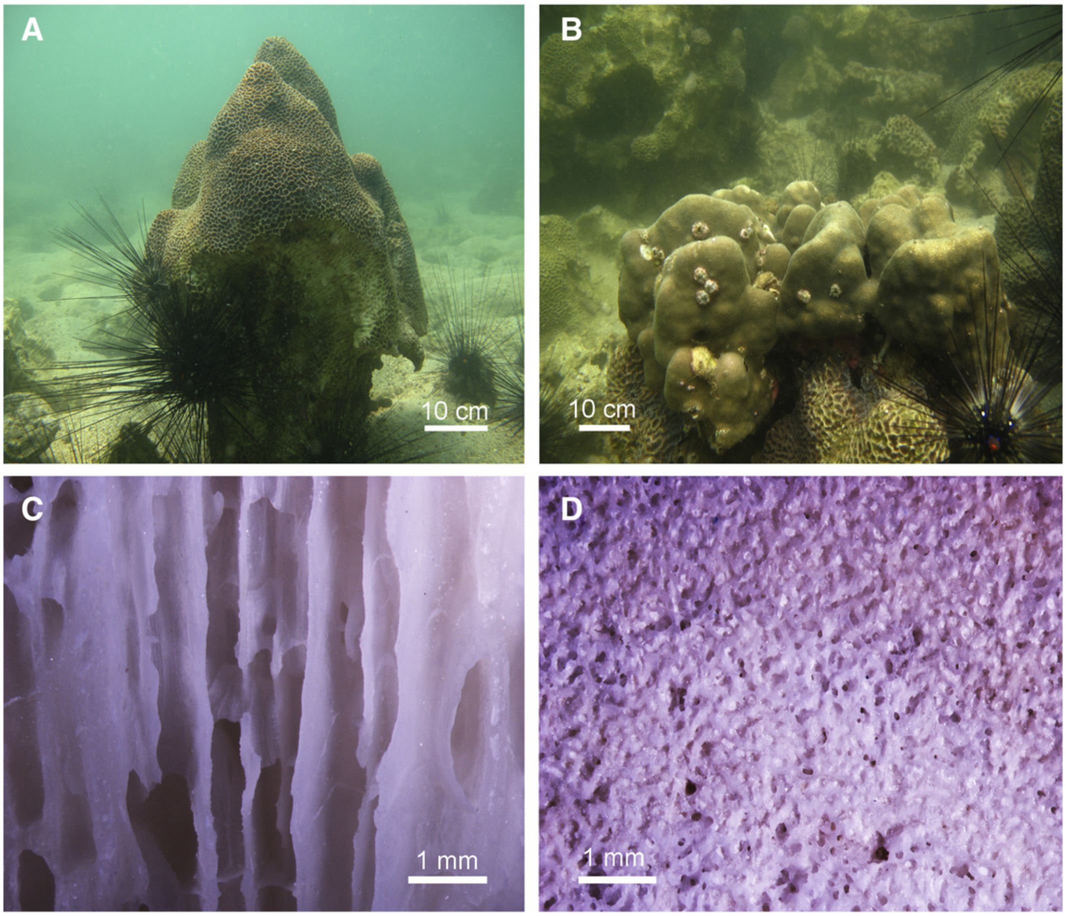

Fig. 1. Two species of dominant massive coral in Hong Kong: a colony of *Platygyra carnosus* showing serious bioerosion by *Diadema setosum* at the base (A); a colony of *Porites lutea* among eroded colonies of *P. carnosus* (B); skeleton of *P. carnosus* (C) and *P. lutea* (D), exposed by cutting with a saw paralell to the axis of coral maximum growth.

common species of the respective genus of massive coral along the coasts of southern China.

2. Material and methods

2.1. Field surveys

Hong Kong waters can be roughly divided into an estuarine zone in the west, an oceanic zone in the east, and a transitional zone between these two (Fig. 2). Hard corals inhabit both the oceanic zone and transitional zone but are more diverse and abundant in the former (Chan et al., 2005). We selected 8 sites within the transitional and oceanic zones along a north–south direction to include sites of high to low coral coverage and composition (Hodgson and Yau, 1997). The sea urchin *D. setosum* is common in coral habitats in Hong Kong (Thompson, 1982). Among the study sites, Moon Island lies immediately on the northern boundary of Hoi Ha Marine Park where fishing without a license is prohibited and trawling is banned.

A survey of the 8 sites was conducted in August 2009 to quantify the substrate composition and occurrence of *D. setosum* on each type of substratum. At each site, a pair of divers swam quickly for around 20 min to find the location with the highest coral cover. Three transects, each 50 m long, were then haphazardly placed parallel to the shoreline at 2–5 m depth. Substrate composition was examined using 25 photoquadrats (0.5 × 0.5 m) taken every 2 m along each transect. For each photoquadrat, the substrate composition [i.e. percent sand, bare igneous rock, algal covered igneous rock, dead coral skeleton (always covered by algae), and live coral], and the occurrence of *D. setosum* on the different substrates were quantified with 100 stratified random points (i.e. 4 random points in each of the 25 equal-sized cells forming a 5 × 5 grid) using the software Coral Point Count with an Excel extension (CPCe 3.6) (Kohler and Gill, 2006). For the live corals, the percent cover was estimated for each genus as it was not possible to identify some corals to species in the field. For the three sites with sufficiently high densities of *D. setosum* (i.e. Chek Chau, Moon Island and Pak Lap Tsai, all with >35 *D. setosum* on 18.75 m^{-2} from 75 0.5 m × 0.5 m quadrats), Pearson correlation was conducted to assess the association between substrate composition and occurrence of *D. setosum* on substrate.

A belt transect survey of *D. setosum* density and size distribution was conducted in August 2009 (dry season) and repeated in February 2010 (wet season). *D. setosum* within three haphazardly placed transects (2 m × 50 m) parallel to the shoreline at 2–5 m depth were counted to determine its density. As many as *D. setosum*, not limited to those on the transects, were collected and measured to the nearest 0.1 mm to obtained a representative size–distribution. Those hidden inside rock crevices and that were difficult to catch were not measured. For a few sites where *D. setosum* was highly abundant on the transects, such as Moon Island and Crescent Island, size measurements were made for haphazardly chosen individuals until the data were considered to be sufficient to represent the size-distribution. Size measurements were conducted by flipping over the urchin and inserting the measuring arms of a Vernier caliper from the exposed oral side that has shorter spines than the aboral side. Because night counts might be substantially higher than day counts (Sammarco and Williams, 1982) and for most sites only day counts were possible due to difficulties in logistics, both day and night surveys were conducted on several occasions at three sites (Moon Island, Sharp