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Borehole density on the surface of living *Porites* corals as an indicator of sedimentation in Hong Kong

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ABSTRACT

Borehole density on the surface of *Porites* has been used as an indicator of water quality in the Great Barrier Reef. We assessed the relationship between borehole density on *Porites* and eight water quality parameters across 26 sites in Hong Kong. We found that total borehole densities on the surface of *Porites* at 16 of the studied sites were high (>1000 individuals m^{-2}), with polychaetes being the dominant bioeroders. Sedimentation rate was correlated positively with total borehole density and polychaete borehole density, with the latter relationship having a substantially higher correlation of determination. None of the environmental factors used were significantly correlated with bivalve borehole density. These results provide a baseline for assessing future changes in coral bioerosion in Hong Kong. This present study also indicates that polychaete boreholes can be used as a bioindicator of sedimentation in the South China Sea region where polychaetes are numerically dominant bioeroders.

1. Introduction

Bioerosion, the process of calcium carbonate removal by biota, has been a focus of research in recent decades due to the recognition that its change can tip the balance between reef accretion and destruction (Glynn, 1997). Bioerosion can occur externally or internally. Because internal bioeroders such as bivalves, polychaetes, sipunculans and sponges live inside coral skeleton, they are less visible than external biooeroders such as parrot fish and sea urchins. Nevertheless, internal bioeroders can contribute substantially to the overall bioerosion and should not be overlooked when assessing reef health. For example, the date mussels, *Lithophaga* spp., common internal bioeroders, have been reported to remove 9 kg $CaCO_3$ m^{-2} yr^{-1} (Scott and Risk, 1988), exceeding or roughly equivalent to most of the typical accretion rates of 0.3 to 12 kg $CaCO_3$ m^{-2} yr^{-1} in tropical reefs (Smith, 1983). Polychaetes can also be dominant internal bioeroders, reaching up to 80,000 individuals m^{-2} and removing up to 1.8 kg $CaCO_3$ m^{-2} yr^{-1} (Davies and Hutchings, 1983).

The level of internal bioerosion has been shown to correlate with water quality (Edinger et al., 2000; Holmes et al., 2000), and has been proposed as a bioindicator for assessing reef health in tropical waters (Risk et al., 2001; Le Grand and Fabricius, 2011; Fabricius et al., 2012). Such correlation can be explained by the fact that most internal macro-bioeroders are filter-feeders of plankton, therefore environmental gradients that determine plankton abundance should also affect the abundance of internal bioeroders (Pastorok and Bilyard, 1985). Following the same logic, disturbance of environmental gradients by human activities (e.g., sewage, agricultural runoff, mining) should affect the abundance of internal bioeroders (Le Grand and Fabricius, 2011; Fabricius et al., 2012).

Internal bioerosion has been estimated by several methods (Le Grand and Fabricius, 2011). Collecting live coral colonies and observing their cross-sections can directly provide data on internal bioerosion, but this method is time consuming, labor- and resource-intensive and requires the sacrifice of live coral. Collecting coral rubble for observation is non-destructive, but it suffers from the drawback of unknown age of the rubble, which makes it difficult to interpret the data collected from different sites. Other methods have also been explored such as deployment of experimental blocks to measure the rate of bioerosion on corals, but these methods are generally time consuming and cannot obtain results immediately (Londoño-Cruz et al., 2003; Hutchings et al., 2005). Borehole density on the surface of *Porites* coral heads can indicate the abundance of internal bioeroders and thus the level of bioerosion (Edinger et al., 2000; Holmes et al., 2000). It is easy to determine and non-destructive, therefore this method has been adopted as an index in the bioindicator system for inshore waters of the Great Barrier Reef (Fabricius et al., 2012).

Although the borehole counting method is appealing due to its simplicity, its applicability in other areas has not been explored. A case in point is the coasts along southern China where severe coral bioerosion

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has been reported (Lam et al., 2007; Chen et al., 2013; Dumont et al., 2013, Qiu et al., 2014; Yang and Goodkin, 2014), but no nondestructive method of coral health assessment has been conducted. We therefore aimed to provide baseline data on borehole densities in *Porites*, and to assess the relationship between coral borehole density and water quality. We conducted the study in Hong Kong where there are two gradients of environmental factors (estuarine to oceanic; sheltered to open) (Hodgson and Yau, 1997; Fabricius and McCorry, 2006), which are known to affect the development of bioeroder communities elsewhere (Le Grand and Fabricius, 2011). We assessed such correlation using both total boreholes, as in Le Grand and Fabricius (2011) for *Porites*, and borer taxon-specific boreholes because taxon-specific data might have better correlation with water quality parameters.

2. Materials and methods

2.1. Study area

Hong Kong is situated on the southeastern coast of China, about 130 km south of the Tropic of Cancer. The coasts of Hong Kong are lined with volcanic bedrocks that usually do not extend beyond 10 m below the chart datum (Morton and Morton, 1983). Below bedrock the seabed is usually soft mud, which can easily be stirred up, resulting in high water turbidity. The climate of Hong Kong is monsoonal with a wet season (May–October) and a dry season (November–April). During the dry season water temperature can drop to as low as 14 °C (Fabricius and McCorry, 2006; Yang and Goodkin, 2014). These environmental conditions are not optimal for the development of coral communities. Therefore, corals in Hong Kong can only develop into fringing reef communities; they do not form true reefs. Due to the influence of freshwater discharge from the Pearl River in the west, there is a great difference in coral community development along the east–west or oceanic-estuarine direction. Scleractinian corals are present only in the transition and the oceanic zones, with those in the oceanic zone being more diverse and abundant (Ang et al., 2004; Chan et al., 2005; Goodkin et al., 2011). We selected 26 sites to quantify coral borehole density (Fig. 1). These sites represented environmental gradients such as salinity, sedimentation, and dissolve oxygen that are known to affect coral diversity and coverage (Hodgson and Yau, 1997). They are located in four geographical regions (Fabricius and McCorry, 2006): the Southern Region (S-R) which include 5 sites in the transition zone; the Southeastern Region (SE-R) which include 7 exposed sites in the oceanic zone; the Southern-Coastal Region (SC-R) which include 4 sheltered sites; and the Northeastern (NE-R) which include 10 sheltered sites.

2.2. Coral borehole density

Surveys of coral borehole density were conducted from late October to early December 2012. Self-contained underwater breathing apparatus (scuba) was used for underwater surveys. At each site, a photographic quadrat method (Le Grand and Fabricius, 2011) was applied by recording digital photographs of *Porites* coral surfaces. Specifically, two 50 m transects were laid parallel to the coastal line at 3–5 m depths in locations with the highest coral cover. For every *Porites* colony (3–29 colonies depending on their availability at the site) within 1 m of the transect, five digital photographs of a 15 × 15 cm quadrat were taken using a Canon G10 camera with an underwater housing. Several coral colonies with different shapes of boreholes were collected from the field and cut open in the laboratory in order to match the shape of the borehole with the identity of the internal macroeroder. The photo quadrats were analyzed in the laboratory to determine the identity and abundance of macrobioeroders based on the shape and number of their external boreholes (Fig. 2). Because previous studies have shown that the externally visible boreholes on *Porites* in Hong Kong are mainly caused by the boring polychaete *Spirobranchus tetraceros* (Sun et al., 2012) and the boring bivalves, *Lithophaga* spp. (Scott, 1980), for ease of data presentation, they were classified as bivalve boreholes which are keyhole-shaped, polychaete boreholes which are circular, and other boreholes (i.e. boreholes created by other borers such as barnacles and sponges) which are often irregular.

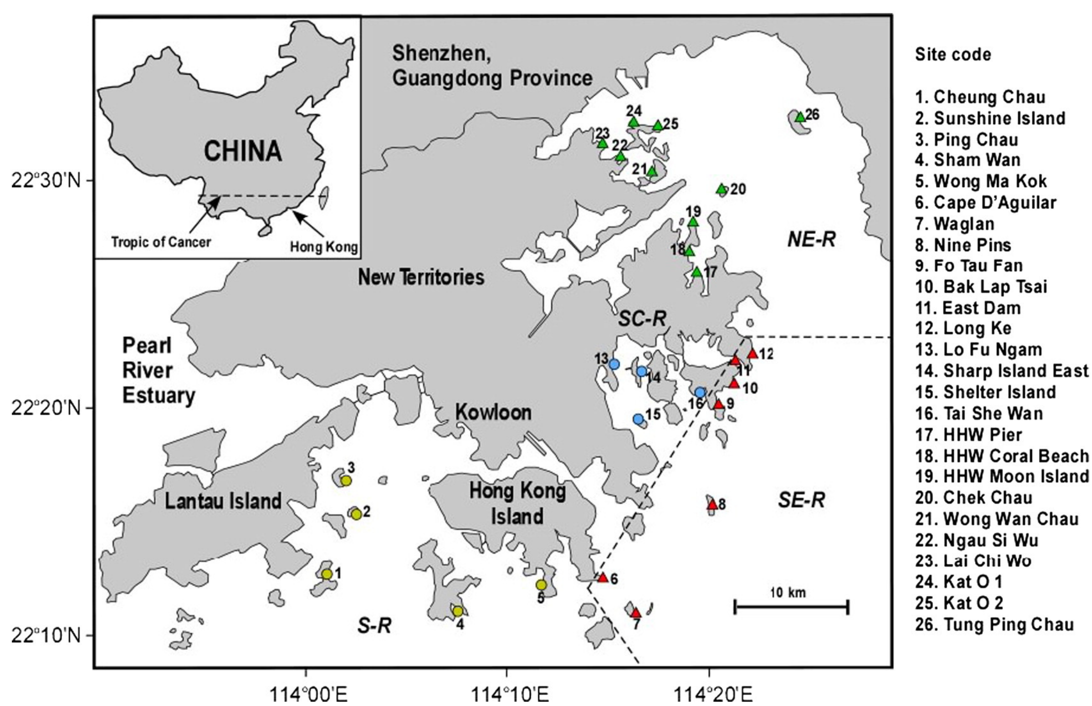

Fig. 1. A map of Hong Kong showing the 26 study sites. Sites are color-coded by hydrological region: southern region (S-R, yellow circle), southeastern region (SE-R, red triangle), southern coastal region (SC-R, blue circle) and northeastern region (NE-R, green triangle). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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