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Heavy metal pollution recorded in *Porites* corals from Daya Bay, northern South China Sea

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ABSTRACT

We examined metal-to-calcium ratios (Fe/Ca, Mn/Ca and Zn/Ca) in the growth bands of two *Porites* corals from Daya Bay, South China Sea, in order to trace long-term trends in local ambient pollution levels. Although Fe and Mn did not show any obvious increasing trends over 32 years in the period 1976–2007, peak values of Fe/Ca and Mn/Ca occurred in the mid-late 1980s, temporally-coeval with the local construction of a nuclear power station. Furthermore, both corals showed rapid increases in Zn concentrations over the past 14 years (1994–2007), most likely due to increases in domestic and industrial sewage discharge. The Daya Bay corals had higher concentrations of metals than other reported corals from both pristine and seriously polluted locations, suggesting that acute (Fe and Mn) and chronic (Zn) heavy metal contamination has occurred locally over the past ∼32 years.

1. Introduction

As a marginal sea surrounded by land, the South China Sea (SCS) has been heavily impacted by human activities, especially its estuaries and bays which are seriously threatened by high rates of population growth as well as agricultural and industrial developments (Scott, 1990; Morton and Blackmore, 2001). Daya Bay, located in the subtropical region of the northern SCS (Fig. 1), is one of the most important economic development districts and aquaculture areas in China. The first commercial nuclear power station in Mainland China, the Daya Bay Nuclear Power Station (DNPS), is located here. Since the 1980s, however, rapid expansions of urbanization, aquaculture, and industry have adversely affected the water quality in Daya Bay. There is mounting evidence for notable environmental deterioration in Daya Bay, such as degradation in water quality (e.g. nutrients, pH, COD, BOD, DO, Chl-*a*) (Wang et al., 2006, 2008a; Wu and Wang, 2007; Wu et al., 2009), increased organic contaminants (e.g. DDT, PAH, PCB) in water and sediments (Zhou et al., 2001; Zhou and Maskaoui, 2003; Wang et al., 2008b; Xing et al., 2009; Yan et al., 2009), thermal pollution from the DNPS (Tang et al., 2003), and episodes of harmful algal blooms (Song et al., 2004, 2009; Yu et al., 2007a, 2007b). Large coastal constructions, such as the DNPS and Huizhou Port, have caused a significant increase in sedimentation input into seawater, however, the impacts on water quality and ecosystems are still unclear. Plastics manufacturing, petrochemical, printing and other industries are continually emerging around Daya Bay and surrounding areas (Song et al., 2009). As such, monitoring of long-term heavy metal pollution is crucial to the management of this area. Moreover, heavy metals can remain unchanged in the environment for years and may thus pose a threat to marine organisms and humans. For example, accumulation of heavy metals in aquacultural seafood is potentially harmful to human health. However, monitoring is still non-existent in the bay. Du et al. (2008) profiled 100 years of heavy metal history in the sediments via 4 cores (dated by ^{210}Pb) drilled in Dapeng'ao cove (Fig. 1), Daya Bay, and the results showed that the concentrations of As (7.7–30.8 mg/kg), Cd (23.2–60.5 μg/kg), Cr (22.1–48.1 mg/kg), Pb (22.0–111.0 mg/kg), Cu (4.9–24.1 mg/kg) and Zn (57.5–120.0 mg/kg) increased gradually from the bottom (i.e., oldest) to the surface (i.e., youngest) layer for all core samples. However, heavy metal trends in Daya Bay sediments may not clearly represent their variations in aquatic systems, because slow sedimentation rates and biological effects tend to obscure short-term variations in metal levels.

Scleractinian corals, such as *Porites*, have proved to be excellent material for high-resolution paleoclimatic (or other historical events) reconstruction as they are widely distributed, sensitive to environmental changes, and their annual growth bands can be accurately

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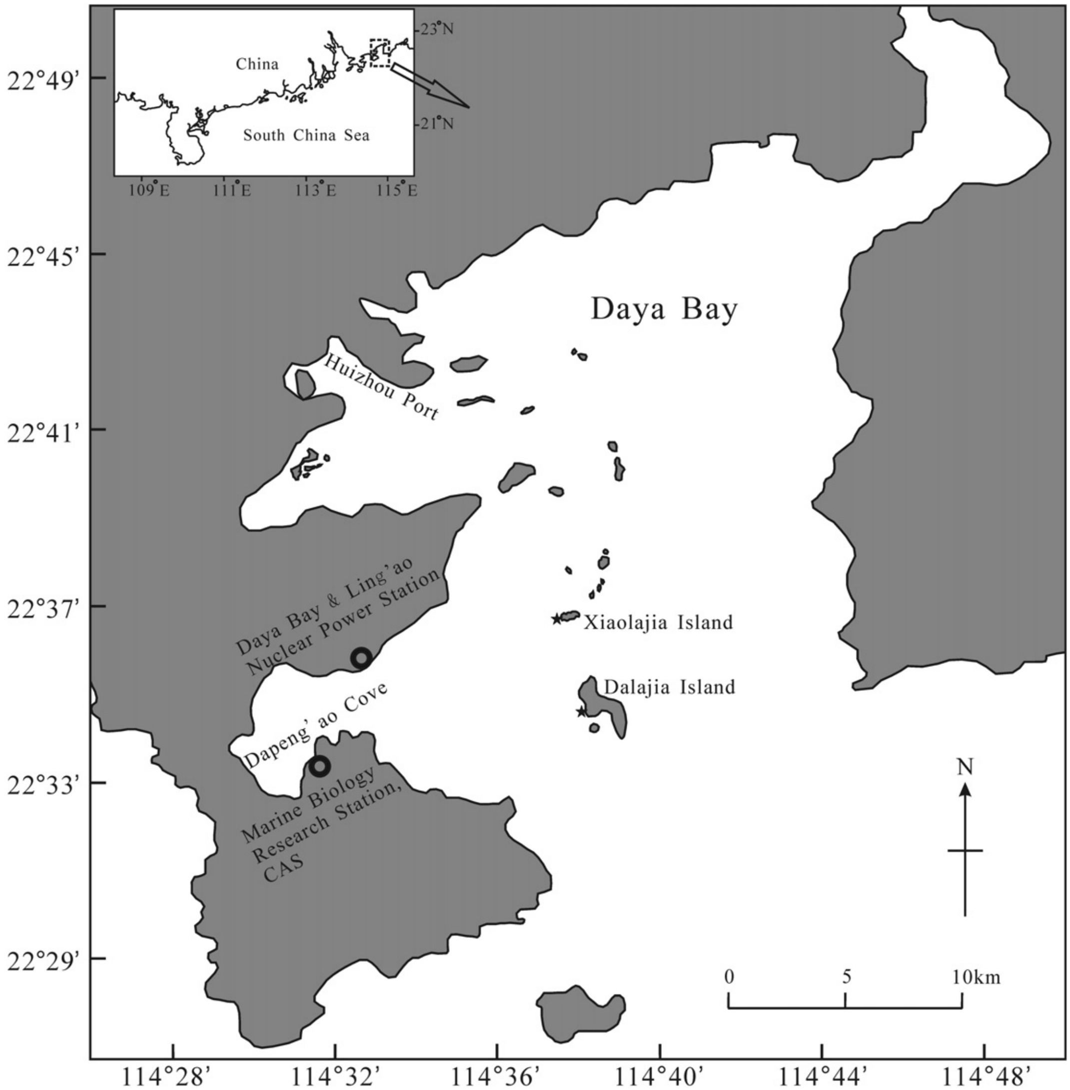

Fig. 1. Map of Daya Bay, South China Sea, indicating the sampling sites (Dalajia and Xiaolajia Island) and position of local nuclear power stations.

dated (Gagan et al., 2000; Yu et al., 2005). Furthermore, they have a high tendency to accumulate metals continuously in their skeletons during growth and have therefore been suggested to be useful indicators of historical pollution events such as chronic (long-term) metal pollution, including oceanic lead contamination linked with gasoline and other industries (Dodge and Gilbert, 1984; Shen and Boyle, 1987; Medina-Elizalde et al., 2002; Inoue et al., 2006; Inoue and Tanimizu, 2008; Kelly et al., 2009), and sewage and industrial discharges (Hanna and Muir, 1990; Scott, 1990; Guzmán and Jiménez, 1992; Runnalls and Coleman, 2003; Ramos et al., 2004; Al-Rousan et al., 2007). They may also record relatively short-time (few months or years) acute metal pollution caused by some specific events such as mining (David, 2000, 2003; Fallon et al., 2002; Edinger et al., 2008) and harbor dredging (Esslemont, 2000; Esslemont et al., 2004). However, little attention has been focused on metal pollution caused by large-scale coastal construction.

Metal elements are incorporated into corals by a variety of pathways, such as direct replacement of calcium by dissolved metals in aragonite lattice, inclusion of detritus materials into skeletal pore spaces, uptake of organic materials incorporation of metals into coral skeletons, or coral feeding (see review by Howard and Brown, 1984; Hanna and Muir, 1990). It has been well documented (Hanna and Muir, 1990; Esslemont, 2000; Ramos et al., 2004) that corals from polluted areas show a much higher concentration of trace metals in their skeletons than corals from unpolluted areas. The history of marine pollution is not well known in regions such as Daya Bay due to the lack of continuous monitoring systems. However, bio-monitoring techniques based on elemental concentrations in annual coral skeletons can be used to overcome this problem.

Non-reefal coral communities are patchily and sporadically distributed along offshore islands in Daya Bay (Chen et al., 2009). The aims of this study are to: (1) establish baseline levels of trace metals (Fe, Mn, Zn) in corals from a typical bay effected by various human activities in the northern SCS; (2) investigate temporal variation of metals in the aquatic environment by examining long-term (32 years) heavy metal variations in the growth bands of local *Porites* corals; and (3) investigate the role of corals as biomonitors of metal pollution in the water environment of Daya Bay.

2. Materials and methods

2.1. Coral collection

Two coral specimens of living *Porites* were collected for metal analysis. One (DLJ-1) was collected in June 2006, from a depth of