ARTICLE IN PRESS

Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Macrobenthic communities in Hong Kong waters: Comparison between 2001 and 2012 and potential link to pollution control

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ARTICLE INFO

Keywords:
Benthos
Bivalves
Hong Kong
Pollution
Polychaetes
Sediment

ABSTRACT

Macrobenthic communities in 2001 and 2012 were compared across the marine environment of Hong Kong based on sediment grab samples collected from 28 stations. CLUSTER analysis showed in both surveys that the stations could be divided into four groups at 20% faunal similarity. However, there were notable changes in the macrobenthic community structure between 2001 and 2012 in three focal areas of pollution control (i.e., Victoria Harbour, Deep Bay and Tolo Harbour). The potential link between macrobenthos and pollution abatement measures, and the contributions of environmental conditions to the differential responsiveness of macrobenthos were explored. Notably, a reduction in nutrient input to the eastern part of Victoria Harbour might have led to recovery of benthic communities therein.

1. Introduction

Macrobenthos are widely used as bioindicators in marine pollution monitoring due to their limited motility and responsiveness to pollutant loading (Snelgrove and Butman, 1994; Magni et al., 2009). Different types of sediment are usually inhabited by macrobenthos of different life-history traits (Gray and Pearson, 1982; Gray et al., 1990), and their changes in abundance and species composition could correspond to the loading of pollutants (Warwick and Pearson, 1987; Clarke and Green, 1988; Wildsmith et al., 2011). For instance, along a gradient of organic pollution from highly polluted to pristine sites, macrobenthic community usually changes from a dominance of few opportunistic species to a diverse fauna (Pearson and Rosenberg, 1978); therefore, determining their community structure can reveal the status of organic pollution in the sediment. Nevertheless, there is limited knowledge on the recovery of degraded benthic communities from cessation of organic enrichment (Sanz-Lázaro and Marin, 2006; Shin et al., 2008). Although it is generally assumed that recovery in low latitude, tropical areas is rapid due to the dominance of short-living opportunistic species (Santos and Simon, 1980; Wu, 1982; Lu and Wu, 2000), other forms of disturbances in tropical marine systems such as storm and dredging may affect benthic community, making it difficult to detect the recovery from organic enrichment (Shin, 1989; Qian et al., 2003; Cheung et al., 2008).

Assessment of benthic community changes caused by various human activities requires baseline data on the abundance, species composition, and community structure. However, such updated data are generally lacking in Hong Kong (Shin and Thompson, 1982; Shin et al., 2004). In this study, we therefore conducted a territory-wide survey of macrobenthic communities in 2012, and compared with data collected in 2001 (Shin et al., 2004) to provide an updated baseline, and identify areas that might have undergone substantial faunal changes. The period between 2001 and 2012 was interesting because several organic pollution control projects had either been completed or under construction (Nicholson et al., 2011). Around Victoria Harbour, Stage I of the Harbour Area Treatment Scheme (HATS) which aimed to collect and treat 75% of the sewage generated by an urban population of 4.5 million inhabiting the area, was commissioned in December 2001 (Shin et al., 2008; Xu et al., 2011). Under this scheme, sewage collected from Kowloon and northeastern Hong Kong Island was conveyed to the Stonecutters Island through deep tunnels, treated there and discharged to the western part of Victoria Harbour through a submarine outfall (Fig. 1). In the Tolo Harbour area, implementation of the Tolo Harbour Action Plan, especially the export of effluent from the Sha Tin and Tai Po Sewage Treatment Works to Victoria Harbour, had resulted in a reduction in total nitrogen load of 6000 kg d^{-1} in 1987 to

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http://dx.doi.org/10.1016/j.marpolbul.2017.04.026
Received 30 September 2016; Received in revised form 13 April 2017; Accepted 13 April 2017

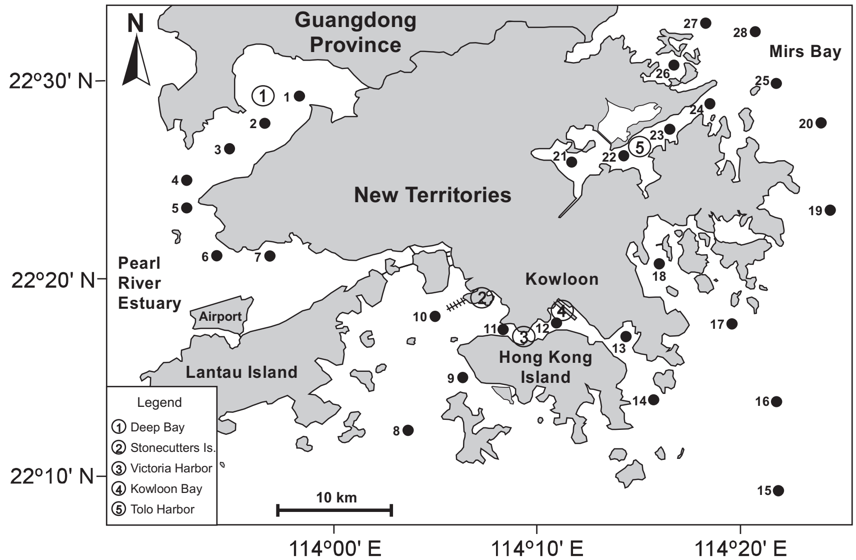

Fig. 1. A map of Hong Kong showing the 28 studied stations. Several places mentioned in the main text are marked with a circled number: Deep Bay (①); Stonecutters Island (②); Victoria Harbour (③); Kowloon Bay (④); Tolo Harbour (⑤).

600 kg d^{-1} after 1998 (Shin, 2003). Deep Bay, which receives freshwater discharges from rivers in New Territories of Hong Kong to the south and Shenzhen to the north, has suffered from serious organic pollution since the 1980s (Qiu, 1999; Xu et al., 2010). The Hong Kong and Shenzhen governments have implemented various pollution control measures in recent decades, especially the Deep Bay (Shenzhen Bay) Water Pollution Control Joint Implementation Program (DSD, 2009; Zhao et al., 2014).

In the present study, we aimed to test the hypothesis that the macrobenthic communities would display considerable temporal changes in these three focal areas (i.e., Victoria Harbour, Tolo Harbour and Deep Bay) where pollution control intervention measures had been implemented. We expected more changes in macrobenthic community in both harbours than in Deep Bay due to the complicated issue of controlling trans-border pollution. In addition, we aimed to understand how the changes in sedimentary parameters might have restructured the benthic communities.

2. Materials and methods

2.1. Study area and field sampling

Samples were collected on 5–8 June 2012 from 28 stations covering the entire Hong Kong waters that are different in hydrology and human impact (Fig. 1). The station localities and numbers corresponded to a subset of stations in the Environmental Protection Department (EPD)'s regular sediment monitoring program (EPD, 2012). The stations were located by differential Global Positioning System (GPS) and the water depths determined by echo sounding. At each station, five sediment samples were collected using a 0.1 m^2 van Veen grab for faunal analysis, and one sediment sample was collected for sediment analysis. The sediment samples for faunal analysis were gently rinsed through a 0.5 mm sieve. The residues retained on the sieve were carefully transferred into plastic containers and preserved in 5% formalin in seawater stained with 1% Rose Bengal. For sediment analysis, approximately 400 g of each sediment sample was kept in a Ziplock bag and placed on ice in a cooler on board the survey vessel, and stored at −20 °C in a refrigerator after the samples were transported to Hong Kong Baptist University.

2.2. Faunal analysis

For faunal analysis, sediment residues retained on the sieve were sorted, and macrobenthos were transferred to 70% ethanol and later identified to the lowest possible taxonomic level. Specimens with an anterior fragment were counted to determine the abundance, and biomass was determined as ethanol-preserved wet weight using a SHIMADZU AUW220 electronic balance after the sample was blotted dry with a paper towel. To facilitate the determination of temporal changes in macrobenthic fauna, 28 of the 120 stations sampled in 2001 by Shin et al. (2004) that overlapped with our 28 stations were included in the analysis. Since Shin et al. (2004) showed that samples collected in summer (June–July) and winter (November–December) of the same year showed substantial differences in abundance and composition, we used their summer dataset only to avoid the confounding effect of season.

2.3. Sediment analysis

Several sedimentary parameters were analyzed to understand their influence on the faunal structure. The sediment samples were freeze-dried. For determination of total organic matter (TOM) content, approximately 20 g freeze-dried sediment from each sample was treated with 35% H_2O_2 overnight, dried at 100 °C to constant weight and combusted at 500 °C for 8 h in a muffle furnace. The content of TOM was calculated as the loss in weight after combustion, as compared with the weight after drying at 100 °C. Data for other sedimentary parameters, including chemical oxygen demand (COD), electrochemical potential (EP), silt and clay (S & C) content, total carbon (TC) content, total Kjeldahl nitrogen (TKN) content and total sulphide (TS) content were obtained from the Environmental Protection Department (Table 1).

2.4. Statistical analysis

Faunal data from the five grab samples of each station were pooled for calculation of univariate and multivariate community parameters. Univariate diversity parameters (i.e., Shannon-Wiener diversity index and Pielou's evenness index) were calculated for each station. Based on the species-abundance data, the stations were grouped using CLUSTER analysis, followed by non-metric multi-dimensional scaling (MDS) to spatially depict the relationships among the stations.

CLUSTER analysis was carried out based on the Bray-Curtis coefficient values between every pair of stations (Clarke and Warwick, 2001). The Bray-Curtis coefficient is a commonly used coefficient to describe the