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Baseline

Sediment characteristics and benthic ecological status in contrasting marine environments of subtropical Hong Kong

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ABSTRACT

Sediment characteristics and benthic communities on a finer sampling scale in four contrasting environments in subtropical Hong Kong were analyzed in summer and winter 2012. In two harbour habitats which suffered from historic sewage pollution or hypoxic events, organic carbon, nutrient and trace metal content in the sediment were significantly higher than that in an offshore area and a marine reserve. The relatively low organic and nutrient content in the offshore habitat could be resulted from enhanced resuspension of such materials from the seabed owing to intense water mixing and disturbance caused by bottom trawling. The biotic indices AMBI and M-AMBI were shown to be useful in assessing the benthic ecological status of these habitats. Such indices can also be more sensitive than sediment physico-chemical parameters in differentiating the response of macrofauna to seasonal changes in the benthic environment.

Species composition and structure of marine benthic communities are closely associated with sediment characteristics, including particle granulomtery (Seiderer and Newell, 1999; Van Hoey et al., 2004; Cooper et al., 2011), nutrient content (Gao et al., 2005; Yasuhara et al., 2007; Giani et al., 2012), and environmental contaminants such as trace metals and organics (Calabretta and Oviatt, 2008; Johnston and Roberts, 2009; Ryu et al., 2011). In general, finer sediment supports a higher proportion of deposit feeders whereas coarser sediment harbors more suspension or filter feeders (Mancinelli et al., 1998; Santos and Pires-Vanin, 2004). Excessive nutrient and/or contaminant levels in the sediment are also detrimental to many benthic species, as illustrated in the classical model of changes in species, abundance and biomass along a disturbance/pollution gradient (Pearson and Rosenberg, 1978). Hence, in addition to monitoring of physico-chemical parameters within the sediment, studies of composition and structure changes have been used to reflect the ecological response of benthic communities to anthropogenic activities, e.g., bottom trawling, dredging and infilling of seabed, discharge or disposal of wastewater and wastes, which often result in alterations of the seabed environment at large (Thrush and Dayton, 2002; Chou et al., 2004; Tillin et al., 2006; Hinz et al., 2009; de-la-Ossa-Carretero et al., 2012). However, identification of benthic organisms and analysis of species data for meaningful interpretations can be a challenge, especially in places where species are not well known (Terlizzi et al., 2003; Bacci et al., 2009; Musco et al., 2011). Apart from the application of multivariate statistics to discern community structure and pattern (Shin and Fong, 1999; Mistri et al., 2000; Gogina et al., 2010), various forms of diversity indices have also been developed to indicate the status of the benthic environment (Heip et al., 1998; Ranasinghe et al., 2003). One major constraint of the use of such indices is that the derivation is based on taxonomic information without taking into account the ecological function/response of the species to the environment (Bremner et al., 2003; Shojaei et al., 2015; Törnroos et al., 2015).

The recent development of ecological status indicators for assessing environmental quality based on evaluations of benthic communities and sedimentary habitats has widely been studied (for review see Borja et al., 2009), and applied to assess spatial and temporal changes in Ecological Status (ES) caused by natural/induced disturbance (Borja et al., 2000; Kennedy et al., 2011) and evaluate stress level induced by anthropogenic activities (Spagnolo et al., 2014; Brauko et al., 2015). Among many such indicators, the AZTI Marine Biotic Index (AMBI, Borja et al., 2000) and its multivariate extension M-AMBI (Borja et al., 2007) are the most commonly reported (Carvalho et al., 2006; Simboura and Reizopoulou, 2008; Tataranni and Lardicci, 2010; Hutton et al., 2015). AMBI assigns macrobenthic species to one of five ecological groups (EGs) according to their sensitivity to an increasing stress gradient, e.g., nutrient enrichment, and based on literature

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information on response of such species in benthic environments described in literature. The scores of AMBI are then derived from the relative proportion of individuals across the five EGs. Provided that the sensitivities of species are known, AMBI-based indicators thus allow ES to be assessed without reference to baseline data at the site under study (Kennedy et al., 2011). AMBI tools have been reported successfully to discriminate macrobenthic responses, and hence ES, under various scenarios of environmental disturbances in coastal waters over different regions of the world (e.g., Muniz et al., 2005; Bigot et al., 2008; Borja and Tunberg, 2011; Wu et al., 2012; Tweedley et al., 2014; Brauko et al., 2015).

Although Hong Kong has relatively limited 1650 km^2 sea area, the territory exhibits contrasting marine environments due to oceanic and estuarine influences (Morton and Wu, 1975) as well as various anthropogenic activities including sewage disposal (Yung et al., 1999), shipping activities and accidental spillages of petroleum (Zheng and Richardson, 1999), and bottom trawling (Morton, 1996; Liu et al., 2009). While the distribution and spatial patterns of soft-sediment assemblages in the territorial waters are known (Shin et al., 2004; Shin and Ellingsen, 2004), the ecological status of the coastal benthic habitats has not been fully evaluated except for a general assessment based on M-AMBI from a macrofaunal dataset collected from a gross-scale sampling exercise (Fordes et al., 2013). The present study aimed to update the sediment characteristics and macrobenthic communities on soft bottom under four different environmental conditions in Hong Kong and assess the benthic ecological status of these habitats based on AMBI and M-AMBI.

The four study areas selected were Victoria Harbour, Tolo Harbour and Channel, southeast of Mirs Bay and Cape D'Aguilar (Fig. 1). Victoria Harbour has suffered from sewage pollution over the past three decades, receiving 1.7 million m^3 of partially screened municipal and industrial wastewater daily (Richardson et al., 2000). In 2001, a central primary treatment system was installed to alleviate part of the pollution problem in the harbour. However, the sediment quality of the harbour remains organically polluted (Shin et al., 2008). Tolo Harbour and Channel have experienced natural hypoxic events, especially in summer, owing to the semi-enclosed nature of the embayment. Periodic defaunation in the benthic environment is apparent (Fleddum et al., 2011). The level seabed in southeast of Mirs Bay is composed of fine sediment, where bottom trawling has been intensive (Liu et al., 2009) until the implementation of a trawl ban by the government in 2013. Cape D'Aguilar has been designated as a Marine Reserve in Hong Kong since 1996, and these 20 hectares of sea area are protected from human disturbance (Morton and Harper, 1995). The first three selected study areas thus represented different environmental stressors: sewage pollution; natural hypoxia and bottom trawling, whereas the last selected study area represented relatively undisturbed environment.

In each study area, sampling locations were determined based on a grid system (see Fig. 1). In Victoria Harbour (VH) and Tolo Harbour and Channel (THC), these locations were about 1 km apart; in southeast of Mirs Bay (MB), they were 2 km apart and in Cape D'Aguilar (CD), sampling locations were 100 m apart. In total, there were 20 sampling locations in Victoria Harbour and Tolo Harbour and Channel, 26 in southeast of Mirs Bay and 12 in Cape D'Aguilar. At each sampling location, five replicate macrofaunal samples were collected with a 0.1 m^2 van Veen grab. The sediment samples were washed through a stack of 1 and 0.5 mm mesh sieves and the residues fixed in 4% buffered formalin. An additional grab sample was collected for particle size, water content, nutrient analyses, including total organic carbon (TOC), total Kjeldahl nitrogen (TKN) and total phosphorus (TP), and trace metal determination (Cd, Pb, Cu, Zn, Ni, Cr, Fe, Co). Field sampling was conducted in dry, winter (February, March and December 2012) and wet, summer season (August 2012), prior to the trawl ban.

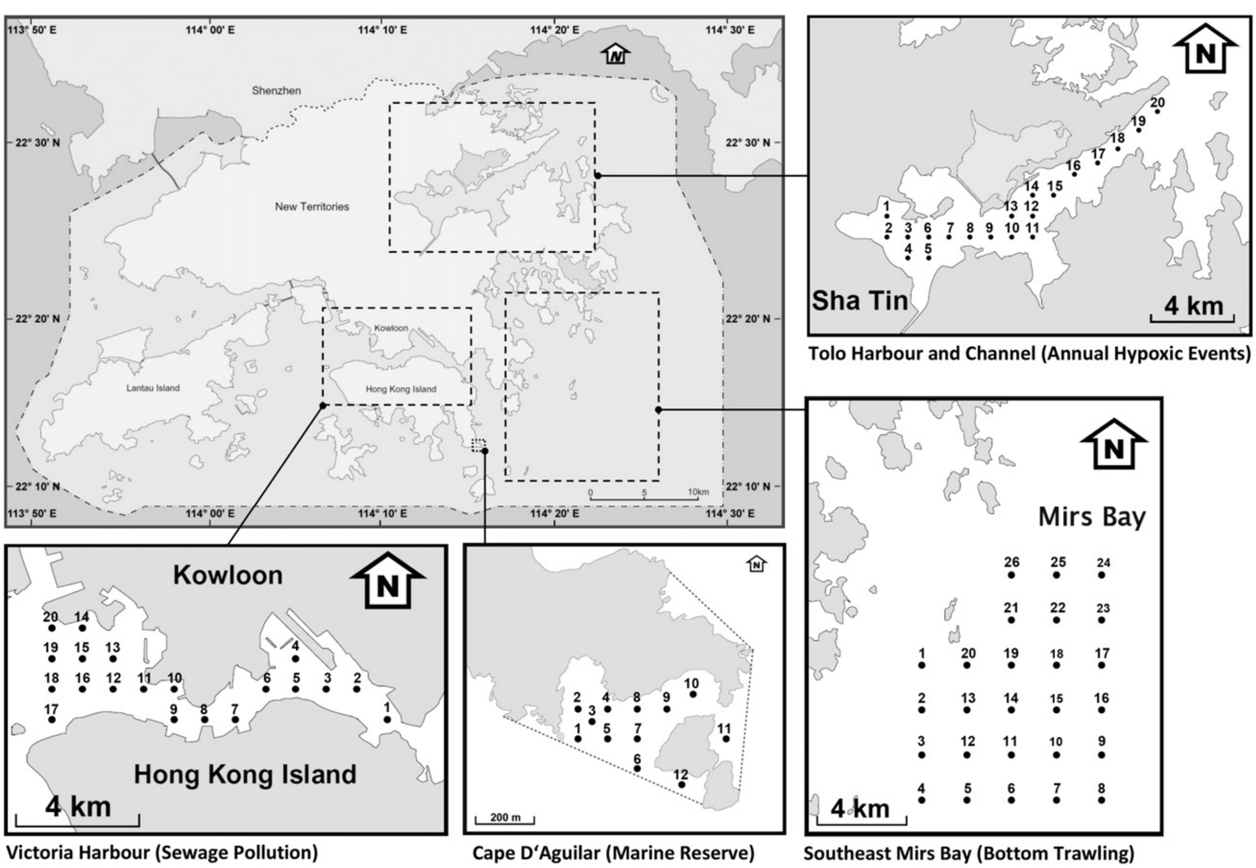

Fig. 1. Map of Hong Kong showing the sampling locations of the four study areas.