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Benthic habitat health assessment using macrofauna communities of a sub-tropical semi-enclosed bay under excess nutrients

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A B S T R A C T

This research was conducted to assess the ecosystem health of Daya Bay benthic habitat, investigate the effects of anthropogenic nutrients, and evaluate the application of ecological indicators for benthic health assessment. Environmental indicators and macrobenthic communities, were investigated during summer and winter 2015. Results indicated a strong seasonality in biotope of intertidal and subtidal zones. Lower macrobenthic diversity were calculated from subtidal inner bay, reflecting the effects of anthropogenic nutrients. However, intertidal sites in that part were indicated to be in a relatively healthier ecological status. Seasonal effects of excess nutrients on benthic habitat were reflected in ecological indicators. It is concluded that the excess nutrients at spatiotemporal scales, influences on the health of benthic habitat. Eventually, it is recommended by this research that, with considering the natural/anthropogenic circumstances, the taxonomic and phylogenetic ecological indicators would be helpful tools to evaluate the benthic health of a typical sub-tropical semi-enclosed bay.
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1. Introduction

Bays and estuaries play a fundamental role in supporting the marine resources. However, their functions and structures have been threatened globally by human activities through direct and indirect effects (De Lange et al., 2010). Health assessment of their condition provides a tool for ecosystem-based management of such a valuable habitats, and among the diverse components of which, benthic invertebrates community condition has been proven to be useful ecological indicator. The effectiveness of their application in environmental health assessment is owing to the relatively sessile mode of life and long-term exposure to the potential pollutants (Gray and Elliot, 2009). Also, their (species or assemblages) sensitivity and tolerance to the anthropogenic sources and impacts are variable (Borja and Dauer, 2008).

In recent decades, several ecological indicators have been used to assess estuarine ecosystem health (Simboura and Zenetos, 2002; Borja et al., 2004; see Cardoso et al., 2012; Feebarani et al., 2016). In addition to the diversity (and related attributes) - based indicators, the other groups of indices such as (M-) AMBI have attracted considerable attention of researchers and been developed recently. However, the latter were reported to be unreliable in some cases e.g. inner parts of the coastal systems, high dependency on the number and type of species, and the diverse habitat type (which represent limitation because of the requirement for setting up the reference condition for each specific habitat) (Borja and Tunberg, 2011). Therefore, diversity indices seem to facilitate judgment about the semi-enclosed coastal systems with mentioned conditions. It should be noted that the traditional indicators based only on species diversity attributes may not be advantageously able to reflect the real environmental status, and potential impacts on benthic habitats on their own (Subida et al., 2012). Therefore, multiple sets of new indicators, integrating the taxonomic and phylogenetic information to the health assessment have been developed. While some researchers believe in the usefulness of taxonomic approach (e.g. Hu and Zhang, 2016), the others are still doubtful about its application for health assessment (Cummins et al., 2005; Peng et al., 2013). This conflict is resulted from factors influencing on the spatiotemporal variations of biotic and abiotic components of the ecosystem, e.g. specific tolerance of given taxa, habitat type, pollution variables, and natural environmental governors (see Hu and Zhang, 2016). These factors and their effects are more complicated in the semi-enclosed bay with the poor water exchange with the open ocean (Lim et al., 2012), where ecosystem health is expected to be declined as a consequent upon increased pollutant concentrations (Peng et al., 2013). In this study, spatial and temporal (natural and anthropogenic) conditions were considered in using (and evaluating the application of) the mentioned multiple sets of ecological indicators for health assessment of a semi-enclosed bay in South China.

In the coastal zone of China during the recent decades, industrial and urban developments, and the resulted anthropogenic activities have

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occurred in Daya Bay and its surrounding area (Wang et al., 2008; Wu et al., 2009). Numerous researches have been carried out to address the different ecological aspects and anthropogenic causes and effects in the bay (e.g. Xu, 1989; Wang et al., 2006a, 2006b, 2008, 2011 and references therein). However, few ones were conducted based on the macrobenthic community structure, and its use to evaluate the benthic habitat health of Daya Bay has not been paid attention so far. Du et al. (2008) compared the species composition and diversity of benthic fauna of Daya Bay subtidal zone based on the samples collected in 1984–85, 1987–88, and 2004. They reported significant decreases in the abundance and diversity of species. Wang et al. (2008) described the decadal ecological environment changes in the study area. They affirmed the impacts originated from industrial such as mariculture and nuclear power plants (NPPs) and also the urban development on the benthic faunal biomass and abundance. However, the ecosystem health in Daya Bay using the taxonomic approach and multiple ecological indicators has not assessed yet.

Thus, in this study, we investigated natural and anthropogenic agents' spatiotemporal pattern, influencing on the functions and structures of benthic habitats in the intertidal and subtidal zones of Daya Bay. The objectives of this research were to 1) assess the ecosystem health of benthic habitat; 2) investigate that which natural and anthropogenic factor(s) is governingits ecological status; and 3) evaluate the application of multiple (species, taxonomic, and phylogenetic) sets of indicators for benthic health assessment in a semi-enclosed bay under excess nutrients.

2. Materials and methods

2.1. Study area

Daya Bay is a semi-enclosed coastal system in the northern part of South China Sea (22.50′–22.85′N, and 114.50′–114.85′E). This shallow embayment (water depth ranges 6 to 16 m, with an average of 10 m) has an area of about 600 km^2 and 92 km shoreline (Xu, 1989). It has mild, wet subtropical weather with prevailing northeasterly and southwesterly monsoons during October to April and May to September respectively (Wang et al., 2011). Accordingly, in the mentioned durations, the bay is influenced by flood and dry (80% and 20% freshwater discharge respectively) seasons (Cai et al., 2004). In this study, intertidal sites and subtidal locations were designed as followings (Fig.1): A: next to NPPs and mariculture operations; B: mariculture and the residential area C: dense residential area and Dan'ao River inlet; D: mangrove swamps in the study area.

S1 (shellfishery), S2 (petrochemical industry), S3 (River inlet and land reclamation), S6 (mariculture), and S7 (fishing port and residential

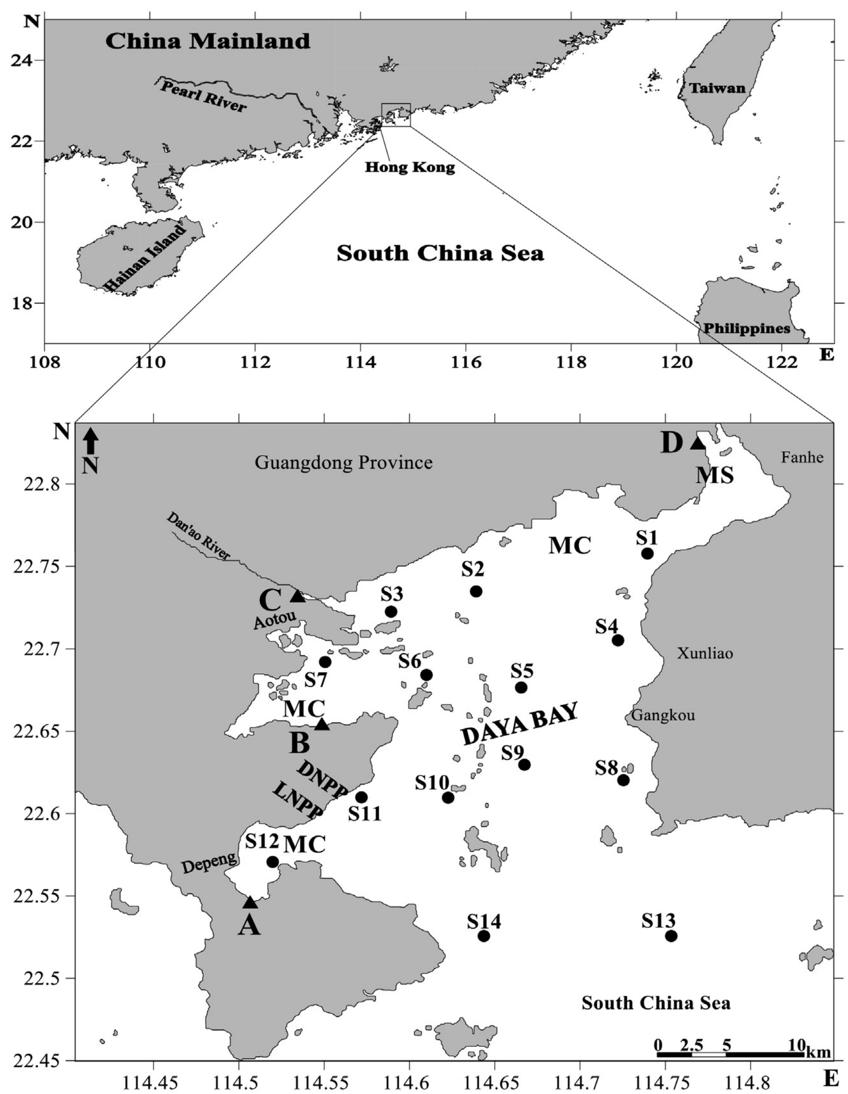

Fig. 1. Subtidal (S1–14) and Intertidal (A–D) sampling sites in Daya Bay, South China (LNPP: Ling'ao nuclear power plant; DNPP: Daya Bay Nuclear power plant; MC: Mariculture; MS: Mangroves swamps).

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