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Functional diversity of benthic ciliate communities in response to environmental gradients in a wetland of Yangtze Estuary, China

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ABSTRACT

Researches on the functional diversity of benthic ecosystems have mainly focused on macrofauna, and studies on functional structure of ciliate communities have been based only on trophic- or size-groups. Current research was carried out on the changing patterns of classical and functional diversity of benthic ciliates in response to environmental gradients at three sites in a wetland in Yangtze Estuary. The results showed that changes of environmental factors (e.g. salinity, sediment grain size and hydrodynamic conditions) in the Yangtze Estuary induce variability in species composition and functional trait distribution. Furthermore, increased species richness and diversity did not lead to significant changes in functional diversity due to functional redundancy. However, salt water intrusion of Yangtze Estuary during the dry season could cause reduced functional diversity of ciliate communities. Current study provides the first insight into the functional diversity of ciliate communities in response to environmental gradients.

Over the past twenty years, there has been an increasing body of literature demonstrating that classical diversity indices based on species identity and abundance provide an incomplete view of biodiversity as they do not take into account the functional differences among species (Bremner et al., 2003; Villéger et al., 2010). While functional diversity quantifies the value and range of species functional traits which affect ecosystem properties or processes (Bremner et al., 2006; Gagic et al., 2015). Studies on relationships of classical and functional diversity of macrobenthos suggest that their patterns across environmental gradients do not always follow the same trends (Paganelli et al., 2012; Villéger et al., 2010; Wan Hussin et al., 2012; Wong and Dowd, 2015). Therefore, an integrative approach combining both classical and functional diversity is likely to be more informative and provide a better understanding of general relationships between community structure and ecosystem functions (Gusmao et al., 2016; McGill et al., 2006; Villéger et al., 2011).

To date, studies on functional diversity of benthic fauna have mainly focused on the macrobenthos and the accumulation of more than ten years studies has generated a comparatively mature framework (MarLIN, 2006; Paganelli et al., 2012; Tillin et al., 2006). By contrast, little is known about the environmental factors regulating the functional diversity of ciliate communities in marine benthic ecosystems (Mazei and Burkovsky, 2006). Considering their high sensitivity to environmental change, wide distribution, large abundances, and key roles in microbial food webs, studies of their functional diversity are likely to enhance our understanding of benthic ecosystem function and improve our ability to assess environmental quality (Hamels et al., 2005).

Several pioneering studies have been carried out on trophic or body-size structure of ciliate communities (e.g. Xu et al., 2017). Although these studies have shown that functional structures can provide necessary understanding for ecological research and monitoring programs, allocating species to trophic- or size-groups reflects only one or two traits thereby limiting the information available for capturing a more comprehensive view of ecosystem function (Bremner et al., 2003). Thus, there is a need to investigate the functional diversity of ciliate communities by quantifying their functional traits following the framework suggested by Villéger et al. (2010).

The present study was carried out in the Yangtze Estuary to investigate the functional diversity of benthic ciliate communities in response to environmental gradients. The main aims were to assess: (1) how species composition and functional traits distribution of estuarine ciliate communities vary along environmental gradients; (2) how functional diversity is regulated by environmental factors, and; (3)

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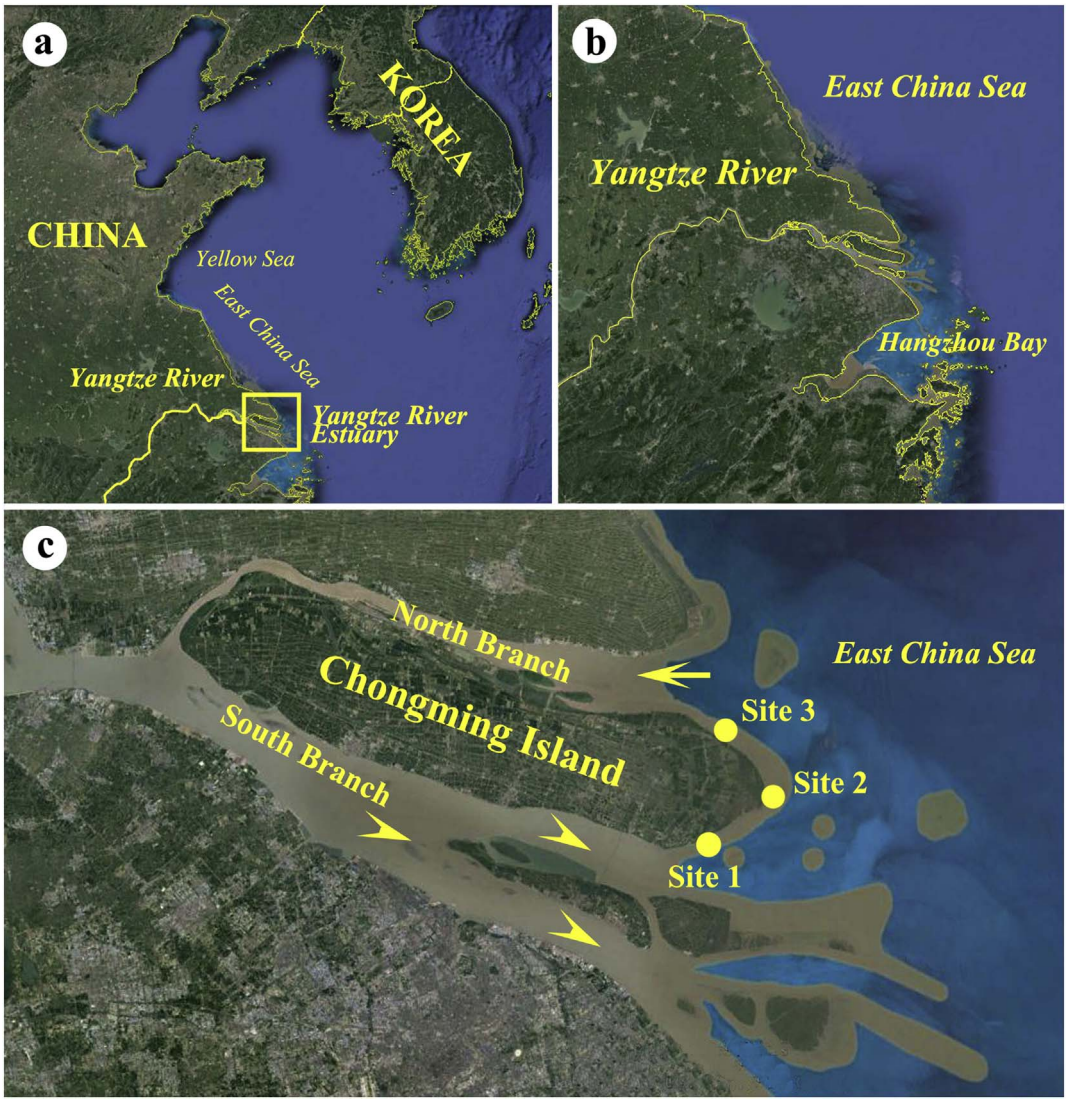

Fig. 1. Sampling sites in Yangtze Estuary, Shanghai, East China. Site 1 (31°27′1.88″N, 121°53′40.03″E) is close to the South Branch of the Yangtze Estuary and mostly influenced by the flow of fresh river water; Site 2 (31°30′35.00″N, 121°57′33.00″E) faces the East China Sea and is influenced by the mixing of fresh and salt water; Site 3 (31°34′46.00″N, 121°54′28.16″E) is close to the North Branch of the Yangtze Estuary and therefore mainly influenced by salt water. Arrowheads in (c) refer to the direction of freshwater flow coming from Yangtze River, and arrow in (c) indicates the direction of salt water intrusion from the East China Sea.

Table 1
Biological trait variables and categories used to describe functional diversity of benthic ciliate communities at Dongtan wetland on Chongming Island in the Yangtze Estuary.

Trait	Category
Feeding type	Bactivores
	Algivores
	Predators
	Parasite
Body size (measured as cell length)	Small (< 50 μm)
	Medium (50–150 μm)
	Large (> 150 μm)
Movement type	Attached to substrate
	Free-swimming
	Crawling
Respiration type	Anaerobic
	Aerobic
Body form	Dorso-ventrally flattened
	Cylindrical
Degree of flexibility	Cell nonflexible
	Cell flexible

whether combining functional and classical diversity indices can provide a deeper understanding of the relationships linking ciliate communities to their environment.

The Yangtze Estuary is influenced by a combination of fresh water discharge and tidal saline inflow and therefore has salinity gradients in both its North and South Branches (Fig. 1). The North Branch, located north of Chongming Island, is intruded by salt water, especially during the dry season when the river discharge is low (from November to April). The South Branch, located south of Chongming Island, is mainly influenced by the flow of fresh water down the river. Samples were collected at three typical sites with environmental gradients (e.g. salinity and sediment grain size) in the Dongtan wetland which is located at the eastern end of Chongming Island and is an internationally important conservation area for migratory bird (Fig. 1). Twenty replicate samples were collected at each site along a short transect in the mid-intertidal zone at low tide during 29th to 31th March 2015. The upper 2 cm of sediment was sampled using a 5 ml cut-off syringe (inner diameter 16 mm) with sharpened edges. Each sample was immediately fixed with an equal volume of glutaraldehyde (2% final concentration) until further processing. Ciliates were sampled, extracted and stained