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Indication of spatial variations in annual cycles of functional groups of planktonic ciliates to environmental change in marine ecosystems

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ABSTRACT

The indication of spatial variations in annual cycles of functional groups of planktonic ciliates to environmental changes was studied in a bay, northern Yellow Sea. Samples were biweekly collected at five stations with different hydrographic conditions during a 1-year cycle. The second-stage-matrix-based multivariate approach was used to summarize the internal interactions of the ciliate functional groups among five stations during a 1-year period. The functional groups of the ciliates represented a clear spatial variation in annual cycle among five stations. Mantel analysis demonstrated that the spatial variation in annual cycles of the ciliate functional groups were significantly correlated with the changes nutrients (mainly soluble reactive phosphates and nitrates), alone or in combination with salinity among five stations. Based the results, it is suggested that the spatial variation in annual cycles of functional groups of planktonic ciliates may indicated the changes of hydrographic conditions.

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1. Introduction

Planktonic ciliates play important roles in the functioning of microbial food webs including cycling elements and transferring energy fluxes (Sime-Ngando et al., 1995; Crawford et al., 1997; Finlay and Esteban, 1998; Kchaou et al., 2009). Ciliates have several advantages for use in bioassessment (e.g., short life cycles, rapid response to environmental change) and consequently have been widely used to indicate environmental/ecological quality status in many aquatic ecosystems (e.g., Jiang et al., 2011, 2014; Feng et al., 2015). Several investigations on bioassessment using planktonic ciliates have been carried out in both Chinese and polar seas (Jiang et al., 2011, 2013a, 2013b; Feng et al., 2015).

Jiang et al. (2013a) identified several functional groups of planktonic ciliates based on their occurrence under specific hydrographic conditions and at specific times during a 1-year cycle. However, few studies have investigated the relationship between environmental factors and the spatial variation of functional groups during annual cycles (Montagnes and Lynn, 1989; Dolan and Coats, 1990; Crawford et al., 1997; Kchaou et al., 2009; Jiang et al., 2013a; Xu et al., 2016).

In this study, the spatial changes in annual cycles of ciliate functional groups were studied based on a dataset from Jiaozhou Bay, northern China. The objective of this study was to determine whether functional of groups of planktonic ciliate communities can be used as indicators of environmental change in marine ecosystems.

2. Materials and methods

2.1. Data collection

A total of 120 samples were collected at a depth of 1 m from five stations in Jiaozhou Bay, northern China, during 1-year cycle (June 2007–May 2008). The functional groups of the ciliates were determined according to Jiang et al. (2013a) (Table S1).

Salinity (Sal), pH, dissolved oxygen (DO), soluble reactive phosphate (SRP), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) were measured as described by Jiang et al. (2011) and APHA (1992).

2.2. Data analyses

Boxplots were used to summarize the variations in environmental variables by whiskers (minimum and maximum), boxes (±25%) and lines (medians).

Multivariate analyses were carried out using the software package PRIMER v7.0.11 (Clarke and Gorley, 2015). Bray-Curtis similarity matrices for the ciliate communities were computed on fourth-root-transformed functional-group abundance data. Euclidean distance matrices for environmental variables were calculated from log-transformed and

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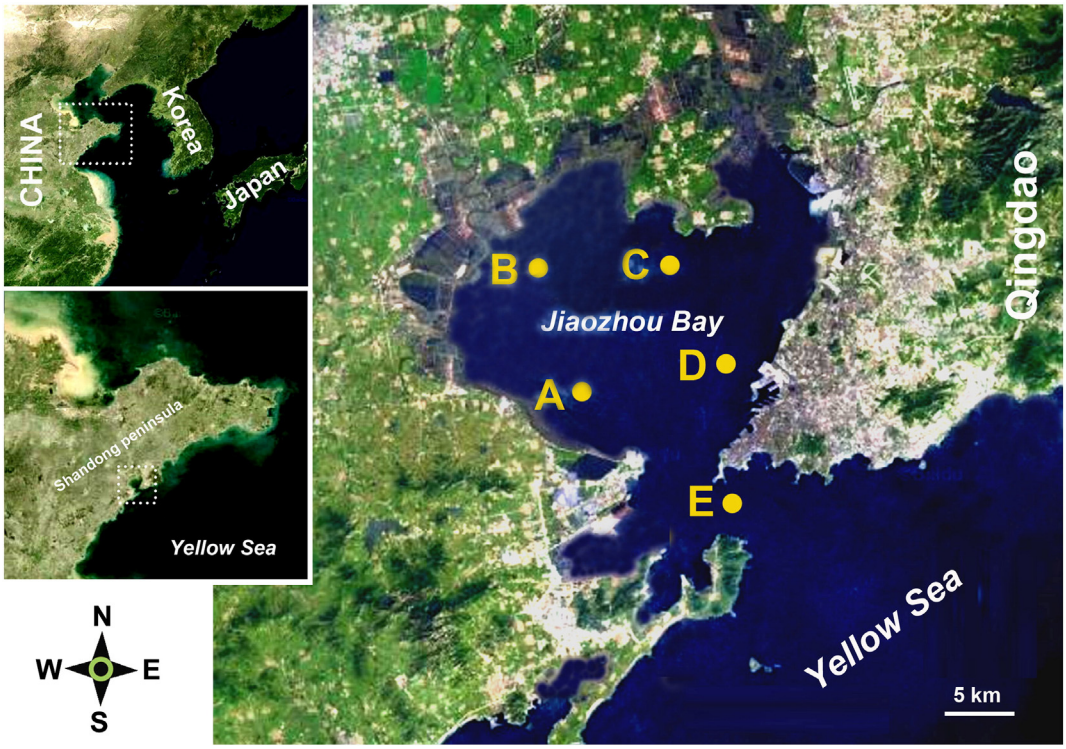

Fig. 1. Sampling stations in Jiaozhou Bay, near Qingdao, northern China. Station A was an area far from the sources of pollutants; station B was located in an area near two rivers with organic pollutants, nutrients and heavy metals (e.g., Pb, Zn) entering the bay; station C was in a mariculture area; station D was near a small river with both organic and heavy-metal pollutants (e.g., Cr, Cu); and station E was an area in the mouth of the bay and subjected strong water exchanges (Fig. 1) (Liu et al., 2004, 2005).

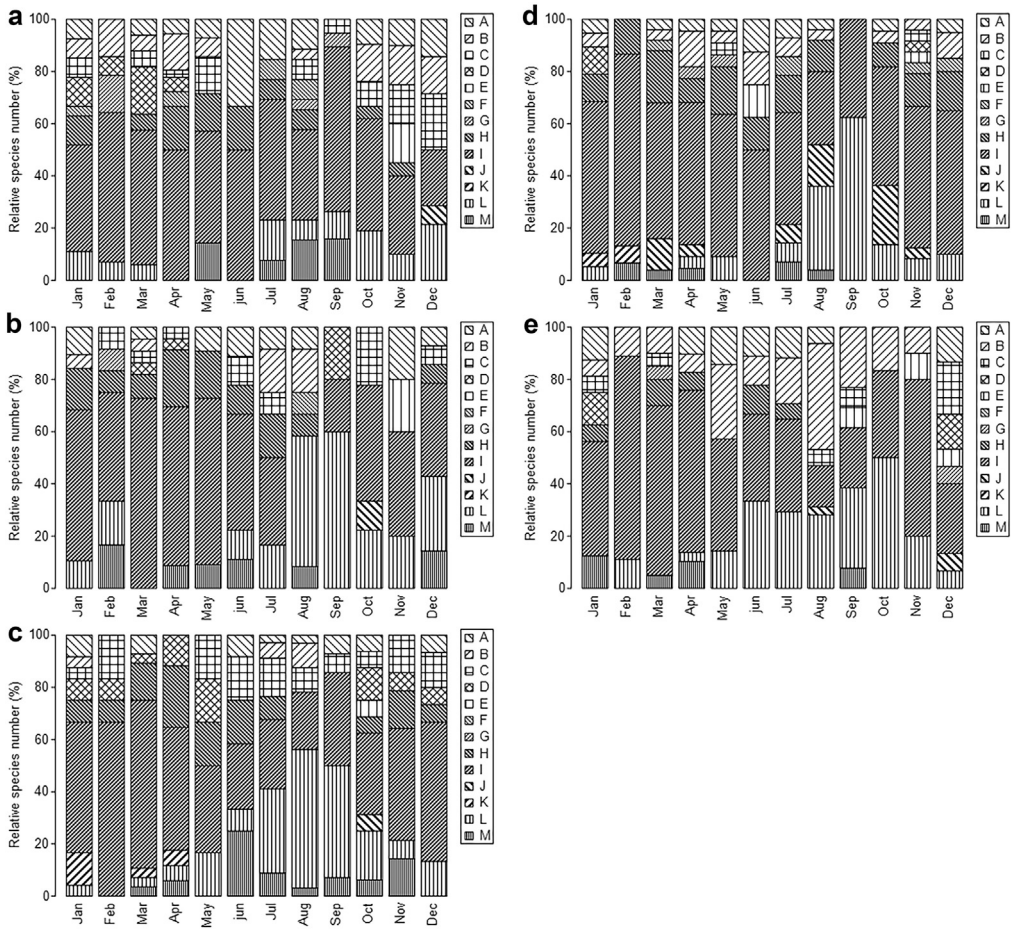

Fig. 2. Temporal variations in relative species number of the ciliates in each functional group during a 1-year cycle at five stations A (a), B (b), C (c), D (d) and E (e). For abbreviations, see Fig. 2.

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