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Body-size spectra of biofilm-dwelling protozoa and their seasonal shift in coastal ecosystems

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Abstract

Community-based assessment of protozoa is usually performed at a taxon-dependent resolution. As an inherent 'taxon-free' trait, however, body-size spectrum has proved to be a highly informative indicator to summarize the functional structure of a community in both community research and monitoring programs in aquatic ecosystems. To demonstrate the relationships between the taxon-free resolution of protozoan communities and water conditions, the body-size spectra of biofilm-dwelling protozoa and their seasonal shift and environmental drivers were explored based on an annual dataset collected monthly from coastal waters of the Yellow Sea, northern China. Body sizes were calculated in equivalent spherical diameter (ESD). Among a total of 8 body-size ranks, S2 (19–27 μm), S3 (28–36 μm), S4 (37–50 μm) and S5 (53–71 μm) were the top four levels in frequency of occurrence, while rank S1 (13–17 μm), S2 and S4 were the dominant levels in abundance. These dominants showed a clear seasonal succession: S2/S4 (spring) → S2/S4 (summer) → S4 (autumn) → S2 (winter) in frequency of occurrence; S1 (spring) → S4 (summer) → S2 (autumn) → S1 (winter) in abundance. Bootstrapped average analysis showed a clear seasonal shift in body-size spectra of the protozoa during a 1-year cycle, and the best-matching analysis demonstrated that the temporal variations in frequency of occurrence and abundance were significantly correlated with water temperature, pH, dissolved oxygen (DO), alone or in combination with chemical oxygen demand (COD) and nutrients. Thus, the body-size spectra of biofilm-dwelling protozoa were seasonally shaped and might be used as a time and cost efficient bioindicator of water quality in marine ecosystems.

Keywords: Bioassessment; Biofilm-dwelling protozoa; Body-size spectrum; Marine ecosystems; Seasonal succession

Introduction

Biofilm-dwelling protozoa are a primary component of periphytic microfauna and play an important role in the functioning of microbial food webs by mediating the transfer of elements and energy from plankton to benthos in aquatic ecosystems (Norf et al. 2009; Wey et al. 2009; Früh et al. 2011; Kathol et al. 2011). Recent investigations have demonstrated that these microbiota can be used to indicate water quality status in marine ecosystems (Xu et al. 2014a, Xu et al. 2014b). However, many microbial communities seem to be extremely functionally redundant (Franklin and Mills 2006; Rousk et al. 2009). This means that several co-occurring taxa complete the same function under a given environmental status, and implies that species diversity greatly exceeds ecological diversity (Dolan et al. 2013; Xu et al. 2014b; Zhong et al. 2014).

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As an inherent 'taxon-free' trait, body-size spectrum is a highly informative indicator to summarize functional structure of a community in both community research and monitoring programs in aquatic ecosystems (Sheldon et al. 1972; San Martin et al., 2006; Kamenir et al. 2010; Jiang et al. 2012; Xu et al. 2013). Notably, recent studies have indicated that the investigations of body-size spectra could significantly correct the bias effects of the functional redundancy on community research and monitoring programs at taxonomic species resolution (Kamenir et al. 2010; Zhang et al. 2014; Zhong et al. 2014). So far, a number of studies on body-size spectra have been well reported in many taxonomic fields, such as macroinverbrates, phytoplankton and nematodes (Beaver and Crisman 1982; Beaver and Crisman, 1989; Gaedke 1992; Ruhl, 2007; Basset et al. 2012; Vadrucci et al. 2013; George and Lindo 2015). However, as regards the relevant understandings of body-size spectra of protozoa, little information was documented (Jiang et al. 2012; Xu et al. 2013; Wang et al. 2016).

In this study, the seasonal shift in body-size spectra of protozoa were studied using multivariate approaches based on a dataset collected form coastal waters of the Yellow Sea, northern China during a 1-year period. The objectives of this study were to explore the temporal dynamics and seasonal shift in body-size spectra of biofilm-dwelling protozoa in coastal ecosystems.

Material and Methods

Data collection

A total of 40 samples were collected monthly at four stations in coastal waters of the Yellow Sea, northern China during a 1-year period from August 2011 to July 2012 (Fig. 1, stations A–D). Protozoan identification and enumeration were conducted following the methods outlined by Xu et al. (2011). Protargol staining was carried out for species identification (Pan et al. 2010). Taxonomic classification of ciliates was based on published keys and guides such as Fan et al. (2010), Jiang et al. (2010) and Song et al. (2009).

The enumeration of ciliates in vivo was conducted at a 100-fold magnification under an inverted microscope as soon as possible after sampling (generally within 24 h) in order to prevent significant changes in community structure (Xu et al. 2011). In order to recover all species colonizing the glass slides, one surface of an entire slide (17.5 cm^2) from a total of 10 slide-replicates was examined at each station using bright field illumination and occurrences were recorded. For the enumeration of individual abundances, 10 randomly chosen fields of view per slide were examined and the dominant ciliates were enumerated. The ciliate abundances were calculated for each sample with 10 slide-replicates to confirm the average abundance of ciliate individuals (ind. cm^{-2}).

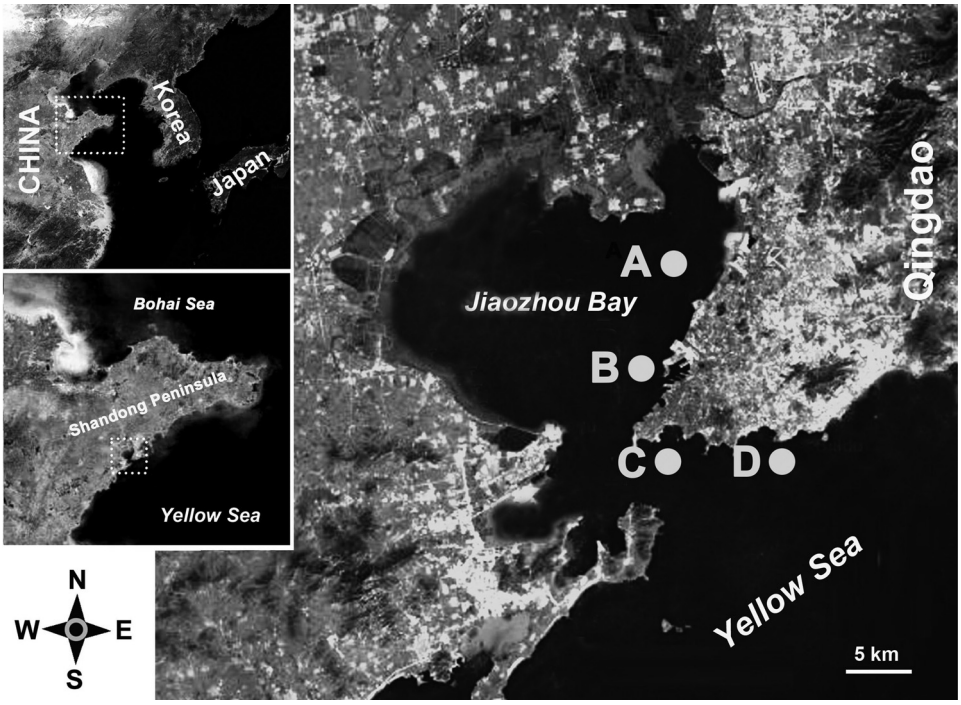

Fig. 1. Sampling stations in coastal waters of the Yellow Sea, near Qingdao, northern China. (A) Station A, heavily stressed area in Jiaozhou Bay, the pollution being mainly in the form of organic pollutants and nutrients from domestic sewage and industrial discharge from several rivers. (B) Station B, Jiaozhou Bay, an area moderately polluted by minor discharges from a small river entering the bay. (C) Station C, slightly polluted area near the mouth of Jiaozhou Bay and relatively distant from the rivers entering the bay. (D) Station D, relatively clean area which was out of this bay and more distant from the river discharges.