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Spatio-temporal distribution of meiofaunal assemblages and its relationship with environmental factors in a semi-enclosed bay

Chunzi Gao, Xiaoshou Liu*

College of Marine Life Sciences, Ocean University of China, Qingdao 266003, China

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ABSTRACT

In order to reveal the spatio-temporal distribution of meiofaunal assemblages and its relationship with environmental factors in semi-enclosed bay habitats, meiofaunal and sediment samples were collected in February (winter), May (spring), August (summer) and November (autumn) 2014 in Jiaozhou Bay, China. A total of 20 meiofaunal taxa were identified. The most dominant group was free-living marine nematode, followed by benthic copepod. During the four sampling seasons, the values of meiofaunal average abundance were (912.3 ± 603.1), (1576.4 ± 659.5), (1074.6 ± 417.6), (2152.4 ± 1062.3) ind./10 cm^2 while those of biomass were (575.0 ± 398.5), (874.3 ± 518.4), (617.9 ± 337.8), (1203.6 ± 719.6) μg dwt/10 cm^2, respectively. In terms of vertical distribution, meiofauna were mainly found in the (0–2) cm sediment layer (59.92%), followed by (2–5) cm layer (28.25%) and (5–8) cm layer (11.82%). Results of correlation analysis showed that bottom water temperature was the main factor influencing meiofaunal distribution and food source (sediment organic matter content) was the main factor influencing meiofaunal assemblages.

Meiofauna are a group of benthic animals that can pass through 0.5 mm mesh but retained by 0.042 or 0.031 mm mesh. Most of meiofaunal taxa are metazoans, such as free-living marine nematodes, harpacticoid copepods, small polychaetes and so on (Higgins and Thiel, 1988; Zhang and Zhou, 2004; Giere, 2009). The main food sources of meiofauna were organic detritus, heterotrophic bacteria and benthic diatoms while they can provide food for many fish, shrimps and shellfishes. Thus, they are important components in benthic food web (Montagna et al., 1995; Liu et al., 2005; Liu et al., 2014). Meanwhile, meiofauna play important roles in matter cycling and energy flow in marine ecosystems (Raghukumar et al., 2001). Some studies showed that meiofauna can stimulate microbial production, accelerate organic matter decomposition and promote nutrients recycling (Montagna et al., 1995; Semprucci et al., 2013; Tenore et al., 1977). The biomass of meiofauna in estuaries, coastal areas, bays and deep-sea sediments are similar even higher than those of macrofauna which make them important in global biogeochemical cycles (Platt and Warwick, 1980; Heip et al., 2000). In addition, meiofauna have ubiquitous distribution, high species richness, high fecundity, short life history and can make significant responses to natural and anthropogenic disturbances, which make them very popular and ideal in marine environmental quality monitoring (Semprucci et al., 2015; Vassallo et al., 2006; Schratzberger and Ingels, 2016). Meiofauna have been taken as important indicators in marine ecological monitoring and ecosystem health assessment for a long history (Kennedy and Jacoby, 1999; Schratzberger et al., 2000; Zhang et al., 2017).

Jiaozhou Bay is a typical semi-enclosed bay in the north-west of Yellow Sea, approximately like a fan. It is a shallow bay with the coastline of 163 km and area of 425 km^2. The average water depth of Jiaozhou Bay is 7.0 m (Dong and Jiao, 1995). It is located in the transition zone of north temperate Pacifica and Indo-West Pacifica areas, with good natural conditions and rich nutrients, which provide suitable habitat for marine organisms (Fan, 1981). Until now, there have been several studies of meiofauna in this area. For example, Zhang et al. (2001) reported meiofauna of 7 sites in northern Jiaozhou Bay. Yang et al. (2009) studied meiofauna at 2 sites in Jiaozhou Bay and Ji (2015) presented meiofauna at 8 sites in northwestern part of Jiaozhou Bay. However, all of the above mentioned meiofaunal studies were very limited in terms of time and space. In the present study, a grid of 14 sites were sampled which covered most of the area of Jiaozhou Bay, including coastal area, central part and estuaries in four seasons. Through this comprehensive investigation, meiofaunal abundance, biomass, assemblage composition and their relationships with environmental factors were reported, which can provide baseline information for meiofaunal studies in semi-enclosed bay habitats.

Jiaozhou Bay is also one of the largest bivalve culture areas in northern China and affected intensely by anthropogenic activities, including aquaculture, sewage pollution, transportation and so on (Wang

* Corresponding author at: College of Marine Life Sciences, Ocean University of China, 5 Yushan Road, Qingdao 266003, China.
E-mail address: liuxs@ouc.edu.cn (X. Liu).

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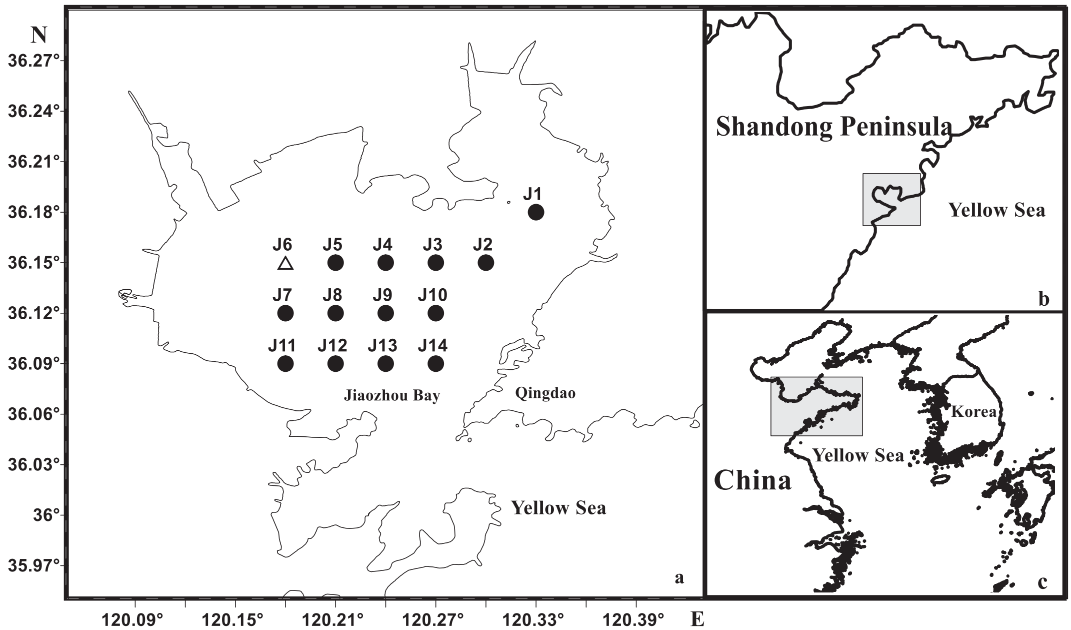

Fig. 1. Maps of the sampling sites in Jiaozhou Bay (a), Shandong Peninsula (b) and the Yellow Sea (c).
Note: ● Sampling Sites sampled in four seasons 2014; Δ Sites sampled in only in February and August 2014.

et al., 2017). Sediment samples for meiofauna and environmental factors analysis were collected in February (winter), May (spring), August (summer) and November (autumn) in 2014 at 14 sites in Jiaozhou Bay (Fig. 1). Due to the weather and logistical condition, samples at Site J6 were not collected in May and November 2014. Seawater characteristics including temperature, salinity were measured in situ using YSI 600XLM Multi-Parameter Water Quality Sonde (YSI Inc., USA).

At each sampling site, undisturbed sediment was collected with a 0.05 m^2 box corer. Three core meiofaunal subsamples were collected using a syringe of 2.9 cm inner diameter with end cut-off to a depth of 8 cm from the sediment in three box cores carefully to avoid compression during the processing of the core. To examine the vertical distribution of meiofauna, cores were sectioned into three layers (0–2, 2–5 and 5–8 cm). All the core samples were fixed on board with 5% buffered formaldehyde solution. In addition, surface sediment (the top 5 cm) samples were also collected and frozen to −20 °C at each site to determine the grain size, organic matter content, water content, chlorophyll *a* (Chl-a) and phaeophorbide (Pha).

In the laboratory, sediment samples for meiofauna were stained with 1‰ Rose Bengal for > 24 h, followed by sieving with 0.5 mm and 0.031 mm meshes. Materials retained on the smaller mesh size were collected. Meiofauna was extracted by flotation and centrifugation (1800 rpm, 10 min) using a colloidal silica solution (Ludox™, Aldrich Chemical Company) with a specific gravity of 1.15 g cm^{-3} (Liu et al., 2015b). The procedure was repeated three times to ensure that most of meiofauna was extracted from the sediment. Each sample was poured through a 0.031 mm sieve and washed into a lined petri dish. All meiofauna individuals were sorted into higher taxon level following Higgins and Thiel (1988) and counted under a stereomicroscope.

For sediment grain size, a pre-weighed (dry-weight) sediment sample was first passed through a 2 mm sieve. The sediment that passed through this sieve was then analyzed using a Mastersizer 3000 particle size analyzer, which could detect fractions between 2 and 2000 μm. The weight of sediment retained by the 2 mm sieve was incorporated with the data obtained from the sieving method. Measurement of sediment organic matter content was conducted using the wet titration method (Walkley and Black, 1934). The organic carbon in specifically weighed sediment samples was oxidized with acidified (concentrated sulfuric acid) potassium dichromate ($K_2Cr_2O_7$) followed by titration with iron (II) sulfate ($FeSO_4$). The water content of sediment was measured as a percentage of weight loss by drying the sediment at 60 °C for 24 h. Chl-a and Pha contents were determined with spectrophotofluorimetry following the protocol given by Liu et al. (2007) for wet sediment. A frozen sediment section (about 2 g) was weighed, thawed and placed into a 15 ml centrifuge tube with the addition of 10 ml 90% acetone and some solid magnesium carbonate. The centrifuge tube was plugged and shaken thoroughly until the material was emulsified and was put in a refrigerator at 4 °C in the dark thereafter. After 24 h, the material was centrifuged at 4000 rpm for 15 min. A fluorescence spectrophotometer was then used to determine the content of sediment Chl-a and Pha. The concentration of Pha was calculated according to the corrected formula presented by Wang (1986). The contents of Chl-a and Pha were expressed in mg pigment kg^{-1}sediment dry weight.

The abundance of identified higher meiofaunal taxa was standardized for a 10 cm^2 area, which is a generally accepted unit in meiofaunal studies (Pfannkuche and Thiel, 1988). The biomass of different meiofauna group was determined by using the individual dry weight values with the method refers to Widbom (1984) and Liu et al. (2005).

Sampling map was plotted by Surfer 8.0 (Golden Software, Inc.). Correlation analysis was performed to investigate the relationships between meiofauna and environmental variables using SPSS 19 statistical software package. Multivariate analyses were carried out using PRIMER 6 statistical software package (Clarke and Gorley, 2006), including nonparametric multidimensional scaling (MDS), hierarchical clustering (CLUSTER), principal component analysis (PCA) and BIOENV. The multivariate analysis was performed on higher meiofaunal taxa densities and composition. Prior to analyses, abundances of main taxa in the samples were fourth-root transformed.

Analyses of variance (ANOVA) were carried out to investigate the spatio-temporal differences of environment factors and meiofaunal assemblages. Correlation analyses were used to reveal the relationships between environmental factors and meiofaunal assemblages. The abovementioned univariate analyses were performed using SPSS 19.0 statistical software package.

Water depth in the sampling area showed an increasing trend from coastal to sublittoral areas and from the north to the south areas. It ranged from 2 to 18 m with an average of 8.02 ± 4.55 m. The deepest sites were J13 and J14, with the annual average water depth of