Revista de Biología Marina y Oceanografía
Vol. 46, Nº2: 281-286, agosto 2011
Research Note

Tempo-spatial variation of macrobenthic communities on a tidal flat of Wenzhou Bay, China

Variación espacio-temporal de las comunidades macrobentónicas en el plano mareal de Wenzhou Bay, China

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Abstract. The tempo-spatial variation of macrobenthic communities was studied on a tidal flat of Wenzhou Bay, China from November 2003 to August 2004. We collected 38 macrobenthic species belonging to 23 families, 8 classes and 7 phyla, most of which were arthropods and molluscs. Species richness, density and biodiversity significantly differed between tidal zones, seasons and the interaction between them. The tempo-spatial variations of the macrobenthic communities were also shown in cluster and ordination analysis. The middle tidal zone during autumn tends to have the highest values of the community descriptors. Thus, tidal zone and seasons have significant roles in structuring these communities.

Key words: Species distribution, tidal flat zones, Zhejiang Province

Introduction

The macrobenthos represents one of the most important permanent resident animal groups in coastal wetlands. Because of their sedentary life style, the distribution and abundance of benthos are particularly sensitive to local environmental conditions (Luckenbach *et al.* 1990), thus, this group is often used as an environmental indicator in environmental monitoring (Warwick *et al*. 2002, Ysebaert *et al*. 2002). The macrobenthos are important food resources, which partly explain the high reliance of wildlife on wetland habitats (Zwarts & Wanink 1991, Warwick *et al.* 2002).

There are several factors determining the structure of macrobenthic communities, such as sediment, vegetation, temperature and salinity (Al Bakri *et al*. 1997a, b, Wu & Shin 1997, Kaiser *et al*. 2001, Armonies & Reise 2003). A number of studies demonstrated the existence of temporal variation for soft sediment benthic communities in temperate and subtropical regions (McCall 1977, Zajac & Whitlatch 1982a, Lu & Wu 2000), as well as in tropical regions (Lu 2005). However, no study has been carried out to determine tempo-spatial variations of macrobenthic communities at the Wenzhou Bay up until now.

Wenzhou Bay is the most important wintering and migration stop-over habitat for the endangered black-mouse gull (*Larus saundersi*) and black-faced egret (*Platalea minor*) (Liu *et al*. 2001), with the macrobenthos being an major food resource (Cai *et al.* 2001). Studying the tempo-spatial variation of macrobenthic communities can thus help us to outline nature protection measures.

This study aims to quantify the macrobenthic communities at Tianhe flat (China) and determine the community structure, including its temporal and spatial variation.

Materials and methods

All samples were taken from tidal flats at Tianhe flat (27°50’18"N, 120°50’26"E), the south shore of Wenzhou Bay, Zhejiang Province, China. The climate is sub-tropical; the tide type is informal semidiurnal tide with an average 4.5 m tidal range (Lu *et al.* 2005). The sediment is soft, most of its composition being silt. The average salinity of the seawater at the tidal flat is 30 psu.

Field sampling took place at the upper, higher, middle and lower tidal zones in November (autumn) 2003, February (winter), May (spring) and August (summer) 2004. Then 5 replicates were randomly spread throughout the middle of each tidal zone by using a 0.099 m^2 (33 cm × 30 cm) stainless steel sampling box (depth of 20 cm). In total, 80 samples were processed for quantitative analyses, and then additional qualitative samples were collected for species identification. Samples were washed through a 1.0 mm mesh sieve on the spot, and then fixed and preserved in neutral formalin–rose bengal mixture. Macrobenthic animals were stored, identified to the lowest possible taxonomic levels and counted. The species richness, density and biodiversity indices such as *R* - Margalef's species richness index, *H´* - Shannon's diversity index and *J* - Pielou's evenness index were calculated for each sample as follows:

Margalef's species richness index (Margalef 1957):

$$R = (S - 1) / \ln N$$

Shannon's diversity index (Shannon & Weaver 1949):

$$H' = -\sum_{i=1}^{N} P_i \ln P_i$$

Pielou's evenness index (Pielou 1966):

$$J = (-\sum_{i=1}^{N} P_i \ln P_i) / \ln S$$

P_i = proportion of individuals in the sample that belong to species *i*. S = total number of species (species richness) encountered. *N* = the number of individuals.

Mean species richness, density and biodiversity indices were compared among seasons and zones by two-way ANOVAs (through a GLM). Then the data of 5 replicate samples were accumulated as a dataset, 16 datasets were used for multivariate analysis on communities. The Levene's test was used to determine equality of variance prior to using the GLM. When a dataset did not pass Levene's test the data was natural log transformed (Cleary *et al*. 2008), in the study, the datasets of abundance and *H'* of each sample were transformed.

For the multivariate analysis on the accumulated data sets of communities, the classification (Cluster Analysis) with the Euclidean distance similarity matrix method and ordination by non-metric Multi Dimensional Scaling (NMDS) were used to analyze community structure and species distribution based on accumulated abundance data with 4th root transformation (Heip *et al*. 1988, Olbers *et al*. 2009, Gogina *et al*. 2010). Clustering was carried out by a hierarchical, agglomerative method using average linkage; the results are displayed in dendrograms.

SPSS 16.0 (SPSS Inc.) and Microsoft Office Excel 2003 (Microsoft Inc.) were employed for statistical analysis.

Results and discussion

In total 38 species were recorded, belonging to 23 families, 8 classes and 7 phyla recorded in the qualitative investigation, most of them were arthropods (11 species), molluscs (15 species) and annelids (6 species) (Table 1).

There were significant differences in almost all community descriptors between zones, seasons and interaction; species richness [zones ($F_{(3, 64)}$ = 61.89, P < 0.001), seasons ($F_{(3, 64)}$ = 35.82, P < 0.001), zone × season interaction ($F_{(9, 64)}$ = 15.53, P < 0.001)]; abundance [zones ($F_{(3, 64)}$ = 63.88, P < 0.001), seasons ($F_{(3,64)}$ = 44.71, P < 0.001), and zone × season interaction ($F_{(9,64)}$ = 17.31, P < 0.001)]; *H'* [zones ($F_{(3, 64)}$ = 36.08, P < 0.001), seasons ($F_{(3, 64)}$ = 16.30, P < 0.001), and zone × season interaction ($F_{(9, 64)}$ = 8.11, P < 0.001)]; *R* [zone ($F_{(3, 64)}$ = 39.39, P < 0.001), season ($F_{(3, 64)}$ = 15.21, P < 0.001), zone × season ($F_{(9,64)}$ = 6. 57, P < 0.001)]; *J* differed between zone only ($F_{(3, 64)}$ = 43.358, P < 0.001), but no difference was found between seasons ($F_{(3, 64)}$ = 2.49, P = 0.068) and zone × season interaction ($F_{(9, 64)}$ = 0.95, P = 0.486).

The analysis of the accumulated data sets of communities showed that the higher biodiversity/abundance occurred in summer/autumn and the high/middle zone, while lower biodiversity/abundance occurred in winter/spring and the upper/low tidal zone (Fig. 1).

In the cluster and ordination analysis, three community groups were classified by tidal zones; upper tidal (CG1), high-middle tidal (CG2) and middle-low zones (CG3) (Fig. 2A, C). The results show a gradient indicating that the communities were changing among habitats. Three specie groups were then classified as within the non-low tidal zone with extensive species distribution (SG1), the non-upper tidal zone with extensive species distribution (SG2) and narrowly distributed species (SG3) (Fig. 2B, D), and the results showed that most of the species were distributed in two or three tidal zones (SG1 & SG2), with a few species distributed in only one zone (SG3).

It has been reported that the community construction and biodiversity varied among seasons and tidal zones in some researches (Lui *et al*. 2002, Elliott *et al*. 2007, Tian *et al*. 2009). The abundances of molluscs were generally higher in winter and spring, those of crustaceans in autumn and summer. Temporal changes in macrobenthic community densities in predation pressure and the reproductive output of the animals were indicated by many studies (Ólafsson & Persson 1986, Kneib 1992, Covi & Kneib 1995, Sarda *et al*. 1998). Seasonal fluctuations in physical environmental parameters may also cause

Table 1. Macrobenthic species found on the tidal flat of Tianhe, Wenzhou Bay, China. Code named species which were used in the quantitative analysis, which are ordered by abundance / Especies macrobentónicas encontradas en el plano mareal de Tianhe, Wenzhou Bay, China. Los códigos identifican las especies utilizadas en el análisis cuantitativo y ordenadas por su abundancia

Phylum	Class	Family	Species	Code
Mollusca	Gastropoda	Assimineidae	*Assiminea brevicula*	S1
		Potamididae	*Cerithidea cingulata*	S3
			C. largillierti	S20
		Littorinidae	*Littorina scabra*	S18
			L. brevicula	S17
		Stenothyridae	*Stenothyra glabra*	S13
		Atyidae	*Bullacta exarata*	S4
		Nassidae	*Nassarius* sp.	S5
	Lamellibranchia	Solenidae	*Sinonovacula constricta*	
		Corbulidae	*Potamocorbula ustulata*	S11
		Tellinidae	*Moerella iridescens*	S9
Arthropoda	Crustacea	Grapsidae	*Helice sheni*	
			H. wuana	S12
			Sesarma haematocheir	S16
			Eriocheir sinensis	S28
			Metaplax sheni	S24
			M. longipes	S25
			Macrophthalmus japonicus	S23
		Ocypodidae	*Uca arcuata*	S14
			U. lactea	
			Ilyoplax sp.	S7
		Leucosiidae	*Philyra pisum*	S27
			P. olivacea	S15
			P. carinata	S21
		Alpheidae	*Alpheus japonicus*	
		Palaemonidae	*Exopalaemon modestus*	S26
Annelida	Polychaeta	Nephtyidae	*Nephthys caeca*	
		Glyceridae	*Glycera chirori*	
		Nereidae	*Neanthes japonica*	
			Nereis japonica	S2
			Tylorrhynchus heterochaeta	
		Eunicea	*Diopatra* sp.	S10
Nemertina			Not identified	S8
Nematoda			Not identified	S6
Chordata	Osteichthyes	Periphthalmidae	*Scartelaos viridis*	S19
			Boleophthalmus pectinirostris	S22
		Gobiidae	*Rhinogobius* sp.	
Sipuncula	Phascolosomata	Phascolosomatidae	*Phascolosoma esculenda*	

temporal differences in species abundance (Odum & Heald 1972, Daiber 1977, Lui *et al*. 2002).

The macrobenthic communities were affected by the tidal zone, seasonal change and the interaction between them on the tidal flat of Wenzhou Bay. The higher biodiversity occurred in the high and middle tidal zone, which was related to higher habitat complexity (Yuan *et al*. 2005), and habitat complexity was affected by environmental factors, such as vegetation, tide, grain size and the food web (Whitlatch 1977, Probert 1984, Ouisse *et al*. 2011). NMDS was used to analyze differences in the community structure of macrobenthic fauna in some similar studies (Clarke & Warwick 1994, Lui *et al*. 2002, Steffens *et al*. 2006).The results of NMDS supported the cluster analysis, and also confirmed that the macrobenthic communities were significantly affected by tidal zone.

The seasonal change also can be described in this research. A significant difference was found among

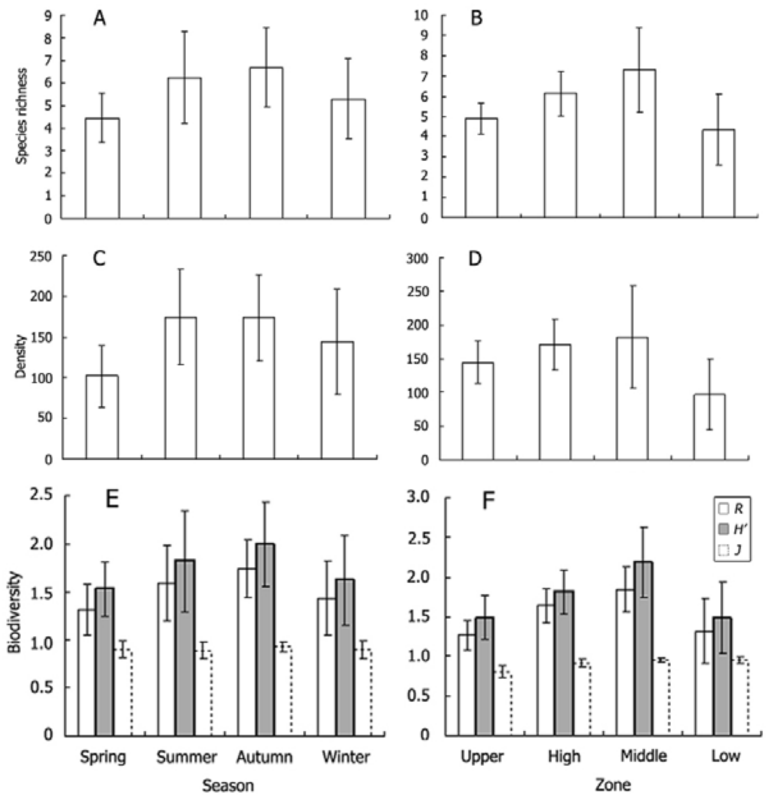

Figure 1. The tempo-spatial variation of: A, B) species richness, C, D) density and E, F) bio-diversity. ***R:*** **Margalef's species richness index,** ***H´:*** **Shannon's diversity index and** ***J:*** **Pielou's evenness index** / Variaciones espacio-temporales de: A, B) la riqueza de especies, C, D) densidad y E, F) biodiversidad. *R*: índice de riqueza de especies de Margalef, *H´:* índice de diversidad de Shannon, y *J:* índice de uniformidad de Pielou's

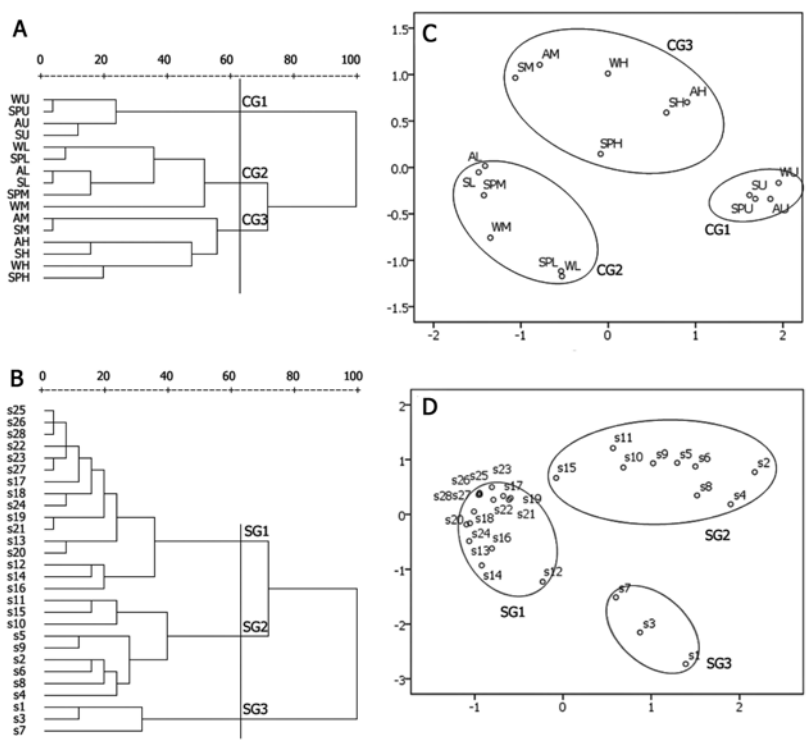

Figure 2. The hierarchical cluster dendrograms according to A) communities; B) species and the 2-dimensional nMDS ordinal configurations, C) communities, stress = 0.068; D) species, stress = 0.079). The species' codes are in Table 1; communities according to the flat tidal zones where found are: upper tidal (CG1), high-middle (CG2) and middle-low (CG3) / Dendrograma del análisis de cluster jerárquico, A) comunidades, B) especies, y la configuración ordinal bidimensional nMDS, C) comunidades, stress = 0,068; D) especies, stress = 0,079. Los códigos de las especies están indicados en la Tabla 1; comunidades por zonas del plano mareal son: alta (CG1), intermedia (CG2) y baja (CG2)

seasons, which was proved by some previous studies in temperate and subtropical regions, where some researchers found that the highest abundance and species richness were generally found in spring/summer, while the lowest values were found in autumn/winter (McCall 1977, Zajac & Whitlatch 1982b, Lu & Wu 2000). Different to this previous research, in this study the higher abundances and species richness were found in autumn/summer, and the lower values were found in winter/spring.

The factor of season changes significantly affected macrobenthic community structuring in this research, but the relationship between a lower density and the impact of migratory birds in winter/spring should be considered cautiously in wildlife habitat management. The coast of southeast Asia is an important wintering and migration stop-over wetland for some kind of birds (Butler *et al*. 2001), resulting in the macrobenthos and birds to be both involved in a complex food web (Valiela *et al*. 2004), therefore the macrobenthos contribution to energy flow and especially to the diet of birds should be elucidated in the future (Ouisse *et al*. 2011). The effect of birds on macrobenthic communities should be investigated on the tidal flat of Wenzhou Bay.

Acknowledgements

We would like to thank Xiang Zheng for participating in the field work and Professor Yong-Pu Zhang for help with species taxonomy. We thank the referees for the advice and suggestions given in order to improve the paper. This research was supported by Zhejiang Provincial Natural Science Foundation of China (No. ZE0204).

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Received 01 December 2010 and accepted 06 June 2011