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Zoological Research

The Community Structure of Benthic Macroinvertebrates Associated with *Spartina alterniflora* in the Yangtze Estuary，in China

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Abstract：Benthic macroinvertebrate communities in *Spartina alterniflora* zones in the Yangtze Estuary，in China，were investigated seasonally in 2005，and their structure and biodiversity were analyzed. Twenty-one species were identified，across four Classes；10 species of Crustacea，five species of Polychaeta，five species of Gastropoda，and one species of Lamellibranchia. Dominant species included：*Assiminea* sp.，*Notomastus latericeus*，*Cerithidea largillierl*，*Glauconome chinensi* and *Gammaridae* sp. Functional groups were comprised of a phytophagous group and a detritivorous group. The average density of all benthic macroinvertebrates was 650.5 ± 719.2 inds/m^2 in the survey area. The high value of the standard deviation of the average density was a result of abundant *Assiminea* sp. at Beihu tidal flats. The average density of macroinvertebrates from Beihu tidal flat，Chongming Dongtan to Jinshanwei tidal flat decreased gradually. There was significant difference between compositions and abundance of macroinvertebrates along the estuary gradient ($P < 0.05$). The density and biodiversity were highest in summer and lowest in winter. The mean biomass of macroinvertebrates was 20.8 ± 6.1 g/m^2. Biomass changed seasonally in the same way as density，with the change in biomass being：summer (Aug.) > autumn (Oct.) > spring (Apr.) > winter (Dec.). A BIO-ENV analysis showed that the mean grain size of sediment，height of *Spartina* and salinity were the major factors which affected the structure of the macroinvertebrate community. Variations in the community structure were probably caused by the population dynamics of *S. alterniflora* along with the variation in sampling time and location.

Key words：Benthic macroinvertebrate；*Spartina alterniflora*；Yangtze Estuary；Community structure

长江口互花米草生长区大型底栖动物的群落特征

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摘要：2005 **年对长江口潮滩湿地互花米草**（*Spartina alterniflora*）**生长区不同季节大型底栖动物群落特征的研究表明：长江口互花米草生长区的大型底栖动物有** 21 **种，其中甲壳纲** 10 **种、多毛纲** 5 **种、腹足纲** 5 **种、瓣鳃纲** 1 **种。主要种类有拟沼螺**（*Assiminea* sp.）、**背蚓虫**（*Notomastus latericeus*）、**尖锥拟蟹守螺**（*Cerithidea largillierli*）、**中国绿螂**（*Glauconome chinensis*）、**钩虾**（*Gammaridae* sp.）**等。食性功能群均以碎屑食者和植食者为主。大型底栖动物平均栖息密度为**（650.5 ± 719.2）**个**/m^2，**标准误主要是由于北湖的拟沼螺密度很大。栖息密度从大到小的顺序为沿河口梯度从内到外分布的北湖边滩、崇明东滩、金山卫边滩。大型底栖动物群落分布不均匀，沿河口梯度变化存在明显的空间差异。栖息密度和物种多样性在夏季最高，冬季最低。大型底栖动物平均生物量为**（20.8 ± 6.1）g/m^2，**季相变化为夏季 > 秋季 > 春季 > 冬季。**BIO-ENV **分析表明沉积物粒径和盐沼高度是大型底栖动物群落特征的主要影响因素。不同研究结果的差异除了时空因素外可能与互花米草的种群动态有关。加强不同时间尺度的研究有助于正确评价互花米草对大型底栖动物的影响。**

关键词：大型底栖动物；互花米草；长江口；群落结构
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Spartina alterniflora is an invasive species introduced from North America which has become a dominant species in the Yangtze Estuary (Lu, 2003). Impacts of *S. alterniflora* on benthic macroinvertebrates had drawn a lot of attention, as it has altered many macroinvertebrate habitats. Many studies have described the community structure, distribution patterns and temporal variability of benthic macroinvertebrates in *S. alterniflora* zones around the world (Daiber, 1982; Capehart & Hackney, 1989; Alkemade et al, 1994; Netto & Lana, 1999). However, the impacts of *S. alterniflora* on macroinvertebrates in the Yangtze Estuary remain unknown. There have been some studies focussing on the difference in benthic macroinvertebrates associated with vegetation types at Chongming Dongtan, Jiuduansha Shoal (Zhu & Lu, 2003; Chen et al, 2005; Zhou et al, 2006). This paper describes the change of benthic macroinvertebrate community structure induced by *S. alterniflora* in the Yangtze Estuary.

1 Materials and Methods

1.1 Study area

Three sampling sites were established along estuarine gradients (Fig. 1) of the Yangtze Estuary in China. These sites are: Beihu tidal flats (BH), Chongming Dongtan tidal flats (CMDT) and Jinshanwei tidal flats (JSW). BH is located at the outside of the dam which was constructed under the Shanghai Beach Reclaiming project in 2003, and is influenced by the northern branch of the Yangtze River. The dominant species of the salt marshes were *Phragmites australis* and *Scirpus mariqueter* before *S. alterniflora* was introduced in 2004. CMDT is the National Nature Reserve where *S. alterniflora* appeared in 1995, competing with the local salt marshes. The area of JSW is small and most of the tidal flats are covered by *S. alterniflora*, which was first introduced in 1983 (Editing Committee of 'Shanghai Water Conservation Chorography', 1997).

1.2 Sampling methods

Samples were collected during every season in 2005, in April (Spring), August (Summer), October (Autumn) and December (Winter). At each sampling site, six replicate samples were collected for characterization of the macroinvertebrates. Each sample had a surface area of 0.25 m × 0.25 m with a depth of 0.20 m. Each replicate was sieved separately through a 1 mm mesh, then the macroinvertebrates was preserved with 5% buffered formalin solution. The coverage, height, density and above-ground biomass (dry weight) of *S. alterniflora* were measured. Environmental variables, including salinity, DO (Dissolved oxygen), pH of interstitial water, grain size and organic matter content of sediment were analyzed, using the analysis methods based on Lu (2003).

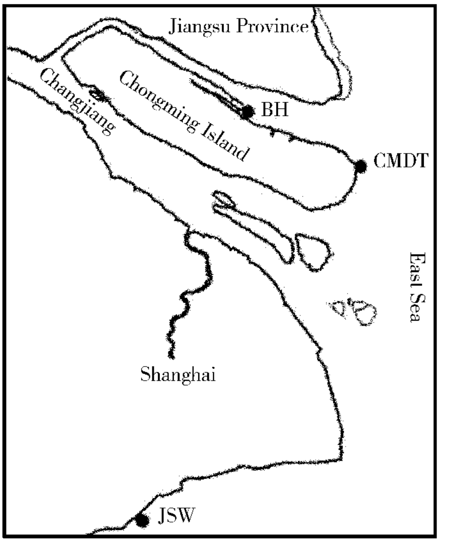

Fig. 1 Sampling sites of benthic macroinvertebrates in the Yangtze Estuary

BH: Beihu tidal falts; CMDT: Chongming Dongtan tidal falts; JSW: Jinshanwei tidal falts.

1.3 Data processing

Following Ludwig & Reynolds (1988), for each site we analyzed:

(a) Species richness using the Margalef index,

$$d = \frac{S-1}{\ln N}$$

(b) Species diversity using the Shannon-Wiener index,

$$H' = -\sum_{i=1}^{S} Pi \ln Pi$$

(c) Evenness using the Pielou index,

$$J' = H' / H'\max$$

where S = total number of species, N = total number of individuals, Pi = the proportional abundance of the first species compared to the total number of individuals in the n samples and $H'\max = \ln S$, maximum evenness.

The significance of differences in composition and abundance of macroinvertebrates were tested using ANOVAs. Multivariate analyses were performed using PRIMER 5 (Software package from Plymouth Marine Laboratory, UK) which included hierarchical clustering into sample groups (CLUSTER) and the linking test of multivariate biotic patterns to suites of environmental variables (BIO-ENV). Data (species abundance and biomass) were double square root transformed. The Bray Curtis similarity matrix was also calculated (Clarke & Corbey, 2001).

2 Results

2.1 Species composition

Twenty-one species were recorded in the survey (Tab. 1), including four Classes: 10 Crustacea, five Polychaeta, five Gastropoda, and one Lamellibranchia. There were 16 species at JSW, 12 species at CMDT, and only one species at BH.

2.2 Dominant species

According to the annual average abundance, the dominant species across all sites were *Assiminea* sp., while the abundance of *Notomastus latericeus*, *Cerithidea largillierli*, *Glauconome chinensis*, *Gammaridae* sp. were also high. The main species are listed in Tab. 2.

2.3 Functional groups

Macroinvertebrates were classified into five functional groups: Planktophagous (Pl), Phytophagous (Ph), Carnivorous (Ca), Omnivorous (Om) and Detritivorous (De) (Zhu, 2003). There was only the Ph at the BH site. The functional groups at JSW and CMDT mostly consisted of the Ph and De groups (Fig. 2).

2.4 Abundance and biomass

The mean density of macroinvertebrates was 650.5 ± 719.2 inds./m^2. The order of density at three sampling sites was BH > CMDT > JSW. There was a seasonal effect on density, with density in summer (Aug.) > autumn (Oct.) > spring (Apr.) > winter (Dec.) (Fig. 3).

The mean biomass of macroinvertebrates was 20.8 ± 6.1 g/m^2. Macroinvertebrates had the highest biomass at CMDT (25.7 ± 3.6 g/m^2) and the lowest at BH (15.7 ± 4.4 g/m^2) (Fig. 4). The seasonal effect on biomass was the same as for density: summer (Aug.) > autumn (Oct.) > spring (Apr.) > winter (Dec.).

2.5 Species diversity index

The richness index and Shannon-Wiener diversity index were highest at JSW, measuring 3.11 and 2.18, respectively (Fig. 5). BH had only one species in every season, making the biodiversity lowest among all sampling sites. The value of biodiversity was lower in spring and winter than in summer and autumn at JSW. At CMDT, biodiversity was lowest in winter.

Tab. 1 Species composition of macroinvertebrates at the three sampling sites

Taxonomical groups	Species	JSW	CMDT	BH
Polychaeta	*Tylorrhynchus heterochaetus*	+	−	−
	Perinereis aibuhitensis	+	−	−
	Perinereis nuntia	+	−	−
	Nephtyidae sp.	+	+	−
	Notomastus latericeus	+	+	−
Gastropod	*Assiminea* sp.	−	+	+
	Assiminea latericea	+	+	−
	Assiminea violacea	−	+	−
	Cerithidea sinensis	+	+	−
	Cerithidea largillierli	+	+	−
Crustacea	*Glauconome chinensis*	+	−	−
	Gammaridae sp.	+	−	−
	Uca arcuata	−	+	−
	Macrophthalmus dilatatus	+	−	−
	Ilyoplax deschampsi	−	+	−
	Pachygrapsus crassipes	+	−	−
	Sesarma dehaani	−	+	−
	Sesarma haematocheir	+	+	−
	Helice pingi	+	−	−
	Helice tientsinensis	+	+	−
Lamellibranch	*Metaplax longipes*	+	−	−

JSW: Jinshanwei tidal falts; CMDT: Chongming Dongtan tidal falts; BH: Beihu tidal falts. +: Occurrence; −: Not occurrence.

Tab. 2 Mean densities (inds./m^2) of main species

Species	JSW	CMDT	BH	Average
Assiminea sp.	0	78.0	1569.0	549.0
Notomastus latericeus	7.4	61.0	0	22.8
Cerithidea largillierli	37.3	25.4	0	20.9
Glauconome chinensis	33.3	0	0	11.1
Gammaridae sp.	16.7	0	0	5.7

JSW: Jinshanwei tidal falts; CMDT: Chongming Dongtan tidal falts; BH: Beihu tidal falts.

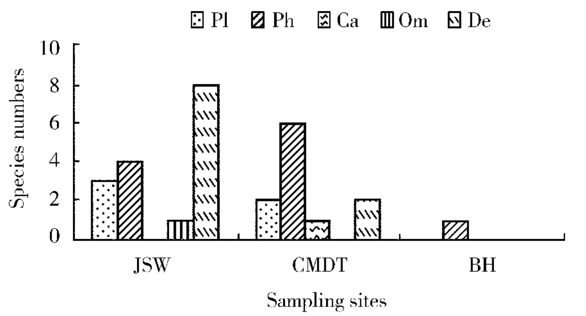

Fig. 2 Functional groups of benthic macroinvertebrates at the three sampling sites

JSW: Jinshanwei tidal falts; CMDT: Chongming Dongtan tidal falts; BH: Beihu tidal falts.
Pl: Planktophagous group; Ph: Phytophagous; Ca: Carnivorous; Om: Omnivorous; De: Detritivorous.

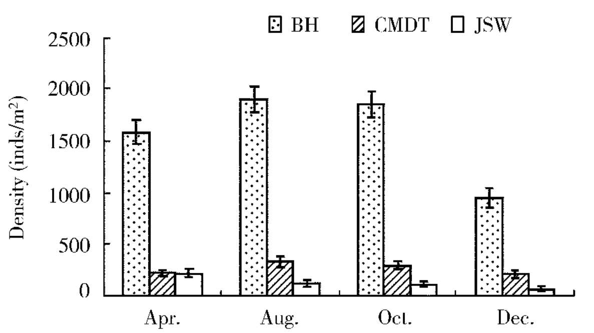

Fig. 3 Seasonal change of density of macroinvertebrates at the three sampling sites

BH: Beihu tidal falts; CMDT: Chongming Dongtan tidal falts; JSW: Jinshanwei tidal falts.

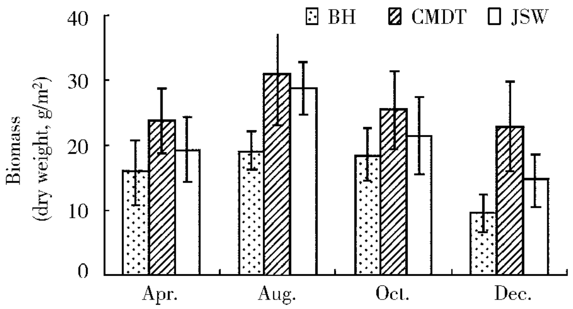

Fig. 4 Seasonal change of biomass of macroinvertebrates at the three sampling sites

BH: Beihu tidal falts; CMDT: Chongming Dongtan tidal falts; JSW: Jinshanwei tidal falts.

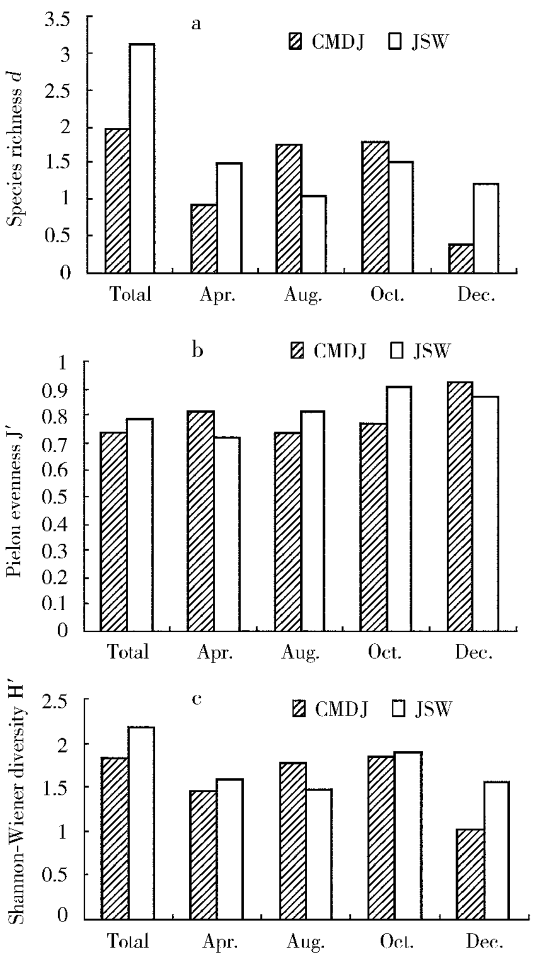

Fig. 5 Biodiversity of macroinvertebrates in Spartina alterniflora zones, at Chongming Dongtan and Jinshanwei tidal falts

a: Species richness; b: Pielou evenness; c: Shannon-Wiener diversity.

3 Discussion

3.1 Spatial distribution of macroinvertebrate

Cluster analysis of the macroinvertebrate community (Fig. 6) showed that there were three groups. Disregarding that BH has 100% similarity among seasons,

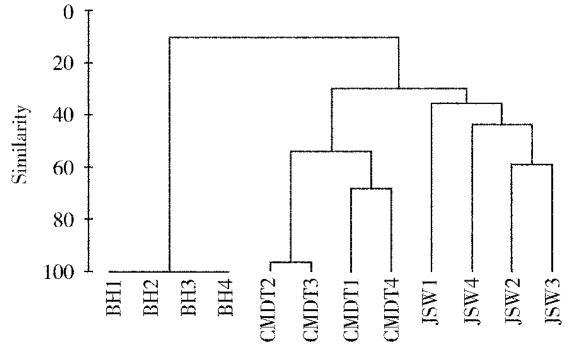

Fig. 6 Cluster analysis of abundance of macroinvertebrates at the three sampling sites

1: Spring; 2: Summer; 3: Autumn; 4: Winter.

BH: Beihu tidal falts; CMDT: Chongming Dongtan tidal falts; JSW: Jinshanwei tidal falts.

the highest similarity is between CMDT and JSW in summer and autumn. The species composition and abundance of benthic macroinvertebrates were similar in summer and autumn. This may be caused by the spatial distribution of *S. alterniflora*.

3.2 Variation of abundance and biomass

The high standard deviation of density was a result of the abundant *Assiminea* sp. at the BH site where *Assiminea* sp. reached densities of up to 1569 inds./m^2. *Assiminea* sp. are tiny molluscs which used to be identified as *Rissoina* sp. Therefore the biomass was lowest at BH. Spatial distribution of benthic macroinvertebrates was complicated in *S. alterniflora* zones in the Yangtze Estuary. Macroinvertebrates varied in species composition and abundance along estuarine gradients.

3.3 Variation of biodiversity

Biodiversity was obviously different between the sampling sites and seasons (ANOVA, $P < 0.05$). At JSW, *Cerithidea largillierli* and *Notomastus latericeus* were common in every season, while the number of polychaetes increased in summer. At CMDT, macroinvertebrates were dominated by *C. largillierli* and *Assiminea latericea*. Density of *N. latericeus* was highest in spring. Only a single macroinvertebrate species existed at BH, making its diversity the lowest among the three sampling sites.

The species richness index, Shannon-Wiener diversity index and Pielou's average index of macroinvertebrates were 2.42, 1.16, 0.76 respectively in the upper *S. marigueter* zone at Chongming Dongtan (Yuan, 2002). Our study showed that biodiversity was greater in *S. alterniflora* zones than in *S. marigueter* zones except for species richness. Previous analysis in Jiuduansha Shoal affirms this conclusion (Zhou et al, 2006). However, Chen et al (2005) suggested that invasion of

Tab. 3 Spearman correlation coefficients between the abundance of macroinvertebrates in the three sampling sites and the environmental factors

Environmental factors	Correlation coefficients
Salinity	0.543
DO	0.118
pH	0.043
Grain size	0.725
Organic content	0.461
Spartina coverage	0.094
Spartina height	0.688
Spartina density	0.134
Spartina above-ground biomass	0.096

S. alterniflora could decrease the biodiversity.

3.4 BIO-ENV analysis

Macroinvertebrates were affected by many factors, including physical and biotic factors. We used nine factors (salinity, DO, pH of interstitial water, grain size and organic matter content of sediment, coverage, height, density and above-ground biomass of *S. alterniflora*) and the abundance of macroinvertebrates to analyze the relationship between environmental variables and benthic assemblages. The calculation was concluded by a BIO-ENV analysis using PRIMER. Tab. 3 shows that the grain size of the sediment, *Spartina* height and salinity were the primary factors.

Environmental variables were mostly affected by hydrology, sediment from upstream and human impact. The difference at the three sampling sites are mostly in characteristics of the sediment and salinity. Sediment characteristics are all a reflection of the estuary environment. *S. alterniflora* plays an important role altering the compounding habitat (Netto & Lana, 1999).

Salinity, hydrology, sediment and salt marsh are the major factors affecting benthic macroinvertebrates (Yuan, 2001). However, the pattern of change in abundance of macroinvertebrates showed an integration of the responses of the major community parameters. BIO-ENV analysis showed that there was a significant gradient variation in community structure and biodiversity of macroinvertebrates at the three sampling sites (ANOVA, $P < 0.05$).

S. alterniflora grows rapidly, having a high biomass, increasing the availability of food for macroinvertebrates (Netto & Lana, 1997), and changing the environment into complex habitats. Functional groups in the three sampling sites were mostly composed of Ph and De macroinvertebrates. A study in subtropical Paranaguá bay also shows that the above- and below-ground components of *S. alterniflora* and detritus biomass play a key role in structuring benthic macroinvertebrate communities (Netto & Lana, 1999).

In conclusion, the variation of macroinvertebrate community structures may be due to the population dynamics of *S. alterniflora* as well as variations in sampling time and location. Exotic species have to adapt to new habitats before invading into native ecosystems. *S. alterniflora* may take a long time to reach ecological adaptation after its introduction to the Yangzte Estuary. It is necessary to study the impacts of *S. alterniflora* on different time scales to help to manage this effect.

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