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Spatial and temporal variations of macro- and mesozooplankton community in the Huanghai Sea (Yellow Sea) and East China Sea in summer and winter

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Abstract
The study was conducted during two cruises of June–August 2006 (summer), and January–February 2007 (winter) in the Huanghai (Yellow) Sea and East China Sea. Spatial and temporal variations of zooplankton abundance, biomass and community structure and its relation to currents and water masses over the continental shelf were examined. A total of 584 zooplankton species/taxa and 28 planktonic larvae were identified during the two surveys. Copepods were the most abundant component among these identified groups. Zooplankton abundance and biomass fluctuated widely and showed distinct heterogeneity in the shelf waters. Five zooplankton assemblages were identified with hierarchical cluster analysis during this study, and they were Huanghai Sea Assemblage, Changjiang Estuary Assemblage, Coastal Assemblage, East China Sea Mixed-water Assemblage and East China Sea Offshore Assemblage. Seasonal changes of zooplankton community composition and its geographical distribution were detected, and the locations of the faunistic areas overlap quite well with water masses and current systems. So we suggest that the zooplankton community structure and its changes were determined by the water masses in the Huanghai Sea and East China Sea. The results of this research can provide fundamental information for the long-term monitoring of zooplankton ecology in the shelf of Huanghai Sea and East China Sea.

Key words: zooplankton, abundance, biomass, community structure, the Huanghai Sea (Yellow Sea), the East China Sea

1 Introduction

Zooplankton inhabits almost every type of marine environment, and they are major secondary producers grazing on phytoplankton and providing food for ichthyoplankton and carnivorous invertebrates (McKinnon et al., 2005; Mackas, 1999). Zooplankton abundance is a primary index of trophic potential and could directly affect fisheries resources (Xue et al., 2007; Marrari et al., 2004; Longhurst and Harrison, 1989). Some zooplankton has been suggested to be good biological indictors for water masses (Hsieh et al., 2004; Zheng et al., 1989).

The complex hydrographic condition of the Huanghai (Yellow) Sea and East China Sea was caused by the presence of waters from several origins. Generally, Coastal Water, Huanghai Sea Water, Mixed Water and Kuroshio Water are the most fundamental waters in this area (Feng et al., 1999; Hur et al., 1999; Su, 1989; Ho et al., 1959), and their properties vary seasonally with the variation of air temperature, river discharge and wind stress (Hur et al., 1999; Liu et al., 1992; Su, 1989). Such complicated water properties are believed to ultimately affect the spatial distribution pattern of zooplankton. Knowledge of the spatial scale of zooplankton distributions is essential to understand the mechanisms by which physical and biological processes structure marine ecosystems (Hitchcock et al., 2002). Although many studies on zooplankton have been conducted, most of the literature was limi-

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ted to some local area (Liao et al., 2006; Xu et al., 2004; Hong et al., 2001; Shih and Chiu, 1998; Liu et al., 1991; Chen et al., 1980; Cheng et al., 1965) or some special taxonomic components (Xu, 2007; Liao et al., 2006; Zuo et al., 2006; Xu and Jiang, 2006; Xu and Li, 2005; Xu et al., 2003; Lin et al., 1998; Shih and Chiu, 1998), few papers have concerned the whole Huanghai Sea and East China Sea shelf (Zuo et al., 2005; Cheng, 1965).

This study was conducted during two cruises of June–August 2006 (summer) and January–February 2007 (winter). The spatial and temporal variations of zooplankton abundance, biomass and community structure were studied, so was the environmental effect on the distribution of zooplankton in the Huanghai Sea and the East China Sea. This research can provide fundamental information for the long-term monitoring of zooplankton ecology in the Huanghai Sea and East China Sea.

2 Materials and methods

2.1 *Study area and sampling methods*

Two surveys were conducted at 37 stations along ten transects in June–August 2006 (summer), and 55 stations along 12 transects in January–February 2007 (winter) in the Huanghai Sea and East China Sea on board RV *Dongfanghong 2* (Fig.1). Zooplankton was sampled with a 0.8 m diameter, 505-μm mesh ring net hauled vertically from bottom (or 200 m in deeper water) to sea surface at a rate between 0.8 and 1 m/s. The filtered water volume was determined by the rope length multiplying mouth area. After the completion of each tow, nets were washed and the samples were preserved in 5% formalin (in seawater) for further analyses. Data on temperature, conductivity and depth of the water were obtained using a CTD (Sea-Bird SBE 9) profiler.

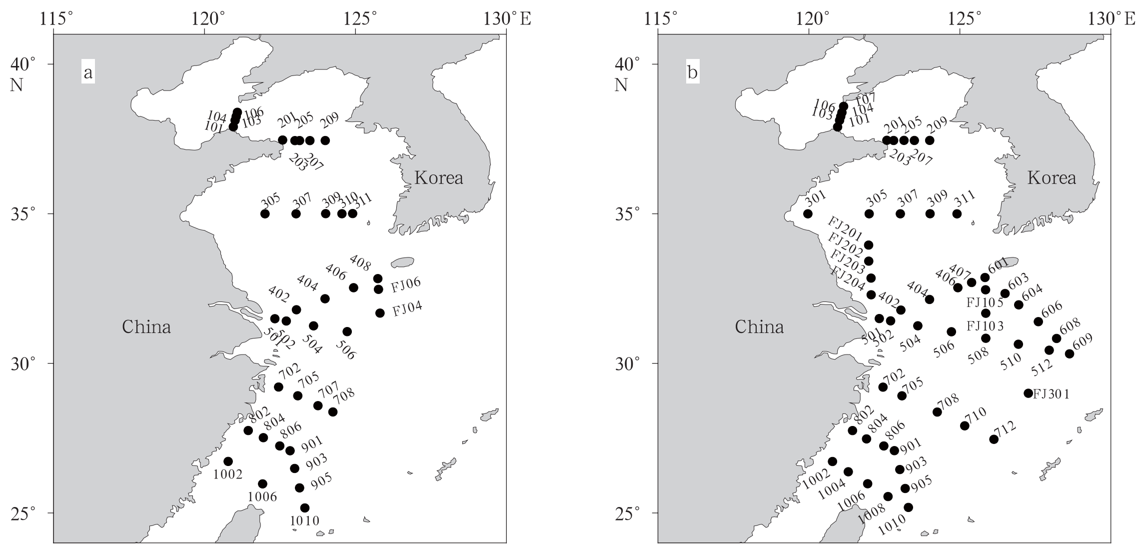

Fig.1. Sampling stations in the Huanghai Sea and East China Sea. a. summer, b. winter.

2.2 *Laboratory procedures*

Zooplankton wet weight was measured using an electronic balance after removing large detrital particles, and eliminating excess and interstitial water by the vacuum extraction technique. All zooplankton taxa present in the samples were identified to species or lowest taxonomic level possible and enumerated under a stereo microscope (Leica S8APO). For this purpose, a subsample was obtained from each sample with a Folsom Plankton Splitter. Its volume was determined according to the density of organisms in the original sample to include at least 200 adult individuals. Zooplankton abundance and wet weight biomass were expressed as ind./m^3 and mg/m^3, respectively.

2.3 *Data analysis*

Biological data were $\log_{10}(x + 1)$-transformed. Species present in less than 5% of the samples were excluded from these analyses. The hierarchical cluster and multidimensional scaling (MDS) analyses of similarity between stations during the two seasons were computed on the basis of the Bray-Curtis similarity index and the transformed data using the PRIMER v5.2 statistical package (Clarke and Gorley, 2001).

Pearson correlation analysis was conducted using SPSS 11.0 to find the relationship between the distribution of zooplankton and the environmental variables. Diversity index (H') was calculated using the Shannon-Wiener diversity index (Clarke and Warwick, 2001).

$$H' = -\sum_{i=1}^{S} P_i \log_2 P_i, \tag{1}$$

where P_i is the proportion of individuals in a sample unit belonging to species i, S is the number of species identified in the sample. Differences in Shannon-Wiener diversity between zooplankton communities (defined by the cluster analysis) were tested with a Kruskal-Wallis ANOVA followed by a non-parametric multiple post hoc test. Contours of temperature, salinity were produced from gridded data using the Kriging method.

3 Results

3.1 *Environmental variables*

3.1.1. *Temperature*

The temperature characteristics varied substantially between summer and winter. Surface temperature ranged from 17.9 to 29.7°C in summer and 4.2 to 24.7°C in winter, and bottom temperature (or 200 m in deeper water) ranged from 6.8 to 23.6°C in summer and 3.9 to 22.9°C in winter (Fig.2). The temperature

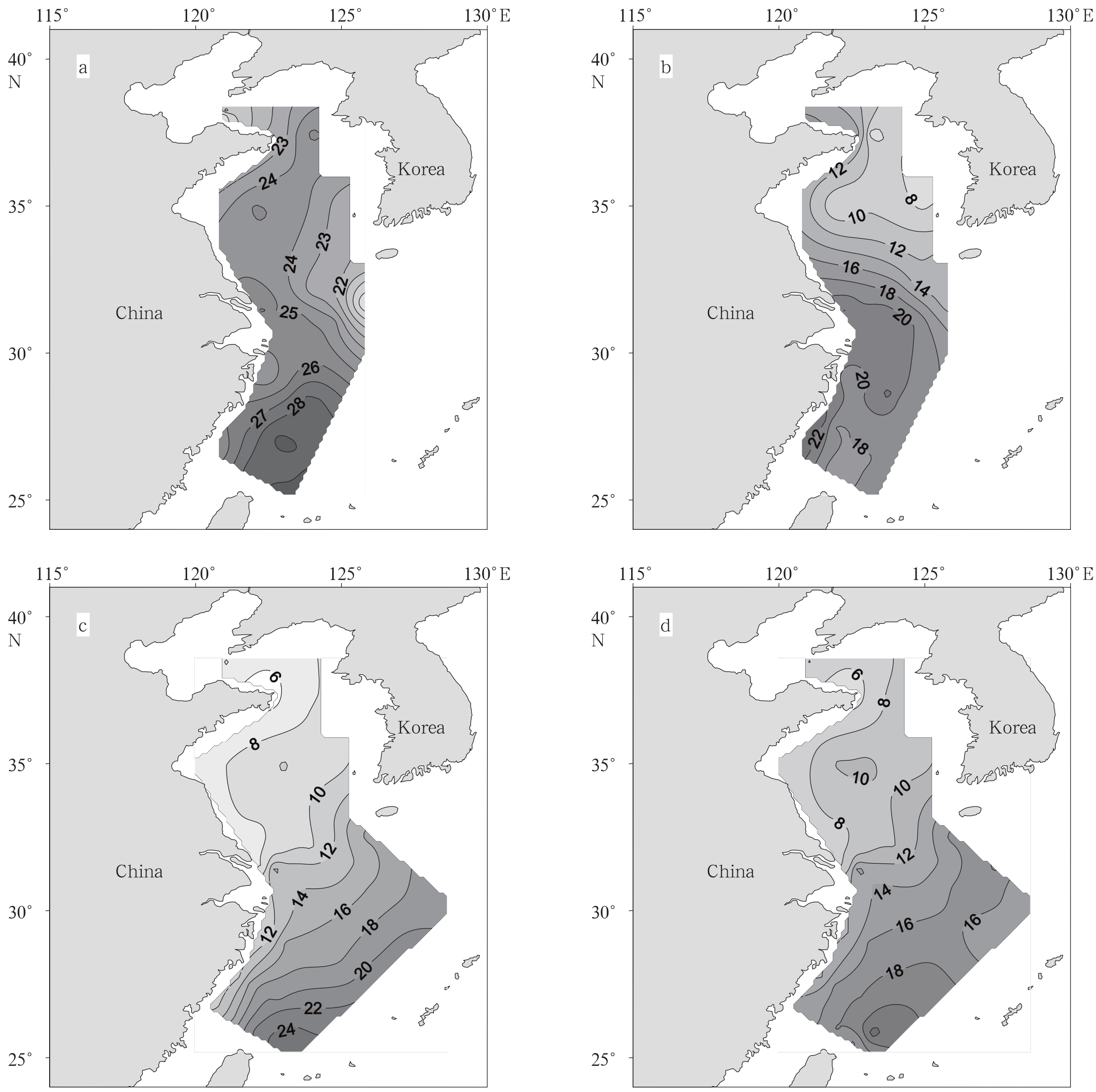

Fig.2. Horizontal distribution of surface and bottom temperature in the study area. a. Surface temperature in summer, b. bottom temperature in summer, c. surface temperature in winter, d. bottom temperature in winter.

range was greater in winter since the winter cruise included stations that were further offshore, which introduces bias in the data since offshore waters tend to be warmer.

3.1.2. *Salinity*

Surface salinity ranged from 21.6 to 34.2 in summer and 29.9 to 34.6 in winter, and bottom salinity (or 200 m in deeper water) ranged from 29.5 to 34.8 in summer and 26.5 to 34.8 in winter. Spatial distribution of salinity in both the surface and the bottom was as shown in Fig.3, indicating lower surface salinity near shore as a result of river discharges.

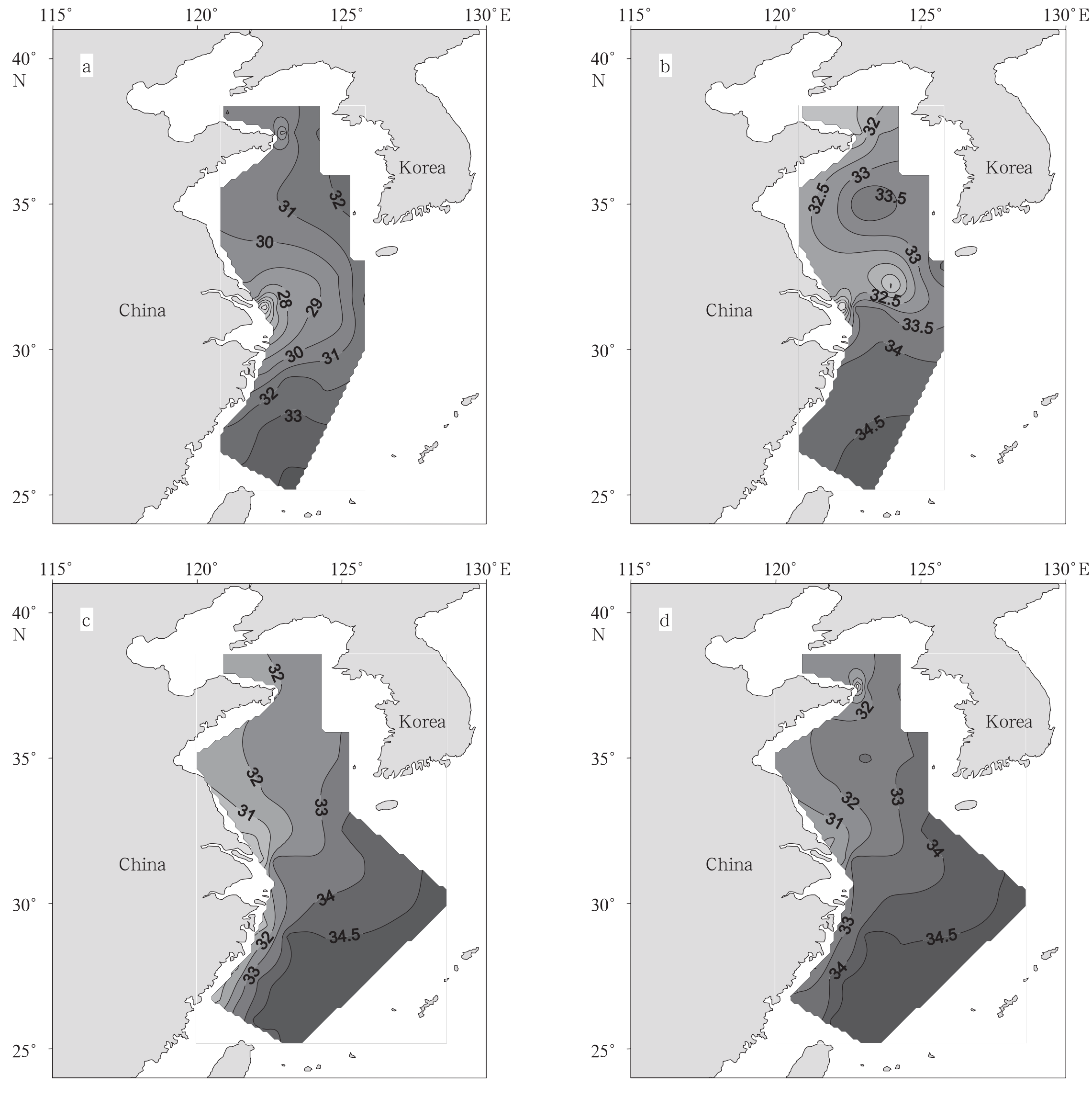

Fig.3. Horizontal distribution of surface and bottom salinity in the study area. a. Surface salinity in summer, b. bottom salinity in summer, c. surface salinity in winter, d. bottom salinity in winter.

3.2 *Abundance and biomass*

The average zooplankton abundance was higher in summer (1 118.8 ind./m^3) than that in winter (178.4 ind./m^3) (Table 1), and the zooplankton biomass was higher in summer with the mean of 485.6 mg/m^3 than that in winter with the mean of 94.6 mg/m^3. Figures 4 and 5 showed the distribution patterns of zooplankton abundance and biomass in the Huanghai Sea and the East China Sea.

In summer, the peak abundance occurred in the adjacent area of the Changjiang River Estuary and the coastal area of East China Sea. The offshore area of the Huanghai Sea and East China Sea had relatively low abundance. However, the highest biomass occurred in the offshore area of Huanghai Sea, while the biomass of offshore area of East China Sea was lower. Zooplankton abundance decreased sharply during winter time, and the distribution of abundance in the investigated area was relatively uniform. Again, the maximum biomass was observed in the Huanghai Sea, while the coastal area of East China Sea had the lowest biomass.

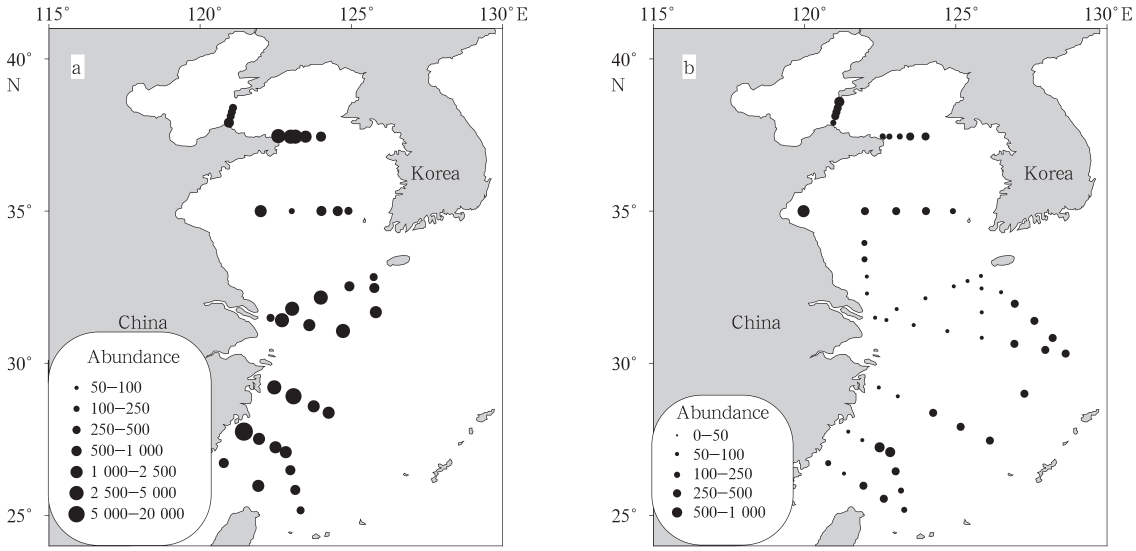

Fig.4. Distribution of zooplankton abundance in surveyed area (ind./m^3). a. summer, b. winter.

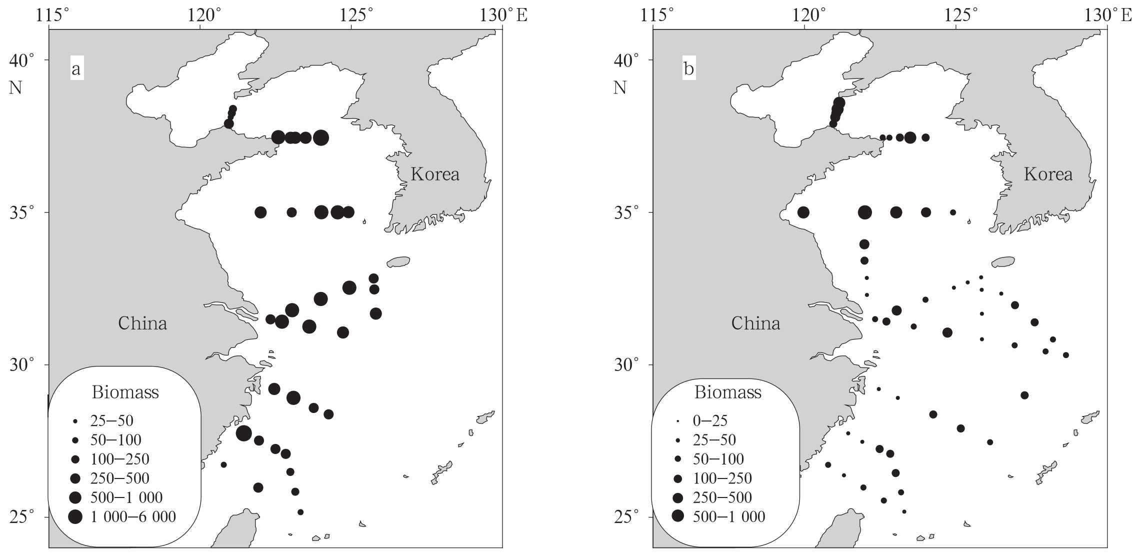

Fig.5. Distribution of zooplankton biomass in surveyed area (mg/m^3). a. summer, b. winter.

Pearson correlation analysis indicated that zooplankton biomass was positively correlated to its abundance in winter (r=0.348, P <0.01) and summer (r=0.203, P >0.05). In summer, the abundance was positively correlated to sea bottom temperature (r=0.346, P <0.05), but in winter, the abundance was negatively to all the environmental factors with no significance (P >0.05).

3.3 *Community structure*

A total of 584 zooplankton species/taxa and 28 planktonic larvae were identified during the two surveys in the study area. Four hundred and sixty-six taxa were represented in 55 winter samples, and 432 taxa were in 37 summer samples. Pearson correlation analysis indicated that the spatial distribution of species richness was positively correlated to depth, salinity and temperature (summer, p <0.05; winter, p <0.01). Table 1 showed the variations of zooplankton species richness and abundance during the two seasons. Crustacea was the most abundant component among these identified groups, and represented above 50% of total species richness. Among the crustaceans, copepods were the most abundant in both the summer and winter cruises. Medusa including Hydromedusae and Siphonophorae were commonly collected with high species richness. Planktonic larvae was also the important groups mainly including larvae of macrura, polychaete, Ophiopluteus and Calyptopis.

Table 1. Variations of zooplankton species richness and abundance during two seasons

Group	Summer				Winter				Total	
	Species/taxa		Abundance		Species/taxa		Abundance		Species/taxa	
	Number	(%)	/ind.m^{-3}	(%)	Number	(%)	/ind.m^{-3}	(%)	Number	(%)
Protozoa	6	1.31	16.3	1.46	17	3.46	43.3	24.26	18	2.94
Hydromedusae	50	10.92	4.1	0.37	41	8.35	1.0	0.58	69	11.27
Siphonophorae	32	6.99	8.7	0.78	37	7.54	1.0	0.54	42	6.86
Scyphomedusae	1	0.22	0.002	0.000 2	1	0.20	0.002	0.001	1	0.16
Ctenophora	3	0.66	0.4	0.04	3	0.61	0.2	0.10	3	0.49
Cladocera	3	0.66	356.7	31.88	1	0.20	0.004	0.002	3	0.49
Ostracoda	24	5.24	38.6	3.45	36	7.33	2.2	1.23	41	6.70
Copepoda	135	29.48	443.9	39.68	165	33.60	58.7	32.93	191	31.21
Cumacae	2	0.44	0.1	0.004	2	0.41	0.02	0.01	2	0.33
Isopoda	2	0.44	0.01	0.001	3	0.61	0.002	0.001	3	0.49
Amphipoda	42	9.17	6.6	0.59	28	5.70	0.8	0.47	47	7.68
Mysidacea	16	3.49	2.1	0.19	10	2.04	0.2	0.09	19	3.10
Euphausiacea	17	3.71	15.1	1.35	19	3.87	1.6	0.89	23	3.76
Decapoda	7	1.53	15.6	1.39	5	1.02	0.2	0.13	8	1.31
Chaetognatha	21	4.59	45.5	4.06	18	3.67	20.6	11.52	23	3.76
Polychaeta	18	3.93	1.1	0.09	17	3.46	0.1	0.08	21	3.43
Pteropoda	20	4.37	5.2	0.46	23	4.68	0.9	0.49	25	4.08
Heteropoda	8	1.75	0.8	0.08	7	1.43	0.1	0.04	8	1.31
Cephalopoda	3	0.66	0.04	0.004	4	0.81	0.02	0.01	6	0.98
Tunicata	22	4.80	100.5	8.99	29	5.91	15.4	8.62	31	5.07
Pelagic larvae	26	5.68	57.4	5.13	25	5.09	32.2	18.02	28	4.58
Total	458	100	1 118.8	100	491	100	178.4	100	612	100

Table 2 showed that dominant species shifted seasonally in the Huanghai Sea and East China Sea. *Evadne tergestina* and *Calanus sinicus* dominated in summer with the average of 342.6 and 296.8 ind./m^3, respectively. *Noctiluca scientillans* showed high abundance in winter at an average of 41.8 ind./m^3, and appeared only in the inshore area. Dominant species were distributed in patchiness. For example, *Evadne tergestina* pooled at Sta. 802 in summer.

Results of the hierarchical cluster analyses suggested that four assemblages presented in summer, and four in winter, respectively (Figs 6, 7 and 8). In the two-dimensional MDS plots, stresses of 0.12 and 0.12 were obtained for summer and winter, respectively. According to Clarke and Warwick (2001), stress levels between 0.1 and 0.2 provide a useful two-dimensional picture. So the dendrogram groups agreed with each of the MDS plots, which provided confidence in the two-dimensional representation of the MDS plots (Li et al., 2006; Froneman, 2004; Kibirige and Perissinotto, 2003; Clarke and Warwick, 2001). The one-way ANOSIM (analysis of similarities) test was used to test the null hypothesis of difference between zooplankton communities (Clarke and Warwick, 2001). The result showed significant differences between communities (summer, p <0.001; winter, p <0.001).

During summer, Huanghai Sea Assemblage (Hs) comprised those stations located in the Huanghai Sea, and it was dominated by *Calunus sinicus, Sagitta crassa* and *Euphausia pacifica*. Changjiang Estuary Assemblage (CJs) was characterized by oligohaline species such as *Centropages dorsispinatus* and *Labidocera euchaeta*, corresponding to Sta. 501, which located at the mouth of the Changjiang River. Coastal Assemblage (Cs) located in the coastal region of the East China Sea and the adjacent areas off the Changjiang River estuary, and neritic species *Evadne tergestina* was in dominance. East China Sea Mixed-water Assemblage (EMs) located in the middle part

Table 2. Average abundances of the most abundant species/taxa (cumulative abundances being greater than 80%) in summer and winter

Summer		Winter	
Species/taxa	Abundance/ind.m^{-3}	Species/taxa	Abundance/ind.m^{-3}
Evadne tergestina	342.6	*Noctiluca scientillans*	41.8
Calanus sinicus	296.8	*Ophiopluteus larvae*	19.2
Dolioetta gegenbauri	69.0	*Sagitta crassa*	17.0
Euconchoecia aculeata	36.0	*Calanus sinicus*	16.1
Euchaeta plana	18.0	*Paracalanus parvus*	10.0
Euchaeta concinna	16.4	*Oithona plumifera*	8.9
Sagitta nagae	16.2	*Oikopleura longicauda*	6.0
Noctiluca scientillans	14.7	*Euchaeta copepodid*	5.1
Penilia avirostris	14.1	*Oikopleura dioica*	2.7
Lucifer intermedius	13.8	*Paracalanus aculeatus*	2.7
Sagitta crassa	12.0	*Clausocalanus arcuicornis*	2.3
Macrura larvae	11.6	*Oncaea venusta*	1.8
Calyptopis larvae	11.6	*Sagitta nagae*	1.6
Doliolum denticulatum	11.5	*Bivalve larvae*	1.6
Pesudeuphausia sinica	9.8	*Oikopleura rufescens*	1.4
Labidocera bipinnata	9.8	*Calyptopis larvae*	1.3
		Scolecithricella longispinosa	1.3
		Euphausia pacifica	1.0

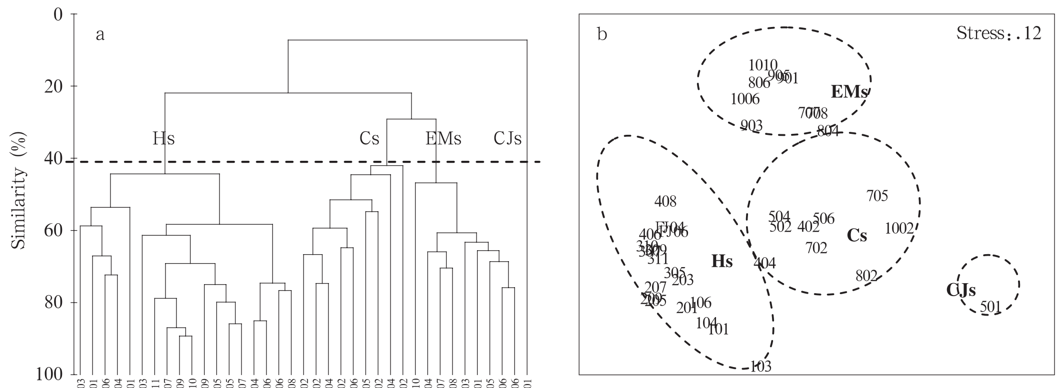

Fig.6. Results of the cluster and MDS analyses of the zooplankton community structure in summer.

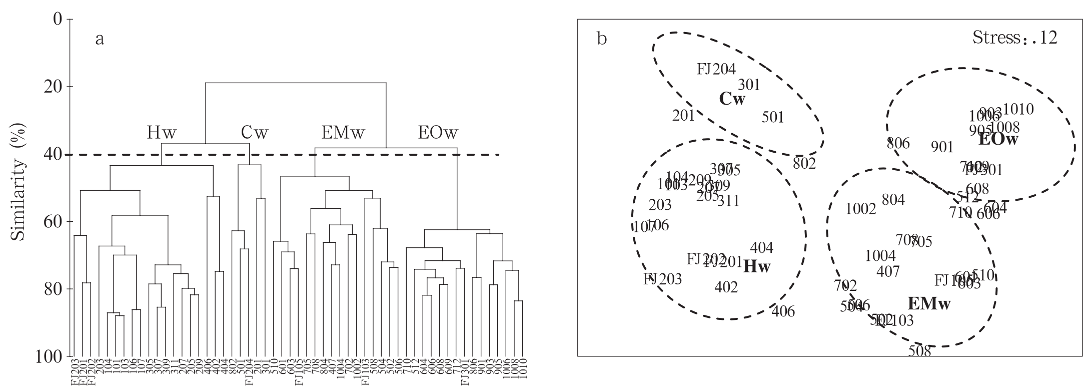

Fig.7. Results of the cluster and MDS analyses of the zooplankton community structure in winter.

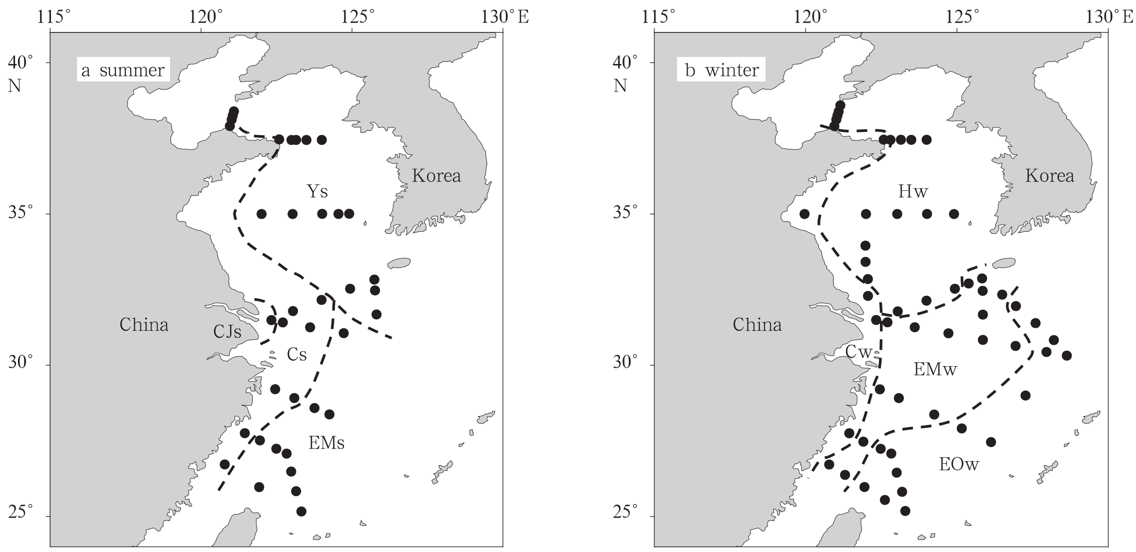

Fig.8. Geographical distributions of each assemblage in summer (a) and winter (b).

of the East China Sea where the Kuroshio branch current mixed with the Coastal Current, species adapted to high temperature and high salinity such as *Undinula vulgaris, Eucalanus subcrassus, Temora tubinata* and *Lucifer intermudius* were in dominance.

In winter, the location and dominant species of the Huanghai Sea Assemblage (Hw) was similar to Hs. Coastal Assemblage (Cw) located in a thread-like coastal region of the Huanghai Sea and East China Sea, and neritic species such as *Paracalanus parvus, Oithona similis, Corycaeus affinis* and *Oikopleura dioica* were the dominant species. It was difficult to distinguish CJs from Cw. Accompanying with the decreasing of temperature and salinity, widely-distributed species including *C.sinicus, Paracalanus aculeatus, P. parvus, Oithona plumifera* and *Sagitta nagae* took place of the warm-water species dominated the East China Sea Mixed-water Assemblage (EMw). East China Sea Offshore Assemblage (EOw) located in the offshore area of the East China Sea which was influenced by the Krushio. Its dominant species included both widely-distributed species such as *C.sinicus, Paracalanus aculeatus, Oithona plumifera, Oikopleura longicauda* and warm-water species such as *Clausocalanus arcuicornis* and *Oncaea venusta*.

The univariate analyses indicated strong spatial patterns in the diversity indices calculated for the five communities defined in the cluster analysis. The Shannon-Wiener diversity index value was higher in winter (3.5) than that in summer (2.8). Zooplankton diversity increased from the Huanghai Sea to the East China Sea, and from inshore to offshore area. The Shannon-Wiener diversity index showed significant variation between communities (in summer, X^2: 27.401, $p<0.000\,1$; in winter, X^2: 47.347, $p<0.000\,1$). Figure 9 showed the average zooplankton biodiversity indexes of each assemblage in summer and winter.

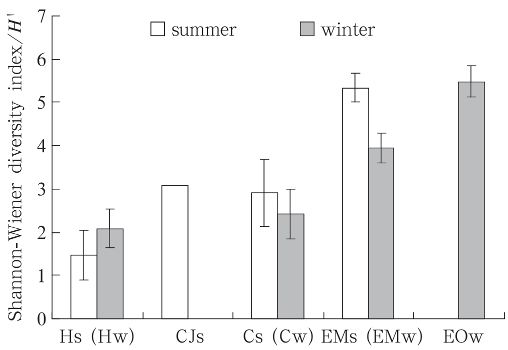

Fig.9. Average diversity index value of each assemblage in summer and winter.

4 Discussion

4.1 *Spatial and temporal distribution of zooplankton abundance and biomass*

Pearson correlation analysis showed that neither total abundance nor total biomass of the zooplankton was found to be correlated with the environmental factors in winter, and only abundance was positively correlated to sea bottom temperature in summer with a low correlation coefficient. It was possibly because that there were many different ecological categories in zooplankton community in this region, for example, eurythermal low-saline species, warm-temperate thermophilic species, thermophilic and halophilic tropical species, etc. Each category had its relevant hydrographic, and the proportion of each category varied following the change of environmental conditions. Therefore, zooplankton abundance and biomass show different relationships with environmental factors in the two seasons.

In order to discriminate the differences of correlations between zooplankton biomass and abundance between summer and winter, the analyses were conducted separately. The results indicated that the biomass was positively correlated to abundance in winter with a weak coefficient and positively in summer with no significance. The correlation between zooplankton abundance and biomass were also different between the Huanghai Sea and East China Sea. In the East China Sea, the biomass was greatly associated with abundance, but in the Huanghai Sea, the biomass was not obviously affected by abundance. The different relationship between biomass and abundance in the Huanghai Sea and East China Sea were caused by the species component otherness in the two sea areas. Small size components (such as cladoceran and copepods) were in dominance in the East China Sea, and the abundance of large size species were low, so the biomass increased along with the abundance; In the Huanghai Sea, despite the dominance of copepods, the large size species such as salp and Euphausiids also become important contributors of the biomass, and made the Huanghai Sea possess high biomass with relative low total abundance. And this is the main reason of the weak correlations between biomass and abundance when we conducted the analyses with data combined the Huanghai Sea and East China Sea.

The patchy distribution of zooplankton abundance and biomass was in agreement with previous studies conducted in surveyed area (Xu et al., 2004; Xu et al., 2003). In summer, zooplankton abundance and biomass were much higher than that in winter in surveyed area, especially in the East China Sea (Figs 4 and 5). The high abundance and biomass were mainly due to the fitting temperature and the availability of macronutrients supplied by rivers freshwater discharge of China mainland that promoted the growth of prey phytoplankton. Zooplankton species in the Changjiang River Estuary and the coastal area of East China Sea were mostly warm-water species, whose optimum temperature ranges from 20 to 25°C (Shen and Shi, 2002), and during present research, the temperature in summer was in that spectrum. *Evadne tergestina* at Sta. 802 (11 315.2 ind./m^3) was the main contributor of the high abundance and biomass. Many species of Cladocera adopt parthenogenetic breeding mode in favorable conditions to achieve rapid growth (Zheng and Cao, 1984), and *Evadne tergestina* is a typical parthenogenetic Cladocera species. During winter, zooplankton abundance decreased rapidly with temperature in the inshore area of East China Sea. Comparatively, the offshore part of East China Sea became the abundance peak area. Although its abundance was lower than that in summer, the extent of decline was slender. The abundance and biomass had no significant difference between the two seasons at the stations affected greatly by Kuroshio.

Spatial and temporal variations of zooplankton biomass of the Huanghai Sea varied dramatically in different investigations (Wang et al., 2005; Meng et al., 1993; Wang et al., 1985)[1)]. The biomass of present study in the Huanghai Sea was higher than any investigation before, and it is unclear why the variations occurred.

4.2 *Spatial and temporal distribution of zooplankton community structure*

The present study detected seasonal changes of zooplankton community composition and its geographical distribution (Fig.8), and the location of the faunistic areas overlap quite well with water mass (Feng et al., 1999). The coverage area of zooplankton communities varied with the seasonal change of hydrological conditions, and especially transferred with the moving of currents and water mass (Cheng, 1965).

The Huanghai Sea Assemblage (Hs, Hw) mainly located in the central part of the Huanghai Sea. Chen et al. (1980) and Cheng (1965) suggested that the Huanghai Sea community of zooplankton was confined in the central part of Huanghai Sea in summer and branch out to the south in winter, which was opposite to the present study. Zuo et al. (2005) suggested that zooplankton community in the south Huanghai Sea outspreaded southward in autumn and drew back in spring. The coverage area of Huanghai Sea Assemblage matched the Huanghai Sea Surface Water in

[1)] The Office of Comprehensive Oceanographic Survey, Oceanography Group in the Committee of Science and Technology of the People Repubic of China. 1977. Reports of the General Oceanographic Survey of Bo Hai, Huang Hai, Dong Hai and Nan Hai.

summer, and matched Huanghai Sea Water in winter. In summer, the Changjiang River discharge was strong, and the Kuroshio orbit leaned east (Su, 1989), so the Huanghai Sea Water extended southeastward, accompanied with Assemblage Hs. In winter, the Changjiang River discharge shrinked shoreward, the Kuroshio was puissant and declined westwardly, so the Huanghai Sea Water withdrew to the southwest and arose the corresponding change of Assemblage Hw. The Huanghai Sea Cold Water was active in summer (Liu et al., 1992; Ho et al., 1959), so there was a distinct thermocline and the bottom temperature was very low in Assemblage Hs. In the present study, samples were collected vertically from bottom to sea surface, so we cannot clearly tell the differences between zooplankton communities above and below the thermocline. The zooplankton abundance was relatively low, but the biomass was high, and the bodiversity was the lowest in all the communities (Fig.9).

The Changjiang Estuary Assemblage (CJs) corresponding to Sta. 501, was only detected in summer, and the salinity of the surface water was low. In winter, as the weakening of Changjiang River discharge, it was difficult to distinguish CJ from the Coastal Assemblage (Cw).

The location of Coastal Assemblage varied dramatically between summer and winter. Huanghai Sea Coastal Current flow southward all year round, but the East China Sea Coastal Current was northward in summer and southward in winter (Su, 1989). So, in winter, the stations located in a threadlike coastal region of the Huanghai Sea and East China Sea belonging to the Coastal Assemblage (Cw). In summer, there was a lack of stations in the inshore part of the Huanghai Sea, so the Coastal Assemblage (Cs) only included the stations of East China Sea inshore area. As a result of the abundant runoff from rivers, the area of Assemblage Cs extended further offshore and the abundance and biomass was high.

East China Sea Mixed-water Assemblage corresponded to water masses with great complexity (Feng et al., 1999), and its location varied with ebb and flow and displacement of water masses. Assemblage EMs corresponded to Huanghai Sea-East China Sea Mixed Water and East China Sea Surface Water, and Assemblage EMw corresponded to Huanghai Sea-East China Sea Mixed Water, East China Sea Surface Water and Kuroshio Modified Water. Relative wide-distributed tropical species, such as *Undinula vulgaris, Eucalanus subcrassus*, and *Temora turbinata*, etc., dominating this assemblage. Besides, neritic species *Clytia hemisphaerica* and *Evadne tergestina* etc. and typical indicator species of Kuroshio, such as *Undeuchaeta incisa* and *Haloptilus mucronatus*, occurred frequently. Zooplankton species composition reflected the mixed-water particularity of the community. Many papers in literature (Zuo et al., 2005; Lin et al., 1998; Chen et al., 1980; Cheng, 1965) suggested that there were Mixed Water Communities existing in the transition zone of the Huanghai Sea and the middle part of East China Sea. We had not detected those communities, and we think those communities were contained inside the East China Sea Mixed-water (EM) Assemblage in the present study.

According to Miao et al. (1998), the west boundary of Kuroshio located approximately between 100 and 200 m isobaths and its position varying with seasons. The boundary of Kuroshio was close to 100 m isobath in spring, to 200 m isobath in summer, while in autumn and winter, its positions are in between spring and summer. As the result of the Kuroshio seasonal swinging and station default in the offshore area of the East China Sea in summer, East China Sea Offshore Assemblage (EOw) was only detected in winter. The community with low abundance, low biomass and high biodiversity measure to the ecological characteristics of Kuroshio area (Hong et al., 2001). Typical Kuroshio species *Euchirella pulchra, Undeuchaeta plumosa, Xanthocalanus agilis, Scolecithricella ovata* etc. accounted for a great proportion. Meanwhile, kinds of deep-water species (e.g. *Arietellus setous*) was also recorded in some individual stations.

The choice of sampling gear used to collect zooplankton samples has a considerable influence on the sizes and types of zooplankters collected, and hence our impression of the overall zooplankton community composition (McKinnon et al., 2005). The present study has focused mainly on the zooplankton whose body length is greater than 500 μm, many species whose body length is less than 500 μm were not fully represented or neglected. Previous studies detailing zooplamkton community structure in China seas have mainly used nets of 505 μm mesh (Li et al., 2006; Zuo et al., 2005; Xu et al., 2004; Shih and Chiu, 1998). Many species body length being less than 500 μm, such as *Oithona, Corycaeus, Oncaea*, and *Paracalanus*, presented with a high abundance in the 505 μm mesh net samples, and this result was also detected in other area

(Li et al., 2006). For example, *Oithona plumifera* was an important dominant species especially in the East China Sea. *Oithona* has been described as the most ubiquitous and abundant copepod in the world's ocean (Gallienne and Robins, 2001), and played a crucial food sources for commercially species (Nip et al., 2003; Sánchez-Velasco, 1998). According to McKinnon et al. (2005), in Great Barrier Reef area, 37% of zooplankton biomass was in the 73–150 μm size fraction, 26% in the 150–350 μm fraction, and 38% was greater than 350 μm. So there was a general lack of good estimates of microzooplankton abundances and biomass in present study. In the future, the zooplankton studies in China seas should be conducted with nets being less than 200 μm or smaller mesh to avoid the underestimation of smaller organisms to understand the zooplankton community structure thoroughly.

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