Zooplankton Community Characteristics and Their Relationship with Environmental Factors in Yantai Sishili Bay: Postprint

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Abstract

From March 2009 to December 2010, a comprehensive survey comprising 20 consecutive cruises was conducted in the Yantai Sishili Bay to investigate the zooplankton community structure and its environmental factors, during which 8 major groups totaling 64 species (taxa) of zooplankton were recorded. The main zooplankton groups were copepods and planktonic larvae, with 22 species and 18 taxa identified, respectively, accounting for 34% and 28% of the total species (taxa); followed by hydromedusae, with 13 species identified, accounting for 20%; and 1 species each of chaetognaths and ctenophores. The dominant zooplankton species were Calanus sinicus (Y=0.183), Centropages abdominalis (Y=0.078), Sagitta crassa (Y=0.078), and Acartia hongi (Y=0.026). The ecological types of zooplankton were primarily temperate coastal species and cosmopolitan species. The seasonal variation in zooplankton community structure in the Sishili Bay was relatively pronounced, with significant differences among spring, summer, autumn, and winter communities ($P<0.05$), and relatively high similarity within the same season, reaching over 55%. The median value of zooplankton abundance reached its peak in May (546.3 individuals/m^3); the median values of species number and diversity index both peaked in August, at 18 species and 3.20, respectively; zooplankton biomass exhibited a bimodal variation pattern, reaching the first peak in May (median value 870.4 mg/m^3) and the second peak in October (median value 362.0 mg/m^3). High-value areas of zooplankton species number were mainly distributed in the northern waters of Yangma Island, while high-value areas of abundance were mainly distributed in coastal waters, especially in the Xin' an River estuary. Zooplankton species number and diversity index were significantly positively correlated with water temperature, chemical oxygen demand, and silicate ($P<0.01$), and significantly negatively correlated with salinity, dissolved oxygen, and inorganic nitrogen ($P<0.01$); water temperature and salinity were the main environmental factors

affecting zooplankton distribution, followed by silicate, chlorophyll a, and chemical oxygen demand, while active phosphate, dissolved oxygen, transparency, and inorganic nitrogen had relatively minor effects on zooplankton distribution.

Full Text

Preamble

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Zooplankton Community Structure in Sishili Bay and Its Relationship with Environmental Factors

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Abstract

Coastal waters are ecosystems of great human and ecological interest where complex processes occur. The interaction of physical (e.g., coastal currents, upwelling, tides, and advection), chemical (variable chemical properties including nutrient inputs), and ecological (e.g., biological production and its dynamics, and prey/predator interactions) processes induces high spatial and temporal variability in the water. This variability determines the abundance and structure of different biological communities present in coastal waters, in particular zooplankton, which are at the lower levels of the oceanic food chain. To understand coastal zooplankton community structure and explore its relationship with various environmental factors, a zooplankton survey was conducted in Sishili Bay. Fifteen sampling stations were chosen to study water temperature, salinity, transparency, DO, COD, inorganic nitrogen, phosphorus, silicate, and Chl *a* from March 2009 to December 2010. Sampling and testing methods followed those of the *Specifications for Oceanographic Surveys* and *Specifications for Marine Monitoring*. The relationships between zooplankton communities and various environmental factors were analyzed using Pearson correlation analysis and canonical correspondence analysis (CCA).

A total of 64 zooplankton species, belonging to 8 taxonomic groups, were recorded in Sishili Bay over the study period. Copepods and zooplankton larvae were the main taxonomic groups, accounting for 34% and 28% of total species, respectively, followed by Hydromedusae (20%). Only one species each of Ctenophora and Chaetognatha were identified. The dominant species, which exhibited significant seasonal variability ($P < 0.05$), were *Calanus sinicus* (dominance = 0.183), *Centropages abdominalis* (= 0.078), *Sagitta crassa* (= 0.078), and *Acartia hongi* (= 0.026). The ecological type of zooplankton in Sishili Bay was primarily temperate coastal and widespread species.

Four zooplankton community structure types were observed from the cluster dendrogram. Similar seasonal variations in the zooplankton community were observed in 2009 and 2010. The zooplankton community had high stability and reproducibility, with similarity in different months of the same season reaching more than 55%. The median total zooplankton abundance in Sishili Bay from 2009 to 2010 ranged from 40.5 individuals/m³ to 546.3 individuals/m³, with highest median abundances observed in May. The highest median values of zooplankton species number and diversity index were recorded in August. Zooplankton biomass exhibited a significant seasonal difference ($P < 0.05$). The zooplankton biomass revealed an obvious bimodal annual variation trend, reaching a major peak in May (870.4 mg/m³) and a minor peak in October (362.0 mg/m³). Stations with high zooplankton species number were mainly distributed in the northern area of Yangma Island, whereas the inshore area, especially the Xin' an River mouth, exhibited the highest zooplankton biomass.

In the present study, water temperature, COD, and silicates revealed a significant positive relationship with zooplankton species number and diversity index, whereas salinity, DO, and inorganic nitrogen exhibited a significant negative relationship. Canonical correspondence analysis (CCA) indicated that water temperature and salinity accounted for most of the zooplankton species variation, followed by silicates, Chl *a*, and COD, whereas phosphorus, DO, transparency, and inorganic nitrogen exhibited weak influence on zooplankton community distribution.

Keywords: Sishili Bay; zooplankton community; environmental factors; CCA

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1. Study Area and Methods

The survey area was Sishili Bay, Yantai. Sampling stations were arranged as shown in Figure 1

. Monthly surveys of water quality and zooplankton were conducted from March 2009 to December 2010 at 15 sampling stations, comprising 24 cruises over two years. Zooplankton collection methods and sample processing followed the *Specifications for Oceanographic Survey* [12]. Zooplankton nets were towed vertically from bottom to surface, fixed with formaldehyde solution, and classified in the laboratory. Environmental parameters including water temperature (WT), salinity, transparency, dissolved oxygen (DO), chemical oxygen demand (COD), inorganic nitrogen (DIN), inorganic phosphorus (DIP), silicate (DISi), and Chl *a* were measured synchronously at each monitoring station. All opera-

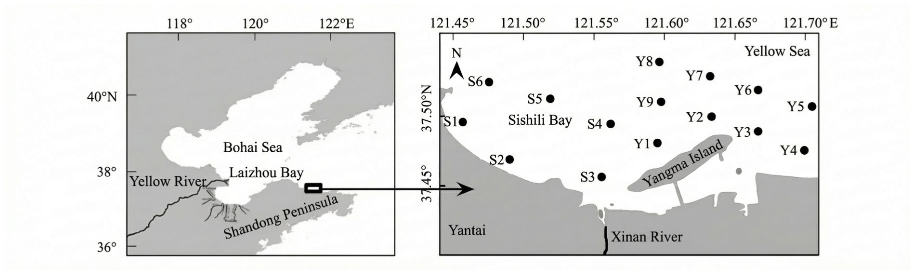

Figure 1: Figure 1

tions followed the *Specifications for Marine Monitoring* [13], excluding *Noctiluca scintillans*.

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2. Data Analysis

Zooplankton abundance was expressed as individuals per cubic meter. Dominant species were identified using the dominance index ($Y > 0.02$). Species diversity was calculated using the Shannon-Wiener index:

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

where ni is the number of individuals of species i, fi is the frequency of occurrence of species i across stations, Pi is the proportion of individuals of species i relative to total individuals in the sample, N is the total number of individuals of all species, and S is the total number of species in the sample.

Multivariate statistical methods included cluster analysis and canonical correspondence analysis (CCA), both ordination methods based on species and environmental datasets. We selected water temperature, salinity, transparency, COD, DIN, DIP, DISi, and Chl a as eight indicators to analyze their influence on zooplankton community structure. Species and environmental data were square-root transformed. STATISTICA 6.0 was used for all statistical analyses, PRIMER 6.0 for community structure cluster analysis, and CANOCO 4.5 for CCA. CCA has been widely applied in marine ecological community structure analysis. Common species in the study area were selected, excluding those with occurrence frequencies less than 20%.

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3. Results

3.1 Species Composition

A total of 64 zooplankton species were identified, predominantly copepods and zooplankton larvae (34% and 28%, respectively), followed by hydromedusae (20%). Appendicularians, decapods, chaetognaths, cladocerans, and ctenophores accounted for 6%, 5%, 3%, 3%, and 2%, respectively. Only one species each of chaetognaths and ctenophores was recorded. The dominant species were *Calanus sinicus* (= 0.183), *Centropages abdominalis* (= 0.078), *Sagitta crassa* (= 0.078), and *Acartia hongi* (= 0.026). The ecological types were primarily temperate coastal and widespread species, consistent with the ecological characteristics of zooplankton species composition in the Yellow Sea

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3.2 Seasonal Variation

Zooplankton species number showed obvious seasonal fluctuation with a unimodal pattern: low from January to March, increasing from April, peaking in August, then gradually declining from September. The median species number in December was only 13. Zooplankton abundance showed dramatic seasonal change with a bimodal pattern: low from January to March, rapidly increasing from April as water temperature rose, peaking in May (546.3 individuals/m^3), declining from June to July, remaining at low levels from August to December (median 37.1 individuals/m^3 in December). Zooplankton biomass showed a significant bimodal pattern: low from January to March, rapidly increasing from April, reaching the annual peak in May (870.4 mg/m^3), declining from June to July (362.0 mg/m^3 in June), reaching a second peak in October (216.1 mg/m^3), then declining from November to December

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3.3 Horizontal Distribution

Zooplankton species number increased from nearshore to offshore, with lower values and smaller fluctuations nearshore. Higher species numbers occurred north of Yangma Island with greater monthly fluctuations. Zooplankton abundance distribution showed the opposite pattern, with highest abundances in nearshore areas, particularly at the Xin' an River mouth, showing the most dramatic monthly fluctuations. Diversity index high-value areas were mainly distributed around Yangma Island, while values were relatively low and fluctuated more dramatically in the Xin' an River mouth and northern offshore areas [FIGURE:3].

3.4 Community Cluster Analysis

Cluster analysis of zooplankton community composition across 20 months in Sishili Bay revealed four distinct community types: spring (March-May), sum-

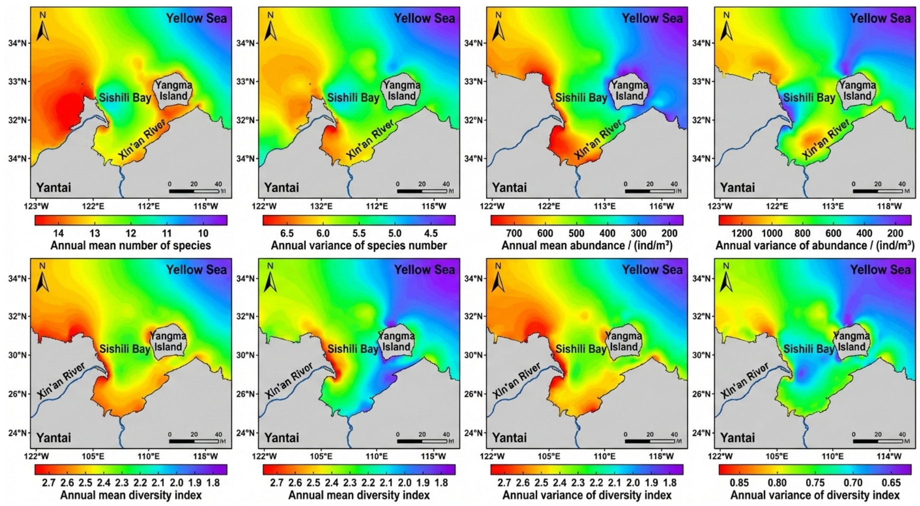

Figure 2: Figure 2

mer (June-July), autumn (August-October), and winter (November-February). The zooplankton community structure showed very obvious seasonal characteristics that did not vary between monitoring years, demonstrating good stability and reproducibility [FIGURE:4].

3.5 Relationship Between Community Structure and Environmental Factors

Pearson correlations between zooplankton species number, abundance, biomass, diversity index and nine environmental factors showed: species number and diversity index were significantly positively correlated with water temperature, COD, and silicate, and significantly negatively correlated with salinity and inorganic nitrogen ($P < 0.01$); biomass was significantly positively correlated with silicate ($P < 0.05$) and significantly negatively correlated with inorganic nitrogen ($P < 0.01$); abundance showed no significant correlation with any selected parameters .

CCA indicated that water temperature and salinity were the main environmental factors affecting zooplankton distribution, followed by silicate and COD. Different zooplankton species had different environmental requirements. Zooplankton larvae such as fish eggs, crab zoea, and decapod larvae were mainly distributed in low-salinity areas with higher water temperatures, while *Centropages abdominalis*, *Themisto gracilipes*, and *Eurytemora pacifica* were more common in low-temperature, high-salinity areas. *Labidocera euchaeta*, copepod larvae, and *Oikopleura dioica* showed strong positive correlations with silicate [FIGURE:5].

4. Discussion

4.1 Species Composition

Copepods were the dominant group in Sishili Bay, consistent with reports that copepods are the main zooplankton group in the Bohai Sea [14] and the dominant status reported for the East China Sea [15]. The dominant species (*Calanus sinicus*, *Centropages abdominalis*, *Sagitta crassa*, *Acartia hongi*) are all common species in the Yellow Sea and Bohai Sea. Previous studies found *Acartia hongi* and *Centropages abdominalis* were spring dominants in the Bohai Sea [14], while *Sagitta crassa* was a dominant species in the North Yellow Sea [16-17]. Our findings align with these reports, indicating no significant change in dominant species.

4.2 Seasonal Variation

Zooplankton community structure showed obvious seasonal characteristics, clearly divided into four seasonal types. From March to May, rising surface water temperature and abundant nutrients led to rapid diatom proliferation, and zooplankton began mass reproduction with adequate food and suitable temperature, peaking in May. With increasing grazing pressure, zooplankton biomass gradually declined. With secondary phytoplankton blooms, zooplankton biomass reached its second annual peak. As temperatures gradually decreased from November to December, both zooplankton species number and biomass declined to lower levels. Studies in the Adriatic Sea over 30 years [18] confirm that zooplankton seasonal distribution characteristics have good stability, which our results also verify.

4.3 Environmental Factors

Zooplankton communities in coastal waters are affected by multiple environmental factors (physical, chemical, and biological) [6]. Different zooplankton have different tolerances to temperature and salinity changes, and their species composition and quantity distribution vary accordingly [2]. This study found high zooplankton abundance in nearshore high-temperature, low-salinity waters. Temperature directly affects zooplankton body temperature, determining metabolic intensity and influencing growth and reproduction [22-24]. Previous studies reported that nauplii numbers increase with rising water temperature [25], and indoor experiments showed optimal reproduction at 30°C [26].

Salinity is another important factor affecting zooplankton community structure [19-21], showing negative correlation with most species distribution. CCA revealed significantly higher zooplankton abundance in the low-salinity Xin’ an River mouth area. Studies on the Pearl River estuary [27-28], English Channel [29], and Yangtze River estuary [30-31] all confirm salinity’ s important role in zooplankton distribution.

Besides temperature and salinity, Chl *a* and COD also significantly affect zooplankton distribution. As essential nutrients for plankton growth, their relationship with zooplankton is not simply linear but mediated through phytoplankton. The weak correlation between phosphate and zooplankton may relate to high nutrient levels, imbalanced N/P ratios, and strong human disturbance in Sishili Bay' s nearshore waters [11, 32]. The selected environmental factors explained only part of zooplankton species variation, indicating that besides environmental factors, fish predation pressure, phytoplankton community structure, and aquaculture activities also influence zooplankton distribution. Further investigation of zooplankton community structure mechanisms requires large-scale spatiotemporal surveys and consideration of both internal dynamics and external environmental influences.

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