Postprint: Spatiotemporal Variation Characteristics of Zooplankton Communities in the Adjacent Waters of the Yellow River Estuary

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Abstract

Using field survey data from four quarters between December 2012 and September 2013, this study investigated the spatiotemporal distribution characteristics of zooplankton communities in the waters adjacent to the Yellow River estuary. The results revealed that a total of 70 zooplankton species were identified, including 19 categories of planktonic larvae. Dominant species mainly comprised Noctiluca scintillans, Paracalanus parvus, Acartia bifilosa, Oithona similis, Paracalanus crassirostris, Corycaeus affinis, Sagitta crassa, Bivalvia larvae, and Polychaeta larvae. Zooplankton abundance was highest in summer (60620 individuals/m<3), followed by spring (31228 individuals/m3) and autumn (21540 individuals/m3), and lowest in winter (7594 individuals/m3). The spatial distribution of abundance exhibited seasonal variations: in spring, abundance decreased from nearshore to offshore waters; in summer, two high-abundance zones formed in the estuary-adjacent waters and the eastern estuary waters; in autumn and winter, high-abundance areas were both located in the eastern estuary waters. Zooplankton biodiversity indices showed an increasing trend from the estuary to offshore waters, with low values in the vicinity of the Yellow River mouth. Correlation analysis indicated that zooplankton abundance was significantly positively correlated with seawater temperature ($r=0.212$, $P< 0.05$), suggesting that temperature is the primary factor influencing zooplankton abundance variation in this region.

Full Text

Preamble

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Spatial and seasonal variability of the zooplankton community in the Yellow River Estuary' s adjacent sea

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Abstract

The unusual dynamic conditions in estuaries cause their zooplankton distribution, as well as the zooplankton distribution in the adjacent sea, to be spatially and temporally heterogeneous. To investigate this heterogeneity in the adjacent sea of the Yellow River Estuary, zooplankton samples were collected there in December 2012, April 2013, June 2013, and September 2013. The samples were collected using a plankton net with mesh size 0.160 mm, while during the four cruises, environmental parameters such as seawater temperature, salinity, and chlorophyll a concentration were determined. Spearman rank correlations were used to analyze the relationship between zooplankton abundance and various environmental factors.

Overall, 70 zooplankton species were identified, including 19 pelagic larvae. The copepods were the most abundant group, representing 30% of the total species, followed by hydromedusae. For the study region, the most dominant organisms were *Noctiluca scintillans*, *Paracalanus parvus*, *Acartia bifilosa*, *Oithona similis*, *Paracalanus crassirostris*, *Corycaeus affinis*, *Sagitta crassa*, Bivalvia larvae, and Polychaeta larvae. Among these, *P. parvus*, *A. bifilosa*, and *O. similis* dominated the zooplankton communities for three of the measured seasons. Furthermore, the composition of dominant species varied with seasons, with the seasonal turnover rate of dominant zooplankton species being high (67%–88%).

The abundance of *P. parvus* averaged 93,200 ind/m^3 in summer, 37,040 ind/m^3 in autumn, 38,910 ind/m^3 in winter, and 16,500 ind/m^3 in spring. For the Yellow River mouth, *P. parvus* reached the greatest abundance in summer, while for the eastern sea area, this occurred in autumn and winter. Furthermore, the abundance of *A. bifilosa* averaged 40,218 ind/m^3 in summer, 17,815 ind/m^3 in spring, and 21,270 ind/m^3 in winter. In spring, the abundance of *A. bifilosa* showed a decreasing trend from the Yellow River mouth to the outer sea area. For the Yellow River mouth, this species reached its highest abundance in summer, whereas for the eastern sea area, this occurred in winter.

In addition, the abundance of *O. similis* averaged 4,245 ind/m^3 in summer, 2,776 ind/m^3 in spring, 1,154 ind/m^3 in winter, and 88 ind/m^3 in autumn. In spring, *O. similis* reached the highest abundance on both sides of the Yellow

River mouth, while for the Yellow River mouth this occurred in summer and for the eastern sea area in winter. The abundance of *N. scintillans* averaged 28,194 ind/m^3 in spring and 13,679 ind/m^3 in autumn. In spring, *N. scintillans* reached the highest abundance in the southern area of the Yellow River mouth, whereas for the eastern sea area, this occurred in autumn.

Overall zooplankton abundance averaged 60,620 ind/m^3 in summer, 31,228 ind/m^3 in spring, 21,540 ind/m^3 in autumn, and 7,594 ind/m^3 in winter, while its spatial distribution varied among the four seasons. In spring, zooplankton abundance showed a decreasing trend from the Yellow River mouth to the outer sea area. In summer, zooplankton density was higher in the Yellow River mouth and the eastern sea area. The higher zooplankton abundance occurred in the eastern sea area in autumn and winter. The zooplankton community' s diversity index (H') showed an increasing trend from the Yellow River mouth to the outer sea area. Finally, the zooplankton abundance had a clear positive correlation with seawater temperature ($r = 0.212$, $P < 0.05$), suggesting that for the Yellow River Estuary, seawater temperature was one of the main factors determining zooplankton abundance.

Keywords: zooplankton; Yellow River Estuary; spatial and temporal distribution; dominant species

1. Materials and Methods

1.1 Sample Collection and Analysis

Four seasonal surveys were conducted in the Yellow River Estuary adjacent sea area in December 2012, April 2013, June 2013, and September 2013. A total of 29 sampling stations were set up from the river mouth to the outer sea area. Zooplankton samples were collected using a conical plankton net with a mesh size of 0.160 mm, mouth diameter of 31.6 cm, and length of 140 cm. Vertical tows were performed from near-bottom to the surface at each station. Samples were immediately fixed with 5% formalin solution for subsequent species identification and counting. Environmental parameters including water temperature, salinity, and depth were measured in situ using a YSI-600 multi-parameter water quality analyzer. Chlorophyll a concentration was determined spectrophotometrically after acetone extraction.

1.2 Data Analysis

Dominant species were determined using the dominance index (Y), calculated as $Y = (n /N) \times f$, where n is the number of individuals of species i, N is the total number of individuals in the sample, and f is the frequency of occurrence of species i across stations. Species with $Y > 0.02$ were considered dominant. The Shannon-Weaver diversity index (H') and Pielou' s evenness index (J') were calculated using standard formulas. Spatial and seasonal variations in zooplankton abundance and diversity were visualized using Surfer 12.0 software. Spearman rank correlation analysis between zooplankton abundance and environmental factors was performed using SPSS 19.0.

2. Results

2.1 Species Composition and Dominant Species

A total of 70 zooplankton species were identified across the four seasonal surveys, including 15 species of copepods, 7 species of chaetognaths, 5 species of jellyfish, and 19 species of pelagic larvae. Copepods accounted for 21.4% of the total species richness and represented the most diverse group. The dominant species composition showed significant seasonal variation, with a high turnover rate of 67%–88% between seasons.

The dominant species in the Yellow River Estuary adjacent sea area included *Noctiluca scintillans*, *Paracalanus parvus*, *Acartia bifilosa*, *Oithona similis*, *Paracalanus crassirostris*, *Corycaeus affinis*, *Sagitta crassa*, Bivalvia larvae, and Polychaeta larvae. Among these, *P. parvus*, *A. bifilosa*, and *O. similis* were dominant across three seasons. *P. parvus* was dominant in summer, autumn, and winter; *A. bifilosa* was dominant in spring, summer, and winter; and *O. similis* was dominant in spring, summer, and winter. The seasonal succession of dominant species was pronounced, with only *P. parvus*, *A. bifilosa*, and *O. similis* being co-dominant across seasons.

shows the seasonal variability of dominant zooplankton species and their dominance indices. The spatial distribution of dominant species abundance varied seasonally, with distinct patterns for each species. In spring, *P. parvus* showed high abundance values, while in summer and winter it was a dominant species. The abundance distribution patterns revealed two high-abundance zones located in the river mouth area and the eastern sea area.

2.2 Seasonal and Spatial Distribution of Abundance

The seasonal distribution of zooplankton abundance showed clear patterns [Figure 4: see original paper]. Spring abundance averaged 31,228 ind/m^3, with high-abundance zones located on both sides of the river mouth and showing a decreasing trend from the river mouth to the outer sea. Summer exhibited the highest mean abundance at 60,620 ind/m^3, with two distinct high-abundance zones in the river mouth area and eastern sea area. The main dominant species were *A. bifilosa* and *P. crassirostris*. Autumn abundance averaged 21,540 ind/m^3, with the high-abundance zone primarily in the eastern sea area, dominated by *N. scintillans* and Bivalvia larvae. Winter showed the lowest abundance at 7,594 ind/m^3, with the high-abundance zone in the northeastern sea area, dominated by *P. parvus* and *A. bifilosa*.

Spatially, zooplankton abundance demonstrated an increasing trend from the river mouth to the outer sea area in spring, while summer and autumn showed more complex patterns with multiple high-abundance zones. The river mouth entrance area consistently showed lower abundance values due to lower species richness and the dominance of few species such as *N. scintillans* and *A. bifilosa*.

2.3 Diversity and Evenness Distribution

The Shannon-Weaver diversity index (H') showed significant spatial and seasonal variation [Figure 5: see original paper]. Spring diversity averaged 1.60, with an increasing trend from the river mouth to the outer sea area. Summer diversity averaged 1.58, with high values in the eastern sea area. Autumn diversity was highest, averaging 1.97, while winter diversity averaged 2.32, showing the highest values in the outer sea area. The evenness index showed similar seasonal patterns, being lowest in summer and highest in winter .

3. Discussion

3.1 Seasonal Variation of Zooplankton Community

Our four-season investigation revealed significant seasonal variation in zooplankton community structure in the Yellow River Estuary adjacent sea area. The seasonal succession pattern, characterized by high turnover rates of dominant species (67%–88%), is consistent with findings from other temperate estuaries [4-5]. The dominance of copepods, particularly *Paracalanus parvus*, *Acartia bifilosa*, and *Oithona similis*, across multiple seasons aligns with previous studies in this region [8, 10-11].

The high abundance of zooplankton in summer, followed by spring and autumn, with lowest values in winter, matches the general pattern observed in other Chinese coastal waters [6, 15]. This seasonal pattern is primarily driven by the reproductive cycles of dominant species and environmental factors. For instance, the peak abundance of *P. parvus* in summer can be attributed to its high reproductive rate during this period, as documented in Jiaozhou Bay studies [16, 18]. Similarly, the high abundance of *N. scintillans* in spring and summer is associated with optimal temperature conditions (16–27°C) for its growth and reproduction [19].

3.2 Spatial Distribution Patterns and Environmental Influences

The spatial distribution of zooplankton abundance and diversity showed distinct gradients from the river mouth to the outer sea area. The decreasing abundance from river mouth to outer sea in spring, contrasting with the increasing diversity trend, reflects the complex interplay between river discharge and marine environmental conditions. The river mouth area, influenced by high turbidity and variable salinity, supports fewer species but can harbor high abundances of euryhaline species like *N. scintillans* and *A. bifilosa*.

The positive correlation between zooplankton abundance and seawater temperature ($r = 0.212$, $P < 0.05$) indicates temperature as a key controlling factor, consistent with findings from other estuarine systems [23-24]. However, the relationship is moderate, suggesting that other factors such as food availability (chlorophyll a), salinity, and river discharge also play important roles. The high-abundance zones in the eastern sea area during autumn and winter are likely associated with the dispersal of nutrient-rich river plumes and subsequent phytoplankton blooms that support zooplankton growth [25].

The spatial heterogeneity observed in this study underscores the importance of considering both seasonal and spatial scales when assessing zooplankton community dynamics in estuarine-coastal systems. The Yellow River Estuary, with its high sediment load and variable discharge regime, creates a dynamic environment where zooplankton communities respond rapidly to both natural and anthropogenic changes.

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Note: Figure translations are in progress. See original paper for figures.