Species diversity and distribution for zooplankton in the inter-tidal wetlands of the Pearl River estuary, China

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Abstract

Zooplankton is the important component of aquatic ecosystems and has become an important aspect of research in estuarine areas. However, zooplankton species composition and distribution in the inter-tidal wetlands are rarely studied. We investigated the zooplankton communities in the inter-tidal wetlands of the Pearl River estuary during March and April 2009 to study the species diversity and distribution of zooplankton. A total of 132 species of zooplankton were identified among the 39 sampling stations in the inter-tidal wetlands. The results of the research show that zooplankton abundance and biomass fluctuated widely and showed distinct heterogeneity among the different sampling sites. Canonical correspondence analysis (CCA) revealed that the significant spatial variability in the distribution of zooplankton species, abundance and biomass can be significantly affected by changes in the water environment. Distribution of the dominant species varied with the salinity of the sea water, and their amounts correlated negatively with nutrients. This study is important if we are to be able to identify the influence of the environmental characteristics of water on the distribution of zooplankton in the inter-tidal wetlands of estuaries, and it can provide a basis for the evaluation of the quality of inter-tidal wetlands based on zooplankton.

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1. Introduction

Generally, tidal wetlands are transitional areas between land and ocean, and the inter-tidal wetlands in this paper are only riparian wetlands, which are buffer zones between tidal river and land. In the estuary there are highly productive ecosystems, and estuaries are regarded as a source of aquatic production. Primary production and nutrients were once thought to be directly transported from the terrestrial to the aquatic ecosystem by the tides, but now the role of nektonic animals is emphasized [1]. As a nektonic animal, zooplankton is the important component of aquatic ecosystems, and it has become an important aspect of research in estuarine areas. The distribution of zooplankton is always affected by physical and chemical factors, and this has been confirmed in studies of various bodies of water, including lakes, reservoirs and seas [2-4]. However, few papers have reported on zooplankton species composition and distribution in inter-tidal wetlands [5].

The Pearl River and its tributaries cover about 58,000 km² and involve many inter-tidal wetlands that are invaluable resources of great biotic diversity, including bird, fish and plankton, due to the large enough size of the river and tributaries to accommodate diverse habitat types [6]. In the PRE, the inter-tidal wetlands service the surrounding communities for agriculture and aquaculture. In particular, many constructed inter-tidal wetlands were reclaimed between 1800 and 2008, and the reclaimed land area is extending seaward at the rate of 60m to 150m per year. These wetlands are clearly dominated by tidal processes and are flooded twice a day with the mean amplitude 1.4m, according to field observation. These channels ensure that the freshwater naturally flows into farmland for irrigation during the high tide and provide drainage during low tide. Thus, these wetlands have historically received wastewater discharged from a variety of anthropogenic sources. Many zooplankton species can respond to changes in the trophic level of water, which offers the possibility for the use of zooplankton in the bio-monitoring of water quality [4]. Therefore, an investigation that adequately identifies the diversity index and distribution of zooplankton in these wetlands is noteworthy [7].

This study aimed to investigate the species composition, abundance, and diversity occurring in the inter-tidal wetlands of the Pearl River estuary, to detect spatial distribution patterns in wetlands of different salinities.

2. Materials and methods

2.1. Study area

The study area is located in the southern plain of the Pearl River estuary, south of Guangdong Province in China. The inter-tidal wetlands studied in this research are located at three types of buffer zones of different types and scales of rivers systems, including river, stream and constructed channels. In this study, 39 stations at different inter-tidal wetlands locations were selected as sampling sites for water and zooplankton. A map of the study area showing sampling locations is shown in Figure 1.
2.2. Sampling

Zooplankton samples were collected during March and April 2009 from various types of inter-tidal wetlands. Triplicate-integrated zooplankton samples from each site were collected using a 64µm conical mesh net with a mouth diameter of 0.3m, by single vertical hauls from 1.5 to 2m below the surface. All samples were back-washed into 60ml polyethylene bottles and preserved immediately in 5% formalin [8]. The filtered water volume was estimated by a rope length multiplying mouth size. In-situ measurements of water salinity from each sampling site were made with potable water quality analyzers, HACH SensION 5 and HACH SensION 2, for pH and temperature.

In the laboratory, zooplankton were identified to species level when possible, and counted. From each sample, a 0.1-mL quantitative subsample was examined in a Fuchs-Rosenthal counting chamber under magnification (400×). Zooplankton wet weight was measured using an electronic balance after removing large detrital particles under a dissecting microscope and after eliminating excess and interstitial water by the vacuum extraction technique [9]. Zooplankton abundance and wet weight biomass are expressed as ind/m³ and mg/m³.

2.3. Data analysis

The dominance index was calculated as follows:
where \( n_i \) is the individual number of \( i \) species, \( N \) is the total individual number of sampling sites, \( f_i \) is the frequency of the presence of \( i \) species in all of sampling sites. \( i \) is considered the dominant species if \( Y \geq 0.02 \).

Diversity index \( (H') \) was calculated using the Shannon-Wiener diversity index:

\[
H' = -\sum_{i=1}^{S} p_i \log_2 p_i
\]

where \( S \) is the total number of species and \( p_i \) is the relative abundance of the \( i \) species, calculated as the proportion of individuals of a given species to the total number of individuals in the community.

Pielou evenness index was calculated as:

\[
J = \frac{H'}{\log_2 S}
\]

where \( H' \) is the Shannon-Wiener diversity index and \( S \) is the total number of species.

A one-way ANOVA was applied to test if differences observed among different stations were statistically significant. Pearson correlation was used to analyze the correlation between environmental variables and the abundance of zooplankton. CCA was applied to explore the distribution of the zooplankton communities in relation to the salinity and sampling sites. Species whose occurrence frequency was less than 10% were arbitrarily excluded from the CCA analysis. All continuous environmental variables were log- \((1+x)\) transformed. The statistical significance of the CCA was determined using Monte Carlo permutations, and the level of significance was set at \( P<0.05 \) [10].

3. Results and discussion

3.1. Salinity

Based on previous research, the salinity gradient is obvious in the estuarine wetlands and has been found to be one of the main factors influencing the distribution of zooplankton [11]. Understanding the relationship between zooplankton distribution and salinity is essential, since it is always closely correlated with the ecological functions of aquatic food webs. Fig. 2 shows that salinities were significantly different among the different sampling sites of the inter-tidal wetlands. Higher salinity values (3.1-5.9) were consistently observed in the southern stations and lower values (0.1-1.1) in the northern stations. Based on the variation of salinity among the sampling stations, we found that salinity was significantly related to the distance between the sampling station and the sea (\( P<0.05 \)). The positive correlation between abundance and salinity suggests that the abundance of zooplankton is elevated toward the higher-salinity parts of the estuary (\( P<0.05 \)), which is consistent with the findings of Lin et al. [6] that there are more species in the open water area than in the onshore area. Zhou et al. [1] also found that zooplankton densities in the inter-tidal creeks of the Yangtze River estuary showed a strong spatial variation with relatively higher values in the more saline creeks than in the freshwater creeks.
3.2. Zooplankton community composition

The zooplankton in the wetlands of the PRE has a high species biodiversity due to the complexity of the environment. A total of 132 species of zooplankton were identified during the survey. These belonged to 9 communities: protoza, rotifera, medusa, piperopoda, cladocera, ostracoda, copepoda, amphipoda and plankton larval. The main zooplankton were rotifera (21 species), cladocera (30 species) and copepoda (53 species). The predominant species (Y ≥ 0.02) in these wetlands were Paracalanus parvus, Acartiella sinensis, Paravyclops fimbriatus, Sinocalanus dorii and Schmackeria poplesia.

The species number, abundance and wet weight biomass are shown in Figure 3-5. The mesh size of nets, sampling methods and regions and counting methods may influence the number of taxa and the abundance of zooplankton reported in different studies [12, 13]. The zooplankton abundances fluctuate obviously and indicate distinct heterogeneity among different inter-tidal wetlands in the PRE. Fig. 4 shows that zooplankton abundance is higher and the distribution is patchier in our study, which is consistent with the results of previous studies carried out in the Pearl River estuary [14]. It should be noted that there are differences in the zooplankton community observed in coastal wetlands as compared with that in inland wetlands.

The abundance of zooplankton in each station is mainly attributed to the individual number of dominant species (Fig. 4 and 6). The peak values of zooplankton species number, abundance and wet weight biomass were all found in station 13 (3008 ind, 10026.67 ind/m³ and 766.67 mg/m³) (Fig. 4), where freshwater and seawater are mixed relatively well and with the highest salinity, 4 3‰ (Fig. 2).
Fig. 3. Species number in the different sampling sites of the inter-tidal wetlands.

Fig. 4. Zooplankton abundance in the different sampling sites of the inter-tidal wetlands.
Fig. 5. Wet weight biomass of zooplankton in the different sampling sites of the inter-tidal wetlands.

Fig. 6. Dominant species number in the different sampling sites of the inter-tidal wetlands.
3.3. Zooplankton diversity

The diversity and Pielou evenness index are shown in Figures 7 and 8. The results of the research show an average diversity index and evenness of 3.18 and 0.78, respectively. Diversity indices varied from 2.11 to 4.06, and the evenness index from 0.54 to 0.96 (Figs. 7 and 8). The Shannon-Wiener diversity index values were the highest for station 3 (4.06) and lowest for station 32 (2.11). The Pielou evenness index values were the highest for station 31 (0.96) and the lowest for station 18 (0.54).

![Fig. 7. Shannon-Wiener diversity index values in the different sampling sites of the inter-tidal wetlands.](image)

Fig. 7. Shannon-Wiener diversity index values in the different sampling sites of the inter-tidal wetlands.

Overall, higher values were found near sea waters and lower values in the inland waters. The distribution of the zooplankton species was uneven in different regions because of some dominant species differences and environmental changes. The zooplankton diversity was found to be higher in these wetlands, and zooplankton diversity may be ascribed to the mixture of fresh water and marine water that is often influenced by tidal and coastal currents. Large variations in tidal water characteristics and flooding frequency (twice a day) in this region were observed. The average diversity index (3.18) obtained from our study was less than the values reported by Li et al.[15], who researched the biodiversity of zooplankton in the PRE in 2006 and found that the biodiversity index was about 3.44 in spring. One of the most important reasons for this is that most of the sampling stations we tested are closer to inland waters than those used by Li et al. [16].
3.4. Distribution of zooplankton

In our previous research, Pearson correlation analysis also indicated that zooplankton wet weight biomass was significantly correlated to its abundance \((r=0.756, P<0.05)\), suggesting that both biomass and abundance can represent the same main changes in the zooplankton community. In our study, abundance was used to depict the variations in zooplankton communities in these wetlands. Pearson correlation analysis indicated that the spatial distribution of species abundance was positively correlated to the salinity \((r=0.766, P<0.05)\).

The bi-plot of the first two CCA axes is found in Figure 9. For clarity, species whose occurrence frequency was more than 10% are displayed in the plot. The first two axes explain 73.9% of the variance in the species-environment relationships. Among the variables included in the CCA, salinity (SAL) and water pH were significant \((P<0.05)\), and the Eigen values of axes 1 was 0.129, which accounts for 46.1% of the total variance. The species-environment correlations were 0.849 for axis 1 and 0.871 for axis 2.
Fig. 9. Canonical correspondence ordination of the zooplankton samples collected in the inter-tidal wetlands and associated environmental parameters. Bi-plots of the species (occurrence frequency >10%) and the environmental parameters.

Fig. 9 shows that zooplankton species distribution was found to be strongly related to water salinity and pH. From the first two axes, the species distribution is mainly ordered according to the gradient of salinity and pH.

4. Conclusion

The data presented in our study provides basic information about the zooplankton community in the surface waters of the inter-tidal wetlands in the PRE. The significant spatial variability in the distribution of the zooplankton community should be attributed to the fact that the zooplankton samples collected from the wetlands were obtained from various water systems, including not only natural and constructed river systems but also from bodies of water of different sizes, and the samples were found distributed in various wetland waters with different salinities. The results of this research indicate that obvious spatial variability in zooplankton abundance and biomass are found in the inter-tidal wetlands of the PRE. Moreover, zooplankton distribution can be clearly affected by the salinity and horizontal gradient in the distance to the estuarine edge. Our study focused on the distribution of zooplankton in a wide range of the inter-tidal wetlands in the Pearl River estuary, and the survey in this study focused on only one time span. It should be noted that the seasonal variations in environmental characteristics would lead to a zooplankton community’s undergoing dramatic and often irregular fluctuations. It is therefore necessary to do long-term and continuous monitoring and research on the zooplankton community in the wetlands of the PRE.
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References


