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Effects of Macrozoobenthos and Zooplankton on the Occurrence of Yangtze Finless Porpoise Via the Bottom-up Force at a Confluence of Rivers

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ABSTRACT

Recent study on the confluence of rivers showed that the fish community has significant effects on the occurrence of Yangtze finless porpoise (YFP). Macrozoobenthos and zooplankton, as food sources for fish, may also have significant effects on the occurrence of YFP via the bottom-up force. To understand the community structures of macrozoobenthos and zooplankton, and further test our hypothesis, field investigations were conducted on a monthly basis between September 2013 and August 2014 at the confluence of the Yangtze and Wanhe rivers and adjacent waters. The results showed that (1) A total of 31 species of macrozoobenthos were identified, and the density and biomass were 107.2 ind./m^2 and 6.15 g/m^2, respectively. More species were detected at the confluence (17 species) than at the adjacent waters because of the occurrence of a large number of Mollusca specimens. However, species number and density among all the sites had no significant differences. (2) Total species number of zooplankton was 64, with a density and biomass of 20.7 ind./m^2 and 0.043 g/m^2, respectively. Species number was the highest at the confluence (53 species), and the density and biomass were obviously higher at the confluence than in the other sites in May-July. However, there were no significant differences in species number, density and biomass among all the sites. (3) There were no significant correlations between the species number, density and biomass of macrozoobenthos and the five fish parameters that significantly affect the occurrence of YFP; however, significantly negative correlations were found between the species number, density and biomass of zooplankton and fish species richness. After comprehensive analyses, we concluded that both macrozoobenthos and zooplankton could not significantly affect the occurrence of YFP via the bottom-up force at the confluence.

INTRODUCTION

The Yangtze finless porpoise (YFP; *Neophocaena asiaeorientalis asiaeorientalis*) is a subspecies of the narrow-ridged finless porpoise, and it is only distributed in the middle and lower reaches of the Yangtze River and adjacent Poyang and Dongting lakes (Wang 2009). Because of serious human disturbances, the natural habitat of YFP has been destroyed dramatically (Zhao et al. 2008, Wang 2009, Mei et al. 2012). The population size of YFP in the whole basin has decreased from 1800 individuals in 2006 to 1040 individuals in 2012 (Mei et al. 2014), and it may become extinct in the next 10 years (Mei et al. 2012). Food availability is the most important factor that influences the survival of YFP (Wang et al. 2014, Zhang et al. 2015). Under natural conditions, YFP usually prefers the confluence of the Yangtze River and its tributaries or the surrounding area of sand bars as habitats, and the main reason was often considered to be rich fish resources (Zhang et al. 1993). However, our recent study showed that the occurrence of YFP at a confluence was not affected by total individual number and yield of fish, and was significantly positive correlations with fish species richness, individual number and yield of edible fish, especially the upper edible fish, were observed (Zhang et al. 2015). This is mainly because of YFP's preference for fish; species with a hard spine on the body surface or a body height of more than 6 cm are not the main prey (Zhang et al. 2015).

Bottom-up and top-down forces play important roles in freshwater ecosystems, and the former mainly emphasizes on the control and regulation of high trophic level organisms by low trophic level organisms (Mcqueen et al. 1986). At a confluence, macrozoobenthos and zooplankton are not only important components of the river ecosystem but also the food source for fish (Wetzel 2001). Therefore, they may also significantly affect the occurrence of YFP via the bottom-up force.

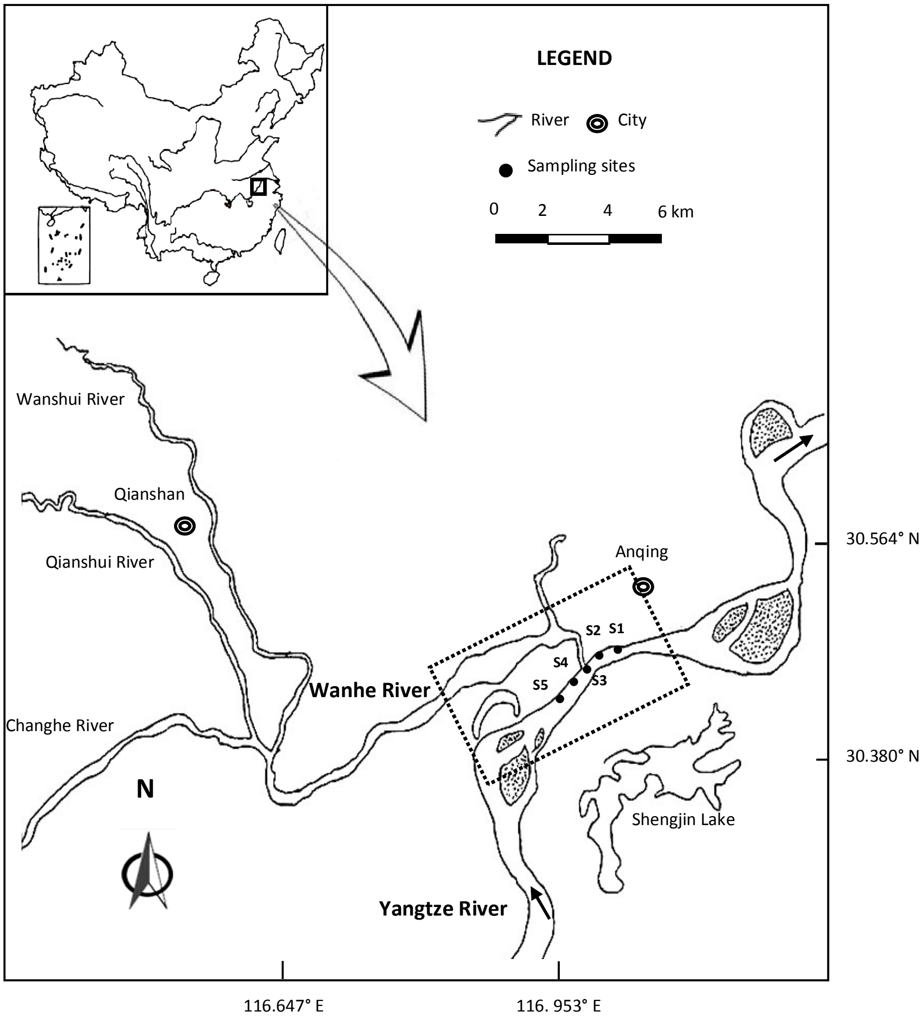

Fig. 1: Location of the sampling points at the confluence of the Wanhe and Yangtze rivers and adjacent waters.

The confluence of Yangtze and Wanhe rivers has long been the main habitat for YFP. In this study, macrozoobenthos and zooplankton at the confluence and its adjacent waters were investigated. YFP and fish data were also used for the analysis. We had the following questions: (1) What are the characteristics of macrozoobenthos and zooplankton communities at the confluence and adjacent waters? (2) Can macrozoobenthos and zooplankton significantly affect the occurrence of YFP via the bottom-up force at the confluence? Because the Wanhe River has relatively abundant nutrients and high transparency, we hypothesized that the species richness and stand crop of macrozoobenthos and zooplankton are higher at the confluence than in the adjacent waters. However, considering that YFP mainly prey on upper edible fish that feed on zooplankton, we thought that only zooplankton could significantly affect the occurrence of YFP.

MATERIALS AND METHODS

Study area: The Wanhe River (total length, 227 km) is located southwest of the Anhui Province. It is a tributary of the Yangtze River and mainly composed of three tributaries (i.e., Wanshui River, Qianshui River, and Changhe River) in its upper reaches (Fig. 1). The Wanhe River originates from Dabie Mountain, and the surrounding land is mainly dominated by farmland and forestland; therefore, the water is only lightly polluted. The Wanhe River Basin has a subtropical monsoon climatic, with a total area of 6442 km^2. The annual average air temperature and rainfall are 16.5°C and 1435.8 mm, respectively; rainfall mainly concentrated in May-September, accounting for 60.8% of the total rainfall.

The confluence of Wanhe and Yangtze rivers is located west of Anqing City, with a width of 140 m and a bottom elevation of 2.21 m (Fig. 1). Because of huge water level fluctuations in the Yangtze mainstream, the maximum water level fluctuating amplitude at the confluence is more than 10 m.

Field sampling: Between September 2013 and August 2014, field investigations of macrozoobenthos and zooplankton were conducted monthly at the confluence of the Yangtze and Wanhe rivers and adjacent waters. A total of five sites were selected, and the distance between the sites was 1 km (Fig. 1). The macrozoobenthos were sampled using a weighted Petersen grab (1/16 m^2) and then passed through a 420-μm sieve. All the specimens were sorted manually from the residue and preserved in 10% formalin. Then, individual number and wet weight of each species were measured.

In this study, the zooplankton include three types, i.e., Rotifera, Cladocera and Copepoda. A 1-L water sample was collected from each site for quantitative analysis of Rotifera. Cladocera and Copepoda samples were collected with a 5-L bucket. A total of 20 L of water was filtered through a conical plankton net (64-μm mesh) at each site, and the cladocera and Copepoda samples were preserved *in situ* in 5% buffered formalin. Identification and quantification of the three types of zooplankton were performed in the laboratory.

The fish communities and occurrence of YFP were also surveyed synchronously only at the confluence (S3 site). An electronic trawl-net and multi-mesh drift gillnets were used for the fish sampling. All the catches were brought to the laboratory and identified. On the basis of vertical distribution, all fish were divided into upper, lower and demersal fish. According to the feeding preferences of YFP, only fish without a hard spine on the body surface and a body height of less than 6 cm were regarded as edible fish (Zhang et al. 2015). Stationary observation of YFP was performed. From 8:00 am to 4:00 pm, monitoring was conducted for 10 min every hour, and a total of 80 min were spent every day. Individual number and frequency out of the water surface of YFP were measured every 10 min. Then, cumulative individual number and cumulative frequency out of the water surface in a day were calculated. For more information on the sampling of the fish communities and YFP, please refer to our published literature (Zhang et al. 2015).

Data analyses: One-way analysis of variance (ANOVA) was used to examine differences in species number, density, and biomass of macrozoobenthos and zooplankton among the five sites. Before statistical analyses, all variables were log (x+1) transformed to meet the assumptions of normality and homogeneity. If a significant difference was found, Tukey's honest significant difference multiple comparison test was used to evaluate variances between groups. Five fish parameters (fish species richness, individual number and yield of edible fish and upper edible fish) that significantly affect the occurrence of YFP were used to analyse the correlations between species number, density, and biomass of macrozoobenthos and zooplankton. All the data were analysed with SPSS 13.0.

RESULTS

Temporal and spatial dynamics of macrozoobenthos: A total of 31 species were collected: 7 Oligochaeta, 1 Polychaeta, 8 Mollusca, and 15 Insecta. Among the five sites, species number was the highest at the confluence (17 species), with 9, 9, 13, and 10 species found at S1, S2, S4, and S5, respectively.

Density and biomass of macrozoobenthos in the study area were 107.2 ind./m^2 and 6.15 g/m^2, respectively. Monthly changes in species number, density, and biomass at the five sites are shown in Fig. 2. Species number at S1 in February and S3 in July was greatly increased, but little difference was observed at the other sites. Density of S4 in October and December was obviously higher than that of other sites because of the emergence of a large number of Gammaridae species, while the biomass of S3 was obviously larger than that of other sites because of the collection of many Mollusca species. The ANOVA analyses showed that both species number ($F = 0.215$, $P = 0.929$) and density ($F = 0.236$, $P = 0.917$) had no significant differences among all the sites, but the biomass of S3 was significantly higher than that of S1 and S4 ($F = 3.647$, $P = 0.011$).

Temporal and spatial dynamics of zooplankton: A total of 64 species were collected: 20 rotifera, 16 cladocera, and 28 Copepoda. The confluence showed the highest species number (53 species), followed by S2 and S4 (41 and 40 species, respectively). S1 and S5 only showed 35 and 26 species, respectively.

Density and biomass of zooplankton in the study area were 20.7 ind./m^2 and 0.043 g/m^2, respectively. Monthly changes in species number, density, and biomass at the five sites are shown in Fig. 3. All the three variables were the lowest in winter and highest in late spring and summer at all the sites, and density and biomass of S3 were obviously higher than those of the other sites in May-July. However, the ANOVA analyses showed that the species number ($F = 1.580$, $P = 0.194$), density ($F = 1.815$, $P = 0.140$), and biomass ($F = 2.303$, $P = 0.071$) among all the sites showed no significant differences.

Effects on the occurrence of YFP: YFP was more likely to be detected in autumn and winter at the confluence (Fig. 4).

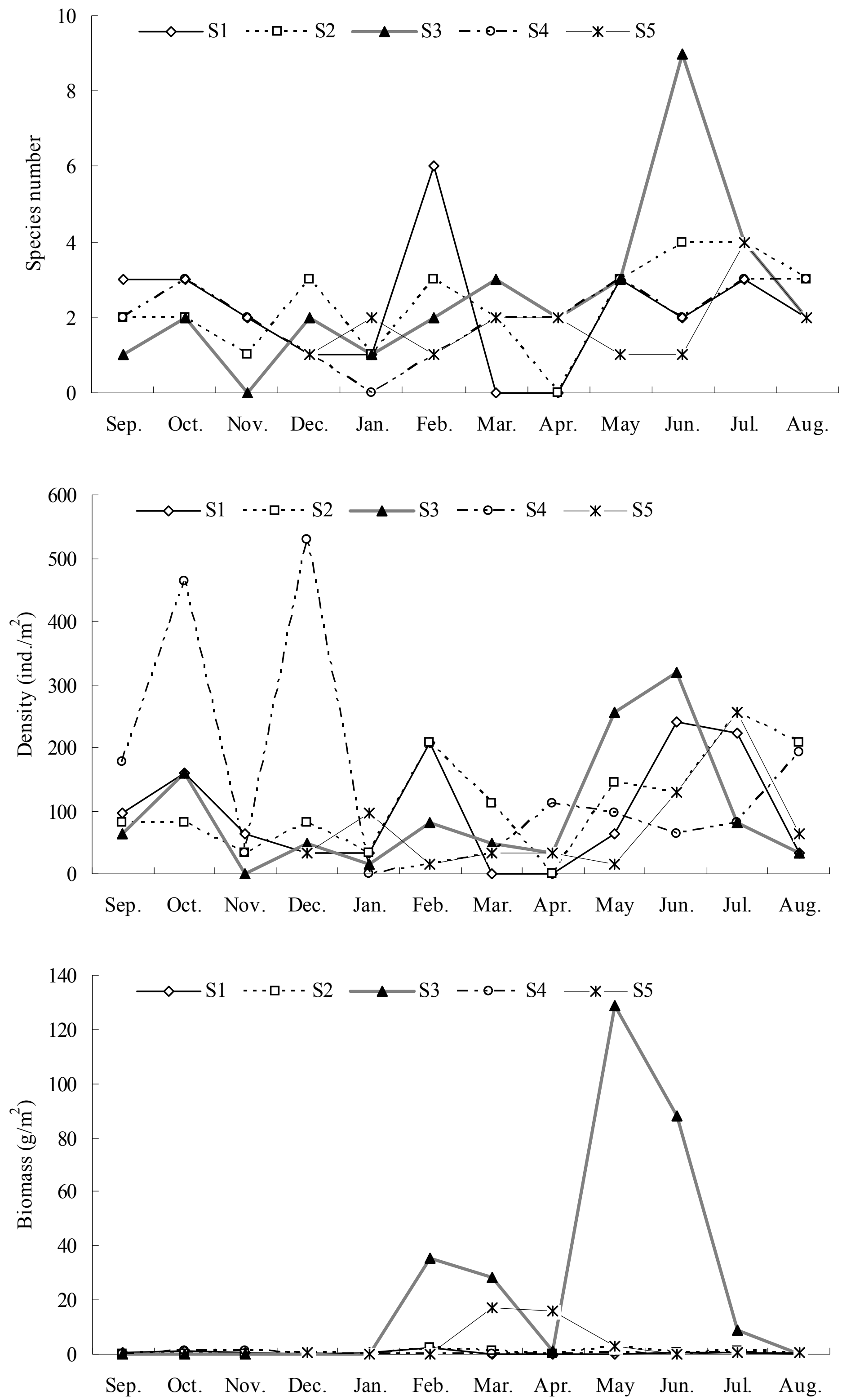

Fig. 2: Monthly changes in species number, density and biomass of macrozoobenthos at different sites (S5 was not sampled between September and November).

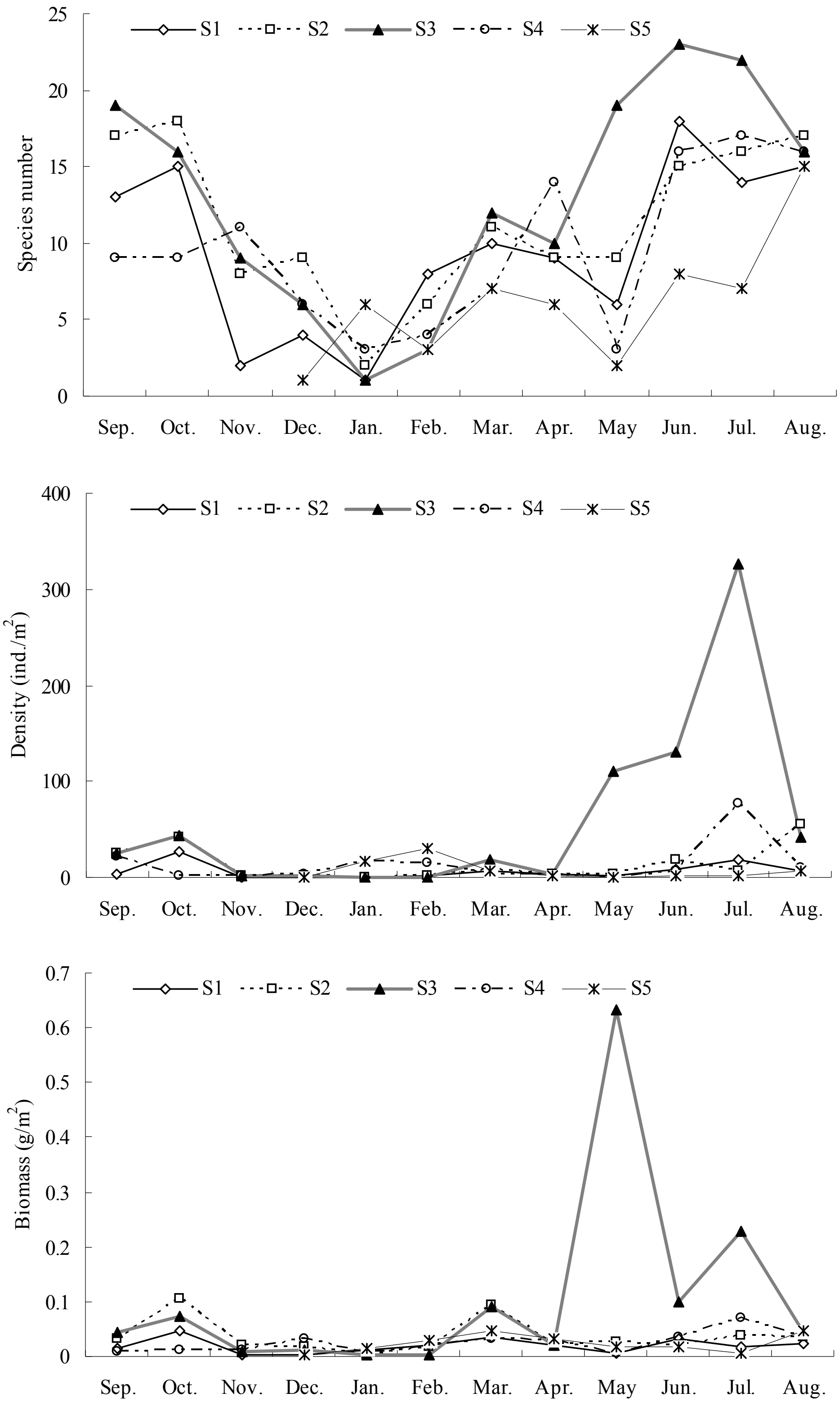

Fig. 3: Monthly changes in species number, density and biomass of zooplankton at different sites (S5 was not sampled between September and November).

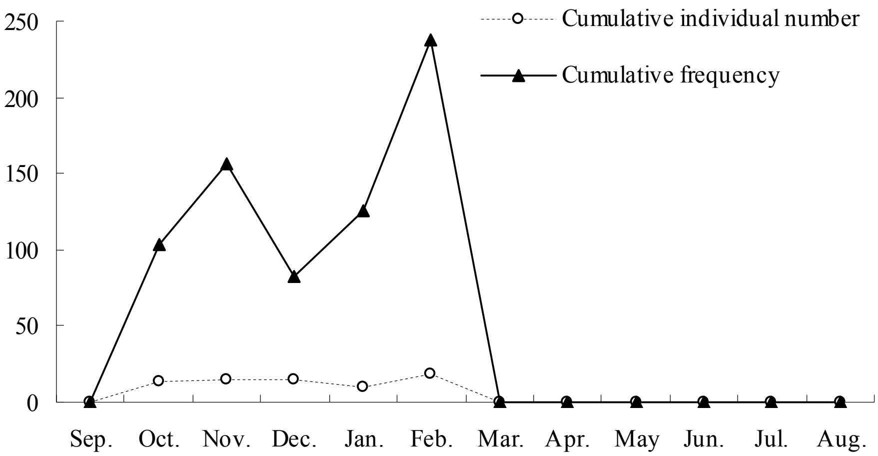

Fig. 4: Cumulative individual number and cumulative frequency out of the water surface for the Yangtze finless porpoise at the confluence.

Interestingly, this was opposite to the tendency of occurrence of zooplankton. No significant correlations were observed between species number, density, and biomass of macrozoobenthos and the five fish parameters; however, significantly negative correlations were found between species number, density, and biomass of zooplankton and fish species richness (Table 1).

DISCUSSION

Temporal and spatial dynamics of macrozoobenthos: The Yangtze River is the largest river of China, and many studies had been performed on macrozoobenthos in the river (Liang 1987, Xie et al. 1999, Pan et al. 2015). However, only Zhao (2010) studied the Anqing section in 2005-2007. In this study, a total of 31 species were collected, which is obviously higher than the 20 species reported by Zhao (2010). This may be mainly due to the different sampling efforts, and only two times of investigations were conducted in the latter. The species composition observed in this study is similar to that found in other studies, and mainly dominated by Insecta, followed by oligochaeta and Mollusca (Wu & Chen 1986, Xie et al. 1999, Zhao 2010). In terms of density and biomass, the results of this study and that of Zhao (2010) had little difference, but the values were obviously lower than 6487.5 ind./m^2 and 11.64 g/m^2 recorded in the lower reaches of the Yangtze River (Xie et al. 1999). This indicates that there has been a serious decline in macrozoobenthos resources in the Anqing section.

Among the five sites, more Mollusca specimens were collected at the confluence; thus, biomass at S3 was significantly higher than that at S1 and S4. The distribution variance of Mollusca may be mainly caused by the different substrates and suspended sediment contents in the water. Many studies have shown that substrate is one of the most important factors that determine the species composition of macrozoobenthos (Buss et al. 2004, Beauger et al. 2006). At the confluence, the substrate was a mixture of sand and silt, and the relatively abundant nutrients were more favourable to the survival of gastropods (Zhao et al. 2011). Some studies have indicated that a large amount of suspended sediments in the water cause the death of bivalves by blocking the gill aperture (Wu & Chen 1986). Therefore, the relatively low content of suspended sediments at the confluence had minimum adverse effects on bivalves. The ANOVA analyses indicated that the species number and density of macrozoobenthos were not significantly different, and this may be mainly due to the poor stability of the substrate at the five sites. The large velocity and water level fluctuation frequency in the Yangtze River heavily erode and reconstruct the substrate, which leads to a high variation in macrozoobenthos communities.

Temporal and spatial dynamics of zooplankton: In this study, a total of 64 species of zooplankton were collected, which is higher than the 50 species reported by Dai et al. (2011) in the adjacent Zhenjiang section. However, the species number was obviously lower than that observed in some tributaries and river-connected lakes (Wang et al. 2003, Zhou et al. 2009), and this may be mainly due to the high water velocity and suspended sediment contents in the Yangtze River. Because of the small individual size, some zooplankton will be easily destroyed under high water velocity, so the quantity of zooplankton is usually negatively correlated with velocity (Chen 1985). The suspended sediments can not only hinder the filtering and absorption

Table 1: Correlations between species number, density and biomass of macrozoobenthos and zooplankton and fish parameters.

		Fish species richness	Number of edible fish	Number of upper edible fish	Yield of edible fish	Yield of upper edible fish
Macrozoobenthos						
Species number	*r*	-0.478	-0.314	-0.027	-0.025	-0.138
	P	0.116	0.320	0.933	0.937	0.668
Density	*r*	-0.429	-0.061	-0.261	-0.035	-0.151
	P	0.164	0.851	0.412	0.914	0.639
Biomass	*r*	-0.171	-0.245	-0.239	-0.252	-0.147
	P	0.596	0.443	0.454	0.430	0.649
Zooplankton						
Species number	*r*	-0.838	-0.305	-0.203	0.067	-0.007
	P	0.001	0.335	0.527	0.837	0.983
Density	*r*	-0.865	-0.341	-0.102	0.049	0.098
	P	0.000	-0.278	0.753	0.880	0.762
Biomass	*r*	-0.701	-0.252	-0.13	0.077	0.105
	P	0.011	0.429	0.687	0.812	0.746

of some species (Dai et al. 2011), but also influence their survival through collision and friction (Chen 1985, Ekwu & Udo 2014).

In this study, the zooplankton demonstrated obvious seasonal dynamics at all the sites, and the species number was the lowest in winter and highest in late spring and summer; this was mainly determined by the water temperature. Many studies have shown that water temperature is an important factor that influences the growth, development, and species composition of zooplankton (Dussart et al. 1984), and the growth rate of some species is usually increased with an increase in water temperature (Benider et al. 2002). Among the five sites, maximum species number was observed at the confluence, and density and biomass was obviously higher at the confluence than at the other sites in May-July. Relatively low velocity, abundant nutrients, and high transparency may be the main reasons for this phenomenon, and the zooplankton can live better and reproduce under these conditions. However, the species number, density, and biomass at the five sites were not significantly different, which indicated that the zooplankton community also had large temporal and spatial variations.

Effects on the occurrence of YFP: Many studies have shown that the field distribution of dolphins is closely linked to the food source (Hastie et al. 2004, Kimura et al. 2012). Besides, our recent study further indicated that fish species richness, individual number and yield of edible fish and upper edible fish had significantly positive correlations with the occurrence of YFP at the confluence (Zhang et al. 2015). Macrozoobenthos and zooplankton, as the middle links of the food chain, play important roles in nutrient cycling and energy flow. However, macrozoobenthos are not the food source for upper edible fish; thus, they have little effects on the occurrence of YFP via the bottom-up force, and this is consistent with our hypothesis. With respect to zooplankton, an interesting phenomenon observed was that, YFP was only detected in autumn and winter because of more abundant upper edible fish resources; however, the stand crop of zooplankton was the lowest at the same time. A question that needs to be answered first is whether the low stand crop of zooplankton at the confluence was induced by the predation of upper edible fish. Although the correlation analyses showed that species number, density, and biomass of zooplankton were significantly negatively correlated with fish species richness, we thought the low temperature in autumn and winter was more important than predation of upper fish. Therefore, zooplankton may also have little effect on the occurrence of YFP via the bottom-up force. The ANOVA analyses showed that the species number, density, and biomass of zooplankton among the five sites had no significant differences. Another question that needs to be answered is why more upper edible fish appeared in winter and autumn only at the confluence. A possible reason may be that they live at the confluence; the slow water velocity at the confluence can not only reduce energy loss in upper fish but also increase the surface water temperature quickly.

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