Study on the relationship between zooplankton and water quality in urban lakes

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Abstract: Zooplankton played an important role in freshwater ecosystem. Its distribution was affected by the water quality of the water body. The urban lake water body performed the functions of ecology and social services, and the water environment was easily influenced by human activities. By analyzing the responses of zooplankton to the changes of water quality of urban lakes, including the difference in species and abundance, the influence of eutrophication on zooplankton in urban lakes was analyzed, and the relationship between zooplankton and water quality indicators and trophic level was analyzed with examples of tropical shallow water lakes. The results showed that zooplankton distribution was related to water quality and nutrient levels. The correlation could provide references for the ecological and environmental health inspection and ecological restoration of urban lakes.

1. Introduction
Zooplankton played a connecting role in the material cycle of water body[1]. It was one of the functional groups that regulated the energy and material cycle, which was closely related to the water quality. Many of them were sensitive to environmental changes. As a part of biological monitoring and an important mean of water environment monitoring, zooplankton was comprehensive and long-term evaluation compared with general physical and chemical monitoring, with sensitivity, amplification and simplicity. The sensitivity, accumulation and transfer of zooplankton of many substances, especially foreign pollutants, also made them play an important role in the study of the ecotoxicological effects of substances on ecosystems and the succession and stability of ecosystems.

2. Analysis of the relationship between water quality index and zooplankton in urban lakes
In the clean water, zooplankton generally had the characteristics of more species and less quantity. On the other hand, in heavily polluted water, it could be hard to survive for almost all aquatic organisms. In the serious or moderate eutrophication water body, the dominant population was usually formed by some pollution resistant species, so the growth and decline of zooplankton was closely related to the degree of water pollution besides other environmental factors. The comprehensive indicators of zooplankton community structure (species composition difference, species number change, individual number change, biomass distribution, diversity index) were used to detect and evaluate water quality and change trend. There were some studies on the relationship between water quality and zooplankton in urban lakes, such as the impact of some ecological factors on rotifer community in West Lake was studied and clarified the relationship between rotifer and water environment quality. The annual survey result was reported about species composition and standing biomass of zooplankton in Xuanwu Lake, Nanjing. Through the analysis of zooplankton population and quantity changes and pollution indicator species at various sites, the pollution status of the lake was evaluated effectively. Compared
with the survey results ten years ago, the species of zooplankton decreased while the number of individuals increased, indicating that the pollution increased. Furthermore Shannon weaner diversity index method was used to analyze the species and quantity of zooplankton in different waters of Dianchi Lake[2].

Rotifers, common zooplankton in lake ecosystem, had fast development time, short life cycle, could respond to the change of environment more quickly, and were relatively easy to collect. They were considered as good indicator organisms. It was pointed out that rotifers could be divided into three main indicator groups: poor and middle eutrophic lake species, middle eutrophic lake species and eutrophic lake species[3]. 620 species of rotifers near the former Czechoslovakia were classified into three classes: heterofouling, oligofouling, β - medium fouling and α - mediumfouling[4]. In addition, QB / T (ratio of the number of Brachionus to that of Trichocerca) could be used to indicate the nutritional status of lake plankton and coastal plankton. It was also pointed out that the pollution level should not only be based on the species and quantity of rotifers, but also on the presence and quantity of Moina macrocopa and Moina micrura, hydrochemistry, water color and environmental conditions. It was generally believed that Synchaeta stylata, Ploesoma hudsoni, Gastrops stylifer, Ascomorpha ovalis and Conochilus unicornis were the dominant species of oligotrophic water body; there were many kinds of medium trophic water body, which were generally transitional species; Brachionus, Anuraeopsis fissa, Pomphyx sulcata, Trichocerca, Filinia longiseta, Hexarthra mira, Polyarthra trigla and Keratella cochlearis were the dominant species of eutrophic water body. At the same time, because rotifer was a strict aerobic invertebrate, it could indicate the situation within the pollution scope of lake, and couldn’t indicate the strong pollution situation of anaerobic water body such as sewage and industrial sewage. It couldn’t simply depend on the composition of water rotifers and the indicator species of rotifers to determine the nutritional level of water. A biological scoring system was constructed that based on the composition of rotifer community instead of indicator species to evaluate the nutritional level of water[5]. On the indicators of Cladocera and Copepoda, Daphnia pulex, Chydorus sphaericus, Diaphanosoma brachyurum, Moina macrocopa and Moina micrura were common in eutrophic water bodies. Simocephalus vetulus were suitable for water body with low pollution, while Sida crystallina and Bosminopsis deitersi liked water body with rich grass. In the eutrophic water body of β - and α - mesofouling, there were Eumycelops serrulatus, Mesocyclops thermocyclopoides, etc. which could live, while Argyrodiaptomus ferus was a kind of oligofouling. According to the observation of East Lake of Wuhan, with the development of water eutrophication the number of Cyclops increased and Calanus decreased. Generally speaking, the determination of water nutrition level should not only be based on the indicator species, but on the characteristics of the whole community composition.

According to the investigation, there were 56 species of rotifers, 19 species of Cladocera and 19 species of Copepoda in the zooplankton of Xinghu Lake in Zhaoqing. Base on the results of rotifers as an indicator, the water of Xinghu Lake had been polluted by certain organic matters, and the water quality was generally of medium nutrition type, in which the lake was in the stage of transformation to eutrophication type. It could be estimated that if the eutrophication of water body develops further, the species structure of rotifers would tend to be simplified and the diversity index would decline. Since 1998, the water ecological environment of Xinghu Lake had been continuously monitored. The comprehensive data showed that the water body of Xinghu Lake had developed from the surface eutrophication (1996: surface level 2 water) to the eutrophication water body (2004: surface level 5 water). It was investigated the crustacean zooplankton in Xinghu Lake. From the point of view of species composition, Xinghu Lake was also in the process of transition from medium nutrition to eutrophication. For the lakes in Guangzhou City, PFU method was used to study the protozoa community and water quality of Liuhua Lake, Liwan Lake and Luhu lake, which were the main lakes in Guangzhou city. The results showed that the species number of protozoa community, the number of plant whipworm fingers, the cluster parameters, the community diversity index D and the community pollution value (CPV) measured and calculated by PFU method could better indicate the three lakes.
The order of water quality from superior to inferior was Luhu lake, Liwan Lake and Liuhua Lake, all of which were in eutrophic state at that time.

3. The effect of eutrophication on zooplankton

With the different eutrophication degree of water body, zooplankton also changed. According to the research, with the increasingly serious eutrophication of East Lake in Wuhan, the diversity index of zooplankton decreased, resulting in obvious secondary succession, and the number of zooplankton increased sharply with the aggravation of eutrophication. The species diversity of Cladocera, Copepoda and rotifer showed the opposite change trend with the nutrition level, that was, when the water body from the medium nutrition type to the super eutrophication type, the species diversity decreased. However, the density and biomass of zooplankton increased, and zooplankton showed a trend of miniaturization. Similar phenomena were found in some temperate and tropical lakes[6].

When the concentration of nutrients in the water increased, the bacterial abundance also increased, which the density of efficient bacterial herders (such as *Daphnia magna*) correspondingly increased, or the density of small omnivorous species (such as *Ceriodaphnia, Bosmina*). However, the high concentration of cyanobacteria was not only low in nutrition, but also hindered the filter feeding organs of large individuals and consumed a lot of energy. Therefore, in the eutrophic cyanobacterial lakes, in spring, the species of microalgae that were mainly herbivorous (such as *Daphnia*) were dominant, while in summer, when the "water bloom" of cyanobacteria occurred, the species that were mainly herbivorous bacteria and organic debris were dominant (such as *Bosmina, Ceriodaphnia*). The relationship between the number of species and the level of nutrition in European and American lakes were analyzed[7]. It was found that the number of species in poor nutrition lakes was less than that in medium nutrition and eutrophic lakes, especially the number of Cladocera increased, but when the level of nutrition increased further, the number of species decreased. Generally speaking, in a wide range of temperate tropical lakes, zooplankton density also increased with the increase of nutrition, and sometimes small species also increased[8].

4. Analysis of the water condition and zooplankton in the tropical shallow city lake

4.1. relationship between zooplankton abundance and water quality index

Through the correlation analysis of zooplankton abundance and water quality indexes, with total nitrogen, total phosphorus, permanganate index, suspended solids, transparency, etc. of tropical shallow urban lakes in the Pearl River Delta (Table 1), it could be seen that there was a positive correlation between the total abundance and total nitrogen, total phosphorus, permanganate index and suspended solids in each lake sample point, including total nitrogen \((r=0.286, P<0.05)\), permanganate index \((r=0.289, P<0.05)\), suspended solids \((r=0.404, P<0.01)\) while positively correlated with transparency \((r=-0.242)\). Previous studies had shown that there was a significant correlation between rotifer population and total nitrogen and phosphorus content among many nutrient factors[9]. It was also found a significant positive correlation between rotifer density and PO₄-P, NO₂-N and NO₃-N content of nitrogen and phosphorus nutrients in Yamuna River, India[10]. Among them, the abundance of rotifer, Cladocera, Copepoda and other types were positively correlated with the content of suspended solids, and basically positively correlated with the total nitrogen. The content of suspended solids, including plankton, bacteria, organic debris and inorganic particles, was the main food source of zooplankton, so the abundance of zooplankton was positively correlated with it.
Table 1. The correlation analysis of zooplankton abundance and trophic indexes of Tropical shallow urban lakes

|         | Abundance ind·L⁻¹ | TN(mg·L⁻¹) | TP(mg·L⁻¹) | COD(mg·L⁻¹) | SS(mg·L⁻¹) | SD(m) |
|---------|------------------|------------|------------|-------------|------------|-------|
| Rotifer | 0.362*           | 0.129      | 0.354*     | 0.353*      | -0.297*    |
| Cladocera | -0.027          | -0.056     | -0.118     | 0.168       | 0.006      |
| Copepoda | 0.134           | -0.047     | 0.166      | 0.472**     | -0.144     |
| Total   | 0.286*           | 0.055      | 0.289*     | 0.404**     | -0.242     |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

4.2. relationship between zooplankton abundance and eutrophication level
There was a significant positive correlation between zooplankton abundance and eutrophication score \((r=0.374, P<0.01)\) in tropical shallow urban lakes, among which rotifer abundance was also positively correlated with eutrophication score \((r = 0.479, P < 0.01)\), while Copepoda abundance, Cladocera abundance, nauplius abundance and eutrophication score were not significantly correlated. The abundance of zooplankton was in direct proportion to eutrophication, especially the abundance of rotifers.

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y = 15x - 552.54 \\
R^2 = 0.1399
\]

5. Conclusions
Through the analysis of the relationship between zooplankton and water conditions, including the interaction between zooplankton and water quality indicators and the level of water nutrition, a good foundation and support could be provided to understand the health status of water ecological environment and to carry out water ecological restoration. In particular, the activities of zooplankton in tropical shallow water urban lakes were less sensitive towards water temperature and so on, and this characteristic could be conducive to the maintenance of lake ecological health.

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