Analysis on the changes of zooplankton in the restoration of urban lake water

Guangrong Chen
Guangdong Construction Polytechnic, Guangzhou, Guangdong, 510440, China
email: gzcgr@qq.com

Abstract: The combination of aquatic vegetation restoration and biological manipulation had become one of the important ways of ecological restoration of lake water. Zooplankton was closely related to aquatic plants, which affected the species composition, density and diversity index of zooplankton. Zooplankton was also part of biological manipulation, which helped to control phytoplankton and improve the transparency of water body. Through the analysis of the role of zooplankton in ecological restoration and the response of zooplankton to the ecological restoration of water body fully reflected the complementary relationship between biological manipulation and aquatic vegetation restoration. Combined with the practice of zooplankton changes in the ecological restoration of typical tropical shallow city lake, it was expected to provide basis and support for the restoration of urban lake.

1. Introduction
Zooplankton played an important role in freshwater ecosystem. On the one hand, they constituted an important link in the food chain of natural waters. Some zooplankton took phytoplankton as food, some took bacteria and debris as food, and they were the food of other aquatic organisms. The change of their species and quantity directly or indirectly affected the distribution and abundance of their higher aquatic organisms. On the other hand, zooplankton was closely related to water quality, many of which were sensitive to environmental changes. Zooplankton was also one of the key factors of biological control [1], so the change of zooplankton in the process of lake water restoration deserved attention.

2. The role of zooplankton in water ecological restoration
Most species of zooplankton were phytophagous, especially crustaceans mainly depended on phytoplankton, bacteria and organic debris for food. In the water body rich in phytoplankton, filter feeding zooplankton was generally more. Some study had suggested that if phytoplankton was the main primary producer in the lake and proliferates in a large amount in the warm season, with the increase of the production of phytoplankton in the primary productivity, the production of zooplankton that the secondary producer living on phytoplankton would also increase. In the multivariate analysis of the relationship between plankton, it was found that the density and biomass of zooplankton in the East Lake of Wuhan were determined by the content of chlorophyll $a$, and the order of correlation with chlorophyll $a$ was rotifer, copepod and protozoa [2]. There was also study that phytoplankton feeding activities lead to a decrease in the number of phytoplankton population, and when the number of phytoplankton decreased to a certain level, it would inevitably affect the number of zooplankton, and with the decrease of the number of zooplankton, the feeding pressure decreased, and the phytoplankton population would increase again, thus forming a double fluctuation of the inter species...
quantity variation characteristics.

It was generally believed that the filtration efficiency of zooplankton was not determined by the species of phytoplankton but the size of phytoplankton. According to feeding habits rotifers could be divided into three kinds, the first one including most rotifers such as *Conochilus* and *Keratella* which fed suspended particle in 1-15 μm, the second one which could plunder the species with larger grain size such as *Polyarthra*, *Synchaeta*, *Tricocerea*, *Ascomorpha* and *Gastropus*, the third one was predatory or omnivorous species such as *Asplanchna* and *Ploesoma*. It depended on the nature of the food in the water which diet rotifer dominated. Some rotifers were more common in rich food water such as *Brachionus*, *Trichocerea*, *Colurella*, *Lepadella*, *Lecane*, *Monostyla*, *Macrochaetus* and *Cephalodella*. The preference of rotifer species for nutrition range was related to the size and nature of food in terms of dominant species, Oligotrophic indicator species such as *Conochilus* mainly fed on microalgae, while eutrophic indicator species such as *Brachionus* mainly fed on microalgae and organic debris, the indicator species with nutrition level between oligotrophic and eutrophic fed on particles (algae) with relatively large size.

Daphnia was a key species in freshwater ecosystem and the most widely distributed planktonic Cladocera which was extremely important in the control of planktonic algae. On the one hand, their special filter feeding system enabled them to ingest the algae and its population in a larger range of individuals (0.5-150μm), protozoa and even bacteria and other suspended matter. On the other hand, the wider feeding range made these zooplankton still maintain a high population or community density through ingestion of other suspended substances, even the algae was inhibited and the amount of phytoplankton and its population was not easy to be ingested, so as not to cause population collapse due to lack of food. Compared with other zooplankton, *Daphnia* was a very successful competitor because it could eat larger particles of food and had higher fecundity[3]. However, in many tropical, sub tropical and temperate lakes, the species composition, density and diversity index of zooplankton were high. In shallow lakes, when the area covered by submerged plants reaches 15% - 20%, fish predation had only a small impact on the community structure of zooplankton, which may be because submerged plants provided better shade for zooplankton and reduced the pressure of fish predation[6]. It had been observed that the biomass of zooplankton increased nine times with the recovery of aquatic vegetation[7]. The species composition, density and diversity of zooplankton in Baoan lake and other five lake areas in the middle and lower reaches of the Yangtze River were studied, the results showed that the species of zooplankton increased with the increase of water grass biomass, the density of zooplankton decreased with the increase of water grass biomass, and the change of zooplankton diversity index was closely related to the abundance of water grass[8]. With the increase of water grass biomass in lakes, the diversity index of zooplankton also increased. The distribution, structure and biomass of aquatic vegetation were affected by water eutrophication. With the development of water eutrophication, phytoplankton dominated, aquatic vegetation died out, zooplankton density increased, zooplankton species and diversity index decreased. In different types of lakes, the peak of zooplankton was different. The general trend was: the peak of zooplankton density in lakes with water grass appeared in spring and winter, and that in lakes without water grass appeared in summer.

3. Response of zooplankton in water ecological restoration

Aquatic plants were one of the important factors that affected the species composition, density and diversity index of zooplankton[4]. Aquatic vegetation could provide shelter for zooplankton[5]. In shallow lakes, when the area covered by submerged plants reaches 15% - 20%, fish predation had only a small impact on the community structure of zooplankton, which may be because submerged plants provided better shade for zooplankton and reduced the pressure of fish predation[6]. It had been observed that the biomass of zooplankton increased nine times with the recovery of aquatic vegetation[7]. The species composition, density and diversity of zooplankton in Baoan lake and other five lake areas in the middle and lower reaches of the Yangtze River were studied, the results showed that the species of zooplankton increased with the increase of water grass biomass, the density of zooplankton decreased with the increase of water grass biomass, and the change of zooplankton diversity index was closely related to the abundance of water grass[8]. With the increase of water grass biomass in lakes, the diversity index of zooplankton also increased. The distribution, structure and biomass of aquatic vegetation were affected by water eutrophication. With the development of water eutrophication, phytoplankton dominated, aquatic vegetation died out, zooplankton density increased, zooplankton species and diversity index decreased. In different types of lakes, the peak of zooplankton was different. The general trend was: the peak of zooplankton density in lakes with water grass appeared in spring and winter, and that in lakes without water grass appeared in summer.

By changing the species composition of predators (Fish), the structure of phytophagous zooplankton community could be manipulated to promote the development of macrozooplankton with high filtration efficiency, especially the Cladocera population, so as to reduce the algae biomass. The specific methods were to reduce filter feeding fish by 50%-100%, or the high-density carnivorous fish to reduce the filter feeding fish. Through increased carnivorous fish to control or remove plankton and
benthos feeding fish which could promote the development of macrozooplankton and benthos invertebrates (which fed on benthos, epiphytic and phytoplankton algae). After the carnivorous fish were released in Michigan, Tuesday and Peter lakes, the number of filter feeding fish decreased significantly, which led to the proliferation of phytophagous zooplankton, resulting in a significant reduction of chlorophyll content and primary productivity[9].

Biological manipulation and vegetation restoration complemented each other in shallow lakes. In shallow lakes in Europe such as the Netherlands, biological manipulation was used to control phytoplankton and improve water transparency, then large aquatic plants could grow[10]. At the same time vegetation could promote biological manipulation and maintain the stability of the ecosystem for a long time.

4. Case analysis of tropical shallow urban lakes
At present, the response of zooplankton to ecological restoration was mainly concentrated in the temperate water, but few studies had been carried out in the tropics. Huizhou West Lake is a typical tropical shallow urban lake. In recent years, the construction of water ecosystem had been implemented, including the removal of plankton and benthos feeding fish, and the construction and restoration of aquatic vegetation including emergent plants, floating leaves and submerged plants. The water quality had been significantly improved, and the change of its zooplankton had a typical significance.

4.1 Species composition of zooplankton
48 species of zooplankton were detected in the restoration area, including 34 species of rotifers, 9 species of Cladocera, 5 species of Copepoda, 40 species of zooplankton were detected in the unrestored area, including 31 species of rotifers, 5 species of Cladocera, 4 species of Copepoda. There were more species in the restoration area, especially the species of Cladocera. The species that were detected in the restoration area but not in the unrestored area included *Ploesoma hudsoni*, *Ploesoma lenticulare*, *Bosminopsis deiteresi*, *Sida crystalline*, *Leptodora kindti* and *Argyrodiaptomus ferus* which were the oligotrophic water species. Among that *Sida crystalline* and *Bosminopsis deiteresi* like to live in the grass tufted water, *Argyrodiaptomus ferus* and *Leptodora kindti* are large species like clean and clear water. In addition, the number of oligofouling species including trichoceridae (8 species) and lecanidae (3 species) in the restoration area also increased. The pollution indicator species distribution of rotifers were shown in the table. In the restoration area, the dominant species were oligofouling and oligofouling - β- medium pollution ones, while in the unrestored area, there were more β-medium pollution species.

| Table 1 The saprobic indicator species distribution in restoration area and unrestored area |
|---------------------------------------------|--------|--------|--------|--------|--------|
| Rotifer species                             | o      | o-b    | b-o    | b      | b-a    |
| restoration area                            | 9      | 9      | 1      | 6      | 3      |
| unrestored area                             | 6      | 8      | 2      | 7      | 3      |

Note: o represents oligofouling, o-b represents oligofouling - β- medium pollution, b-o represents β-medium pollution - oligofouling, b represents β-medium pollution, b-a represents β-medium pollution - α-medium pollution

4.2 Zooplankton abundance and dominant species
The average abundance of zooplankton in the restoration area was \(94.36 ± 10.21\) ind \(\cdot\) L\(^{-1}\). Compared with the unrestored area, the abundance of Cladocera in the restoration area significantly increased (P<0.01) and Copepoda also increased a lot, while the abundance of rotifer significantly decreased (P<0.05). The dominant species in the restoration area were *Polyarthra* sp., *Brachionus angularis*, *Argyrodiaptomus ferus* and nauplius, the dominant species in the unrestored area were *Brachionus diversicornis*, *Filinia longiseta*, *Brachionus forficula*, *Brachionus calyciflorus*, *Asplanchna brightwelli*, *Anuraeopsis fissa*, *Polyarthra* sp., *Mesocyclops thermocyclopoides* and nauplius.
Since March, with the rise of water temperature, the algae and bacteria in the water body had increased, the abundance of zooplankton had increased accordingly, among that the abundance of Cladocera and Copepoda in the restoration area had increased, while the abundance of rotifer had decreased gradually. By July, the abundance of Copepoda in the restoration area had increased, while the abundance of Cladocera had decreased significantly, which may be brought by fish in the restoration area. The pressure of predation was related to the size and shape of zooplankton. Generally, Macrozooplankton was the first choice, when at the same size the order of feeding was Cladocera, Daphnia, Cyclops. Although aquatic plants provided shelter, the abundance of Cladocera still decreased. At this time, the abundance of rotifers increased to a peak in the unrestored area, and the abundance of Copepoda and Cladocera were quite low, which may be related to the fish’s predation and food’s discomfort. In general, the total zooplankton abundance in the restoration area was higher in spring, in which rotifer continuously decreased, while the abundance of macrozooplankton was higher in summer and autumn. The abundance of zooplankton in the unrestored area was higher in autumn and winter. Among them, the relationship between zooplankton, aquatic plants, and fish in the restoration area needed further study.

4.2 Zooplankton diversity index

The diversity index not only reflected the characteristics of population structure, but also indicated the degree of organic pollution. The monthly average of Shannon Wiener diversity index (H) in the restoration area was $3.03 \pm 0.15$, and that in the unrestored area was $1.89 \pm 0.38$. There were many species and low abundance of zooplankton in the restoration area, and Shannon Weaver diversity index was high. According to the relationship between $H$ and water pollution degree ($H$ value was 0-1 for heavy pollution, 1-2 for α-medium pollution, 2-3 for β-medium pollution, and > 3 for clean water), the water quality in the unrestored area was at the medium pollution level, while that in the restoration area was good, which was consistent with the monitoring results of water quality indicators.

5. Conclusion

With the restoration of aquatic vegetation, the water quality in the restoration area had been improved. Meanwhile, zooplankton also changed accordingly. The species of clear water type increased, the abundance of Cladocera and Copepoda increased, and the abundance of rotifer decreased. The
restoration of aquatic vegetation provided habitat and shelter for zooplankton. The species of zooplankton in the restoration area increased with the coverage of aquatic vegetation, and the diversity of zooplankton community also increased. The increase of macrozooplankton in the restoration area was conducive to the grazing and control of phytoplankton in water body, so as to improve the transparency of water body and promote the restoration of aquatic vegetation. It could be seen that there was a complementary relationship between zooplankton and aquatic vegetation. The restoration of aquatic vegetation affected the development of zooplankton, and the development of zooplankton could also promote the restoration of aquatic vegetation.

The aquatic vegetation not only provided shelter for zooplankton, but also provided a place for the breeding of omnivorous fish, which indirectly increased the pressure of predation on zooplankton. The tilapia in the recovery area was a common tropical fish, with fast reproduction speed and large quantity. Its omnivorous nature formed a certain pressure of predation on zooplankton, and the zooplankton in the recovery area was still dominated by small individuals. Compared with temperate zone, the zooplankton in tropical lakes were mainly rotifers and small Cladocera, which had limited predatory control ability to phytoplankton and could not achieve the same effect of biological control in temperate zone. Therefore, the relationship among zooplankton, aquatic vegetation and fish in the process of ecological restoration of tropical lakes needed further study.

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