Study on the relationship of ecological effect in the ecological restoration of urban lakes

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

Abstract. The combination of biological manipulation and aquatic vegetation restoration had become an important way of ecological restoration of lake water. The research on the relationship among fish, zooplankton and aquatic vegetation was helpful to lake ecological restoration. By investigating the distribution of fish, aquatic vegetation and zooplankton in some urban lakes in the South of the five ridges, the abundance and relative abundance of Cladocera and Copepoda were generally lower in the lakes where fish was farmed, while the abundance of Cladocera and crustacea was relatively higher in lakes with hydrophytes. The ecological restoration of typical tropical shallow urban lake showed that the combination of aquatic vegetation restoration and fish regulation was an effective measure for the control of tropical shallow eutrophication urban lake. It provided a reference for how to take biological control measures to restore the water body and how to maintain the stability of the ecosystem after the ecological restoration.

1. Introduction
The combination of biological manipulation and aquatic vegetation restoration had been studied in eutrophication lake management and had shown some effects[1]. Biological control measures could improve the transparency of water body, which was conducive to the restoration of aquatic vegetation[2]. More and more attention had been paid to the study of the relationship among aquatic vegetation, zooplankton and fish in the process of lake ecological restoration[3]. The physical and chemical conditions and ecosystems of tropical lakes were different from those of temperate ones, the effect of some biological control measures was not as obvious as that in temperate zone, and the measures taken were also different[4-5]. The relationship among aquatic vegetation, zooplankton and fish in the ecological restoration of tropical lakes needed more research.

2. Ecological relationship of urban lakes in Lingnan
Most of the urban lakes in Lingnan had fish (table 1). According to the survey, except for a few of the lakes where fish grew and distributed naturally, Fish in most lakes were specially farmed by humans. Fish had a certain impact on the lake ecosystem, especially zooplankton. Predation had been identified as the most important factor determining the density and structure of zooplankton community and leading to the succession of zooplankton community[6]. The predators of zooplankton in fresh water could be divided into invertebrate predators and vertebrate predators, both of which could greatly change the community structure of zooplankton. Vertebrate predators mainly referred to plankton eating fish, including particulate feeding fish and filter feeding fish. The feeding mode of particulate feeding fish was to attack single zooplankton through visual sense, at the same time several other zooplankton might be accidentally inhaled into the mouth. The filter feeding fish didn’t need visual
guidance, and it could effectively capture zooplankton which was larger and stronger in escape.

The abundance of Cladocera and Copepoda were generally low in lakes where fish was farmed, such as Liuhua Lake (difficult to detect), Dongshan Lake (5.00±1.67ind·L⁻¹), E lake (4.44±2.26ind·L⁻¹), Panlongtian Lake (5.40±1.14ind·L⁻¹), Yixian Lake (4.00ind·L⁻¹, sample points 1 and 2), Dong Lake (4.77±1.43ind·L⁻¹), etc., which was generally only 5.0ind·L⁻¹. Even more Ximen lake that lakelet of E lake which could hardly detect large zooplankton due to the high density of fish. Meanwhile, the relative abundance of Cladocera and Copepoda were also very low, such as Dongshan Lake (0.77±0.26%), E lake (2.51±1.29%), Panlongtian Lake (0.98±0.17%), Yixian Lake (1.24±0.20%, sample points 1 and 2), East Lake (2.04±0.55%), etc. The low abundance and relative abundance of Cladocera and Copepoda had a certain relationship with the predation of fish. The results showed that the community structure and size composition of zooplankton could be greatly changed by fish predation[7]. The predation of zooplankton mainly depended on size selection and prey visibility, usually the first choice was large zooplankton in the selection of size and shape, and the order of choice was Cladocera, Daphnia, Cyclops with the same size. It usually led to the dominance of large species in zooplankton community being replaced by small species. In many water bodies, the dominance of small zooplankton increased due to the introduction of particulate feeding fish or the increase of fish biomass. It was generally believed that small zooplankton was dominant in water bodies with high fish biomass, while large crustaceans were dominant in water bodies with low fish biomass or lack of fish.

The total zooplankton abundance of Hong Lake was not high but the abundance of Cladocera and crustacea were high (table 1), especially Lianxiang Lake (95.00 ind·L⁻¹, 36.68%) and Jingyi Lake (45.00 ind·L⁻¹, 15.41%) that lakelets of Hong Lake, which might be related to the distribution of aquatic vegetation. Some studies had suggested that water grass was one of the important factors that affected the change of species composition, density and diversity index of zooplankton[8]. Aquatic vegetation could provide shelter for zooplankton, fish predation had only a small impact on the community structure of zooplankton in shallow lakes when the area covered by submerged plants reached 15%-20%[9]. The abundance of macrozooplankton was high might because aquatic vegetation provided better shade for zooplankton and reduced the pressure of fish predation. However there was only in Hong Lake, and similar experiments needed to be carried out in other urban lakes.
Table 1 The fish, aquatic vegetation and zooplankton in urban lakes of Lingnan

| Lake name        | Fish     | Aquatic vegetation | Zooplankton abundance (ind L⁻¹) ±SE | Abundance of macrozooplankton (ind L⁻¹) ±SE | Relative abundance of macrozooplankton ±SE |
|------------------|----------|--------------------|-------------------------------------|---------------------------------------------|------------------------------------------|
| Liuhua Lake      | Farmed   | —                  | 600.75±47.14                       | —                                           | —                                        |
| Liwan Lake       | —        | —                  | 603.33±101.99                      | 43.33±9.62                                  | 7.04±0.42%                              |
| Lu Lake          | —        | —                  | 185.00±15.00                       | 5.00±1.67                                   | 0.77±0.26%                              |
| Dongshan Lake    | Farmed   | —                  | 624.25±38.27                      | 15.00±5.00                                  | 8.38±3.38%                              |
| West Lake        | Farmed   | —                  | 320.11±29.94                      | 13.09±1.22                                  | 4.14±0.22%                              |
| Lianxiang        | —        | About 40% of the water surface | 259.00                             | 95.00                                       | 36.68%                                  |
| Hong Lake        | —        | About 10% of the water surface | 368.00                             | 19.00                                       | 5.16%                                   |
| Jingyi           | —        | About 90% of the water surface | 292.00                             | 45.00                                       | 15.41%                                  |
| Dongmen1         | Farmed   | —                  | 227.33                             | 7.33                                        | 3.23%                                   |
| Dongmen2         | Farmed   | —                  | 139.50                             | 6.00                                        | 4.30%                                   |
| Ximen            | High-density farmed | —                | 785.00                            | 0.00                                        | 0.00%                                   |
| Dongmen Pond     | —        | —                  | 1071.56±234.42                    | 123.78±27.71                                | 11.49±0.59%                            |
| Xing Lake        | —        | A few              | 285.00±30.65                      | 34.00±6.00                                  | 12.44±2.81%                            |
| Panlongtian Lake | Farmed   | A few              | 539.93±25.64                      | 5.40±1.14                                   | 0.98±0.17%                             |
| 1 Farmed         | —        | 278.00             | 4.00                              | 0.14%                                       |
| 2                | Farmed   | —                  | 385.20                            | 4.00                                        | 0.10%                                   |
| 3 Farmed         | —        | —                  | 51.20                             | 21.20                                       | 41.41%                                  |
| Dong Lake        | Farmed   | A few              | 227.97±10.97                      | 4.77±1.43                                   | 2.04±0.55%                             |
| Fuhai Lake       | —        | —                  | 79.93±0.52                       | 11.13±0.87                                  | 13.91±1.01%                            |
| Yuanyang Lake    | —        | —                  | 483.20±81.58                     | 34.45±13.28                                 | 6.69±1.52%                             |

3. Analysis on the relationship of ecological effect in the ecological restoration of typical urban lakes

Huizhou West Lake is a typical tropical shallow urban lake, it was in a state of eutrophication before. Through the implementation of biological control measures and the construction of water ecosystem in the restoration area, including the control of planktonic feeding fish and benthic feeding fish, and the construction and restoration of aquatic vegetation including emergent plants, floating leaves plants and submerged plants. After years of continuous maintenance and monitoring of the water ecosystem in the restoration area, the results showed that the water quality in the restoration area had been significantly improved, the transparency of the water body could be basically clear to the bottom, it had certain effect by ecological restoration in contrast with the yellow and green water of other sub lakes. On this basis, the interaction among zooplankton, aquatic vegetation and fish in the restoration area was studied, and how to further maintain the stability of the clear water system after ecological restoration of the tropical eutrophic urban lake.

3.1. The distribution of aquatic vegetation

The aquatic vegetation types in the restoration area included *Vallisneria* sp., *Hydrilla verticillata*,
Myriophyllum spicatum, Nymphaea sp., and Nelumbo nucifera, etc. with Vallisneria sp. as the dominant species, Hydrilla verticillata and Myriophyllum spicatum were scattered, Nymphaea sp. and Nelumbo nucifera as the fixed points and a small amount of distribution played an aesthetic role. The total area of the dominant species Vallisneria sp. distributed from about one fifth of the lake bottom in March to about one half of the lake bottom in September, and Nelumbo nucifera gradually withered in September. Among them, there were Vallisneria sp., Hydrilla verticillata, Myriophyllum spicatum in each month. The average biomass in September was as high as (9.167±0.804) kg·m⁻², the lower in March and May were (1.249±0.077) and (1.660±0.222) kg·m⁻² respectively, and in July was (2.502±1.514) kg·m⁻² (figure 1). In the unrestored area, there was almost no growth of aquatic vegetation, which might be caused by the low transparency of the water body and the stone and cement slope protection in the lake shore, which was not conducive to the growth of aquatic vegetation especially submerged plants.

3.2. The situation of fish
In the restoration area, there were Oreochomis sp., Cyprinus carpio, etc., among which tilapia was the dominant species. In March, May and July, the monthly catches were 17.5, 22.5 and 30.95 kg respectively, while in September the catch was 7.61 kg, which might be caused by continuous fishing. The catch on the sampling day of each month was 0.85, 1.13, 0.45 and 1.31 kg respectively, with little difference (figure 1). There were more fish in the unrestored area, including carp, Carassius auratus, Cirrhinus molitorella, tilapia, Hypophthalmichthys molitrix, Aristichthys nobilis and Coilia sp. etc. and there was no quantitative fishing due to the large ones of the unrestored area and connect with other sub lakes.

3.3. The dynamics of zooplankton
Although the zooplankton abundance in the unrestored area was high, there was little difference in zooplankton biomass between the restoration area and the unrestored area, with an average of (0.64±0.39) mg·L⁻¹ and (0.65±0.31) mg·L⁻¹ respectively. In July they were all the highest, the unrestored area was 1.106 mg·L⁻¹, and the restoration area was slightly higher than the unrestored area that was 1.223 mg·L⁻¹ (figure 1). The dominant species of zooplankton biomass in the unrestored area were predacious rotifers such as Asplanchna brightwelli, Asplanchna priodonta, Brachionus diversicolor and Cyclops such as Mesocyclops thermocyclopoidez, Thermocyclops taihokuensis, etc., while the restoration area mainly included Cyclops such as nauplius and Thermocyclops taihokuensis, Mesocyclops thermocyclopoidez and Calanoida such as Argyrodiaptomus ferus. With the increase of the coverage of aquatic vegetation in the restoration area, the concentration of chlorophyll gradually decreased and the abundance of zooplankton decreased, but the biomass of zooplankton increased. The dominant species of biomass composition was macrozooplankton.

4. Analysis and conclusion
Aquatic vegetation affected the feeding of fish and the species composition, density and diversity of zooplankton. With the increase of aquatic vegetation coverage and biomass in the restoration area, the
total abundance of zooplankton in the restoration area was lower than that in the unrestored area. Among them, the abundance of rotifers was lower, and that of large zooplankton such as Cladocera and Copepoda were higher than that in the unrestored area. In terms of the total biomass of zooplankton, the restoration area also had an increasing trend. The dominant species of zooplankton abundance and biomass in the restoration area tended to large species, while the small individual rotifers tended to decline. On the one hand, the aquatic vegetation might reduce the probability of predation by fish, on the other hand, the food was less in the clear water lake so the macrozooplankton had a more competitive advantage.

The increase of macrozooplankton 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. In shallow lake ecosystem, zooplankton (especially large species) could reduce the amount of algae by eating phytoplankton. When the nutrient level of water body reduced to a clear state in which large aquatic plants were dominant, biological manipulation might as an important role in the change from the dominant state of phytoplankton to large aquatic plants and lake ecosystem restoration. It showed that there was a complementary relationship between zooplankton and aquatic vegetation. The restoration of aquatic vegetation affected the distribution of zooplankton, and the development of zooplankton could promote and maintain the growth of aquatic vegetation.

In tropical lakes, with the recovery of aquatic vegetation, a large number of omnivorous fish proliferated which increased the predation pressure on zooplankton. While aquatic vegetation provided shelter for zooplankton[10], it also provided a place for the breeding of omnivorous fish, which indirectly increased the pressure on zooplankton. It was believed that in the process of restoration of tropical lakes, small and medium-sized filter fishes were on the dominant and concentrated in aquatic vegetation, and the protection of aquatic vegetation for large zooplankton was limited. It was also suggested that phytoplankton feeding fish might be a more suitable tool for biological manipulation in tropical and subtropical regions because of the small number and smaller size of Cladocera. The tilapia in the restoration area was a common tropical fish with fast propagation speed and large quantity, and its omnivorous nature formed certain predation pressure on zooplankton. Through continuous fishing in the restoration area, the biomass of fish had been reduced and effectively controlled. The biomass of aquatic vegetation had reached the highest level in September. The body length of zooplankton, the abundance of large zooplankton and the biomass of zooplankton had increased. The transparency of the lake water was clear to the bottom, and the clear water state had been maintained and developed. Therefore, the restoration of aquatic vegetation combined with fish regulation was an effective measure for the management of tropical shallow eutrophic urban lake.

Acknowledgments
This work was supported by the project of Department of Education of Guangdong Province (Grant No. 20130201018).

References
[1] Scheffer M, Hosper S H, Meijer M L. (1993) Alternative Equilibria in Shallow Lakes. Trends in Ecology&Evolution, 8: 275-279.
[2] Chen G. (2012) Study on biomanipulation and its effect in restoration of eutrophic water in tropical shallow urban lake. Environmental science & management, 9: 141-143.
[3] Stansfield J H, Perrow M R, Tench L D, Jowitt A J D, Taylor A A L. (1997) Submerged macrophytes as refuges for grazing Cladocera against fish predation: observations on seasonal changes in relation to macrophyte cover and predation pressure. Hydrobiologia, 342/343: 229-240.
[4] Talling J F. (2001) Environmental controls on the functioning of shallow tropical lakes. Hydrobiologia, 458: 1-8.
[5] Bachmann R W, Horsburgh C A, Hoyer M V, Mataraza L K, Canfield Jr D E . (2002) Relations between trophic state indicators and plant biomass in Florida lakes. Hydrobiologia, 470:
[6] Fernando C H, (1990) Tudorancea C, Mengeston S. Invertebrate zooplankton predator composition and diversity in tropical lentic waters. Hydrobiologia, 198: 13-31.

[7] Brooks J, Dodson S. (1965) Predation, body size and composition of plankton. Science, 150: 28-35.

[8] Schriver P, Bogestrand J, Jeppesen E, Søndergaard M. (1995) Impact of submerged macrophytes on fish-zooplankton-Phytoplankton interactions: large-scale enclosure experiments in a shallow eutrophic lake. Freshwater Biol, 33: 255-270.

[9] Lauridsen T L, Lodge D M. (1996) Avoidance by Daphnia magna of fish and macrophytes: Chemical cues and predator-mediated use of macrophyte habitat. Limnology and Oceanography, 41: 794-798.

[10] Person L, Eklöv P. (1995) Prey refuges affecting interactions between piscivorous perch and juvenile perch and roach. Ecology, 76: 70-81.