

Study on Eutrophication in Landscape Lake of Different Trophic Levels by Microcosm Experiment

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Abstract.In this paper, a microcosm system was designed targeting at the landscape lake to study the eutrophication mechanism of the water by controlling the eutrophication level in water, measuring and comparing the water quality indicators. Firstly, the microcosm trophic level configuration and ecological balance cycle experiment were designed. Secondly, omnivorous fish and zooplankton were put into the system to simulate the biological population structure in the landscape water, the relations and trend of change among the elements of temperature, pH and dissolved oxygen, nitrogen, phosphorus, and chlorophyll a in the water were measured and analyzed. The results show that the one-level trophic microcosm system has good effect on controlling the nitrate nitrogen, phosphate and total phosphorus; the two-level trophic microcosm system has good effect on controlling chlorophyll a; the three-level trophic microcosm system has good effect on controlling the nitrate nitrogen and total phosphorus and maintains good stability of pH. Finally, relative suggestions and measures on the control of eutrophication lake were proposed based on data analysis, in order to promote the sustainable development of water.

1. Introduction

As a dual-carrier of both the landscape and the water ecological functionalities, the landscape lake have become an important composing part of urban infrastructural facility improvement and upgrading. However, due to its characteristics of slow flow rate, poor self-cleaning ability and easy to be contaminated, the eutrophication problem has become more and more serious. Eutrophication of water is actually harmful to both human body health and the aquatic ecosystem. Microcosm is a kind of technology mainly used in laboratory or small-scale ecosystem. It has been widely applied in water eutrophication research during recent years due to its good properties of controllability and applicability. Based on the consideration from the perspective of ecological trophic level, the microcosm method has been continuously deepened in recent years: from the one-level trophic model (phytoplankton-nutrient model)[1] to the two-level trophic model (zooplankton-phytoplankton-nutrient model)[2] to the three-level eutrophication model (plankton-phytoplankton-nutrient model)[3,4] etc. Milstein et al.[5] used microcosm experiments to simulate the effects of zooplankton composition on the predation intensity of fry in order to study the problem of whether the species and morphology of zooplankton could meet the demand of predation growth of the fry, and the results showed that the predation growth of the fry requires for a higher concentration of zooplankton.

Ristau et al.[6] set different concentrations of nutrient in microcosm simulation to study the process of phytoplankton and zooplankton population changes from oligotrophic to eutrophication.



Based on previous researches, in this study, it decided to use the microcosm experiment to study eutrophication. A one-level trophic microcosm system, a two-level trophic microcosm system, a three-level trophic microcosm system, were set in this study. The nutrient concentrations in water of different trophic levels and other affecting factors were measured, analyzed and summarized, thus proposing the suggestions and measures for the control of eutrophication lake to promote the sustainable development of water.

2. Materials and methodology

2.1. Experiment area and devices

The experiment were carried out in the laboratory. The water source was taken from Mingli Lake in TianJin, China, for which, the annual average temperature is around 14 °C, maximum reaching 28°C in July. The water supply of Mingli Lake mainly relies on rainfall runoff.

Totally six microcosm aquariums (as shown in Fig. 1) were adopted, which is made of plexiglass with dimension of 100 cm x 50 cm x 50 cm. 200 L water sample was added to reach 40cm water level with 10 cm reserved above the water surface. With improve the controllability of the system, the microcosm aquariums were placed in indoor environment, fluorescent lamp were set up to simulate natural light. The daily irradiation time was 7:00-21:00, the ratio of light to dark cycle was 14/10hr; for the temperature, it was tried to keep the same as that of the sampling landscape lake. In addition, the thermometer and a temperature-controlled heater were added in the aquarium. The water level control was realized by the ruler attached to the aquarium: maintaining the water level by calculating the water to be supplemented according to the measurement of the water level. Inside the aquarium, a circulating pump (filter cotton was removed) was equipped, so as the aeration device, for oxygenation and circulation disturbance in order to promote the circulation of nutrients and avoid the sinking of plankton. The schematic diagram of the microcosm experiment is shown in Figure 1.

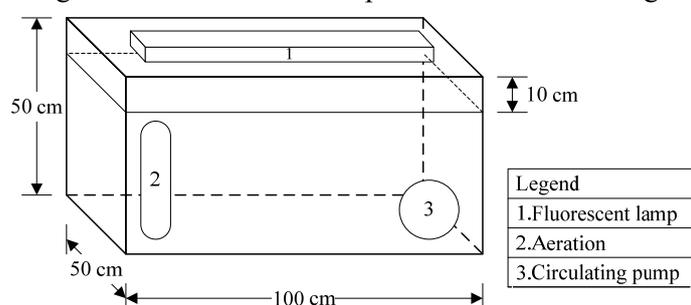


Figure 1. Schematic diagram of the aquatic simulation experiment

2.2. Experimental materials

For the phytoplankton of this experiment, the *Scenedesmus Obliquus* was adopted. This *Scenedesmus Obliquus*, widely spread in lake, belongs to Scenedesmaceae and *Scenedesmus*, and is one of the standard algae for experiment use. For the zooplankton, *Carassius auratus*, which belongs to Pulicidae and Daphnidae, was adopted. It widely spread in eutrophic waters where aquatic plants grow vigorously. For fish, the *Carassius auratus*, also known as "golden carp", was adopted. It is evolved from crucian for ornamental fish and is omnivorous fish preference eating zooplankton.

2.3. Experimental method

The raw water taken from Mingli Lake was treated and then used as the experimental water. The experiment began on July 13, 2017 and ended on August 12, 2017. The six aquariums were numbered 1, 2, 3, 4, 5, 6. The lake water was filtered and taken to create different trophic levels of environment by biological meshes of different orifice diameters. For No.1, 2 aquariums, the No. 25 biological mesh with aperture of 0.064mm was used to filter out most of the zooplankton, creating a one-level trophic environment with only phytoplankton. For No.3, 4 aquariums, the No. 13 biological net with aperture

of 0.112mm was used to create a two-level trophic environment containing phytoplankton and zooplankton. For No. 5, 6 aquariums, 4 *Carassius auratus* were added on the basis of No.3, 4 aquariums to create a three-level trophic environment. Then the lighting and aeration systems were turned on. After 48 hours of normal operation, all indicators were measured once every two days.

3.Results and Discussion

3.1. Temperature

The temperature range of the water in the experiment was between 28.5-30 °C, which is more suitable for the growth and reproduction of algae. But the water temperature at the late stage of test became higher than 30 °C. Over-hot temperature can inhibit the growth and reproduction of algae.(see Figure 2)

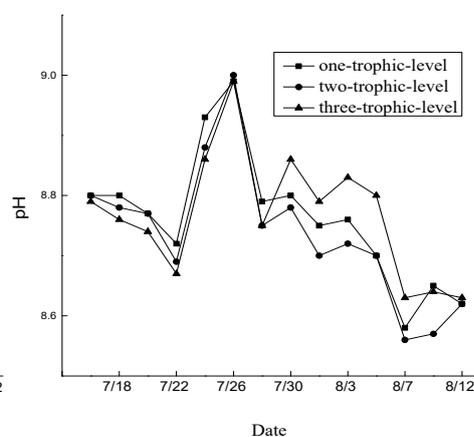
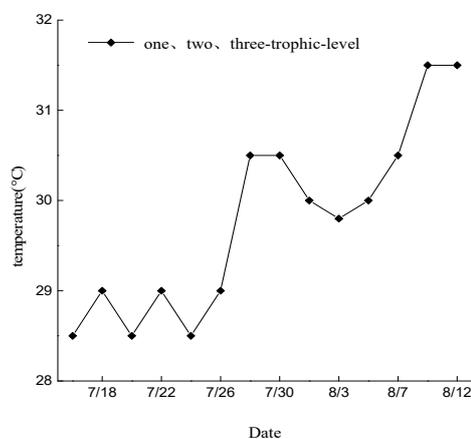


Figure 2. temperature changes over time Figure 3. pH changes over time

3.2. pH

The pH reduction at the initial stage is due to the sufficient organic matter content in the water at the initial stage, which leads to the growth and reproduction of bacteria. The bacteria can produce carbon dioxide, so the pH value of the water body is reduced. The subsequent increase is due to the growth of algae in the water which consumes carbon dioxide for photosynthesis. After that, the decrease in pH is caused by the decrease of nutrients in the water, which leads to the death of algae, so that photosynthesis effect on decomposing carbon dioxide is reduced. When the algae dies, it is decomposed by microorganisms to produce acidic substances. The pH in the one-level microcosm system fluctuates from 8.58-8.99. The same data fluctuates 8.56-9.00 in the two-level microcosm, fluctuates between 8.63-8.99 in the three-level microcosm. The fluctuation in the three-level trophic system was smaller than the other two systems, which indicates that the fish in the water has a certain buffering effect on the water pH. (See Figure 3)

3.3. Dissolved Oxygen

The rise of dissolved oxygen content at the initial stage is because that the aeration to the water increases the content of the dissolved oxygen in the water. The reason for the decrease later is because the large amount of dissolved oxygen is consumed by the growth and increase of algae in the water. The second time of dissolved oxygen increase is due to the death of a large number of algae, which reduces the oxygen consumption in the water and makes the dissolved oxygen concentration in the water rise again. The difference in dissolved oxygen concentrations in the three aquariums is not very large. But the three-level trophic system with fish had a lower dissolved oxygen concentration than the other two trophic systems because the fish also consume oxygen from the water. (See Figure 4)

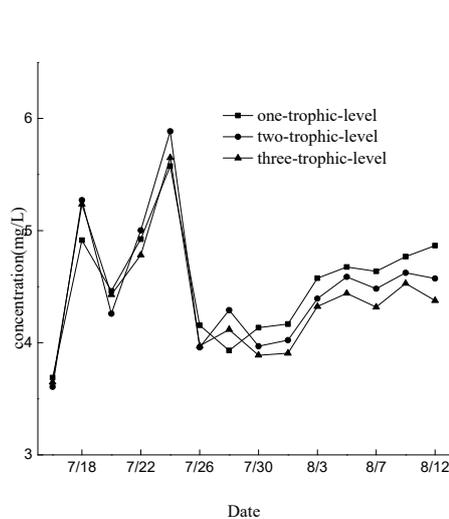


Figure 4. DO changes over time

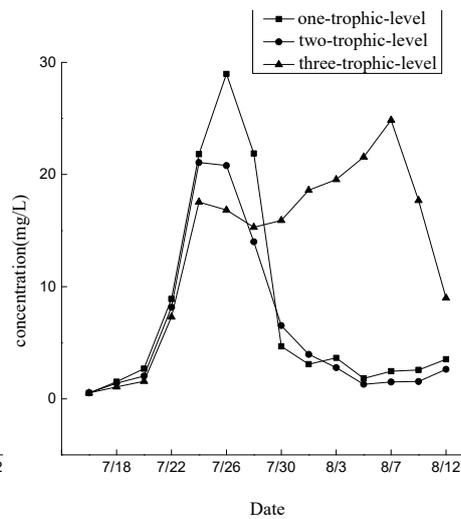


Figure 5. Chl-a changes over time

3.4. Chlorophyll a

The concentration of chlorophyll a in water systems respectively having zooplankton and only algae shows a trend of increasing first and then decreasing. That's because, the phytoplankton increases when the nutrition is abundant, and the chlorophyll a content increases accordingly. With the increase of algae, the nutrients in the water were insufficient, the algae began to die a lot, and the concentration of chlorophyll a decreases rapidly. Among the three microcosms, the one-level trophic system has the maximum peak value of chlorophyll a concentration, reaching 28.96 mg/L. This is related to the fact that there's no enemy of phytoplankton in the system, so that the growth of phytoplankton is not restricted, resulting in serious eutrophication of the water. The peak concentration of the system added with zooplankton was 21.06 mg/L, indicating that prey of zooplankton on phytoplankton can inhibit the growth of phytoplankton biomass. The peak concentration of the three-level trophic system with fish was 24.84 mg/L. Due to the prey of the fish, the amount of the phytoplankton was relatively small compared with the one-level and the two-level trophic systems. However, due to the metabolism of fish, which converted the organic matters into inorganic nutrients, the phytoplankton could have sufficient nutrition for survival, and since these are omnivorous fish, their predation on zooplankton reduces the pressure on phytoplankton, so the peak of chlorophyll a in the fish comes later than that of the other two systems. (See Figure 5)

3.5. Nitrogen

3.5.1. Total Nitrogen The trend of total nitrogen change in all the three aquariums were: decreasing firstly then rising, and then decreasing again. The fluctuation of the total nitrogen concentration in the one-level trophic system ranged between 5.91-10.96 mg/L. The same data in the two-level trophic system ranged between 6.95-10.60 mg/L, ranged between 6.76-10.08mg/L in the three-level trophic system. The concentration rising at the initial stage is because the phytoplankton can absorb nitrogen in the air and convert it as nitrate nitrogen by its fixation effect, then release it into the water, which can rise with the increase of phytoplankton. Later, with the death of algae, the nitrogen fixation effect decreases, accordingly resulting in a decrease in total nitrogen content. Compared with the other two trophic systems the total nitrogen content in the three-level trophic system is more stable. That may be because the metabolism of fish accelerates the circulation of nitrogen. The three-level microcosm has the highest total nitrogen concentration, but the lowest peak concentration; the one-level system has the lowest valley concentration. It can be seen that the more complex the ecosystem structure, the less fluctuation of nitrogen. (See Figure 6)

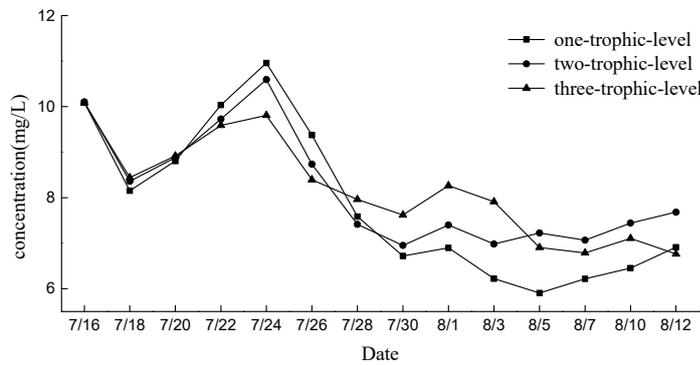


Figure 6. TN changes over time

3.5.2. *Ammonia Nitrogen* The concentration of ammonia nitrogen in the one-level microcosm ranged between 0.21-3.75 mg/L. This data in the two-level microcosm ranged between 0.28 - 3.76 mg/L, and the ranged between 0.14 -3.75 mg/L in the three-level microcosm. The reason for the sharp decline of the ammonia nitrogen contents in the three aquariums at the initial stage is because the activities of algae in the water consume a large amount of ammonia nitrogen. Later, with the death of algae, the bacteria decomposes the organic nitrogen of the algae and makes it convert into ammonia nitrogen. The growth rate of ammonia nitrogen in the three-level trophic system was lower than that of the other two trophic systems, indicating that the addition of *Carassius auratus* into the water has an effect on reducing the ammonia nitrogen. (See Figure 7)

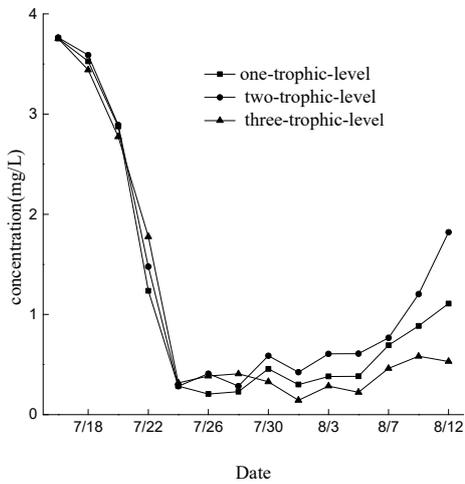


Figure 7. NH₃-N changes over time

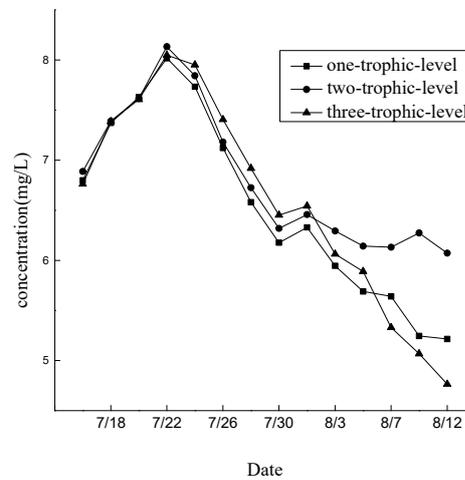


Figure 8. NO₃-N changes over time

3.5.3. *Nitrate Nitrogen* The concentration change of nitrate nitrogen ranged between 5.21-8.02 mg/L in the one-level microcosm, between 6.07-8.13 mg/L in the two-level microcosm, and between 4.76-8.05 mg/L in the three-level microcosm. The slight increase of nitrate nitrogen at the initial stage is due to the formation of nitrification in the water. The decrease in the concentration of nitrate nitrogen later is because of the reason that the concentration of ammonia nitrogen in the water is too low, and the algae in the water consumes nitrate nitrogen as the main nitrogen source to maintain normal physiological activities, resulting in a decrease in its concentration. The concentration of nitrate in the three-level system was lower than that of the other two trophic levels, probably because the amount of algae in the three-level trophic system is large, the algae uses nitrate as nutrients. (See Figure 8)

3.6. Phosphorous

3.6.1. Total Phosphorous For the three trophic systems, the concentration of total phosphorus decreased. The concentration change of total phosphorus ranged between 0.01 - 0.11 mg/L in the one-level microcosm, ranged between 0.02 - 0.12 mg/L in the two-level microcosm, and ranged between 0.04 - 0.12 mg/L in the three-level microcosm. The concentration of total phosphorus in the water decreased due to the predation of fish and debris sedimentation. The total phosphorus content in the three-level trophic system with fish was higher than that of the other two trophic systems. Because of the metabolism of the fish, the organic phosphorus can be converted into phosphate, then be discharged into the water. (See Figure 9)

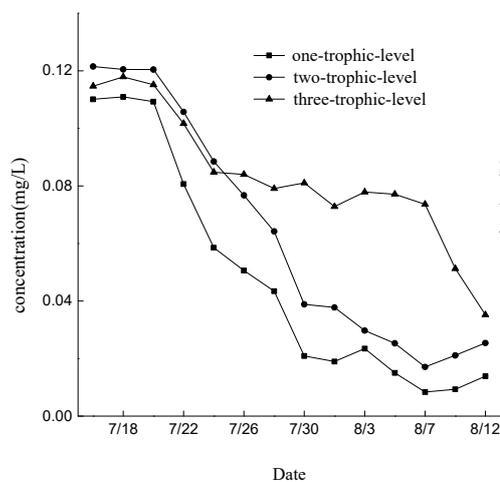


Figure 9. TP changes over time

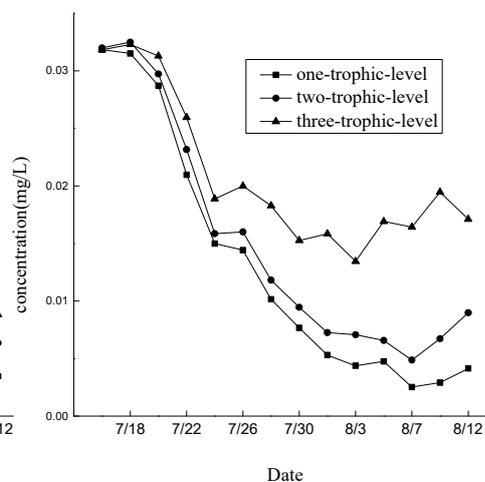


Figure 10. Phosphate changes over time

3.6.2. Phosphate The trend of phosphate change was similar to that of total phosphorus. The change of phosphate concentration ranged between 0.003 - 0.032 mg/L in the one-level microcosm, ranged between 0.005 - 0.032 mg/L in the two-level microcosm, and ranged between 0.013-0.032 mg/L in the three-level microcosm. The phosphate concentration of the three-level trophic system was higher than that of the other two trophic systems. Due to the growth of algae in water absorbs the phosphate, resulting in a decrease in phosphate concentration. Because of the metabolism of the fish, the circulation of phosphorus is accelerated, and the organic phosphorus is converted into phosphate, then been discharged into the water. The phosphate concentration of the three-level trophic system shows that the fish in water has a great influence on phosphate. (See Figure 10)

4. Conclusions

According to the analysis of the experiment data, it can be concluded that, the one-level trophic microcosm system has good effects on controlling the nitrate nitrogen, phosphate and total phosphorus; the two-level trophic microcosm system has good effect on controlling the chlorophyll a, also has a comparatively good effect on controlling the phytoplankton biomass; the three-level trophic microcosm system has good effect on controlling the ammonia nitrogen and total nitrogen, the pH stability is good as well; but controlling effect of the three-level trophic microcosm on the algae is not so good, probably because the fish is omnivorous.

Suggestions for controlling eutrophication: ① Add plant-eating fish such as crucian, chub, and *aristichthys nobilis* to control the phytoplankton biomass. ② Add the zooplankton in the landscape lake to increase the predation of phytoplankton in the water. At the same time, add large carnivorous fish and small fish that feed on zooplankton reduce the predation pressure of zooplankton. ③ Plant a large amount of aquatic plants to absorb nutrients in water, and remove the aquatic plants through fishing

and other means to reduce the content of nitrogen and phosphorus in water. ④ In the landscape lake dominated by one-level or two-level trophic systems, it shall pay attention to the management and control on the nitrogenous elements in the water; in the landscape lake dominated by the three-level trophic system, it shall pay attention to the control of the concentration of ammonia nitrogen and phosphorus in the water to effectively control the eutrophication of water.

Prospect: The microcosm system can be further improved: add the substrate sludge in the aquarium, thus considering the exchange process of substances as nutrients between the substrate sludge and water, and exploring its influence on the eutrophication of the water; add aquatic plants to explore the mechanism of aquatic plants acting on eutrophication of water, and the interaction between aquatic plants and phytoplankton, zooplankton and fish.

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