

Practice of Water Ecological Restoration of Large Urban Eutrophication Lake—A case of study of Donghu Lake, Wuhan

Shenghua Hu^{1,2,*}, Feichao Shu¹, Junwei Deng², Zhongkui Wu², Changwen Zhou², Xiaoming Li¹

¹ Wuhan Bridge Engineering Co., Ltd, Wuhan 430071, China

² Wuhan Hangfa Ruihua Ecological Technology Co., Ltd., Wuhan 430063, China

Abstract: Submerged macrophytes are the main components of lake ecosystems, and restoration of submerged macrophyte community is an important part of restoring lake ecosystems. Taking Water Ecological Restoration Projects in Wuhan Donghu Lake as an example, Combined with the current situation of the Donghu Lake environment, the submerged phytoremediation area, the restoration species of each sub-lake and the submerged plant configuration plan were determined. The planting of submerged macrophyte adopts the process of "selecting the area - removing debris and repelling fish ecologically - improving the substrate - setting the line - planting". Since the project was implemented, the submerged macrophyte grow well, the coverage of plants reaches more than 70%, and the transparency can reach more than 120cm, which meets the design requirements basically.

Key words: Hydroecology restoration; Submerged macrophyte; Urban lake

1. Introduction

Donghu Lake is the second largest lake in Wuhan city (with a water area of about 33.63km²), which has played an important role in urban development. However, with the development of the city, the ecosystem function of Donghu Lake has been seriously degraded, which needs to be systematically repaired. There are some problems in aquatic ecology, such as single community structure of aquatic plants, small distribution range and serious degradation of aquatic vegetation[1]. The submerged plant restoration project is a process of increasing species diversity of submerged plants[2] and an effective means to improve the water quality and ecological environment of urban eutrophic lakes[3, 4]. At present, the application and successful implementation of aquatic plant community restoration technology in China are mostly concentrated in small and medium-sized lakes, such as Nanjing Yueya Lake[5], Ma'anshan East Lake[6], Guangzhou Xiaocui Lake[7] and urban park landscape water bodies[8]. How to effectively restore submerged plant communities in large freshwater lakes is still a blank in China. With the country's emphasis on water environment, it advocates the concept of ecological civilization of respecting nature, conforming to nature and protecting nature. Therefore, the water ecological project of Donghu Lake in Wuhan has a strong demonstration significance and function, which can provide reference and engineering application demonstration for the treatment of eutrophic shallow lakes in large cities.

2. Project overview

Wuhan Donghu Lake Water Ecological Restoration Project is one of the sub-projects of Donghu Lake Water Environment Improvement Project, which covers the whole Donghu Lake. The submerged plant restoration area includes 8 sub-lakes, including Shaojiu Lake, Tanglinghu Lake, Xiaotianhu Lake, Guozhenghu Lake, Miaohu Lake, Lingjiaohu Lake, Houhu and Tuanhu Lake. The restoration of aquatic vegetation in Donghu Lake follows the principle of planting submerged plants, partially dotted with floating plants and emergent plants. According to the present situation of lake water environment, the submerged vegetation restoration area is determined to be about 3.2km².

3. Goal of water ecological restoration

By constructing a perfect ecological community, a submerged plant community with complex spatial structure, rich species and good water purification effect will be formed, and finally the goal of repairing the water environment of Donghu Lake will be achieved.

* Corresponding author: otto2003@126.com

4. Restoration design of submerged plants

4.1 Selection principle of submerged plants

The first step in the implementation of aquatic vegetation restoration is the selection of species for aquatic vegetation restoration. According to the field situation of the restoration area, the following principles are followed: selecting the species or species combination that once appeared as dominant species in this area; choosing species with strong colonization ability, wide ecological range and strong tolerance as pioneer species; selecting species with fast amplification speed, large biomass and easy management as constructive species; selecting species with long life cycle and stable biomass as redundant species to improve the level of community diversity; trying to use native species, strictly control or put an end to the use of exotic species, especially invasive species; choosing to purify the water quality and stabilize the sediment as the main starting point, taking into account the landscape effect.

4.2 Submerged plant species

According to the historical investigation results[1] and previous research data[9], submerged plants suitable for planting in Donghu Lake were screened. The Donghu Lake in Wuhan was once widely distributed with submerged plants such as *Vallisneria natans*, *Ceratophyllum demersum*, *Vallisneria denseserrulata*, *Myriophyllum spicatum*, *Potamogeton malaianus* and *Potamogeton maackianus*. Based on the existing research results[10-13], the environmental status of each lake, and the above selection principles, it is determined that six submerged plants, namely, *Sophora alopecuroides*, *Myriophyllum spicatum*, *Haematococcus verticillata*, *Potamogeton microphylla* and *Potamogeton malayi*, are the submerged plants planted in the water ecological restoration project of Donghu Lake.

Compared with a single species, the combination of submerged plants has a better purification effect on pollutants such as organic matter, nitrogen and phosphorus[14], and the algae inhibition efficiency is significantly higher than that of single planting[15]. Submerged plant combinations such as "*Sophora alopecuroides* and *Ceratophyllum*", "*Haematococcus verticillata* and *Ceratophyllum verticillatum*" and "*Sophora alopecuroides* and *Ceratophyllum verticillatum*" all have good purification effects on water pollutants. Therefore, the submerged plant planting combination of each sub-lake in Wuhan Donghu Lake is finally determined. The results are shown in Table 1, and the submerged plant planting area of each sub-lake is shown in Figure 1.

Tab. 1 The kinds of submerged macrophyte in every sub-lake of Donghu Lake in Wuhan

Lake name	Major repair species	Collocation species
Guozhenghu Lake	<i>Vallisneria natans</i> 、	<i>Hydrilla verticillata</i> 、
	<i>Myriophyllum spicatum</i>	<i>Ceratophyllum demersum</i> 、
	<i>Vallisneria natans</i> 、	<i>Potamogeton maackianus</i> 、
Tanglinghu Lake	<i>Myriophyllum spicatum</i> 、	<i>Potamogeton malaianus</i>
	<i>Hydrilla verticillata</i>	<i>Potamogeton maackianus</i> 、
	<i>Vallisneria natans</i> 、	<i>Potamogeton malaianus</i>
Lingjiaohu Lake	<i>Myriophyllum spicatum</i> 、	<i>Hydrilla verticillata</i> 、
	<i>Potamogeton maackianus</i>	<i>Ceratophyllum demersum</i>
	<i>Vallisneria natans</i> 、	
Xiaotanhu Lake	<i>Hydrilla verticillata</i> 、	<i>Potamogeton maackianus</i> 、
	<i>Ceratophyllum demersum</i>	<i>Potamogeton malaianus</i>
	<i>Vallisneria natans</i> 、	
Shaojihu Lake	<i>Ceratophyllum demersum</i> 、	<i>Potamogeton maackianus</i>
	<i>Potamogeton malaianus</i>	
	<i>Vallisneria natans</i> 、	
Tuanhu Lake	<i>Hydrilla verticillata</i>	<i>Myriophyllum spicatum</i> 、
	<i>Vallisneria natans</i> 、	<i>Potamogeton malaianus</i>
	<i>Hydrilla verticillata</i>	
Houhu Lake	<i>Hydrilla verticillata</i>	<i>Ceratophyllum demersum</i> 、
	<i>Vallisneria natans</i> 、	<i>Potamogeton malaianus</i>
	<i>Hydrilla verticillata</i>	
Miaohu Lake	<i>Hydrilla verticillata</i> 、	<i>Hydrilla verticillata</i> 、
	<i>Ceratophyllum demersum</i> 、	<i>Ceratophyllum demersum</i> 、
	<i>Myriophyllum spicatum</i>	<i>Potamogeton maackianus</i>

4.3 Planting submerged plant

(1) Planting process

Submerged plants: selecting the area - removing debris and repelling fish ecologically - improving the substrate - setting the line - planting.

The submerged plant planting area is separated from the main lake area of Donghu Lake by impermeable enclosure to reduce the influence of external environment on the planting area. The watertight enclosure is laid with steel pipe (DN80 galvanized steel pipe, 6m single) piles. Then remove the sundries and floating objects on the water surface in the watertight enclosure; Ecological measures such as trawling, artificial flapping on the water surface and ground cages are adopted to drive herbivorous fish and large-scale omnivorous bottom fish (carp, crucian carp, etc.) to designated lakes. Then, before the aquatic plants are planted, the improver is sown to improve the bottom material in the purse seine, and the corresponding seed-throwing seedlings, cutting seedlings and bed-sinking seedlings are prepared. Finally, the planting line is calibrated with bamboo poles and ropes in the planting area, and the submerged plants are planted according to the planting line. In the later stage, the seedlings of submerged plants should be managed and maintained, and the floating and dead seedlings should be salvaged in time and replanted.

(2) Planting area and planting density

Submerged plant recovery areas are mainly distributed in areas with a water depth of about 2m, high water transparency, suitable nearshore sediment, less wind and waves and far from the waterway. The planting density of submerged plants in Donghu Lake is 16 clumps/m² and 5 plants/clump.

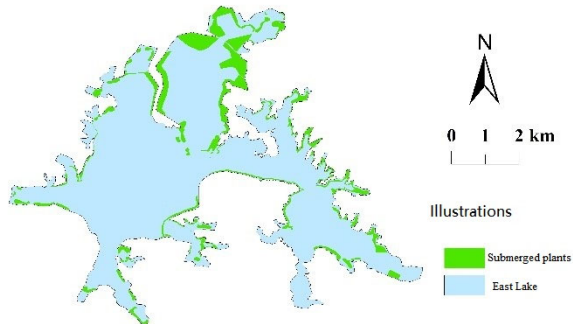


Fig. 1 The distribution of submerged macrophyte restoration areas of Donghu Lake in Wuhan

(3) Planting method

The sediment types of Donghu Lake can be roughly divided into riprap-gravel hard sediment, natural silt sediment and the combination of them. The roots of submerged plants in riprap gravel base can not be planted, so it is necessary to use degradable non-woven fabric to wrap and throw seeds. The natural basement has a lot of subsoil and soft soil, which is suitable for cutting. Therefore, the restoration of submerged plants in Donghu Lake mainly adopts seed throwing method and cutting method, and the submerged bed planting method is adopted in the local deep water area. According to the underwater topography and sediment characteristics of different sub-lake areas, seed throwing method and submerged bed planting method are adopted in areas with deep water depth; Seed throwing method and cutting method can be used in other areas. Three construction methods of submerged plant are shown in Figure 2.



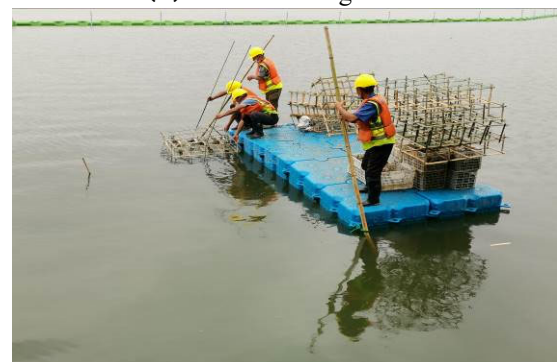
(a) Cutting method-artificial cutting



(b) Cutting method-auxiliary tool cutting



(c) Seed throwing method



(d) Immersed bed planting method

Fig. 2 Three planting methods of submerged macrophyte of Donghu Lake in Wuhan

5. Effect evaluation

Through the construction of perfect ecological community, scientific planting and maintenance technology, the sub-lakes of Donghu Lake are targeted and improved, and the water environment of Donghu Lake is obviously improved. Submerged plants grow well, the plant coverage is obviously improved, and the transparency of water body is obviously improved.

Taking the demonstration area of Donghu Lake Ezui area as an example, in the submerged plant restoration area, the plants grow well, the underwater forest appears, the water quality is clearly distinguished from the enclosure, the transparency of the water in the enclosure is significantly improved, and the overall sensory effect is better. The coverage of submerged plants in the impermeable enclosure can reach more than 70% and the transparency can reach 120cm. The growth of submerged plants in the remediation area is shown in Figure 3 and Figure 4.



Fig. 3 Aerial photo of submerged macrophyte planting area of Donghu Lake in Wuhan



Fig. 4 Underwater photography of submerged macrophyte planting area of Donghu Lake in Wuhan

References

1. ZHONG Aiwen, SONG Xin, ZHANG Jing, et al. Diversity and distribution of aquatic plants in Lake Donghu in Wuhan in 2014 [J]. *Research of Environmental Sciences*, 2017, 30(3): 398-405.
2. HU Shenghua, LIN Qingwei, DAI Zhigang, et al. Change of species diversity during the restoration process of submerged macrophyte in Xihu Lake, Hangzhou [J]. *Ecology and Environmental Sciences*, 2018, 27(8): 1440-1445.
3. HUANG Xiaolong, GUO Yanmin, WAN Bin, et al. Effect of submerged macrophytes restoration on the ecological environment of urban eutrophic lake[J]. *Environmental Engineering*, 2018, 36(07):17-21.
4. CHENG Xiaoying, LI Shijie, PU Peimin. Ecological restoration of urban eutrophic lakes—a case study on the physical and ecological engineering in Lake Mochou, Nanjing[J]. *Journal of Lake Sciences*, 2006, 18(3):218-224.
5. YUAN Peng, XU Liankui, KE Baoling, et al. Treatment and ecological restoration of black and odorous water body in Yueya Lake in Nanjing City[J]. *Journal of Environmental Engineering Technology*, 2020, 10(5): 696-701.
6. WU Shuyuan, FENG Zhifei, ZHU Hongsheng. Engineering design of water purification and water ecological remediation for urban inner lake—A case of Ma'anshan East Lake[J]. *Water Purification Technology*, 2020, 39(S2): 149-154.
7. XIE Danping, JIANG Dong, LIU Aiping, et al. Study on Ecological Restoration of Xiaocui Lake[J]. *CHINA WATER & WASTEWATER*, 2009, 25(07):17-21.
8. ZHAN Meida, LIN Peibin, ZHANG yang, et al. Practice of ecosystem restoration and water quality improvement project on urban landscape water —— Taking landscape lake of Shenzhen Longtan Park as an example[J]. *Environmental Ecology*, 2020, 2(11):57-62.
9. YU Dan, TU Manghui, LIU Lihua, et al. Changes of floristic composition of aquatic plants in a shallow, eutrophic Chinese lake(Donghu Lake) from 1954 to 1994[J]. *ACTA HYDROBIOLOGICA SINICA*, 1998(03):219-228.
10. ZHANG Zhihao, WU Xiaofu, LI Wei. Functions of submerged macrophytes in in-situ ecological restoration of eutrophic waters[J]. *Journal of Central South University of Forestry & Technology*, 2018, 38(03):115-121.
11. WANG Shoubing, XU Ziran, ZHANG Jie. Dynamic changes of higher submerged macrophytes in Dianchi Lake in recent 50 years and implication for ecological restoration[J]. *Water Resources Protection*, 2016, 32(06):1-5.
12. ZHANG Miao, LI Mingmeng, LIU Lv, et al. Effects of in-situ ecological restoration in nanhu lake, a hypertrophic urban lake, China[J]. *Oceanologia et Limnologia Sinica*, 2021, 52(06):1399-1407.
13. ZHANG Meng, CAO Te, GUO Longgen et al. Restoration of Constructed Hydrophytes Community in East Lake of Wuhan and Experimental Study on Water Quality Improvement[J]. *ENVIRONMENTAL SCIENCE & TECHNOLOGY*, 2010, 33(06):154-159.
14. QIAN Zhenyu, CHEN Mei. Purification Effect of Different Submerged Macrophytes and Their Combinations on Water Quality[J]. *Journal of Anhui Agricultural Sciences*, 2019, 47(01):64-67.
15. LI Wei. The Research on purification effect of 6 common submerged plants on eutrophic water in Hunan Province[D]. *Central South University of Forestry&Technology*, 2018.