

The Aquatic Vegetation Recovery Plan in Dianchi Lake, China*

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Abstract: *The specific methods used for recovery of the aquatic ecological system in the shallow lake are proposed. This research has been done from three aspects: 1) the design of the species used for the ecological recovery; 2) the design of optimization and allocation of the aquatic communities; and 3) the design of regional arrangement of the aquatic communities. On the basis of research, the pioneer plant and the species used to establish the communities are proposed. The aquatic plant allocation focuses on the emergent aquatic plant and submergent aquatic plant. Meanwhile, the regional arrangement has been done in the aquatic plant recovery area in the Caohai Lake and the east west bank of the outer lake.*

Keywords: *Dianchi Lake, aquatic vegetation, recovery*

1. Introduction

Dianchi Lake, a big famous fresh lake in China, is located in the lower reach of Kunming City, Yunnan Province. It is an important water source for people on one hand. On the other hand, the waste water are discharged into it. In the 1960s, the water quality in Dianchi Lake is very high and it is abundant in aquatic life. But, with the development of social economy and population, the eutrophication is now becoming more and more serious. Take the tracheophyte as an example, there are 28 families and 44 species in the 1950s. There are 22 families and 30 species in the 1970s. There are only 12 families and 20 species at the end of 1980s. Moreover, there are fewer of them in the 1990s. Now, some sensitive aquatic communities are on the verge of extinction. The area of aquatic vegetation has been reduced dramatically and these aquatic communities are migrating towards the shallow area. The ecological conditions and ecological systems formed the inner mechanism for the ecological evolution of the lake. Moreover, the eutrophication appeared because of nutrient factors and environmental factors.

The attention from national, provincial and municipal government has been paid to the pollu-

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tion problem of Dianchi Lake. A lot of foreign investment such as the World Bank loan, Swedish government loan and Australian government loan are introduced for this treatment. The specific projects include: point pollution treatment (eight urban waste water treatment plants with the treatment capacity of $585\ 000\text{m}^3\cdot\text{d}^{-1}$), waste interception project, internal pollution treatment (sediment dredging project of Caohai Lake) and key industries pollution control. Totally, there are 18 projects and total investment is 3.5 billion RMB. The foreign investment used for the comprehensive treatment is about 0.15 billion dollars and is about 39 percent of the total investment. The implementation of above projects is just one part of the Dianchi Lake pollution treatment. What is more, the ecological projects are also necessary for setting up a beneficial ecological cycle and for the improvement of the water quality.

2. Species design of the ecological recovery project

This project focuses on the submergent plant and emergent plant that are suitable for the water environment of Dianchi Lake.

2.1 Choice of the pioneer plant and community establishing plant

Four principles would be satisfied: 1) wide adaptability and certain pollution resistibility; 2) high water-purification ability; 3) easy reproduction and plantation; and 4) direct or indirect value and benefit.

2.1.1 Choice of submergent plants

(1) *Myriophyllum spicatum*: It is one of the existing aquatic plant in the Dianchi Lake and can grow in the water as deep as 4m under the water. The ratio of depth and transparency is 3 to 1. *M. spicatum* has a high pollution tolerant ability. It is the best pioneer plant and community establishing species for the aquatic vegetation recovery in Dianchi Lake.

(2) *Potamogeton pectinatus*: It is one of the existing submergent plants of Dianchi Lake. It grows in those places between 0.4m-2.5m under the water. The *P. pectinatus* can be the dominant species of the community and associated species are *M. spicatum* and *P. crispus*. The *P. pectinatus* has a wide adaptability and pollution tolerant ability. It even can grow in those places with serious pollution and low water transparency.

(3) *Potamogeton crispus*: It is one of the existing submergent plant of Dianchi Lake. It grows as deep as 1.5m under the water. It can grow better in those shallow areas with deep sediment and small waves. It always can be the dominant species and the associated species are *M. spicatum* and *P. pectinatus*.

(4) *Elodea nuttallii*: The *E. nuttallii* belongs to the Frogbit family and it is one of the perennial submergent plants. It was originated from Africa and was transplanted to Europe and Japan. We know from the experimental results that it has a high adaptability and high reproduction ability. Meanwhile, it is easy to cultivate.

Except the above species, we also could choose the following allocation species: a) *Vallisneria*

giganter; b) *Ceratophyllum demersum*; c) *Hydrilla verticillata*; d) *Chara vulgaris*.

2.1.2 Choice of emergent plants

(1) *Zizania caduciflora*: It is one of the existing plant of Dianchi Lake. It grows between 0.5-2.0m under the water. Commonly, there are some other submergent plants among the *Z. caduciflora*. The *Z. caduciflora* has a high organism quantity and grows very fast. It also has high pollution resistibility and fertility resistibility. Its tender leaves and fruit are edible as vegetables. The *Z. caduciflora* can be used as green fertilizer and feed stuff, too.

(2) *Phragmites australis*: As one of the dominant emergent plants in the history of Dianchi Lake, *P. australis* can grow as deep as 1.5m under the water. It has a high adaptability and has no strict requirement for the soil. It always can be the dominant species because it has strong stem and can creep firmly. The stems of *P. australis* can be used as the raw material for paper and handicrafts. It is a good water retention plant, too.

3. The design of optimization and allocation of the aquatic communities

The community types and allocation can meet the requirement of the entire ecological recovery. Furthermore, the chosen communities used to have a wide distribution in Dianchi Lake in history. These are the basic principles of allocation.

Four submergent plants are used in allocation communities, i.e. *M. spicatum*, *P. petinatus*, *P. crispus*, and *E. nuttallir*, *P. australis*, *Z. caduciflora* communities are considered as emergent plants.

From the bank of the lake to the center of the lake, the allocation orders of all different kinds of communities are: 0.5 m-1.5 m in depth, *P. australis* community; 1 m-2 m, *Z. aduiflora* community; 1.5 m-2.5 m, *P. crispus* and *P. petinatus* community; 2.5 m-3.5 m, *M. specatum* community. On the basis of the successful recovery of the above endemic species, the *E. nuttallir* can be introduced to some suitable places.

The main community characteristics after the recovery of different communities are showed in the Table 1, Table 2, Table 3 and Table 4, respectively.

Tab.1 Main Characteristics of the Communities

Species	Myripyllum spicatum			Potamogeton petinatus			Potamogeton crispus		
	Structure level	Abundant(%)	Coverage(%)	Structure level	Abundant %	Coverage %	Structure level	Abundant %	Coverage%
Myripyllum spicatum	I	60-70	70-80	I	10	60-80	I	10	70-80
Potamogeton petinatus	II	10	70-80	II	50-70	60-80	II	20	70-80
Potamogeton crispus	II	10	70-80	I	10	60-80	I	50	70-80

4. Regional arrangement design of the aquatic communities

The shape of Dianchi Lake is just like a bow and it is hunch-backed towards the east. A man-made barrage into a small inner lake, the Caohai Lake (8 km²) and the much larger outer lake, the Waihai Lake (292 km²), divides the lake. There is only a watercourse between them. The Caohai

Lake is the key area of the aquatic vegetation recovery. The eastern and western banks of Waihai Lake are the aquatic vegetation recovery areas.

Tab.2 Main Characteristics of *Elodca nuttallir*

Species	Elodca nuttallir		
	Structure level	Abundant %	Coverage %
Elodca nuttallir	I	70	70-80
Chara vulgaris	II	10	70-80

Tab.3 Main Characteristics of *Zizania caduciflora*

Species	Zizania caduciflora		
	Structure level	Abundant %	Coverage %
Zizania caduciflora	I	70-80	
Ceratophyllum demersum	II	5	90
Hydrilla verticillata	II	5	90
Potamogeton malainus	II	5	90

Tab.4 Main Characteristics of *Phragmites australis*

Species	Structure level	Abundant %	Coverage %
Phragmites australis	I	70-80	70-80

4.1 Regional arrangement of the aquatic plant of Caohai lake

(1) Dagan Park to Louwailou: Recover the *V. giganter* and *C. demersum* communities for the sake of the navigation.

(2) Louwailou to the holiday village of public security: Recover the submergent plant, especially the *V. giganter* community, allocate the *M. spicatum* and *P. crispus* that have high pollution durability on the western bank and allocate some *C. demersum* and *H. verticillata* on the eastern bank.

(3) The broken bridge between the inner and outer lake: Natural recovery is favored.

As for other parts of Caohai Lake, various submergent plants can be recovered because of the improvement of water quality. The allocation of other species among the dominant community can form diversified vegetation belt in order to improve the stability of community.

From the mouth of Chuanfang River and Xiba River to the broken bridge (50 hm²), the *P. petinatus*, *M. spicatum*, *P. crispus*, *P. petinatus* and *P. crispus* are recovered in turn from the bank to the center of the lake.

(4) The water area of Xiyuanwan and Yang village of outer Caohai Lake is the fishery area. The *E. nuttallir* is recovered because of its good economic benefit.

(5) As more as possible species, especially the submergent plant, are recovered in the eastern, southern and central part of the outer Caohai and the submergent botanical gardens are established. After the establishment of the submergent plant which are pollution tolerant, more species are introduced to the central lake and the bank at the middle stage in view of the historical distribution

law of the aquatic life and the present environmental conditions of Caohai lake.

4.2 Regional arrangement of the aquatic vegetation recovery of outer lake

(1) On the eastern bank of Dianchi Lake, the main recovered community is submergent plant. From 0m to 1.5 m on the bank, the *P. australis* is recovered. From 1.5 m to 3.5 m, the submergent plant area is established. The *P. crispus*, *P. petinatus* and *M. spicatum* are allocated in turn. The main recovery area is the Luojiayin from which the potable water are taken.

(2) On the western bank of Dianchi Lake, the *Z. caduciflora*, *C. demersum*, *P. crispus* and *M. spicatum* are recovered in turn from the lakeside to the place as far as 2.5m. In the spawning area of fish such as Huiwan and Xihuawan, other species are allocated in order to recover the previous biodiversity.

5. Concluding remarks

The aquatic plant is a main component of the lake ecological system and their existence is very important for the establishment and operation of the ecological system. The recovery of the aquatic vegetation of Dianchi Lake can adjust the nutrient structure of the ecological system, promote the beneficial cycle of the ecological system. Accordingly, the environmental capacity and self-purification can be improved and the goal of water quality improvement and eutrophication control can be reached.

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