Quantitative Evaluation of Plant Priority Protection in Cao Lake Wetland Nature Reserve

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Abstract. Based on the survey data of plant resources in Cao Lake Wetland Nature Reserve, using analytic hierarchy process (AHP) and square root method, the evaluation system of plant priority protection was constructed. From three aspects of endangered coefficient, genetic coefficient and species coefficient, the plant species in the reserve were evaluated quantitatively and comprehensively, and the protection levels were divided. The results showed that there were 179 plant species in nature reserve, including 5 endangered species, 9 vulnerable species, 41 near threatened species and 124 least concerned species. The priority protection levels of plants were determined, including 1 species of the primary protection, 12 species of the secondary protection, 20 species of the tertiary protection and 146 species of the delayed protection, and corresponding protection suggestions were put forward. The purpose is to provide more effective background information and data support for the plant protection work and to help protect biodiversity.

1 Preface

With the rapid development of global economy and the rapid growth of population, the research and protection of biodiversity had become a global concern. As one of the important resources for human survival, wetland plays an important role in the global climate environment, ecosystem and biodiversity. In order to protect and restore the wetland ecological environment, a large number of wetland nature reserves had been established in large and medium-sized lakes and important rivers in China [1].

As the background composition of wetland nature reserve, plants are also the primary productivity of the ecosystem. Plant diversity is the basis of biodiversity. The key to the protection of plant diversity is the protection of rare and endangered plants. The establishment of plant protection area and the priority of plant protection can improve the efficiency of plant protection. Therefore, it is of great practical significance to slow down or contain the loss of plant diversity for the protection of regional ecosystem diversity [2].

2 Research area and methods

2.1 Overview of research area

Cao Lake Wetland Nature Reserve is located in Huangpi district, Wuhan city, Hubei province. The geographical location is 30°44'01.5"~30°46'29.2" N, 114° 26'53.07"~114°29'13.3" E. The total area of the reserve is 1148.2 hectares. The core area of the reserve is 387.8 hectares, the buffer area is 3.9 hectares, and the experimental area is

756.5 hectares.

The key protected objects are white crane, Oriental White Stork, cygnet and other rare water birds, wetland ecosystem and biodiversity. The nature reserve is a combination of natural and constructed wetlands. The terrain in the reserve is flat and belongs to the geomorphic type of lacustrine plain. It is mainly composed of yellow brown soil and fluvo aquic soil and herbaceous plants. The climate has four distinct seasons, the annual average sunshine hours are 1540~2180 hours, the average annual precipitation is 1104.6 mm, and the average temperature is 16.4°C. It belongs to the subtropical monsoon climate [3].

2.2 Survey methods

From July to August 2017, the team visited the reserve for many times to conduct plant resource survey and plant priority protection level study. The investigation team used the route survey method and ecological typical sample method.

The survey route was formulated according to the current situation of the wetland nature reserve. Multiple lines covered the whole reserve as much as possible, and the survey sample line perpendicular to the center of the lake was set to find out the ecological environment with different characteristics in the reserve. GPS was used to locate the whole survey, and the plant species along the survey route were recorded.

At the same time, according to the distribution of vegetation and hydrogeological conditions, a total of 10 sample plots with different habitats and vegetation types were set up. The names of plant species, longitude and latitude, altitude, soil condition and human disturbance

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were recorded. Combined with relevant literature and previous investigation reports, the plant list of Cao Lake Wetland Nature Reserve was determined [4].

2.3 Methods of evaluation system construction

2.3.1 Evaluation model

The evaluation model of plant priority protection level in Cao Lake Wetland Nature Reserve was constructed based on analytic hierarchy process (AHP) [5-6], which included three levels: evaluation target layer, evaluation criteria layer and evaluation index layer (Table 1).

Table1. Evaluation model of plant priority protection level

Evaluation target layer (A)	Evaluation criteria layer (B)	Evaluation index layer (C)
Species priority protection value (A)	Endangered coefficient (B ₁)	Domestic distribution frequency (C ₁)
		Provincial distribution frequency (C ₂)
		Sample plot distribution frequency (C ₃)
	Genetic value coefficient (B ₂)	Species type (C ₄)
		Endemic condition (C ₅)
	Species value coefficient (B ₃)	Ecological value (C ₆)
		Medicinal value (C ₇)
		Other values (C ₈)

2.3.2 Evaluation model weight

Using the analytic hierarchy process (AHP), on the basis of the ordered hierarchical structure model, the weight coefficient of the index was comprehensively calculated by comparing the relative importance of each index at the same level. The weight of evaluation index system of plant priority protection level in Cao Lake Wetland Nature Reserve was determined. The result of composite ranking of index layer and target layer of evaluation system was obtained (Table 2). From the consistency test results, the consistency ratio is less than 0.1, so the results of hierarchical total ranking have satisfactory consistency.

Table2. Composite ranking of evaluation index layer and target layer*

Evaluation index layer	B ₁ (0.6370)	B ₂ (0.2583)	B ₃ (0.1047)	Composite weight (ω_i)
C ₁	0.637			0.4058
C ₂	0.2583			0.1645
C ₃	0.1047			0.0667
C ₄		0.75		0.1937
C ₅		0.25		0.0646
C ₆			0.1047	0.0110
C ₇			0.2583	0.0270
C ₈			0.637	0.0667

* $i=1, 2, 3 \dots 7, 8$.

2.3.3 Evaluation index assignment and calculation of endangered coefficient

The endangered coefficient refers to the endangered degree of a plant population in natural distribution.

According to the existing living conditions of plants in Cao Lake Wetland Nature Reserve and relevant literature, the evaluation criteria of endangered coefficient were determined (Table 3).

Table3. Evaluation index assignment of endangered coefficient

Index subdivision	Qualitative description	Score
Domestic distribution frequency (C ₁)	1 province	5
	2 to 3 provinces	4
	4 to 6 provinces	3
	7 to 10 provinces	2
	≥11 provinces	1
Provincial distribution frequency (C ₂)	1 county	5
	2~3 counties	4
	4~6 counties	3
	7~10 counties	2
	≥11 counties	1
Sample plot distribution frequency (C ₃)	1 plot	5
	2 to 3 plots	4
	4 to 5 plots	3
	6 to 7 plots	2
	≥8 plots	1

According to the indexes in Table 3, the plant species in the reserve were graded, and the endangered coefficient of plant species in the reserve was calculated according to Formula 1.

$$V_i = \sum_{i=1}^3 \left(\omega_i \frac{X_i}{X_{i\max}} \right) \quad (1)$$

In the formula, ω_i is the composite weight of index C_i , X_i is the actual score of index C_i , and $X_{i\max}$ is the highest score of index C_i , ($i=1,2,3$).

According to the calculated values, the endangered grades of plants were classified in different value ranges.

Table4. Standards of plant endangered grading

Score of endangered coefficient	Endangered grading
$V_1 \geq 0.7$	Endangered
$0.6001 \leq V_1 < 0.7$	Vulnerable
$0.4 \leq V_1 < 0.6$	Near threatened
$V_1 < 0.4$	Least concern

2.3.4 Evaluation index assignment and calculation of genetic coefficient

According to the genetic loss caused by the extinctions of the investigated plant species to the existing plant diversity, the evaluation criteria of the genetic value coefficient were determined (Table 5).

Table5. Evaluation index assignment of genetic coefficient

Index subdivision	Qualitative description	Score
Species type (C ₄)	Only 1 species in family	5
	2 to 3 species in family	4
	Only 1 species in genus	3
	2 to 3 species in genus	2
	≥4 species in genus	1
Endemic condition (C ₅)	Only in here	5
	Only in Hubei	4
	In region specific	3
	Only in China	2
	In China and other countries	1

The species type was determined according to the classification of families and genera in Flora of China, and the number of families and genera containing species of the investigated plant species was evaluated. The endemic situation was evaluated according to the records of the Flora of China and the Flora of Hubei.

The plant species in the reserve were graded by various indexes in Table 5, and the genetic value coefficient of plant species in the reserve was calculated according to Formula 2.

$$V_2 = \sum_{i=4}^5 \left(\omega_i \frac{X_i}{X_{imax}} \right) \quad (2)$$

In the formula, ω_i is the composite weight of index C_i , X_i is the actual score of index C_i , and X_{imax} is the highest score of index C_i , ($i=4,5$).

2.3.5 Evaluation index assignment and calculation of species coefficient

According to the value of the investigated plant species recognized and exploited by human beings, the evaluation index of plant utilization value coefficient in Cao Lake Wetland Nature Reserve was determined mainly in the aspects of medicine, food, industry, raw materials and Ecology (Table 6).

The ecological value was determined according to the community structure in the sample plots. The medicinal value was determined according to the records of New Chinese Materia Medica and Chinese Pharmacopoeia. The value of other plants was determined according to the records of China Resource Plants.

According to the indexes in Table 6, the plant species in the reserve were graded, and the species value coefficient of the plants in the reserve was calculated according to Formula 3.

Table6. Evaluation index assignment of species coefficient

Index subdivision	Qualitative description	Score
Ecological value (C_6)	Edificators	5
	Co-species of a community	4
	Dominant species other than edificators	3
	Subdominant	2
	Others	1
Medicinal value (C_7)	Included in the Chinese Pharmacopoeia	4
	Included in the New Chinese Materia Medica	3
	General folk medicinal plants	2
	Others	1
Other values (C_8)	Having 3 kinds and above	4
	Having 2 kinds	3
	Having only 1 kind	2
	None	1

$$V_3 = \sum_{i=6}^8 \left(\omega_i \frac{X_i}{X_{imax}} \right) \quad (3)$$

In the formula, ω_i is the composite weight of index C_i , X_i is the actual score of index C_i , and X_{imax} is the highest score of index C_i , ($i=6,7,8$).

2.3.6 Calculation of priority protection coefficient

The endangered coefficient, genetic value coefficient and species value coefficient of each plant species in Cao Lake Wetland Nature Reserve were calculated based on the established plant priority protection level model. According to the proportion weight of each coefficient, the species priority protection coefficient (V) was calculated according to Formula 4.

$$V = B_1 \times V_1 + B_2 \times V_2 + B_3 \times V_3 \quad (4)$$

According to the score of species priority protection coefficient, the standards of plant priority protection grading were developed (Table 7).

Table7. Standards of plant priority protection grading

Score of species priority protection coefficient	Protection grading
$V \geq 0.6$	Primary protection
$0.5 \leq V < 0.6$	Secondary protection
$0.4 \leq V < 0.5$	Tertiary protection
$V < 0.4$	Delayed protection

3 Research results and analysis

3.1 Plant species composition

There were 179 species of plants belonging to 143 genera and 62 families in Cao Lake Wetland Nature Reserve. There were 1 family, 1 genus and 1 species of gymnosperms and 61 families, 142 genera and 178 species of angiosperms. Plant species were not abundant.

The above plant composition characteristics were related to the wetland type of the reserve and the protection object was rare waterfowl. Although the number of plant species was not much, but the proportion of herbs was rich. There were 165 species of herbs, accounting for 92.18% of the total number of seed plants in this area. These characteristics were determined by the environmental factors such as soil and hydrology in Cao Lake Wetland Nature Reserve.

3.2 Endangered coefficient evaluation

According to the data obtained from the survey, combined with the classification standard of plant endangered grade and the classification standard of plant priority protection level, the endangered situation of plants in the reserve was counted.

It can be seen from Table 8 that most of the plants with high endangered coefficient in the reserve were distributed less in the whole country and only exist in some provinces in China. For example, *Ceratopteris pteroides*, *Polygonum bistorta*, etc. There were also a few plants widely distributed in China, but they were rare in Hubei province and had low frequency in the sample plots. For example, *Dichondra repens*, *Daucus carota*, *Pluchea indica*, etc.

It can be seen from Table 9 that among the 179 plant species in Cao Lake Wetland Nature Reserve, 5 species were endangered species, accounting for 2.79% of the total. They were scattered in the reserve and their

individual volume was rare. There were 9 species of vulnerable species, accounting for 5.03% of the total. Some species had special growth environment and few individuals. There were 41 species of near threatened species, accounting for 22.91% of the total. They had a large number of individuals, scattered scattered or dominated by small patches and zonal distribution. There were 124 least concerned species, accounting for 69.27% of the total. On the whole, the species with $V_1 \geq 0.4$ and above account for more than one third of the total, indicating the necessity of establishing the reserve. The existing endangered species, vulnerable species and near threatened species should be monitored and protected in time to make their living environment stable and the population number stable.

Table8. Evaluation of plant endangered coefficient*

Species name	C ₁	C ₂	C ₃	V ₁
<i>Ceratopteris pteroides</i>	4	5	5	0.8715
<i>Oxalis pes-caprae</i>	3	5	5	0.7441
<i>Solanum pseudocapsicum</i>	3	5	5	0.7441
<i>Alnus cremastogyne</i>	3	5	5	0.7441
<i>Leersia hexandra</i>	3	5	5	0.7441
<i>Setaria faberii</i>	3	4	5	0.6927
<i>Geranium carolinianum</i>	3	5	2	0.6813
<i>Commelina communis</i>	4	1	5	0.6657
<i>Polygonum bistorta</i>	4	1	5	0.6657
<i>Artemisia lavandulaefolia</i>	3	4	3	0.6508
<i>Daucus carota</i>	3	3	5	0.6412
<i>Euphorbia hypericifolia</i>	2	5	4	0.6376
<i>Pluchea indica</i>	2	5	5	0.6167
<i>Zoysia japonica</i>	2	5	5	0.6167

* $V_1 \geq 0.6$ are listed.

Table9. Evaluation of plant endangered grading

Endangered grading	Number of species
Endangered	5
Vulnerable	9
Near threatened	41
Least concerned	124

3.3 Genetic coefficient evaluation

According to the data obtained from the survey, combined with the evaluation index of plant genetic value coefficient, the scores of plant genetic value coefficient were calculated.

Table10. Evaluation of plant genetic coefficient*

Species name	C ₄	C ₅	V ₂
<i>Myosoton aquaticum</i>	3	1	0.50
<i>Houttuynia cordata</i>	3	1	0.50
<i>Aeschynomene indica</i>	3	1	0.50
<i>Nelumbo nucifera</i>	2	1	0.35
<i>Nymphaea tetragona</i>	2	1	0.35
<i>Hydrocharis dubia</i>	2	1	0.35
<i>Humulus scandens</i>	2	1	0.35
<i>Gelsemium elegans</i>	2	1	0.35
<i>Melia azedarach</i>	2	1	0.35
<i>Cirsium setosum</i>	2	1	0.35
<i>Zizania latifolia</i>	2	1	0.35
<i>Polygonum bistorta</i>	1	2	0.25

<i>Alnus cremastogyne</i>	1	2	0.25

* $V_2 \geq 0.25$ are listed.

It can be seen from Table 10 that there were 13 species with genetic value coefficient of 0.25 and above in the reserve. Among them, *Houttuynia cordata*, *Aeschynomene indica* and *Myosoton aquaticum* were the highest ($V_2=0.5$). There were 8 species with genetic value coefficient of 0.35. Such as *Nelumbo nucifera*, *Nymphaea tetragona*, *Hydrocharis dubia* and so on. There were 2 species with genetic value coefficient of 0.25. They were *Polygonum bistorta* and *Alnus cremastogyne*. There were no rare and ancient relic plants in the reserve, so the overall genetic value coefficient was not high.

3.4 Species coefficient evaluation

According to the survey data, combined with the evaluation index of species value coefficient, the species value coefficient scores were calculated.

It can be seen from Table 11 that there were 14 species with value coefficient above 0.8 in the reserve. Some of them were important constructive species or dominant species in the reserve, such as *Cynodon dactylon*, *Vicia sepium*, *Imperata cylindrica*, etc. Some of them were widely exploited and utilized by human beings, such as *Morus alba*, *Typha orientalis*, *Zizania latifolia*, etc. There were also some plants with great medicinal value, such as *Celosia argentea*, *Broussonetia papyrifera*, *Phragmites australis*, etc.

Table11. Evaluation of plant species coefficient*

Species name	C ₆	C ₇	C ₈	V ₃
<i>Broussonetia papyrifera</i>	4	4	4	0.9791
<i>Phragmites communis</i>	4	4	4	0.9791
<i>Typha orientalis</i>	1	4	4	0.9162
<i>Celosia argentea</i>	1	4	4	0.9162
<i>Eichhornia crassipes</i>	5	2	4	0.8709
<i>Humulus scandens</i>	5	2	4	0.8709
<i>Cynodon dactylon</i>	5	2	4	0.8709
<i>Imperata cylindrica</i>	5	2	4	0.8709
<i>Vicia sepium</i>	5	2	4	0.8709
<i>Sapium sebiferum</i>	4	2	4	0.8499
<i>Cinnamomum camphora</i>	3	2	4	0.8290
<i>Melochia corchorifolia</i>	3	2	4	0.8290
<i>Morus alba</i>	3	2	4	0.8290
<i>Zizania latifolia</i>	2	2	4	0.8081

* $V_3 \geq 0.8$ are listed.

3.5 Priority protection evaluation

According to the quantitative evaluation indexes and calculation methods of species priority protection value, the endangered coefficient, genetic coefficient, species coefficient and species priority protection value of 179 species in Cao Lake Wetland Nature Reserve were calculated. Then the priority protection order of plant species was analyzed.

It can be seen from Table 12 that there were 13 species with $V \geq 0.5$, accounting for 7.26% of the total. The highest priority protection coefficient ($V=0.6646$) was *Ceratopteris pteroides*. Plants with high endangered

coefficient generally had higher priority protection coefficient. Plants with $V \geq 0.5$, their endangered coefficient was greater than 0.6. For example, *Oxalis pes-caprae*, *Alnus cremastogyne*, *Alternanthera philoxeroides*, etc. Although the weight ratio of genetic coefficient and species coefficient asw not high, it also played a key role in plant evaluation system. For example, the endangered coefficient of *Setaria faberii* was not in the top five, but its genetic coefficient was the highest, so its priority protection coefficient ranks fourth.

It can be seen from Table 13 that among the 179 plant species in Cao Lake Wetland Nature Reserve, 1 species was of the primary protection, accounting for 0.56% of the total. They were rare in the nature reserve and have weak anti-interference ability, so it is urgent to protect and stabilize the population. There were 11 species of secondary protection, accounting for 6.70% of the total. The number of them in the reserve was small. So they need to monitor the status of the population in time, maintain and feel the living environment of the population, and prevent the population from greatly reducing. There were 20 species of tertiary protection, accounting for 11.17% of the total. Most of them were dominant species or sub dominant species in the reserve. They can be used reasonably without special protection measures. There were 147 species of delayed protection, accounting for 81.56% of the total. Most of them were constructive species in the nature reserve, and their self recovery ability is strong after disturbance.

Table12. Evaluation of plant priority protection*

Species name	V_1	V_2	V_3	V
<i>Ceratopteris pterioides</i>	0.8715	0.20	0.4686	0.6646
<i>Oxalis pes-caprae</i>	0.7441	0.20	0.5633	0.5921
<i>Alnus cremastogyne</i>	0.7441	0.25	0.4040	0.5883
<i>Setaria faberii</i>	0.6927	0.20	0.6278	0.5655
<i>Alternanthera philoxeroides</i>	0.7441	0.20	0.3093	0.5655
<i>Solanum pseudocapsicum</i>	0.7441	0.20	0.3093	0.5655
<i>Leersia hexandra</i>	0.7441	0.20	0.2448	0.5587
<i>Geranium carolinianum</i>	0.6813	0.20	0.4594	0.5406
<i>Commelina communis</i>	0.6657	0.20	0.4385	0.5283
<i>Polygonum bistorta</i>	0.6657	0.25	0.2448	0.5209
<i>Daucus carota</i>	0.6412	0.20	0.4686	0.5156
<i>Artemisia lavandulaefolia</i>	0.6508	0.20	0.3076	0.5049
<i>Zoysia japonica</i>	0.6167	0.20	0.4878	0.5017

* $V \geq 0.5$ are listed.

Table13. Evaluation of plant priority protection grading

Protection grading	Number of species	Percentage
Primary protection	1	0.56%
Secondary protection	12	6.70%
Tertiary protection	20	11.17%
Delayed protection	146	81.56%

4 Conclusion and discussion

The evaluation results of the endangered coefficient of 179

plants species in Cao Lake Wetland Nature Reserve showed that there were 5 endangered species, 9 vulnerable species, 41 near threatened species and 124 Least concerned species, accounting for 2.79%, 5.03%, 22.91% and 69.27% of the total respectively. Among them, there were 14 endangered and vulnerable species, accounting for 7.82% of the total. The assessment results of the priority protection level of plants were as follows: 1 species under primary protection, 12 species under secondary protection, 20 species under tertiary protection, and 146 species under delayed protection, accounting for 0.56%, 6.70%, 11.17% and 81.56% of the total respectively.

The protection of rare and endangered plants depends on the overall natural environment and reasonable human intervention. Corresponding protection measures should be taken according to different priority protection levels of plants. For the primary protected plants, artificial propagation should be adopted to increase the population number while preventing human destruction. For the secondary protected plants, it is necessary to prevent man-made destruction. In general, it is not necessary to take special protection measures for them. If the population continues to decline, corresponding measures should be taken in time. The tertiary protected plants can be slightly developed and utilized in the reserve. Avoid the irreversible consequences of over exploitation. Strengthen management and strictly control the development intensity. The number of the population was kept at a relatively stable level. Generally, there is no need to pay too much attention to the delayed protection plants and get corresponding safety protection in the reserve.

Rare and endangered plants, due to their special habitat and rare number, are the strong evidence of plant origin, flora evolution and paleogeological changes. Therefore, the research on the protection of rare and endangered plants plays a key role in the protection of plant diversity and has irreplaceable scientific significance. According to the actual situation of Cao Lake Wetland Nature Reserve, the plants priority protection grading was determined. Compared with the national list of endangered plants, it can provide more effective background information and data support for the reserve to formulate targeted protection plan.

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References

1. R. R. Yan, X. B. Cai, X. L. Wang, Y. Chen, X. Han, WS, 11, 1, 136-144 (2013)
2. Z. R. Liu. IMAU, 101-134 (2017)
3. X. Y. Zhang, S. Y. Tan, H. D. Pang, JAU(NSE), 2, 103-108 (2020)

4. X. Y. Zhang, J. H. Shang, S. J. He, STE, 21, 92-98, (2019)
5. X. Y. Zhang, X. Y. Cai, E3S web of conferences (EDP Sciences, 79, 03010, 2019)
6. Q. Q. Peng, Z. X. Wang, T. T. Li, B. M. Xiong, Q. C. Yang, GUI, 37, 7, 859-867 (2017)