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LANDSCAPE PATTERN AND DESIGN FOR THE ECOSYSTEM IN CONSTRUCTED WETLAND

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Abstract

The urban eco-environment is greatly affected by the ecosystem and landscape pattern of the wetlands nearby. Based on geological information system (GIS), this paper explores the landscape, plant distribution and animal distribution in a constructed wetland of the Yellow River Basin through field survey, identifies the landscape pattern of the ecosystem in the study area through correlation analysis, and thoroughly evaluates the health of the wetland ecosystem based on statistical results. The main conclusions are as follows: First, the water body has the greatest impact on landscape integrity of the constructed wetland, followed by the woodland. The two factors, together with other landscape types, form the overall landscape of the study area. Second, the landscape of the ecosystem in the study area features good continuity, as evidenced by the low degree of fragmentation. Third, the study area enjoys a normal ecological resilience, but has an average ecological value. The research findings lay the theoretical basis for restoring the ecosystem of constructed wetlands, as well as designing, optimizing and evaluating landscape patterns.

Keywords: constructed wetland, ecosystem, landscape design, landscape pattern

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1. Introduction

Wetland is a comprehensive ecosystem with rich biological resources, it provides an important and indispensable place for the survival of biology and ecological development. Scientific research on wetland ecosystems is of great practical importance to the global ecological environment, climate and resources (Chang et al., 2014; Song et al., 2010; Zhang et al., 2014). China has abundant natural and constructed wetland resources, and the wetland types are diverse (Li et al., 2009; Xie et al., 2012; Yuan and Zhang, 2010). However, due to the increase of human activities in the area where wetlands are located, the area of wetland has decreased little by little, the natural wetlands have transformed to constructed wetlands gradually, and the ecological balance and health status of wetlands have been weakened (Li et al., 2011; Yu et al., 2014). In addition, due to the influence of human activities such as resource development and industrial production, the climate environment has gradually deteriorated, the natural wetland structure has been severely damaged around the world, and the wetland area has been greatly reduced, eventually resulting in wetland ecosystem imbalance (Dronova et al., 2012; Joyal et al., 2010; Webb et al., 2010).

As the merging area for the interaction of waterways, wetlands are of great significance for both land and water ecology (Larsen and Harvey, 2011; Murray et al., 2013). The relationship between wetlands and cities is relatively close. As an ecological vitality area that can regulate climate, purify air and water, and adjust drainage and biodiversity, the ecological environment of wetlands has a particularly important influence on the urban living environment. However, survey showed that the situation of natural wetlands is not optimistic. Due to insufficient protection and development planning, natural

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wetlands have suffered great damage and gradually turned into constructed wetlands (James et al., 2009; Passeport et al., 2013; Vetesnik et al., 2010). At present, there are few professional researches on wetland protection, and planning and design of landscape and biology, so it can't effectively guide the wetland protection and maintain the balance of the ecological environment in the region (De Martis et al., 2016; Quesnelle et al., 2015). The continued deterioration of the wetland ecology will result in severe ecological problems. Therefore, we need to carry out researches on natural wetlands and constructed wetlands, and strengthen the implementation of the wetland protection policies.

Based on the above problems, this paper studies the constructed wetland in a certain area of the Yellow River Basin, and combines the field survey and GIS technology to collect the information of the landscape morphology, (Zhang, 2018) plant and animal distributions of the constructed wetland; then it analyzes, designs and evaluates the ecosystem landscape pattern of the constructed wetland, then on this basis, it conducts evaluation on the health status of the ecosystem in the wetland. This study provides a theoretical basis for the restoration of constructed wetland ecosystem, and the design, optimization and health state evaluation of landscape patterns (Li et al., 2018a).

2. Research methods and landscape pattern of constructed wetlands

2.1 Research methods

The research content of wetland landscape pattern usually includes wetland ecological structure, functions, and the change of the pattern (Johnson et al., 2010, Sulman et al., 2013). The analysis of landscape pattern usually conducts systematic researches on the composition, layout characteristics and distribution law of the landscape, and the relationship among various factors; it uses correlation analysis to quantitatively or qualitatively describe the landscape pattern evaluation indices. The landscape pattern evaluation indices are quantitative indices that characterize the spatial distribution of the landscape, the structure of the patches, and the relationship among various factors, generally including landscape fragmentation, diversity index, patch characteristics and continuity etc. When conducting landscape evaluation, proper indices need to be selected according to the environmental conditions.

The research object of this paper is the constructed wetland in a certain area of the Yellow River Basin. The study adopted field investigation and modern geographic information system (GIS) to statistically analyze the landscape distribution and vegetation types in the constructed wetland. Finally, the AHP and other mathematical analysis methods are applied to statistically analyze the data, thereby achieving mathematical analysis and quantification of the landscape pattern of the ecosystem in the constructed wetland (Zhang et al., 2019).

The evaluation of the constructed wetland ecosystem should follow the following principles: first, the indicators of the evaluation system can fully reflect the ecosystem in the evaluation area; second, the indicators can correctly reflect the results and process of human influence; third, the research results of the ecosystem can provide theoretical reference for related departments and provide effective suggestions for the restoration of wetlands. Based on the above principles, the indicators of the constructed wetland ecosystem include: natural characteristics, selection vitality, organizing capacity, resilience and artificial interference, the constructed evaluation system is shown as Fig. 1.

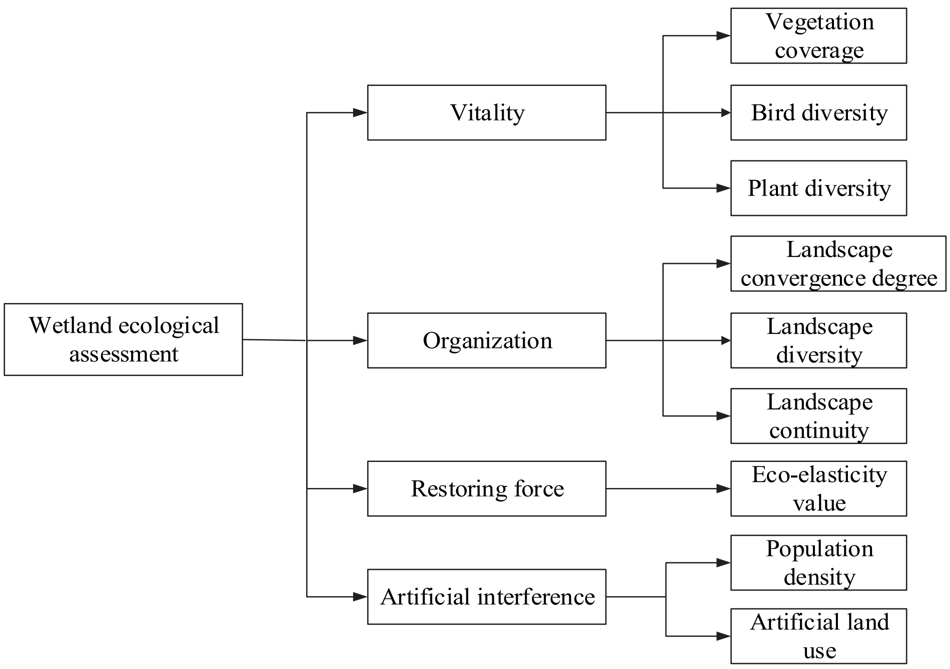

Fig. 1. Evaluation system for the wetland ecosystem

2.2. Constitutive characteristics of constructed wetland landscape

The main components of the constructed wetland landscape include vegetation, birds and water bodies. The survey methods for plants mainly include the arrangement of sampling points and using sampling method to collect the data; the survey method for birds is the line sampling, through which the investigators pass the areas where bird activities are frequent at a constant speed and record the species and quantity of birds on both sides. The diversity index Q can be calculated by Eq. (1):

$$Q = -\sum_{i=R}^{R} Q_i \ln Q_i \qquad (1)$$

where: R is the number of species; Q_i is the proportion of the type i plants. The survey results of the plants are shown in Table 1.

It can be seen from the survey results that the diversity index of the woodland is relatively high, and the diversity indices of the grassland and the woodland are lower. Generally speaking, the plant diversity of the ecological area is low, more vegetation needs to be introduced to the area subsequently, so as to increase the diversity of the wetland landscape and improve the quality of the landscape. For different landscape types, the survey results of bird diversity are shown in Table 2 and Fig. 2. From the obtained results we can see that, the species and quantity of birds in water areas and woodlands are the most, and the diversity indices are relatively close; in addition, in terms of the uniformity, the distribution of the birds in the woodland is most uniform, while in other land types, the concentration degrees of birds are higher. Generally speaking, in the ecological environment of the constructed wetland, the birds are mainly concentrated in water areas and woodlands. It is recommended to increase the continuity between different landscape types, so as to increase the diversity and uniformity of the birds.

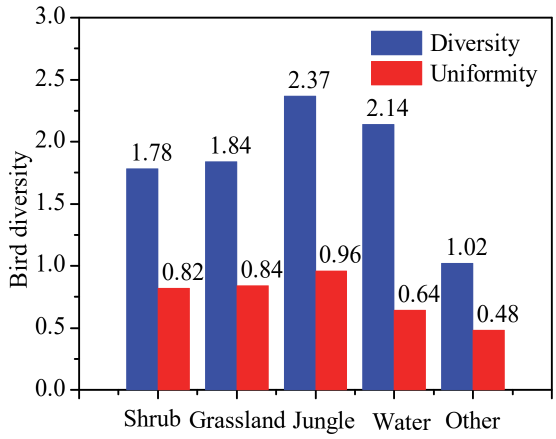

Fig. 2. Bird diversity survey results

3. Analysis and design of the landscape pattern of constructed wetland ecosystem

3.1. Analysis of landscape pattern of constructed wetland

Before analyzing the landscape pattern, first we need to classify the landscape, according to the different land use patterns, the landscape is divided into four types, mainly including: human utilized land, bare land, water area and vegetation. The specific classification is shown in Table 3.

Landscape spatial characteristic analysis contains complex types and various indicators, which are prone to cause mutual interference. To achieve the research goal, proper landscape patter indicators should be selected according to certain principles. Generally, the indicators are divided into three types according to the landscape spatial distribution and complexity, namely the landscape spatial characteristics, the landscape patch characteristics, and the landscape horizontal spatial overall characteristics. (Li et al., 2018b; Li et al., 2019)

Table 1. Vegetation diversity survey results

Type	*Shrub*	*Jungle*	*Grassland*
Diversity index	1.47	2.82	1.24

Table 2. Bird diversity in different landscape types

Type	*Number*	*Bird type*	*Diversity*	*Uniformity*
Shrub	11	50	1.78	0.82
Grassland	8	45	1.84	0.84
Jungle	18	37	2.37	0.96
Water area	23	426	2.14	0.64
Others	5	73	1.02	0.48

Table 3. Landscape classification

Class I Landscape	*Secondary landscape*
Human utilized land	Cultivated land, Orchard, Farming
Water area	Lake, Beach
Vegetation	Jungle, Shrub, Grassland
Bare land	/

Fragstatas was adopted to select the landscape pattern parameters to calculate and analyze the landscape spatial characteristics and overall structure of the constructed wetland, and thereby concluding its distribution law. The landscape patch is the landscape matrix, it can effectively reflect the spatial distribution characteristics of the landscape. The calculation results of the parameters of the constructed wetland landscape space are shown in Table 4.

The total area of the constructed wetland is 56.34 hectares. Other landscape types in the patch type mainly include buildings, farmlands, aquaculture land, and other areas that are largely disturbed by human activities. Histograms for patch area are shown in Fig. 3, the proportion of the patch area is shown in Fig. 4, and the maximum patch area proportion is shown in Fig. 5. It can be seen from these Figures that the patch with the largest area is the water body, which is 27.35 hectares, accounting for 48.54%; shrubs, grassland and other landscape types account for no more than 10%, indicating that the water body is the dominant type of the constructed wetland environment, and the water body and vegetation are dominant in the landscape. In terms of the number of patches, the quantity of shrubs is the most, which is the main landscape type. In terms of the size of the largest patch area, the order from large to small is: water body > woodland > shrub > others > grassland, we can know that the water body has an important role in the landscape integrity of the constructed wetland, the woodland also plays a supporting role, and together with other types of landscape, they constitute the landscape of the constructed wetland.

In order to better analyse the continuity and fragmentation degree of the landscape types of constructed wetland environment, four independent indicators were selected to calculate the landscape pattern, namely the patch density, degree of integrity, landscape shape indicator, and average area of the patch. The landscape fragmentation indicators of constructed wetland ecosystem is shown in Table 5.

To compare the results more intuitively, the data in the Table was converted into corresponding maps, the patch density is shown in Fig. 6 and the average area of the patch is shown in Fig. 7, we can see from these Figures that the patch density of water body is the lowest, the patch density of woodland is the largest, indicating that the water body has a better integrity, its degree of fragmentation is lower.

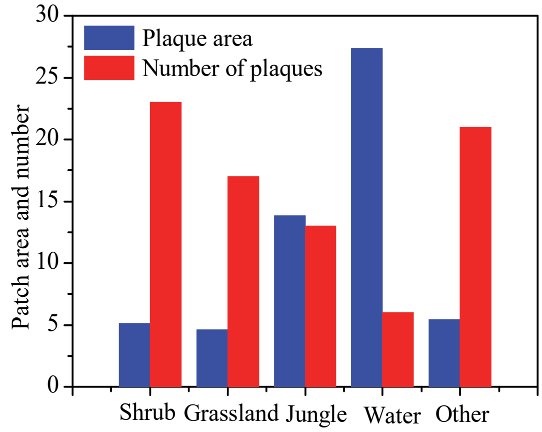

Fig. 3. Number of landscape patches

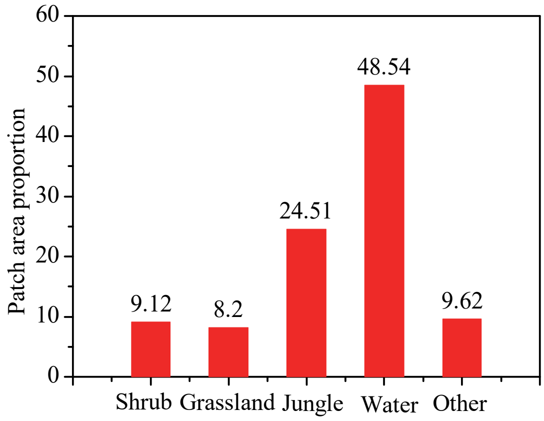

Fig. 4. The proportion of patch area

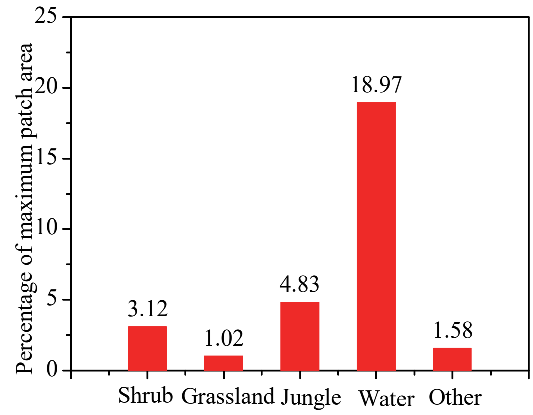

Fig. 5. Maximum patch area

Table 4. Landscape characteristics of different types

Type	*Patch area (hm^2)*	*Patch area proportion (%)*	*Number of patches*	*Percentage of maximum patch area (%)*
Shrub	5.14	9.12	23	3.12
Grassland	4.62	8.20	17	1.02
Jungle	13.81	24.51	13	4.83
Water body	27.35	48.54	6	18.97
Others	5.42	9.62	21	1.58

Table 5. Landscape fragmentation indicators

Type	*Average patch area*	*Patch density*	*Degree of integrity*	*Landscape shape*
Shrub	0.22	38.98	94.31	12.62
Grassland	0.27	35.22	87.42	13.74
Jungle	1.06	62.14	89.53	11.27
Water	4.56	16.23	98.63	7.73
Other	0.26	50.12	92.16	8.35

The densities of woodland and others are larger, indicating the degree of fragmentation is higher, and the distribution is relatively scattered. In terms of the average area of the patch, the degree of fragmentation of the water body is lower, other landscape types have different degrees of fragmentation. From the integrity data we can see that, the landscape of constructed wetland ecosystem has better continuity, the data are close, indicating that the overall degree of fragmentation is not large.

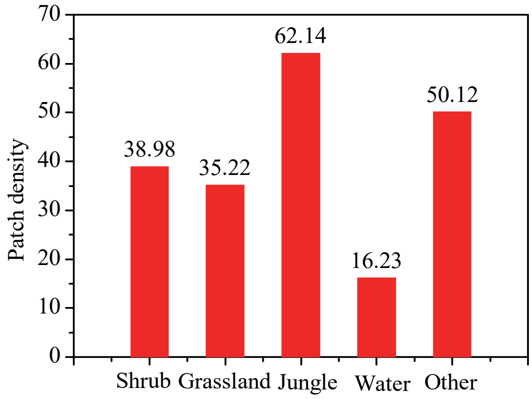

Fig. 6. Patch density map

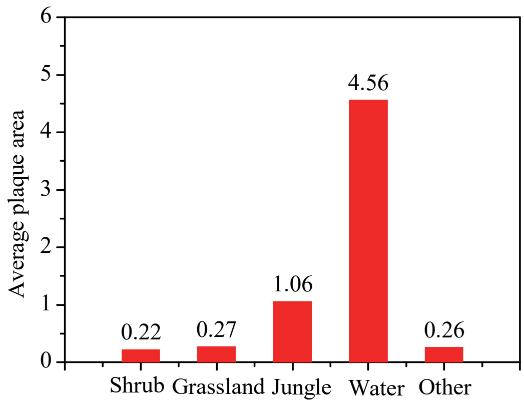

Fig. 7. Average patch area map

The continuity indicator of the landscape is shown in Table 6. The analysis was conducted using three indicators, namely the minimum proximity distance, the average proximity distance, and the continuity degree, which are shown in histograms, respectively (Figs. 8-9). From the analysis of the minimum proximity distance we can see that, the smallest minimum proximity distance of the water body is 8.31, indicating the continuity state of the water body is the best. The largest minimum proximity distance of the shrubs is 26.79, indicating that the distribution of the shrubs is relatively scattered and the continuity is worse.

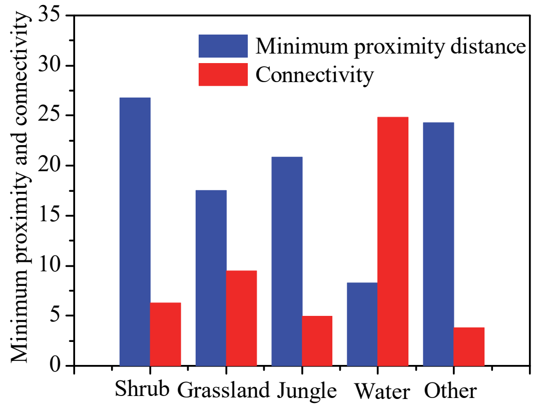

Fig. 8. Minimum proximity and continuity

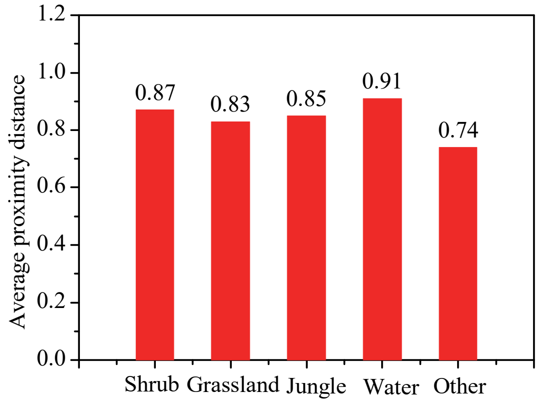

Fig. 9. Average proximity

Table 6. Landscape continuity indicators

Type	*Minimum proximity distance*	*Continuity*	*Average proximity distance*
Shrub	26.79	6.31	0.87
Grassland	17.52	9.52	0.83
Jungle	20.83	4.93	0.85
Water	8.31	24.86	0.91
Other	24.32	3.83	0.74

By comparing the values of the continuity we can know that, the value of the water body is much larger than that of the others, indicating that the water body is less fragmented, followed by the value of the grassland, indicating that the expansion and distribution of the grassland is better than that of the shrubs and the woodland. In terms of average proximity distance, the water body still exhibits the best continuity. Finally, the horizontal characteristics of the landscape of the constructed wetland ecosystem are analyzed, and the results are shown in Table 7 and Fig. 10. It can be seen that the landscape system of the constructed wetland is less complex, the number of vegetation is less, the density is low, and the patch area is smaller, the overall landscape shape is relatively regular, and the continuity is good. The landscape's degree of fragmentation is lower, the vegetation diversity is less, and the landscape shape is not complicated.

Table 7. Indicators of overall landscape pattern

Type	***Number of patches (NP)***	***Index of integrity (AI)***	***Patch density (PD)***
Constructed wetland	80	92.41	40.54
Type	Landscape shape indicator (LSI)	Continuity (CON)	Diversity (SHDI)
Constructed wetland	10.74	9.8	0.63

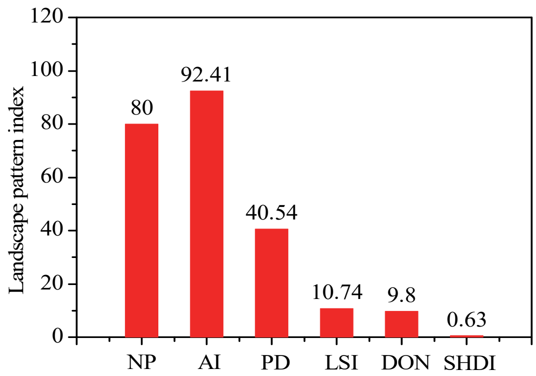

Fig. 10. Indicators of the overall landscape pattern

3.2 Ecosystem design and evaluation

As one of the ways to protect the environment artificially, the constructed wetland ecosystem is of very high research value. According to the indicators of the evaluation system, the relevant indicators were calculated and combined with field investigation to yield the results, each indicator was assigned, and the current status of the ecological environment in the constructed wetland was obtained as shown in Table 8. According to different evaluation indicators and the actual survey results, the following problems need to be solved. In terms of the water body, if the change of water level exceeds 1 meter, it is not conducive to the survival of aquatic plants in the wetland environment, and the water quality is severely polluted by organic matters. In terms of plant composition, the plant coverage is low, the plant diversity is few, the composition structure is simple, there's species invasion phenomenon, and the plant vertical structure distribution is simple. In terms of wetland landscape pattern distribution, the landscape is mainly the woodland and waterscape, the overall continuity of the landscape is average, the water body distribution is uneven, so we can increase the number of islands and the coverage of vegetation.

Table 8. Ecosystem evaluation indicators

Principle	***Evaluation indicators***	***Evaluation Value***
Vitality	Vegetation coverage	38.23
	Plant diversity	1.84
	Bird diversity	1.86
Organization	Landscape Convergence Degree	92.41
	Landscape connectivity	9.8
	Landscape diversity	0.63
Resilience	Eco-elasticity value	0.41
Artificial interference	Population density	36.18
	Human utilized land	7.1
Comprehensive evaluation	/	0.57

In terms of ecological resilience, the overall resilience of the wetland is in a normal state, but its ecological value is not particularly prominent. At last, in terms of human interference, it can be seen that in the study area there are 7 pig pens, living areas, the distribution of the cultivated lands is too scattered, and it greatly interferes with the habitat of birds in the wetland.

4. Conclusions

This paper systematically studied the ecosystem landscape pattern of a constructed wetland in a certain area of the Yellow River Basin, and comprehensively evaluated the health status of the ecosystem in the wetland. The main conclusions are as follows:

(1) In the constructed wetland, the quantity of shrubs is the most, which is the major landscape type in the wetland; the order of the largest patch area from large to small is: water body > woodland > shrub > others > grassland. The water body plays an important role in the landscape integrity of the constructed wetland, the woodland also plays a supporting role, and together with other types of landscapes, they constitute the landscape in the constructed wetland.

(2) The landscape system of the constructed wetland is less complex, the number of vegetation is fewer, the density is low, and the patch area is smaller, the overall landscape shape is relatively regular, and the continuity is good. The landscape's degree of fragmentation is lower, the vegetation diversity is less, and the landscape shape is not complicated.

(3) The landscape is mainly the woodland and waterscape, the overall continuity of the landscape is average, the water body distribution is uneven, so we can increase the number of islands and the coverage of vegetation; the overall resilience of the wetland is in a normal state, but its ecological value is not particularly prominent; the human interference has a great influence on the bird habitats in the wetland.

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