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Landscape Quality Evaluation of Wetland Park Based on AHP Method—Taking Bilianhu Wetland Park in Zhaoqing, Guangdong Province as an Example

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Abstract: Due to the lack of understanding and utilization of wetland parks, some wetland parks have low landscape quality and serious convergence. Such situations are not conducive to the high-quality development of wetland protection and should be given enough attention. This study uses Analytic Hierarchy Process (AHP) to evaluate the landscape quality of Biliang Lake Wetland Park in Zhaoqing City, Guangdong Province. This paper provides a quantitative approach to assessing the landscape quality of parks by developing an evaluation model based on ecological, aesthetic, cultural, and management aspects. Firstly, this paper constructs different levels of evaluation criteria by understanding the landscape conditions of Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province; then, the weights of different indicators are evaluated through the AHP method; finally, this paper evaluates the satisfaction of various landscape elements of Bilian Lake Wetland Park, including aesthetics, comfort, ecological value, cultural services and management. The results show that ecological value and comfort are the two most important factors affecting tourist satisfaction, with ecological value accounting for 30% of the total weight, comfort accounting for 25%, and aesthetic value accounting for 20%. The data shows that its overall ecological indicators perform well, with balanced scores, and can provide tourists with a good natural experience and ecological protection. The 70 points for stand density show that the number and distribution of trees are moderate.

1. Introduction

Wetlands play many important roles, such as maintaining ecological balance, regulating climate, and conserving water resources. With the acceleration of urbanization, the wetland ecological environment is not optimistic. People gradually realize the importance of protecting wetlands, and a large number of wetland parks have emerged. Wetland parks not only play the role of protecting the urban ecological environment, but also should have certain functions such as leisure and entertainment, cultivating sentiment, and popularizing science and education. Only in this way can people's awareness of protecting wetlands be better enhanced, thereby promoting people to develop a conscious awareness of protecting the ecological environment. This study takes Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province as an example and uses the analytic hierarchy process (AHP) to evaluate its landscape quality. By constructing evaluation models in four aspects, namely ecology, aesthetics, culture and management, the landscape quality of wetland parks is quantitatively analyzed, providing a scientific basis for the planning and management of future wetland parks. This study aims to systematically evaluate the various landscape elements of wetland parks, identify key influencing factors, and provide directions for the optimization of wetland park landscapes.

This paper first introduces the importance and research background of wetland park landscape quality evaluation, and clarifies the research objectives and methods. Then, this paper reviews relevant research at home and abroad through literature review to provide support for the theoretical framework of this study. In the method part, the application of analytic hierarchy process (AHP) in wetland park landscape evaluation is introduced in detail, and the construction of the evaluation index system and the weight calculation are explained in detail. Subsequently, the paper gives an overview of the research area, Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province, and presents the experimental results and analysis, exploring the key factors affecting landscape quality. Finally, based on the research findings, suggestions for optimizing the wetland park landscape are put forward, and future research directions are prospected.

2. Related Works

Experts have conducted special research on landscape quality evaluation. Jahani et al. aimed to use artificial neural networks to model the landscape aesthetic quality of urban parks to predict their value and identify influencing variables. They quantified the landscape attributes of 100 urban parks and recorded 15 variables that affect visual quality. The constructed multi-layer perceptron model showed the highest coefficient of determination on the training, validation, and test datasets [1]. In order to establish a digital methodical procedure and criteria for evaluating landscape quality utilizing georeferenced photos along roadways as open source big data, Bianconi et al. concentrated on the importance of visual perception in gauging landscape quality [2]. Mann et al. analyzed four landscape quality indicators (beauty, authenticity, uniqueness and complexity) from two public surveys in 2011 and 2020 to evaluate the impact of different measures on improving landscape quality. The results showed that although most LQP (landscape quality payments) categories did not significantly affect landscape quality [3]. Wang & He used the Swin'Transformer text encoder to represent the demand for rural landscape art, and then input the text features into the GAN (Generative Adversarial Network) model to generate image content [4]. Haobo et al. constructed a waterfront space visual landscape comfort evaluation system based on street view analysis technology and evaluated the visual landscape comfort level along the Huangpu River and Suzhou River in Shanghai [5]. Tweed et al. proposed a landscape visual quality assessment tool applicable to a variety of contexts and discussed the results of their pilot study [6]. Fornal-Pienak & Bihuňová analyzed strategies and projects implemented and realized in selected cities in Poland and Slovakia in terms of landscape architectural environmental protection and sustainable design solutions [7]. Shen et al. explored tourists' perception of the landscape of traditional Chinese villages and provided suggestions for improvement. They analyzed more than 13,000 online comments from tourists, used a Likert scale to rate the landscapes of five traditional villages, and created an evaluation model based on the importance satisfaction analysis method [8]. Xinru et al. took Daopashi Street in the ancient city as an example and constructed a landscape space vitality evaluation model for historical and cultural blocks from three aspects: viewing function, store status and service facilities. Additionally, they determined the indicator weights and they evaluated the landscape space vitality of historical and cultural blocks using the hierarchical analysis approach [9]. Given the increasing importance of "place" and "place making" in geography, there is an opportunity to revitalize landscape assessment in educational settings. Tweed et al. proposed a technique for assessing the aesthetic quality of landscapes that can be used in a variety of contexts [10].

Koryagina et al. explored the potential for the development of health tourism and terrain therapy in Yuzhno-Sakhalinsk, Russia. The results showed that the combination of recreational landscape elements with mountainous terrain, rich plant resources, aesthetic quality of natural landscapes, and moderate bioclimatic patterns provided good prospects for the development of summer and winter health tourism [11]. Stupariu et al. reviewed the application of artificial intelligence, especially machine learning, in landscape ecology research and evaluated the number of papers and the methods used. The results showed that random forests were the most commonly used method, but the use of deep learning tools was increasing, and the research topics ranged from ecologically oriented problems to landscape human-computer interfaces [12]. Omidvar & Tavakoli aimed to assess the perception of ecosystem services by rural communities in Binalood City, Razavi Khorasan Province, with a focus on analyzing the value of trees in rural landscapes. Trees provide ecological, social, and economic services to the rural environment, but their value has been neglected due to human activities [13]. Wang studied the aesthetic expression of ceramic art in urban gardening and greening landscape design, focusing on the evaluation of its beauty. The experimental results showed that the improved fast transfer model showed good robustness and generalization ability when the amount of learning increases, becoming a new method for ceramic aesthetics research [14]. In response to the destruction of traditional villages caused by global urbanization, Li et al. proposed the "cultural landscape gene" theory and its double-chain model to effectively protect and inherit the cultural landscape of traditional villages [15]. Existing research focuses on qualitative research, but lacks systematic quantitative research.

3. Methods

3.1 Landscape of Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province

(1) Overview of the study area

Bilian Lake Wetland Park is located in Zhaoqing City, Guangdong Province. It is a wetland park with important ecological value. The area is located in the northwest of the Pearl River Delta, adjacent to the Beijiang River system, and has rich wetland types, including lakes, swamps and forest wetlands. As an urban ecological barrier, the Bilian Lake Wetland not only regulates the regional climate, but also provides a habitat for a rich variety of flora and fauna. The park, with its superior geographical location and beautiful natural scenery, has attracted a large number of tourists and researchers, and is of great significance to wetland protection and ecological research.

(2) Climate characteristics

The Pearl River Delta region where Zhaoqing City is located has a subtropical monsoon climate, which is warm and humid throughout the year with four distinct seasons. The annual average temperature of Bilian Lake Wetland Park is about 21℃ to 23℃, and the precipitation is abundant, with an annual precipitation of more than 1,500 mm. In summer, the temperature is high and the rainfall is concentrated, so the water level of the lake in the wetland rises, providing good conditions for the growth of wetland plants and aquatic organisms. In winter, the animals and plants in the wetland are more active, forming a unique seasonal landscape of the wetland ecosystem.

3.2 Research Purpose

With the rapid development of economy and the accelerating urbanization process, the wetland area is shrinking. People have adopted many ways to protect wetlands, and urban wetland parks are one of the effective methods. Attempting to evaluate the landscape visual quality of wetland parks will become an effective reference for future wetland park planning suggestions. This paper studies the visual environment quality of the Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province, and obtains the landscape characteristic elements in the wetland park through consulting relevant literature and field investigation. Through eye movement experiments, eye movement data are collected and processed and analyzed to explore the aesthetic preferences of different landscape spaces within the park from the perspective of visitors, the focus of subjects and the location of interest areas under different water areas, the landscape satisfaction under different canopy density, and summarize the subjects' gaze behavior patterns on different wetland types. Based on the combination of the above subjective and objective data, a landscape visual environment quality evaluation model is constructed to provide reference for the future planning and design of urban wetland parks.

3.3 Research Methods

3.3.1 Construction of evaluation index system

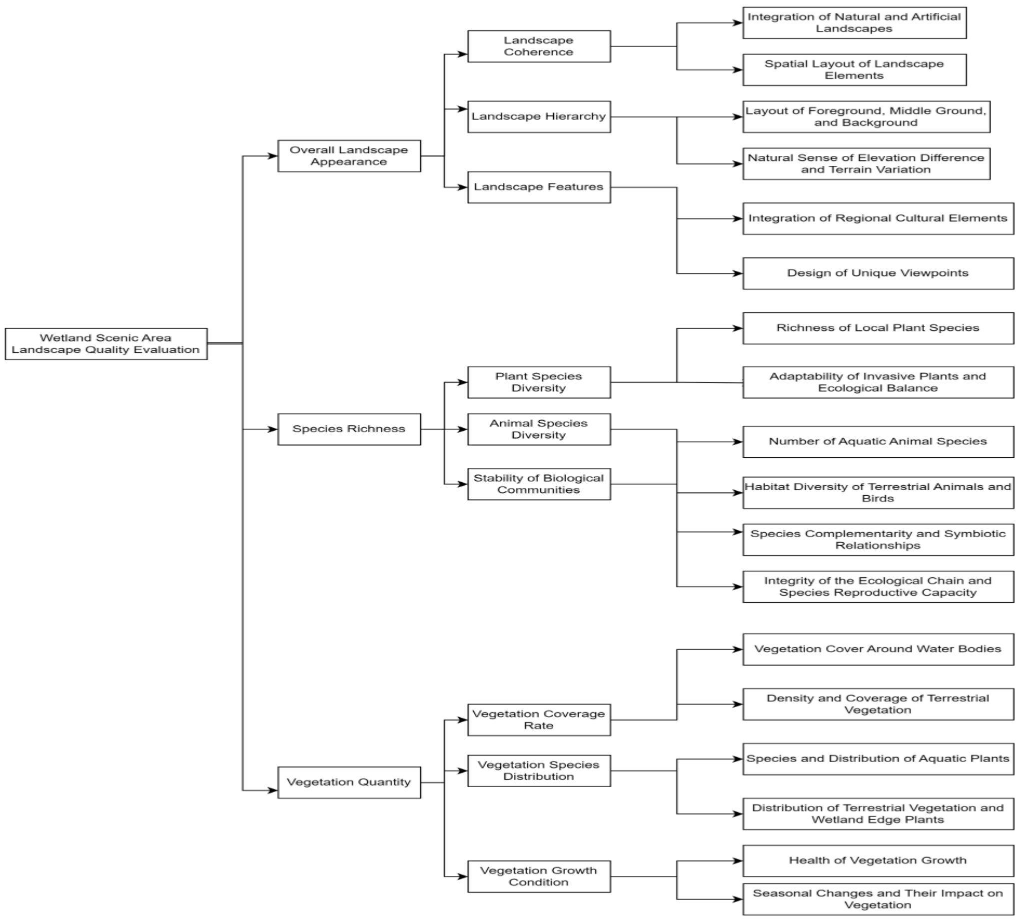

Figure 1: Ecological landscape quality evaluation system framework

The vast wetland ecosystem gives Bilian Lake Wetland Park in Zhaoqing City, Guangdong

Province unique ecological, cultural and aesthetic advantages, and is an important place for public recreation and cultural and educational activities. In view of this, referring to the *National Wetland Park Assessment Standards* and based on a systematic analysis of relevant literature on ecological landscape quality evaluation in various scenic areas, the landscape evaluation index system of Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province was preliminarily determined using literature analysis, frequency analysis and brainstorming methods. Then, 15 experts and scholars with backgrounds in landscape architecture, art, ecology and tourism were selected to conduct secondary screening and optimization of the indicators. Finally, the evaluation criteria layer was constructed from the four aspects of overall style and cultural service value, aesthetic value and ecological regulation, and the scenic area ecological landscape quality evaluation system framework including factor layer and indicator layer was established, as shown in Figure 1.

3.3.2 AHP method

The analytic hierarchy process (AHP) refers to a decision-making method that decomposes elements related to decision-making into levels such as plans, criteria, and goals, and conducts quantitative and qualitative analysis on this basis. The main steps are to first establish a hierarchical structure model, then construct a judgment matrix, then perform hierarchical single sorting and consistency test, and finally perform hierarchical total sorting and consistency test.

(1) Consistency Index (CI) calculation formula

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \tag{1}$$

Where n is the order in the judgment matrix:

Calculating the consistency index of the judgment matrix as follows:

$$CR = CI / RI \tag{2}$$

RI is the average random consistency index. When $CR < 0.1$, the sorting result has satisfactory consistency. If the sorting result does not have satisfactory consistency, the values of each element of the judgment matrix must be readjusted and recalculated. The RI value of the judgment matrix corresponding to the order 1~15.

(2) Construction of Judgment Matrix

Based on the 1-9 scaling method, a pairwise factor judgment matrix was constructed. A pairwise factor comparison questionnaire was issued to 10 experts in the field of wetland landscape design to solicit the experts' index assignment. Then, the arithmetic mean of the weight results obtained by the experts in the field was calculated as the final index weight. Formula (3) is the judgment matrix expression of AHP calculation weight:

$$R = \begin{pmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \cdots & r_{nn} \end{pmatrix} = R(r_{ij}) \tag{3}$$

In the formula, r_{ij} represents the relative importance of the two comparison factors to the previous level. The judgment matrix shown in formula (3) can describe the results of the pairwise comparison of all factors.

(3) Obtaining matrix index weights

Based on the square root method shown in formula (2), the matrix index weight vector is obtained, and the weight calculation result is normalized using formula (3):

$$W_i = \sqrt[n]{\prod_{j=1}^{n} r_{ij}}, i = 1,2,\cdots,n \tag{4}$$

In formula (4), W_i is the indicator weight value, and r_{ij} is the importance of indicator i and indicator j in the same level relative to the upper level indicator.

The extracted data sets were subjected to factor analysis. Factor analysis uses the idea of dimensionality reduction to compress the original numerous variables into a few common factor variables with the least amount of information loss. Since there are positive indicators (the larger the better) and negative indicators (the smaller the better) in the landscape pattern indicators, the data must first be processed positively. The forward-transformed data are then standardized. Before factor analysis, Kaiser-Meyer-Olkin (KMO) test and Bartlett sphericity test are performed. KMO test is used to check the correlation and partial correlation between each element variable, with a value of 0-1. In actual analysis, the KMO statistic is better when it is above 0.7, which is suitable for factor analysis. The number of factors is determined by using the eigenvalues, eigenvectors, variance contribution rates and cumulative variance contribution rates obtained. According to the rotated factor loading matrix, each factor is classified and named, and finally the factor score is calculated to obtain the comprehensive evaluation model of the landscape quality of Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province.

4. Results and Discussion

4.1 Experimental Purpose

This experiment aims to evaluate the landscape quality of Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province. By constructing a landscape quality evaluation model based on the analytic hierarchy process (AHP), the landscape value of the Bilian Lake Wetland Park in terms of ecology, aesthetics, culture, etc. is comprehensively analyzed to provide a scientific basis for wetland protection and improvement and help optimize the landscape planning and design of the wetland park.

4.2 Experimental Methods

(1) Construction of evaluation index system

Based on the literature and expert interview results, combined with the *National Wetland Park Evaluation Standards* and the functional characteristics of wetland parks, the landscape quality evaluation index system of Bilian Lake Wetland Park was constructed. First, we refer to existing research and standards, and use literature analysis, frequency analysis and expert brainstorming to preliminarily determine the evaluation indicators. Secondly, we invite 15 experts in the fields of wetland landscape design, ecology and garden art to screen and adjust the indicator system. Finally, the landscape quality is divided into four criteria layers: ecological function, aesthetic value, cultural service, and management and maintenance, and refined into several factor layers and indicator layers.

(2) Determining the weight of indicators using the AHP method

① Constructing a judgment matrix

To determine the weight of each evaluation indicator, a pairwise judgment matrix was constructed based on the 1-9 scale method. The questionnaire was distributed to 10 experts in the field of wetland landscape design to solicit the relative importance of each indicator and obtain the indicator values assigned by the experts, as shown in Table 1.

Table 1: Judgment matrix

Ecological Value	Comfort	Aesthetic Value	Cultural Value	Management	Importance
Comfort	1	3	5	7	9
Aesthetic Value	1/3	1	3	5	7
Cultural Value	1/5	1/3	1	3	5
Management	1/7	1/5	1/3	1	3
Ecological Value	1/9	1/7	1/5	1/3	1

The judgment matrix is a tool used in the analytic hierarchy process (AHP) to compare the relative importance of factors at each level. By constructing a judgment matrix, we can compare multiple factors pairwise and give an assessment of their relative importance. Each element of the judgment matrix represents the importance of one factor to another, usually expressed on a scale of 1 to 9, as shown in Table 1.

② Weight calculation and consistency test

The weight vector is obtained by the square root method, and the final weight value is obtained by normalization calculation. The consistency of the judgment matrix is tested by the consistency ratio (CR). If the CR value is less than 0.1, the matrix has satisfactory consistency, otherwise the judgment matrix needs to be reconstructed.

4.3 Data Analysis Method

The eye movement data was combined with the landscape type for analysis, with the dwell time and the number of fixations as the main indicators, to explore the degree of tourists' attention to different landscape types and identify the key features that affect the landscape's attractiveness.

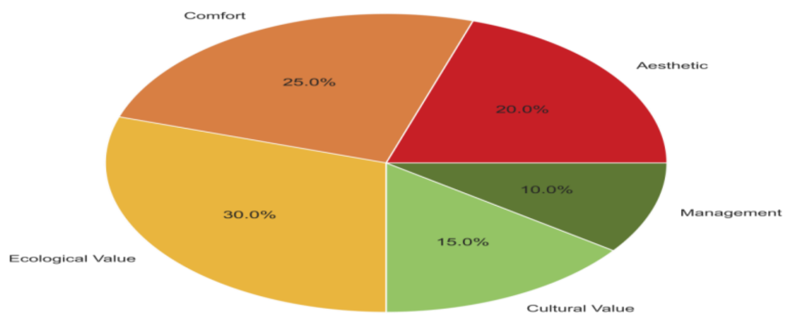

Figure 2: AHP weights for landscape quality evaluation

The weight distribution of landscape quality evaluation obtained by AHP method shows that ecological value accounts for the largest proportion (30%), followed by comfort and aesthetics, accounting for 25% and 20% respectively. Cultural value and management account for a smaller proportion, which may reflect the importance of ecology and comfort in the evaluation of wetland parks. This weight distribution provides a specific direction for the future landscape optimization of the wetland park, suggesting that more attention should be paid to ecological protection and visitor experience in design and management, as shown in Figure 2.

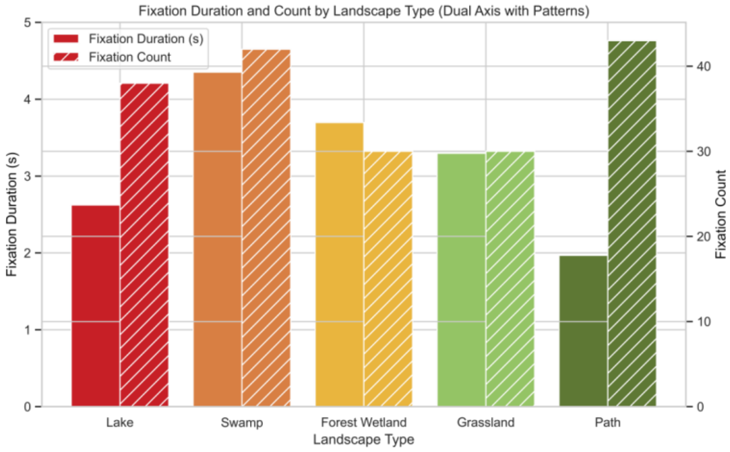

Figure 3: The duration and number of gazes on different landscape types

By analyzing the duration and number of gazes of visitors on different landscape types (lakes, swamps, forest wetlands, grasslands, and trails) in Figure 3, it is found that the gaze duration on lakes and forest wetlands is the longest, which indicates that these landscapes are more attractive to visitors. At the same time, the landscape types with higher gaze frequency are mainly concentrated in water areas and dense forest areas, reflecting that visitors tend to pay more attention to landscape types with higher natural and biodiversity. This result shows that the landscape design of wetland parks should focus on improving the visibility of water areas and vegetation landscapes.

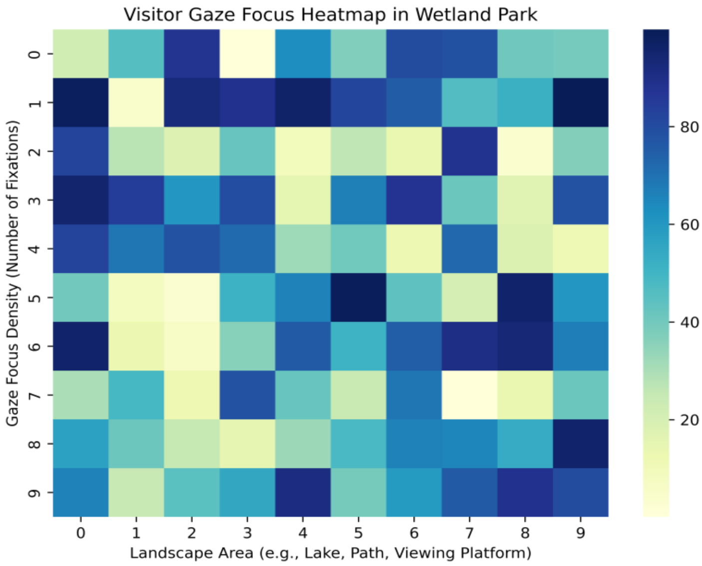

Figure 4: Eye tracking heat map of key areas in the wetland park

The heat map of the focus of attention in Figure 4 shows that visitors' attention in the wetland park is concentrated on some specific areas. This result suggests that the wetland park should focus on improving the visual appeal and convenience of these high-attention areas in landscape planning to improve visitor satisfaction and stay time.

Table 2: Ecological indicators of Bilian Lake Wetland Park

Indicator	Category	Category Assignment FiF_iFi
Canopy Density	0.4 ~ 0.8	70
Shrubs Coverage	≥80%	100
Herbal Coverage	50% ~ <80%	70
Stand Density	Medium Density (600 ~ 1100 plants/ha)	70
Tree Trunk Morphology	Straight or multiple trunks, well-distributed	100
Accessibility	High Accessibility	100
Tree Species Richness	3 ~ 6 species	70
Plant Compatibility	Reasonable	100

The experimental data of Bilian Lake Wetland Park show that its ecological indicators are generally good, with balanced scores, and can provide tourists with a good natural experience and ecological protection. The forest density of 70 points shows that the number and distribution of trees are moderate, ensuring good landscape permeability and ecological balance. The park's accessibility score is 100, indicating that the landscape is easily accessible, which enhances the visitor experience. The tree species richness score of 70 indicates that the park's tree species diversity is moderate, meeting basic ecological needs, but it can be further enriched in the future to enhance ecological resilience and risk resistance (as shown in Table 2).

5. Conclusion

This study constructed a landscape visual environment quality evaluation model for Bilian Lake Wetland Park in Zhaoqing City, Guangdong Province based on the AHP method, and combined eye movement experiments with questionnaire survey data to deeply explore tourists' aesthetic preferences and visual attention behaviors for wetland park landscapes. The study found that factors such as wetland type, canopy density of landscape space, and water area significantly affect tourists' visual focus and landscape satisfaction. In areas with different water areas, tourists focus more on open water, while in areas with higher canopy density, tourists pay more attention to the overall aesthetic effect and visual transparency of the landscape. In addition, the results of eye movement experiments show that different wetland types have different appeal to tourists, especially the combination of wetland ecological functions and aesthetic values, which provides tourists with a better visual experience. Based on the above analysis, this paper puts forward a series of suggestions for optimizing the landscape design of wetland parks, such as enhancing the visual appeal of open water areas, improving landscape sight distance and increasing plant diversity, so as to enhance the overall satisfaction and ecological experience of tourists. This paper also provides a theoretical basis and practical reference for the planning and design of future wetland parks by constructing a comprehensive evaluation model. However, this study still has certain limitations. The study is limited to the Bilian Lake Wetland Park and may not be widely applicable. Future research can consider expanding the sample range to cover different types of wetland parks.

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